

THALANGA ENVIRONMENTAL EVALUATION

Final Report

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EXECUTIVE SUMMARY

On the 14 of September 2017 the Queensland Department of Environment and Heritage Protection issued a notice to conduct or commission an environmental evaluation under the *Environmental Protection Act 1994* to Cromarty Resources Pty Ltd (Appendix A).

Cromarty Resources Pty Ltd commissioned Northern Resource Consultants (since January 2019 SLR Consulting) to prepare the initial environmental evaluation design document (Appendix B) and subsequently conduct the environmental evaluation.

The environmental evaluation notice and design document prescribed a number of progress reports to be compiled and submitted on a 6 monthly basis to cumulate into the final environmental evaluation report due for submission to the Department on or before the 15th of January 2020. Previous letters detailed the progress of the environmental investigation with reference to the milestones in the implementation schedule.

The site history describes the historical development of the mine site over time. Dewatering, mining and backfilling of certain mine sections- as well as the timing of waste rock and tailings deposition- all had an influence on the groundwater development of the Thalanga site. Combined with climatic influences, the hydrogeological and hydrogeochemical changes can subsequently be put into context.

The geological description of the mine site and its surrounds describes the baseline conditions for groundwater movement and chemical development. Together with the site history and climate information, the nature of groundwater movement can be understood.

The hydrogeological description of the Thalanga mine is strongly linked to the site history and the geological characteristics of the site. Groundwater level changes as well as flow directions are strongly influenced by the site operations and the geological nature of the site. As such, potential groundwater migration from the site is restricted to a direction along the strike of the deposit. The mined underground workings in particular have been described as the main conduit for groundwater movement.

Like the hydrogeological development, the hydrogeochemical characteristics of the groundwater have been largely determined by the site operations. Previous backfilling of underground workings above the depth of complete oxidation with tailings and process water have left an impact on the site groundwater. Recent mining of the West 45 and Far West deposits and associated dewatering efforts have resulted in a beneficial reversal of groundwater flow directions and level trends. Keeping future groundwater levels below the depth of complete oxidation should be incorporated into future mine water management plans at Thalanga.

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INTRODUCTION

The Thalanga Zinc-Lead-Copper deposit is located approximately 68km southwest of Charters Towers on Thalanga Station pastoral property and can be accessed via the A6, Flinders Highway. The mine started operation in 1989 and currently operates under EA reference EPML00773613 on ML1392, ML1531, ML10186, ML10185 and ML10137. Throughout its mine life Thalanga has seen several changes of ownership. Operations included open pit and underground mining, as well as processing of ore from mineralogically different satellite ore bodies. The current operator, Cromarty Resources, re-commenced mining and processing of Thalanga ore in 2017. On the 14th of September 2017 the Queensland Department of Environment and Heritage Protection issued a notice to conduct an environmental assessment and Environmental Evaluation (Appendix A). Northern Resource Consultants was commissioned to create the subsequent Environmental Evaluation Design Document (Appendix B).

1 Methodology

This Environmental Evaluation (EE) report is based on an understanding of the Thalanga site history and an interpretation of the long-term groundwater monitoring data available for the site. The report starts with the site history overview of the different operational phases of the Thalanga mine site. The site history presents the framework necessary to understand the hydrogeological development of the Thalanga site.

Following the overview of the site history, the report continues to describe the potential contamination source areas and lists the volumes and tonnages of relevant voids, waste rock and tailings. It continues to highlight the geochemical changes to these potential contamination sources over time and the impact these changes potentially had on the groundwater chemistry.

Having set the stage, the report continues to give a comprehensive account of the climate situation at Thalanga, particularly focussing on rainfall and evaporation.

From here, the geology of the Thalanga deposit and its surrounds are described in detail. Focussing on the bedrock geology and the geometry of the Thalanga deposit, as well as the weathered bedrock geology, the overlying Campaspe Formation and the isolated nature of minor alluvium occurrences.

The geology section is followed by the hydrogeology section, in which- besides further describing all relevant aquifer sections- the hydrogeological development of the site over time is explained and visualised. This is followed by the presentation of measured aquifer parameters and a hydrogeological conceptual site model showing the hydrogeological development of the Thalanga site from pre-mining conditions till today.

The hydrogeology section is followed by a detailed hydrogeochemical assessment describing the geochemical development of all monitoring bores at Thalanga with regards to potential source areas and operational changes over time. The hydrogeochemistry section is concluded by a summary of the groundwater contamination issues at Thalanga.

After having reviewed and evaluated the hydrogeochemical development of all groundwater bores, the report concludes with the solute transport model, summary and recommendations for potential future work to reduce the seepage load along the northern and eastern flanks of the tailings storage facility (TSF).

Any assumptions relied upon and their respective justifications are explained, where relevant, within the individual report sections.

2 Site History

2.1 Mining and Processing History

The mining and processing history of the Thalanga deposit is relevant to the understanding of the groundwater situation at Thalanga. Operations at the site can be divided into five phases:

- Phase One (1989 - 1998) includes the mining of the 75m deep, Central Thalanga pit and subsequent extraction of ore from the East (~420m deep), Vomacka (~150m deep), Central (~175m deep), West (~460m deep) and Far West (~450m deep) underground locations.
- Phase Two (1998 - 2005) comprises the processing of Highway Reward ore and the generation of additional tailings.
- Phase Three comprises the processing of Balcooma ore (2006 - 2009) and the generation of additional tailings.
- Phase Four involves the mining of the 85m deep Vomacka open pit (2008 - 2012) and the creation of additional tailings. Phase Three also saw the initial development of the West 45 deposit, which was halted following the cessation of the Kagara operations.
- Phase Five includes the in September 2017 extended West 45 underground development, the more recent dewatering and remining of the Far West deposit, and the generation of additional tailings.

Aerial photos and maps of the Thalanga Site are presented in Appendix C.

2.1.1 Phase 1

The initial Thalanga mine began production in June 1989. Mining of the volcanic massive sulphide (VMS) deposit by the open pit method was conducted until October 1990 and subsequent underground extraction of ore from the East Underground, Vomacka Underground, Central Underground, West Underground and Far West Underground continued until June 1998. In the nine years of operation, the Thalanga venture extracted 4.753kt of ore at an average grade of 8.52% zinc, 2.65% lead and 1.62% copper. Additional mining of ore from the Crown pillar resulted in the collapse of the pit floor into the Central Underground, opening a potentially direct pathway for future water movement.

Most of the resulting tailings were stored in a series of tailings ponds approximately 600m north of the processing plant. However, between 1990 and 1995 and June 1998 and July 2000 approximately 340,000m³ of tailings were also used as hydraulic underground backfill (Soto, 2001; Scott & Langton, 2002).

Waste rock from the open pit was stored in two separate waste rock dumps (WRDs). The East WRD with a volume of approximately 700,000m³ was located approximately 200m southeast of the Central Thalanga pit. The East WRD comprised a mixture of oxide, supergene and intermediate wastes produced during pit development operations in 1988/1989 (AGC; 1992).

Waste rock from the lower, sulphide rich production area mined during 1989/1990 was stored in the 1,230,000m³ West WRD. The area is now known as the wetland area, 100m west of the Thalanga open pit. Following significant acid seepage issues, the West WRD was relocated into the Thalanga pit during the 1998/1999 wet season, partially (~75%) backfilling the void (URS, 2000) and creating a surface water sink for runoff from mine impacted areas. Apart from this, approximately 407,000m³ of waste rock backfill was placed into the mined underground workings.

2.1.2 Phase 2

Phase Two commenced in 1999 with the cessation of mining of the Thalanga deposit and the reconfiguration of the Thalanga processing plant to treat copper ore from the distant Highway Reward mine. Underground tailings deposition continued till 2002 using Highway Reward copper-gold tailings. The practice of underground tailings deposition was halted when an initially alkaline tailings water pond (decant from the underground tailings deposition) started to fill the remaining shallow Central Thalanga pit void in August 2002.

2.1.3 Phase 3

With the change of ownership of the Thalanga site, the new owners (Kagara) progressed to processing copper ore from their Balcooma operation (2006 - 2009). Process tailings of the Balcooma ore were stored adjacent to the previous tailings dam extensions, in the newly constructed Cell 8 and Cell 9. Phase Three also saw the direct discharge of process water into the remaining Thalanga pit void. This process was only discontinued with the commencement of the Vomacka open pit operation of Phase Four in 2008.

2.1.4 Phase 4

Parallel to the processing of the external Balcooma ore, Kagara progressed to develop the approximately 85m deep Vomacka open pit (2008 - 2012). Waste rock from the Vomacka open pit was used to further fill the remaining Central Thalanga pit void and subsequently create an elevated land-form, from which surface water would shed rather than collect in. Tailings from the Vomacka pit development were also stored in the newly created tailings Cell 9, adjacent to the historical tailings Cells in the north-eastern section of the mining lease. Phase Three also saw the initial development of the West 45 deposit until 2012.

Phase Four saw also a reprocessing of tailings from the adjacent Cells 1 and 7. Dredging methods were employed to re-process approximately 420,000t of gold tailings from the previous Highway Reward operation. The reprocessed tailings were deposited into the new Cell 9, whereas tailings new tailings from the Vomacka pit were used to refill Cells 1 and 7.

2.1.5 Phase 5

Following the cessation of the Kagara operations, another change of ownership to Cromarty Resources has seen renewed activity at West 45, with mining operations re-commencing in April 2017 and, as of October 2017 reaching a depth of 155m. More recent, renewed dewatering of the Far West deposit followed by mining commenced in early 2018.

3 Disturbance Areas

Throughout the five operational phases, the Thalanga site has undergone a number of structural changes. The initial disturbance areas are shown in Figure 2 in Appendix C. The initial main surface features were the open pit, the west WRD, the east WRD, the dacite dump, the tailings dams (note, dam 8 only conceptual), the east evaporation dam and the ROM pad.

As mining on site progressed throughout the last 30 years, the outline of the site remained generally alike. Exemptions are the addition of more tailings dam cells, the excavation of the Vomacka pit and the backfilling of and creation of a waste rock mount on top of the Central Thalanga pit.

In addition, the operational infrastructure comprises the plant area, roads and tracks and the former rail siding as well as a more recent irrigation area. See Table 1 for approximate surface areas of all disturbance sites.

Table 1 Disturbance areas at Thalanga

Tenure	Disturbance type	Surface Area (ha)
1392	Central Thalanga Pit, now WRD	16
	U/G Subsidence, now backfilled	9
	Stockpiles/pads	4
	Waste rock dumps	20
	Roads/tracks	5
	Irrigation area	20
	Vomacka pit	14
1531	Plant	13
	Stockpiles/pads	9
	Wet land area	24
	Dams	20
	Roads/tracks	10
	West 45 box cut/portal	4
10137	Roads/tracks	2.5
	Rail siding	5
10185	Dam	10
	Roads/tracks	2.5
10186	Tailings dams	98

3.1 Central Thalanga pit and underground workings

The exploration of the deposit was initially conducted via a decline through the Pennaroya Portal. The outcome of the initial exploration drive was the Central Thalanga pit.

The Central Thalanga pit was mined to a depth of 70m and was about 540m long and 150m wide. The resulting void was used to access additional underground orebodies via two portals. One portal, accessing the western underground workings, was located at the south western floor of the open pit. The other portal, in the eastern corner of the open pit provided access to the eastern underground workings.

The underground workings consisted of the West, East, Vomacka, minor Far West and finally Central zones. The Central zone was the concluding underground operation of Phase One. Final mining focused on the extraction of ore at the pit floor, the crown pillar, that represents a valuable high-grade ore zone. The process of extracting as much of the high-grade ore as possible eventually resulted in the collapse of the pit floor into the underground workings below – opening a direct vertical connection between the underground and the open pit.

In the meantime, backfilling of the existing East and West zones with tailings had commenced. By 1995, part of the West zone had been backfilled with 134,000m³ of tailings (BFP Consultants, 1998). The East zone received approximately 200,000m³ of tailings. Concurrent with the tailings deposition, both the West zone and the East zone developed large (about 100 x 100m) surface subsidence areas. These subsidence areas were subsequently backfilled with Vomacka Pit oxide waste.

Initial mining from West 45 was only conducted for a brief time during Phase Four and ceased in March 2012. (RLA 2014). Renewed mining of the West 45 commenced in April 2017. With additional mining of the Far West resuming in 2018.

3.2 Waste rock dumps

The initial driving of the Pennaroya decline produced the Dacite waste rock dump close to the Pennaroya Portal.

Subsequent mining of the open pit initially produced oxide ore and, the benign, oxidised waste rock was used in the construction of the ROM pad and stored in the east waste rock dump.

The ROM (while at its core initially benign waste rock) has been used to store ore for processing for almost 30 years. As a result, a reactive veneer of oxidising sulfides has formed on its surface. Leaching, runoff and infiltration of metal rich solutions from the veneer has likely resulted in the saturation of the ROM with soluble secondary salts. These salts now representing a seasonal source of metal rich acid drainage in the surroundings of the ROM pad.

The reactive, sulphide bearing waste rock was stored in the western WRD. Placement of the western waste rock dump proceeded throughout 1989/1990 with acid seepage being observed during the 1990/1991 wet season. Successive reshaping and capping efforts were unable to control the acid drainage problem. Hence, in 1998 (almost 9 years following the onset of acid drainage), the acid generating waste rock was backfilled into the Central Thalanga pit.

The benign oxide waste rock from the development of the early Vomacka pit was used to create a doughnut around the now backfilled Central Thalanga pit. The inside of the doughnut was then filled with the more reactive sulphide waste rock from the lower mineralised reaches of the Vomacka pit.

Waste rock from the underground workings was generally used for stoping or stabilizing of mined out underground sections. Apart from the waste rock created during the early driving of the Pennaroya decline, underground waste rock remained generally underground.

3.3 Tailings dams

The initial tailings Cells comprised of Cells 1 to 5. Cells 1 to 5 are formed from the east to west each comprising a surface area of some 4.4ha. Cells 6 and 7 were formed to the north of and adjoining Cells 1 to 5 and have Cell areas of 10ha and 12ha, respectively. The initial Cells 1 to 7 accommodated tailings created due to the processing of Zn-Pb-Cu ore from the Thalanga deposits. With the exhaustion of then economical orebodies at Thalanga in 1998, the plant was modified to process Cu-Au ore from the Highway Reward deposit, approximately 45km to the East of Thalanga. The process generated additional tailings which at first were discharged into the underground, but from 2002 onwards were stored in the lifted and now combined Cell 1/7.

Tailings Cells 2 to 6 were decommissioned between 1995 and 2000. Rehabilitation works included capping and revegetation, with surface runoff discharging via a number of rock-lined chutes down the external Cell batters. The capping comprises a rock fill capillary breaking layer overlain by a clay fill barrier layer. The total capping layer varies in thickness from 1.5 to 2.6m (Allan Watson Associates, 2010).

Cell 8 was primarily constructed as part of Kagara's recommissioning of the plant in late 2006. The Cell stores tailings from the processing of approximately 1,500,000t of external Balcooma copper ore (Mining Technology, 2018) between 2007 and 2009. The total surface area of the Cell 8 is 6ha.

Cell 9, constructed in late 2008, initially received tailings from the re-processing of Highway Reward tailings from the partial dredging of Cell 1/7. Later, the ore treatment plant was reconverted back to processing multi-metallic Zn-Pb-Cu ore from the Vomacka pit at Thalanga. Cell 9 has an area of 18.5ha with the current capacity to store additional tailings.

In April 2012, a subsurface seepage affected water body was identified within excavated clay borrow pits directly north of the tailings dams. This was followed by repairs to the Cell 5 and Cell 6 seepage interception trenches and a clean out of the clean water diversion drain (RLA 2014).

3.4 Process water and evaporation dams

Initial mine dams comprised of the East Evaporation Dam, the Decant Dam, the Southern Waste Rock Dam and the smaller Temporary Dam, East Evaporation Pond and Sewage Lagoons (Figure 1 in Appendix D). Of these initial dam locations, the East Evaporation Dam, the East Evaporation Pond, the Southern Waste Rock Dam and Sewage Lagoons remained throughout the years. The Decant Dam and part of the Temporary dam were covered by tailings Cell 9. Additional surface water locations exist now in form of the partially flooded Vomacka Pit void and an engineered wetland across the footprint of the former West WRD. To manage accumulating runoff, water from the wetland area was used to irrigate a previously unimpacted area south/ south east of the backfilled Central Thalanga pit.

3.5 Vomacka open pit

The Vomacka open pit was mined to a depth of 85m and was about 500m long and 235m wide. The pit was mined between October 2010 and January 2012, extracting about 640,000t of ore and 2,200,000m³ of waste rock materials (Red River Resources 2014, RLA 2014). Of these waste rock volumes, 2,000,000 m³ were classified as PAF and 4,000,000m³ were classified as NAF. The handling of waste rock from the Vomacka deposit is described in section 2.2.

4 Volumes and tonnages

4.1 Mined areas and backfill till 2002

The Central Thalanga pit had the dimensions of 600m x 150m x 70m and a volume of about 2,300,000m³. The total volume of the underground workings was approximately 1,598,000m³.

In total 4.753kt of ore were extracted with an average grade of 8.52% Zn, 2.65% Pb and 1.62% Cu during the initial Phase One Thalanga operation.

Until July 2000, some 340,000m³ of tailings were used as hydraulic underground backfill (URS, 2000; Soto, 2001 quoted in Scott and Langton 2002).

Waste rock from the Central Thalanga pit was stored in two separate waste rock dumps. The East WRD had a volume of approximately 694,000m³ (AGC, 1992b) covering a surface area of 6.1ha (AGC, 1994) and the West WRD had a volume of 1,230,000m³ and a footprint of 14ha (SKM 2000). At the same time approximately 407,000m³ of waste rock backfill were placed in the underground workings.

The dacite waste rock dump close to the Pennaroya Portal covered an area of approximately 2.6ha and the ROM pad with a volume of about 685,000m³ covers about 6.3ha.

Table 2 Volumes of waste rock and tailings as of August 2002 (Compiled from BFP, 1998; URS, 2000; Scott and Langton, 2002)

Location	initial volume	Waste rock	Tailings	Mine excess water
Open Pit	2,300,000m ³	1,350,000m ³		
West WRD	1,230,000m ³	+		
East WRD	694,000m ³	542,000m ³ ^		
ROM Pad	685,000m ³	685,000m ³		
East & Vomacka Underground	892,000m ³	280,000m ³	202,000m ³	~1,000,000m ³
West & Central Underground	706,000m ³	127,000m ³	134,000m ³	

*Number includes only volumes from the EWRD and WWRD, amounts of other waste materials have been evidently dumped but are not accounted for.

+ replaced into open pit.

^ remained on waste rock dump after partial replacement into open pit.

~ estimate

4.2 Backfill since 2002

Mined areas since 2002 are the Vomacka pit and the more recent West 45 underground workings. Underground deposition of tailings is thought to have halted at the end of Phase Two. Regardless, Rob Lait and Associates reported that in-pit (Central Thalanga Pit) deposition of process water continued till at least February 2008 and only ended with the need for dewatering of the Vomacka pit. Rob Lait reported that in-pit deposition of process waters had resulted in elevated groundwater tables at the Vomacka location (RLA 2008B). In addition, in early March 2008, Kagara staff reported that water had expressed at the Eastern Deeps subsidence area (Figure 5 in Appendix C). That surface water expression was explained with the impacts of a particularly wet 2007/2008 wet season. However, the unexpected surface water expression also evoked fears that artificially raising groundwater tables through the Central Thalanga pit via discharge of process water could impact on the nearby Campaspe Beds (RLA 2008A).

The total volume of process water deposited into the Central Thalanga pit is not known. However, from the historical evidence provided (water levels in the Central Thalanga pit void to less than 10m below crest level; RLA 2008B, groundwater levels artificially elevated to near surface levels; RLA 2008B and expression of surface water in the eastern deeps subsidence area; RLA 2008A), it can be concluded that the volume deposited was able to fill the remaining east and west underground voids (see **Table 2**).

Waste rock from the Vomacka pit operation was used to fill the remaining Central Thalanga pit (section 2.2). Hence, the practice of discharging process water was discontinued. However, following the extraction of the Vomacka orebody, drainage from the ROM, processing area and area south of the open pit, was redirected to the Vomacka open pit via a diversion drain (RLA 2014).

5 Considerations with regards to groundwater quality

It is important to reiterate that process water and tailings composition changed several times during the 30 years of processing at Thalanga. Each of these operational periods would have produced a different geochemical potential seepage signature.

The initial Phase One treated polymetallic zinc-lead-copper, hence any seepage from that period would be Zn dominated.

Phase Two processed copper-gold ore from the Highway Reward Mine, subsequently creating a geochemical signature lacking zinc.

Phase Three saw a continuation of copper ore processing, with a change to processing Balcooma copper-gold ore. Noteworthy, the addition of process water to the Central Thalanga pit that resulted in excessively high groundwater tables in early 2008, occurred during Phase Three.

Phase Four saw, after the initial processing of copper ore from Balcooma, a return to processing polymetallic zinc-lead-copper ore from the Thalanga Vomacka and West 45 deposits.

The earlier described timing of the different ore processing periods must be considered when assessing groundwater quality issues at Thalanga.

6 Climate

6.1 BOM weather stations

The Thalanga mine is located about 300m above sea level within a subtropical savanna area in North Queensland, Australia. The Bureau of Meteorology (BOM) collects weather data from a number of weather stations around the Thalanga site (**Table 3**). The locations are shown on Figure 6 in Appendix C.

Table 3 BOM weather stations in the vicinity of Thalanga

Station Name	Station Number	Long	Lat	Time of record	Record type
Balfes Creek PO	034000	145.91E	20.22S	1889 - 2016	daily rain and solar exposure
Windsor	034011	146.10E	20.30S	1915 - 1965	daily rain
Trafalgar	034010	146.01E	20.43S	1910 - 2017	daily rain
Homestead PO	030023	145.66E	20.36S	1893 - 2018	daily rain and solar exposure
Pentland PO	030040	145.40E	20.52S	1885 - 2013	daily rain and solar exposure

6.2 Temperature and humidity

The climate in the area is semi-arid with distinct dry and wet seasons. Average temperatures range from 10°C to 25°C in the dry season and 20°C to 38°C in the wet season with humidity varying from 40 to 65 % (Commonwealth of Australia, 1986).

6.3 Evaporation

The annual pan evaporation rate of approximately 2,130mm exceeds the average annual rainfall of 668mm (100 year range: 116mm to 1,443mm).

Monthly mean evaporation data has been compiled from Australian-wide pan evaporation data available on the BoM website (**Figure 1**). Average monthly evaporation exceeds average monthly rainfall for all months except January and February, meaning groundwater recharge occurs mostly during the months of January and February.

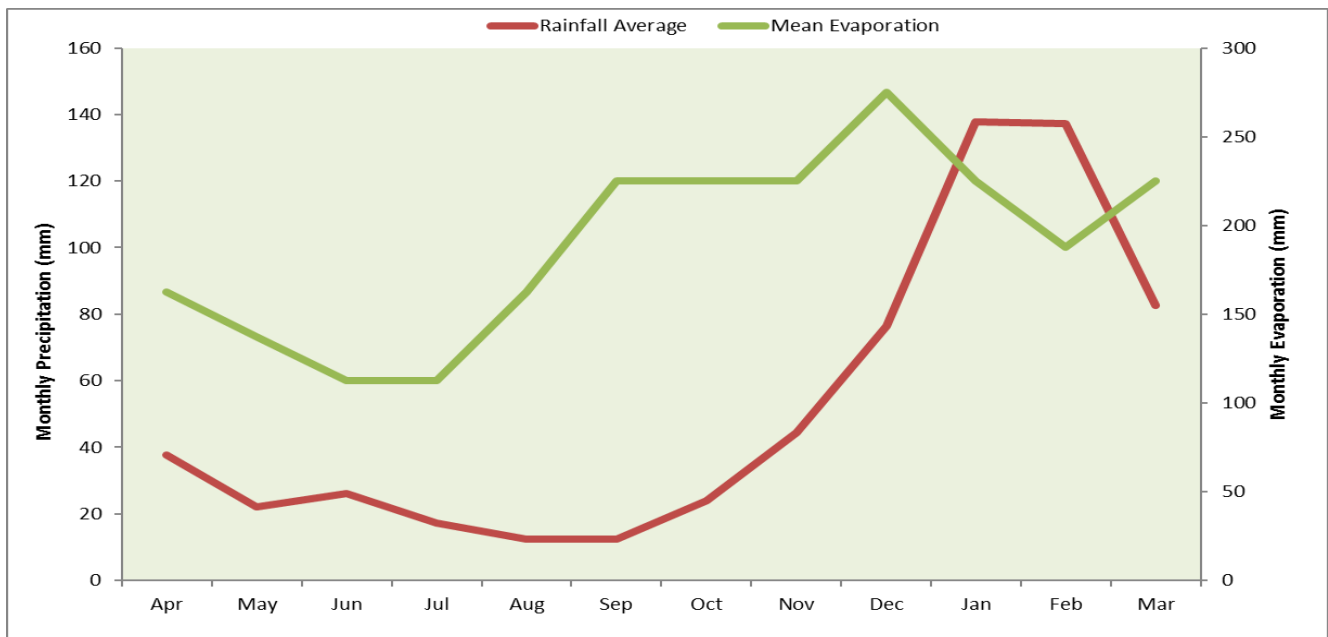


Figure 1 Mean monthly rainfall and mean pan evaporation for Thalanga (inferred from BOM 2005)

Evaporation at the Thalanga site itself has been recorded between August 1992 and December 1996, alongside with rainfall measurements which have been recorded between August 1992 and May 2003 (**Figure 2**).

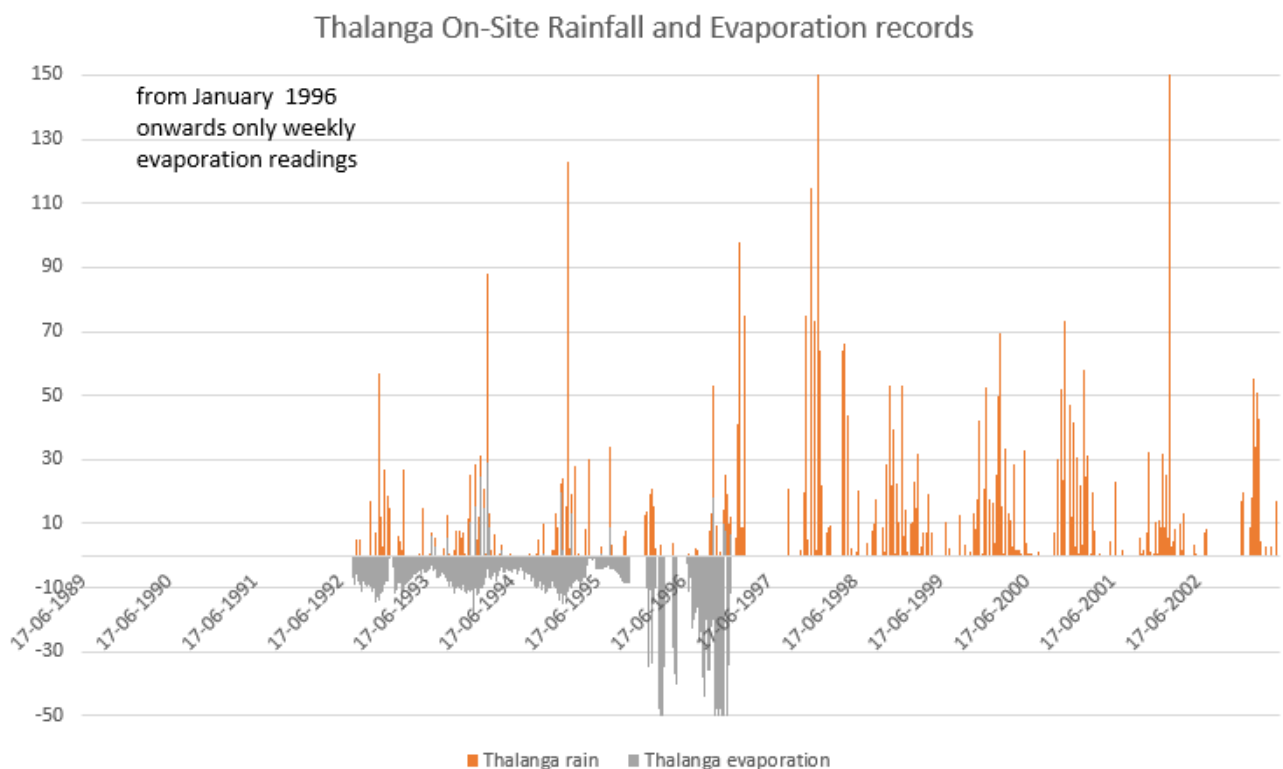


Figure 2 Thalanga on-site rainfall and evaporation records

Complete site evaporation records exist for the period between August 1992 and April 1995. Suggesting that total yearly pan evaporation for the Thalanga site is about 2250mm with monthly pan evaporation rates larger than the inferred values presented in **Figure 1** . Actual measured pan evaporation rates are shown in **Figure 3**.

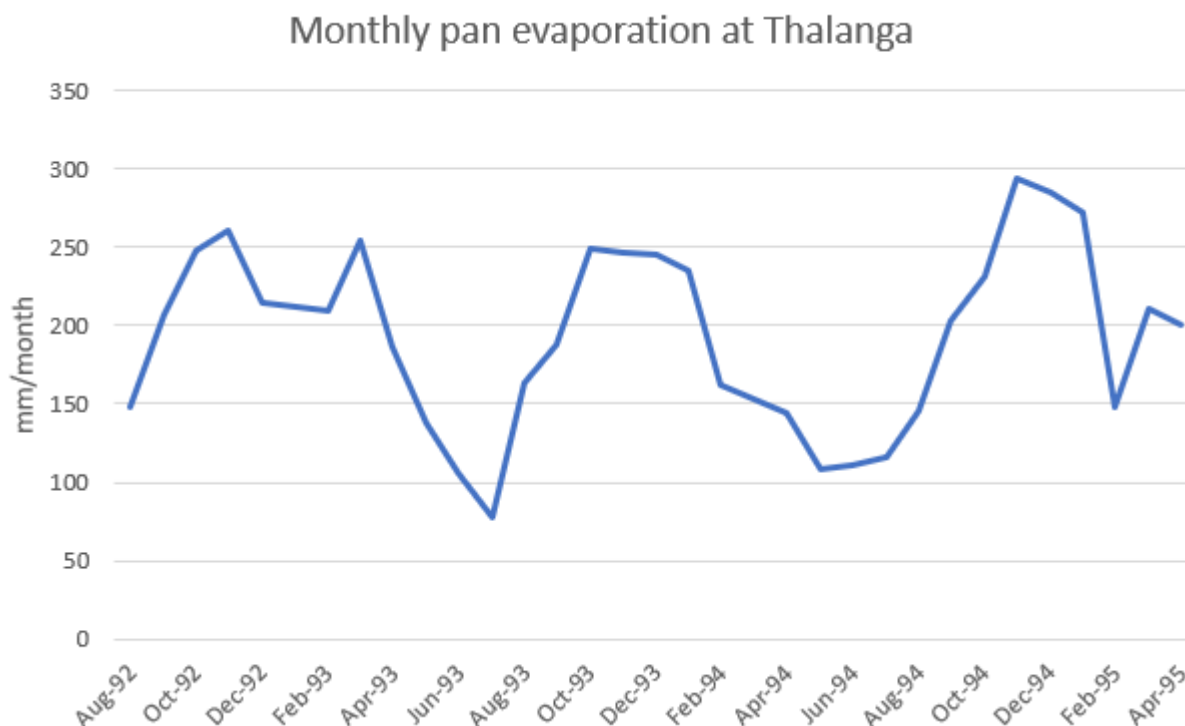


Figure 3 Measured pan evaporation rates at Thalanga between August 1992 and April 1995

6.4 Rainfall

Most of the rainfall at Thalanga occurs in the summer months between December and March. During this period rainfall intensities of 114mm/day have a one in two-year probability, whereas 223mm/day rainfall rates have a one in a 100 year probability (Australian Groundwater Consultants, 1983).

The former BOM Station of Balfes Creek Post Office (34000) is located less than 20km north east of the Thalanga site. The station has been operating between 1889 and 2016 and as such the station is well placed to be representative with regards to rainfall records at the Thalanga site. Recorded rainfall between January 1987 and July 2016 shown in **Figure 4**.

An overlay of Thalanga site measurements and Balfes Creek records suggest that rainfall intensities for the measured period may have been higher at Thalanga than at Balfes Creek. While smaller rainfall events appear to be at a somewhat similar magnitude between both sites, the larger rainfall events appear generally larger at Thalanga (**Figure 5**).

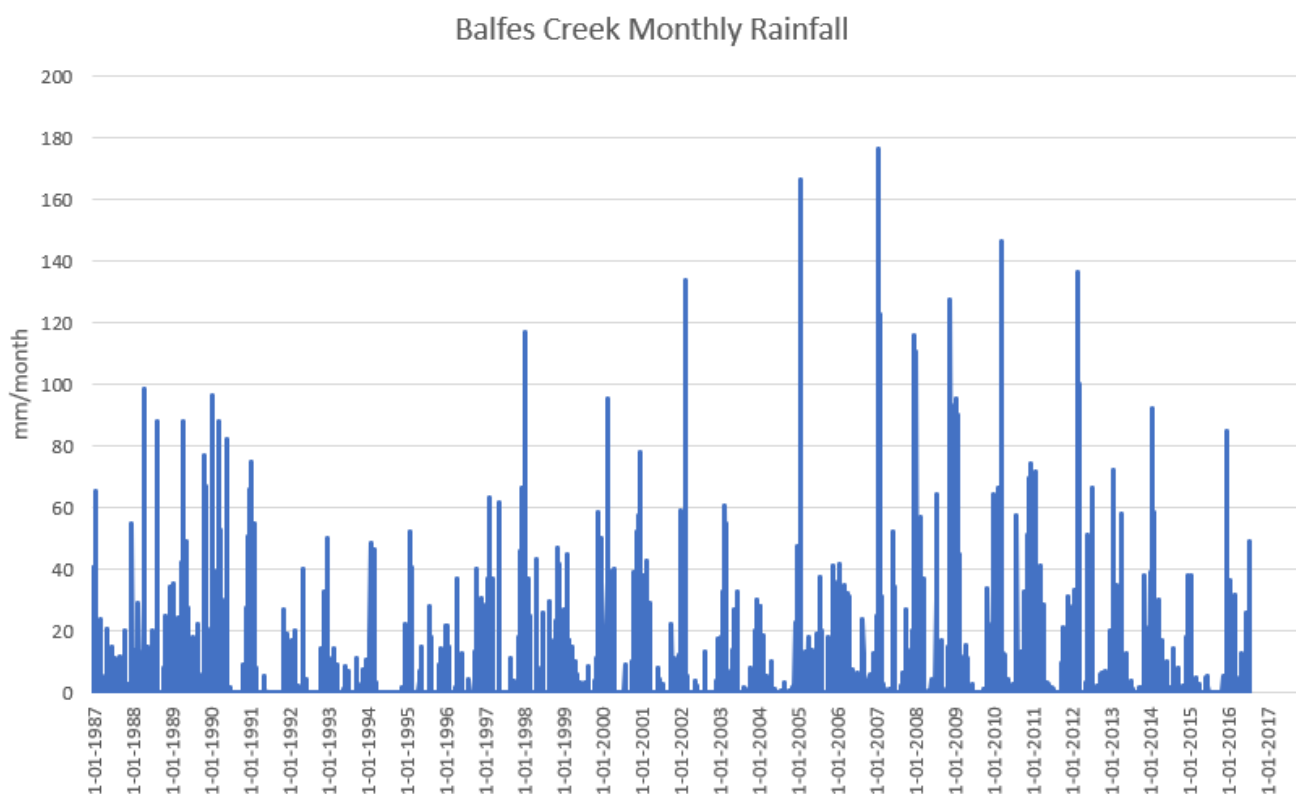


Figure 4 Balfes Creek monthly rainfall records between 1987 and 2016. Station stopped recording in 2016.

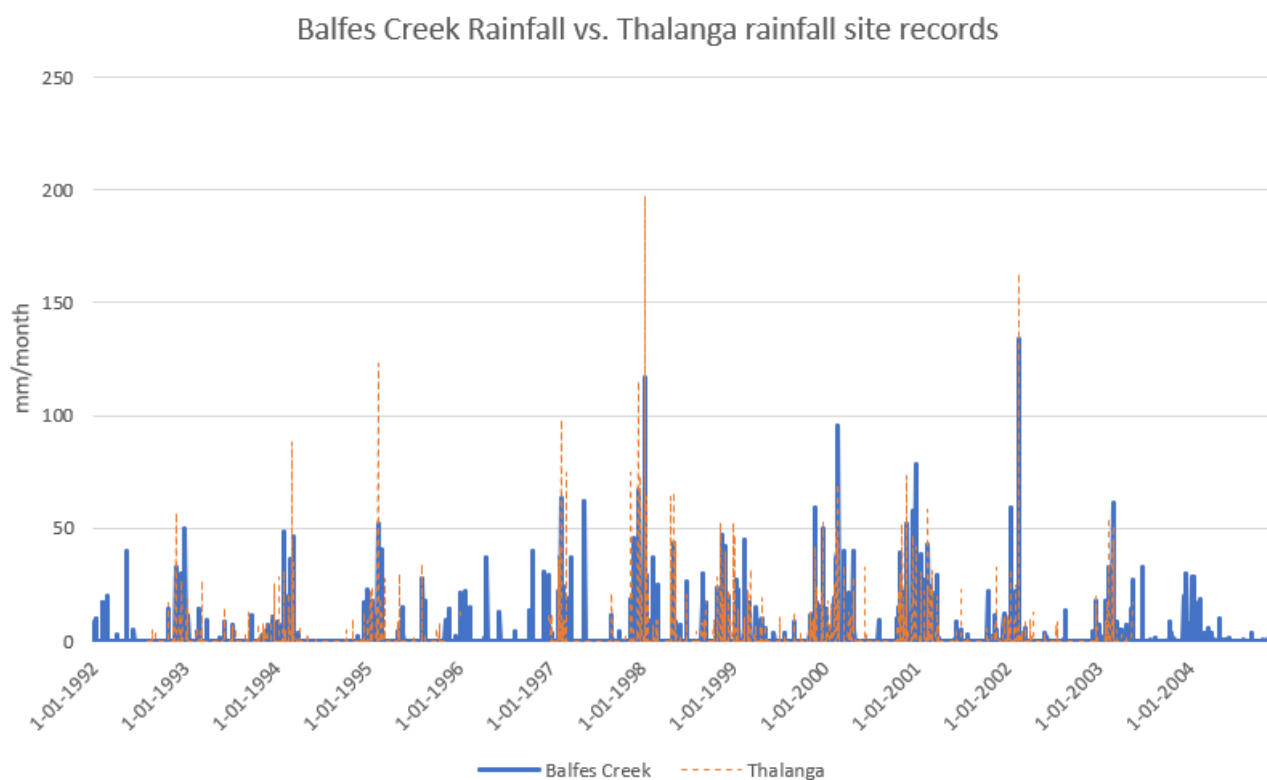


Figure 5 Comparison of rainfall at Balfes Creek Post Office and Thalanga Mine Site between 1992 and 2004

6.5 Cumulative rainfall departure (CRD)

The long-term pattern of variation in rainfall at Thalanga can be described using cumulative rainfall departure (CRD) for the Balfes Creek station. Balfes Creek station only recorded till mid-2016. CRD is a measure showing ongoing rainfall trends compared to historical monthly averages (**Figure 5**). Below-average monthly rainfall is shown as decreases in the CRD (measured in mm), whereas above-average monthly rainfall is shown as increases. The CRD values roughly follow the El Niño cycle (USCPC, 2018). Since about mid-2012, the Thalanga Region is going through a period of below average monthly rainfall, which despite a prediction to a change to La Niña conditions (BOM, 2018) has not materialised.

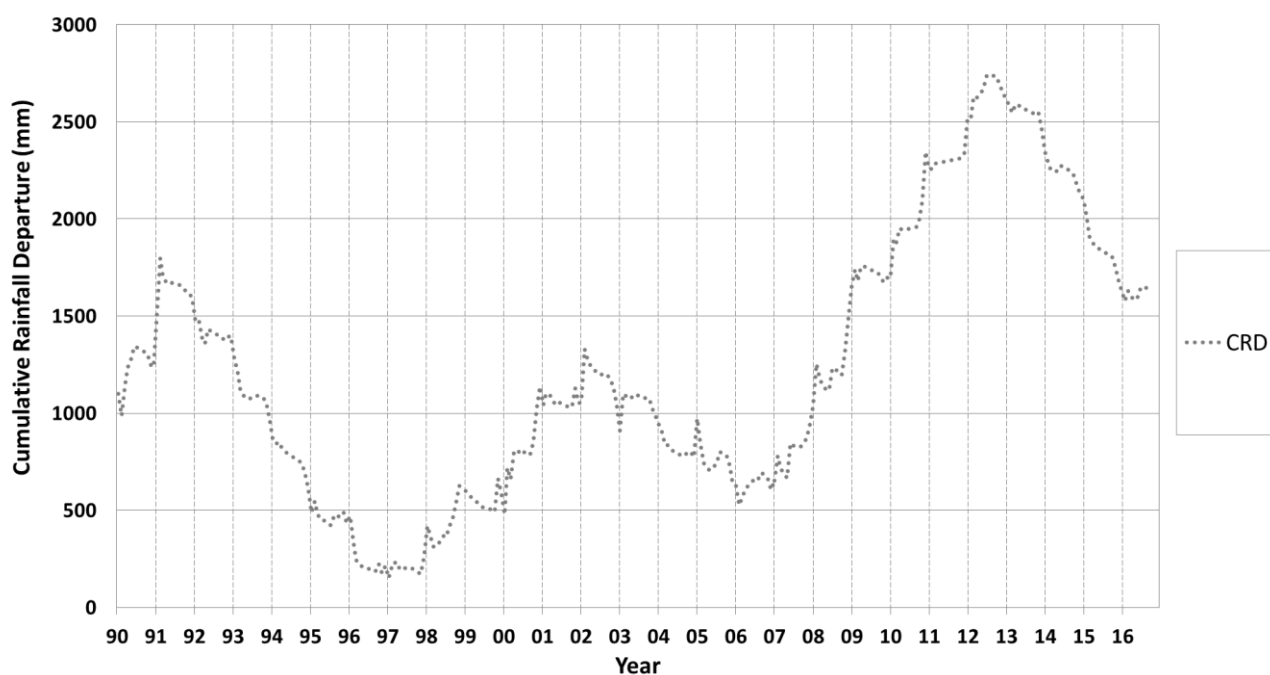


Figure 6 Cumulative rainfall departure curve for rainfall received at Balfes Creek Post Office BOM rainfall station (BOM, 2016)

7 Geology

7.1 Introduction

The geology of the Thalanga area is characterised by the steeply dipping (up to 89°) volcanic sedimentary rocks of the Late Cambrian to Early Ordovician (472 to 488 million years old) Seventy Mile Range Group. The Seventy Mile Range Group, in places, host economic mineralisation of copper, lead, zinc and gold; the Thalanga deposits being a part of these. The volcanic sedimentary rocks, initially lain down flat by ocean floor volcanism, were intruded and steeply tilted by later stage granitic intrusions of the Ordovician to Devonian (408 to 470 million years old) Ravenswood Granodiorite Complex.

The initial deposition and subsequent tilting of the volcanic sedimentary bedrock were followed by an extensive period of weathering and erosion. Long term weathering resulted, at some locations, in the formation of up to 40m thick gossans above the mineralised zones as well as 40 - 70m deep weathering of the surrounds.

Most of the weathered sequence is now unconformably overlain by the 1.3 to 3.5million years old sedimentary Campaspe Formation.

The Campaspe Formation and the surrounding weathered bed rock host isolated minor recent alluvial occurrences within the minor creek lines that criss-cross the area (Appendix D).

7.2 Bedrock geology

The Thalanga volcanogenic massive sulphide (VMS) zinc-lead-copper deposit is located in the Late Cambrian to Early Ordovician Mount Windsor Volcanics. Together with the underlying Puddler Creek Formation and the overlying Trooper Creek Formation, the Mount Windsor Volcanics are part of the Late Cambrian-Early Ordovician volcano-sedimentary Seventy Mile Range Group (Henderson, 1986).

The Seventy Mile Range Group forms a succession of calc-alkaline volcanics and epiclastic deep to moderate deep marine sediments (Henderson, 1986; Murray, 1990). The volcanics are composed of andesitic pillow lavas, rhyolites and dacites. The sediments comprise polymictic breccias, detrital sediments, cherty sediments and greywacke (Gregory et al., 1990; Henderson, 1986).

The deposit, in the form of Kuroko style massive sulphide lenses, is thought to be of submarine, exhalative origin and is stratigraphically underlain by rhyolite (Henderson, 1986; Hill, 1996). The presence of dacite as a cover sequence represents a new volcanic episode and the end of mineral deposition (Gregory et al., 1990). Hutton and Withnall (2007) propose that the initial deposition occurred in a back-arc setting, stating evidence for grabens and thickness changes in volcanic units.

Mineralisation at Thalanga occurs mainly in the form of chalcopyrite, sphalerite, pyrite and lesser galena with minor magnetite, arsenopyrite and tetrahedrite-tennantite (Hill, 1996). Hydrothermal alteration of the rhyolitic volcanics resulted in the quartz-muscovite, chlorite and pyrite rich assemblages, whereas alteration of the dacites resulted only locally in weak silicification and chloritic overprinting of biotite. Feldspars are commonly present as albite and are only weakly altered to muscovite (Hill, 1996).

The Seventy Mile Range Group (Figure 7) has been intruded and metamorphosed by granitoids of the Middle Ordovician Ravenswood Granodiorite Complex (**Figure 8** and **Figure 9**). Metamorphism to upper greenschist facies and major deformation has affected the host rocks and the sulphide lenses, which are now in a near vertical position (Hill, 1996) (**Figure 10**).

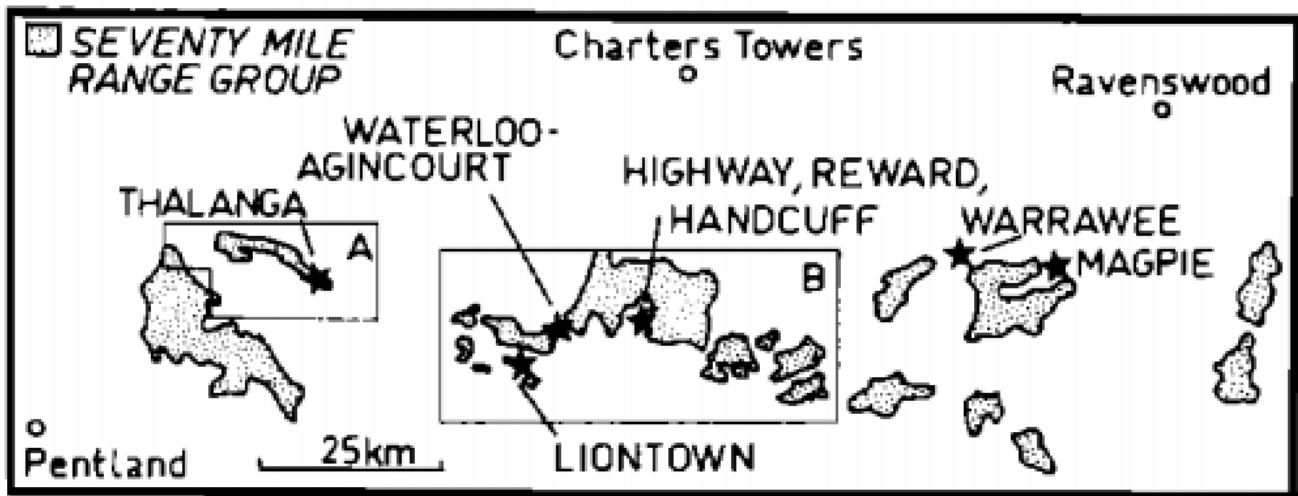


Figure 7 Generalised geologic map of the Mount Windsor volcanic belt (from Berry *et al.*, 1992) Inserts A and B are shown in Figure 8 and Figure 9 below.

The main structural features are pervasive but variably developed foliations sub-parallel to the ore and shearing contacts, particularly along the footwall rhyolite contact with the mineralised Quartz Eye volcanics (Hadlow and Vigar, 1997). A typical cross section of the deposit is shown in **Figure 11**. A complete set of available cross sections is included in Appendix E. The significance of the near vertical placement of the orebody and its structural features has important implications for the groundwater situation at Thalanga as will be discussed in detail in the hydrogeology section of this report.

At Thalanga, the volcano-sedimentary sequence is intersected by two generations of normal faults (**Figure 12**). The older faults are at a high angle to the stratigraphy and separate West and Central Thalanga from the Vomacka Zone and East Thalanga, whereas the younger, low angle faults resulted locally in structurally thickened ore lenses (Hill, 1996). Late Post Ordovician volcanism resulted in the emplacement of north/south trending microdiorite and dolerite dykes (**Figure 13**), which cut through the sequence in the eastern section of the initial now backfilled open pit.

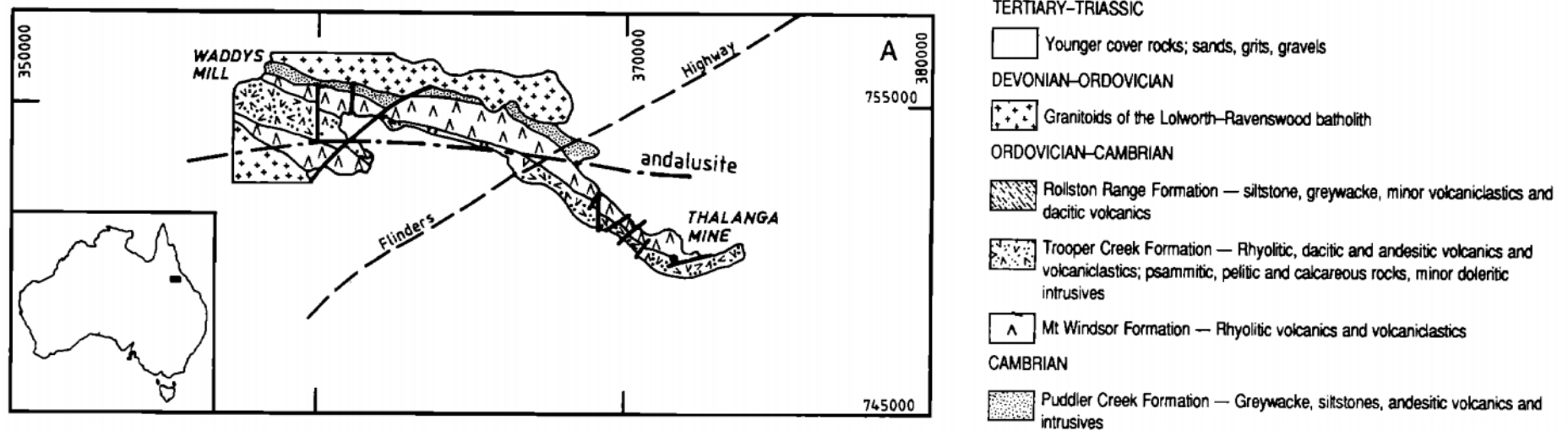


Figure 8 Bed rock geology of the Thalanga section of the Mount Windsor Volcanic Belt (Insert A of previous Figure 7, with legend applicable to Insert A and the following Insert B) (from Berry et al., 1992)

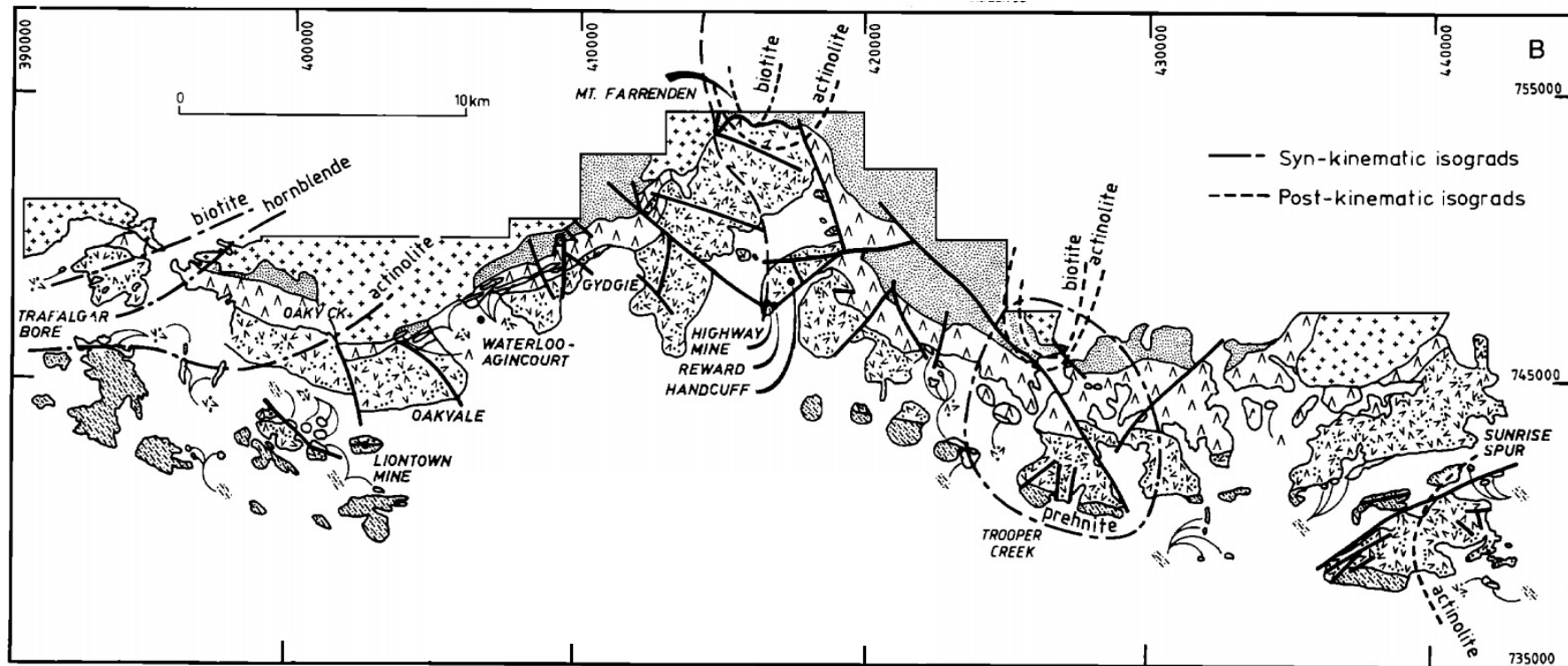


Figure 9 Bed rock geology of the Mount Windsor Volcanic Belt (Highway Reward Section) (Insert B of previous Figure 7, with legend in Figure 8) (from Berry *et al.*, 1992)

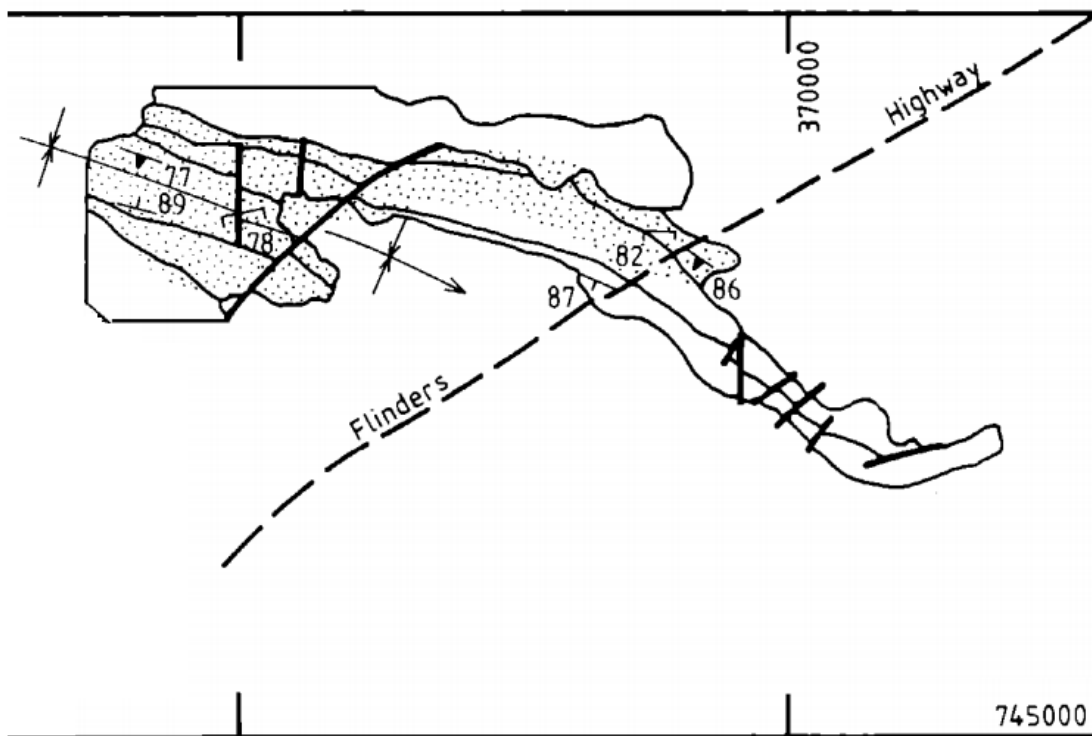


Figure 10 Subvertical dipping strata (as depicted by the numerals) at Thalanga as a result of intruding granitoids of the Middle Ordovician Ravenswood Granodiorite Complex (from Berry *et al.*, 1992)

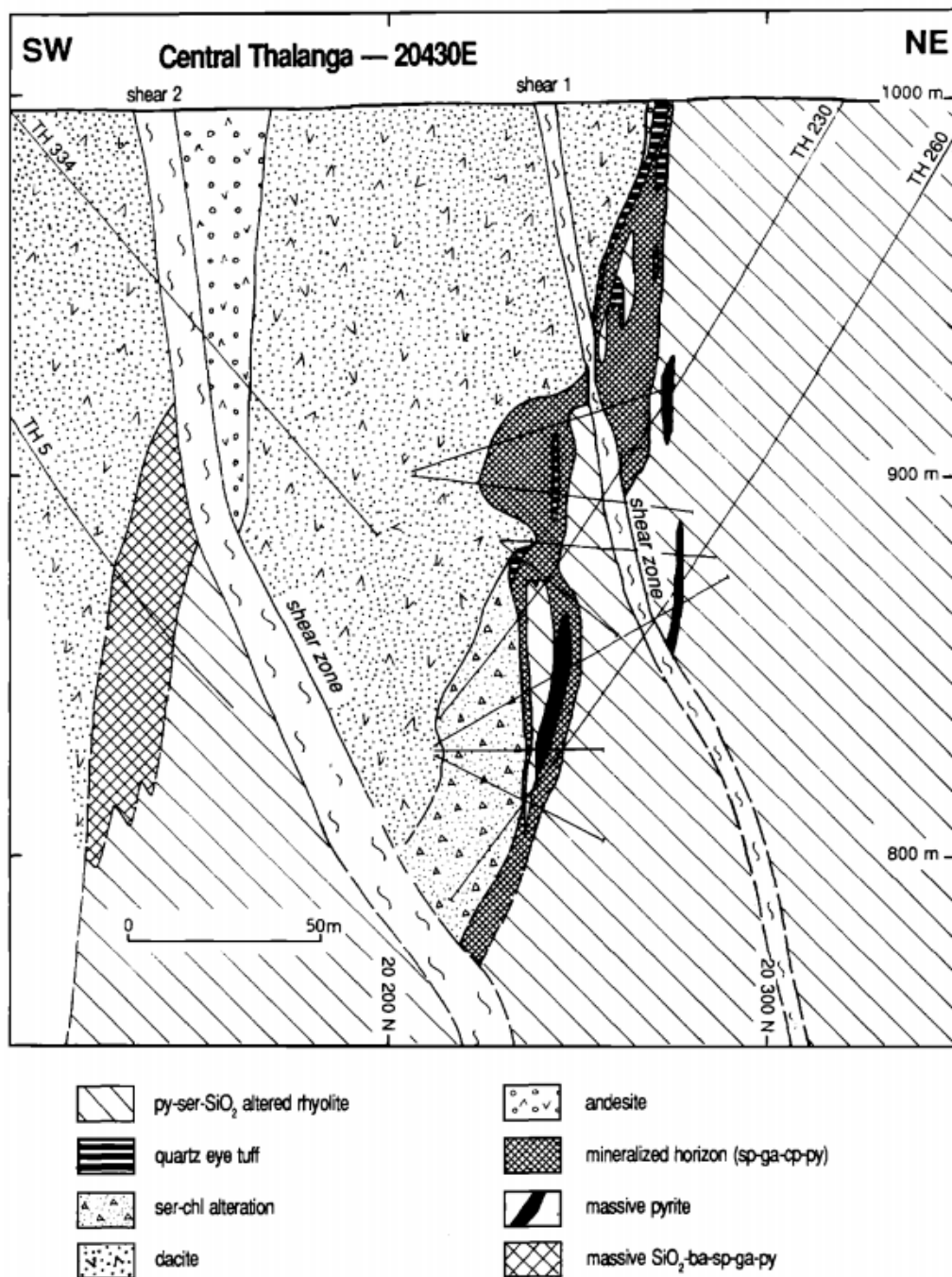


Figure 11 Typical cross section of the Thalanga bed rock geology, showing the geologic relationship of the ore and the host rock (from Berry *et al.*, 1992)

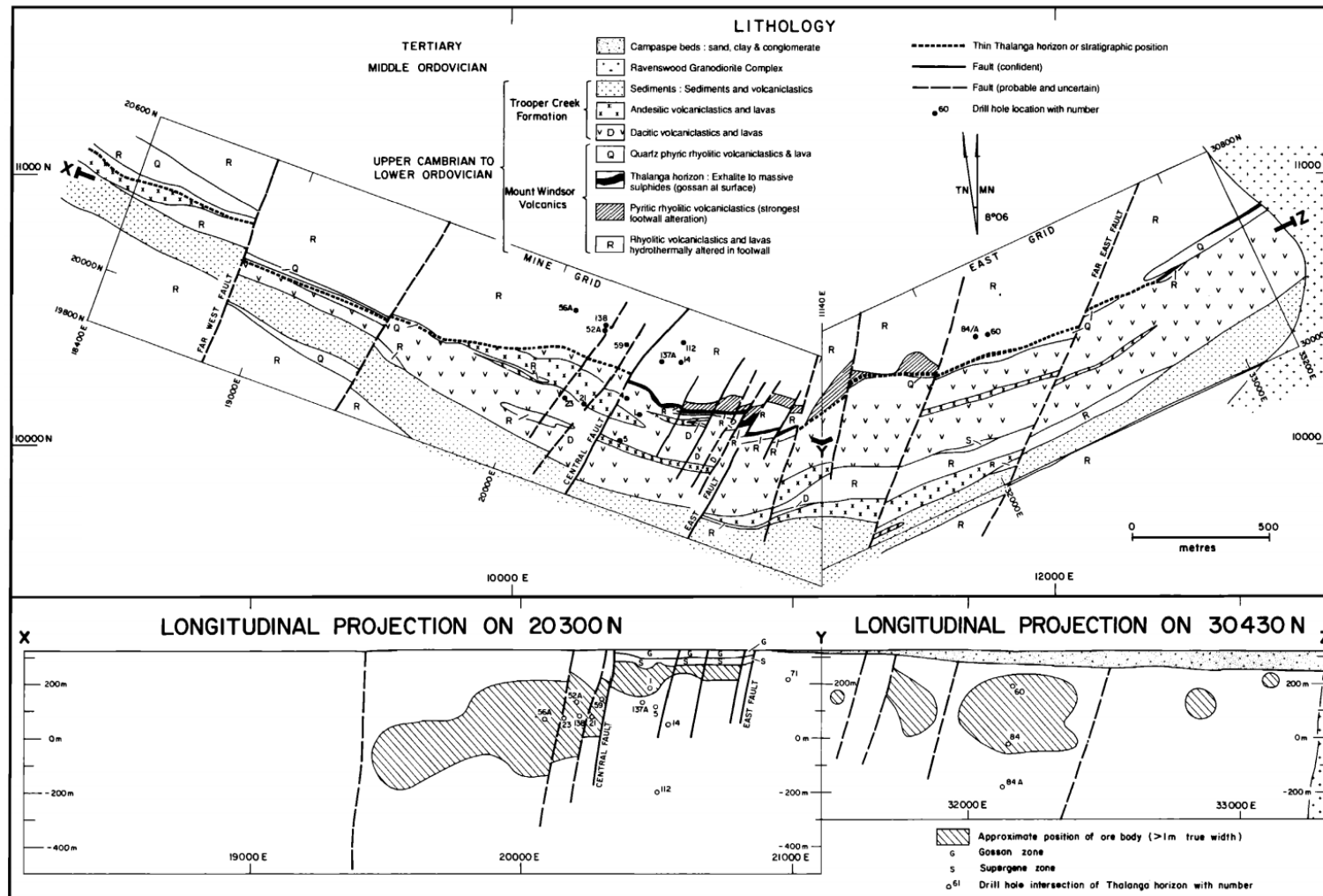


Figure 12 Inferred and confirmed fault locations at Thalanga (from Berry *et al.*, 1992)

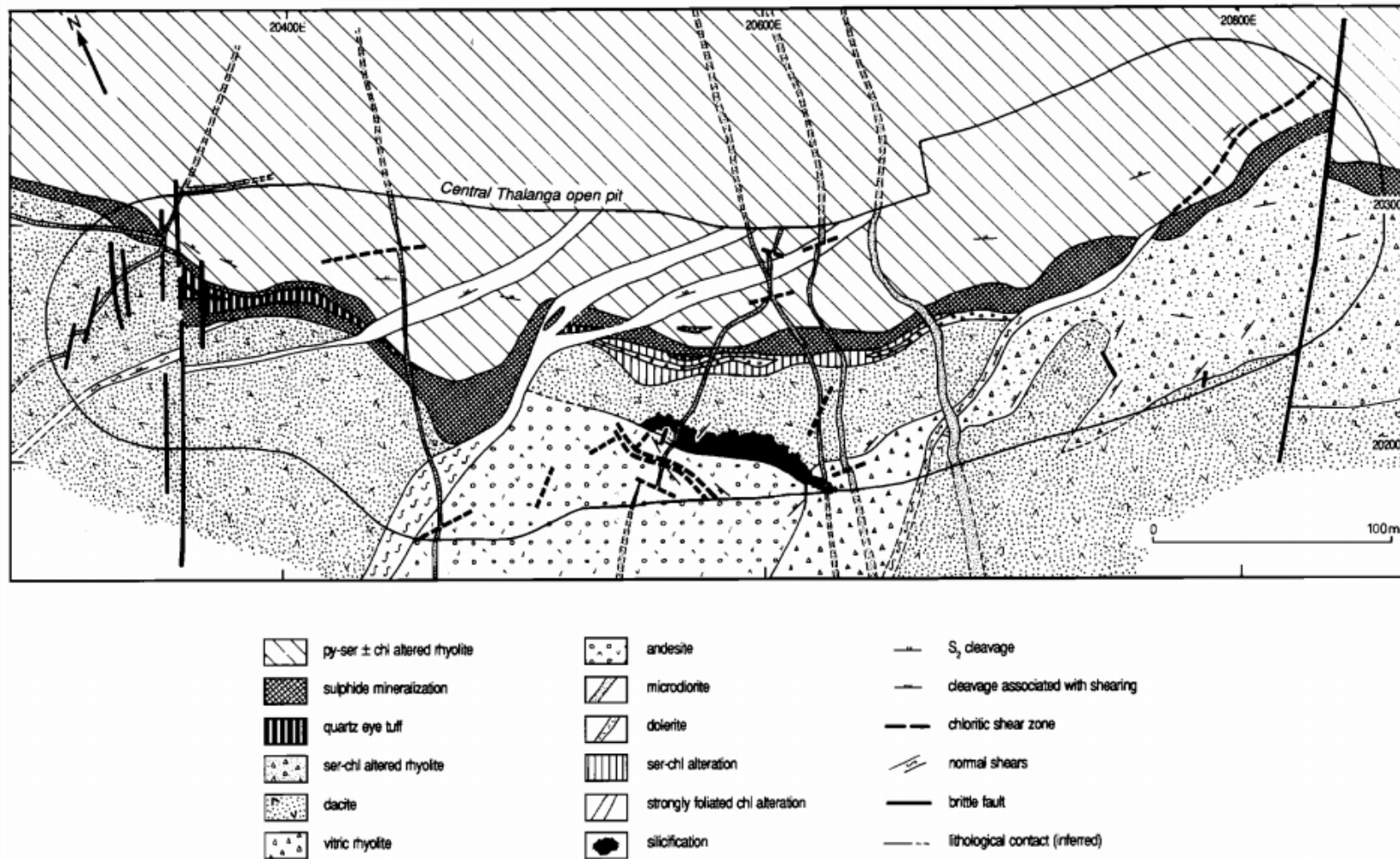


Figure 13 Outline of the initial, now back filled, Thalanga open pit with north south trending microdiorite and dolerite dykes (from Berry *et al.*, 1992)

7.3 Weathered bedrock geology

The rocks around the mining area are intensely weathered up to a depth of 48m. Slight weathering continues to a maximum depth of 72m. The depth of weathering along the ridges to the northwest of the mine site is greatly reduced, where fresh, unweathered material is generally encountered at approximately 40m (Barrett, Askew, Fuller, & Partners, 1982). Berry et al., (1992) described the development of a significant gossan and supergene zone above the Central Thalanga ore lens. The gossan, which consisted dominantly of goethite and limonite to a depth of up to 40m, was the result of prolonged weathering. Below that zone a supergene enrichment zone had formed reaching down to 65m below the surface (**Figure 14**).

The depth to slightly weathered material in the central Thalanga section was approximately 20m (Barrett, Askew, Fuller, & Partners, 1982). Fresh, unweathered rock was generally encountered between 40m and 70m.

During initial exploration groundwater was found to occur in small perched aquifers within very porous, clayey gossan associated with the ore deposit. At times, the water content increased at the gossan/supergene ore boundary, where it presented significant problems for drilling, blasting and sample collection above approximately 960mRL (about 40m below ground level). Below that level, groundwater only caused minor issues (Kendall, 1990).

Fluor Daniel GTI (1998) reported that the ore zone was extensively weathered to a depth of approximately 60m to 70m and overlain by highly porous but generally cemented gossan.

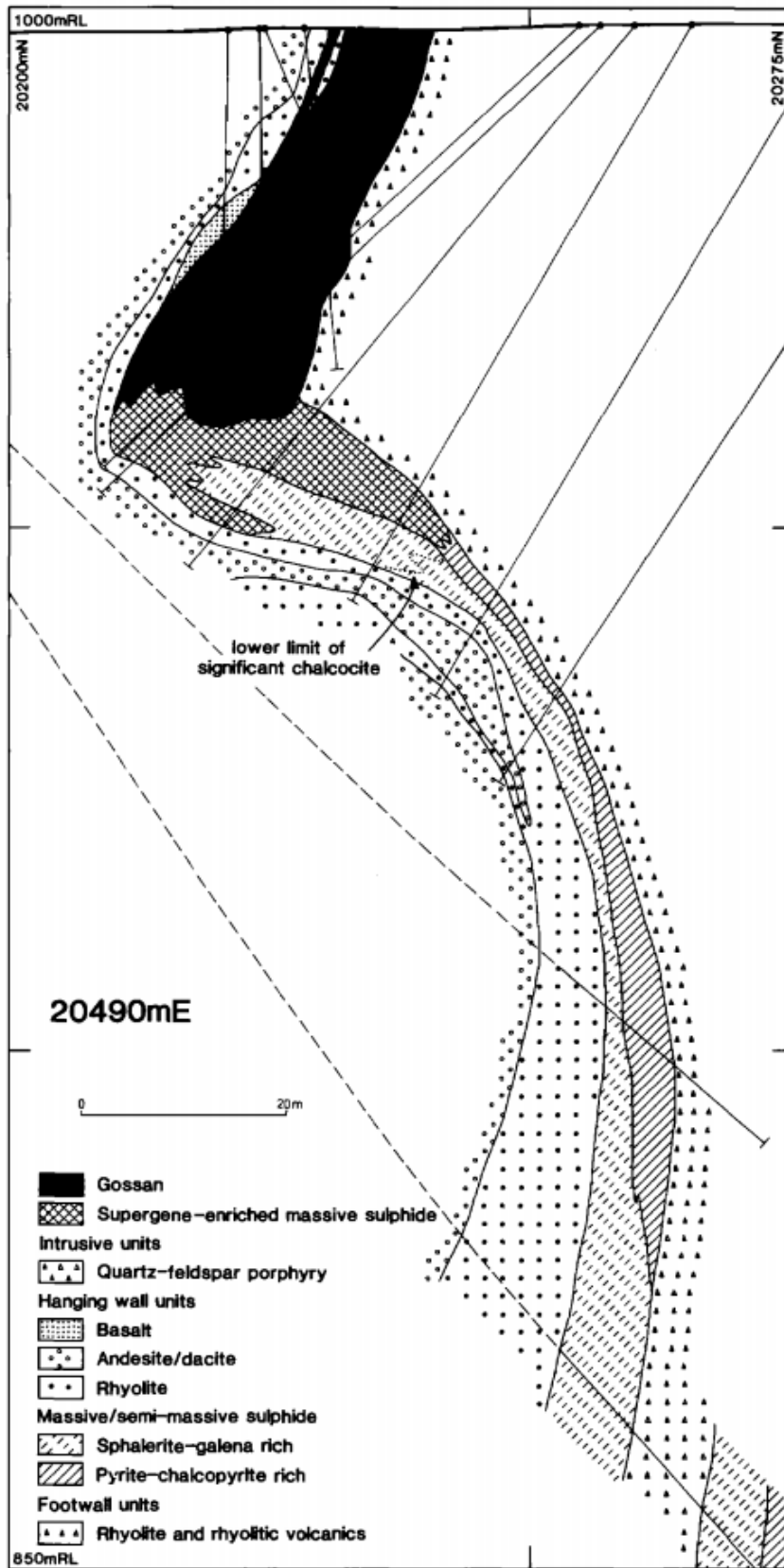


Figure 14 Central Thalanga, showing the development of oxide (gossan) and supergene ores (from Berry *et al.*, 1992)

7.4 Campaspe Formation

Sediments of the Campaspe Formation overlie the Seventy Mile Range Group south and east of the mine site. The Campaspe Beds cover an area of approximately 11,000km² (Henderson and Nind, 2014) and consist of Late Tertiary sediments (1.3 to 3.5 million year old). The sediments are composed of poorly sorted sandstone, coarse conglomerate, ferruginous clay and silt. The sedimentary sequence is in places up to 200m thick (Henderson and Nind, 2014), filling low relief paleochannels. The sediments are often characterised by pore filling by silt and mud, largely emplaced by post depositional infiltration. Due to infilling of pores, this unit is generally expected to have low yield and storage capacity for groundwater (Henderson and Nind, 2014). However, Pitt (1988) found that the Campaspe Formation hosts groundwater reservoirs, the Thalanga mine water supply bore field being one of them. The Campaspe Formation blanket a pre-existing, low relief landscape divided into two sub-basins that mirror the present drainage, by a basement ridge (Henderson and Nind, 2014).

In the Thalanga mine region, a well-defined east, northeast trending palaeochannel has been delineated. The width of this channel varies between 50m and 150m with its base, at its deepest point, being 102m beneath the present-day surface (Pitt, 1988).

Across the Thalanga mine lease, the Campaspe Formation covers mainly the lower lying eastern and northern sections of the lease area. The more elevated western and south-western section of the lease area consist of exposed bedrock of the Seventy Mile Range group and associated shallow colluvium with no aquifer potential. Consistent with the study by Henderson and Nind (2014), the Campaspe Formation appears to have filled a broad valley to the east of the Thalanga lease, becoming thinner towards the west and eventually tapering out against the hills of the Thalanga site (Pitt, 1988). Therefore, there is a gradual increase in the thickness of the Campaspe Beds towards the west, reaching a maximum depth approximately 2km west of the Far West underground workings.

AGC (1981) found that the beds of the Campaspe Formation could further be divided into the generally dominant lower permeability clayey sands of limited aquifer potential, and higher permeability channel deposits. It was noted that these channel deposits were commonly the major source of groundwater in similar comparable Tertiary deposits along the coastal plains.

In 1988 AGC drilled 47 Campaspe locations up to 5700m north and east of the Thalanga mine site. Of these locations, 25 were equipped with casings and one bore was subjected to a 11 month pumping test, leading to the conclusion that the water demand of the future mine could be met by the available supply (AGC, 1988). The same water supply is still being used in 2019.

7.5 Recent alluvium

Recent alluvium at Thalanga is only present along the shallow drainage lines of the creeks in the area. AGC (1981) noted that recent riverbed sediments of the major creeks in the area contained gravels with good aquifer potential. However, it was also found that the volume of these gravels was restricted laterally and in depth. Small pockets of shallow subsurface water storages along the drainage lines are subject to rapid evaporation and hence accumulation of salinity.

Considering the subtropical savanna climate at Thalanga, the shallow alluvial aquifers are considered ephemeral. Seasonal recharge will be provided by rainfall and runoff only. Given low topographic gradients, aquifers present away from the drainage lines are not expected to express on the surface.

8 Hydrogeology

8.1 Pre-mining baseline conditions and environmental values

Pre-mining baseline conditions can be described by utilizing information from pre-existing landholder bores, pre-mining Thalanga mine water supply bores and information obtained from exploration bore holes on the Thalanga site. There are no springs or groundwater dependent ecosystems in the vicinity of the Thalanga lease. The nearest wetland areas of high ecological significance are located 15km to the east (QLD Wetland mapping ID 97079) and 17km to the south east (QLD Wetland mapping ID 97271). Wetland ID 97079 is located hydrological upstream of the Thalanga site, whereas wetland ID 97271 is located with a paleochannel of Homestead Creek and Balfe Creek. The latter receiving flow from Travers Creek, which passes the Thalanga site. All of the creeks in the area are shallow and seasonal in nature, and none are dependent on groundwater flow. There is no hydrogeological connection between the Thalanga site and the creeks surrounding the site.

Environmental values for groundwater are limited to use for livestock (cattle) drinking water and industrial use by the Thalanga mine. Available groundwater occurs besides minor temporary occurrences in alluvium mainly in the Campaspe Formation sediments. There are no natural surface expressions of groundwater in the Thalanga area. Hence, considering that Campaspe Formation groundwater is being used as a mine water supply for the last 30 years, guidelines for livestock drinking water are considered the applicable guidelines with regards to the local Environmental values.

8.1.1 Pre-mining landholder bore inventory

The pre-mining registered landholder bore inventory within 5km of the Thalanga mine site consisted of 6 shallow groundwater bores (Table 4). Information available on these 6 bores is sparse (Map and available bore records in **Appendix F**), generally comprising of depth, bore diameter and installation method. Some limited strata records for available suggesting that most bores have been installed through thin alluvium into the underlying Campaspe Formation. Water quality, standing water levels and yield information varies, possibly as a result of bore installation and the influence of the overlying rainfall fed alluvium.

Table 4 Summary of pre-mining landholder bores within 5km of the Thalanga mine

	RN60286	RN60287	RN60289	RN60633	RN60637	RN60638
Strata	-	Alluvium (Campaspe)	-	Alluvium (Campaspe)	Alluvium (Campaspe)	Alluvium (Campaspe)
Depth	15.2m	18.3m	21.3m	40.8m	43.2m	51.2m
Diameter	910mm	1000mm	1500mm	125mm	125mm	125mm
SWL	-2.1m	-	-	-16.2m	-18.3m	-20.4m
EC	-	203µS/cm	2500µS/cm	-	4050µS/cm	3020µS/cm
Yield	0.19L/s	0.38L/s	0.19L/s	1.26L/s	0.88L/s	0.76L/s
Status	existing	destroyed	existing	existing	existing	existing

8.1.2 Pre-mining Thalanga mine water supply bores

In addition to the few landholder bores RGC Thalanga, in need of a water supply for the then proposed Thalanga mine, engaged Australian Groundwater Consultants (AGC) to test the nearby Campaspe Formation for additional supply bore locations. Between 1983 and 1984 about 45 groundwater exploration holes were drilled into the Campaspe Formation at a distance between 2 and 6.5km north and east of the future Thalanga processing area. Of these groundwater exploration holes, five were converted into production bores while an unknown number of the remainder was used to measure draw down during a 11 months long pumping test. Subsequent installation of additional monitoring bores confirmed the initial assessment that the Campaspe Formation could supply the anticipated water requirements (2000m³/day) for the Thalanga mine.

8.1.3 Pre-mining aquifer information

Prior to the start-up of the Thalanga operation the only available aquifer information was through landholder bores and preliminary drilling of the Campaspe Formation. The suitability of the Campaspe Formation as a water supply was confirmed through the drilling and testing of the Thalanga bore field.

The available records for the registered landholder bores, as shown in **Table 4** state that the bores have been installed within alluvium to a depth of 51.2m (RN60638). It must be stressed that this alluvium was unlikely recently deposited material, but rather the sedimentary sequence of the underlying, older sedimentary Campaspe Formation. As such, the available information for yield and EC seem to confirm this assessment as yields from recent uncemented alluvium would a) be considerably higher; and b) since recharged by recent rainfall, EC would be considerably lower. Also, considering the contemporary local morphology and the absence of significant streams or gradients, the accumulation of up to 51m of recent alluvium would be very unlikely. Nevertheless, the targeting of the Campaspe Formation confirms that this aquifer is of significance for small water supplies in the area. However, as **Table 4** also shows, water quality, even with regards for livestock use, can be marginal.

Prior to the Thalanga operation only limited groundwater information was available for aquifers within the volcanic bed rock. The earliest sighted study by AGC (1981) was the initial attempt to locate a water supply for the then proposed Thalanga mine. Based on the limited information available, AGC (1981) stated that the volcanic bedrock was not expected to yield significant groundwater except along distressed faults or fracture zones.

Barrett et al. (1982) reported on a few geotechnical issues that are directly relevant to the hydrogeological understanding of the Thalanga site. They characterised the rock quality, which has been described in the geology section, and noted that the depth to slightly weathered material in the central Thalanga section was approximately 20m. Fresh, unweathered rock was generally encountered between 40m and 70m. With direct reference to groundwater, Barrett et al. (1982) reported that surface drilling did not encounter groundwater flows and that the development of the initial Penarroya decline encountered flows up to 0.83L/sec from near the surface, or when continuous joints, faults or shears were encountered. Flows of up to 6.94L/sec were encountered from underground drill holes that intersected water bearing structures. The assessment at the time concluded that inflow into the decline was generated by simple groundwater depletion from above the orebody and that the larger measured flow volumes originated from a number of major structures in the production areas, i.e. the ore body, associated sub-parallel foliations. The latter comment is significant with regards to understanding the hydrogeology of the Thalanga site and will be elaborated on in the current aquifer situation section of this EE report.

8.1.4 Pre-mining groundwater flow gradients

Based on the limited information available a detailed assessment of pre-mining flow gradients is only tentative. Overall, groundwater flow across the pre-mining Thalanga site would have been along the weathering boundary, following the topographic gradients. The ore body and associated sub-parallel foliation would have represented an aquifer with storage but since confined with limited flow or interaction with the surrounds.

As for the Campaspe Formation, detailed hydrogeological information is available through the drilling and pumping tests of the Thalanga bore field. AGC (1988) provided a potentiometric map showing the groundwater flow directions within the Campaspe Formation, approximately 1km to 2km northeast of the Thalanga mine site (**Error! Reference source not found.** in Appendix C). Groundwater levels for a large number of these early bores have been measured throughout the initial mine development and subsequent tailings backfill of the underground workings. The water level records for these bores are presented in Appendix G.

8.2 Mining induced changes

8.2.1 Hydrogeological site history

The operational history of the Thalanga mine had profound influences on the hydrogeological development of the site. Groundwater level changes were determined through monitoring bores installed for various purposes at various sections of the mine site, excavated voids, exploration holes, as well as apparent surface soil saturation. A chronological account of groundwater level changes tied to the mining history in the introduction is given below.

8.2.1.1 Phase One (1989 - 1998)

As stated earlier the Phase One operation at Thalanga commenced in June 1989, consisting of the initial Central Pit and connected underground workings. The Central Pit and underground workings required dewatering, therefore lowering the groundwater table within the deposit. Subsequent ore processing produced tailings and process water, potentially creating elevated recharge areas on the original land surface. Both dewatering and the creation of artificial recharge areas have the potential to modify the hydrogeology of the site.

8.2.1.1.1 Central Pit

The initial mining of the Central Pit (1989 - 1990) resulted in the dewatering of the open pit only. A comparison between the dewatered 75m deep Central Pit and bores along the pit rim (WM1, WM2, WM4, WM5 and WM6) showed that dewatering was successful within the deposit, while dewatering had little influence on groundwater levels of the surrounding rock (**Figure 15** and **Figure 16**).

Dewatering of the initial Central Pit progressed through the use of two pumping holes in the central eastern section of the open pit. Mining commenced in late June 1989 and concluded in October 1990 (Kendall, 1990). Monitoring of the drawdown within the ore zone and the adjacent footwall and hanging wall occurred. From the hand-written records (Appendix H), bores WM1, WM2, WM5 and WM6 are located within the footwall and hanging wall of the deposit and have sufficient data to allow for a visual water level trend assessment. The monitoring bores within the open pit were clustered around the pumping bores within the ore deposit (**Figure 16**). Water levels of the bores on the pit floor were reported as 2m to 10m below ground level, which would have been near the bottom of the final open pit at the time of measurement. While the reference point and the groundwater level in the open pit is reduced to approximately 70 - 75m below ground level, groundwater levels in the surrounding footwall and hanging wall bores WM1, WM2, WM5 and WM6 remained fairly stable and at least 20m above the pit floor.

Opportunistic measurements during 2000 and 2001 of the pit rim bores WM1, WM2 and WM3 (Thienenkamp; 2004) showed that groundwater levels in 2 of the 3 bores remained at similar levels than measurements recorded 10 years earlier.

The above observations are consistent with the geological conditions of the ore deposit, which suggests that the ore deposit is the main aquifer section within the volcanics at Thalanga. A strong compartmentalisation of the surrounding bedrock aquifer has been stated in almost every hydrogeological investigation since 1981 (AGC Australian Groundwater Consultants (1981); Barrett, Askew, Fuller, & Partners (1982); Fluor Daniel GTI, (1998); URS (2002); Rob Lait & Associates (2011)). The demonstrated minimal interconnection between different aquifer sections in and around the Central Pit is a key observation confirming such compartmentalisation.

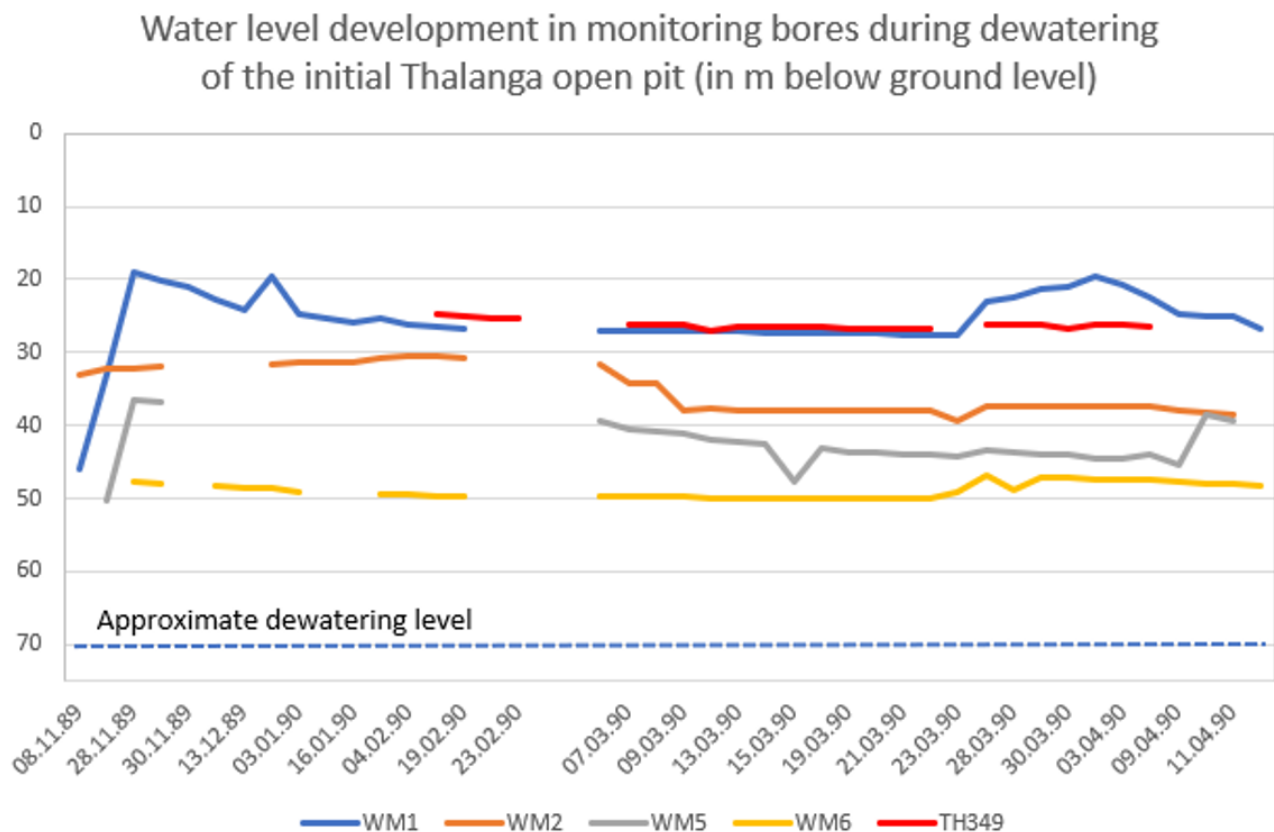


Figure 15 Water level in the initial Thalanga pit compared to dewatering monitoring bores

The early experience of the Central Pit dewatering suggests that there is limited hard rock connection between the deposit and the surrounding country rock.

With continued mining of the various connected Thalanga underground orebodies, the Central Pit remained dry until it was partially backfilled in the 1998/1999 wet season. Importantly, prior to backfilling the Central Pit, the underground workings directly below the Central Pit were driven upwards to excavate as much as possible of the high-grade ore (crown pillar) that commonly forms the bottom of an open pit. As a result of that upwards excavation, the crown pillar collapsed, essentially opening a direct hydraulic connection between the Central Pit and the underground workings below.

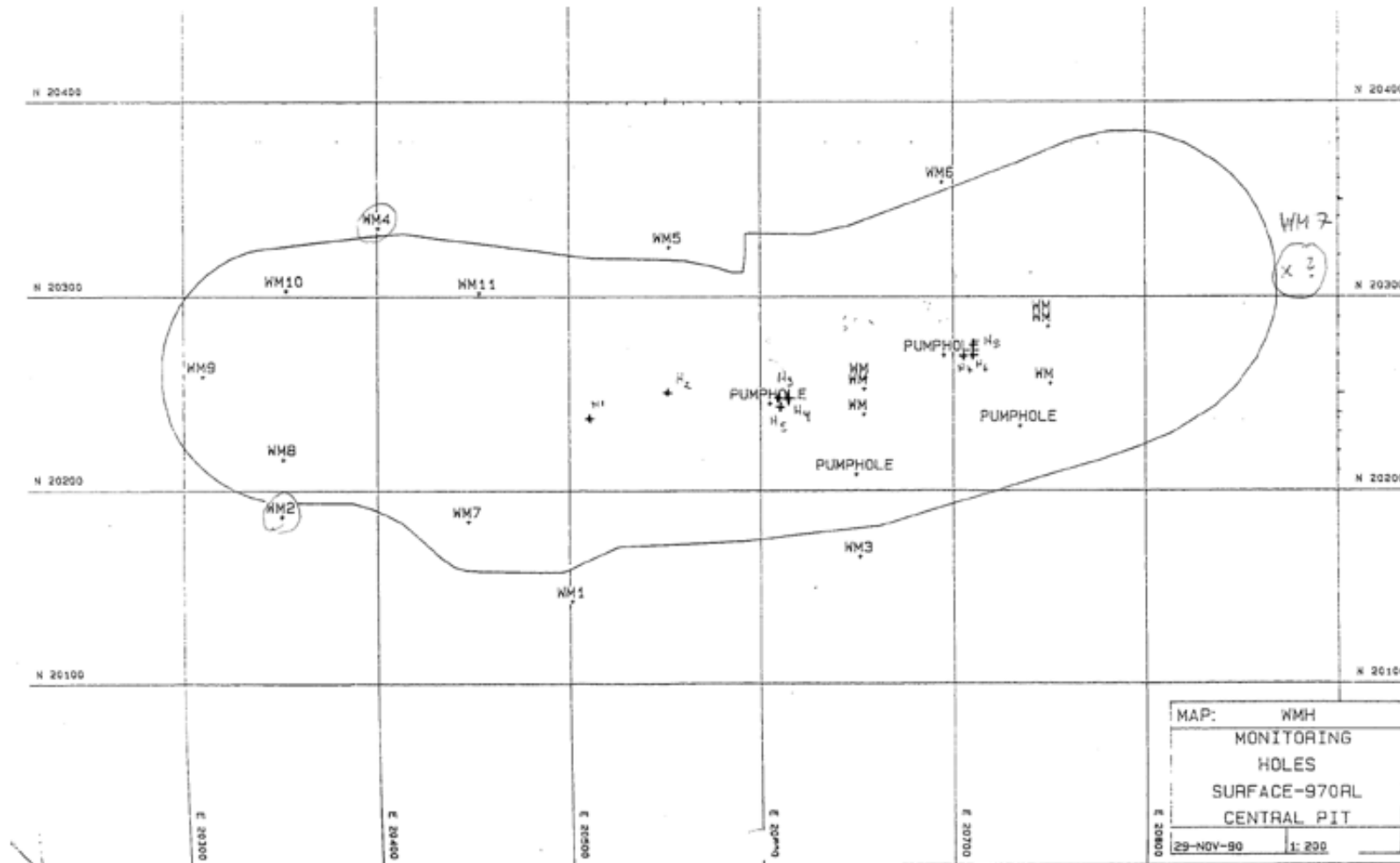


Figure 16 Location of the Central Pit dewatering and monitoring bores

8.2.1.1.2 Waste rock dumps

The presence of the 700,000m³ East WRD and 1,230,000m³ West WRD most likely had an influence on the hydrogeological characteristics of the underlying strata. The effects of the larger West WRD likely greater than these of the smaller East WRD. While the former was positioned off the strike of the orebody, the hydrogeological effect of the latter was probably reduced by its proximity to the Vomacka underground and associated exploration hole connection.

8.2.1.1.3 Underground

Between 1990 and 1998 the underground workings at Thalanga extracted about 4.753.000t of ore from five connected satellite orebodies accessed and spreading away from the initial Central Pit along the strike of the deposit. The Vomacka and Thalanga East deposits were accessed via a decline originating in the upper eastern section of the Central Pit. The Thalanga West, the Far West decline and Central Thalanga deposits were accessed via a decline in the lower south western portion of the Central Pit (**Figure 17** and **Figure 18**). In addition, the collapse of the crown pillar created a direct connection to the Central and West Thalanga underground.

There were no groundwater monitoring bores that could have documented the impact of the 1990-1998 underground dewatering.

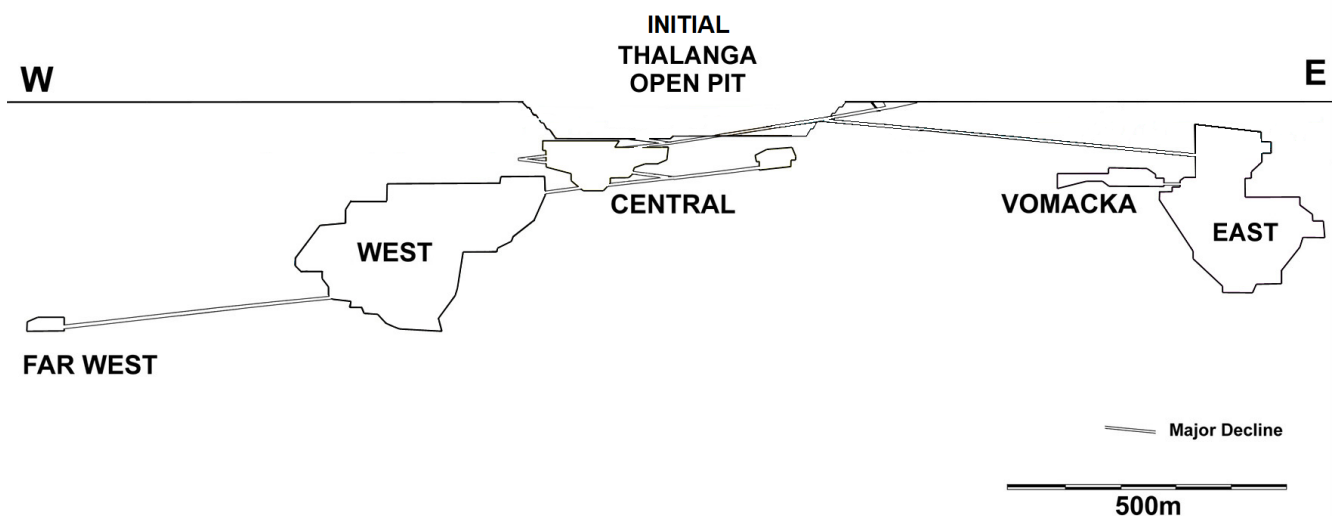


Figure 17 Cross section through the Thalanga underground extent at the end of 1998

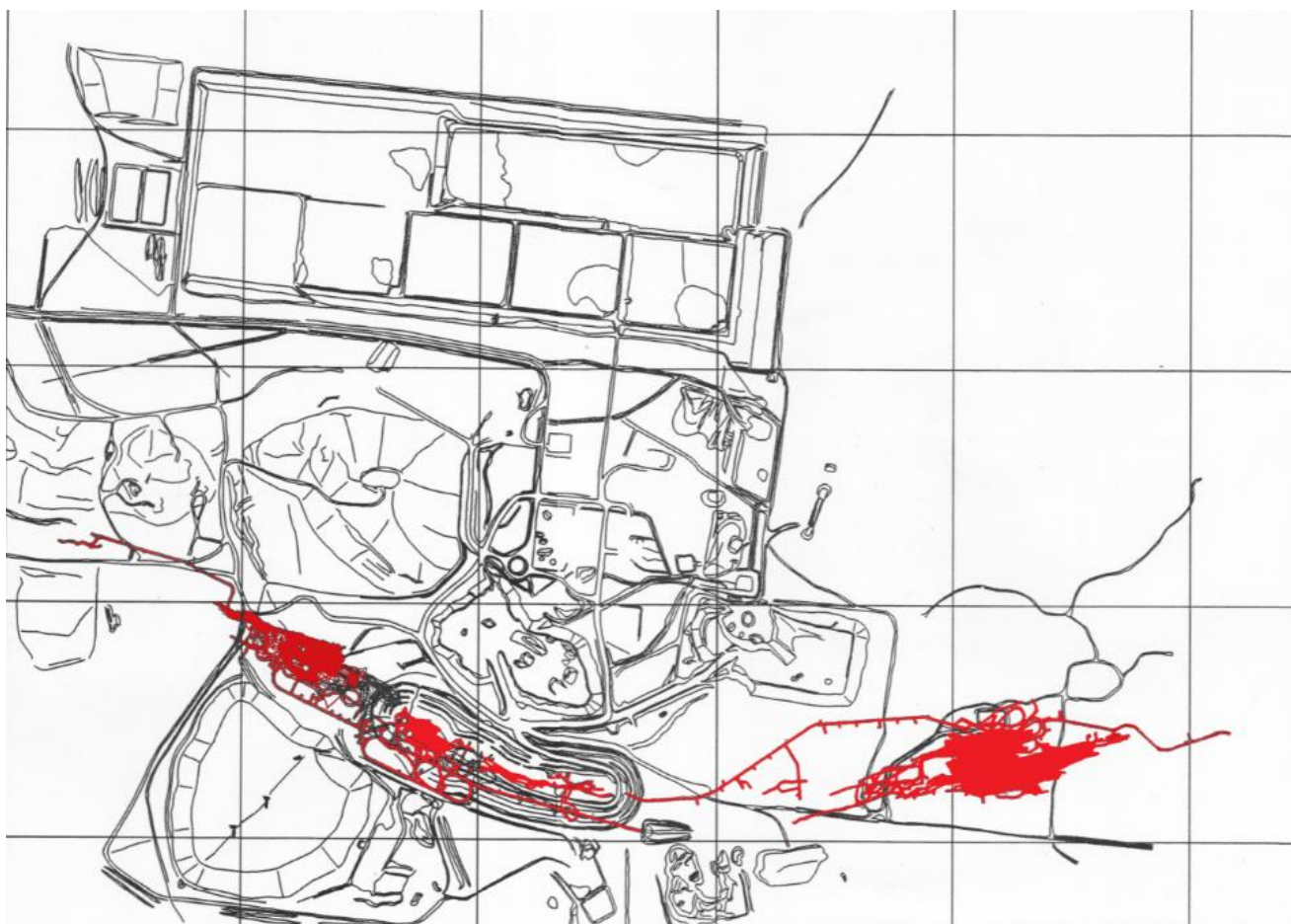


Figure 18 Top down view of the extent of the Thalanga underground workings as of the end of 1998

8.2.1.1.4 Tailings dams and water storage

The tailings at Thalanga were stored in tailings Cells 1 to 7 (45 ha) and decant water was collected in a small (1.2 ha) decant dam, now buried below Cell 9. Process waters and site run-off were stored in the still operational East Evaporation Dam (7.6 ha) and smaller East Evaporation Pond (0.13 ha), the Temp Dam (1.0 ha) and the Southern Waste Rock Sedimentation Dam, the dam now incorporated into the Wet Land area.

Regular groundwater monitoring at Thalanga commenced in September 1989 with monitoring of the initial tailings dam bores (alternative names in brackets) A1(TD2), A3(TD4), NB(TD5) and H(TD6), followed in 1990 by the monitoring of I(TD1), A2(TD3) and F(TD7) and joined in 1995 by TD10 (**Figure 19**). Due to several changes in ownership, the naming of these monitoring bores has changed over time and the expansion of the tailings dam areas resulted in bores B, C, D, E being destroyed. Bores F, G and H were consumed by the later cell 9 extension and the fate of bores A1 and A2 are unknown. Of the initial tailings monitoring bores only bore A3 remained serviceable in 2019.

Data on groundwater levels for a number of historical tailings dam monitoring bores is available from January 1997 to December 2000 (**Figure 20**).

Regardless of their condition, monitoring records for bores A1, A2, A3, H and F exist for the years between 1997 and 2000 (for bore A3 till 2018). The groundwater level records for these bores only start about 7 years after operation began at Thalanga. These measurements are nevertheless useful with regards to interpreting the groundwater level behaviour at Thalanga. Particularly the development at A1, A3 and H offer an insight into groundwater level changes due to the construction and operation of the tailings dams (**Figure 20** and **Figure 21**).

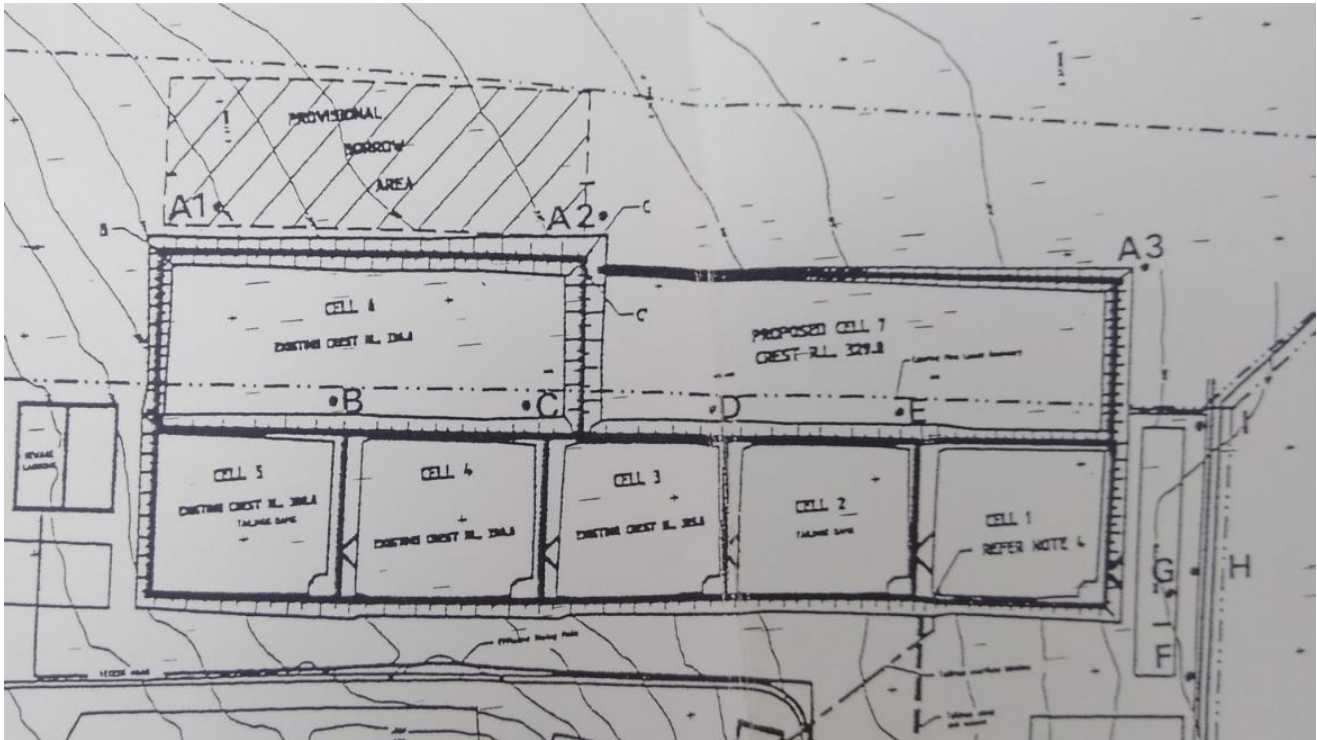


Figure 19 Existing and proposed tailings cells at Thalanga in 1996 (from RGC, 1996)

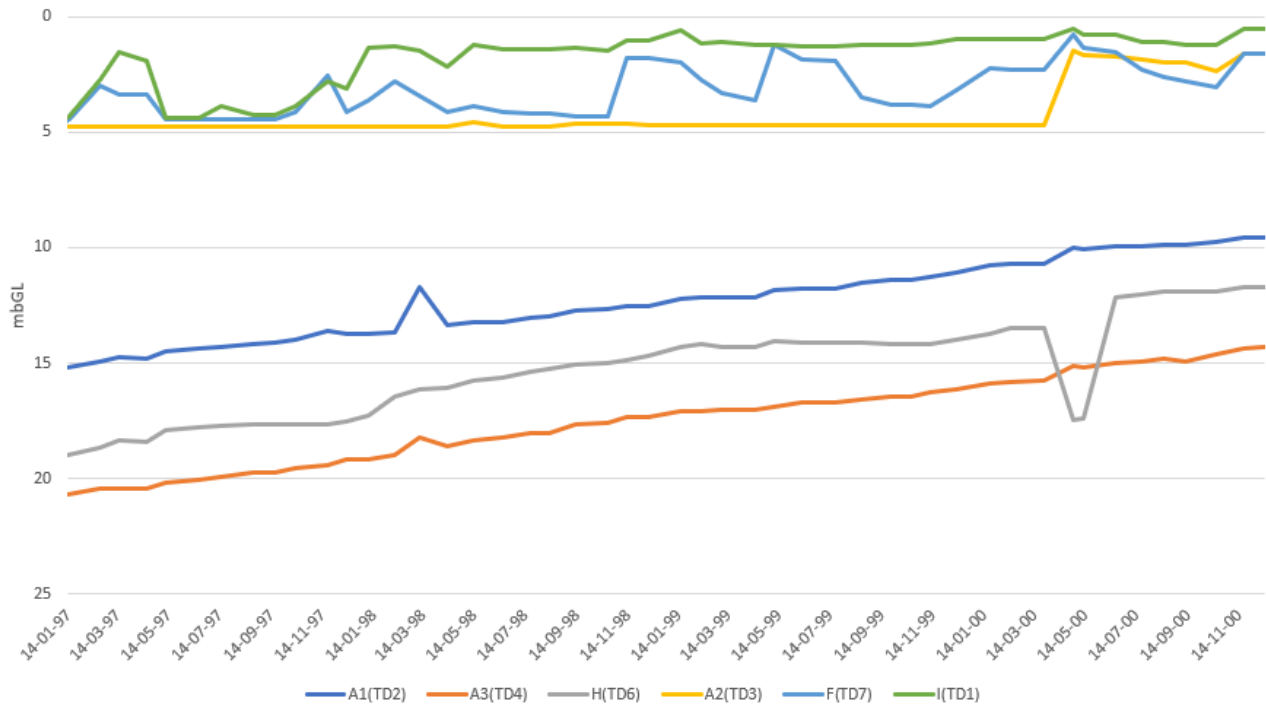


Figure 20 Groundwater level behaviour at tailings dam monitoring bores A1(TD2), A2(TD3), A3(TD4), H(TD6), F(TD7) and I(TD1) between January 1997 and November 2000

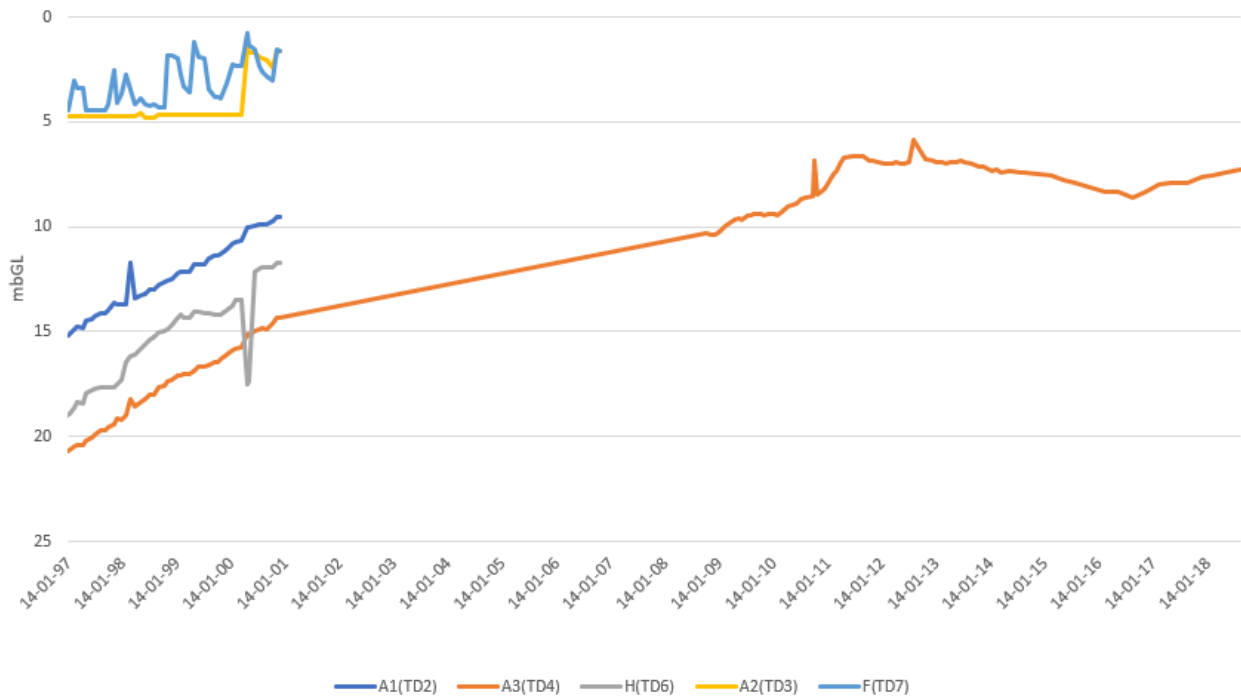


Figure 21 Groundwater level behaviour at tailings dam monitoring bores A1(TD2), A2(TD3), A3(TD4), H(TD6), F(TD7) between January 1997 and August 2018

It is clear from the generally uniform rise of water levels that tailings deposition in the tailings dams had an influence on groundwater tables in the vicinity. From the groundwater tables alone, it is not clear if groundwater level increases are due to direct seepage or are the result of aquifer compression. Also, records for bores A2(TD3) and F(TD7) in **Figure 21**, suggest that shallow bores are either not impacted since their water level is above the rising trend, or alternatively have been impacted prior to the water levels being recorded.

What also becomes obvious by looking at **Figure 20** and **Figure 21** is that groundwater levels within the deeper groundwater horizons of bores A1(TD2), A3(TD4) and H(TD6) have been increasing despite water levels in the underground workings 1,000m to 1,400m to the south being at their minimum (reaching -450m below ground level in May 1998).

8.2.1.2 Phase Two (1998 – 2006)

Phase Two at Thalanga started in 1998/99 and lasted till 2006. Phase Two is marked by the backfilling of the Central Pit with the West WRD. The West WRD, consisting of AMD generating massive sulphide waste, became a source of ongoing acid surface seepage soon after its construction. After several attempts failed to control the acid seepage, the WRD was relocated to partially fill the Central Pit.

Phase Two saw a change of processing technique to treat copper - gold ore from the Highway Reward deposit approximately 45km east of Thalanga, it is also characterised by the uninhibited deposition of tailings into the underground voids. Prior to that (between 1991 and 1995) minor volumes of thickened tailings had been selectively deposited underground behind constructed bulkheads (Thalanga Copper Mines, 2002). However, during Phase Two tailings appeared to have been simply pumped down open exploration holes (Thienenkamp, 2004).

8.2.1.2.1 Central Pit

The Central Pit, partially (~75%) backfilled with acid generating waste rock, remained uncapped and soon became a site surface water sink. Combined with the volumes of underground tailings deposition, water levels rose into the bottom of the open pit, eventually forming an alkaline surface water body in the lowest section of the pit. Water quality soon changed from alkaline to acid.

The first appearance of alkaline water was aided by the method of waste rock deposition into the Central Pit. The method used was 'end dumping', which results in an accumulation of coarser material at the base of the dump slope, forming a basal zone with high hydraulic conductivity. Combined with the collapse of the crown pillar, tailings decant water from below was now able to rise into the remaining pit void encountering mainly coarse grained, unoxidized rock material. Due to the initially limited contact with acid generating materials, the rising tailings decant water was at first able to maintain its alkaline composition. Upon the later rise of water in the pit, saturation of the fine grained, strongly acid generating waste rock occurred. Consequently, alkaline conditions could not be maintained, and the pit water body became acid.

8.2.1.2.2 Underground

Underground operations at Thalanga ceased in 1998 and the only relevant activity consisted of the processing of Highway Reward copper-gold ore and tailings deposition via exploration holes.

It is not clear if the practice of underground tailings deposition halted after the appearance of the pit water body, clear is that water levels continued to increase in the Central Pit.

Besides the created Central Pit water body, the underground tailings deposition concurred also with the development of large surface subsidence areas (about 100 x 100m) both in the West zone and the East zone of the Thalanga lease.

The appearance of a pond in the Central Pit prompted the installation of 8 deep (V1, V2, V3, V4, V5, V6B, V7B and V8B) and 3 shallow (V6A, V7A and V8A) monitoring bores in 2003. The bores were designed to monitor the impact of underground tailings backfill (**Table 5** and Error! Reference source not found.), however due to subsidence issues at the Eastern deeps section, locations V7A/B and V8A/B soon became non-operational.

Table 5 Underground tailings backfill monitoring bores

East	North	Name 1	Name 2	depth	slots	Initial SWL*	Initial TDS**
371071	7750980	PZ-001	V1	50m	32-50m	-41m	1200ppm
371182	7750489	PZ-002	V2	50m	29-50m	-30.2m	5200ppm
371466	7750645	PZ-003	V3	50m	32-50m	-30m	-
371795	7750113	PZ-004	V4	50m	32-50m	-33m	5340ppm
372450	7749855	PZ-005	V5	40m	28-40m	dry	-
372856	7750258	PZ-006a/b	V6a/b	50m	14-20m 29-41m	-40m	1600ppm
372490	7750530	PZ-007a/b	V7a/b	50m	8-14m 32-50m	dry	-
372976	7750530	PZ-008a/b	V8a/b	61m	25-43m 55-61m	-32m	1620ppm

*SWL = standing water level

**TDS = total dissolved solids

A review of the initial historical development at these bores between 2003 and 2006 (**Figure 22**) shows that groundwater levels of most bores in the 3 years following bore installation were relatively stable, indicating that either underground tailings backfill had no immediate impact; groundwater tables had already risen; or tailings deposition was not occurring at the time.

Regardless, by 2006 the acid pond within the Central Pit had flooded the decline connecting the Vomacka and East underground workings to the Central Pit (**Figure 23**).

RGC Thalanga continued to operate till 2004. In 2006 the site was acquired by Kagara starting the third phase of the Thalanga operation.

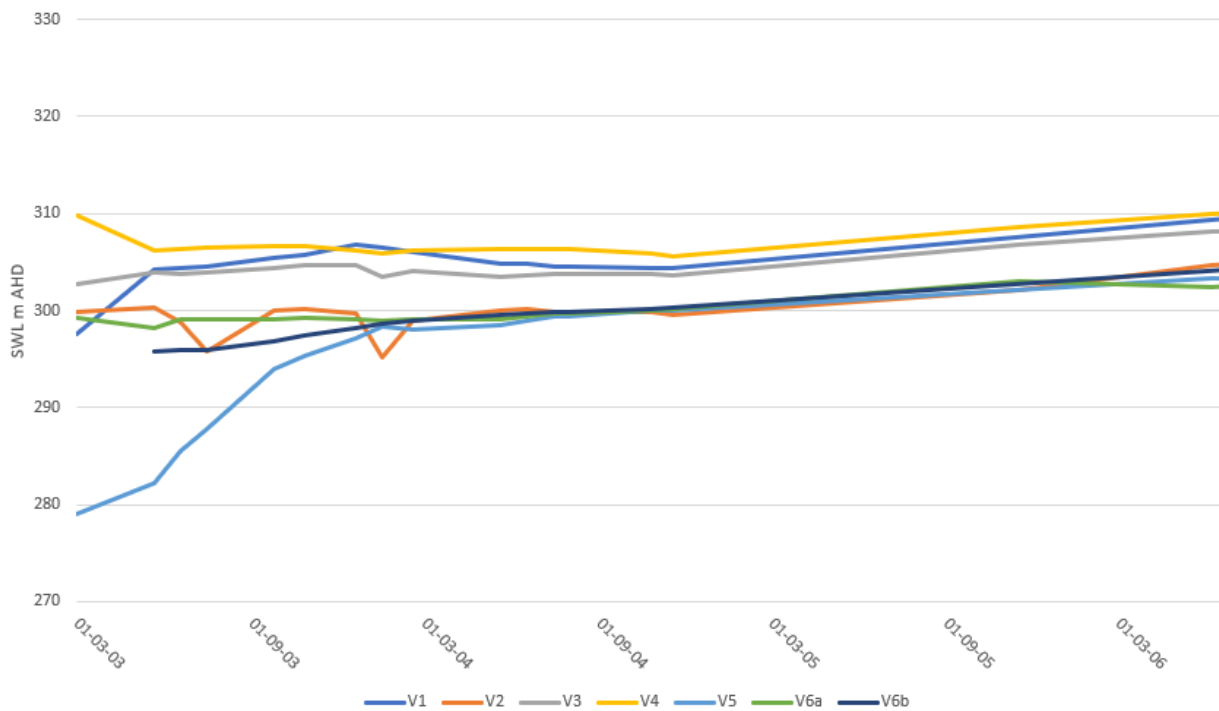


Figure 22 Groundwater level development at V1, V2, V3, V4, V5 and V6A/B between installation in 2003 till mid 2006



Figure 23 Flooded East Thalanga decline within the Central Pit in 2006. Flood level at approximately RL 308m, inferred from a comparison between mine plans and available topographic maps

8.2.1.2.3 Tailings dams, water storage and investigation of perched aquifer

During the later stage of Phase Two the surface tailings storage at Thalanga underwent a minor lift and convergence of tailings cells 1 and 7. Groundwater level records for the tailings dam bores are not available for the period between December 2000 and October 2008 (**Figure 21**).

Kendall (1990) reported the presence of a shallow perched aquifer in the southern portion of the Thalanga lease, south of the initial Central Pit (**Table 6** and Error! Reference source not found.). The removal of the West WRD in 1998 produced an area of permanently ponding acid water in the footprint of the former WRD. To investigate the presence of perched, near surface aquifer sections in the vicinity of the former West WRD, ten shallow and two deeper bores were installed in 2001 (MW-1, MW-2A/B, MW-3, MW-4A/B, MW-5, MW-6, MW-7, MW-8, MW-9 and MW-10). Only two of the shallow bores recorded water at a level between 1.55m and 1.7m, the rest of the other eight shallow bores remained dry (URS, 2002). The two shallow bores containing water were MB-2A and MB-3, closest to the former West WRD and the Dacite WRD respectively. Both locations can be considered impacted by the hydraulic ground loading effects introduced by the prolonged presence of the former WRDs. Initially described in the study of soil mechanics, it is now widely acknowledged that surface loading can impact on the groundwater environment (see, for example, Rodhe & Bockgard, 2006 and Rasmussena & Moteb, 2007). The deeper bore sections both reported groundwater with water levels between 10.7m and 13.61m below ground level, this was despite the remaining ~70m deep Central Pit still being dry at this stage.

Besides the initial measurements following installation there appear to be no additional measurements from MW-1, MW-2A/B, MW-3, MW-4A/B, MW-5, MW-6, MW-7, MW-8, MW-9 and MW-10. Neither are there records of groundwater quality from these locations.

Table 6 Details of shallow and nested monitoring bores installed in 2001

Bore	Easting	Northing	depth	SLOTS	SWL (May 2001)
MW-1	371486	7749806	3	1.6-3	dry
MW-2A	371342	7749784	3	0.5-3	1.55m
MW-2B	371342	7749784	24	20-23	10.7m
MW-3	371770	7749739	2.4	1-2.5	1.7m
MW-4A	371759	7749546	3	1.5-3	dry
MW-4B	371759	7749546	22.5	19.5-23	13.61m
MW-5	372097	7749453	3	1.5-3	dry
MW-6	371202	7749459	3	1.5-3	dry
MW-7	371122	7749408	3	1.6-3	dry
MW-8	371606	7749384	3	1.6-3	dry
MW-9	371937	7749397	3	1.6-3	dry
MW-10	371873	7749591	3	1.6-3	dry

8.2.1.3 Phase Three

Phase Three of the Thalanga operation (2006 - 2008) started with the processing of copper ore from Kagara's initial Balcooma operation, utilising the existing Thalanga processing plant.

Groundwater monitoring records for the period appear to be absent and no additional monitoring bores were installed until 2008.

8.2.1.3.1 Central and Vomacka Pit and underground

Phase Three saw the direct discharge of water from the evaporation pond into the remaining Central Pit void. This process was only discontinued with the commencement of the Vomacka open pit operation of Phase Four in 2008. Rob Lait and Associates reported that process water deposition into the Central Pit continued till at least February 2008 and only ended with the need for dewatering of the Vomacka pit. It can be assumed that by 2006 (see **Figure 23**) the underground voids had no additional capacity. There are no records suggesting that underground tailings deposition was continued following the acquisition by Kagara. Regardless, the deposition of surface water into the remaining Central Pit void would have filled any remaining underground voids.

Rob Lait reported that in pit deposition of process waters to the pit rim had resulted in elevated groundwater tables at the Vomacka location (RLA 2008B). In addition, in early March 2008 Kagara staff reported that water had expressed at the Eastern Deeps subsidence area (see **Figure 5 in Appendix C**). That surface water expression was explained with the impacts of a particularly good 2007/2008 wet season. However, the unexpected surface water expression also evoked fears that artificially raising groundwater tables through process water discharge to the Central Pit could impact on the nearby Campaspe Formation (RLA 2008A). This fear prompting the installation of 2 new monitoring bores C1 and C2 (**Error! Reference source not found.**) to the east of the Thalanga mine site.

8.2.1.3.2 Tailings dams and water storage

Three additional bores (TH1, TH4 and TH5) were placed in the vicinity of the new tailings Cell 9 (**Error! Reference source not found.**). Process tailings of the Balcooma ore were stored in the previously constructed Cell 8 and new Cell 9, adjacent to the south and east of the existing, combined tailings Cell 1-7.

8.2.1.4 Phase Four (2008 - 2012)

Phase Four started in 2008 with renewed mining operations at Thalanga. The mining target was the Vomacka orebody, which was to be mined by developing an 85m deep pit. During the process of establishing dewatering requirements (RLA 2008B) it became clear that both the underground tailings deposition and subsequent process water discharge to the Central Pit resulted not only in the complete flooding of the underground workings, but also caused shallow groundwater tables and saturated ground conditions in the Vomacka area.

The realisation that disposal of process water and tailings underground and in the remaining Central Pit caused flooding issues for the proposed Vomacka Pit resulted in renewed dewatering efforts at Thalanga. Evidence for the increased flooding and subsequent dewatering can be seen in the continuum of groundwater level records of the V-bores between 2006 and 2008. What can be seen in **Figure 24** and particularly **Figure 25** is the rise of groundwater tables across the Thalanga mine site to close to surface levels till late 2008 and the subsequent influence on groundwater tables due to the Vomacka Pit dewatering from 2009 onwards.

Of likely significance is the development of groundwater levels measured at V5. The strong groundwater level increase during 2003 and early 2004 possibly being the result of water levels within the Central Pit reaching the level of the East Decline and starting to flood the, otherwise not connected, underground workings in the east (see **Figure 17**). V5 being the bore closest to the East Decline possibly seeing the greatest initial change in groundwater levels upon the onset of flooding.

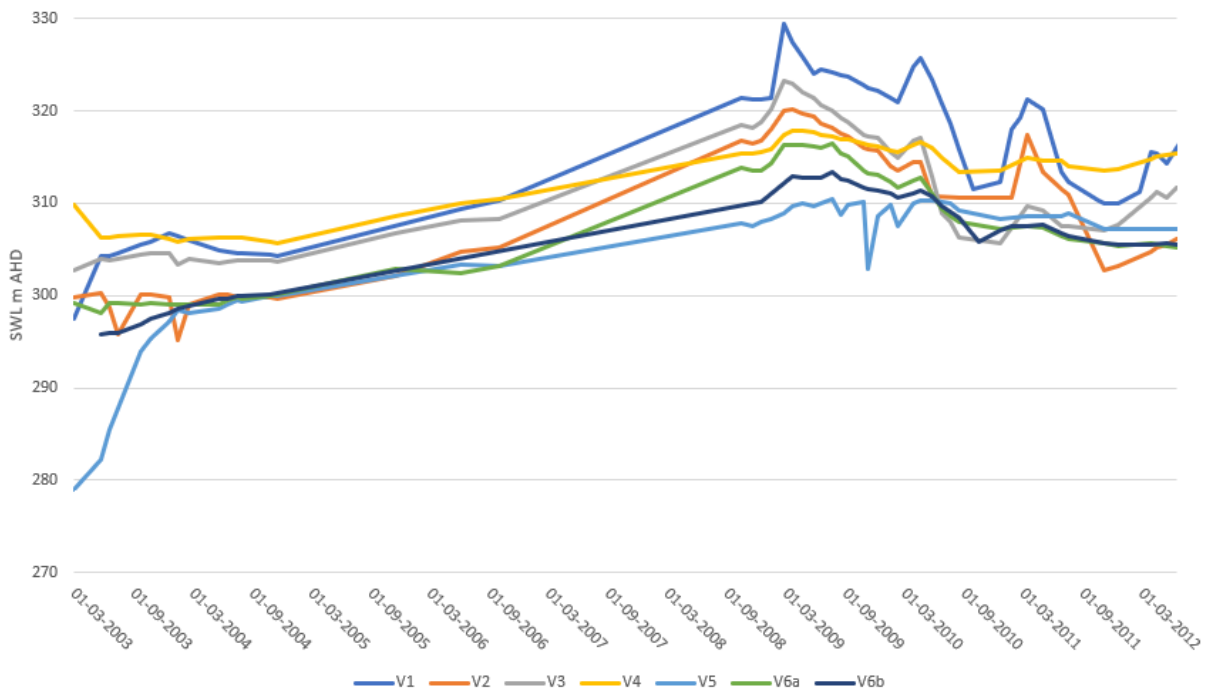


Figure 24 Groundwater level development at V1, V2, V3, V4, V5 and V6A/B between installation in 2003 till mid 2012 in mAHD

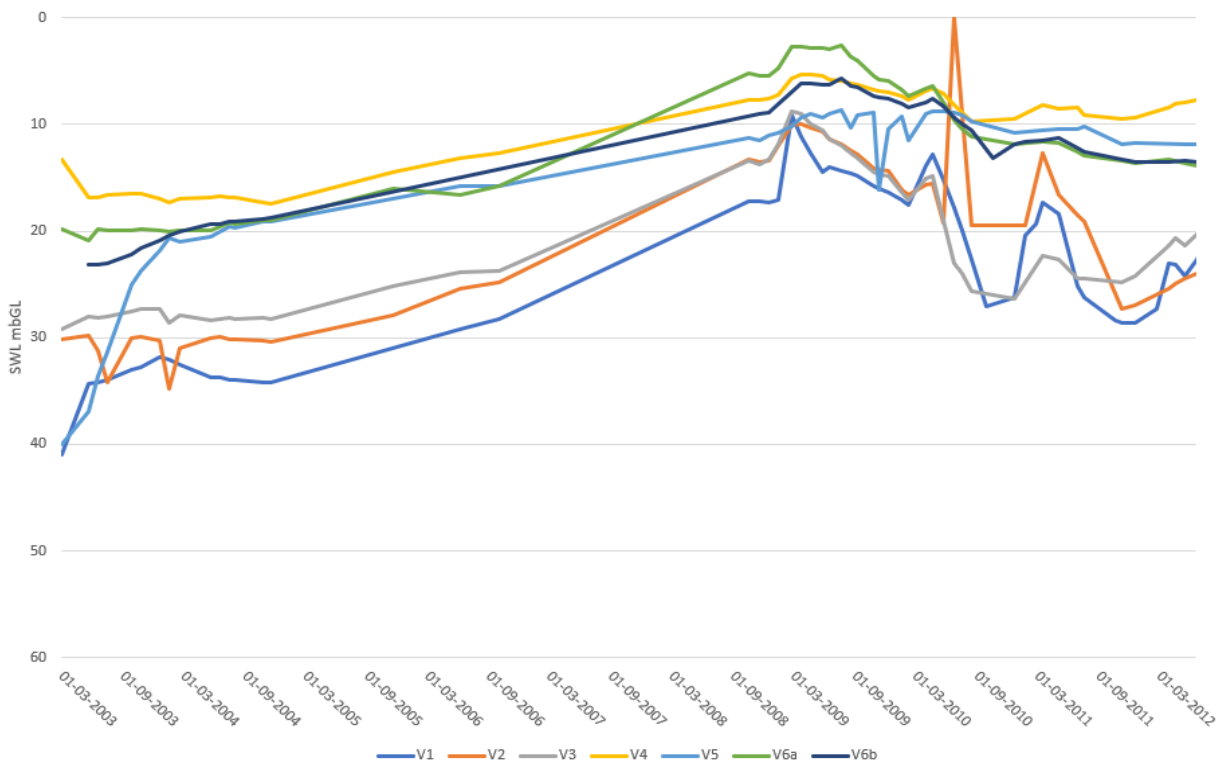


Figure 25 Groundwater level development at V1, V2, V3, V4, V5 and V6A/B between installation in 2003 till mid 2012 in mbGL

8.2.1.4.1 Campaspe Formation bores

Groundwater level records for the in 2008 installed C1 and C2 are presented in **Figure 26**. What can be seen is that groundwater levels for C2 appear to be steadily increasing between 2008 and 2012, while groundwater levels at C1 seem to experience a sudden increase in 2011.

The reasons for both increases are not clear. The climate data shown in **Figure 4** indicates that rainfall between 2008 and 2012 did not increase. Hence, climatic factors are an unlikely reason for groundwater level increases at C1 and C2. The most likely scenario would be the result of reduced pumping rates from the nearby Campaspe bore field **Figure 27** due to lower process water needs. An alternative worst-case scenario could be the manifestation of previously increased groundwater tables across the mine site migrating east. The previously delineated bedrock channel (Pitt, 1988) underlying the Campaspe Formation (**Figure 12 in Appendix C**) would represent a pathway for migration.

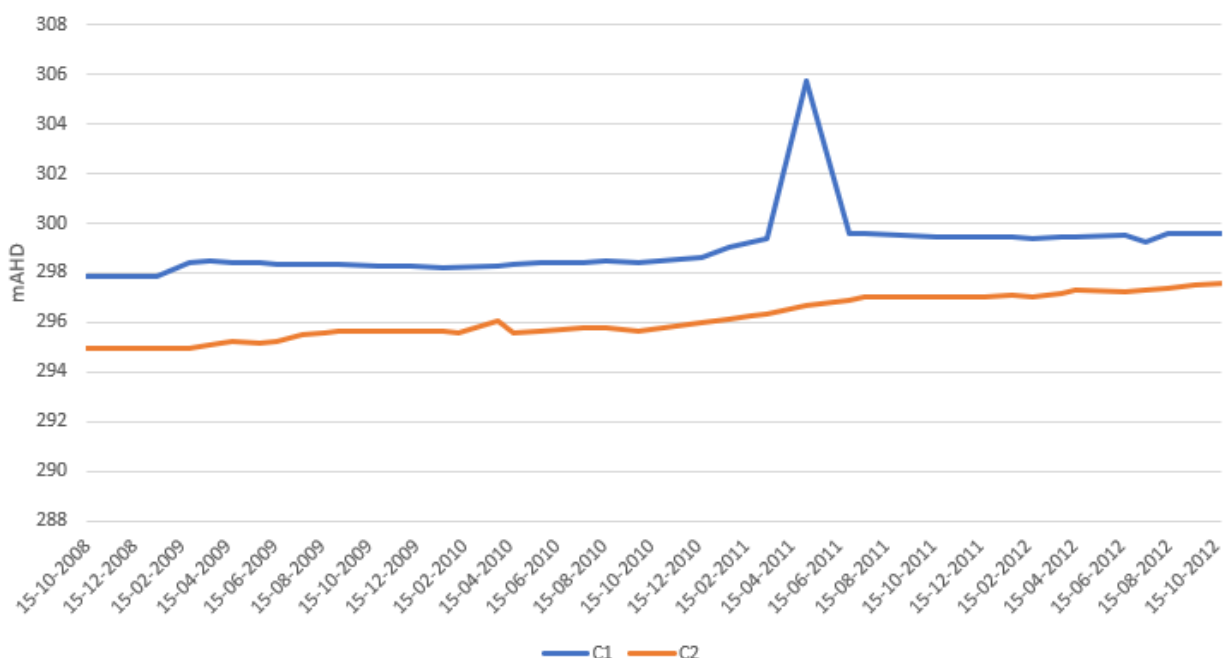


Figure 26 Groundwater level development at C1 and C2 from 2008 to 2012

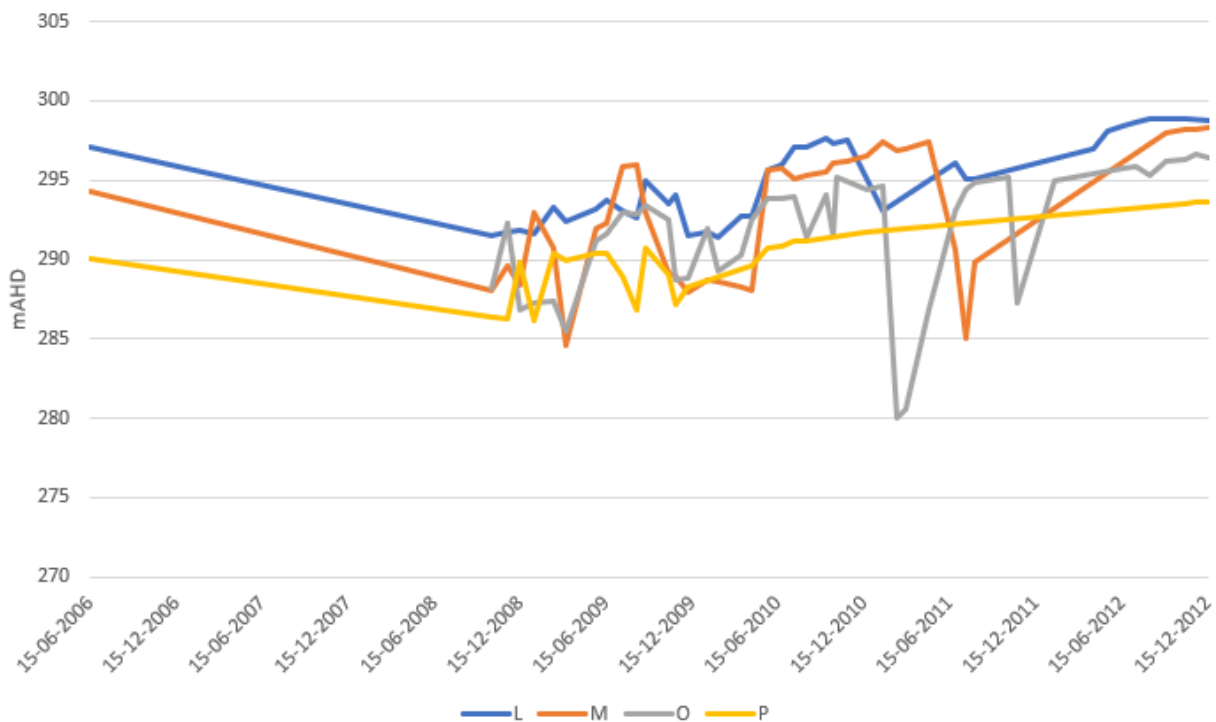


Figure 27 Groundwater level changes in Campaspe Formation bores L, M, O and P between 2006 and 2012

8.2.1.4.2 Central Pit

With the onset of mining at the Vomacka Pit the newly produced surficial benign oxide waste rock was used to create an elevated doughnut structure around the Central Pit. The later, from greater depth, produced reactive sulphide waste rock was used to fill the remaining Central Pit void and the inside of the doughnut core. The Central Pit would no longer receive surface water and the elevated structure would now shed water.

8.2.1.4.3 Vomacka Pit

The newly created Vomacka Pit reached its final depth of 85m by early 2012 (RLA, 2014). Following its excavation, the pit started to fill with water.

8.2.1.4.4 Underground

Phase Four also saw renewed underground interests at Thalanga. Activities included the initial dewatering of the West 45 deposit approximately 1500m North West from the Central Pit between 2011 and 2012. Rob Lait & Associates (2010, 2011a) installed four monitoring bores and two pumping bores to assess the hydrogeology and assist the dewatering of the West 45 deposit (**Figure 13 in Appendix C** and **Table 7**). As intended, to monitor groundwater level impacts the bores were installed close to the deposit, exposing them to groundwater quality impacts, which naturally show the influence of the ore deposit.

The bores were installed to a depth of between 79 and 91m with signs of weathering ranging from 3m to 22m below ground level. According to the drill logs (**Appendix I**), larger groundwater interceptions occurred in the fractured quartz eye rhyolite of the uneconomical part of the orebody (W45B1, ~15L/sec) and the bottom of the foot-wall rhyolite (W45B3, ~10L/sec). The bore solely intersecting the hanging wall dacite (W45B2) yielded only 0.46L/sec. While W45B4 was installed in an alternating sequence of ore deposit type quartz eye rhyolite, footwall rhyolite and hanging wall dacite yielded approximately 5L/sec.

Subsequent dewatering of the West 45 deposit continued until the change into care and maintenance of the Thalanga operation in 2012 (**Figure 25** and **Figure 28**).

Table 7 Details of the 2010 West 45 monitoring bore installation (adapted from Rob Lait & Associates, 2010)

Hole ID	Water bearing intervals	Air lift estimate each interval	Perforated intervals	Final Air Lift Discharge	SWL below GL
	m	L/s	m	L/s	m
W45B1	18.5–21.5	Trace	31–43	15.0	18
	23.5–24.0	1.25	73–79		
	31.0–34.0	6.25			
	39.0–43.0	15.0			
W45B2	17.0–23.0	0.05	33–39	0.46	20
	34.0–38.0	0.5	73–79		
W45B3	21.0–22.0	0.30	55–79	10.0	20
	22.0–27.0	0.75			
	46.0–47.0	1.25			
	64.0–65.0	5.10			
	77.0–78.0	10.0			
W45B4	33.0–34.0	0.04	67–79	5.0	24
	69.0–70.0	5.0			

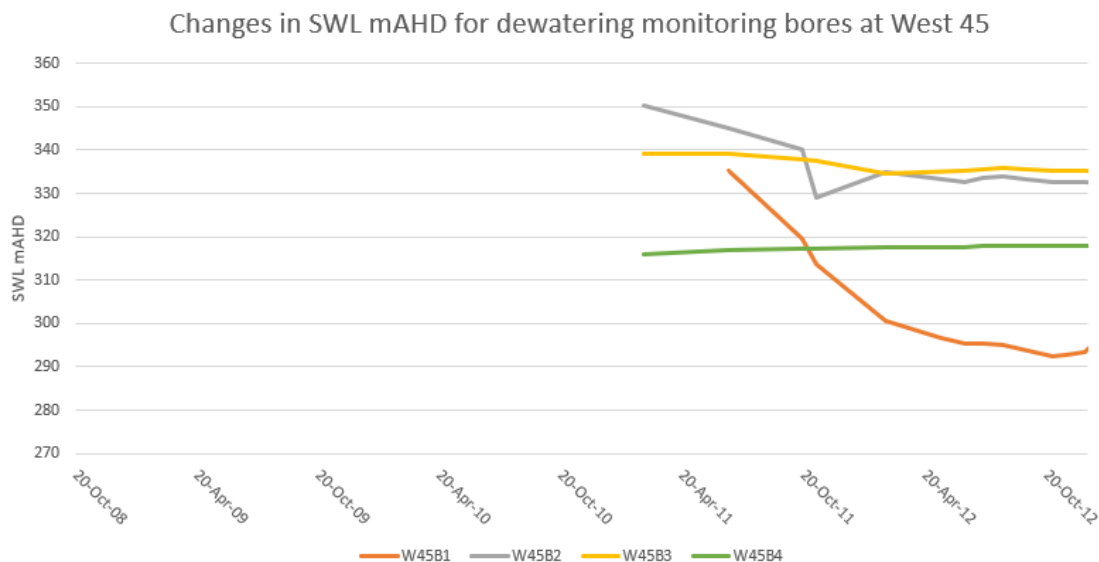


Figure 28 Groundwater development at W45B1, W45B2, W45B3 and W45B4 till December 2012

8.2.1.4.5 Tailings dams and water storage

The 2008-2012 period saw the construction of tailings Cell 9. Cell 9, constructed in late 2008, initially received tailings from the re-processing of Highway Reward copper-gold tailings from the partial dredging of tailings cell 1/7. Later the ore treatment plant was reconverted back to processing multi-metallic zinc-lead-copper ore from the Vomacka pit at Thalanga. Cell 9 covers an area of 18.5ha with the current capacity to store additional tailings. The development of groundwater levels between 2008 and 2012 for the previously installed bores TH1, TH4 and TH5 are shown in **Figure 29**.

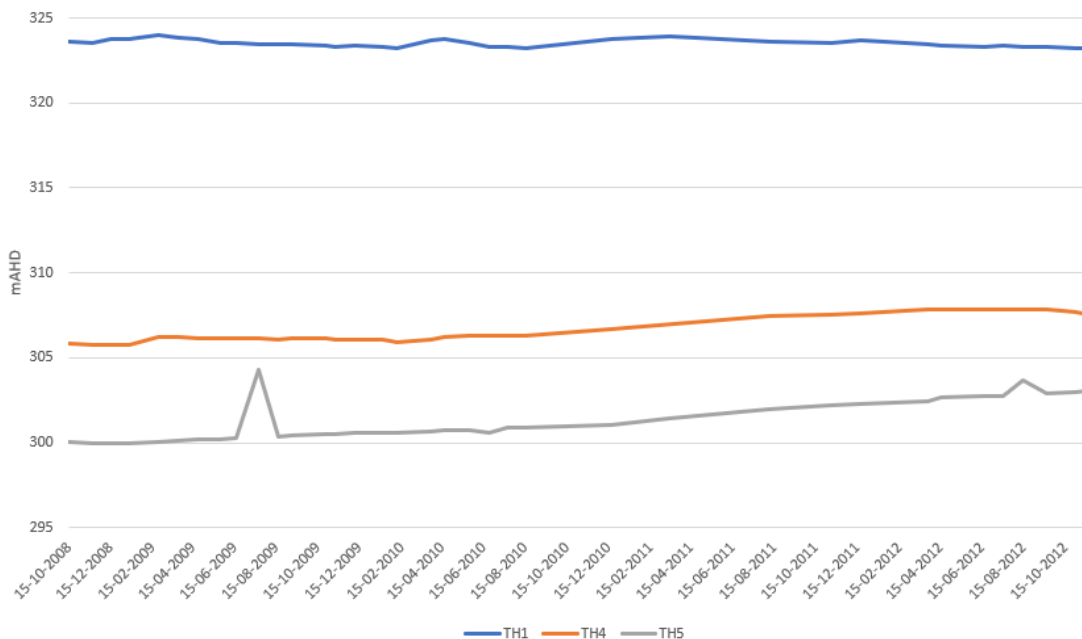


Figure 29 Groundwater level development at TH1, TH4 and TH5 from 2008 to 2012

What can be seen is that groundwater levels in TH1, TH4 and TH5 record several metres of difference between them and only bores TH4 and TH5 experience an increase in groundwater levels following installation. Bore TH1, positioned closer to the Central Pit and underground seems to experience a slight decline in groundwater tables, possibly as a legacy of previously artificially elevated groundwater tables.

8.2.1.5 Phase Five

8.2.1.5.1 Open Pits and Underground

Phase Five (from 2014 onwards) started with an initial 2-year period of the site being in care and maintenance mode. The Central Pit being completely backfilled, now being a water shedding structure. The Vomacka Pit being left to fill with groundwater and limited surface runoff. The initial underground remaining flooded and the new West 45 underground being left to naturally flood with groundwater.

In 2014, the current operator Cromarty Resources acquired the Thalanga site, initially refurbishing infrastructure and completing additional resource studies. Dewatering of the West 45 underground recommenced in 2017 with concentrate and tailings production restarting in September 2017. 2018 and 2019 saw additional dewatering efforts and renewed mining of the previously dewatered (Phase One, 1989-1998) Far West deposit.

To Monitor the impacts of the renewed dewatering of the Far West deposit (the Far West had previously been dewatered between 1995 and 1998 as part of the RGC Thalanga operation) Cromarty Resources installed an additional five monitoring bores to depth between 50 and 100m in the hanging wall dacite and footwall rhyolite surrounding the Far West deposit (Error! Reference source not found.). Observations made during the drilling of the Far West bores and subsequent testing of the aquifer situation confirmed the very low aquifer potential of the hanging wall dacite and footwall rhyolite (**Table 8**) away from the immediate vicinity of the orebody.

Groundwater occurred only in very few fractures between a depth of 19m to 57m, and airlift flow was at times too small to be measured or dried up soon after being encountered. The drying up of encountered groundwater flows is typical of compartmentalised, small capacity aquifers (bore logs in **Appendix I**)

The weathered horizon reached depths between 2m and 28m with no groundwater associated. Importantly, none of the Far West bores encountered groundwater below the depth of 57m, essentially confirming the generally lower fracture density of the rock at depth, as suggested by Barrett et al. (1982) and Rob Lait & Associates (2010).

Table 8 Summary of bore details for FWMB1, FWMB2, FWMB3, FWMB4 and FWMB5

	FWMB1	FWMB2	FWMB3	FWMB4	FWMB5
	UTM	UTM	UTM	UTM	UTM
	55K	55K	55K	55K	55K
Easting	370581	371053	370067	370854	370850
Northing	7750587	7751109	7750831	7751735	7750306
Depth	100m	100m	100m	50m	52m
Hole diameter	0–4m 8 inch (precollar) 4–100m 7 inch	0–4m 8 inch (precollar) 4–100m 7 inch	0–4m 8 inch (precollar) 4–100m 7 inch		
Water encountered @	29m Too small to measure EC 2200 µS/cm 34m 1.5L/s – 2450µS/cm	30m Too small to measure 53m 0.57L/s – 12700µS/cm 57m 1.8L/s – 13047µS/cm	43m 0.0015 L/s – 1455 µS/cm	19m ~1L/sec 23m 13500 µS/cm 30m ~0.5L/s 12000 µS/cm	30m 10820 µS/cm 42m ~0.35L/s 11200 µS/cm 45m ~0.7L/s 10700 µS/cm
Casing	class 12 100mm 0–94m	class 12 100mm 0–94m	class 12 100mm 0–94m	class 12 50mm 0–18m 21–47m	class 12 50mm 0–30m 33–47m
2mm hand slotting	94–100m	94–100m	94–100m	18–21m 47–50m	30–33m 47–50m
Gravel	32–100m	51.5–100m	40–100m	17–50m	29–52m
Bentonite	29–32m	48.5–51.5m	37–40m	16–17m	28–29m
Cement Grout	0–29m	0–48.5m	0–37m	0–16m	0–28m

	FWMB1	FWMB2	FWMB3	FWMB4	FWMB5
Developed	45 minutes	30 minutes	Too small flow. Bore cleaned prior to casing installation		
SWL overnight. Prior to development	27.26m below top of casing. PVC casing 0.65m above ground surface	25.10m below top of casing. PVC casing 0.70m above ground surface	Overnight water recovered to 92m. Not final water level due to very slow inflow	8m	20m
Permeability	Test 1: 2.566E-7m/s Test 2: 2.566E-7m/s Test 3: 2.566E-7m/s	Test 1: 2.696E-7m/s Test 2: 2.903E-7 – 7.498E-8m/s	Test 1: 2.661E-7 – 3.319E-8m/s		

8.2.1.6 Impact of renewed underground dewatering

Renewed dewatering of the flooded West 45 underground started in April 2015, from a level approximately 30m below ground (Karl Spaleck, personal communication, 13 November 2017). **Figure 30** shows the initial groundwater level development in the West 45 monitoring bores till 2012 followed by the subsequent flooding (between 2012 and 2015) and the renewed dewatering of the West 45 deposit since 2015 as well as the impacts of the recent dewatering of the Far West deposit (since 2017).

8.2.1.6.1 West 45 bores

What can be seen is that only bore W45B1, which is located in the uneconomic quartz eye rhyolite along the strike of the ore deposit, shows a groundwater level trend that can be associated with the dewatering and flooding of the West 45 orebody. Important to note is that despite the cessation of pumping in 2012, water levels in W45B1 did not recover to pre-mining levels, confirming that groundwater mining, as suggested by Rob Lait & Associates (2011), was in fact occurring. The groundwater level in bore W45B2, only 60m from the orebody, was not impacted by the dewatering and mining of the West 45 deposit but appears to be impacted by the more recent dewatering of the Far West deposit. Noteworthy, groundwater levels in W45B3 and W45B4 show, despite the bores having reported air lift flow rates of 10L/sec and 5L/sec respectively, only limited changes in groundwater levels. The latter indicating that there is very limited connection between the deposit and the adjacent hanging wall dacite and footwall rhyolite.

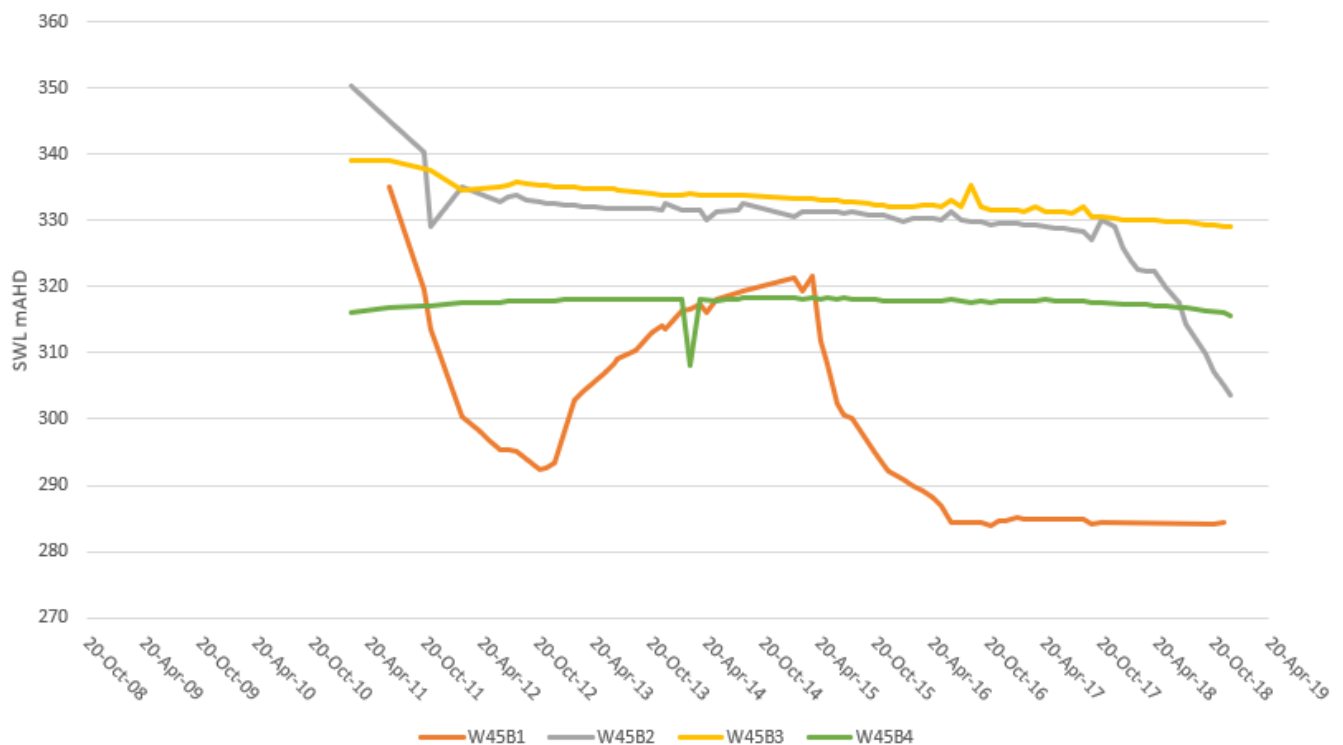


Figure 30 Groundwater level records of W45B1, W45B2, W45B3 and W45B4 till 2019

8.2.1.6.2 V – Series bores

Dewatering of the West 45 bores during 2012 and again in 2015 appears to have had a very limited impact on groundwater levels within the V-Series bores (**Figure 31**). The previous Vomacka Pit dewatering efforts between 2008 and 2010 halted the previous groundwater level increases and started to reverse the trend towards declining conditions. Groundwater levels in the V-Series bores since have seen an initially stronger decline in bores to the west of the Central Pit and a lower rate of decline east of the Central Pit. Between 2012 and 2018 the groundwater level declines east and west of the Central Pit has been fairly uniform. Renewed dewatering of the Far West deposit since 2018 has only seen a significant decrease in groundwater levels in bores west of the Central Pit.

The previously discussed separation of the west and east underground workings is the likely reason behind the different groundwater behaviour of the V-Series bores. Bores V4, V5 and V6A/B are hydraulically disconnected from the western underground section and previous groundwater level increases were only facilitated by the former flooding of the decline in the Central Pit (see **Figure 17**).

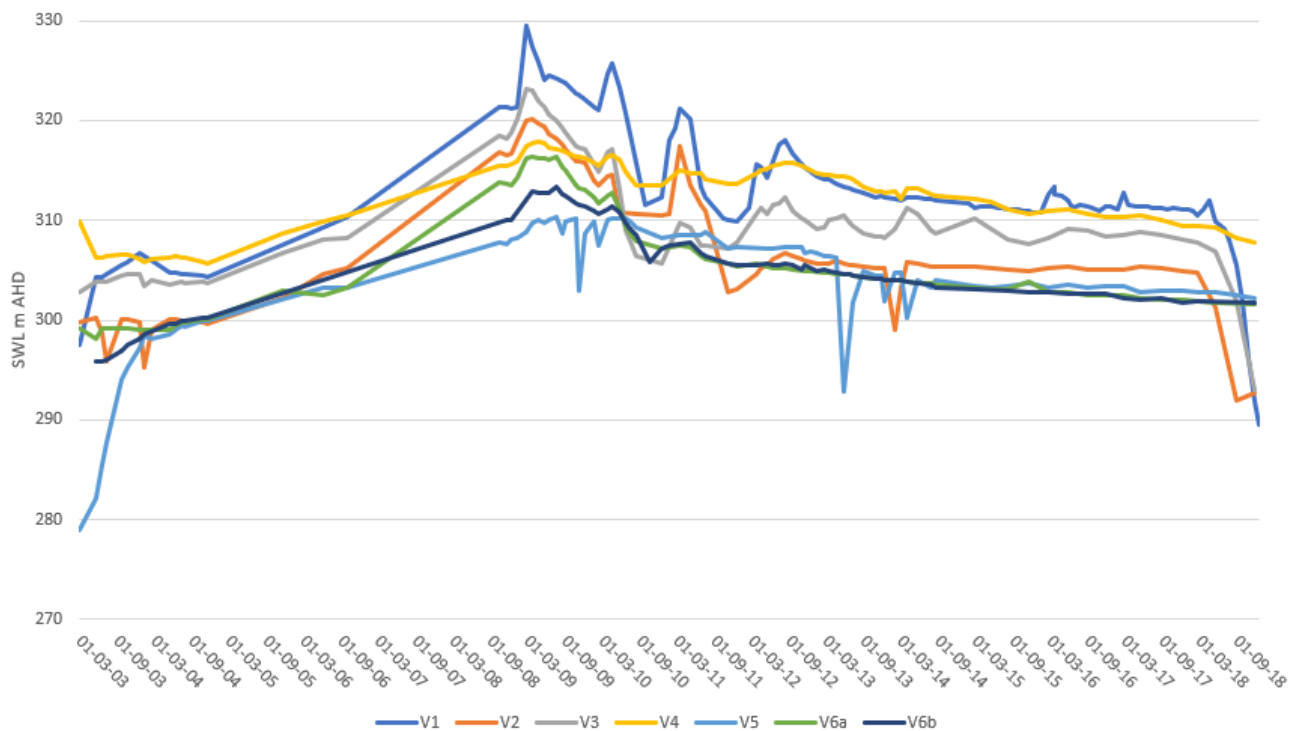


Figure 31 Groundwater level development in bores V1, V2, V3, V4, V5 and V6a/b between 2003 and 2018

8.2.1.6.3 Far West bores

The impact of the Far West dewatering on the recent Far West bores so far appears to be limited. The only bore showing a clear declining trend is FWMB2 (**Figure 32**). The intention for the Far West monitoring bores was for them to be installed outside of the ore zone. However, due to space restrictions FWMB2 has been installed in close proximity to V1 making FWMB2 less useful when assessing groundwater level impacts outside of the ore zone.

Regardless, bores FWMB1, FWMB3, FWMB4 and FWMB5 are not being impacted by the Far West dewatering.

8.2.1.6.4 Combined impact

The combined impact of the West 45 and Far West underground dewatering efforts confirms that main aquifer and hydrogeological feature at Thalanga is the orebody and associated underground workings. Hydrogeological interaction between the deposit and the surrounding rock cannot be established. Out of nine West 45 and Far West monitoring bores that have been drilled only three appear to be impacted by the dewatering efforts. From their respective location and drill logs it can be concluded that the three impacted bores have been installed within uneconomical sections of the ore deposit and not in the surrounding bed rock.

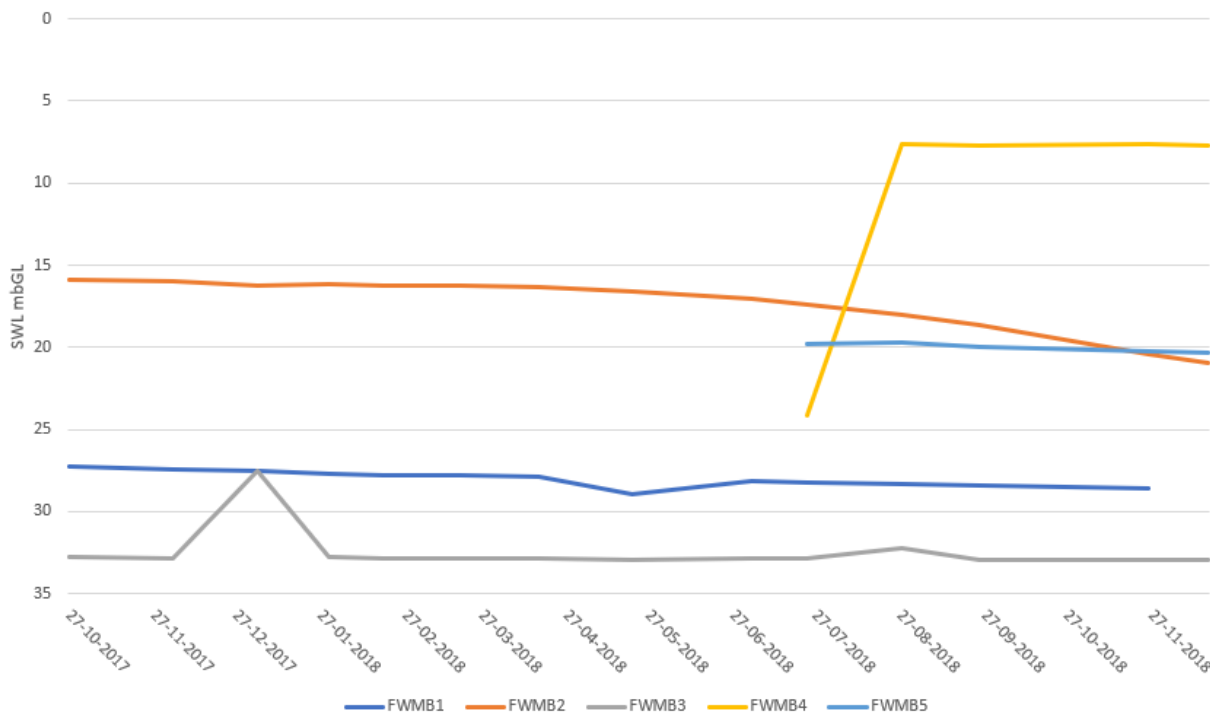


Figure 32 Groundwater level records of FWMB1, FWMB2, FWMB3, FWMB4 and FWMB5

8.2.1.6.5 Tailings Dams and water storage

There has been no extension or lift of the existing tailings storage facilities since 2012. In April 2012 a subsurface seepage affected water body was identified within the excavated clay borrow pits directly north of the tailings dams. This was followed by repairs to the Cell 5 and Cell 6 seepage interception trenches and a clean out of the clean water diversion drain (RLA 2014).

The groundwater level development at bores TH1, TH4 and TH5 is shown in **Figure 33**. What can be seen is that groundwater levels at TH1 further declined till 2015 and subsequently started to increase again from there on. Groundwater levels at TH4 and TH5 appear to have been impacted by the absence of tailings deposition between the start of the care and maintenance period in 2012 and the recommencement of tailings deposition in 2017. Groundwater levels at TH4 decreased during that period, while groundwater levels at TH5 showed a temporary levelling out.

In late 2018 two additional tailings dam monitoring bores (A1 and A4) were installed approximately 130m to the north of the tailings dam area. Monitoring of these two new bores is been conducted since with no perceivable changes in groundwater levels.

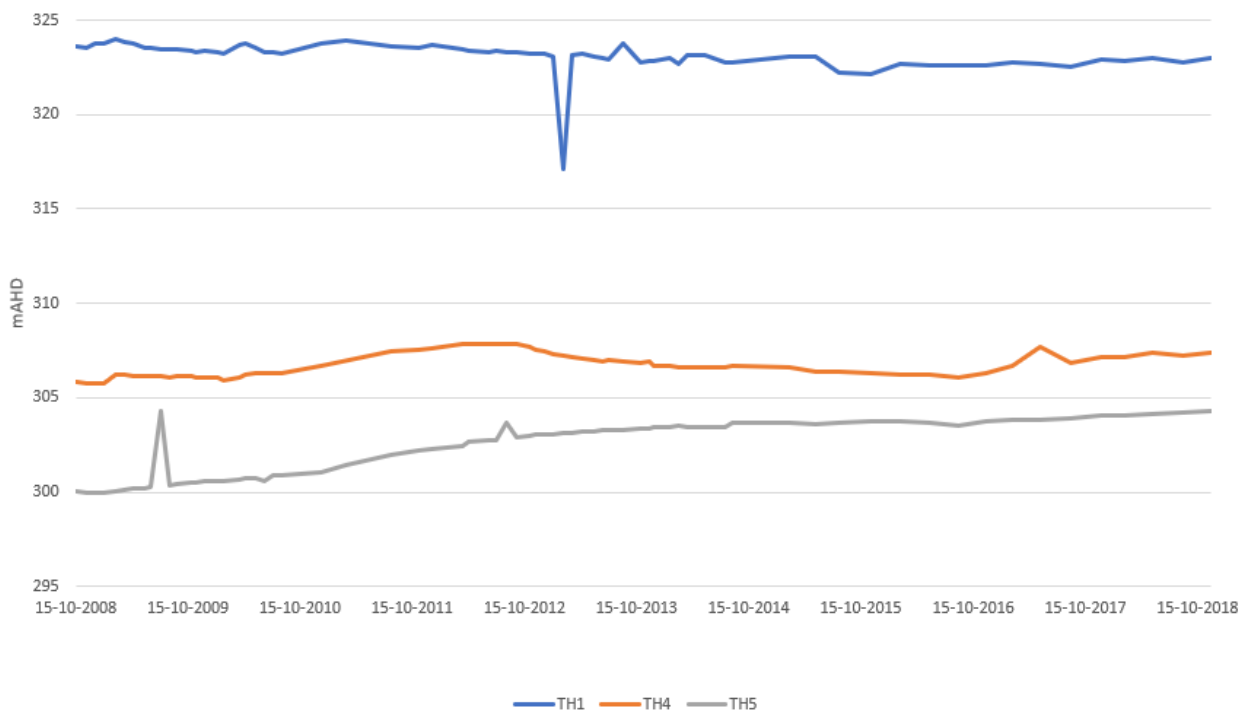


Figure 33 Groundwater level development at TH1, TH4 and TH5 from 2008 to 2018

8.2.1.6.6 Campaspe Formation bores

The groundwater level development of bores C1 and C2, installed to monitor the impact of the artificially increased groundwater levels on the Campaspe Formation is shown in **Figure 34**. The groundwater level in C1 remains almost static during Phase Five, while the groundwater level at C2 continued to slowly increase for another 100cm till early 2018 (**Figure 34**). During the same period, the groundwater level in the Campaspe Formation Production bore M (closest to C2) increased by about 40cm (**Figure 35**).

Groundwater level data for bore M is only available till September 2017. The reason being, bore M being reequipped with a pump and used again for groundwater extraction. The recommissioning of bore M for process water use coincides with a falling groundwater table at C2. The latter confirming that the groundwater table at C2 is influenced by groundwater extraction from the Campaspe Formation bore field. Groundwater level records for bore L are limited and considered unreliable. The two observed dips in groundwater level at bore L are likely due to the pump having been in operation during water level measurements in the associated nearby monitoring bore.

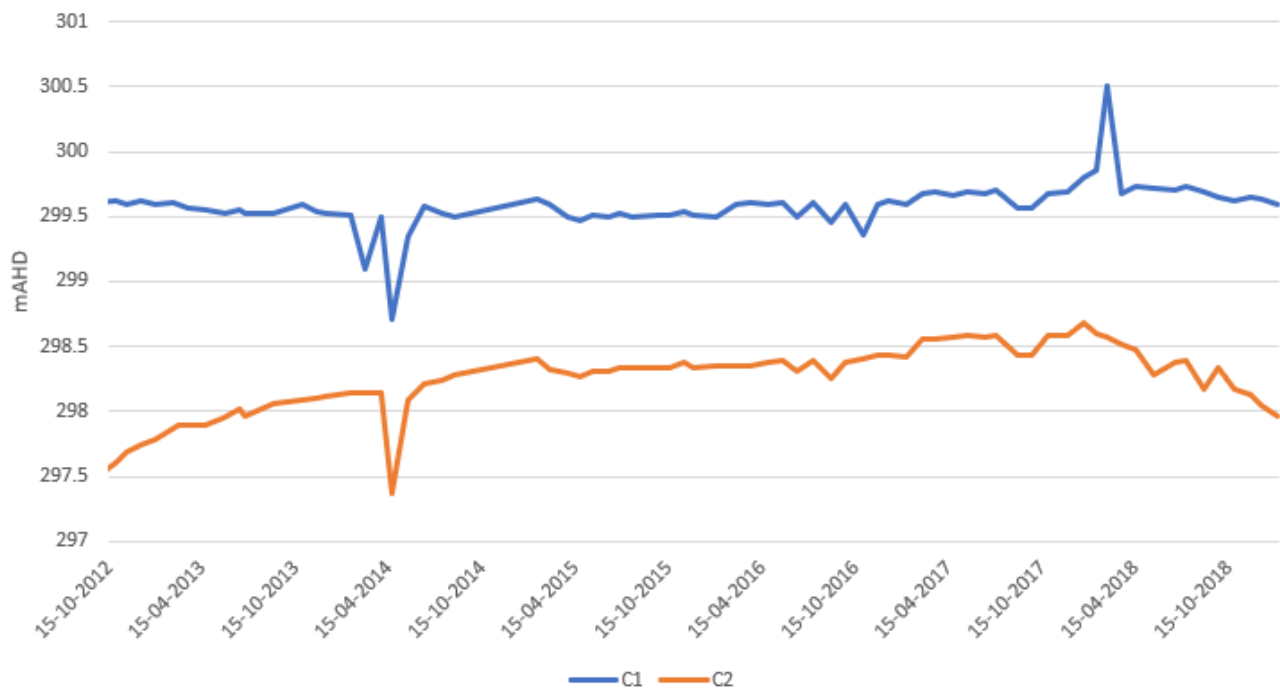


Figure 34 Groundwater level development at C1 and C2 from 2012 to 2018

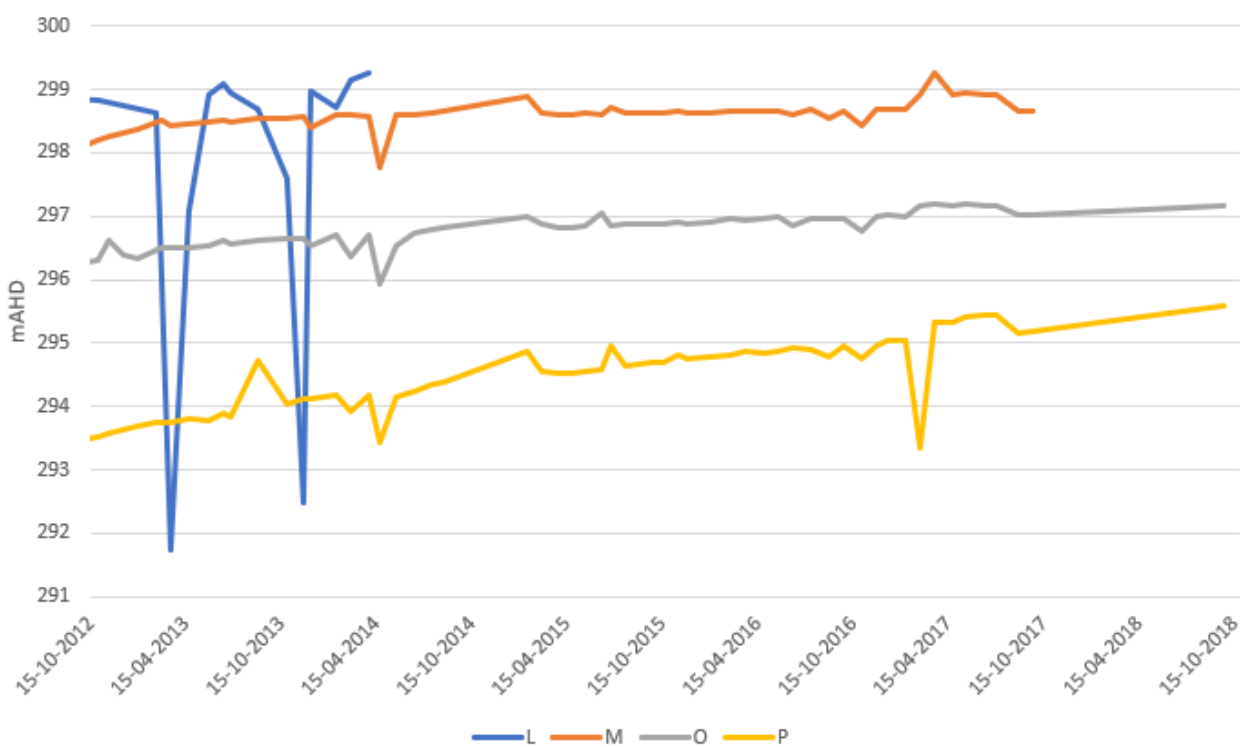


Figure 35 Groundwater level changes in Campaspe Formation bores L, M, O and P between 2012 and 2018

8.3 Hydrogeological site characteristics

The hydrogeological development of the Thalanga site is the result of operational changes. Initial changes were introduced by the dewatering of the Central Thalanga pit and associated satellite underground orebodies. This dewatering lowered the groundwater tables along the strike of the deposit but had little influence on groundwater tables in the adjacent dipping rock units.

The construction and filling of the initial tailings dams in the north and the construction of the main WRD in the south-west resulted in the creation of perched/elevated aquifers in the immediate vicinity of these structures.

Later backfilling of the underground and Central Pit with tailings and process water, resulted in high groundwater tables across wide areas of the mine by 2008. These high groundwater tables were facilitated by the interconnection of underground workings throughout the deposit (**Figure 17** and **Figure 18**) and the presence of hundreds of exploration holes connecting these underground workings to the surface (**Figure 36**).

Renewed dewatering activities for the Vomacka Pit and subsequent for the West 45 and Far West underground workings have reduced, and currently reduce groundwater tables once more along the strike of the deposit.

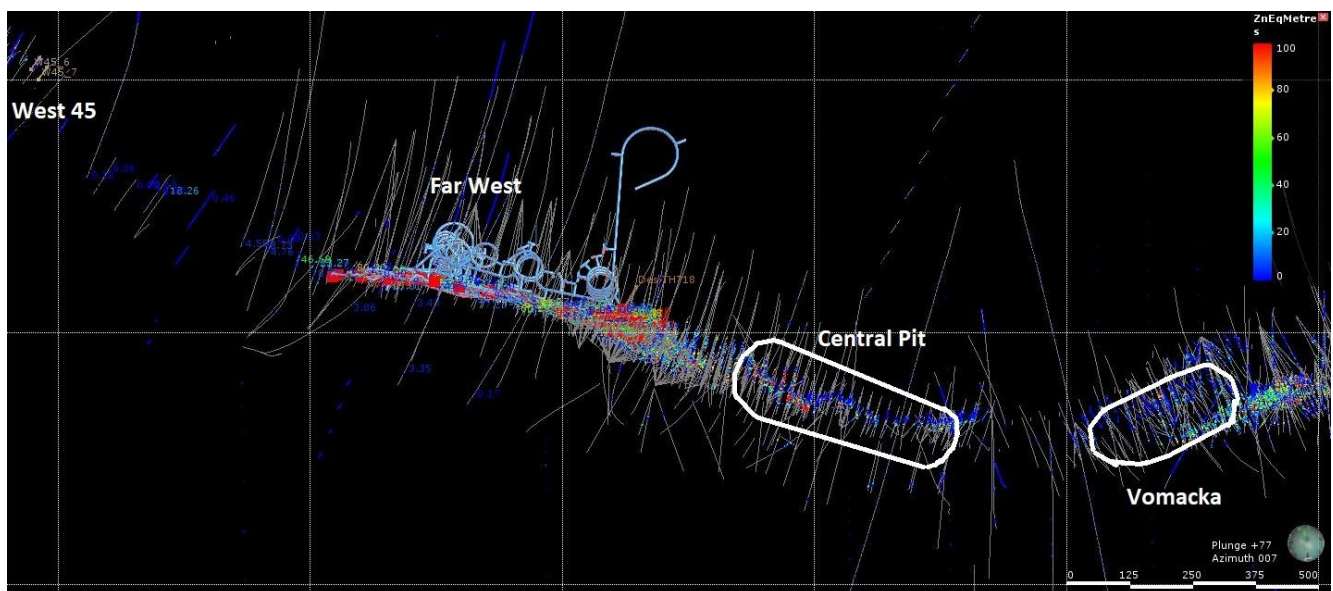


Figure 36 Plan view of locations and directions of more recent Cromarty Resources exploration drill holes with the locations of the West 45, Far West, Central- and Vomacka Pit as reference

8.3.1 Hydraulic conductivity values

Two sets of hydraulic conductivity (k) values exist for the Thalanga site. One set of k values exists for three of the recently installed Far West monitoring bores (**Table 8**). Hydraulic conductivities for the bedrock flanking the deposit ranged from 0.0029m/day to 0.0221m/day.

Another set of k values exists for five locations across the foot print of tailings cell 8 and three monitoring bores installed south and east of Cell 8, now partially covered by Cell 9.

The five locations across the cell 8 footprint were tested at three different depths (0-1m, 1-2m and 2-6m), results are shown in **Figure 37**. What can be seen is that k values across the cell 8 footprint decreased with depth. It is believed that the top 2m of higher permeability soil material was excavated prior to any tailings deposition. The 4m below reported k values between 0.00014m/day and 0.00039m/day.

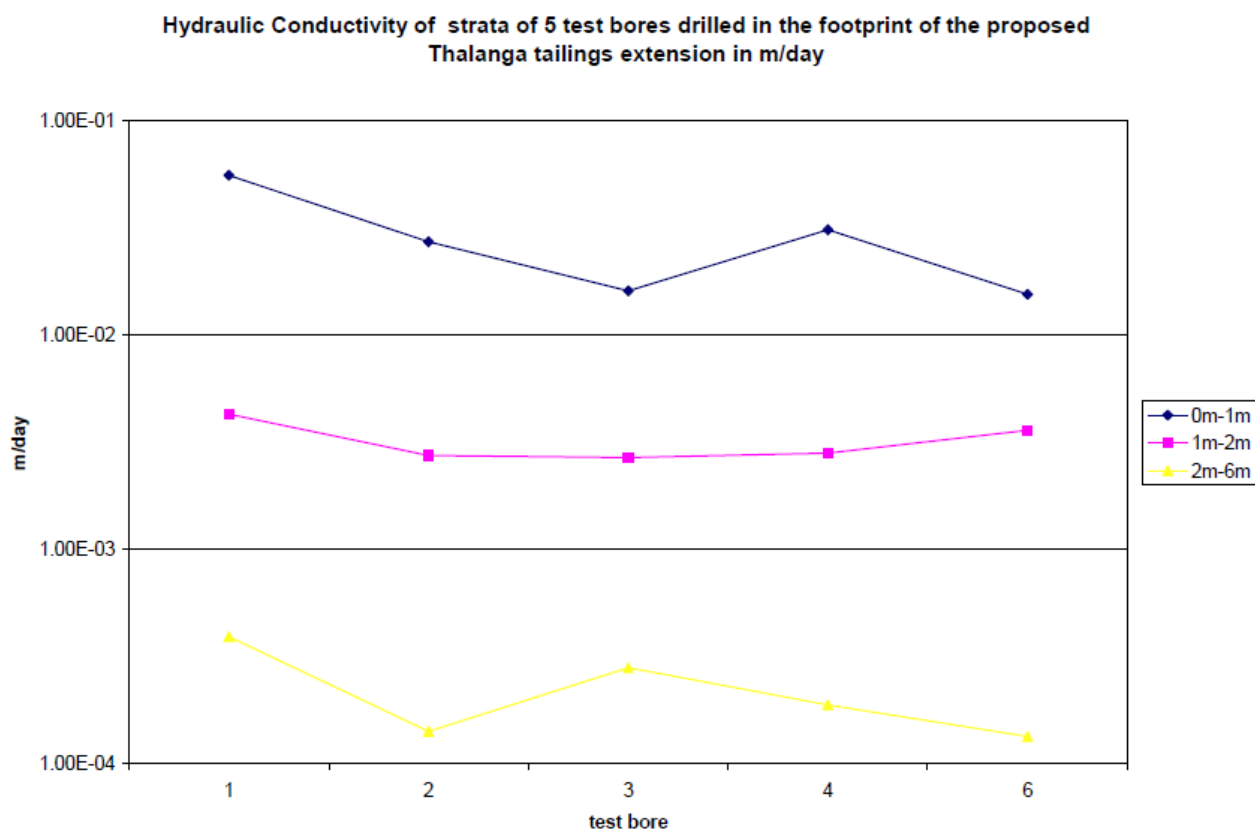


Figure 37 Hydraulic conductivity in m/day of strata in the footprint of cell 8 (from AGE 2006)

The three monitoring bores were all drilled to 30m depth, where they uniformly encountered hard fresh rhyolite. Hydraulic conductivity measurements of the 17-30m bedrock zone recorded k values between 0.000343m/day and 0.122m/day (AGE reported 3.43m/day in error, see evaluation sheets in AGE 2006). The bedrock hydraulic conductivity values were similar to the k values measured for the bulk weathered material above. The higher conductivity value of 0.122m/day was due to a fracture being intersected during drilling, yielding 0.5L/s.

Overall, the results of the hydrogeological testing at Thalanga confirm the generally low k nature of the unmineralized bedrock and most of the overlying weathered material. The greatest k values were recorded from the top 1m, indicating the presence of a potential pathway for seepage, should water levels rise into that level.

8.4 Conceptual hydrogeological model

The main feature of the hydrogeological model for Thalanga is evidently the Thalanga deposit. However, the previous section clearly outlined that the dynamics of the groundwater development changed over time.

Groundwater flow velocities and flow directions depend on hydraulic gradients. With fluctuations in groundwater levels, flow directions at times may be reversed. To demonstrate this with regards to the Thalanga site, hydraulic gradients between V1 and C2 and V6A and C2 have been calculated for three different dates. Date one (14.10.2008) represents the period of highest groundwater tables induced by the process water deposition in the remaining Central Pit. Date two (28.10.2013) is representative of falling groundwater tables following the dewatering and recovery of groundwater tables at the Vomacka Pit and West 45 underground. Date three (26.11.2018) is representative of the current situation characterised by the impacts of the Far West dewatering. Following Darcy's Law for calculating the hydraulic gradient between the groundwater levels at two points (h_1 and h_2) the following equation can be applied:

$$i = \frac{h_1 - h_2}{l}$$

Where i is the hydraulic gradient and l is the distance between the groundwater levels at point h_1 and h_2 . Using the above the following hydraulic gradients can be calculated (Table 9 and Table 10).

Table 9 Change in hydraulic gradient from V1 to C2 over time and changing SWL

	14.10.2008	28.10.2013	26.11.2018
Distance V1 to C2	3600m	3600m	3600m
SWL AHD at V1	321.39m	312.34m	292.68m
SWL AHD at C2	294.94m	298.09m	297.97m
Hydraulic gradient V1 to C2	0.00734	0.00395	-0.00147

Table 10 Change in hydraulic gradient from V6A to C2 over time and changing SWL

	14.10.2008	28.10.2013	26.11.2018
Distance V6A to C2	1980m	1980m	1980m
SWL AHD at V6A	313.86m	304.18m	301.54m
SWL AHD at C2	294.94m	298.09m	297.97m
Hydraulic gradient V6A to C2	0.00955	0.00308	0.00180

What can be seen on Table 9 and Table 10 is that due to the distance between the locations the hydraulic gradients between the individual groundwater locations are extremely low and currently negative between V1 and C2.

The greatest hydraulic gradient between the mine site and the Campaspe Formation existed during 2008 between V6A and C2 (0.00955). Combining this hydraulic gradient with measured hydraulic conductivity values allows for the calculation of Darcy's velocity or flux, using:

$$v = ki$$

Where v is Darcy's velocity and ki is the product of the hydraulic conductivity (k) and the hydraulic gradient (i). Using the highest measured hydraulic conductivity value for bedrock (0.122m/day) in combination with the highest hydraulic gradient (0.00955) results in a calculated Darcy's velocity of 0.001165m/day. Using the highest values available for the site, it becomes apparent that groundwater flow velocities through the natural geology are extremely slow.

The current aquifer situation is marked by rapidly falling groundwater levels across the western section of the mine that is in connection with the underground workings. These major groundwater changes are directly linked to the characteristics of the ore deposit and the mining history.

Besides the major influence of the underground workings, the presence of the tailings dams resulted in increased groundwater levels within the vicinity of these dams. Similarly, the past presence of the Western WRD likely resulted in the compressing of the aquifer producing elevated groundwater tables in its vicinity.

The importance of any original hydrogeological features has been reduced by some orders of magnitude. Perched natural aquifers above the deposit have been dewatered and mined out, as well as previously confined sections in the deposit have been opened, dewatered and refilled with tailings and impacted water.

What remains valid is that the aquifer of the Thalanga orebody is kept within the confines of the Thalanga deposit. Historic and current groundwater monitoring records confirm that surrounding aquifer zones have no or very limited connection to the orebody. The reported presence of fracture zones and faults within the deposit is of little consequence. Figure 12 shows the locations of these fractures and faults. Compared with the locations and groundwater level behaviour of monitoring bores, it becomes clear that the impact these faults and fractures have on the groundwater environment surrounding the orebody is very limited.

8.4.1 Visualisation of the hydrogeological development

In order to better understand the hydrogeological development at Thalanga a visualisation of the hydrogeological site history is provided in the following sections.

8.4.1.1 Pre-mining conceptualisation

Initial pre-mining groundwater flow has been discussed in the Pre-mining baseline conditions section. Error! Reference source not found. shows the measured groundwater gradients through the Campaspe Formation in the east of the mine lease. Additional interpreted groundwater gradients across the pre-mining Thalanga site have been added to a pre-mining 1978 aerial photograph (State of Queensland, 2014), (**Figure 38**).

Following recharge events, groundwater flow would have been mainly along the weathering boundary before reaching the bedrock channel, potentially connecting the Thalanga site with the Campaspe Formation aquifer. Groundwater flow recharge and flow rates would have been low, as indicated by the measured low hydraulic conductivity values and the natural moderately high groundwater EC values. The ore deposit aquifer within the bedrock would have been largely isolated from the above exchange.



Figure 38 Likely pre-mining groundwater flow directions at Thalanga (modified exert from State of Queensland, 2014)

8.4.1.2 Groundwater conceptualisation during Phase One

Figure 39 conceptualises the groundwater situation during Phase One. Due to dewatering, groundwater levels significantly declined within the Thalanga deposit (lower SWL), while groundwater levels around the tailings dams and waste rock dumps only locally increased, likely due to a combination of hydraulic loading and near surface seepage. The hills to the west of the site continue to be the main recharge area. The Campaspe Formation in the east remaining the main aquifer being utilised as the process water source for the Thalanga mine site. Potential recharge to the Bedrock Channel would have been reduced due to the underground dewatering activities and draining of potential recharge via exploration holes. Despite that, groundwater levels within the Campaspe Formation were maintained, indicating that the contribution of any recharge via the bedrock channel is probably low.



Figure 39 Conceptual groundwater situation at Thalanga during Phase One, 1989-1998

8.4.1.3 Groundwater conceptualisation during Phase Two

Figure 40 conceptualises the groundwater situation during Phase Two. Mining of the Thalanga orebody stopped in 1998 and the underground was backfilled with tailings and process water. Subsequently groundwater levels within the mined-out deposit rose to levels where recharge to the bedrock channel became a possibility.

Since processing of the Highway Reward ore continued at Thalanga, tailings continued to be generated, resulting in further increasing groundwater levels around the tailings dams.

Removal of the western waste rock dump into the open pit reduced to pressure on the WRD footprint area. Regardless, due to the effects of compression still being in place, groundwater levels remained high around the former WRD area.

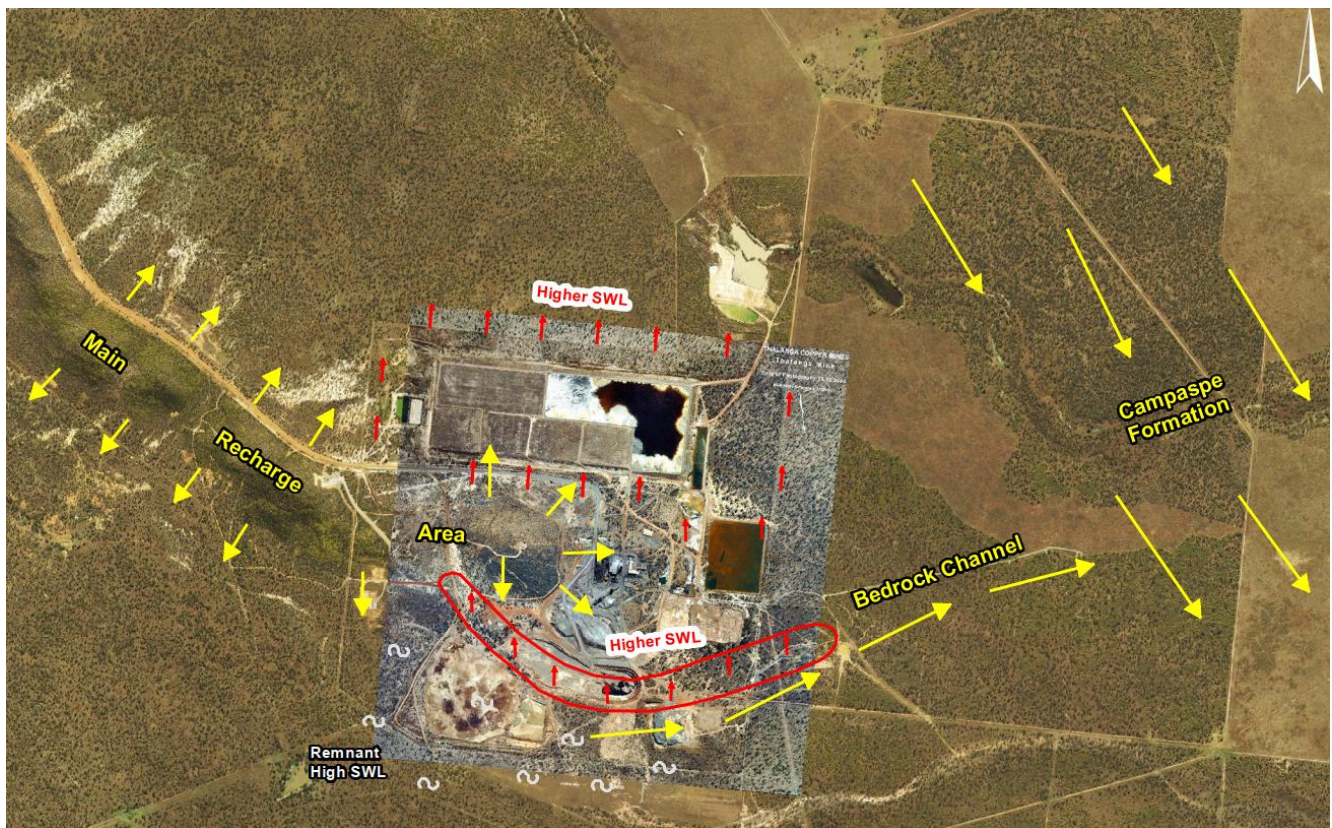


Figure 40 Conceptual groundwater situation at Thalanga during Phase Two, 1998-2006

8.4.1.4 Groundwater conceptualisation during Phase Three

Figure 41 conceptualises the groundwater situation during Phase Three. Due to the discharge of process water into the remaining Central Pit void, groundwater levels in the underground and connected exploration drill holes rose close to the surface (**Figure 42**). Water in the uncased exploration holes saturates the surrounding ground (orange shaded area), possibly allowing for migration towards or along the bedrock channel leading to the Campaspe Formation aquifer in the east.

Deposition of tailings into Cell 8 and Cell 9 likely increased groundwater tables in the vicinity of these dams. The groundwater tables along the southern side of the former West WRD remained high.

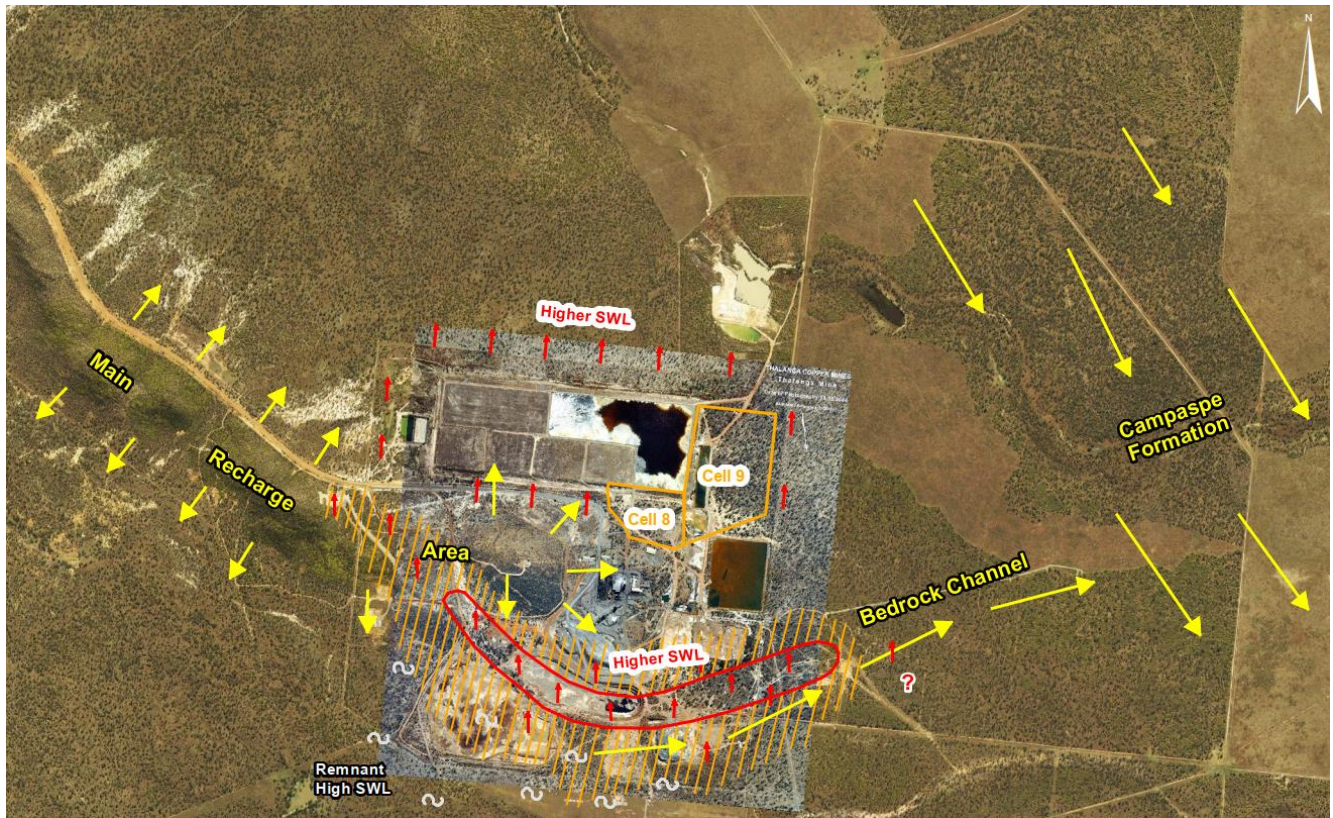


Figure 41 Conceptual groundwater situation at Thalanga during Phase Three, 2006-2008

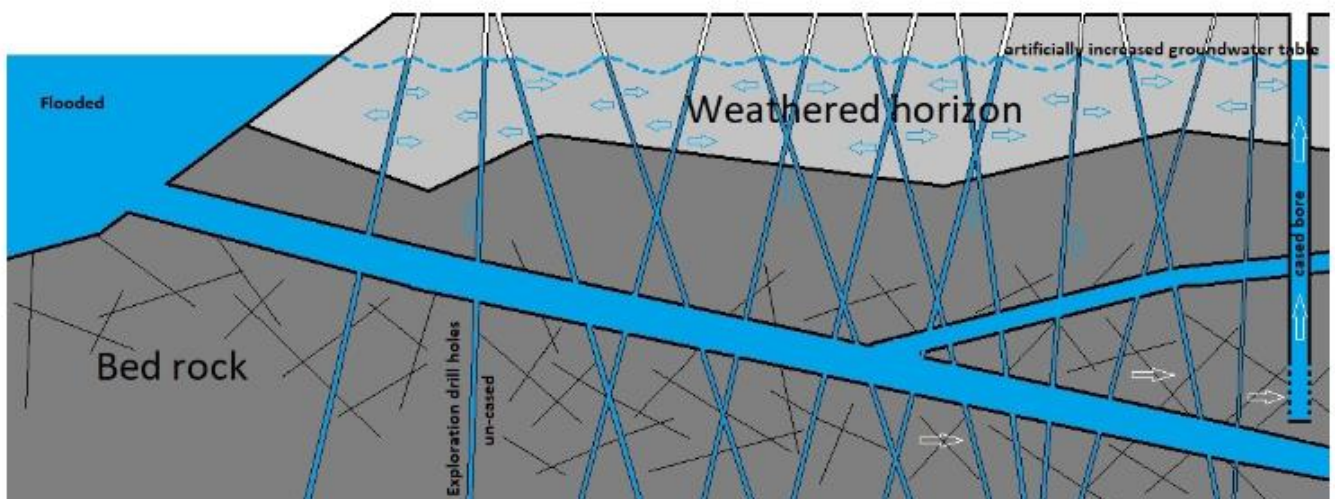


Figure 42 Conceptual cross section of accelerated groundwater level increases through uncased exploration holes in comparison to groundwater level increases in cased bores (on the right).

8.4.1.5 Groundwater conceptualisation during Phase Four

Phase Four, between 2008 and 2012 (**Figure 43**), first saw a reduction of groundwater levels due to the dewatering efforts to allow access to the Vomacka Pit. Due to the interconnection through the underground and exploration holes, groundwater level decreases were broad, including sections directly south of the tailings dams. The area to the east of the new Cell 9, nevertheless, saw an increase in groundwater levels as Cell 9 became operational.

Bores installed in the Campaspe Formation also saw an increase in groundwater levels, this increase appears to be linked to a reduction in groundwater pumping rates due to the 2012 commencement of the care and maintenance mode.

In the months prior to the care and maintenance mode, the 2012 dewatering of the West 45 deposit appeared to have had a localised impact only. Groundwater level decreases from the West 45 dewatering overlapped with groundwater level decreases from the previous Vomacka dewatering.

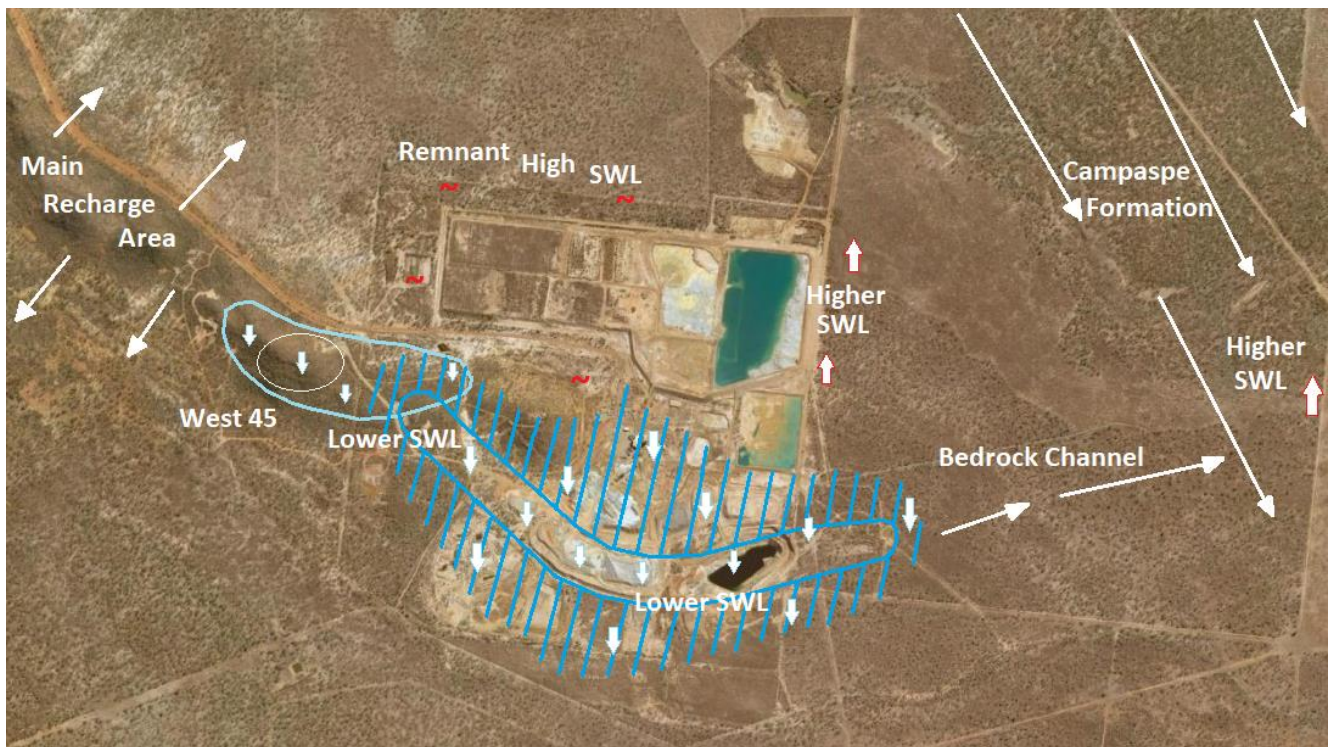


Figure 43 Conceptual groundwater situation at Thalanga during Phase Four, 2008-2012

8.4.1.6 Groundwater conceptualisation during Phase Five

Phase Five, from 2012 till 2019, is marked by dewatering activities associated with the West 45 and Far West orebodies and an accelerated decrease in groundwater tables in the western section of the Thalanga deposit (**Figure 44**). Groundwater tables associated with the Vomacka and eastern side of the mine site experienced minor declines in groundwater tables due to the limited bedrock connection between the deposits. As stated earlier, while connection via underground workings within the individual east and west sections of the Thalanga orebody are extensive, connection between the separate east and west underground workings only exists via a decline in the upper section of the now backfilled Central Pit.

Due to renewed tailings production since 2017, groundwater levels east of Cell 9 started to increase again, after remaining unchanged between 2012 and 2017. Related to this production is the renewed need for process water and decreasing groundwater tables near the Campaspe Formation production bores.

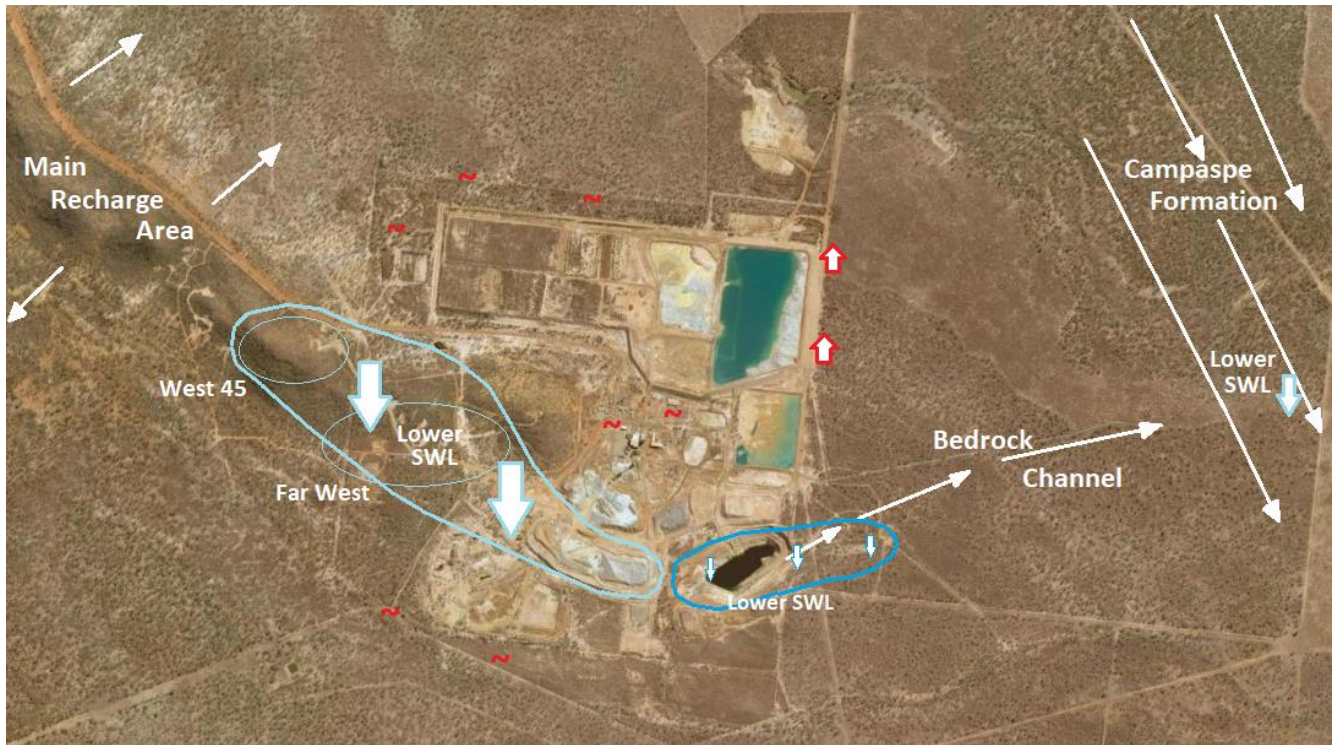


Figure 44 Conceptual groundwater situation at Thalanga during Phase Five, 2012-2019 (Background image from State of Queensland 2016)

8.4.2 Likely future groundwater level development

Due to continued dewatering activities, the future development has the potential to induce a further reduction of groundwater levels within the western section of the Thalanga orebody. Due to the limited connection the eastern section may only see a continued but slow decline in groundwater levels. This decline may in part be facilitated through evaporation from the Vomacka Pit lake surface.

Groundwater levels east of Cell 9 may see some further increases. Like the groundwater tables north of the previous tailings dam cells, this increase will likely be contained within the surrounding strata in the vicinity of the TSF. Similarly, due to the sustained compaction of the strata, groundwater tables around the former West WRD and south of the TSF area will likely remain elevated.

Groundwater levels within the Campaspe Formation will possibly decrease slightly, depending on the process water requirements of the Thalanga Plant.

It is recommended that water tables within the Vomacka Pit should be kept below the level of the Campaspe Formation, which is visible within the southern pit wall. Contact of contaminated groundwater or pit water with the bedrock channel should not occur.

9 Hydrogeochemistry

The hydrogeochemical development at Thalanga is closely linked to the geological characteristics of the deposit and surrounds, the mining history of the site and the hydrogeological development of the groundwater levels at the site. To appreciate changes in groundwater chemistry over time, an understanding of all three components is necessary.

A relevant table with the descriptive statistics for each groundwater monitoring bore at Thalanga, including data range, count, mean, minimum, maximum, median, 80th and 95th percentile has been included in Appendix M. Box plots for all groundwater monitoring bores at the Thalanga Project for each groundwater contaminant showing, the minimum, the median, 20th and 80th percentiles and maximum as well as the relevant water quality objectives for each environmental value are shown in Appendix K. Relevant spatial and temporal trends in groundwater quality are shown in the following sections with time series plots for all contaminants being presented in Appendix L. Combined the above allows for an assessment of the groundwater quality objectives for all contaminants and all environmental values with reference to graphical summaries which include water quality objectives for each environmental value.

9.1 Potential groundwater contaminant sources

The groundwater chemistry development is closely linked to the presence of groundwater contamination sources. Potential groundwater contaminant sources are generally associated with the oxidation of sulphides and prior limited temporary processing of gold ore from the Highway Reward orebody. As such, contaminant sources consist primarily of tailings and waste rock.

Tailings are present at the surface in tailings Cells 1 to 9 and underground in the form of bulkhead-controlled thickened backfill and uncontrolled hydraulic fill pumped down into exploration holes.

Waste rock is present as above ground waste rock dumps, the ROM pad, underground stope backfill and backfill into the initial Thalanga Central pit.

Due to operational changes since the start of operation in 1989, the influences of these individual contaminant sources varied over time. The current main sources of concern are the tailings dams and the backfilled underground workings along the strike of the Thalanga ore deposit.

9.2 Pre-mining baseline conditions

Prior to the start-up of the Thalanga operation in 1989, the only available groundwater quality information was through landholder bores and preliminary drilling of the Campaspe Formation. The earliest information on potential mine impacts is available from a few sources, including regional studies of the Mount Windsor Volcanics and mine site monitoring records.

9.2.1 Pre-mining landholder bores within 5km of the Thalanga mine lease

Historic groundwater information for surrounding landholder bores (**Appendix F**) is shown in **Table 11**. The high EC and chloride concentrations in **Table 11** show that evapotranspiration can play an important role in the groundwater development at Thalanga.

Table 11 Historic groundwater chemistry for landholder bores within 5 km of the Thalanga Mine site

	RN60287	RN60289	RN60637	RN60638
Month/Year	09/1974	09/1974	07/1996	07/1996
pH	7.2	8.0	7.5	8.0
EC ($\mu\text{S}/\text{cm}$)	203	2500	4050	3020
Cl (mg/L)	44	555	935.8	559.1
Na (mg/L)	27	355	723.8	604.4
Ca (mg/L)	2.5	50	103.7	50.7
Mg (mg/L)	3	47	73.5	48.1
K (mg/L)	4.8	50	7.5	6.5
F (mg/L)	0.0	0.4	0.25	0.7
SO ₄ (mg/L)	7.6	0.0	153.3	123.8
NO ₃ (mg/L)	0.0	0.0	0.0	16.9

Figure 45 Landholder bores with historic groundwater chemistry information within 5 km of the Thalanga Lease (on 2016 Google Earth base map)

9.2.2 Oceanic Australia, 1983

Early groundwater chemistry records for Thalanga date back to September 1981 (Oceanics Australia, 1983). Initial groundwater quality measurements from 10 samples collected between September 1981 and October 1982 show that the groundwater samples had a moderate EC (805-2052 $\mu\text{S}/\text{cm}$), circumneutral pH (pH 6.8-8.3) and low sulfate concentrations (24-50mg/L). It is not known which bores or locations were sampled at the time; however, Oceanics Australia highlighted that all averages of chemical measurements of groundwater were well in excess of surface water concentrations.

9.3 Groundwater chemistry development

9.3.1 CSIRO, 1995

A regional study conducted by CSIRO in 1995 included groundwater analysis from 6 bores/exploration holes across the then operating Thalanga site (**Table 12** and Error! Reference source not found. **15 in Appendix C**). As shown in **Table 12** and Error! Reference source not found. **15 in Appendix C**, groundwater/exploration bores (Thal 1 to Thal 3) that are within the influence of the Thalanga orebody recorded high sulfate and zinc concentrations. Exploration holes TH391, TH408 and TH424 recorded significantly lower sulfate and zinc concentrations. The likely reason for the lower concentrations at TH391, TH408 and TH424 is their position outside of the zone of influence of the ore deposit and associated underground workings.

Table 12 Historic groundwater parameters at Thalanga (Zinc included due to its prominence in the ore deposit)

Location	pH	EC (µS/cm)	Sulfate (mg/L)	Zinc (mg/L)
Thal 1	6.2	-	3510	3.108
Thal 2	6.9	-	5967	15.55
Thal 3	3.5	-	2283	90.41
TH391	6.8	400	152	0.457
TH408	6	2000	12	0.014
TH424	7	1000	44	0.01

9.3.2 Campaspe Formation bores

The Campaspe Formation production bores are the oldest continuously monitored bores at Thalanga. These bores consist of bore K (PB1), L (PB2), M (PB3), O (PB4) and P (PB5) (Error! Reference source not found. **Appendix C**).

The bores were constructed in 1988 as a result of a regional water supply study for the Thalanga mine. Continuous groundwater measurements for EC and sulfate are available since 1990. The monitoring results are shown in

Figure 46 and

Figure 47. These results show that groundwater EC and sulfate increases along the general northwest to southeast groundwater flow direction ($K > L > M > O > P$). Since these bores are connected via a pipe network and samples are collected via taps on these pipes, water quality may be influenced by the pumping configuration prior to, or on the day of sampling. For example, the pumps at bore O and bore M feed into the pipeline leading from bore P. This has resulted in samples from bore O and bore M at times showing EC and sulfate concentrations very similar to bore P. Similarly, leaking reverse flow check valves can result in lower EC and sulfate concentrations. The latter seems to have been the case at bores O and P between 2011 and 2015 and during 2017/2018. Due to the site being in care and maintenance, the pumps within the borefield would have not operated, probably resulting in the water standing in the pipes being sampled.

Despite these limitations, which must be considered, general water quality trends for these bores can be observed. The most down-gradient bore P, displays the highest EC and sulfate concentration, likely due to evapotranspiration effects along the groundwater flow path leading to bore P. A comparison with the available chloride data (only continuously measured since 2015) suggests that, due to similar behaviour of chloride (

Figure 48), evapotranspiration is the likely driver for elevated EC and sulfate concentrations. Nevertheless, between 2007 and 2011 a slight crest in EC and sulfate was recorded at bore P. The crest coincided with increased groundwater tables on the Thalanga site which could suggest seepage impact. The subsequent dip is EC likely the result of different sampling methodology during the care and maintenance period.

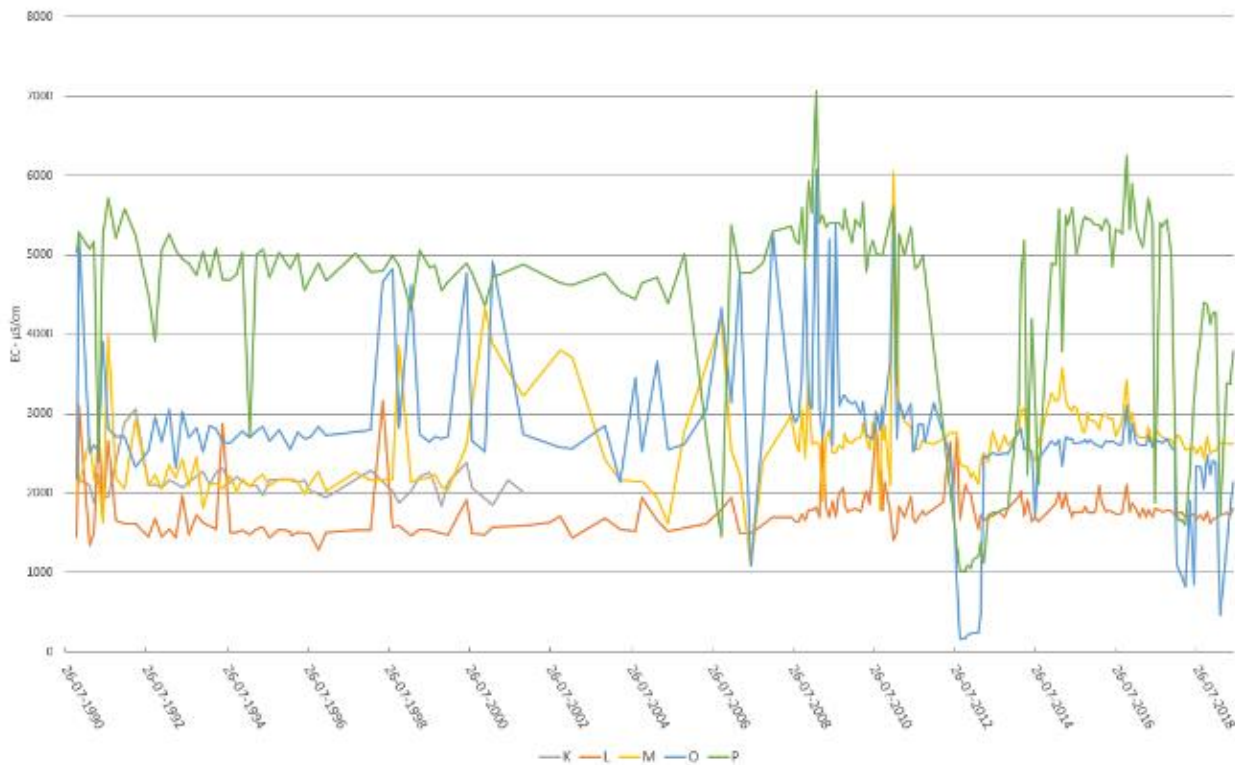


Figure 46 Comparison of groundwater EC between the Campaspe Formation bores K, L, M, O and P between 1990 and 2019

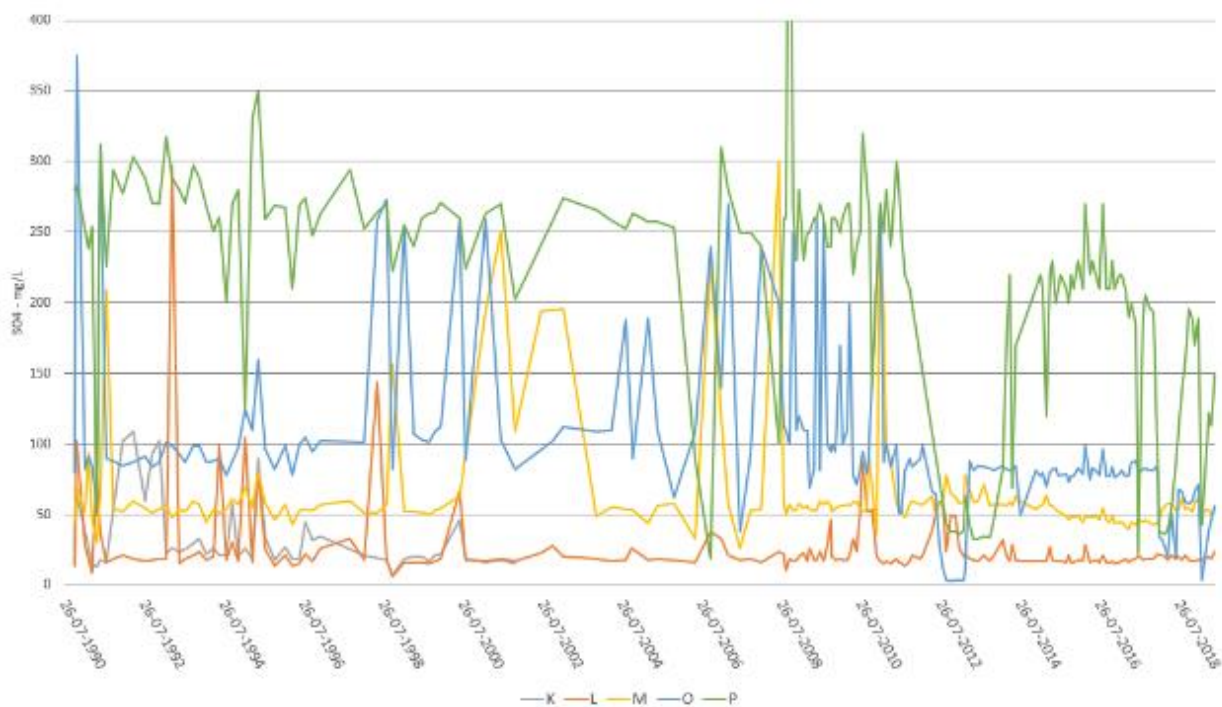


Figure 47 Comparison of sulfate concentrations between the Campaspe Formation bores K, L, M, O and P between 1990 and 2019

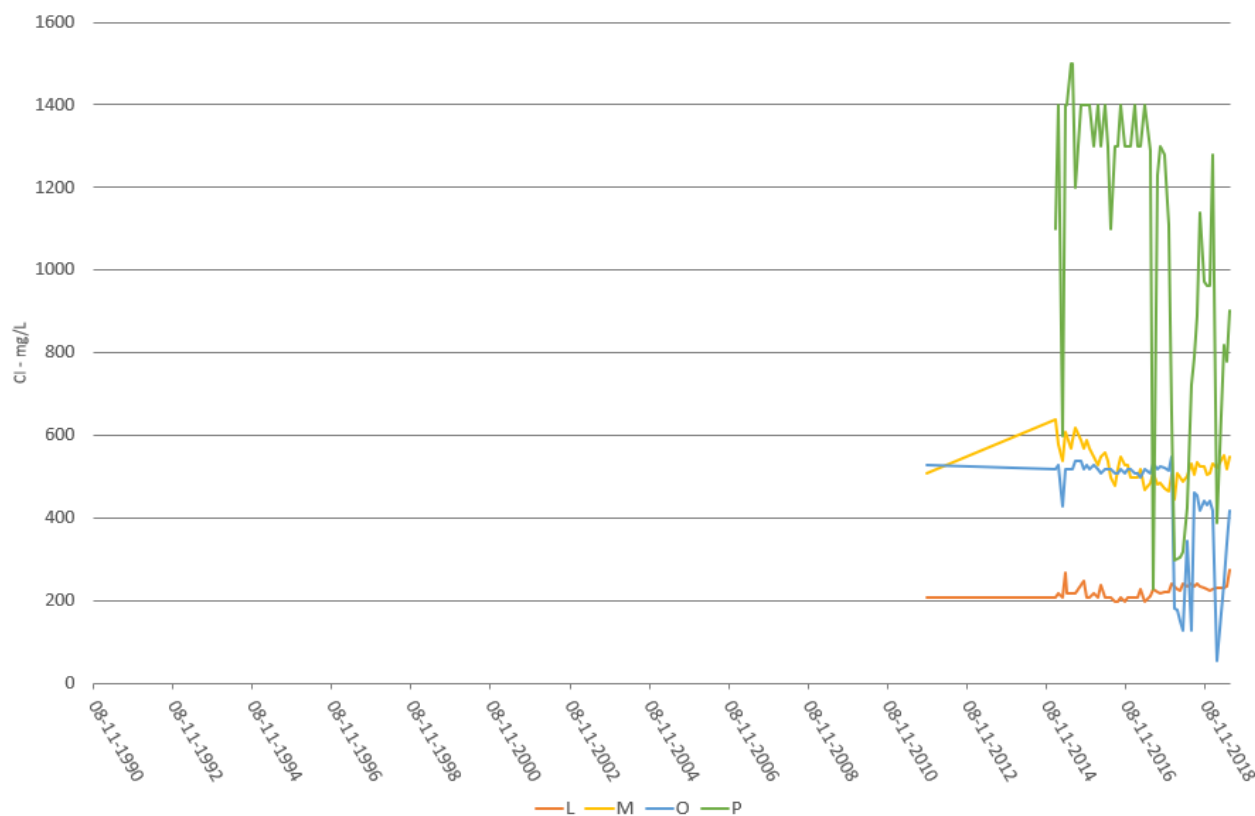


Figure 48 Comparison of chloride concentrations between the Campaspe Formation bores K, L, M, O and P between 1990 and 2019

9.3.3 Tailings Storage Facility monitoring bores

Regular groundwater monitoring at Thalanga commenced in September 1989, with monitoring of the initial tailings dam bores (alternative names in brackets) B (TD2, TMB1), C (TD3, TMB2), D (TD4, TMB3), E (TD5, TMB4), A1 (TD8), A3 (TD10), NB (TD5) and H (TD6, TMB6). This was followed by the installation of bores I (TD1, TMB5) and F (TD7, TMB7) in 1990, and later joined in 1995 by A1 (TD8), A2 (TD9) and A3 (TD10). Due to several changes in ownership, the naming of these earlier monitoring bores changed over time and the expansion of the tailings dam areas resulted in bores B, C, D and E being destroyed in 1994. Bores F, G and H were consumed by the later cell 9 extension and the fate of bores A1 and A2 are unknown. Replacement bores TH1, TH2 and TH3 were installed in October 2006. Bores TH2 and TH3 were also subsequently covered by the Cell 9 extension and replaced by bores TH4 and TH5, installed in August 2008. Most recent additions to the TSF groundwater monitoring are A1 and A4 along the northern flank of the TSF area (Error! Reference source not found.). Of the initial tailings monitoring bores, only bore A3 remained serviceable in 2019.

9.3.3.1 TD2, TD4 and TD6 - EC and sulfate 1989 to 1995

Of the available monitoring records prior to 1995, only three bores (TD2, TD4 and TD6) have sufficient data for early groundwater chemistry changes to be evaluated (**Appendix J**) (**Figure 18 in Appendix C**). Of these, available data records for EC and sulfate are the best indicators for groundwater chemistry change. The uncertain nature of the groundwater samples (i.e. filtered/unfiltered and sample preservation) and accuracy of cadmium and copper concentrations (particularly at TD1, TD5, TD6, TD7, TD8 and TD10) is in doubt and some parameters appear to be displayed in $\mu\text{g/L}$ rather than the stated mg/L .

Initial measurements suggest that groundwater in the north of the TSF had a naturally high EC with around $3,000\mu\text{S/cm}$ and sulfate concentrations generally between about 80mg/L and 330mg/L . At the same time, groundwater to the east of the TSF had an EC between $7,000\mu\text{S/cm}$ and $9,500\mu\text{S/cm}$ and sulfate concentrations generally between 350mg/L and 550mg/L (

Figure 49 to

Figure 51). It is not clear if increases in EC and sulfate at TD2 and TD4 during the early phase of operations were the result of seepage or evapotranspiration. Besides EC and sulfate, no other measured parameters showed an increase in concentrations. A relatively small increase in sulfate in contrast to large increases in EC suggests that most of the EC rise is due to increased evapotranspiration. Without groundwater level data for the TSF bores during the early years of operation, it can only be assumed that the increased evapotranspiration is due to elevated groundwater tables caused by initial aquifer compression.

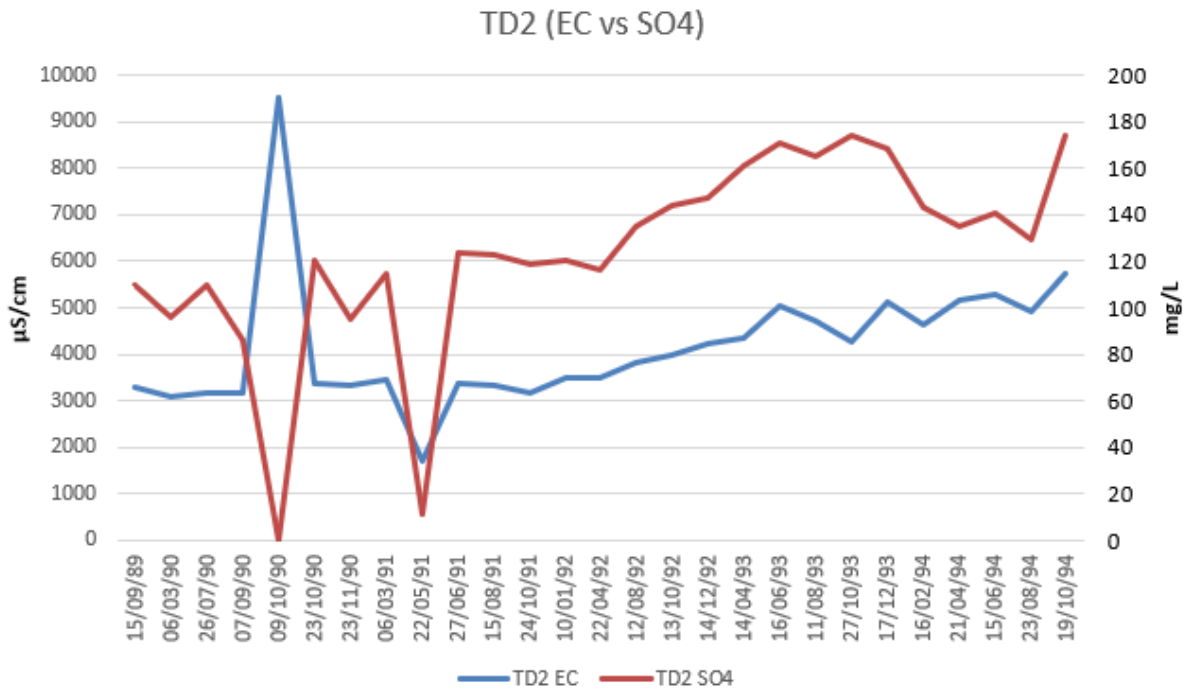


Figure 49 Development of EC (µS/cm) and sulfate (mg/L) concentrations at TSF bore TD2 between 1989 and 1994

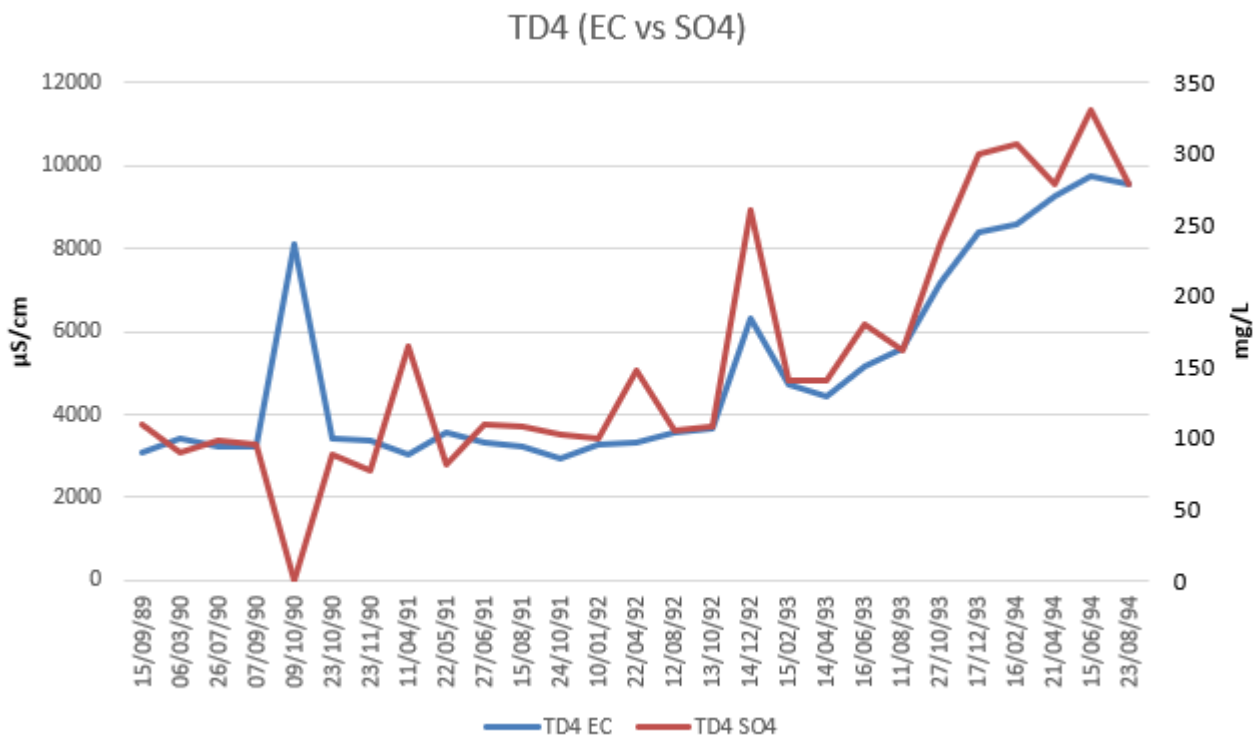


Figure 50 Development of EC (µS/cm) and sulfate (mg/L) concentrations at TSF bore TD4 between 1989 and 1994

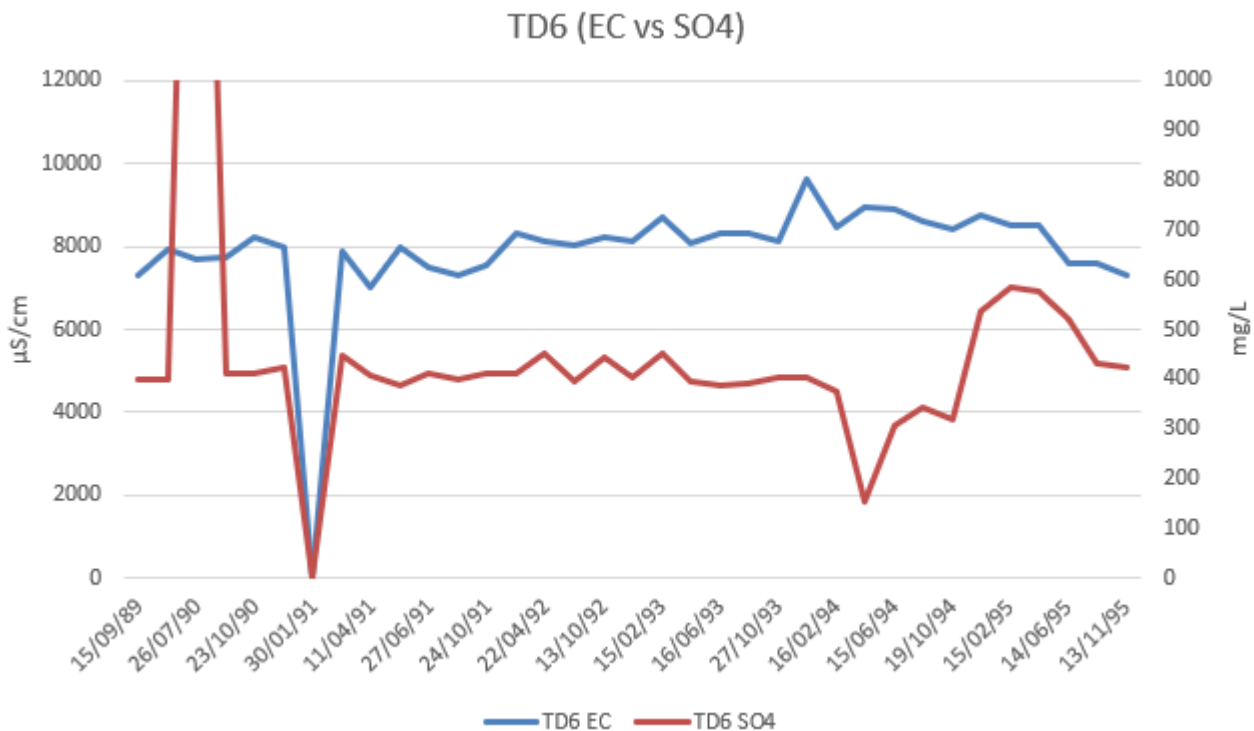


Figure 51 Development of EC (µS/cm) and sulfate (mg/L) concentrations at TSF bore TD6 from 1989 to 1994

9.3.3.2 A1 (old), A2 and A3 - EC and sulfate 1995-2002

Monitoring bores A1(old) (TD8), A2 (TD9) and A3 (TD10) were installed as a response to the TSF being extended to the north (Error! Reference source not found. in **Appendix C**) and TSF bores TD2, TD4 and TD6 becoming subsequently defunct. Groundwater chemistry results for A1(old) and A3 are available between 1995 and 2002. The development of EC and sulfate indicate a temporary freshening of groundwater during 1999 and 2000 (**Figure 52** and

Figure 53). The reason for this is not clearly understood but may be related to:

- Increased rainfall during this period.
- As a result of this increased rainfall a possibly greater reliance on lower EC surface water from the site dams for ore processing.
- A shift in tailings deposition away from eastern Cells 2 to 6 to the more westerly (now combined) Cells 1 and 7.

Throughout the same period as EC and sulfate decreased, groundwater levels at A1 and A3 continued to increase in an almost linear fashion (

Figure 54); hence tailings deposition must have continued. In fact, historic mine records (Appendix B) show an increase in Cell 7 tailings level height from 328.68m RL in October 1999 to 331.56m RL in December 2000. On the other hand, rainfall appears to have had no impact on groundwater levels. In light of the above, reduced EC and sulfate concentrations were likely the result of increased rainfall having an impact on the groundwater composition at A1 (old) and A3. The observed increases in groundwater levels at A1(old) and A3 were the result of aquifer compression and not a product of increased seepage flow.

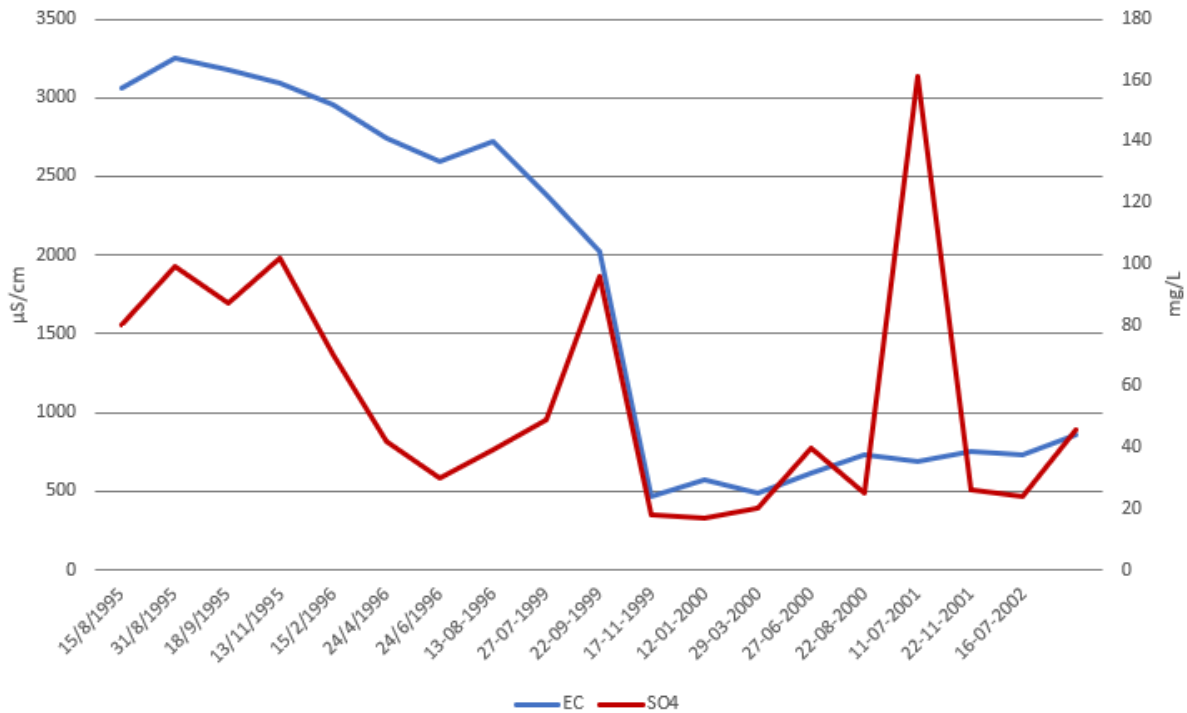


Figure 52 Development of EC ($\mu\text{S/cm}$) and sulfate (mg/L) at bore A1 (old) between 1995 and 2002

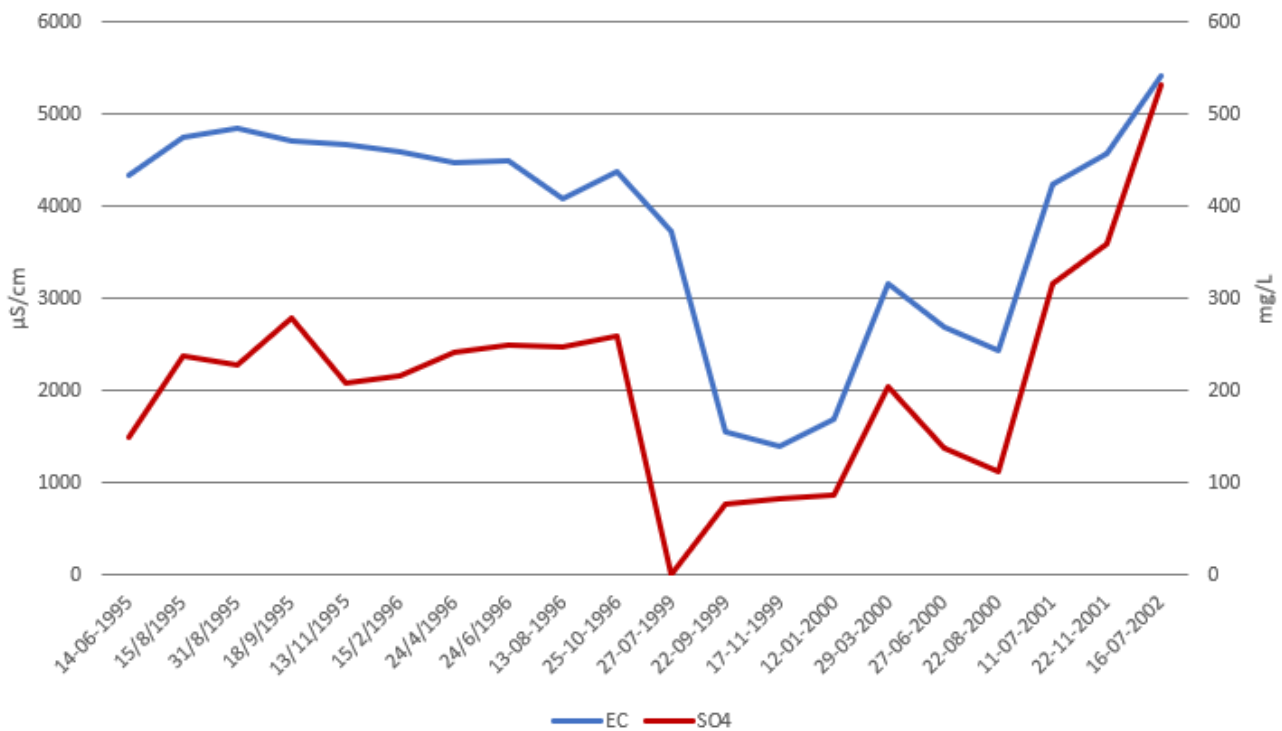


Figure 53 Development of EC ($\mu\text{S/cm}$) and sulfate (mg/L) at bore A3 between 1995 and 2002

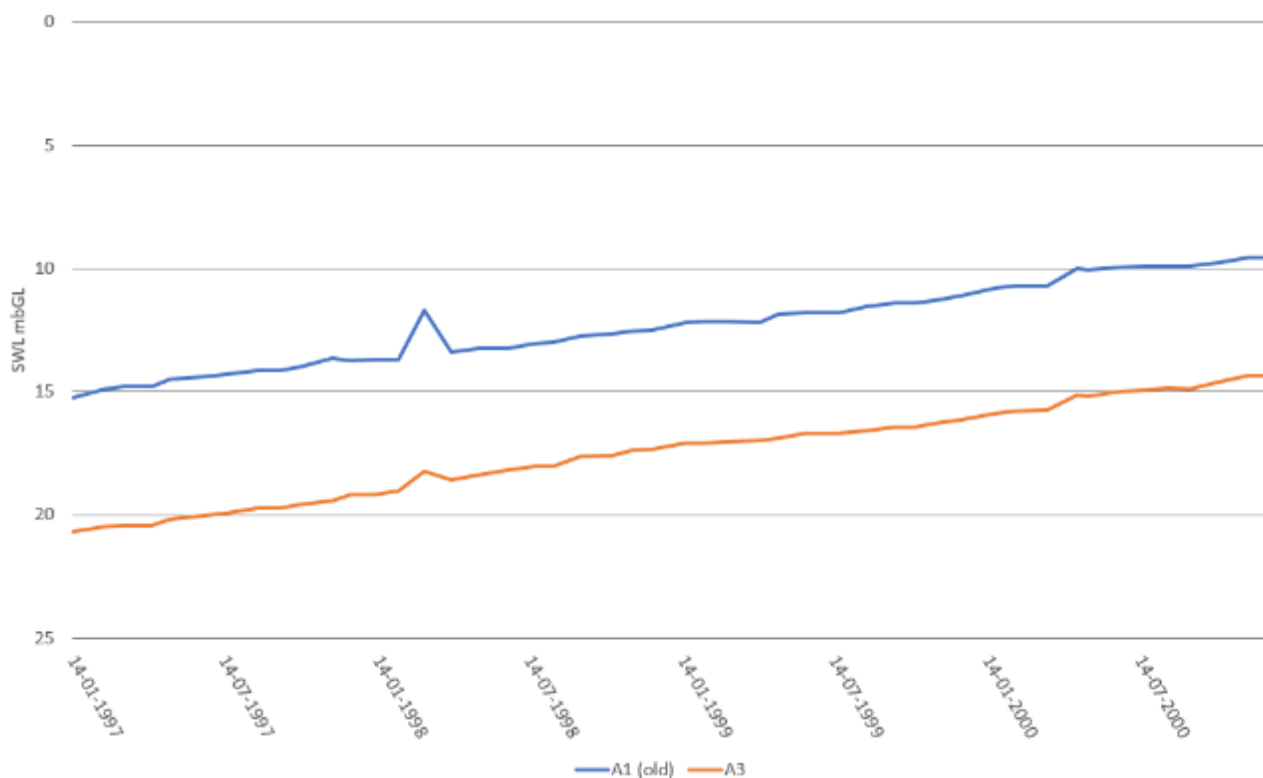


Figure 54 Groundwater level development at A1 (old) and A3 between 1997 and 2001

9.3.3.3 A3 - EC and sulfate 2007-2019

Groundwater measurements from bores at Thalanga were available again from 2007 onwards. Renewed sampling of A3 occurred (

Figure 55 and

Figure 56), but bore A1 (old) does not appear anymore in the monitoring records. Instead, a number of new bores were now sampled to monitor the further extended TSF.

Despite there being no groundwater chemistry data for A3 between 2002 and 2008, there appears to have been a period of stagnation for EC and sulfate at approximately $4,200\mu\text{S}/\text{cm}$ and $600\text{mg}/\text{L}$, respectively. Between 2008 and 2015, an increase in EC and sulfate concentrations is seen again in A3 (

Figure 55). At the same time, groundwater levels at A3 continued to increase until approximately 2012 (

Figure 56). Between 2012 and 2016 groundwater levels at A3 declined (possibly owing to a period of non-production while the site was placed in care and maintenance). Once production recommenced, groundwater levels started to increase once more.

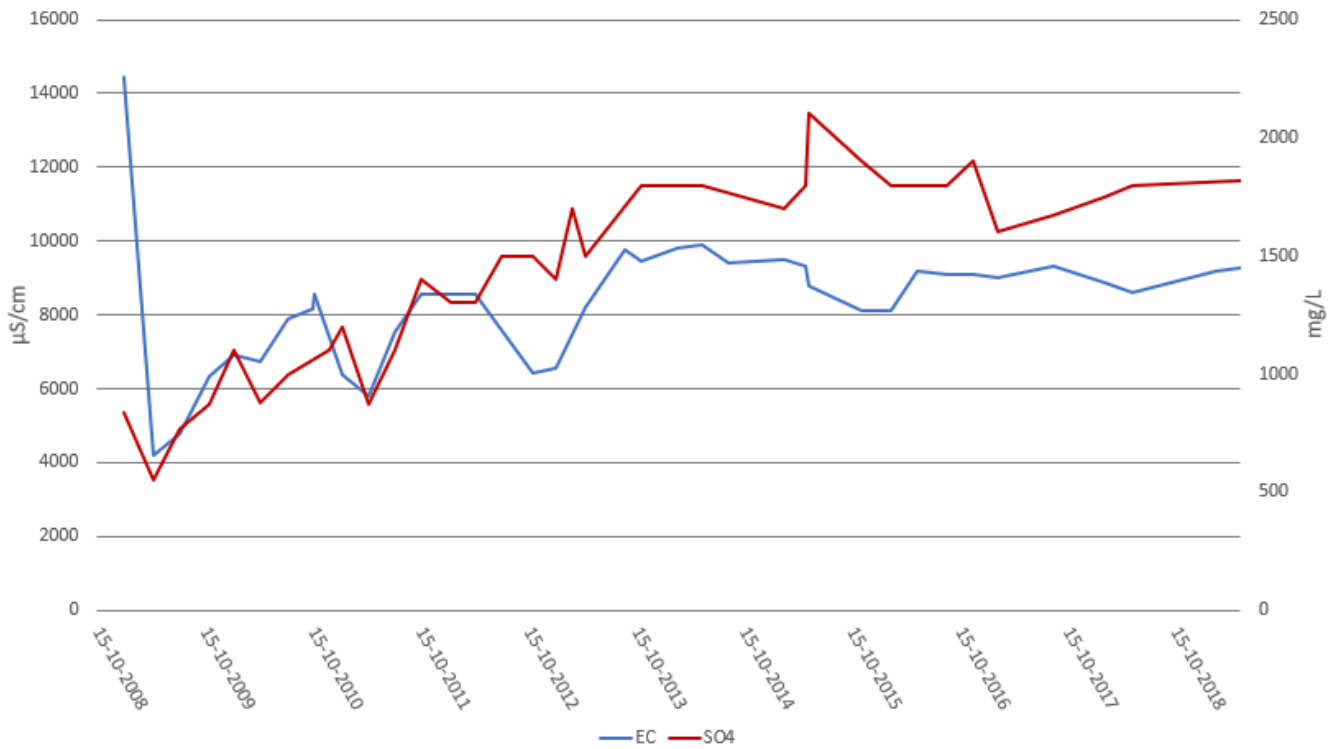


Figure 55 Development of EC (µS/cm) and sulfate (mg/L) at A3 since 2008

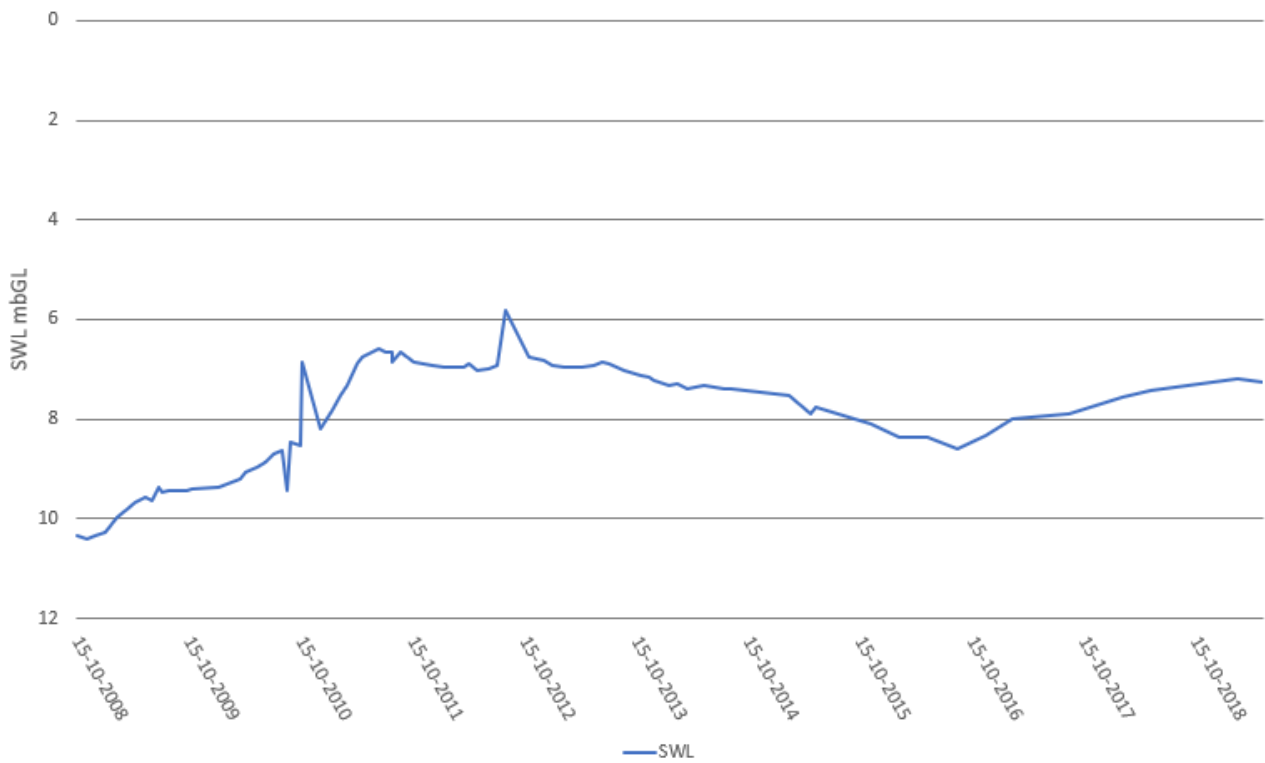


Figure 56 Development of groundwater level at A3 since 2008

9.3.3.4 TH1, TH2 and TH3 – EC and sulfate 2006-2008

The new bores (TH1, TH2 and TH3) were installed in October 2006 (**Figure 20 in Appendix C**) in anticipation of the then proposed Cell 8 TSF extension towards the south. Within two years, all three bores recorded an EC above 10,000 $\mu\text{S}/\text{cm}$ and sulfate concentrations above 1,500 mg/L (

Figure 57,

Figure 58 and

Figure 59). Despite that similarity, it is not certain if the chemistry of groundwater intercepted at TH1, TH2 and TH3 is the result of tailings seepage. Compared to latest groundwater measurements at A3 (EC: 8,000-10,000 $\mu\text{S}/\text{cm}$, sulfate: 1,600-2,100 mg/L), the EC at TH1 and TH2 appears to have been significantly higher (12,000-15,000 $\mu\text{S}/\text{cm}$). The latter either due to greater evapotranspiration resulting from higher groundwater tables (0.55 m below ground level at TH1 in October 2008) or the presence of other surface water dams in the immediate vicinity of these bores. The impact of high water tables can be seen in **Figure 20 in Appendix C**, with salt scalds extending to the east from TH2 and TH3. Salt scalding and ground saturation of this area was confirmed during the drilling of TH1, TH2 and TH3 in October 2006 (M. Thienenkamp personal communication, 2019).



Figure 57 EC ($\mu\text{S}/\text{cm}$) and sulfate (mg/L) development at TH1 between October 2006 and May 2008

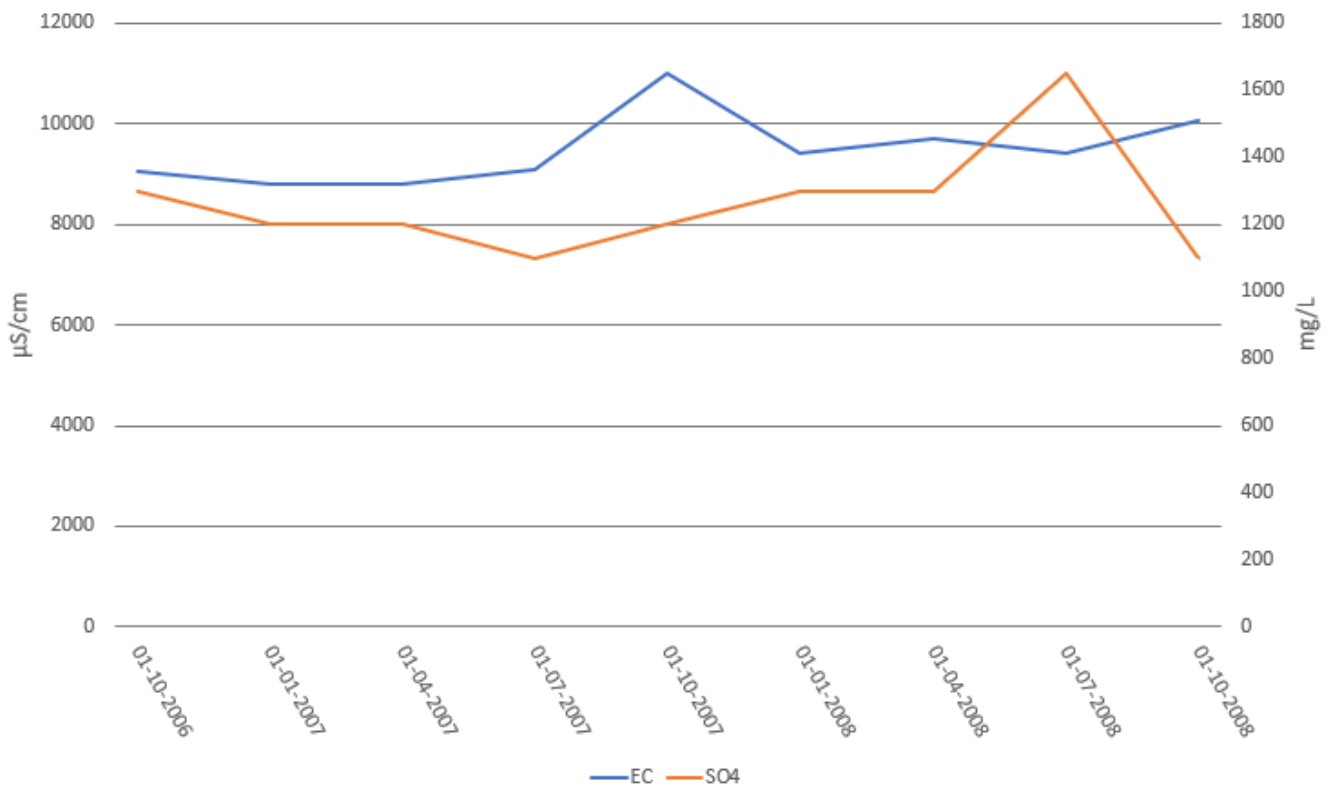


Figure 58 EC ($\mu\text{S/cm}$) and sulfate (mg/L) development at TH2 between October 2006 and October 2008

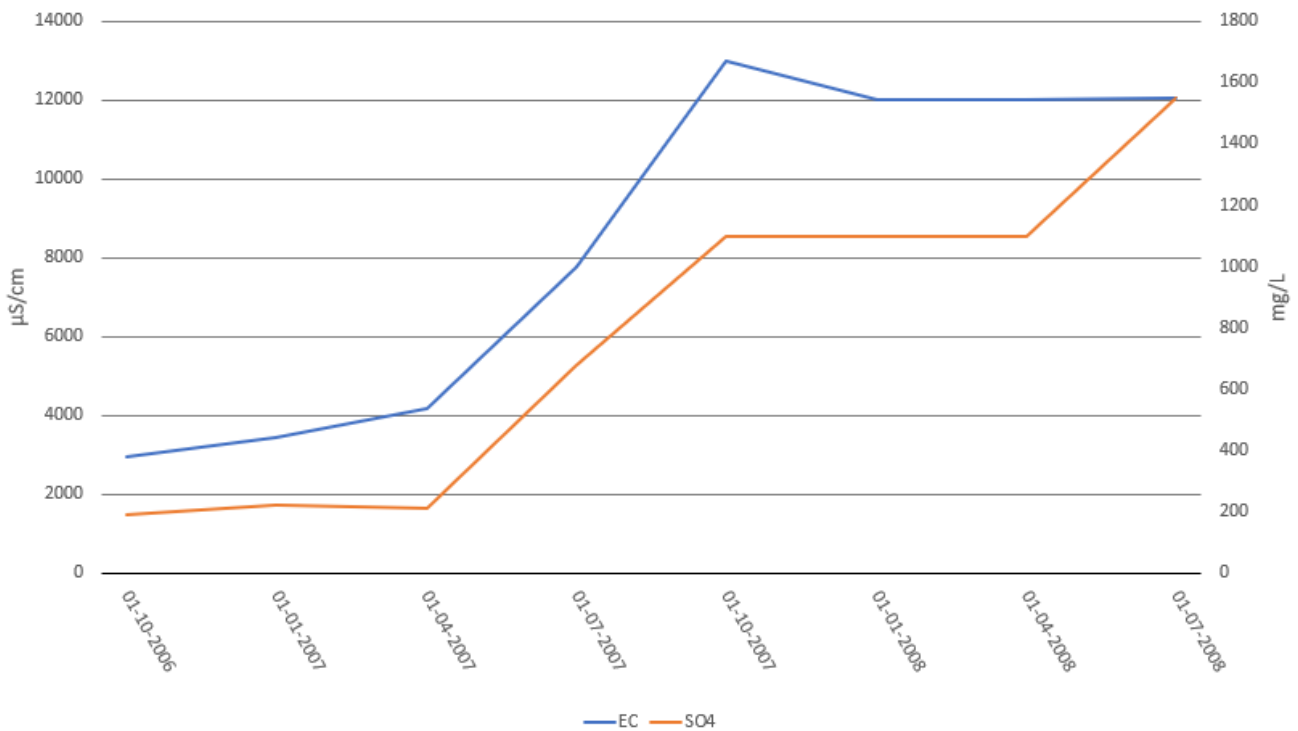


Figure 59 EC ($\mu\text{S/cm}$) and sulfate (mg/L) development at TH3 between October 2006 and August 2008

9.3.3.5 TH1, TH4 and TH5 – EC and sulfate 2008 -2016

Within two years of installation, bores TH2 and TH3 were decommissioned to give way to a further TSF extension, TSF Cell 9. The bores were replaced in August 2008 by TH4 and TH5 (**Figure 11 in Appendix C**). Since installation, EC and sulfate concentrations at TH4 were very varied with EC ranging up to about 11,000µS/cm and sulfate concentrations around up to 2,000 mg/L (

Figure 60). Bore TH5 generally reports EC values between 8,000µS/cm and 10,000µS/cm with sulfate concentrations between about 500mg/L and 600 mg/L (

Figure 61).

The groundwater level developments at the remaining TSF observation bores (TH1, TH4, TH5) and A3 are shown in

Figure 62. Bores TH4 and A3 display a very similar groundwater level behaviour. That is, groundwater levels increase during a period of tailings deposition (2008-2012), decrease during the care and maintenance period (2012-2016) and increase again with renewed tailings deposition since 2016. The uniform groundwater level changes at TH4 and A3 support the notion that both bores are influenced by the same processes. Increasing EC and sulfate at A3 (

Figure 55) since 2008 and recently very similar EC and sulfate concentrations at A3 and TH4 suggest that the changes are possibly due to fluctuating seepage flows.

Bore TH5 shows a continued increase in the groundwater table, which is indicative of some hydraulic loading. EC and sulfate concentrations at TH5 are slightly lower than at TH1 and TH4, hence at this stage TH5 experiences only a limited impact by seepage.

Bore TH1 experienced its highest groundwater levels in 2008 and until 2016 registered a reduction of very high groundwater levels. The reduction in groundwater levels corresponds to slight declines in EC and sulfate concentrations during the same period (

Figure 63). Considering increasing EC and sulfate at A3, it would appear that groundwater quality at TH1 is influenced by additional factors. As discussed in the hydrogeology section, one major factor could have been the raising of site groundwater tables by the back filling of the underground with tailings and process water. The practice of underground discharge was only halted with the dewatering needs for the Vomacka pit in 2008.

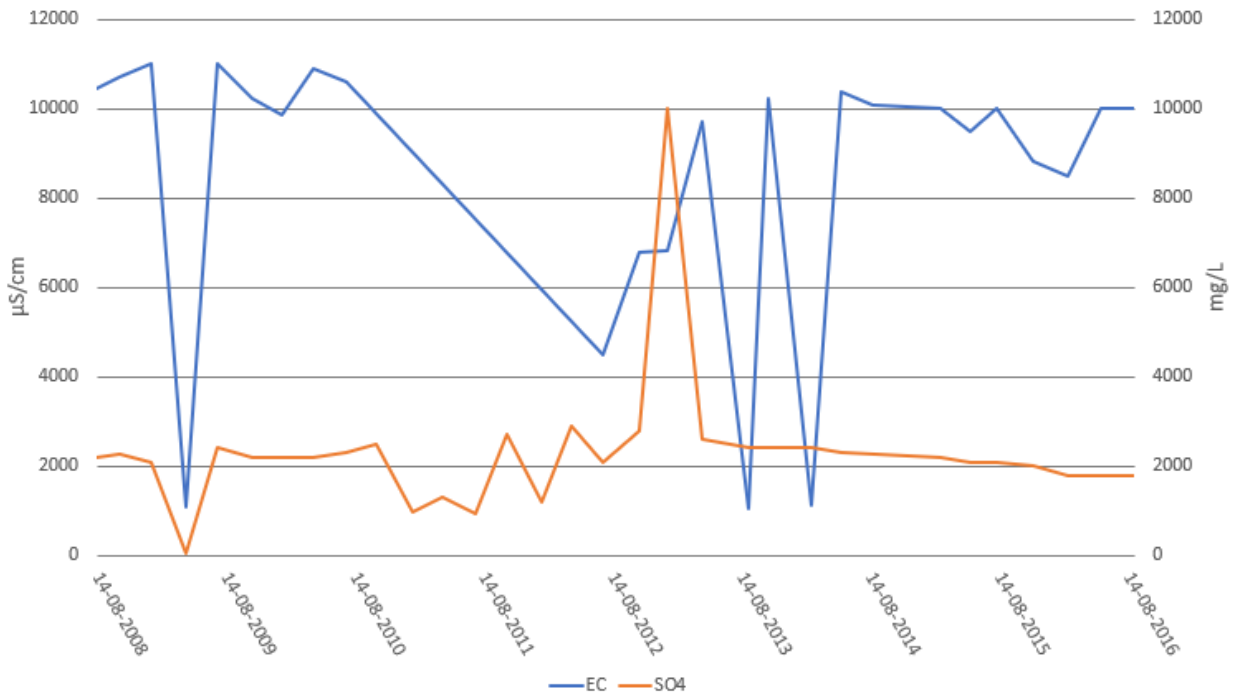


Figure 60 EC ($\mu\text{S/cm}$) and sulfate (mg/L) development at TH4 between August 2008 and August 2016

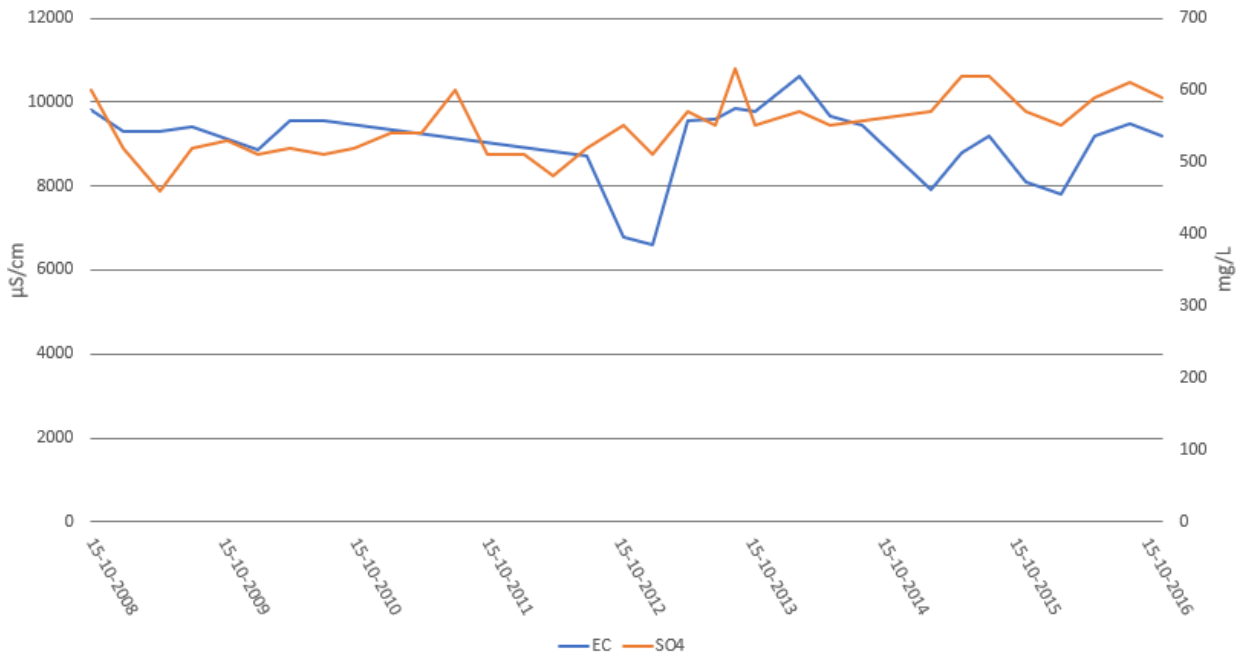


Figure 61 EC ($\mu\text{S/cm}$) and sulfate (mg/L) development at TH5 between October 2008 and October 2016

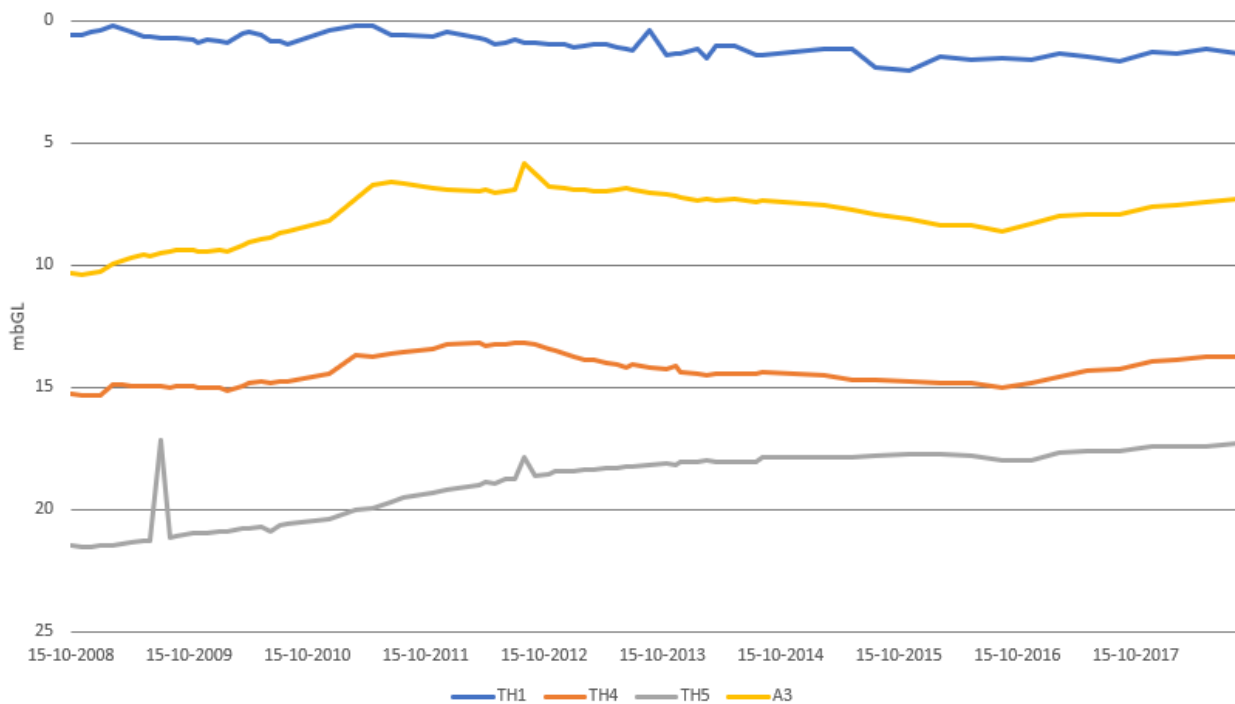


Figure 62 Groundwater level development at TH1, TH4, TH5 and A3 between October 2008 and August 2018

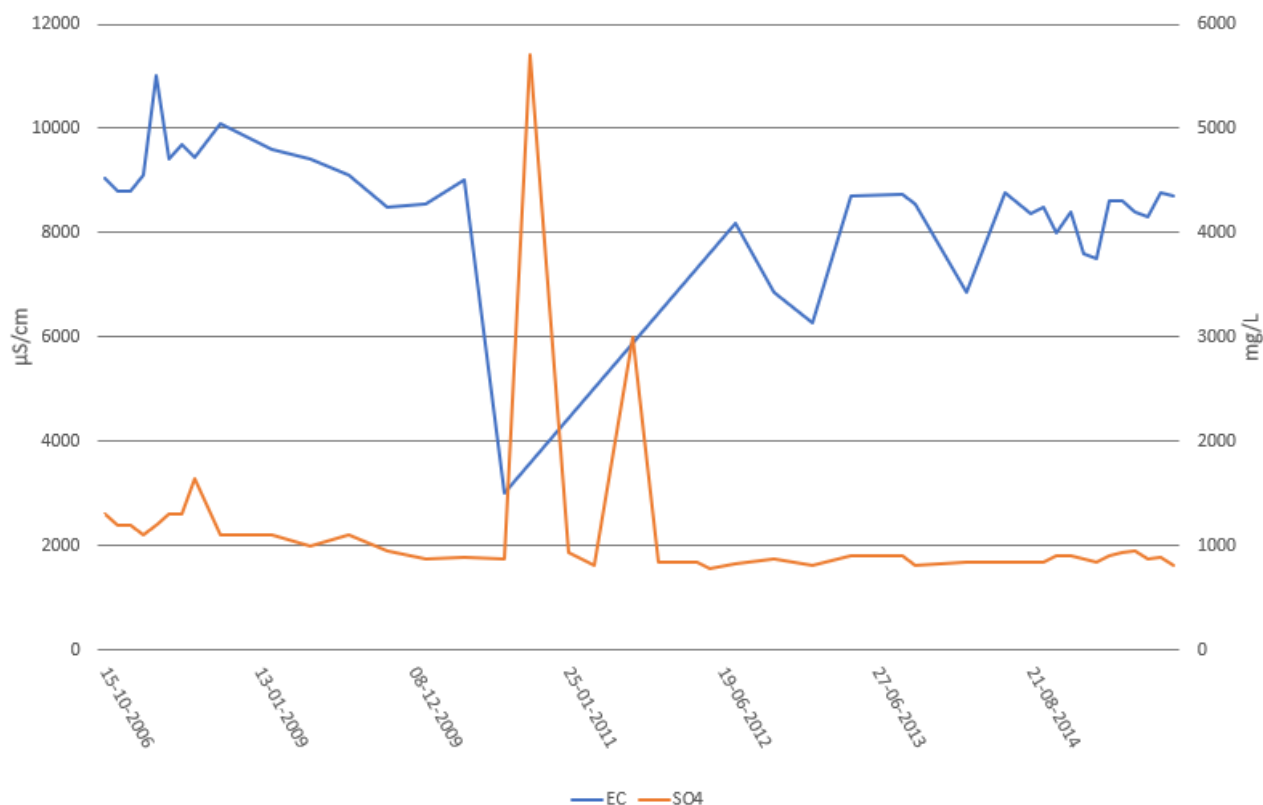


Figure 63 EC (µS/cm) and sulfate (mg/L) development at TH1 between October 2006 and May 2017

9.3.3.6 A3, TH1, TH4 and TH5 - Development of metal and metalloid concentrations

Due to the Thalanga ore deposit mineralogy and processing of ore from Highway Reward and Balcooma, the main metals of interest are zinc and copper, with possible minor influences by lead, arsenic and cadmium. Other metals and metalloids as well as fluoride have been monitored over the years at Thalanga, but have not reached concentrations that could be considered a representation of seepage or contamination.

What can be seen in

Figure 65 to

Figure 71 is that the main exceedances occur for cadmium, copper, zinc and to a lesser extend lead. Concentrations of arsenic, mercury and fluoride are generally below their respective trigger levels or contaminant limits. Of the bores frequently exceeding, TH4 displays the highest concentrations. Exceedances of cadmium, copper and zinc uniformly first start to occur at TH4 in October 2010, hence geochemical changes at TH4 are likely induced by operational changes. Surprisingly, cadmium, copper and zinc concentrations at A3 are considerably lower than the concentrations experienced at TH4; hence, the similarities in groundwater level development at A3 and TH4 (

Figure 56 and

Figure 62) cannot be due to seepage migration. Instead changes in aquifer compression rates and possibly evapotranspiration could be responsible. Compared to the groundwater levels at TH5, which did not respond to the pause in loading during the care and maintenance period, groundwater levels at A3 and TH4 declined. This may be due to the aquifer at A3 and TH4 being only partially confined and able to release aquifer pressure into the surrounding strata.

A closer, direct comparison between groundwater levels at A3 and TH4 (

Figure 64) shows that the initial gradient of decline of the water table at TH4 between October 2012 and October 2013 and subsequent increase from October 2016 was considerably steeper at TH4 than the corresponding changes at A3. The start of additional groundwater level increase at TH4 (about October 2010) coincides with the initial appearance of increased cadmium, copper and zinc concentrations at TH4 (

Figure 66,
Figure 67 and

Figure 69). Similarly, a recent peak in groundwater level in February/May 2019 at TH4 coincides with increased groundwater copper concentrations.

As can be seen, the groundwater chemistry changes at TH4 are fairly sudden, suggesting that a groundwater level threshold has been breached allowing for an increased flow of groundwater/seepage to occur. Similarly, a reduction of groundwater level results in a sudden decline in groundwater/seepage flow.

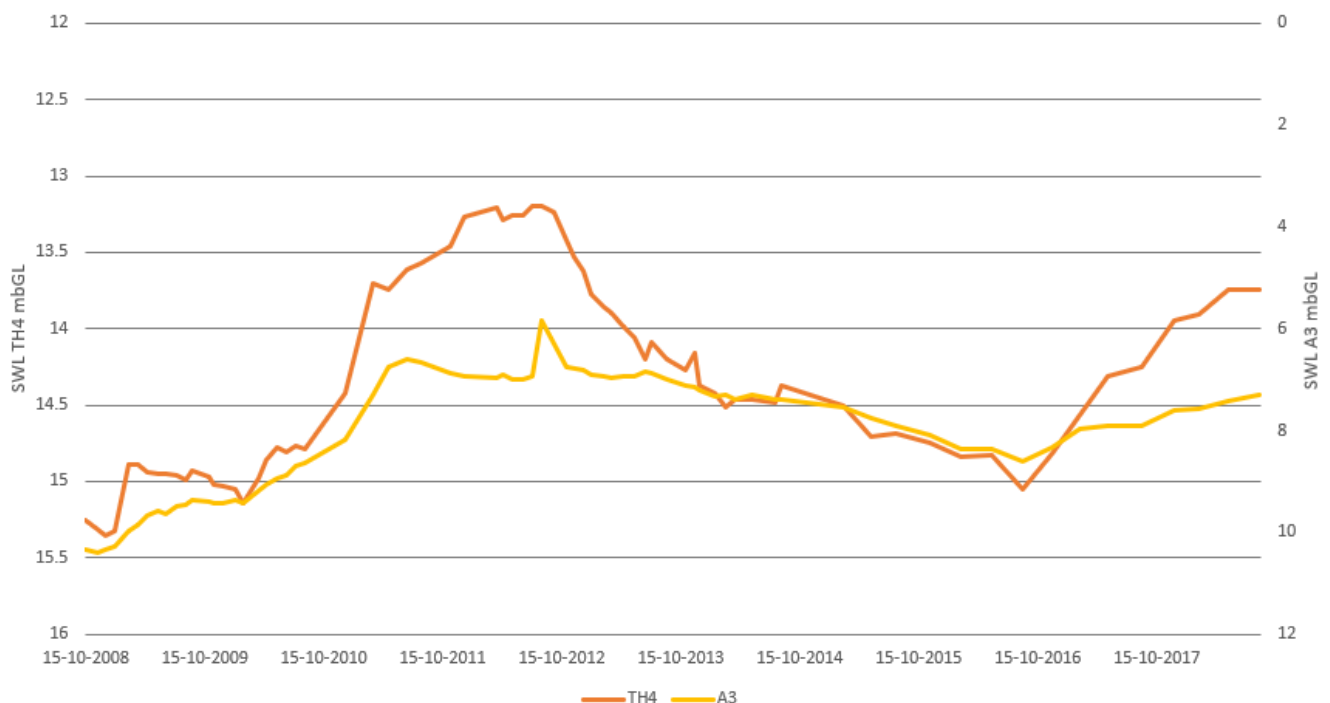


Figure 64 Comparison of groundwater levels between A3 and TH4 (October 2008 to May 2019)

Consequently, the change in tailings water composition should result in changing seepage composition. Such change can be observed in 2016.

Tailings deposition into TSF Cell 9 commenced in late 2008, initially receiving copper tailings from Balcooma and reprocessing of Highway Reward 'copper-gold' tailings from the surface of TSF Cells 1-7. It appears that by the end of 2009 the capacity of Cell 9 was almost exhausted, requiring a lift from RL 326 m to RL 331 m (or increase of embankment height from 5 m to 7 m) to accommodate 'zinc-lead-copper' tailings from the newly developed Vomacka deposit (AWA 2010). It appears that the lift was completed in late 2010, followed by the deposition of additional 'zinc-lead-copper' tailings. Late 2010, coincidentally sees the first spike of cadmium, copper and zinc concentrations at TH4 (

Figure 66,
Figure 67 and

Figure 69).

The change to care and maintenance in 2012 and cessation of tailings deposition to TSF Cell 9 did not result in a substantial reduction of cadmium, copper and zinc concentrations at TH4. In 2016, processing started again and generated 'zinc-lead-copper' tailings. These tailings, like the Vomacka tailings in 2010, contained similar zinc and copper concentrations as previously recorded between 2010 and 2013. Yet, this time copper concentrations did markedly decrease at TH4. The reason for this can be found in that, during the care and maintenance period, tailings within TSF Cell 9 had time to form secondary iron, manganese and aluminium oxides/hydroxides. Upon fresh tailings deposition, these oxides/hydroxides were initially able to adsorb copper from solution. Zinc concentrations on the other hand were not reduced since the mobility of zinc is less dependent on adsorption surfaces but is controlled by the pH and ionic strength of the solution (Malecki et al., 2017). This greater dependence on ionic strength also explains the initially high zinc concentrations during 2012 (

Figure 69). These higher zinc concentrations were likely facilitated by the relatively low EC, and hence ionic strength, of the tailings decant water at the time (

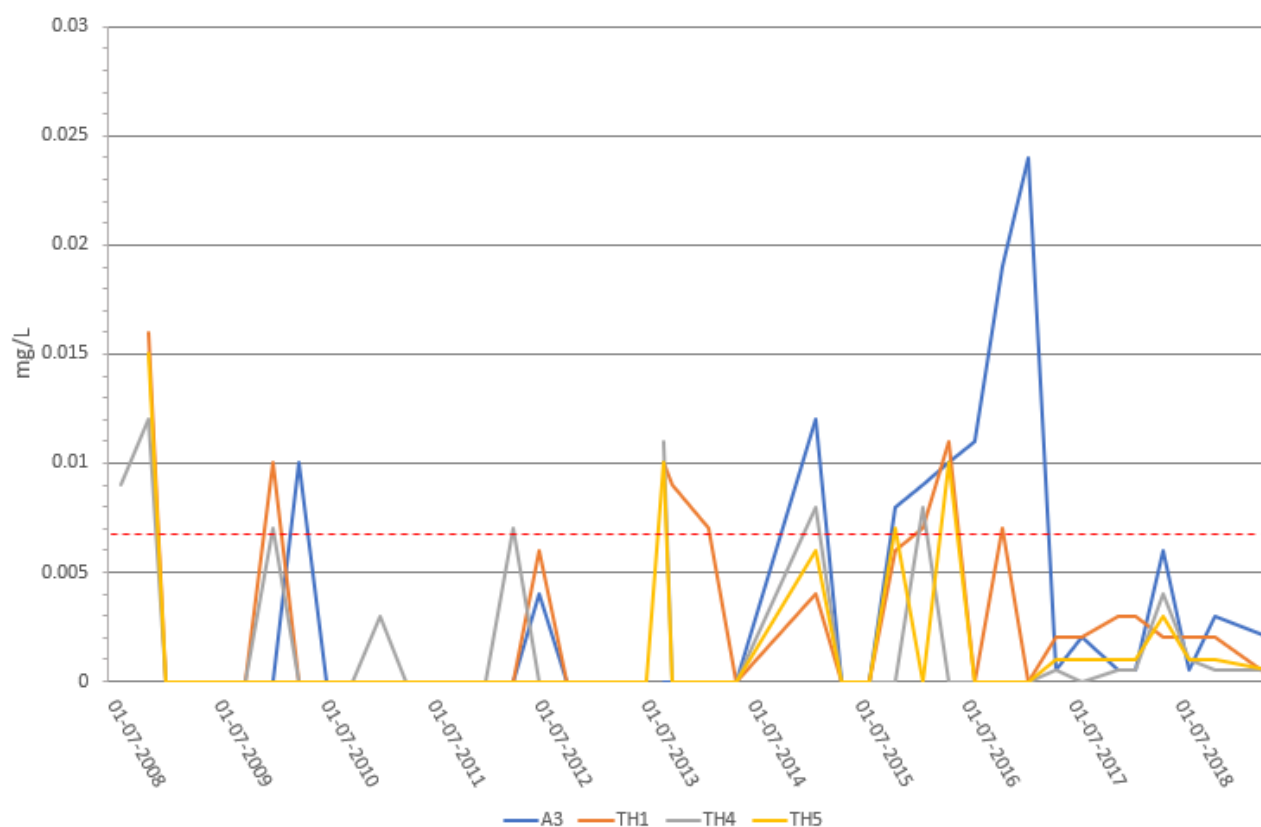
Figure 60).

Figure 65 Development of dissolved arsenic concentrations between 2008 and 2019 at TSF bores A3, TH1, TH4 and TH5 (trigger level at 0.007 mg/L)

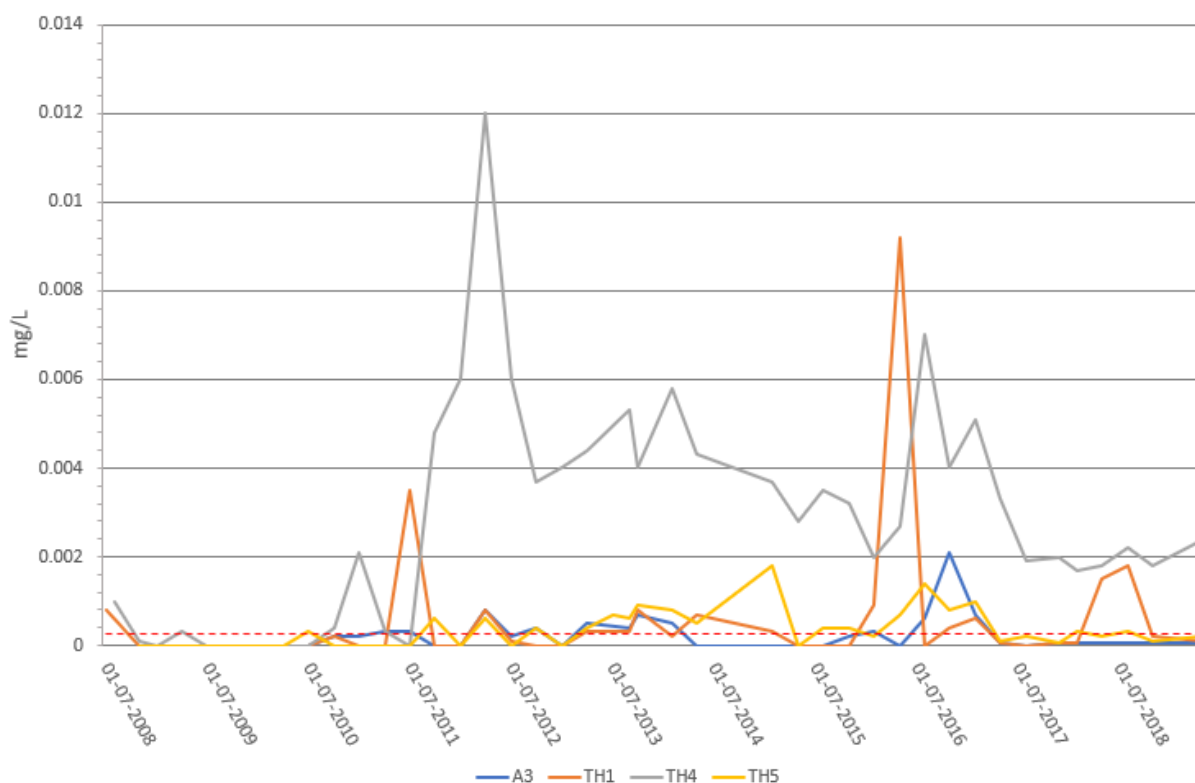


Figure 66 Development of dissolved cadmium concentrations between 2008 and 2019 at TSF bores A3, TH1, TH4 and TH5 (trigger level at 0.0002 mg/L)

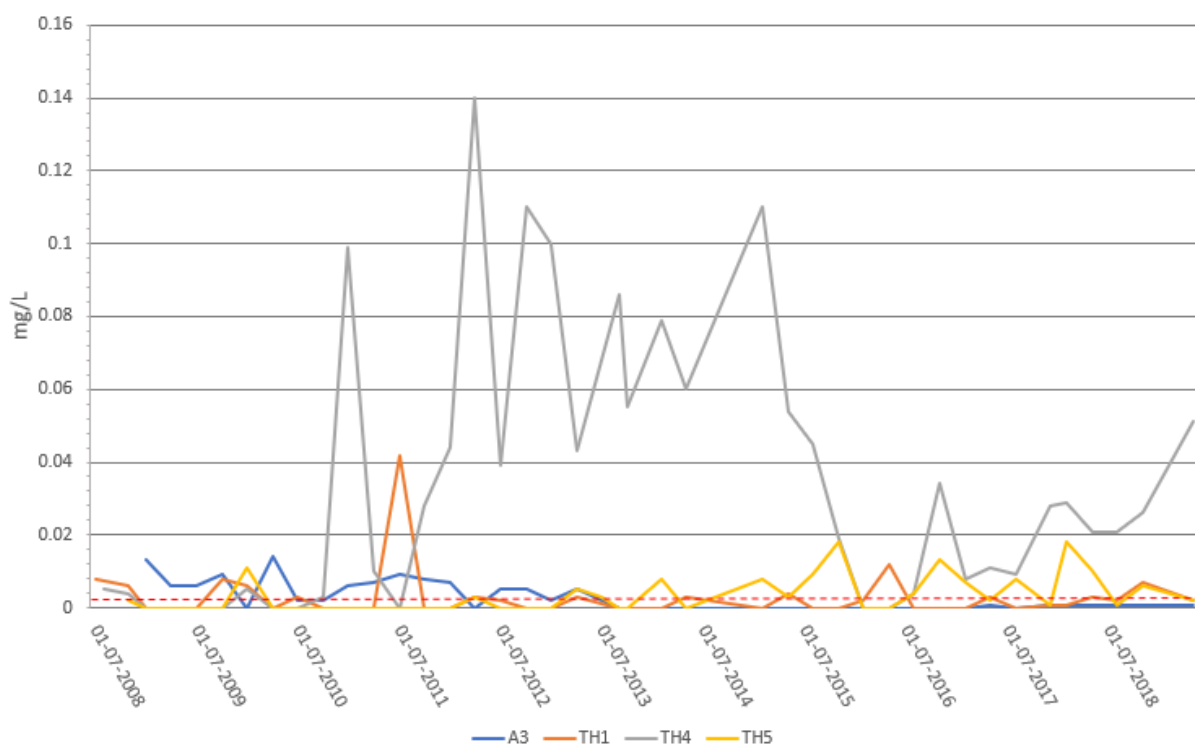


Figure 67 Development of dissolved copper concentrations between 2008 and 2019 at TSF bores A3, TH1, TH4 and TH5 (trigger level at 0.0014 mg/L)

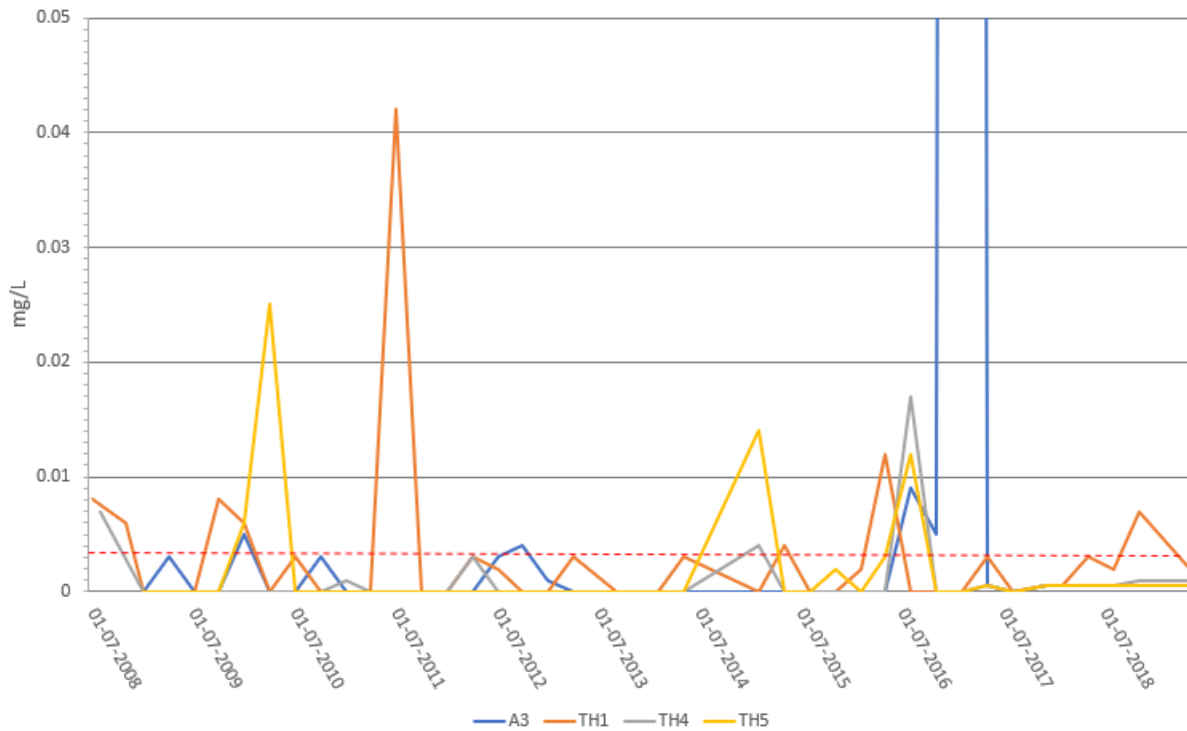


Figure 68 Development of dissolved lead concentrations between 2008 and 2019 at TSF bores A3, TH1, TH4 and TH5 (trigger level at 0.0034 mg/L)

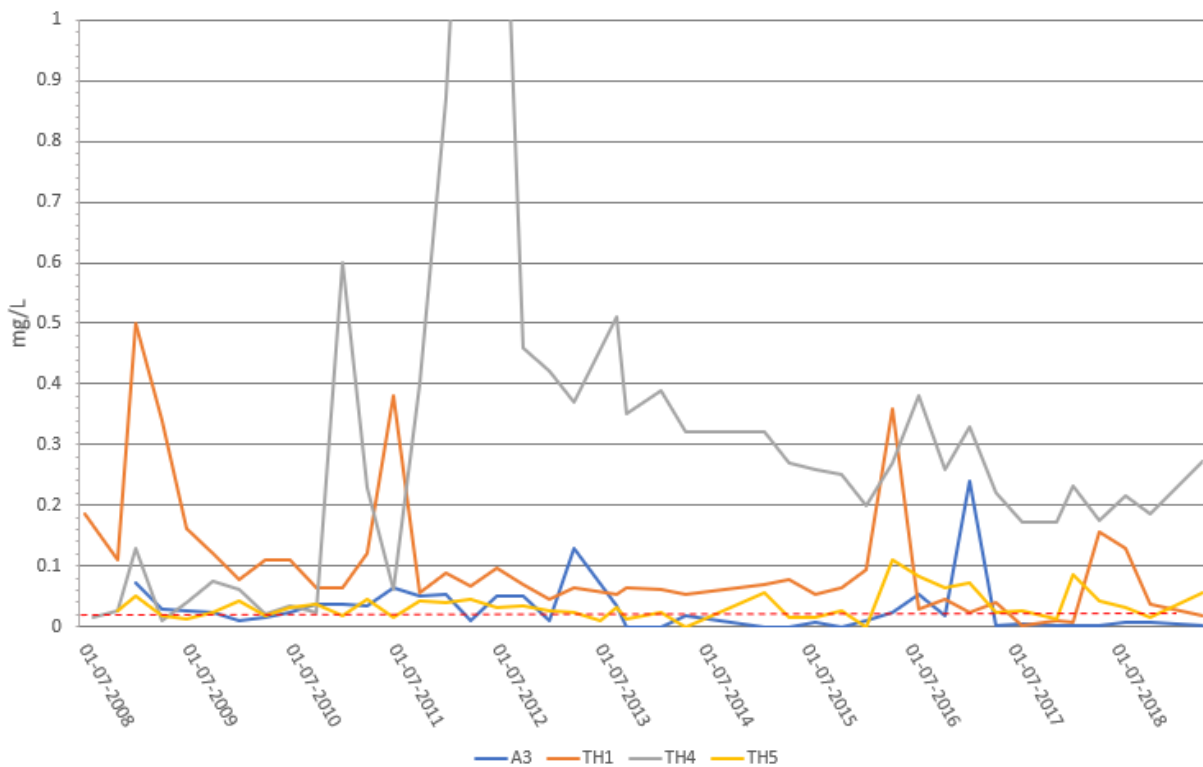


Figure 69 Development of dissolved zinc concentrations between 2008 and 2019 at TSF bores A3, TH1, TH4 and TH5 (trigger level at 0.008 mg/L)

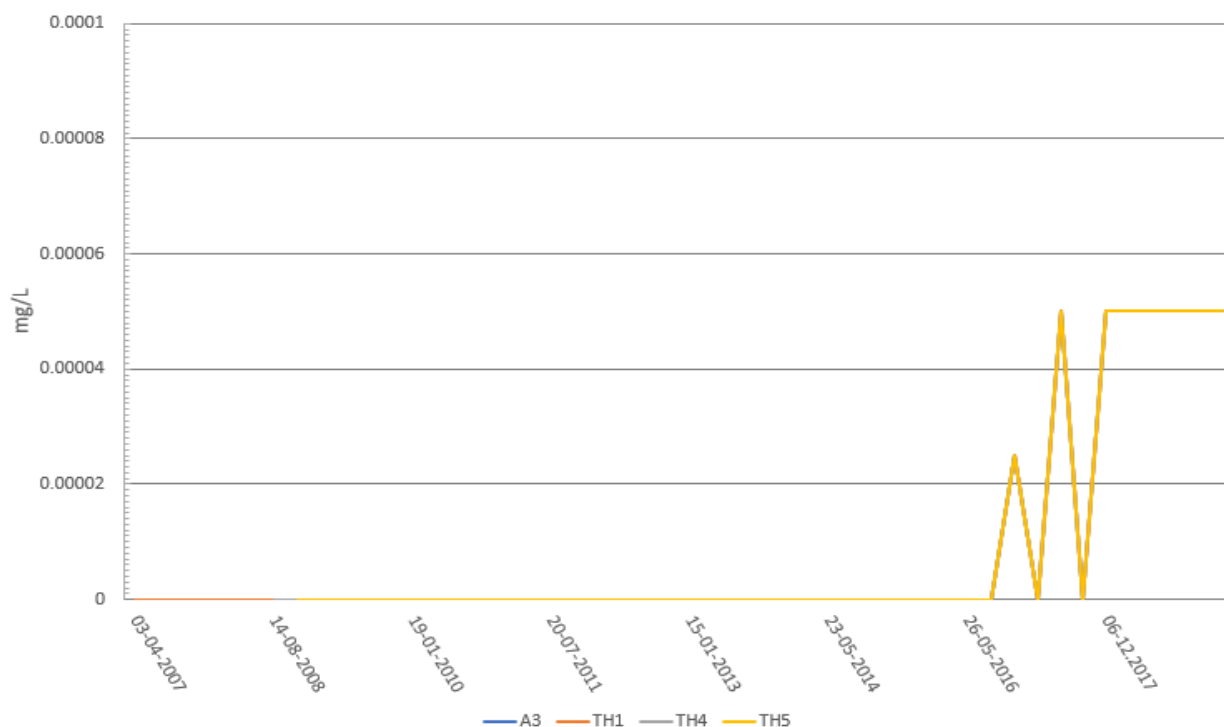


Figure 70 Development of total mercury concentrations between 2008 and 2019 at TSF bores A3, TH1, TH4 and TH5 (trigger level off scale at 0.0006 mg/L)

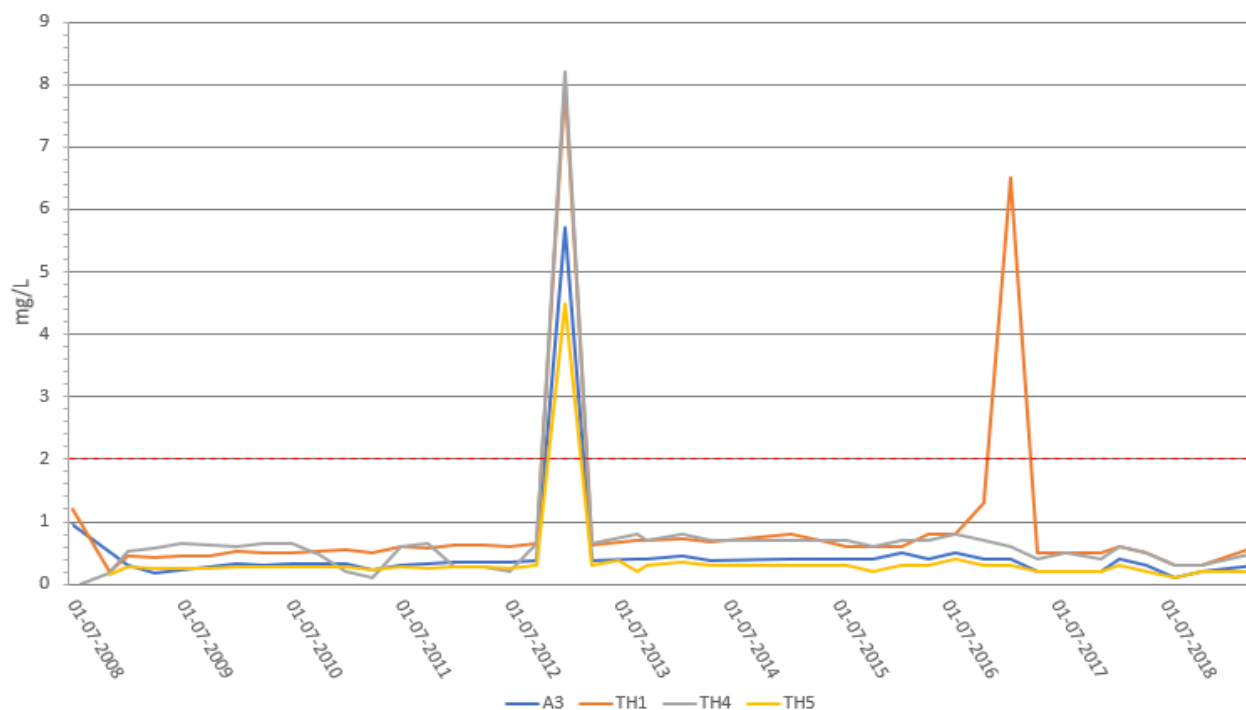


Figure 71 Development of fluoride concentrations between 2008 and 2019 at TSF bores A3, TH1, TH4 and TH5 (contaminant release limit at 2 mg/L)

9.3.3.7 A1 and A4 2018/2019

The recently installed bores A1 and A4 have only been monitored from August 2018 onwards. Since then, groundwater parameters in both bores have shown limited variation. Bore A1 recorded relatively stable EC values above 10,000µS/cm and sulfate concentrations between 640mg/L and 1,030mg/L. Calcium and magnesium concentrations were very stable at about 120mg/L and 400mg/L, respectively. Zinc concentrations ranged from 0.005mg/L to 0.016mg/L. At A4, EC ranged from about 6,800µS/cm to 7,600µS/cm, sulfate from 570mg/L to 670mg/L and chloride from 1,440mg/L to 1,640mg/L. Calcium and magnesium concentrations were very stable at about 100mg/L and 160-200mg/L respectively. Zinc concentrations ranged only from 0.0025mg/L to 0.005mg/L.

9.3.3.8 Comparison of groundwater composition to TSF and East Evaporation Pond

Owing to the nature of the massive sulphide mineralogy of the Balcooma, Thalanga and Highway Reward ore bodies, decant water pH of the tailings dam cells has generally been acidic. The exemptions being short periods of time with regards to gold extraction tailings reporting to Cell 1/7 and more recent measurements since August 2018.

The low pH of TSF Cell 9 between 2009 and 2014 (pH 2.4 to pH 3.6) consequently resulted in elevated metal concentrations in TSF Cell 9 (

Figure 72), which may have migrated towards TH4, albeit at significantly lower concentrations (

Figure 73).

Alternatively, elevated metal concentrations at TH4 between 2009 and 2014 could be the result of seepage from the east evaporation pond (EEP). Water level records for the EEP indicate that the pond generally contains shallow water but at times was empty. When present, pond water pH at the EEP is generally 1 to 3 pH units higher (averaging pH 5.05) than at TSF Cell 9. Similarly, EC of the EEP water averages at 3,985µS/cm, while the average EC of TSF Cell 9 was 7,962µS/cm. A comparison between the current groundwater composition and current water composition within TSF cell 9 or the EEP is of little value since impacts on groundwater composition will be delayed. Hence, the influence of higher dam water pH's since August 2018 have not yet been observed.

Despite water being present, the hydraulic head potentially induced by the shallow EEP is minor when compared to the hydraulic head generated by TSF Cell 9. Hence, it is more likely that elevated metal concentrations at TH4 between 2010 and 2015 are the result of seepage from TSF Cell 9.

However, comparing the EC and sulfate concentrations of the TSF Cell 9 decant and the EEP with the groundwater composition at TH1, TH4, TH5 and A3 suggests that TH1, TH4 and TH5 are not exclusively impacted by TSF Cell 9.

What can be seen in

Figure 74 and

Figure 75 is that EC and sulfate are steadily increasing in Cell 9 and that EC is considerably lower and sulfate significantly higher in the EEP when compared to any TSF monitoring bore over the same period of time (

Figure 55,

Figure 60,

Figure 61 and

Figure 63).

The likely reason for the above is a combination of influences of adjacent tailings cells as well as the impacts of evapotranspiration on the groundwater composition, as shown earlier on the example of EC and sulfate concentrations at A3.

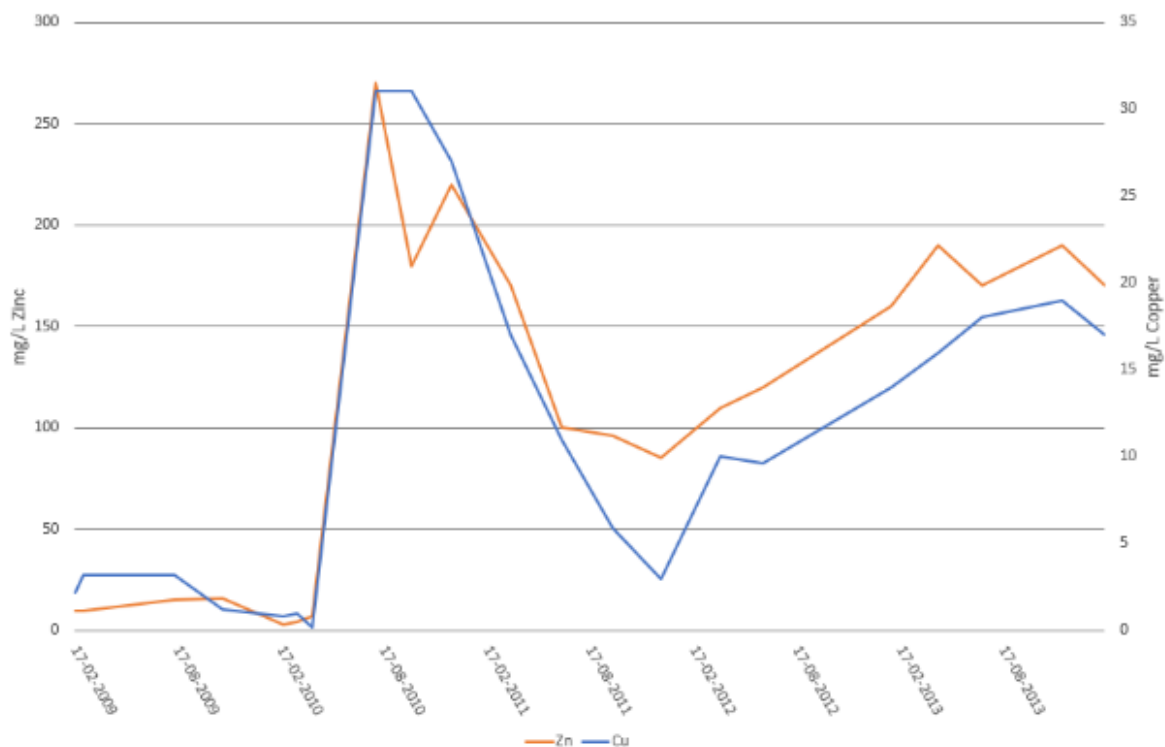


Figure 72 Concentrations of zinc and copper in decant water from Cell 9 between 2009 and 2013

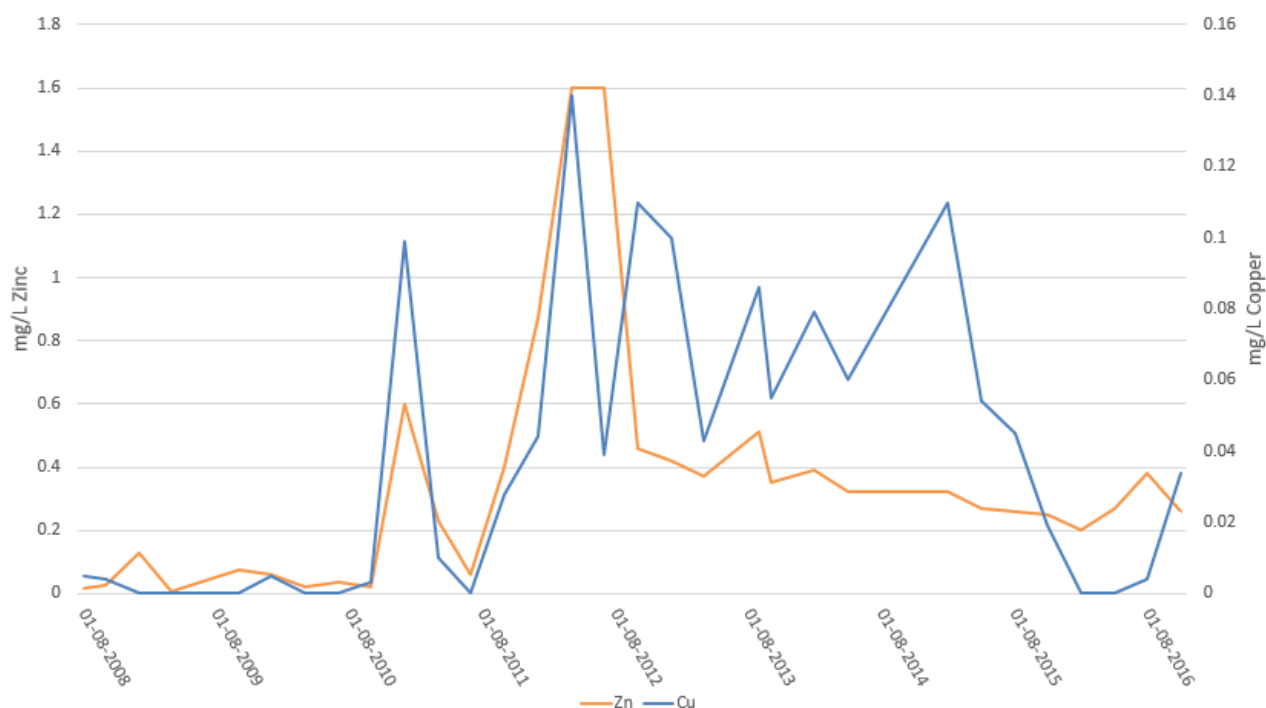


Figure 73 Concentrations of zinc and copper at TH4 between 2008 and 2016

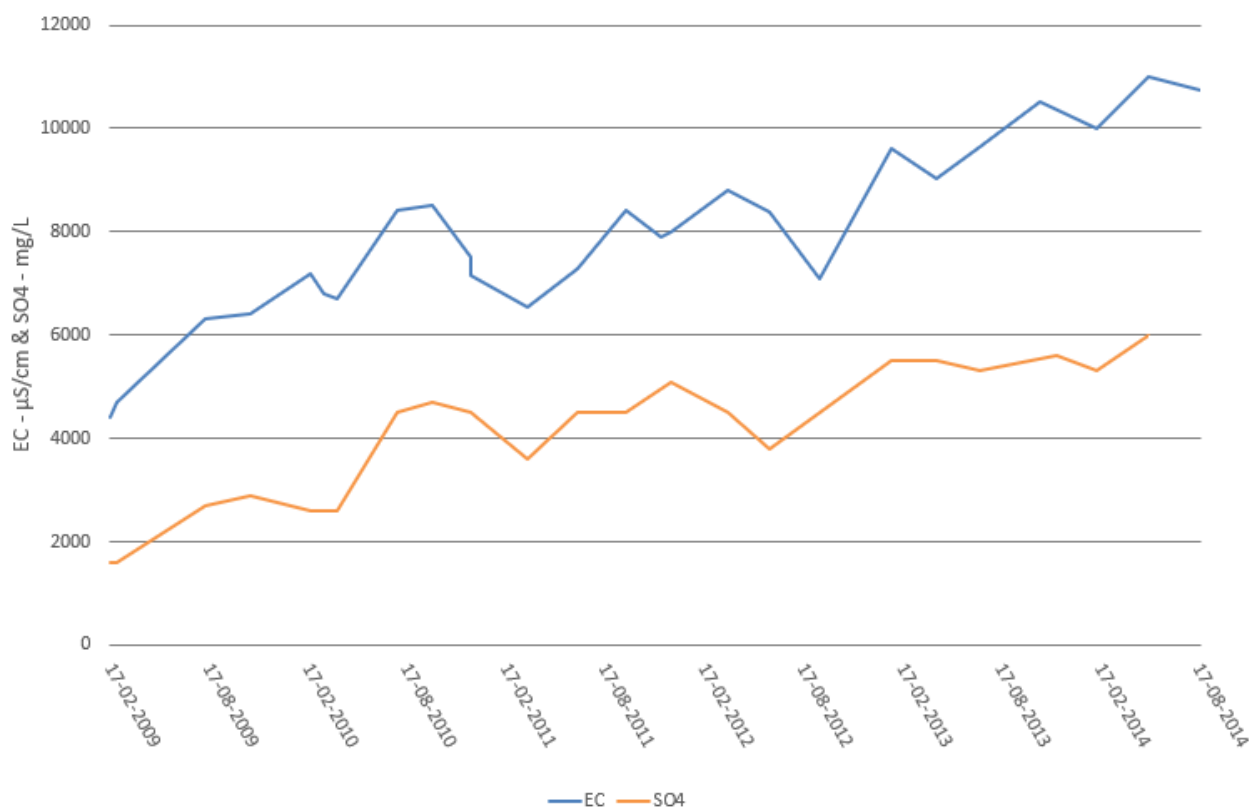


Figure 74 EC ($\mu\text{S}/\text{cm}$) and sulfate (mg/L) development of decant water in TSF Cell 9 between 2009 and 2014

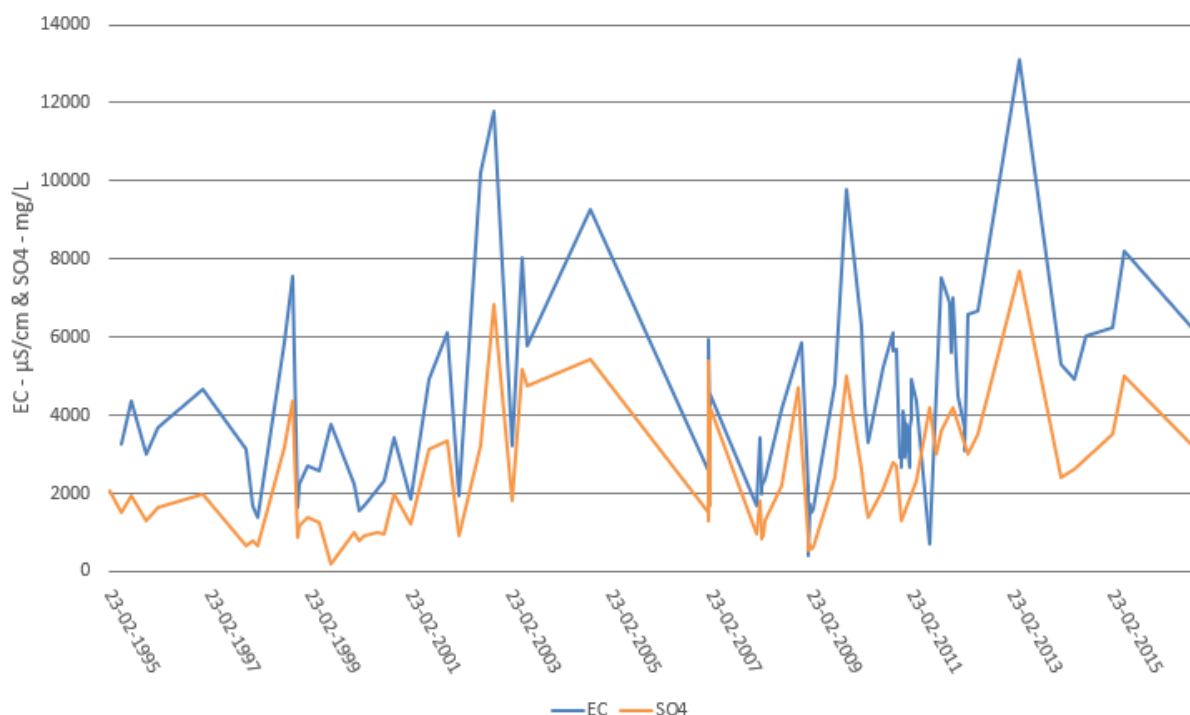


Figure 75 EC ($\mu\text{S}/\text{cm}$) and sulfate (mg/L) development of water in the East Evaporation Pond between 1995 and 2016

9.3.3.9 Nature of seepage generation and groundwater evolution at the TSF

The seepage generation around the current TSF area is the result of direct seepage along preferential pathways (in the case of TH4) and diffuse capillary action and subsequent evaporative concentration (in the case of A3, TH1 and TH5).

9.3.3.9.1 TH4

As has been demonstrated by hydrogeochemical data (

Figure 66,

Figure 67,

Figure 69,

Figure 72 Concentrations of zinc and copper in decant water from Cell 9 between 2009 and 2013

Figure 73) at TH4, direct seepage along preferred pathways can be a fast process. In this case likely triggered by increased water levels in Cell 9, seepage flow has only limited contact with geological materials resulting in increased cadmium, copper and zinc concentrations.

9.3.3.9.2 A3, TH1 and TH5

Evapotranspiration facilitated by capillary action through weathered material on the other hand is a slow process, by nature requiring the solution to pass through the entire regolith material. As a result, relative minor groundwater constituents like cadmium, copper and zinc will have the opportunity to adsorb to clays and secondary iron and manganese oxides, while major ions like sulfate will be able to migrate further. In addition, evaporative concentration may become an additional factor if groundwater levels are close to the surface.

9.3.4 Underground tailings deposition monitoring bores

The underground tailings monitoring bores V1, V2, V3, V4, V5, V6A-B, V7A-B and V8A-B (A-B indicating shallow-deep bore, respectively) were installed in 2003 (**Figure 8 in Appendix C**).in response to underground tailings deposition resulting in the partial flooding of the initial Thalanga Central Pit.

Following the installation of these bores, underground discharge of tailings and discharge of process water to the Thalanga Central Pit continued, resulting in continuous increases of groundwater levels in these bores until dewatering was required due to the proposed mining of the Vomacka pit in 2008/2009 (NRC 2019), (**Figure 76**).

In contrast to the changes in groundwater levels, changes in groundwater chemistry were less prominent. The latter likely since underground tailings deposition commenced at least five years prior to bore installation hence bore locations were likely already impacted in 2003. The groundwater level records suggest that these bores were installed in the vicinity of the deposit and former mine workings, and as intended, monitor the impact of water within the underground. Yet, the groundwater chemistry of each underground tailings monitoring bore seems to react differently to the subsequent dewatering of the Vomacka Pit and dewatering of the West 45 and Far West deposits.

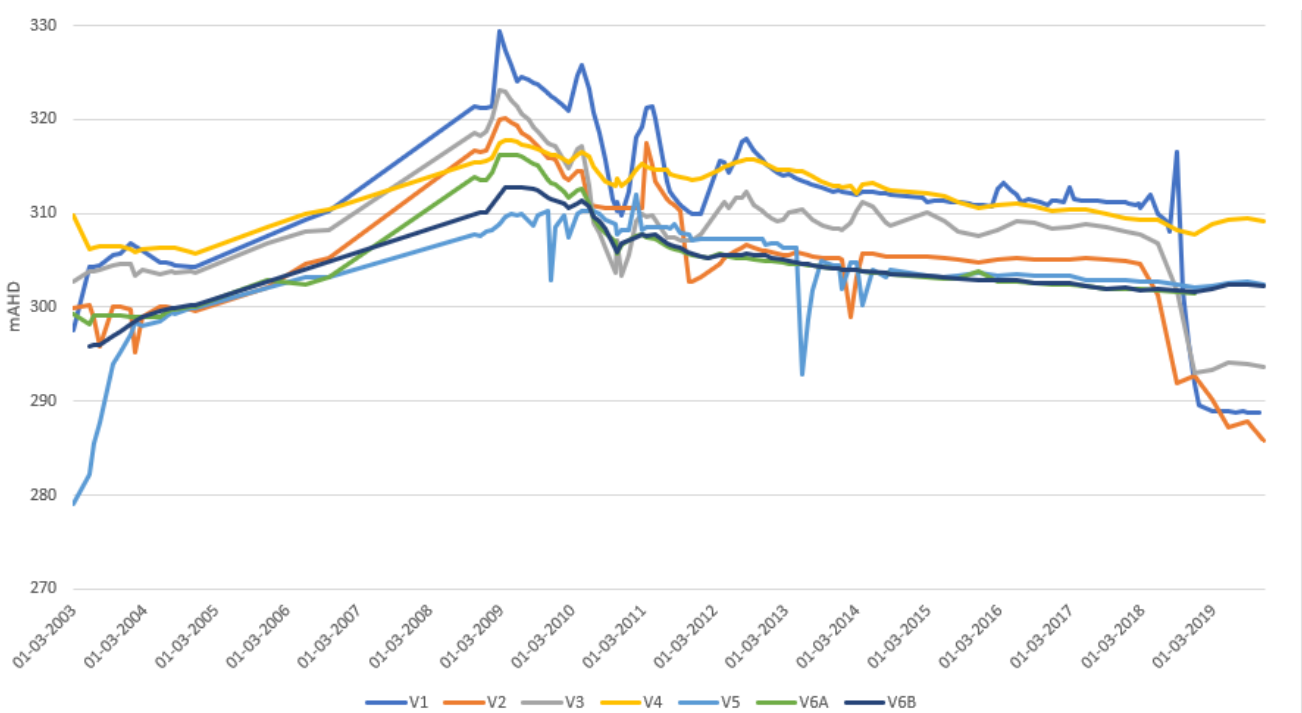


Figure 76 Groundwater level development at V1, V2, V3, V4, V5 and V6A-B between installation and 2019

9.3.4.1 Bore V1

Bore V1 is positioned about 220m north of the original Far West Decline. Between 2003 and 2008 the bore experienced a moderate increase in sulfate (132mg/L to ~250mg/L) and EC (2,000 μ S/cm to ~2,900 μ S/cm) (

Figure 77). Early sulfate concentrations peaked at 350mg/L in 2007 but from there onwards declined again until 2011 to concentrations similar to concentrations of 2004. From late 2011 onwards sulfate, and in response EC, increased significantly at V1, reaching its highest concentrations and levelling out between 2014 and late 2018. Following this period of high EC and sulfate concentrations, readings dropped suddenly with the bore becoming ultimately dry due to the dewatering of West 45 and the Far West Deposit.

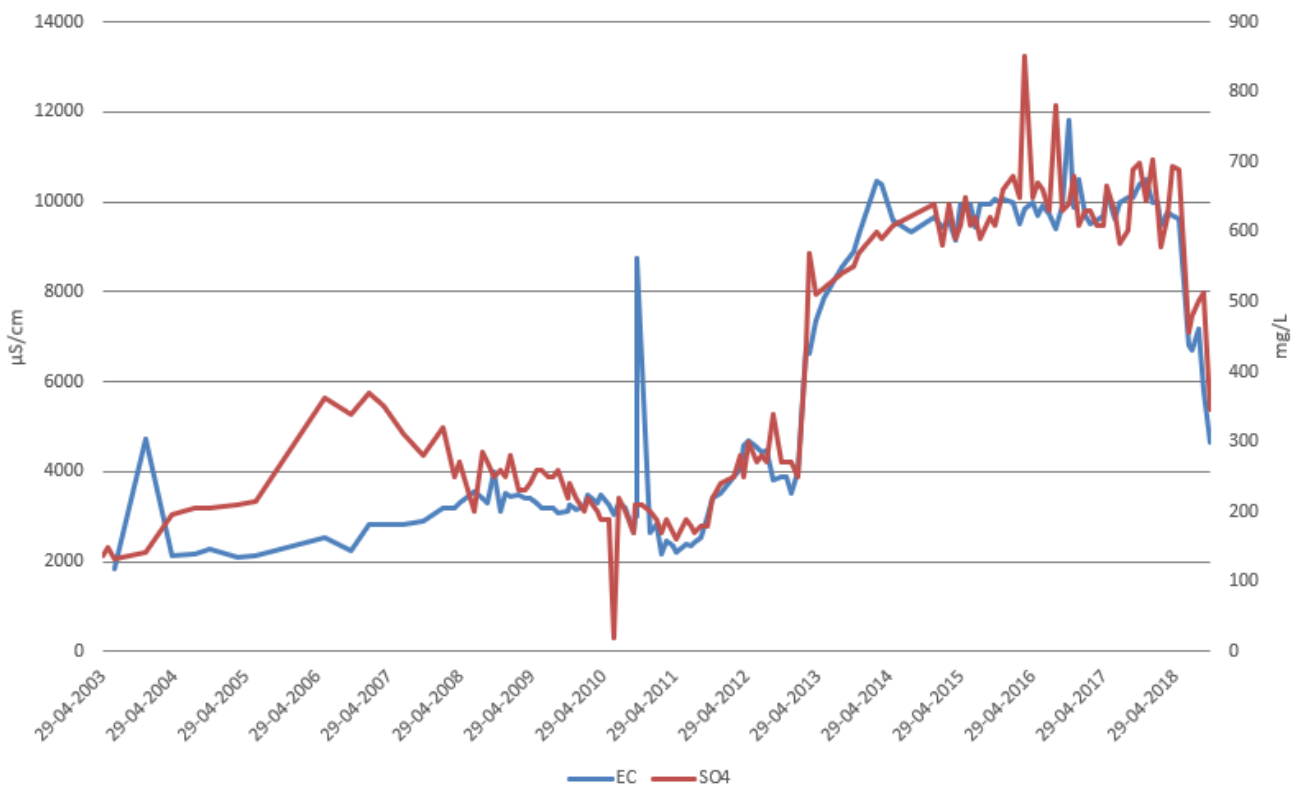


Figure 77 EC (μ S/cm) and sulfate (mg/L) development at V1 between installation in 2003 and October 2018

The two potential seepage sources to consider at V1 are underground backfill and seepage from the TSF. Both water chemistries are tailings based; hence origins of water chemistry changes at V1 are difficult to determine. Yet, water level changes at V1 can only be attributed to the initial flooding of the underground until 2008 and subsequent dewatering of the Vomacka Pit, the West 45 and the Far West deposits. Changes in EC and sulfate concentrations till 2012 (

Figure 77) appear to follow a somewhat similar trend than groundwater levels. That is, EC and sulfate concentrations increasing till 2007-2008 and subsequently decreasing till about 2011-2012.

Initial partial dewatering of the West 45 deposit occurred during Kagara's final months of operation in 2011. The effect of this initial dewatering can be seen in the steep dips in groundwater levels at V1 and V2 during the same period (

Figure 76). Following the initial dewatering (in 2011), there was a brief period of water level recovery at V1 and V2 (until late 2012) followed by further declines in groundwater levels throughout the care and maintenance period. This further decline was likely due to groundwater levels in West 45 still recovering from the initial dewatering in 2011, pulling in water from further afield.

With regards to the changing groundwater chemistry, the lowering of water tables due to the West 45 dewatering resulted in a change of groundwater flow directions.

V1, until 2008 being impacted by a mix of tailings and process water within the backfilled underground workings (

Figure 76 and **Figure 78**), experienced a decline in groundwater levels due to the dewatering of the Vomacka Pit between 2008 and 2011 (

Figure 76 and **Figure 79**). As a result, EC and sulfate concentrations at V1 experienced a reduction. The reduction in EC and sulfate concentration being due to a reduction in impact associated with the underground backfill (e.g. reduction of groundwater level by ~20m and greater influence of 'natural' groundwater with lower EC and sulfate concentrations from north of V1).

Similarly, the reduction in groundwater levels at West 45 in 2011 resulted in a groundwater level depression, which connected via the ore deposit/underground workings, extending towards V1 and V2 and beyond. This additional lowering of groundwater tables to the west of V1 triggering a further recharge response from the north and north west of V1. With the 'natural' lower EC and sulfate groundwater becoming depleted, recharge now coming from aquifer sections impacted by the TSF (

Figure 76 and **Figure 80**). The chemical composition (EC and sulfate) of this recharge eventually being equal to the groundwater composition of tailings monitoring bore TH5 (

Figure 61).

The groundwater behaviour of V1 demonstrates the impact of changing head conditions on the seepage behaviour from the backfilled underground and the TSF. The groundwater level behaviour until 2011 strongly suggests that hydrogeochemical changes at V1 were initially due to underground backfill. Subsequent dewatering of the West 45 deposit resulted in a significant reduction of groundwater levels within the deposit, fundamentally changing hydraulic head conditions and resulting in seepage flow from the TSF cells towards V1 and the underground.

The last measurements of EC and sulfate at V1 before the bore went dry, again showed an improvement of groundwater quality. The latter likely due to changed head conditions in the immediate vicinity of the bore allowing relatively more 'natural' groundwater to enter the bore.



Figure 78 Schematic depiction of the increase in groundwater levels induced by tailings and process water deposition to the Central pit and former underground prior to 2008 (Red arrow- direction of groundwater flow; Orange-Tailings seepage; Red- migration of underground backfill seepage; Blue – natural groundwater. Size of circle anticipated concentrations)



Figure 79 Schematic depiction of decrease in groundwater levels due to dewatering of the Vomacka Pit (2008-2011). 2008 (Red arrow- direction of groundwater flow; Orange-Tailings seepage; Red- migration of underground backfill seepage; Blue – natural groundwater. Size of circle anticipated concentrations)



Figure 80 Schematic depiction of further decrease in groundwater levels due to dewatering of the West 45 underground (2012 and 2016-2018). (Red arrow- direction of groundwater flow; Orange-Tailings seepage. Size of circle anticipated concentrations)

9.3.4.2 Bore V2

As stated above, bore V2 displays a similar groundwater level behaviour to V1, with groundwater levels responding to underground flooding and dewatering activities (

Figure 76). Yet, the hydrogeochemical development of groundwater in V2 is significantly different to V1. Located only 15 m south of the underground workings (**Figure 80**), it seems reasonable to assume that TSF seepage has no influence on the water quality at V2. Initially reporting very high EC and sulfate concentrations (**Figure 81**), which were similar to the TSF seepage composition of the previous TH3 (**Figure 59**), the groundwater quality appeared to have gradually changed to a composition (higher sulfate, lower EC) more alike to the EEP (

Figure 75). The likely reason for the change in groundwater composition is a change from initial underground tailings backfill (during the earlier years of operation) to the discharge of process water to the underground and remaining Central Pit concluded in 2008). Considering that the Central Pit was backfilled with acid generating waste rock, lowering of groundwater tables to the east would result in the migration of process water though that waste rock and impact on the water composition in V2.

Dewatering with regards to the Vomacka Pit appears to have resulted in a significant drop of EC and sulfate concentrations at V2 (**Figure 81**). Combined with a strong reduction in calcium and magnesium (**Figure 82**), this would suggest that these measurements (April 2010 and April 2011) are not in error. However, bore V2 at the time still contained a significant volume of groundwater. Hence, it seems unlikely that these- in April 2010 and April 2011 reported EC, sulfate, calcium and manganese concentrations- are correct. Regardless, the dewatering of the Vomacka Pit and West 45 deposit likely resulted in significant mixing of the water column. Hence, following the dewatering, EC and concentrations of sulfate, calcium and manganese appear initially to be more stable only to become more erratic again with the renewed West 45 dewatering activity in 2017.



Figure 81 EC ($\mu\text{S/cm}$) and sulfate (mg/L) development at bore V2

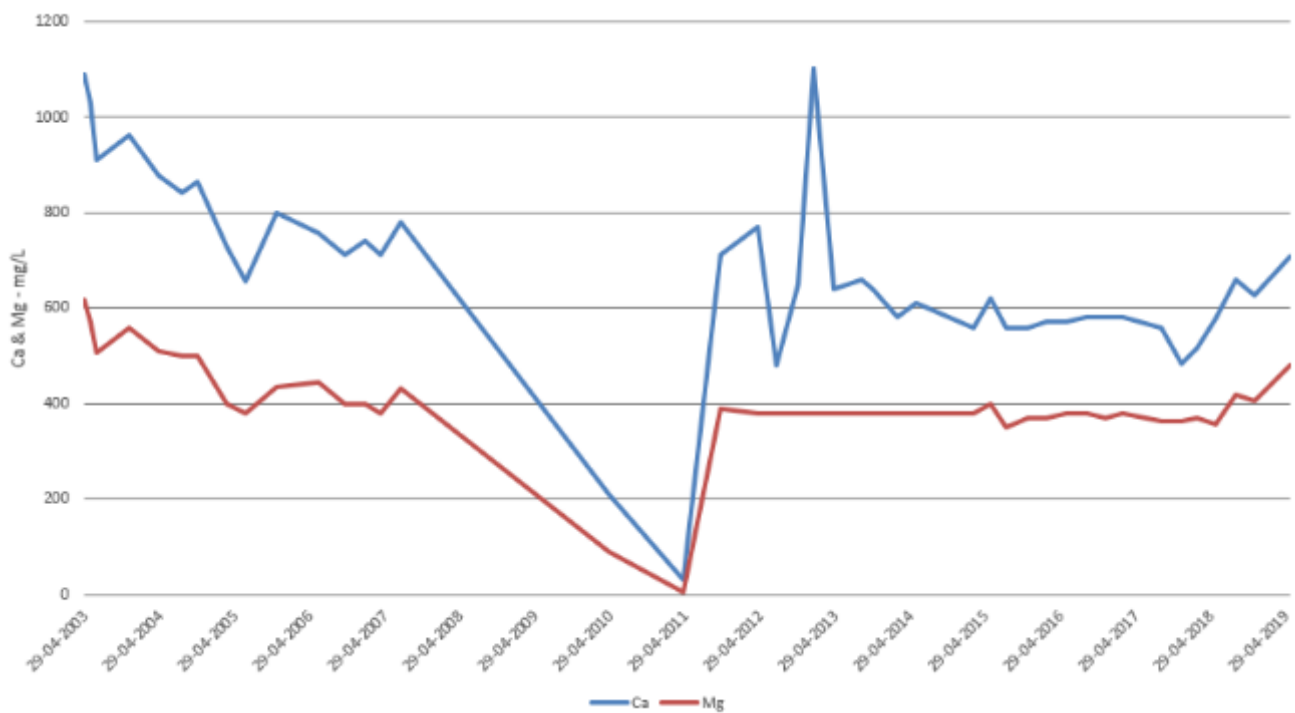


Figure 82 Calcium (mg/L) and magnesium (mg/L) development at V2

9.3.4.3 Bore V3

Bore V3 experienced the same groundwater level fluctuations as the other underground backfill bores, responding to the underground flooding and dewatering activities (

Figure 76). Despite that and its relative proximity to the Central Pit (100m north of the pit rim), the development of the groundwater chemistry does not appear to show direct responses to groundwater level changes. Further, the combined EC and sulfate concentrations at V3 () have developed to levels above what has been experienced in any of the TSF bores (

Figure 49,

Figure 50,

Figure 51,

Figure 52,

Figure 53,

Figure 55,

Figure 57,

Figure 58,

Figure 59,

Figure 60 and

Figure 61), TSF decant (

Figure 74) or EEP (

Figure 75). Similarly, zinc concentrations at V3 (

Figure 84) are about two to three orders of magnitude higher than at A3, TH1, TH4 and TH5 (

Figure 69).

The groundwater at V3 is often more akin to the decant water from TSF Cell 1/7 between 1991 and 1998. Throughout this time period, EC, sulfate and zinc concentrations were at times at similar levels as they are currently at V3 (

Figure 84 and **Figure 85**). In contrast to this, calcium and manganese concentrations at V3 and the prior decant water from Cell 1-7 are significantly different (**Figure 86** and

Figure 87) .

The similarities between EC and sulfate would be indicative of underground tailings backfill (originally akin to tailings from cell 1-7) having an impact on groundwater at V3. Groundwater levels suggest that there is connectivity between V3 and the orebody, however the stark opposite in calcium and magnesium concentrations casts doubt on such assumption. An alternative scenario involves acid water from the partially backfilled Central Pit or seepage from the ROM pad. Lowering of the groundwater water table within the deposit from 2008/2009 onwards makes seepage from the ROM pad the more likely possibility. Supporting this possibility is: a) the increase of sulfate in the absence of increases in EC () – indicating that at the same time as sulfate increases some other major ion concentrations have to decrease in order to maintain EC; and b) a slow decrease in pH (**Figure 88**) indicating greater influence of acid generating material.

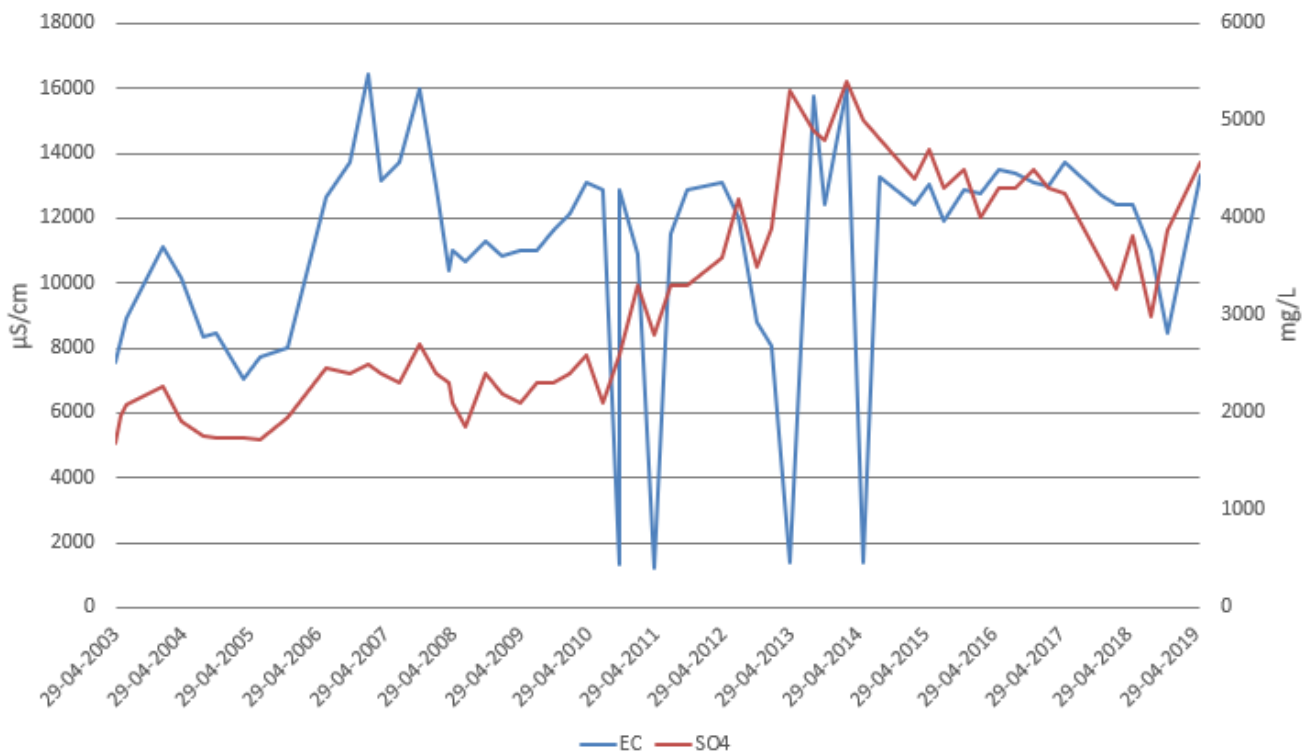


Figure 83 EC ($\mu\text{S/cm}$) and sulfate (mg/L) development at V3

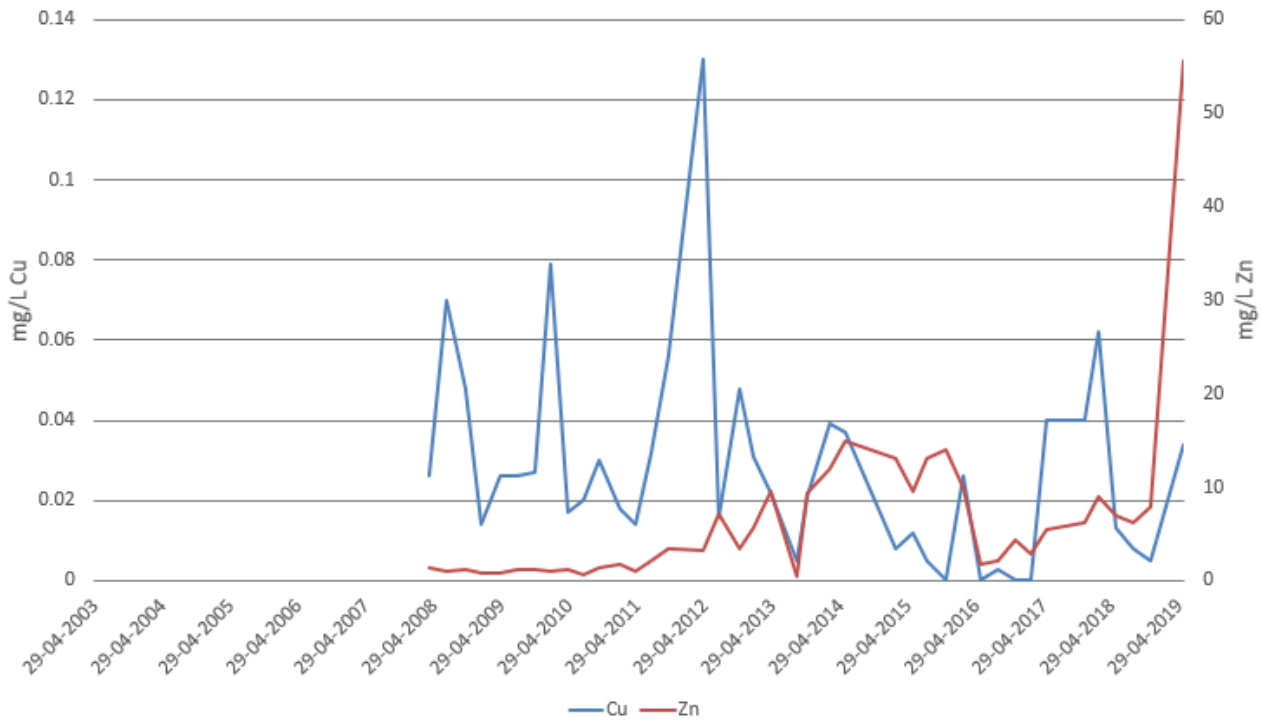


Figure 84 Dissolved copper (mg/L) and zinc (mg/L) concentrations a V3 since 2008

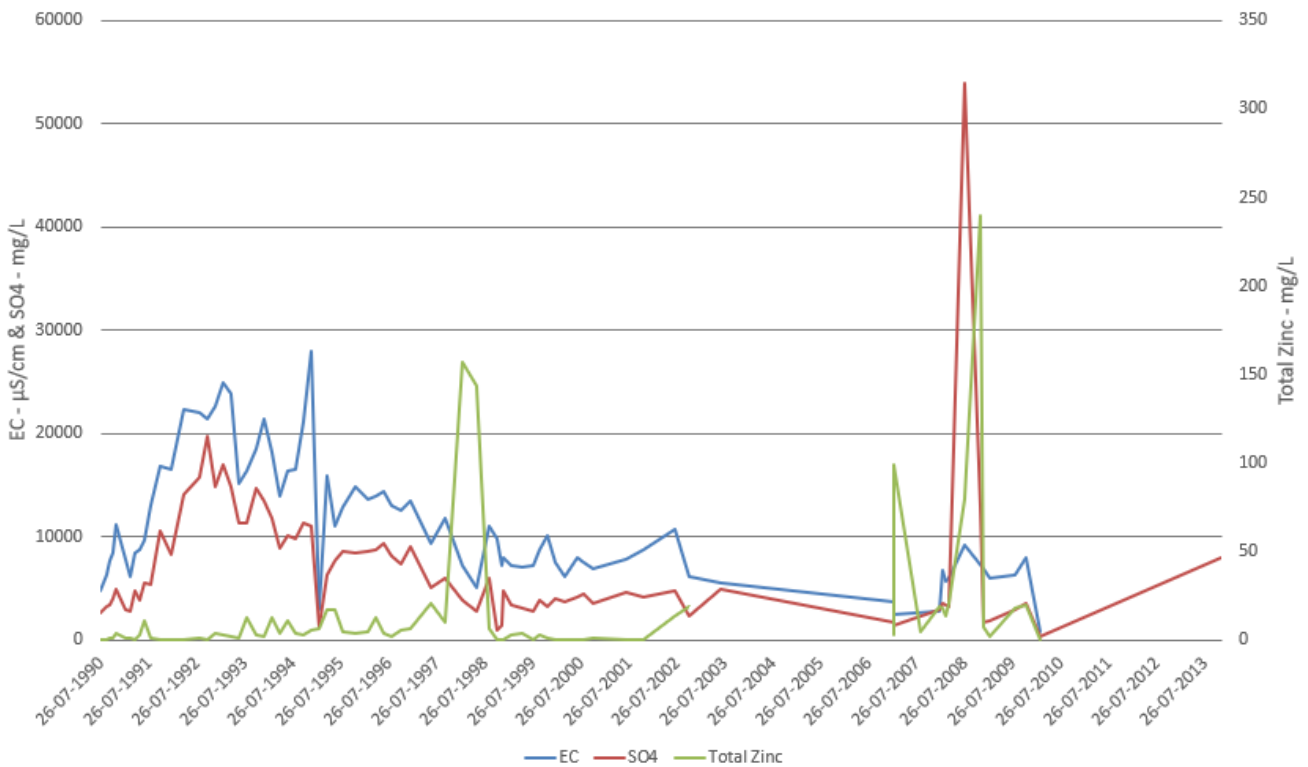


Figure 85 EC (µS/cm), sulfate (mg/L) and total zinc (mg/L) development of the Cell 1-7 decant between 1990 and 2013

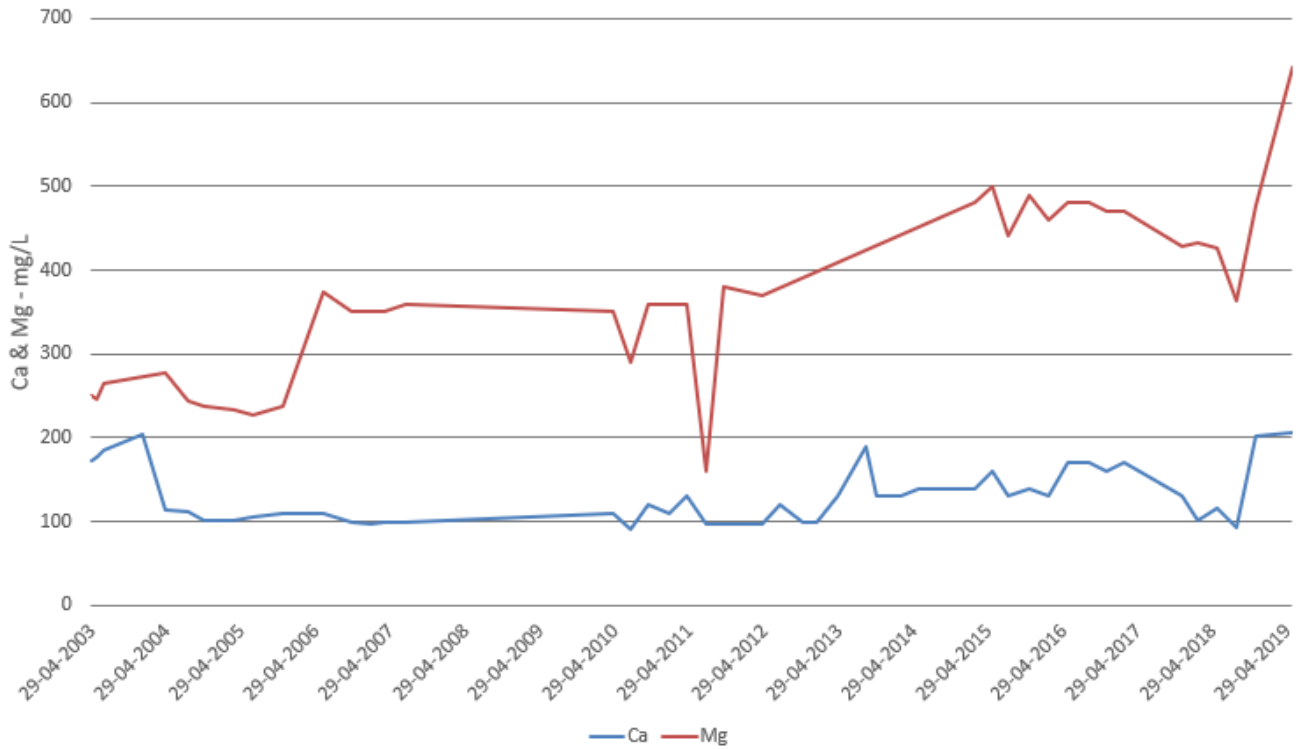


Figure 86 Calcium (mg/L) and magnesium (mg/L) concentrations at V3 between 2003 and 2019

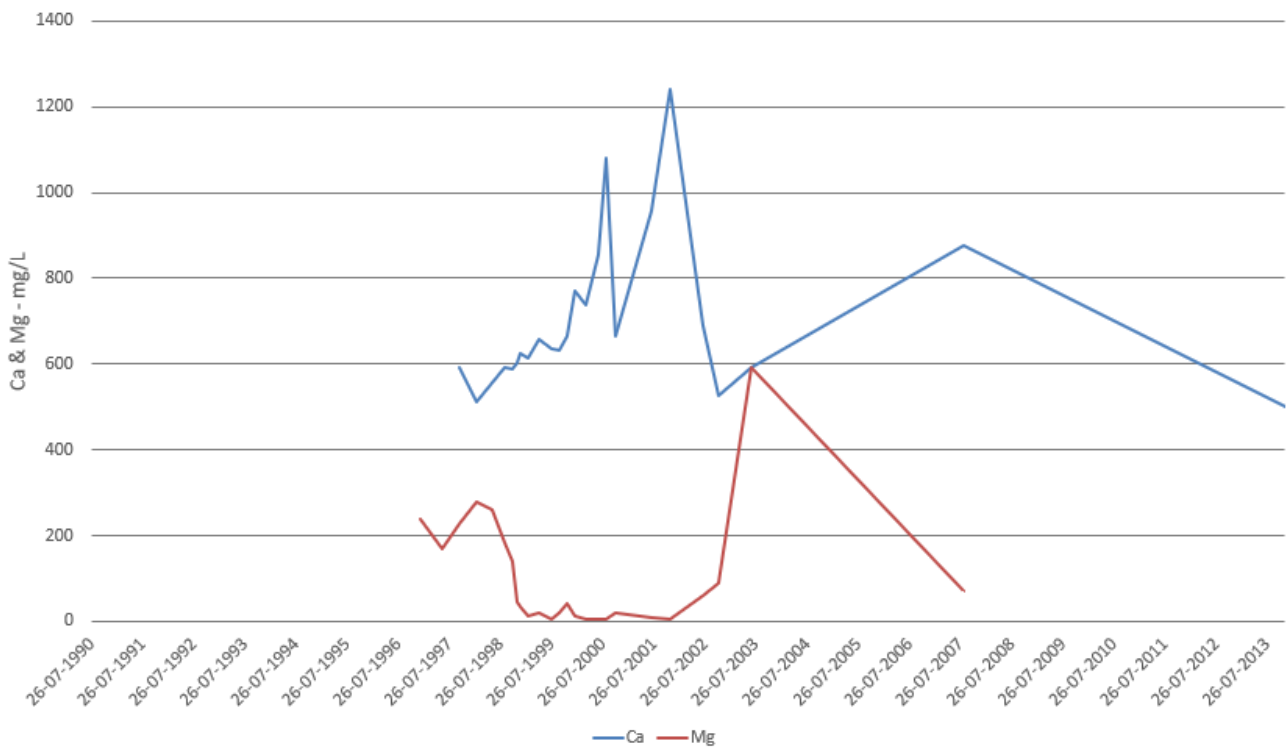


Figure 87 Calcium (mg/L) and magnesium (mg/L) concentrations of Cell 1-7 decant between 1990 and 2013

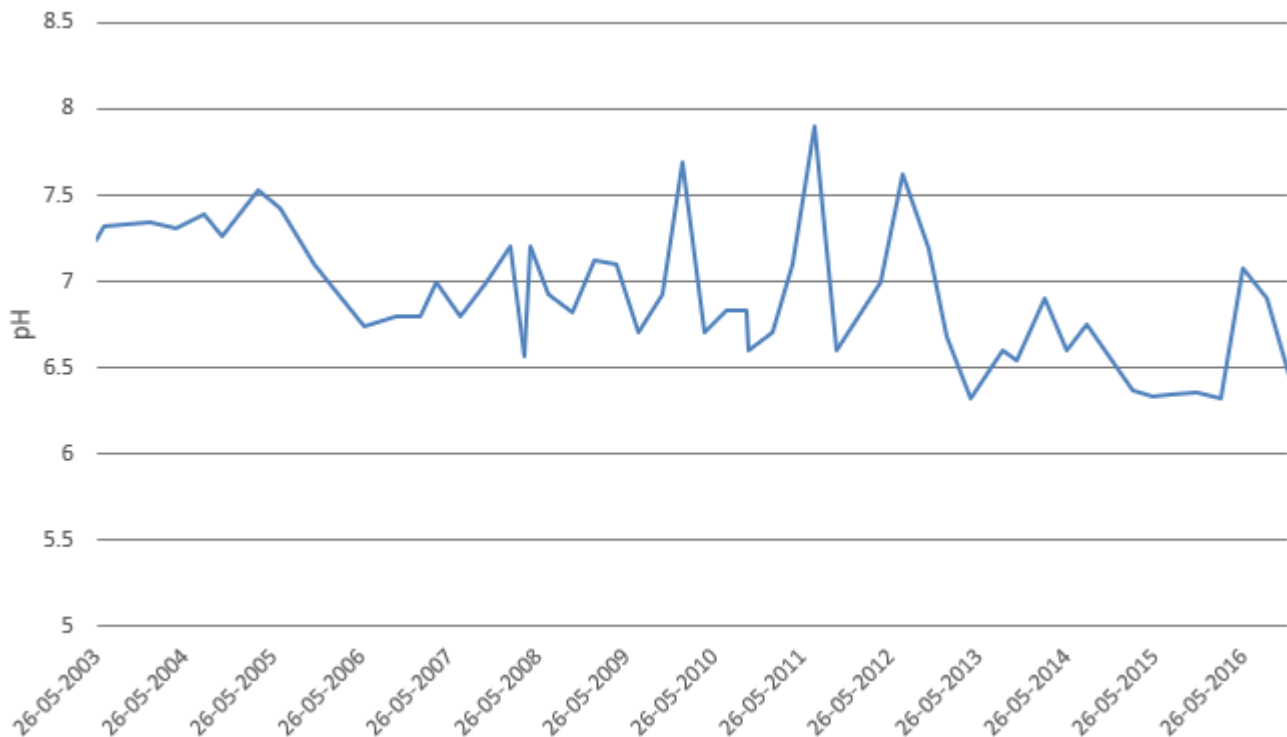


Figure 88 Development of pH at V3 between 2003 and 2017

9.3.4.4 Bore V4

Bore V4 is located about 100m from the southern rim of the Central Pit. The bore experienced similar groundwater level changes as did the other Underground backfill bores. However, groundwater level increases were less strong than at bores V1, V2, V3 and V6a and V6b and groundwater levels subsequently receded only slowly (

Figure 76). The groundwater chemistry at V4 is characterised by slowly receding EC (**Figure 89**), calcium and magnesium (**Figure 90**) concentrations since 2007. Sulfate, to the contrary increased from about 2,000mg/L in 2007 to 3,300mg/L in 2012, before receding back to about 2,000mg/L in 2019 (**Figure 89**). Chloride, only measured since 2015, recorded a decline from about 1,300mg/L to 1,080mg/L in 2019 (**Figure 89**). From the data available it appears that groundwater quality within V4 has seen only minor mine impacts (increase in sulfate between 2007 and 2012). Since 2012 sulfate concentrations have returned to their previous concentrations. Throughout these changes in sulfate, copper and zinc concentrations varied (**Figure 91**). Copper is now measured at concentrations close to, or below the detection limit of 0.002mg/L and zinc is fluctuating between 0.016mg/L to 0.164mg/L. Considering its closeness to the Central Pit the decreasing concentrations of many constituents clearly point to an improvement in groundwater quality at V4.

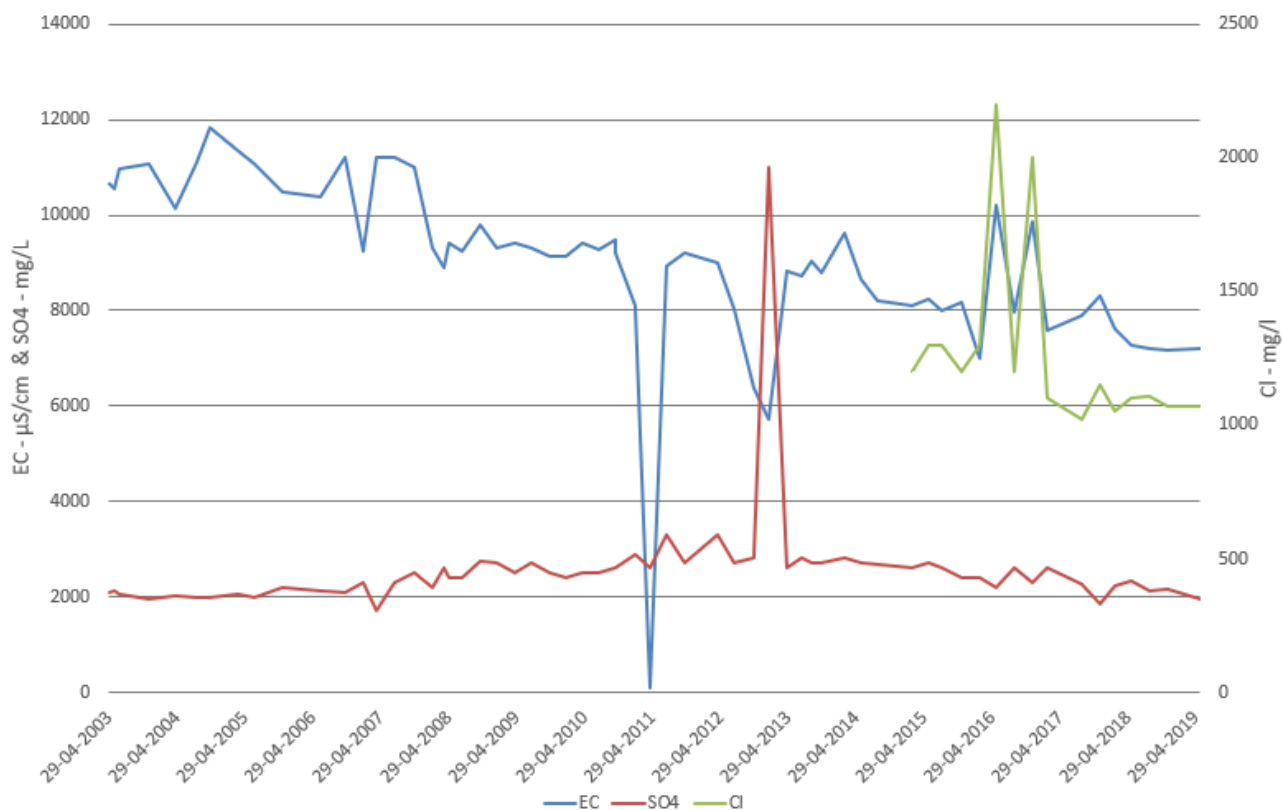


Figure 89 Development of EC (µS/cm), sulfate (mg/L) and chloride (mg/L) at V4 between 2003 and 2019



Figure 90 Development of calcium (mg/L) and magnesium (mg/L) at V4 between 2003 and 2019

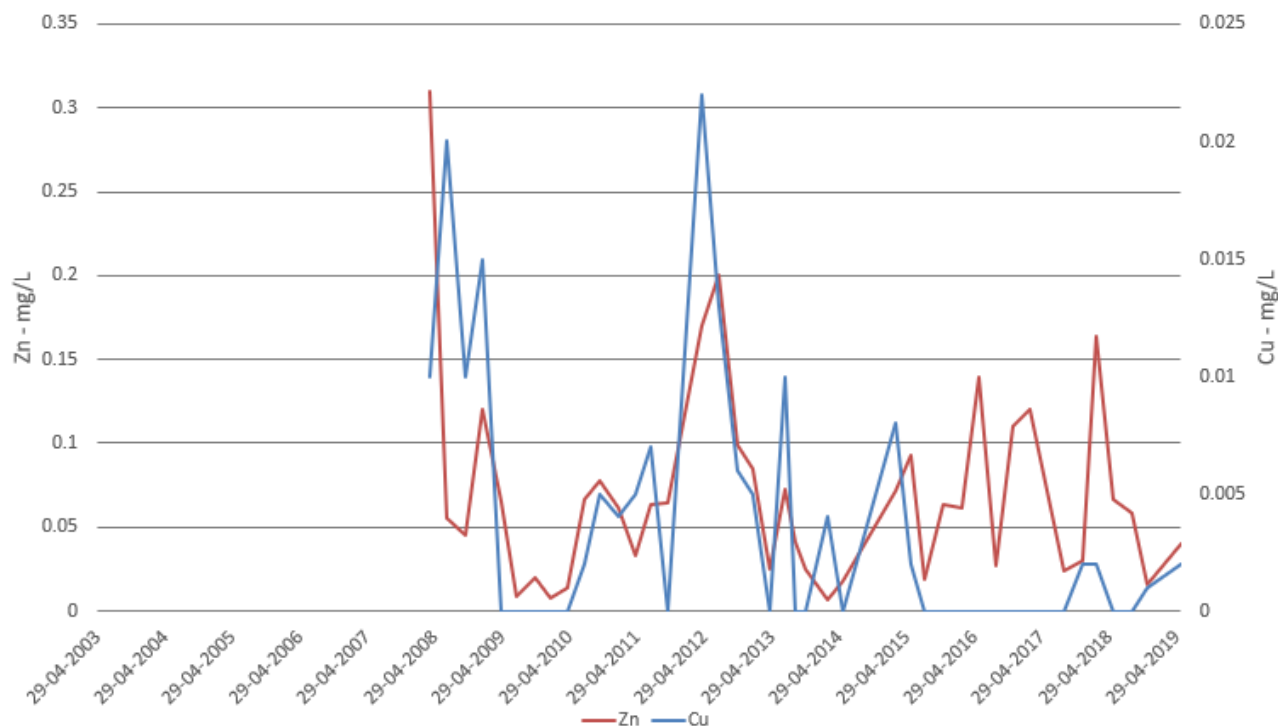


Figure 91 Development of zinc (mg/L) and copper (mg/L) at V4 between 2003 and 2019

9.3.4.5 Bore V5

Like bore V4, groundwater levels at V5 showed a somewhat muted response to underground flooding and dewatering. This occurs despite the bore being only 100m south of the dewatering target, the Vomacka Pit. The groundwater chemistry development displays a rapid initial decrease in EC, sulfate, calcium and magnesium concentrations between bore installation in 2004 and 2006 (

Figure 92 and **Figure 93**). Following this initial decrease sulfate, calcium and magnesium concentrations remained low, with only EC showing a slight renewed increase, likely as a result of increasing NaCl concentrations. Copper and zinc concentrations (**Figure 94**) range from below detection limit to 0.022mg/L for copper and to 0.23mg/l for zinc. Considering the low sulfate concentrations (100-320mg/L), the copper and zinc concentrations at V5 are likely background values from within the sampled aquifer section.

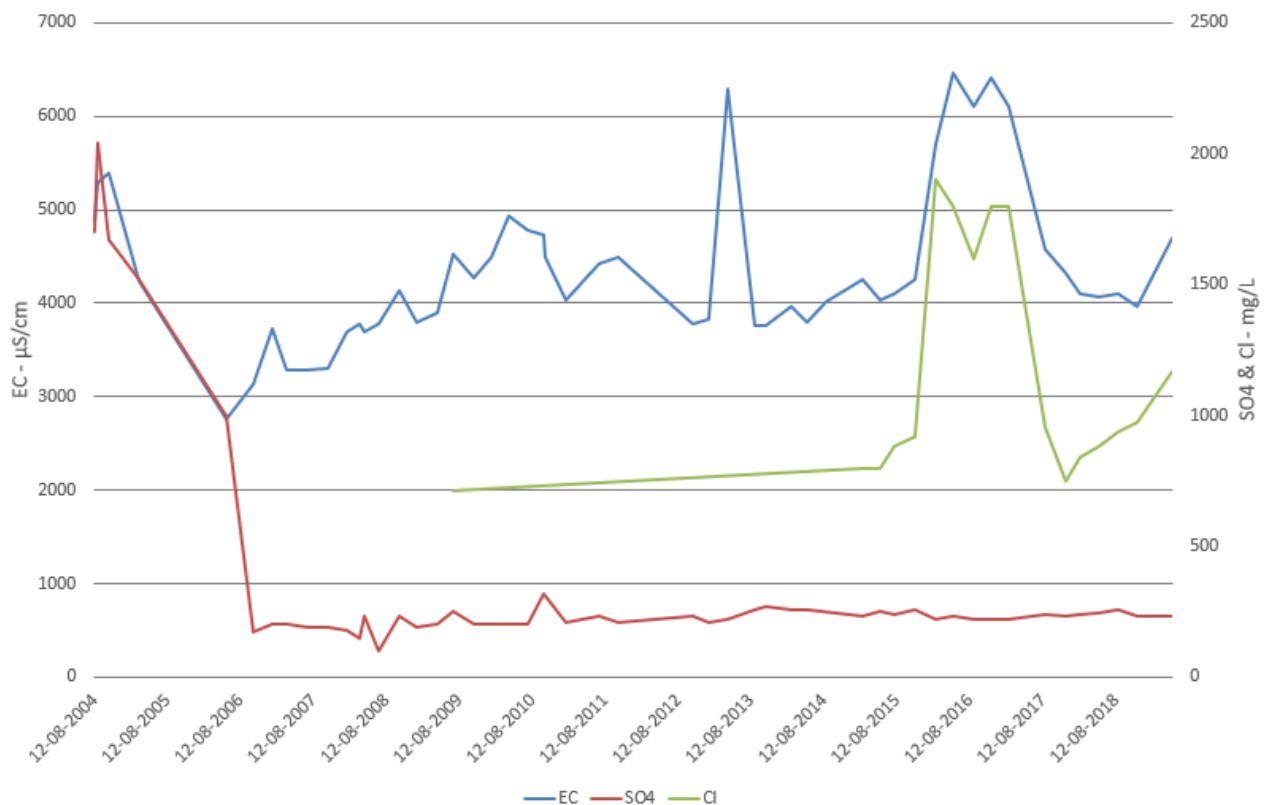


Figure 92 Development of EC ($\mu\text{S}/\text{cm}$), sulfate (mg/L) and chloride (mg/L) at V5 between 2004 and 2019

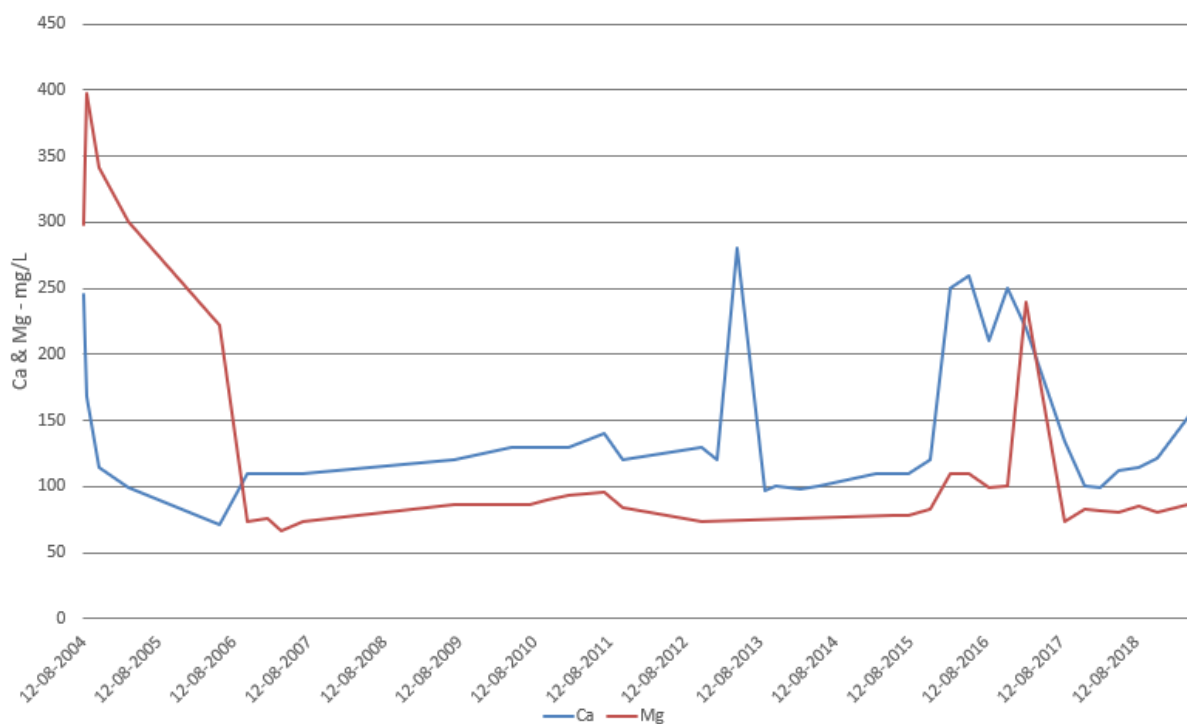


Figure 93 Development of calcium (mg/L) and magnesium (mg/L) at V5 between 2004 and 2019

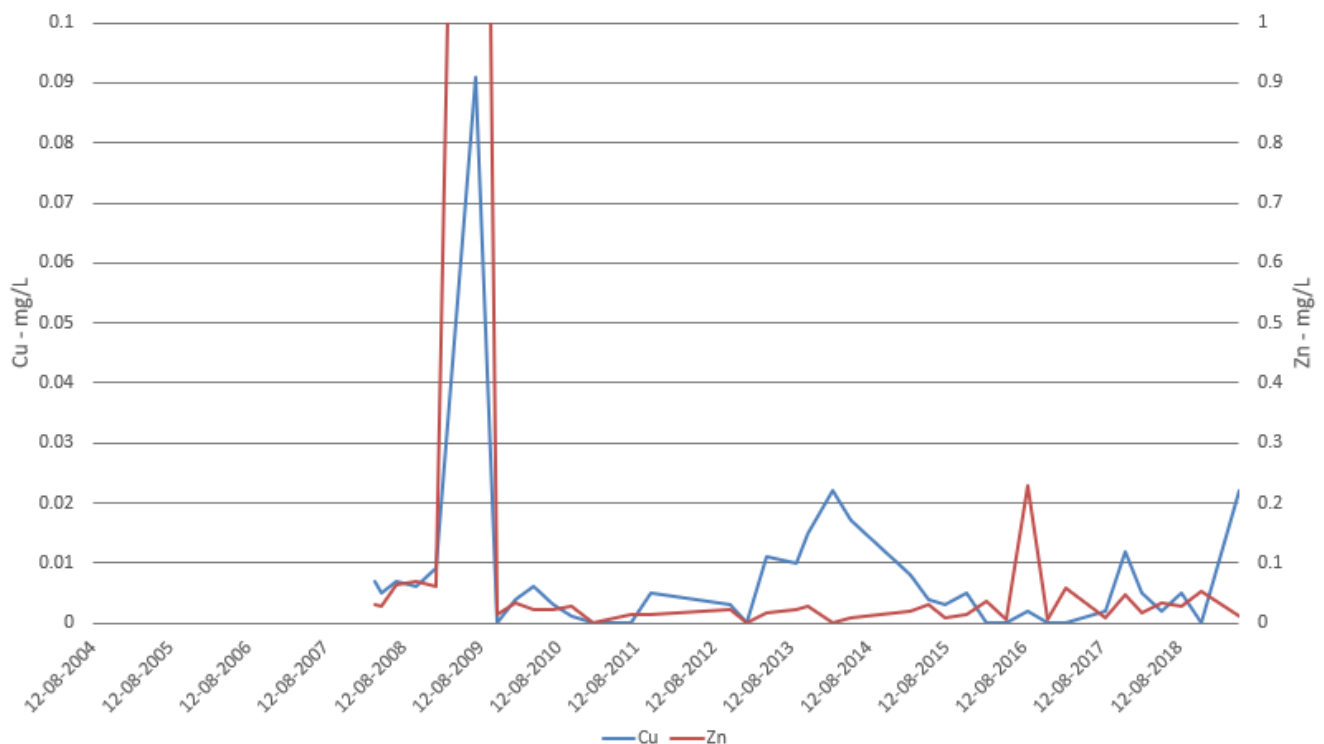


Figure 94 Development of zinc (mg/L) and copper (mg/L) at V5 between 2004 and 2019 (measurement in August 2009 likely in error)

9.3.4.6 Bores V6A and V6B

The grouped bores V6A and V6B are located along and above the southern flank of the East Underground Workings (**Figure 95**). The drill hole for bore V6A/B had a total depth of 50m, of which the bottom 9m were, due to the lack of additional water intercepts, backfilled with drill cuttings. Bore casing V6A has 6m of slots covering the interval between 14m and 20m below ground level and bore V6B has 12m of slots between 29m and 41m depth. The two aquifer sections are separated by 9m of drill cuttings (between 20m and 28m) and 1m of bentonite at 28m.

The groundwater level behaviour of both aquifer sections is almost identical for both depths, with the exemption of the time period of high groundwater tables between 2008 and 2010. During this period, groundwater tables in the shallow bore V6A were almost 3.5m higher than in the deeper V6B (**Figure 96**), which indicates a downward vertical gradient. The difference in groundwater tables is due to different aquifer characteristics. The original drill logs for the Underground Backfill monitoring bores (**Appendix C**) show that the shallow bore V6A monitors “*Stones and sandy clay*” (likely sediments of the Campaspe Formation) between 15m and 20m. The deeper V6B is screened within “*broken volcanics*” between 35m and 40m. As discussed in the hydrogeology report section, the discharge of process water to the remaining initial Thalanga Central Pit void raised groundwater levels that would have potentially allowed flow to and through the Campaspe Formation. Temporarily higher groundwater levels in the shallow V6A bore between 2008 and 2010 are likely evidence of seepage migration through the shallow Campaspe Formation aquifer in this monitored section of the Thalanga mine.

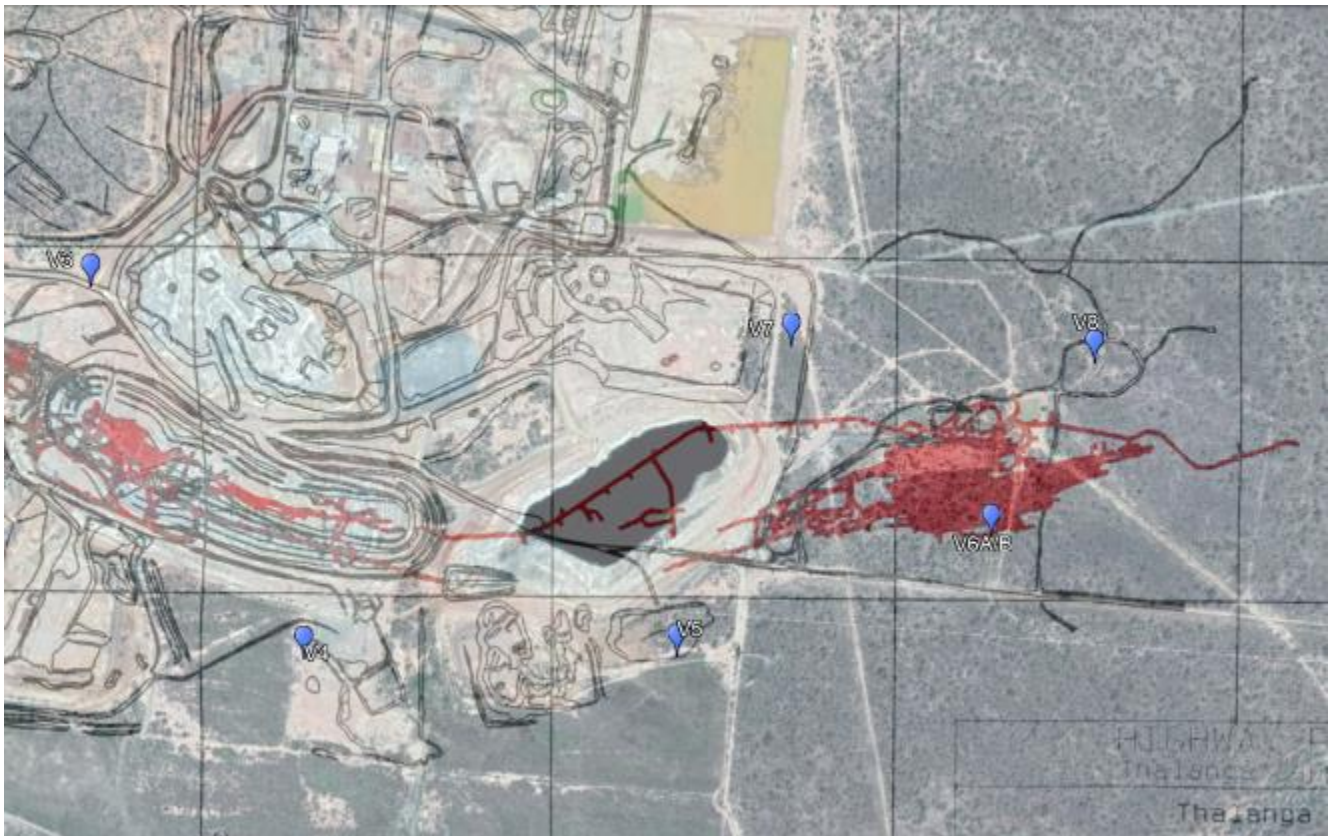


Figure 95 Location of V6A/B in relation to the East Underground Workings at Thalanga

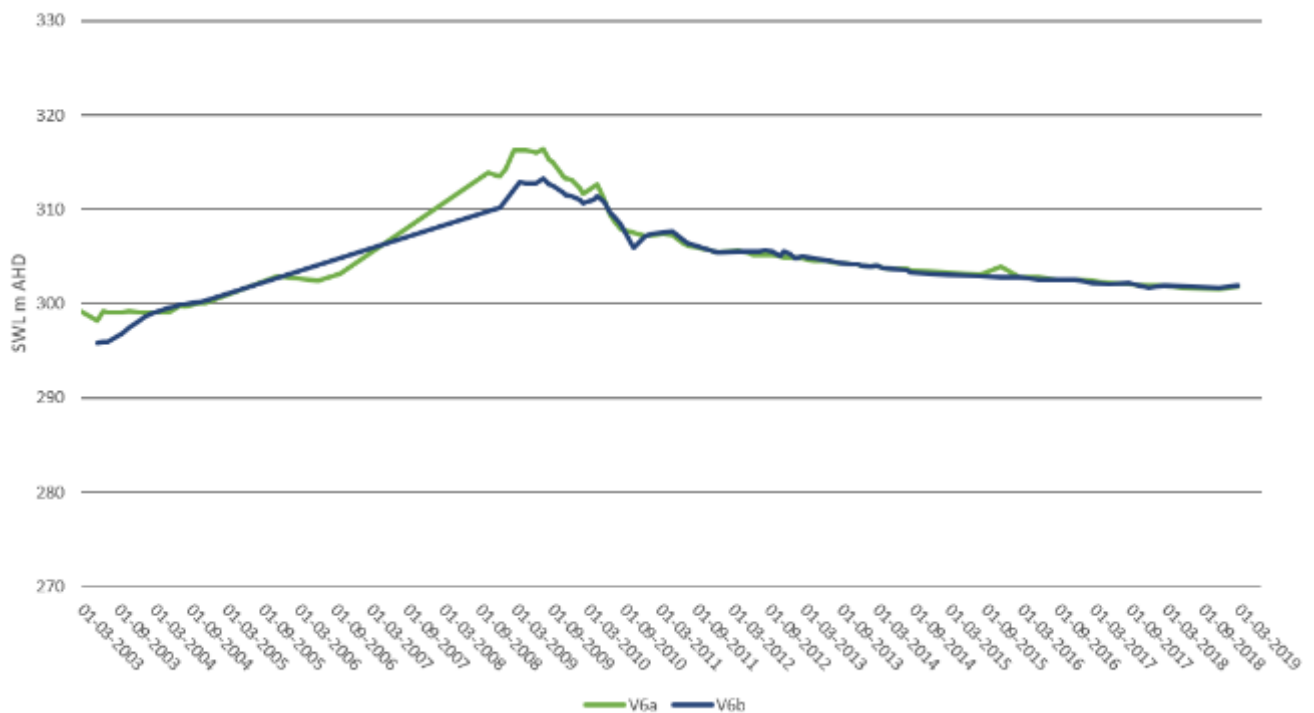


Figure 96 Comparison of groundwater levels between the shallow V6a and deeper V6b

The comparison between the hydrogeochemical development of both bores is partially hampered by the fact that bore V6A could, due to low water tables, not have been pumped until about 2006. Hence, due to limited water in the bore, initial groundwater chemistry records are probably less representative. Regardless, following the peak of groundwater levels in 2008, EC, sulfate, calcium and magnesium (major ions) concentrations in the shallow V6A appear to be, for most of the time, significantly higher than at the deeper V6B (**Figure 97** and **Figure 98**).

Initial measurements of V6B suggest that the bore was not impacted by previous controlled tailings backfill to the underground. However, additional uncontrolled discharge of process water to the Central Pit could have resulted in the disturbance of previously back filled sections and mobilisation of tailings-related contaminants. The potential effects of such disturbance should first become visible in the deeper bore. Hence, the first occurrence of higher concentrations that were observed in the shallow part of the bore suggest that contaminants had been transported along a shallower flow path. Considering this, it appears now likely that lateral seepage along the Campaspe Formation had been occurring during a period of artificially elevated groundwater tables. Subsequent dewatering for the Vomacka Pit and additional underground mining again lowered the groundwater table, resulting in a cessation of seepage flow and a significant reduction of contaminants in V6A and V6B.

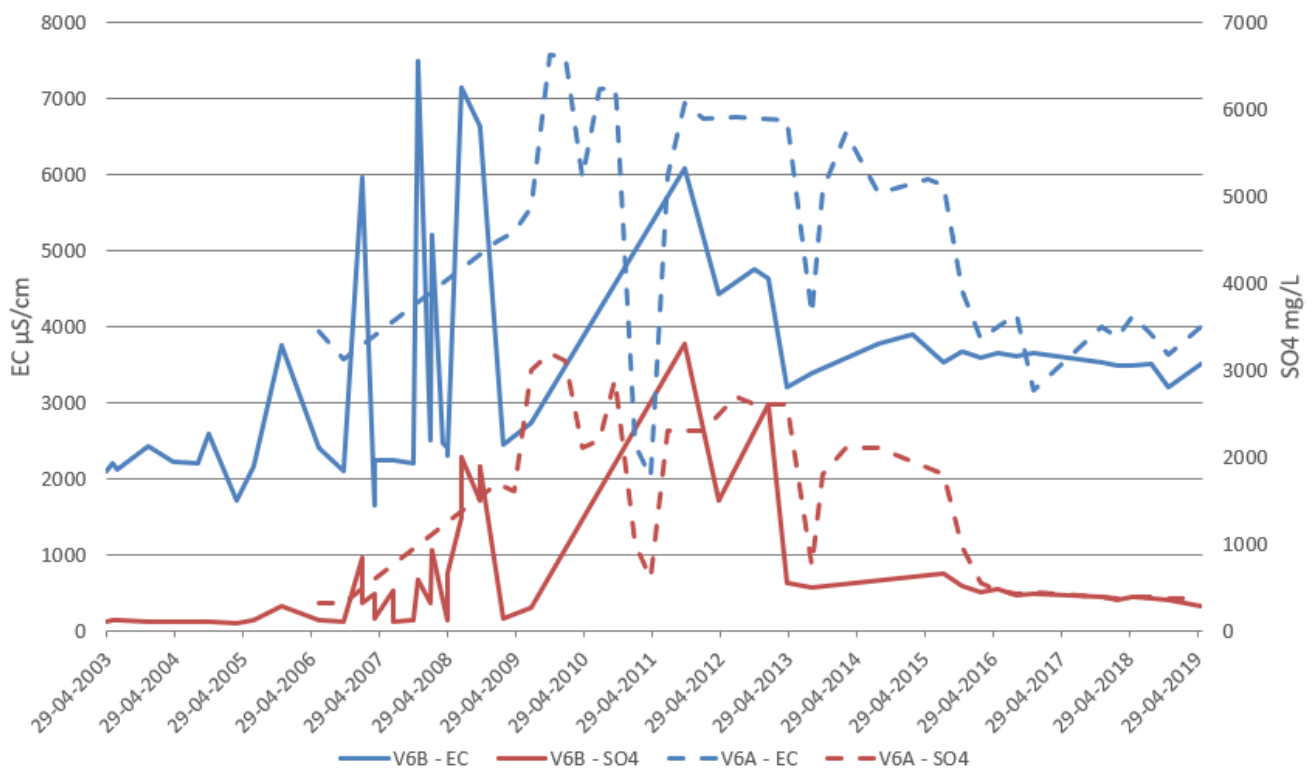


Figure 97 Development of EC (µS/cm) and sulfate (mg/L) in V6A and V6B between 2003 and 2019

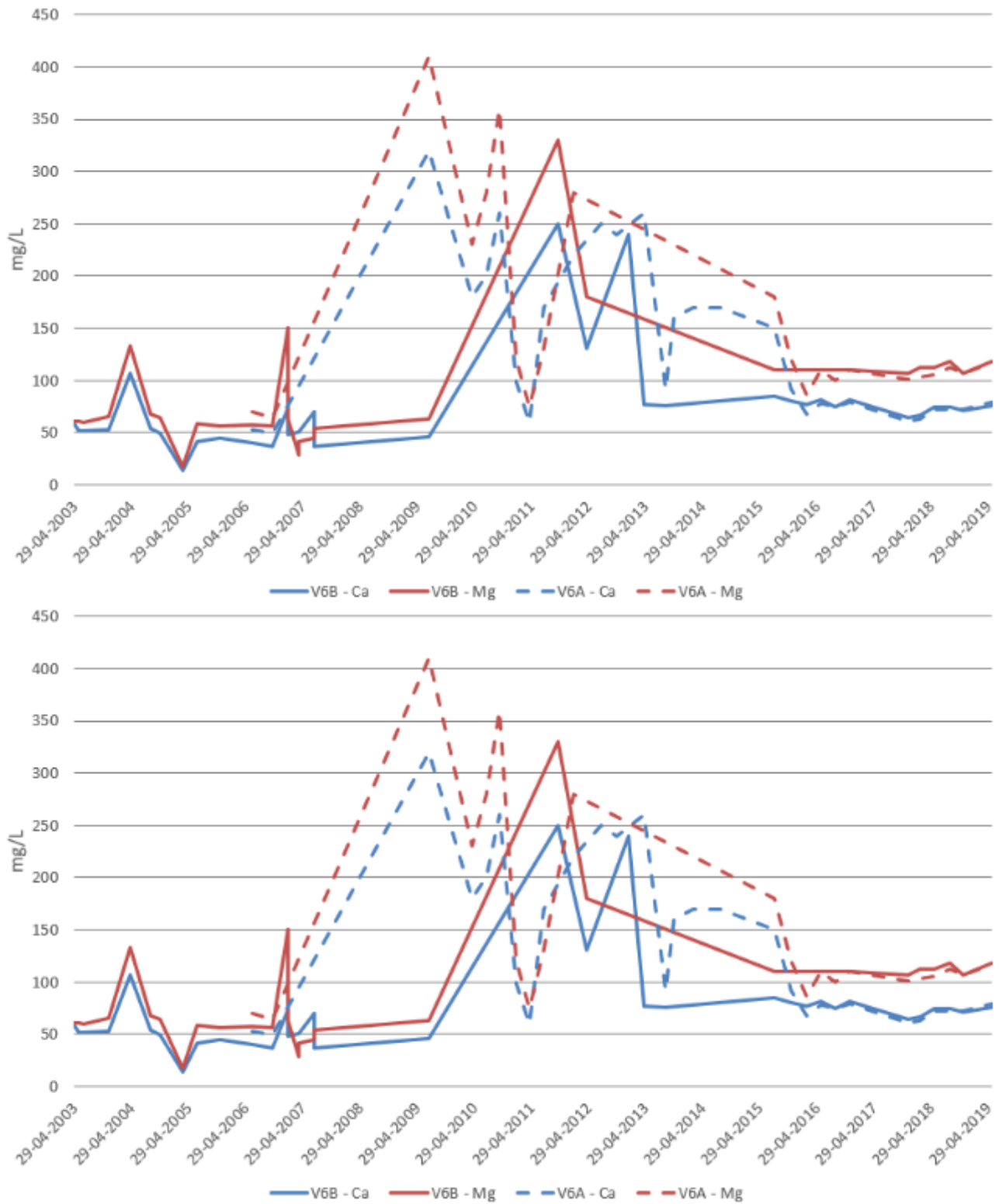


Figure 98 Development of calcium (mg/L) and magnesium (mg/L) in V6A and V6B between 2003 and 2019

9.3.4.7 Bores V7A/B and V8A/B

Measurements from Underground Backfill monitoring bores V7A/B and V8A/B are either very limited or absent. Reason for the lack of monitoring data is that bores were either mostly dry (V7A/B) or, due to underground subsidence, were destroyed or not accessible. Replacement bores for V7A and V7B were installed in 2018, hence monitoring data from these new bores is very limited.

9.3.5 Campaspe channel bores

The Campaspe bores monitoring possible impacts on the Campaspe Formation consist of C1 and C2, installed in December 2007, and V7A/B(new) installed in July 2018.

9.3.5.1 C1 and C2

In response to elevated groundwater levels across the mine site, two additional monitoring bores C1 and C2 were installed in December 2007 to monitor possible impacts on the Campaspe Formation along a previously identified paleochannel (Error! Reference source not found.). Bore installation records for C1 and C2 are only available from DNRM, where bore C1 is quoted to have a depth of 60m, with slots between 48m and 60m. Bore C2 is said to have a depth of 45.7m, with slots between 39.7m and 45.7m. From the logs, it does not appear that these bores were drilled to the bottom of the Campaspe Formation; hence, the depth of the Campaspe Formation at C1 and C2 is likely to be greater than indicated by the drill logs.

Hydrogeologically, the groundwater levels in these bores possibly responded to the reduction of groundwater extraction from the Campaspe bore field between 2012 and 2016. Yet, groundwater level increases are evident, particularly in C2, since these bores were installed. Alternatively, the increase in groundwater tables may be associated with water migrating from the mine site towards the Campaspe Formation in the east. Airlift yield rates reported in the drill logs suggest that the hydraulic conductivity of the strata intersected by C2 is significantly higher than at C1 (yield 0.84L/s for C2 and 0.01L/S for C1). When comparing the locations of C1 and C2 with the inferred position of the paleochannel shown in **Figure 11 in Appendix C** it appears very likely that bore C1 did not intersect the main aquifer channel while bore C2 did. This and the greater hydraulic conductivity of C2 in mind, it is possible that potential seepage flows past C1, only to be detected at C2.

The hydrogeochemical behaviour of the groundwater at C1 and C2 provides little additional information with regards to the origin of increased groundwater tables (**Figure 26** and **Figure 34**).

EC at C1 appears to be almost static between 6,000µS/cm and 7,000µS/cm (**Figure 99**), while sulfate and dissolved zinc concentration may be interpreted as slightly increasing between 2007 and 2012 (**Figure 100**). Compared to the closest monitored mine bore V6A/B, EC and sulfate at C1 are more stable and EC and sulfate concentrations at V6A/B are generally higher.

EC and sulfate concentrations at C2 (**Figure 101** and **Figure 102**) are considerably lower than at C1. Regardless, both EC and sulfate seem to have peaked during 2008/2009. These peaks may be associated with elevated groundwater tables on the mine site due to the flooding of the Thalanga Central Pit and underground with process water. The absence of these peaks at the closer to the mine site located bore C1 likely the result of a lower ground permeability and the 'off centre channel' position of the bore.

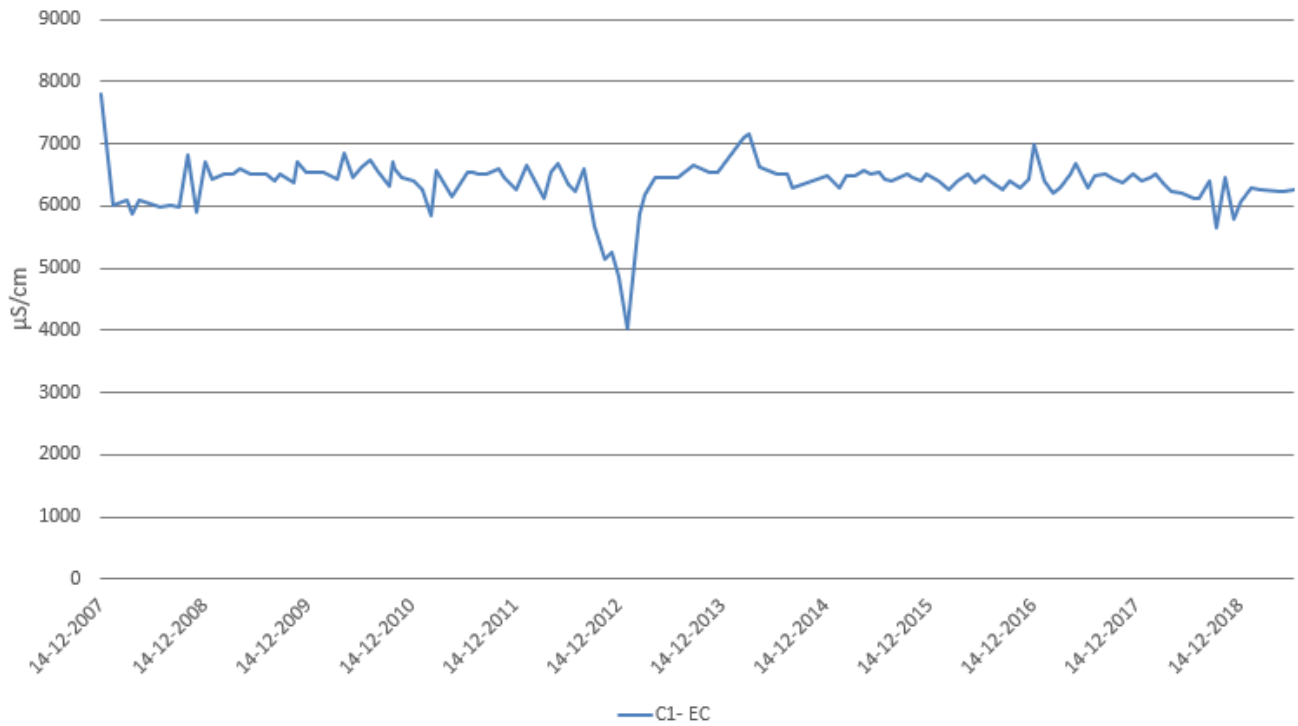


Figure 99 EC ($\mu\text{S}/\text{cm}$) development at C1 between 2007 and 2019

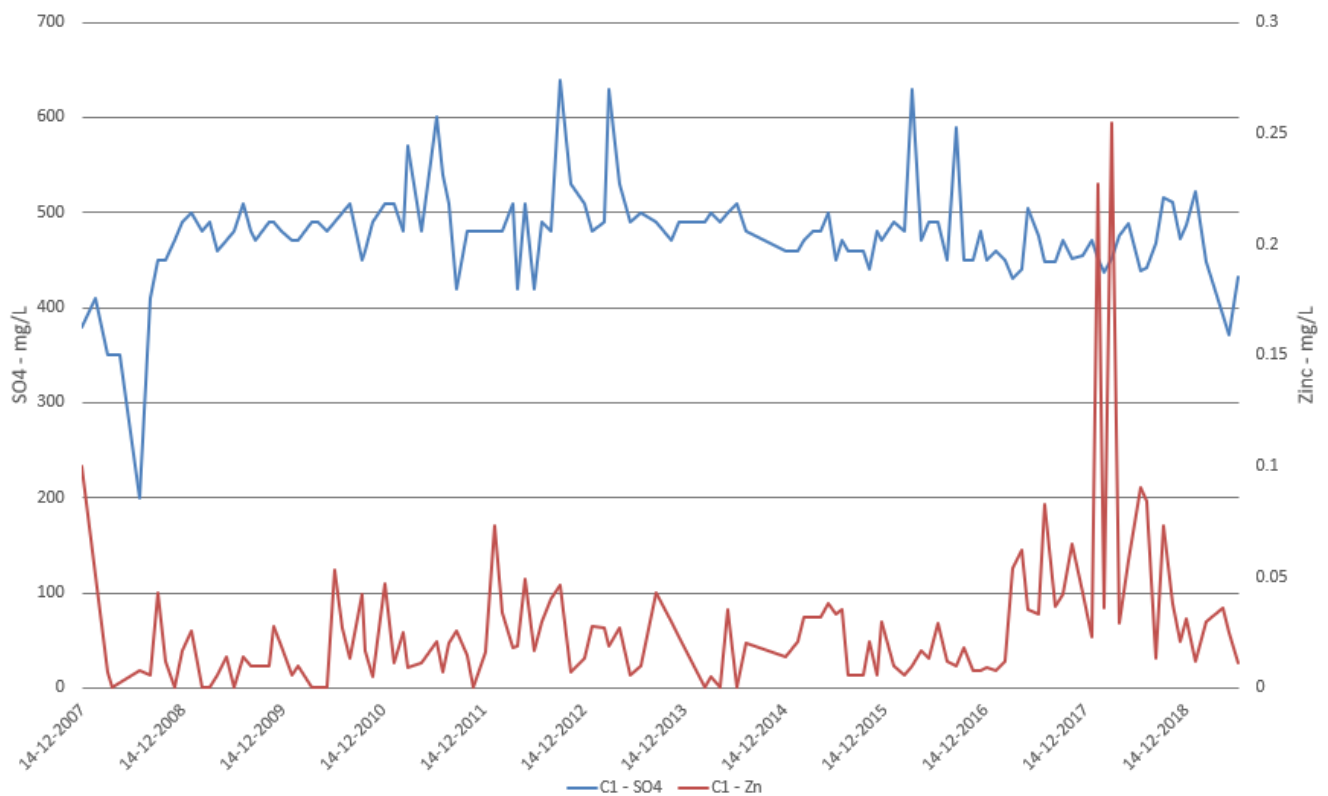


Figure 100 Sulfate (mg/L) and zinc (mg/L) development at C1 between 2007 and 2019

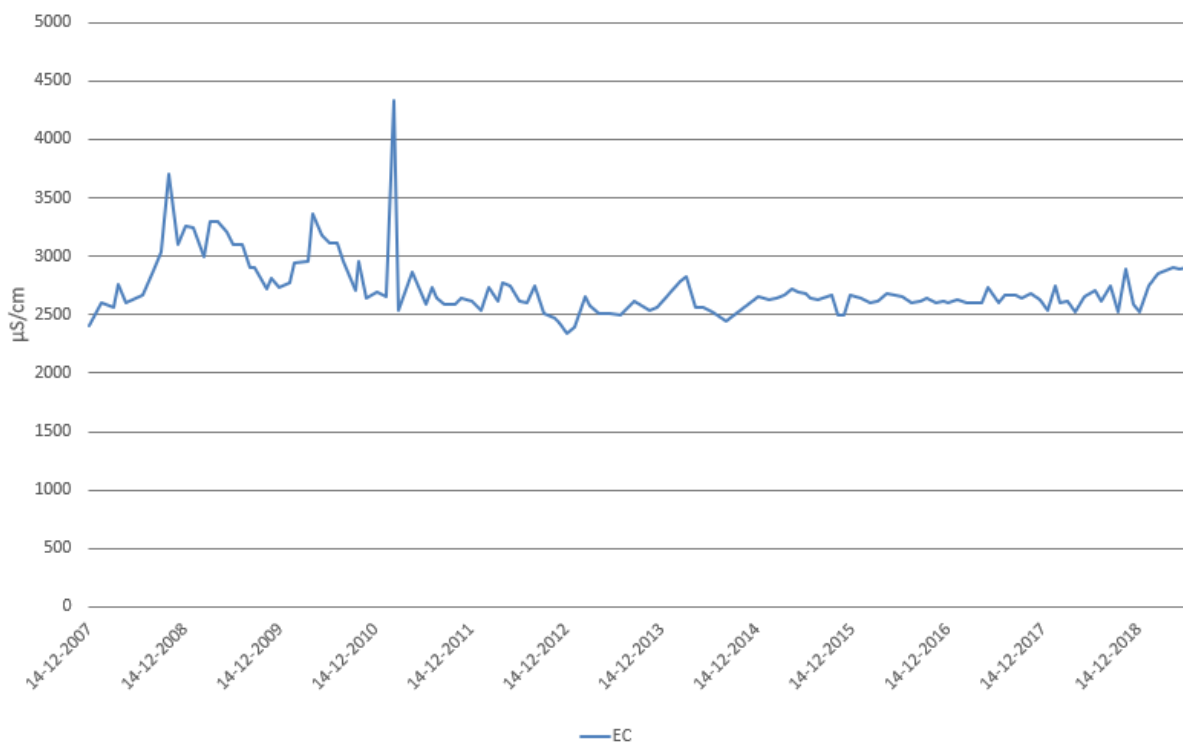


Figure 101 EC (µS/cm) development at C2 between 2007 and 2019

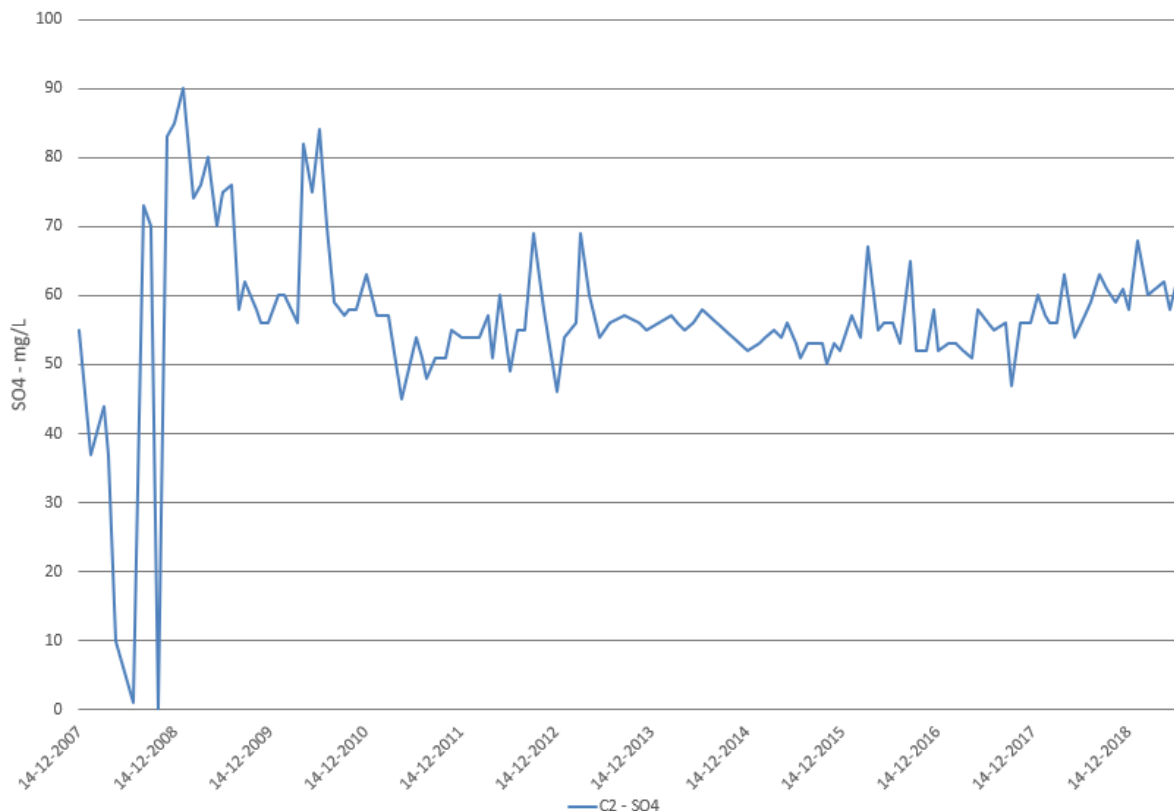


Figure 102 Sulfate (mg/L) developments at C2 between 2007 and 2019

9.3.5.2 V7A/B (new)

A more recent addition to the groundwater monitoring network at Thalanga are bores V7A(new) and V7B(new). These bores were installed as a replacement for the underground tailings deposition monitoring bores V7A and V 7B, which were impacted by the underground tailings backfill and subsequent dewatering. Bore V7A(new) has been installed to a depth of 42m, encountering weathered, fractured rhyolite at 35m. The strata above the rhyolite consisted of mainly clay and distinct sand layers between 3m and 5m; 6m to 7m; 26m to 28m; and 34m to 35m. Bore V7B(new), installed at the same location encountered the same strata but was drilled to 60m, with the section below 35m recording fractured rhyolite. Bore construction of bore V7A(new) focused on the Campaspe Formation sediments with slots and gravel pack designed to monitor groundwater between 21m and 42m. Bore V7B(new) was designed to only monitor the fractured rhyolite with slots and gravel pack only monitoring the section between 53m and 60m. During drilling only bore V7B(new) encountered groundwater, measuring a flow of 0.43L/sec and EC of 4090 μ S/cm. Subsequent groundwater measurements following the completion of bore construction encountered groundwater in both bores. Since construction in July 2018, the results of the limited sampling suggest that initial sampling or laboratory results from August 2018 were presented in error (**Table 13**). Subsequent results for V7A(new) are consistent, however, results for V7B(new) are impacted or unrepresentative since the bore construction had been compromised by cattle impact, essentially breaking off the bore casing below ground level and allowing surface runoff to enter the bore.

Compared to EC, sulfate and chloride concentrations of the other Campaspe channel bore C1 and potential source bores (V6B for the underground tailings backfill and TH4 for Cell 9 TSF bore), the groundwater composition at V7A(new) shows a good correlation to the groundwater composition with EC, sulfate and chloride at V6B (**Figure 103**, **Figure 104** and **Figure 105**). Compared to C1 good correlation exists only with respect to sulfate, while EC and chloride concentrations at V7A(new) are significantly lower. Compared to TH4, EC, sulfate and chloride concentrations are considerably lower at V7A(new).

Table 13 Selected groundwater quality parameters for bores V7A/B(new) since installation in July 2018

	28-08-2018*	26-11-2018	26-02-2019	22-05-2019	29-08-2019
V7A(new) EC	5530 $\mu\text{S/cm}$	3480 $\mu\text{S/cm}$	3520 $\mu\text{S/cm}$	3880 $\mu\text{S/cm}$	3840 $\mu\text{S/cm}$
V7B(new) EC	3680 $\mu\text{S/cm}$	5120 $\mu\text{S/cm}$	1120 $\mu\text{S/cm}$	1170 $\mu\text{S/cm}$	
V7A(new) SO ₄	1150 mg/L	700 mg/L	640 mg/L	630 mg/L	631 mg/L
V7B(new) SO ₄	612 mg/L	1340 mg/L	118 mg/L	99 mg/L	
V7A(new) Cl	952 mg/L	610 mg/L	591 mg/L	658 mg/L	678 mg/L
V7B(new) Cl	646 mg/L	900 mg/L	182 mg/L	184 mg/L	
V7A(new) Cu	<0.001 mg/L	<0.001 mg/L	0.008 mg/L	<0.001 mg/L	<0.001 mg/L
V7B(new) Cu	<0.001 mg/L	<0.001 mg/L	0.003 mg/L	0.003 mg/L	
V7A(new) Zn	<0.005 mg/L	0.009 mg/L	0.025 mg/L	0.008 mg/L	0.008 mg/L
V7B(new) Zn	<0.005 mg/L	<0.005 mg/L	0.007 mg/L	0.064 mg/L	

*Likely presented in error, replaced with data from V7B in **Figure 103**, **Figure 104** and **Figure 105** below

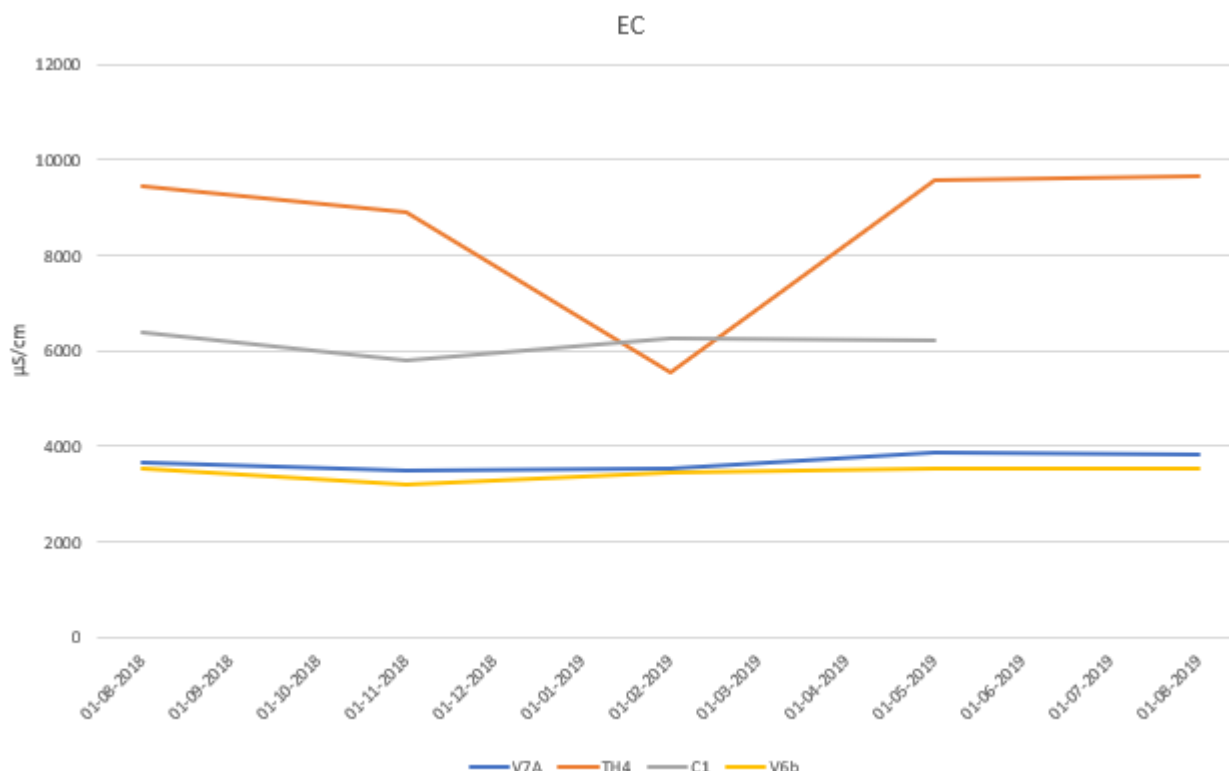


Figure 103 Comparison of groundwater EC between V7A(new), TH4, C1 and V6b

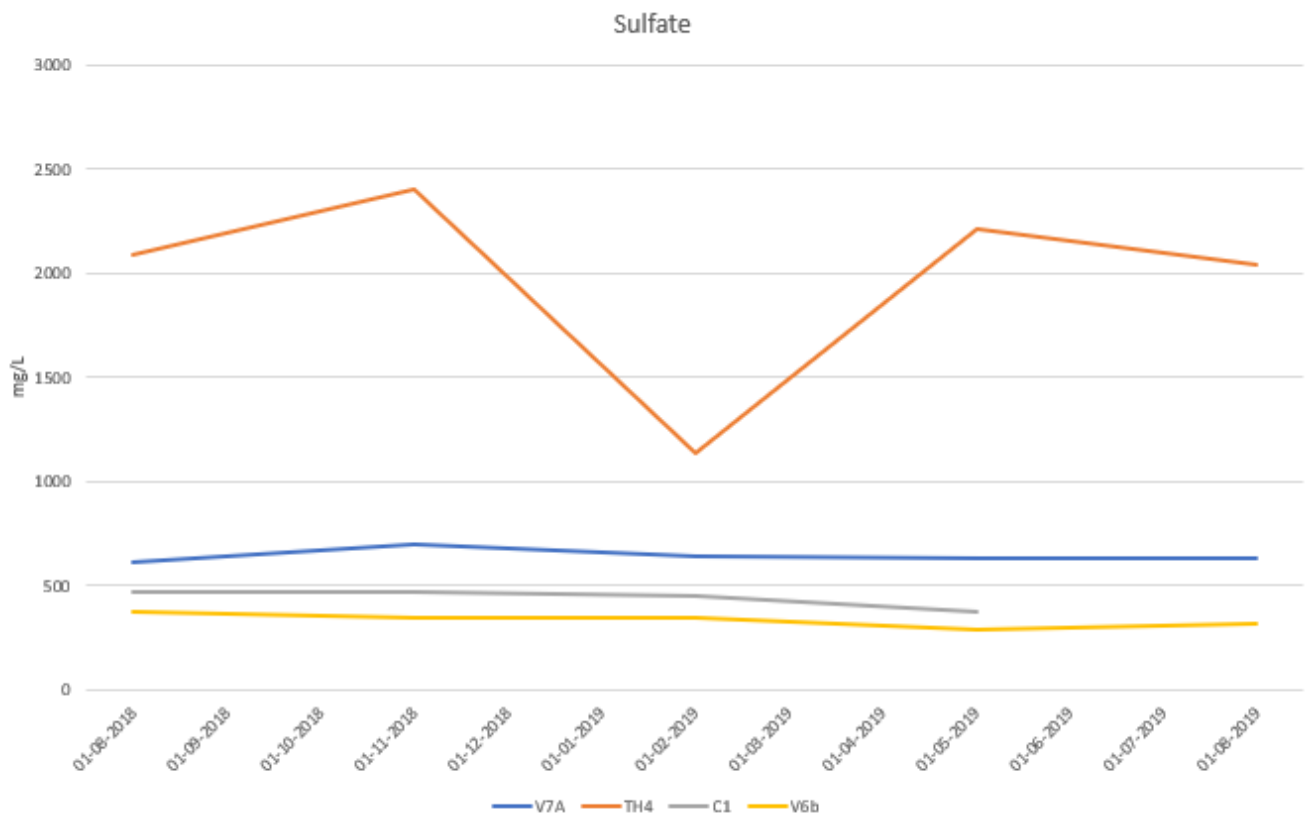


Figure 104 Comparison of groundwater sulfate concentrations between V7A(new), TH4, C1 and V6b

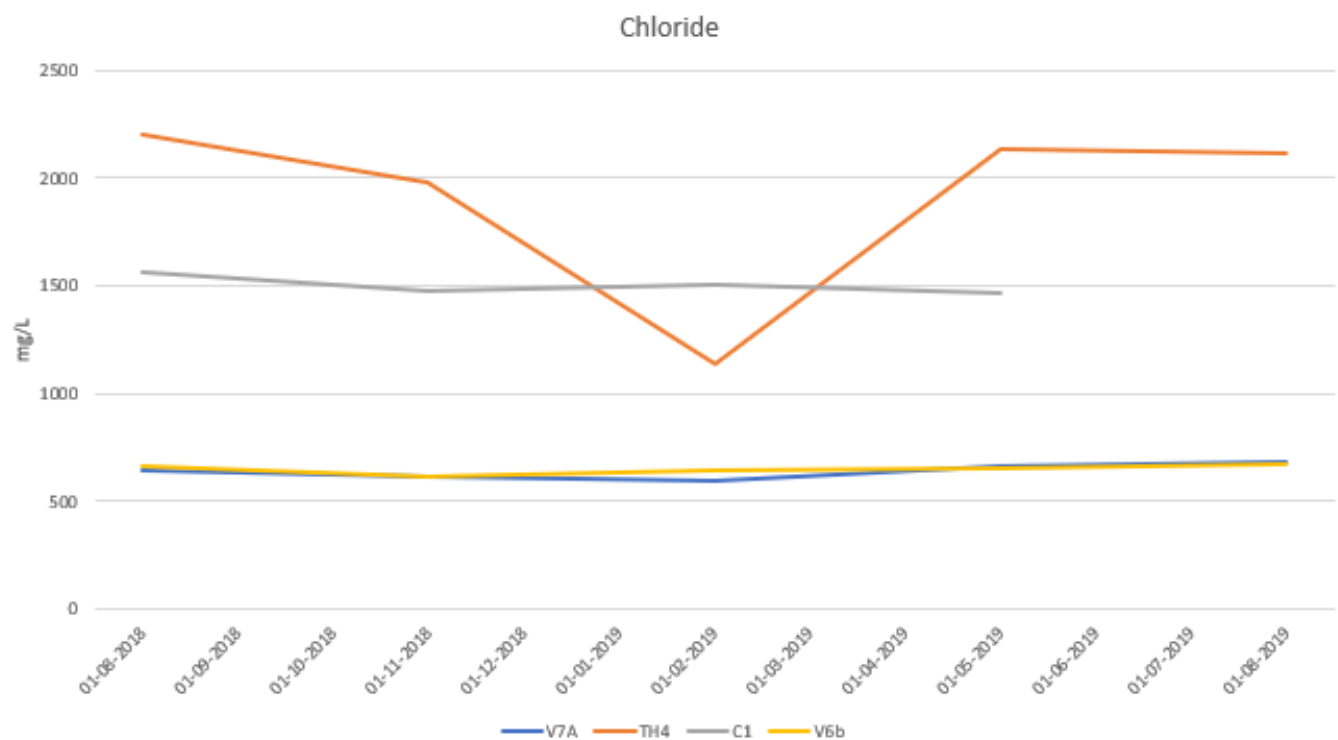


Figure 105 Comparison of groundwater chloride concentrations between V7A(new), TH4, C1 and V6b

The higher EC and chloride concentrations at C1 and TH1 (when compared to V7A) are likely the result of evapotranspiration from the Campaspe Formation and tailings Cell 9. Higher sulfate concentrations at V7A (when compared to the downstream C1 and potential source V6b) are possibly the remnants of previously elevated sulfate at V6b following the underground tailings and disposal and process water discharge (**Figure 97**). Circumstantial evidence for this hypothesis are decreasing sulfate concentrations at V6b and C1 (**Figure 106**). For comparison see also **Figure 100**.

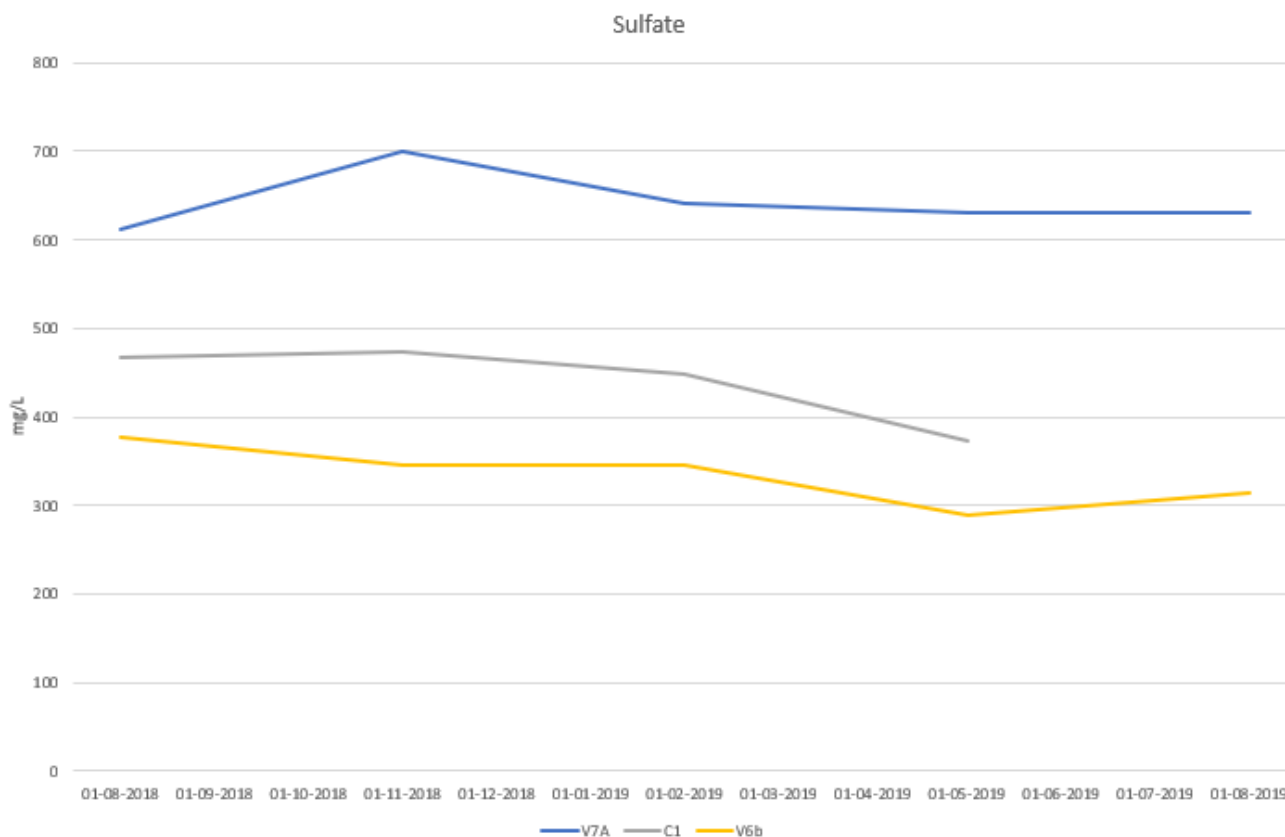


Figure 106 Concentrations of sulfate at V7A, C1 and V6b between August 2018 and August 2019

The influence of rainwater, on the groundwater chemistry has been demonstrated by temporary decreasing chloride concentrations at TH4 (**Figure 105**) and is shown again by the bicarbonate concentrations in **Figure 107**. Bicarbonate increases with distance from the surface and with time. What can be seen is that bore TH4 and to a lesser extent V7A are influenced by freshwater inflow as a result of wet season rainfall. A similar influence is absent at C1 and V6b, likely due to these bores being deeper or otherwise being disconnected from surface water influences. At the same time as bicarbonate decreases at V7A, concentrations of chloride, sodium calcium, magnesium, potassium and sulfate remain relatively stable suggesting that dilution or is not occurring. Striking the similarity to Groundwater at V7A and V6b. Besides EC (**Figure 103**) and chloride (**Figure 105**) concentrations of calcium (**Figure 108**), magnesium (**Figure 109**), potassium (**Figure 110**) and sodium (**Figure 111**) are very similar at V7A and V6b.

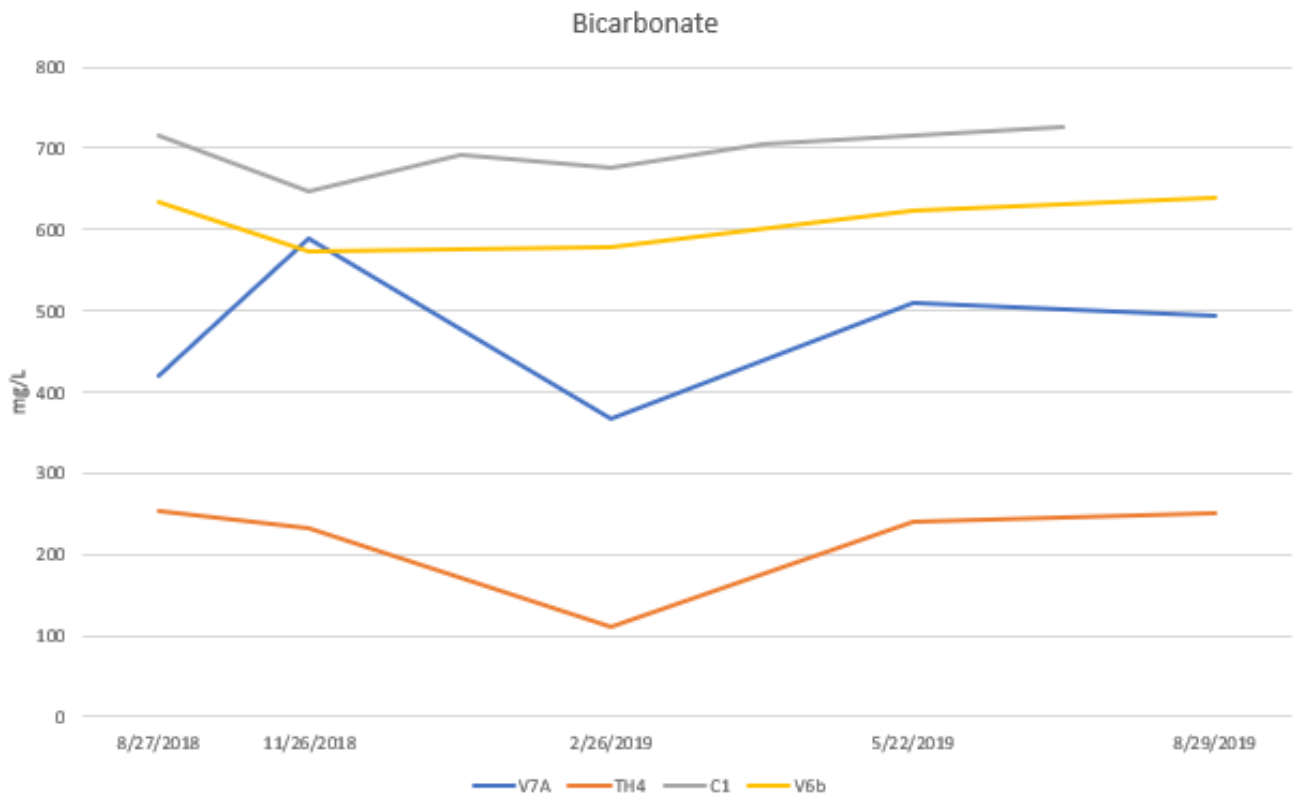


Figure 107 Concentrations of bicarbonate at V7A, C1 and V6b between August 2018 and August 2019

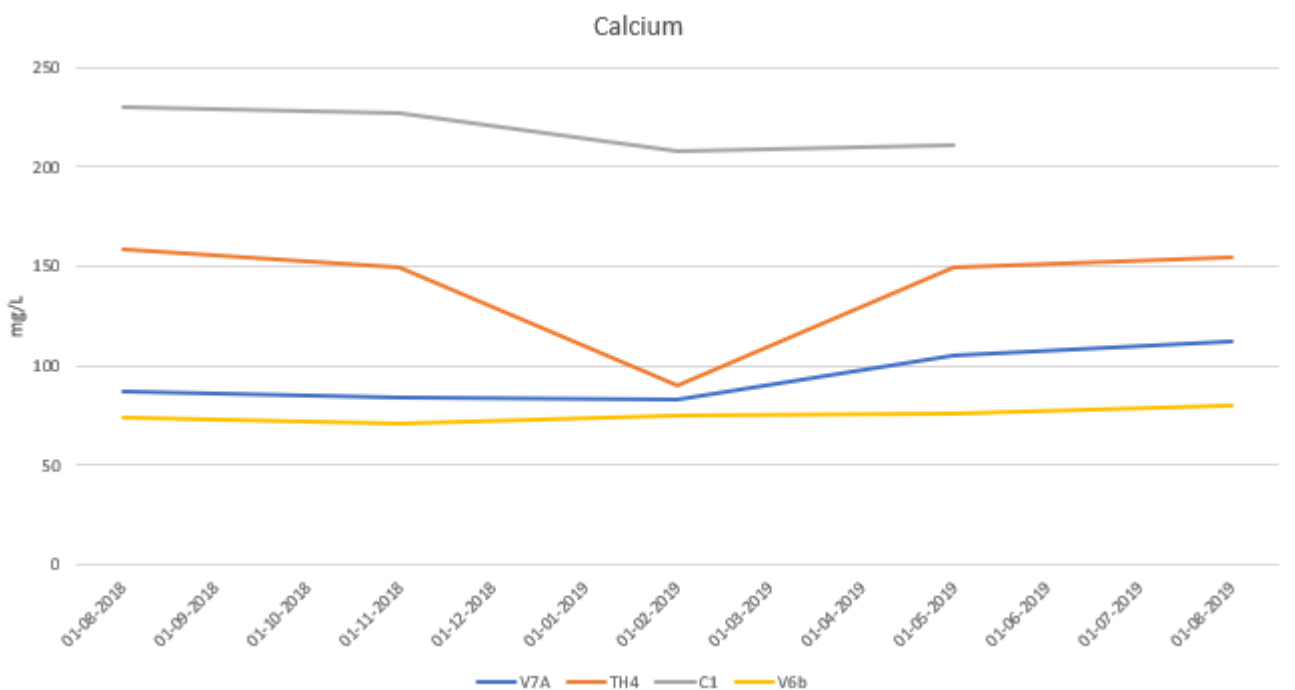


Figure 108 Concentrations of calcium at V7A, C1 and V6b between August 2018 and August 2019

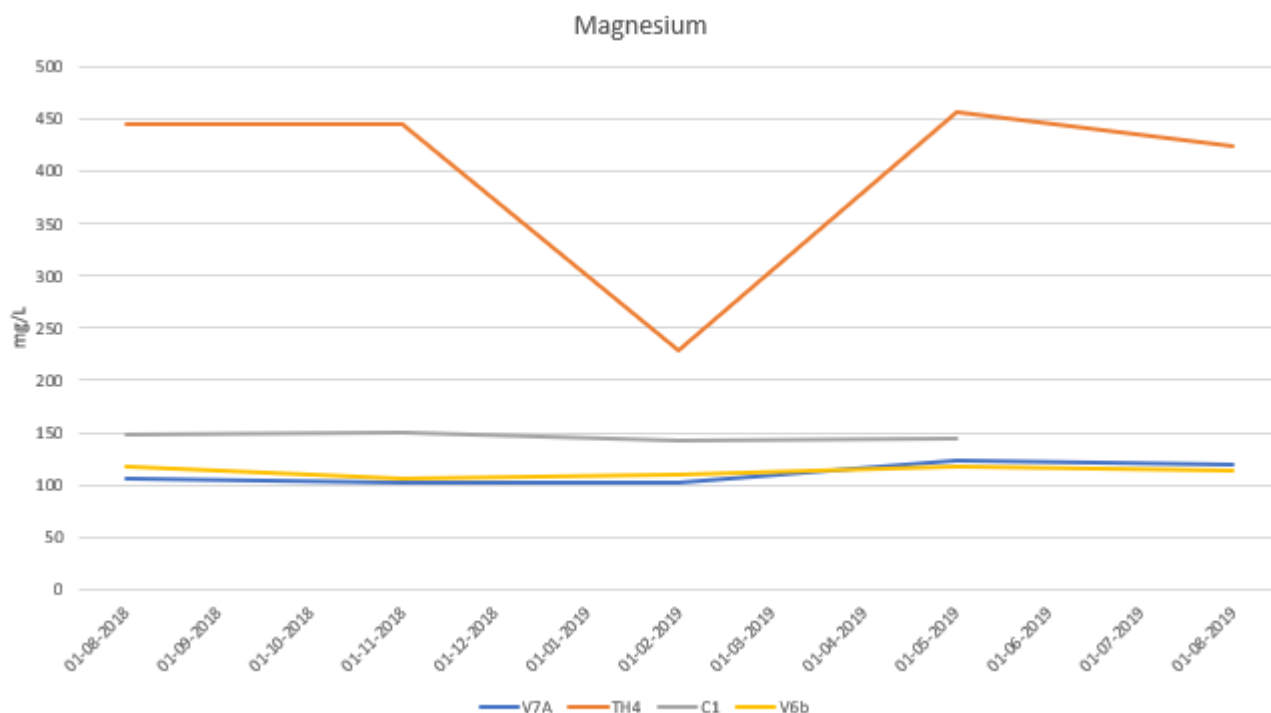


Figure 109 Concentrations of magnesium at V7A, C1 and V6b between August 2018 and August 2019

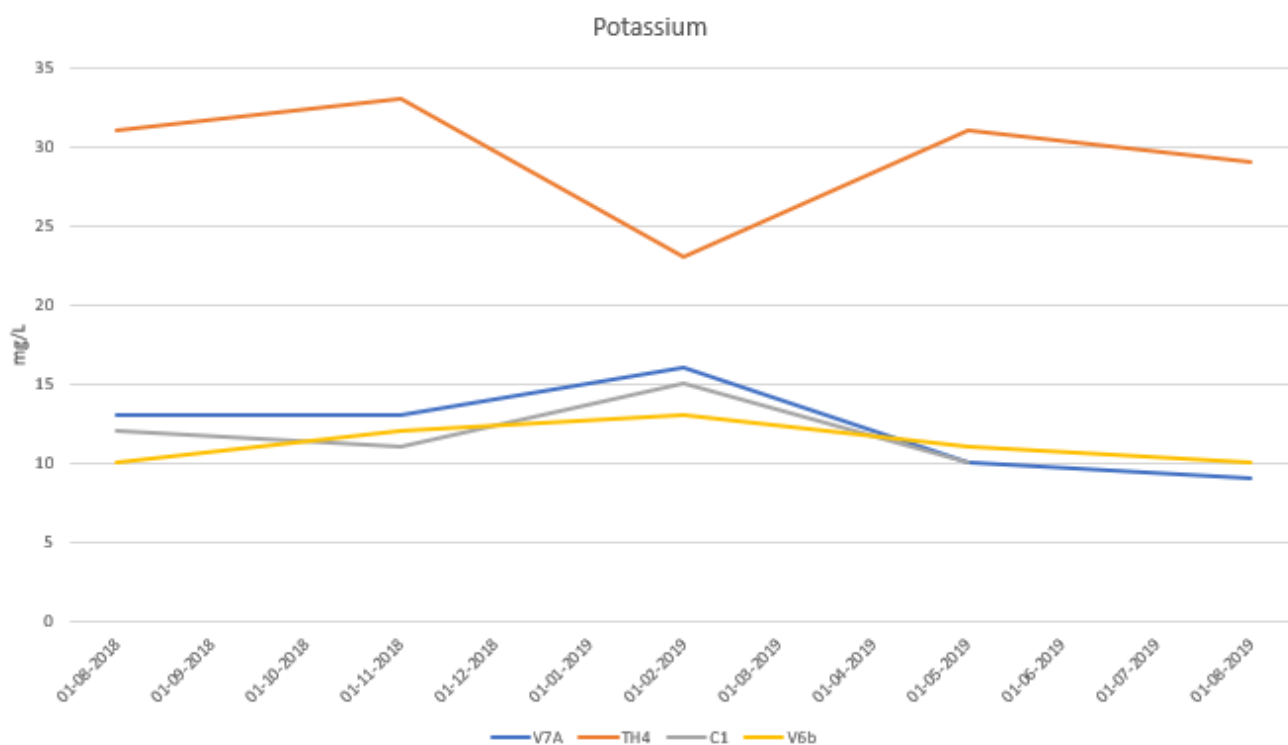


Figure 110 Concentrations of potassium at V7A, C1 and V6b between August 2018 and August 2019

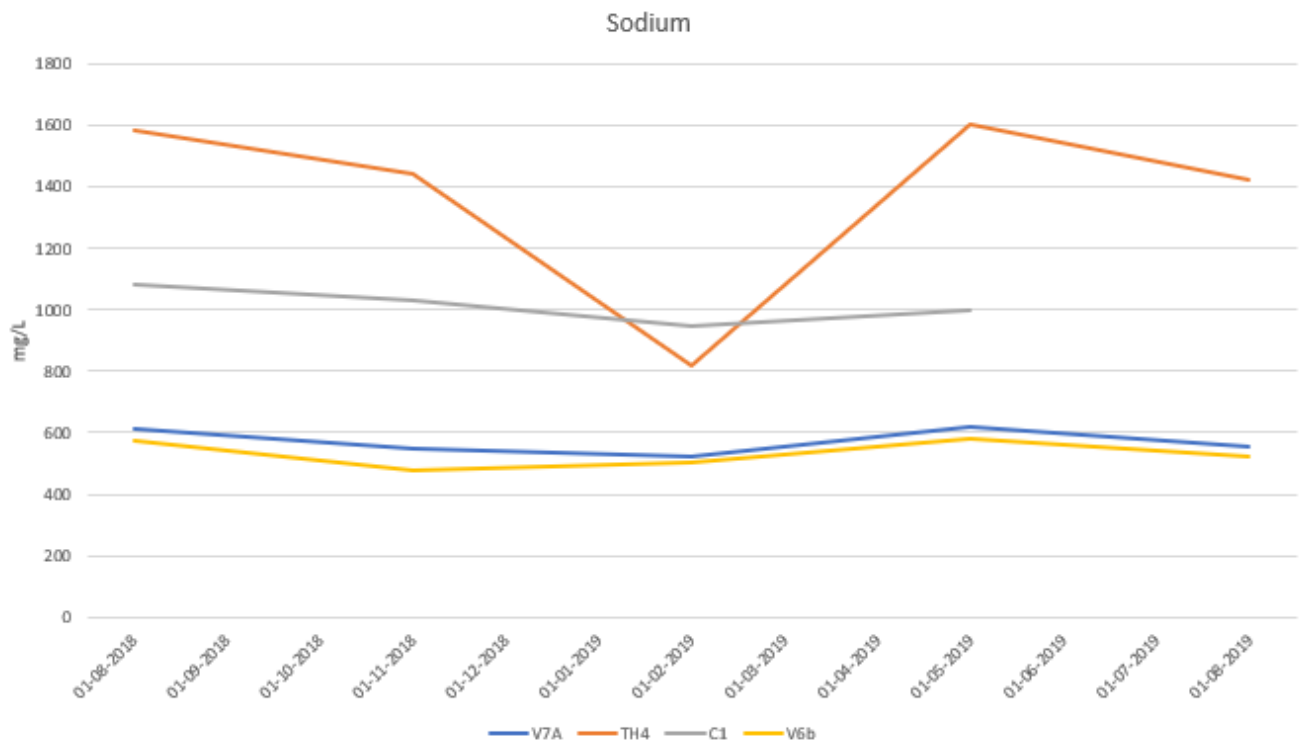


Figure 111 Concentrations of sodium at V7A, C1 and V6b between August 2018 and August 2019

Given the above, it appears likely that the groundwater composition at V7A has previously been impacted by artificially elevated groundwater levels on the mine site. A comparison of the major groundwater parameters strongly suggests that elevated sulfate concentrations at V7A are a remnant of seepage from the underground around V6b and not related to tailings in Cell 9.

9.3.6 West 45 bores

The West 45 bores were installed to assess the efficiency and impact of the West 45 underground dewatering on the groundwater situation surrounding and within the West 45 deposit. Due to their closeness to existing underground workings and proposed underground works of the West 45 deposit, it is likely that the bore strata of the West 45 bores are generally mineralised. The West 45 bores consist of 6 bores W45B1, W45B2, W45B3, W45B4, W45B5 and W45B6 (**Figure 13 in Appendix C**) of which W45B1 to W45B4 are regularly monitored since installation in 2010 and 2011.

Since mining of the West 45 deposit commenced, groundwater levels within these 79m to 91m deep bores has generally been reduced, with bore W45B1 running dry mid-2016 and W45B2 is expected to run dry in the near future (**Figure 112**).

There is no direct connection via underground workings between the West 45 deposit and the previously mined Thalanga underground. The closest Thalanga underground workings consist of the former exploratory Far West decline. The distance between the Far West decline and the West 45 workings is approximately 700m.

As the water table in the West 45 deposit is lowered, groundwater from the surrounding areas is drawn past the West 45 bores towards the centre of the cone of depression. Water chemistry changes therefore do not represent contamination migrating away from the West 45 deposit, but rather represent the groundwater chemistry of the surrounding areas being drawn into West 45. Alternatively, the potential proximity of some bores to mineralisation may result in sulphide oxidation and metalliferous drainage in some bores once groundwater levels are lowered. If such metalliferous drainage has been generated, it too will be drawn past the West 45 bores towards the centre of the cone of depression.

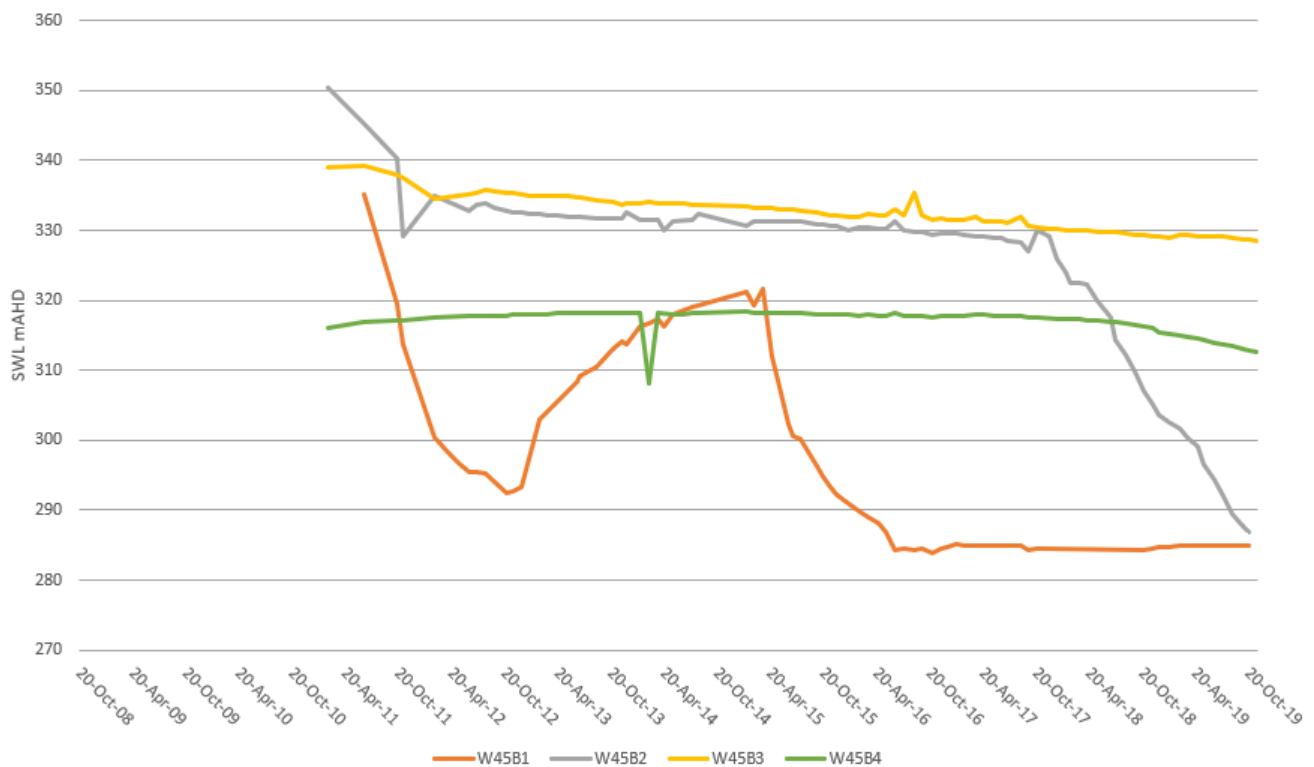


Figure 112 Groundwater levels (m AHD) within the sampled West 45 bores

9.3.6.1 W45B1

Due to the bore running dry, groundwater chemistry changes in W45B1 were only monitored till 2016. Prior to running dry the bore water chemistry displayed increasing EC, sulfate and metal concentration (**Figure 113** and **Figure 114**). The bore is located on the western side of the West 45 deposit, hence contamination from other mine impacted areas can be excluded. The most likely explanation for increases in EC, sulfate and metals is the weathering of sulphides within the strata surrounding the bore.

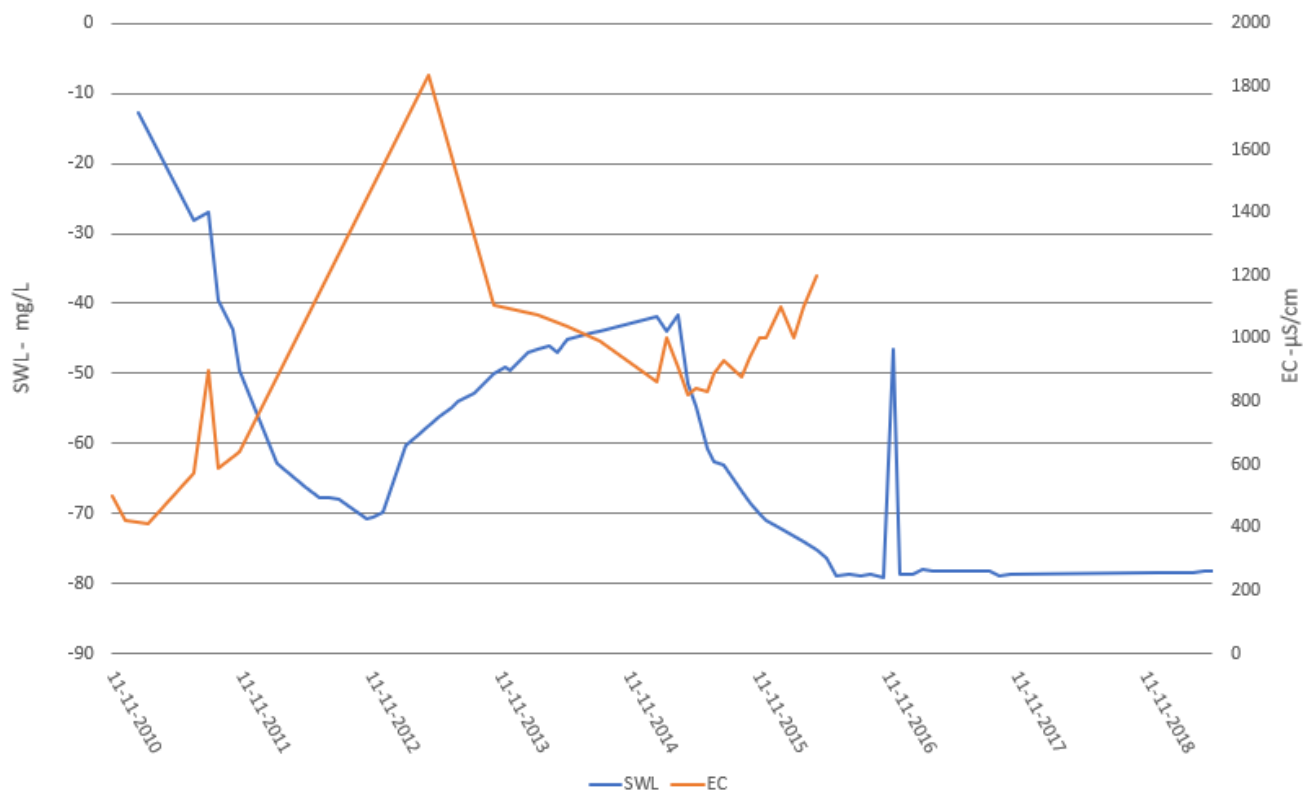


Figure 113 Development of Standing Water Level (m bGL) and EC ($\mu\text{S}/\text{cm}$) at W45B1

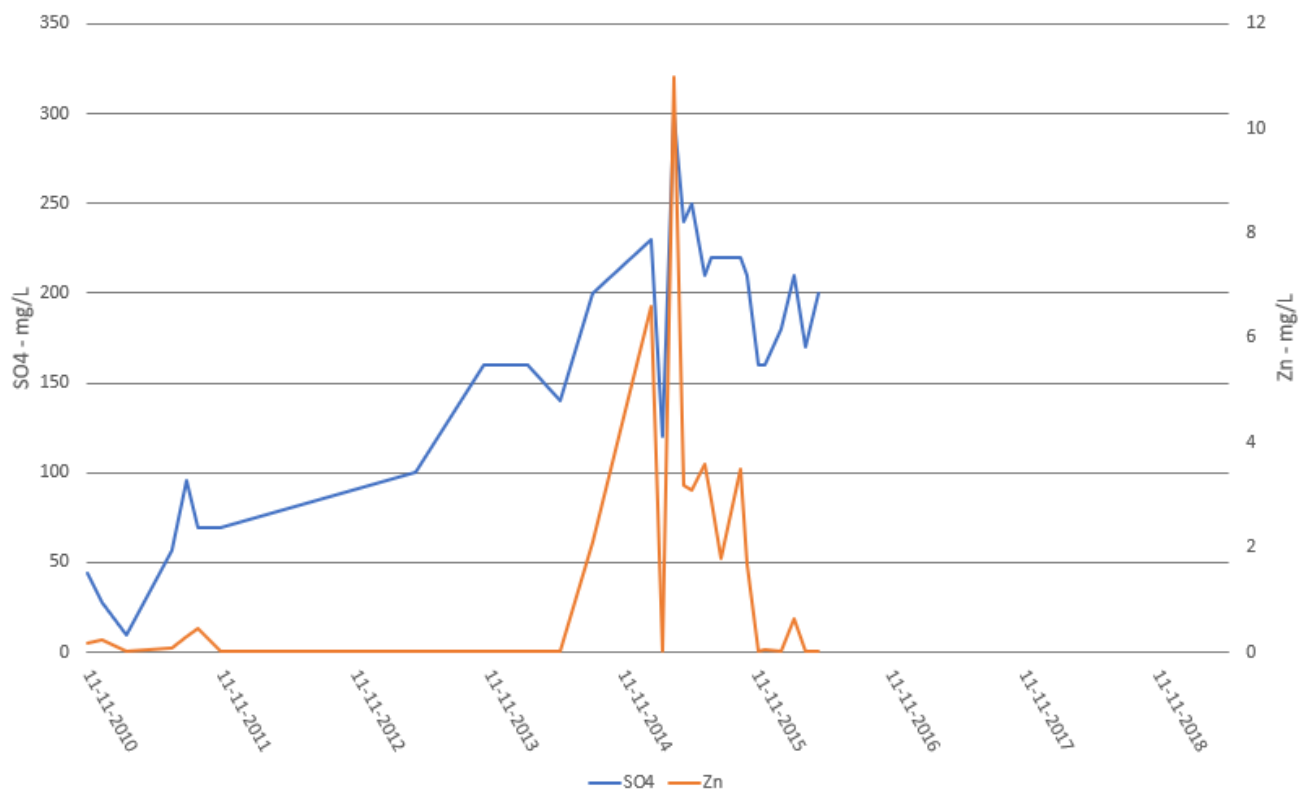


Figure 114 Development of sulfate (mg/L) and zinc (mg/L) concentrations at W45B1

9.3.6.2 W45B2

The groundwater level development of W45B2 indicates that the bore is impacted by dewatering activities at West 45 and possibly more recently dewatering of the Far West deposit. EC initially increased, likely due to the initial mixing of two different aquifer sections (**Figure 115**). Sulfate and zinc somewhat vary (**Figure 116**) but increases and decreases appear to be connected. The strong variations in zinc concentrations may suggest a mineralised area close to the groundwater level between 30m and 35m below ground. Upon wetting and drying of the mineralised strata potential oxidation products would manifest themselves in the bore water. Again, increases in EC, sulfate and metals in W45B2 are not a sign seepage from the West 45 underground workings, but rather a sign of groundwater migrating through potentially mineralised rock towards the cone of depression.

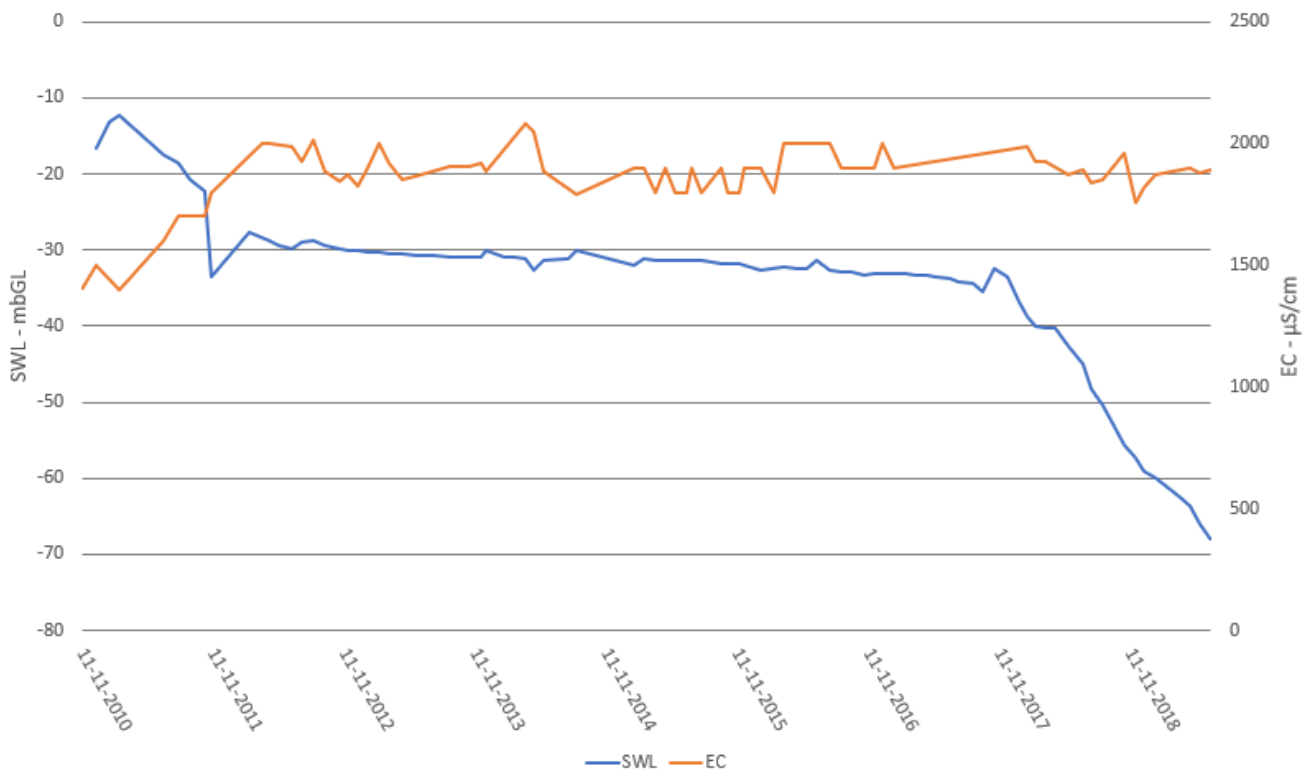


Figure 115 Development of SWL (m bGL) and EC (µS/cm) at W45B2

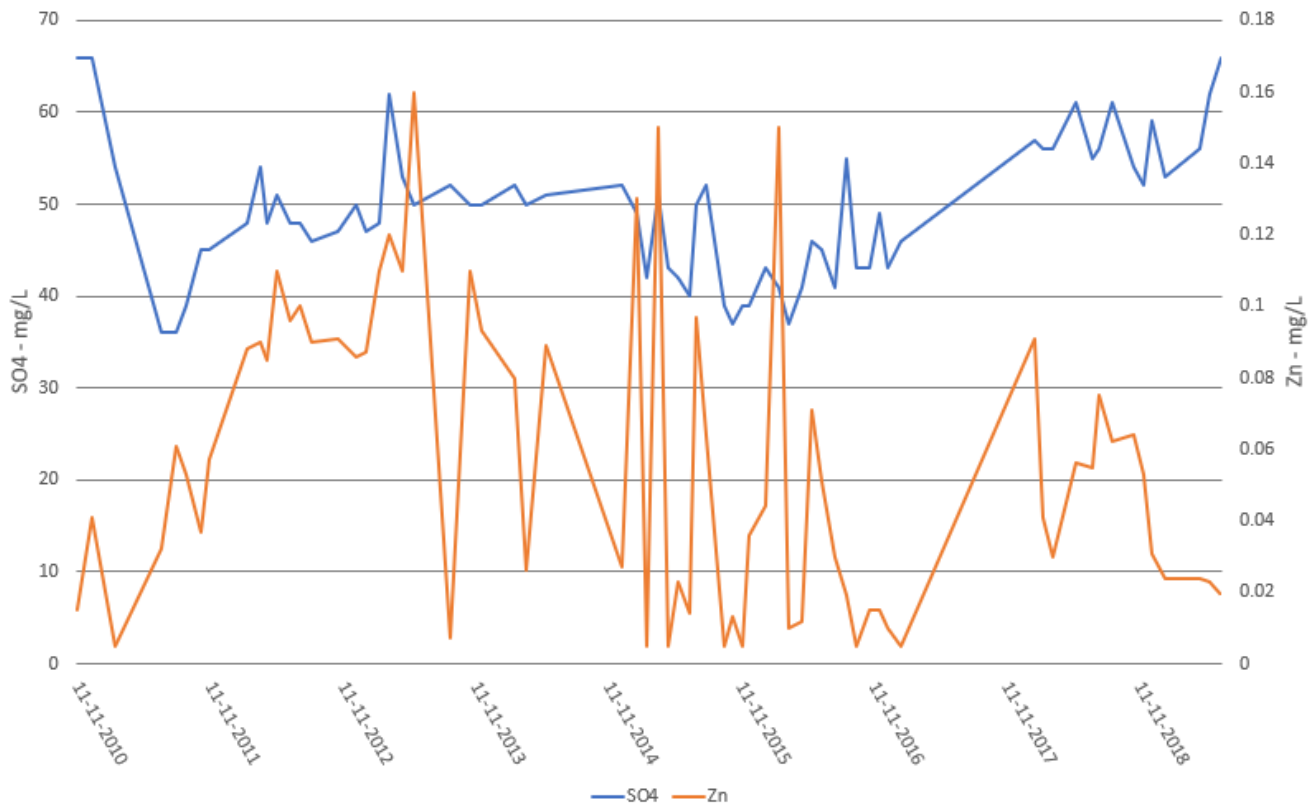


Figure 116 Development of sulfate (mg/L) and zinc (mg/L) at W45B2

9.3.7 W45B3

Bore W45B3 has seen a steady decline in groundwater levels by about 10m since 2010. Corresponding to the decline in groundwater level, the EC doubled from about 800 μ S/cm to about 1,600 μ S/cm (**Figure 117**), sulfate concentrations increased from 50mg/L to about 300mg/L and zinc increased from 0mg/L to more than 0.35 mg/L (**Figure 118**). The almost linear nature of the increases in EC, sulfate and zinc could suggest that an external upgradient source may be the reason for the increases. Considering the dewatering induced hydrogeochemical changes of groundwater at V1 highlights that possibility.

Alternatively, the strata at W45B3 might be strongly or continuously mineralised with depth. Hence, as the groundwater level decreases, more mineralisation becomes exposed and oxidised, increasing sulfate and zinc concentrations in the groundwater column. As previously mentioned, increases in EC, sulfate and metals in W45B3 are not a sign seepage from the West 45 underground workings, but rather a sign of groundwater migrating towards the cone of depression.

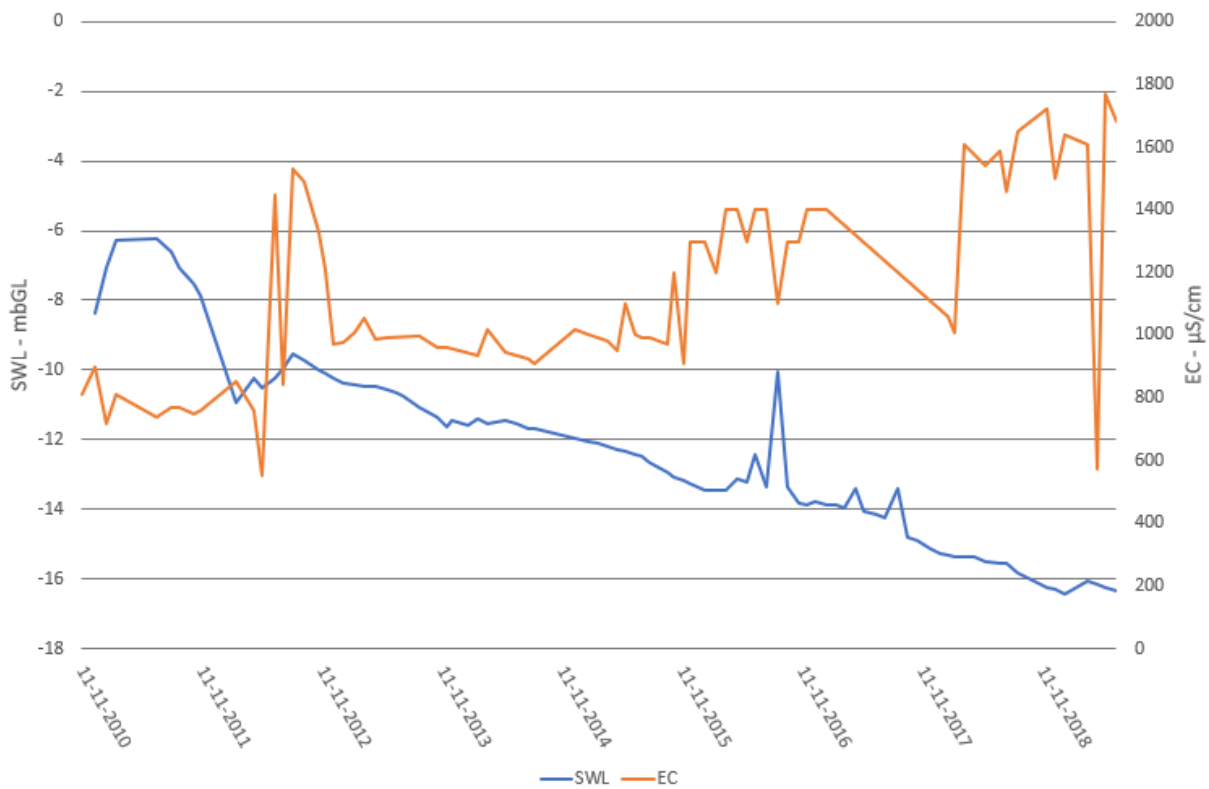


Figure 117 SWL (m bGL) and EC (µS/cm) development at W45B3

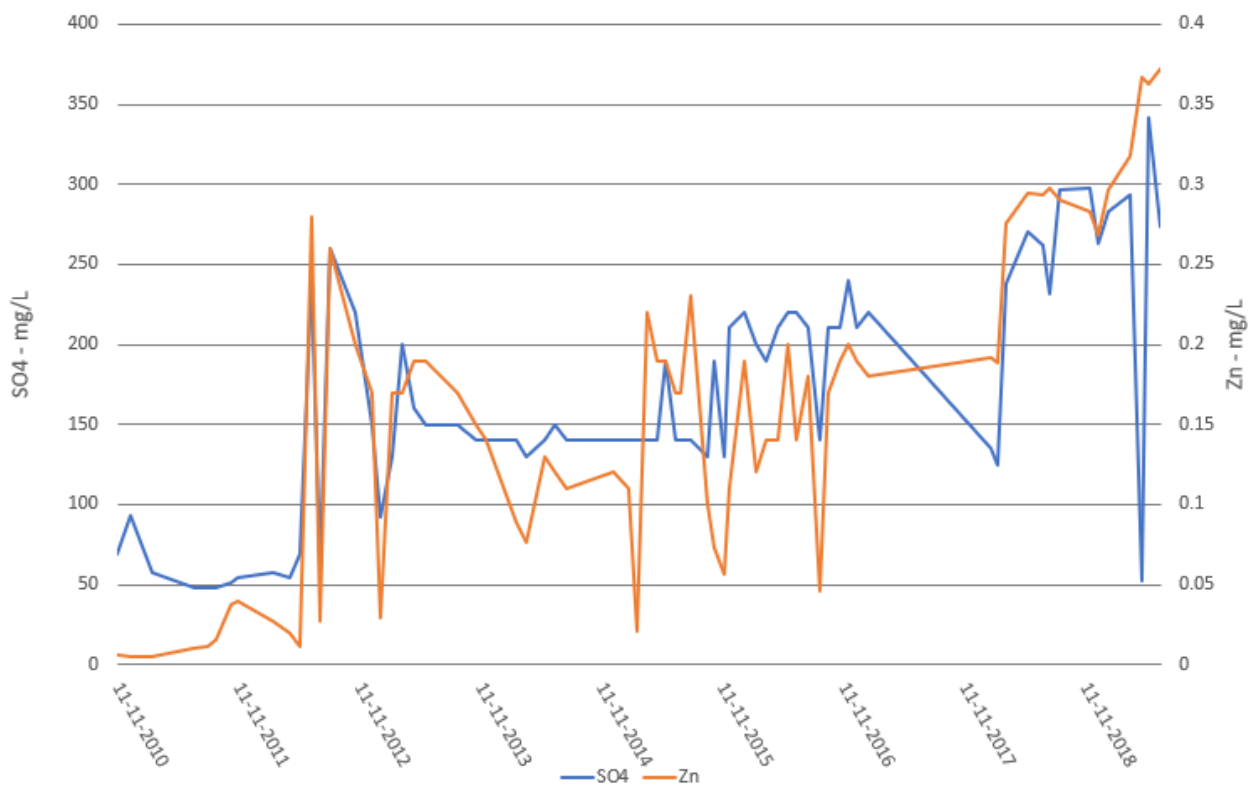


Figure 118 Sulfate (mg/L) and zinc (mg/L) development at W45B3

9.3.8 W45B4

Bore W45B4, located furthest from the West 45 underground mine experienced until recently only minor changes in groundwater levels and chemistry during the West 45 dewatering. Changes only commenced with the onset of the Far West dewatering in 2017 (**Figure 119** and **Figure 120**). Considering that the bore is only metres from the initial Far West decline, dewatering would result in disturbance. Bearing in mind that the underground has been backfilled with tailings and process water, disturbance will result in groundwater movement and likely mobilise contaminants along the flow path. Like the other West 45 monitoring bores, increases in potential contaminants does not constitute a seepage event. To the contrary, changes induced by dewatering are due to flow towards the pumping point in the centre of the cone of depression.

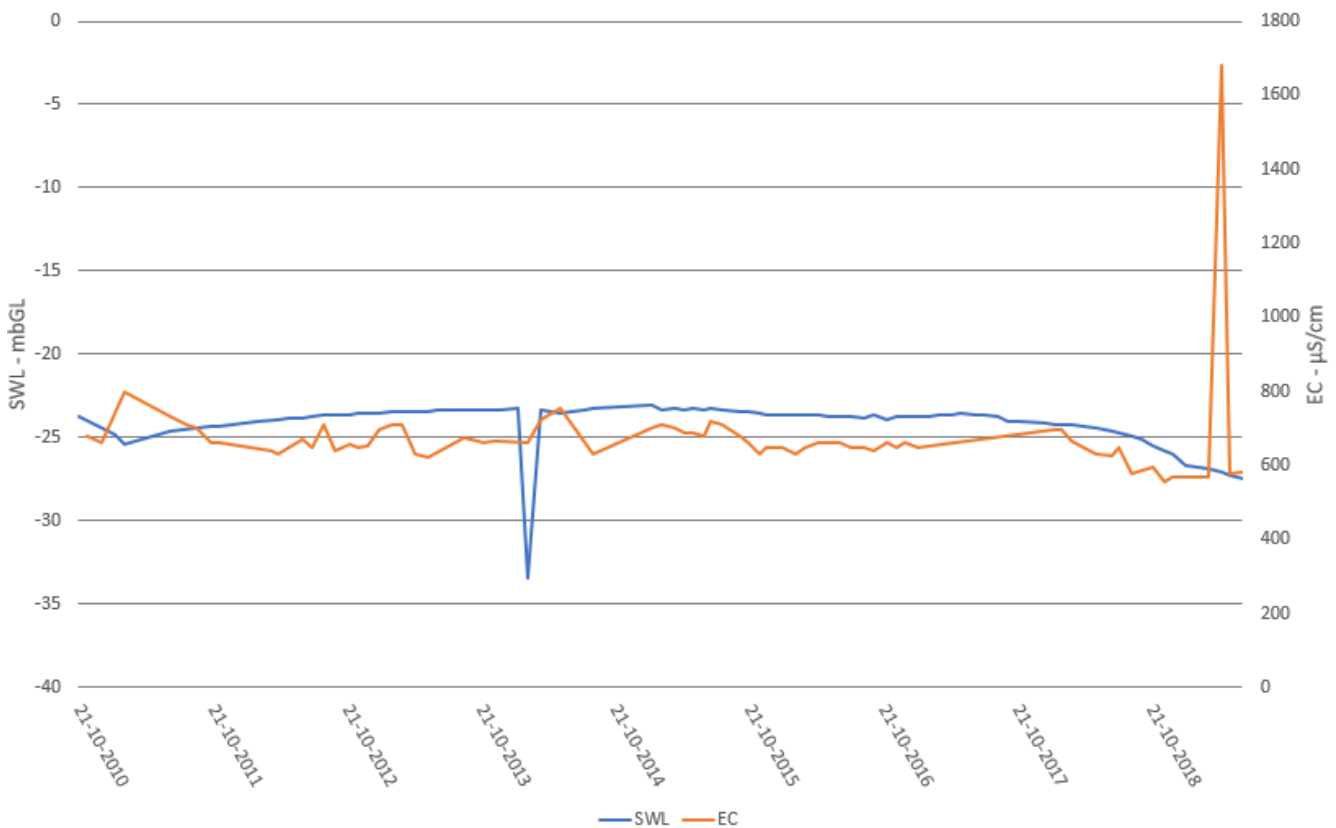


Figure 119 SWL (m bGL) and EC (µS/cm) development at W45B4

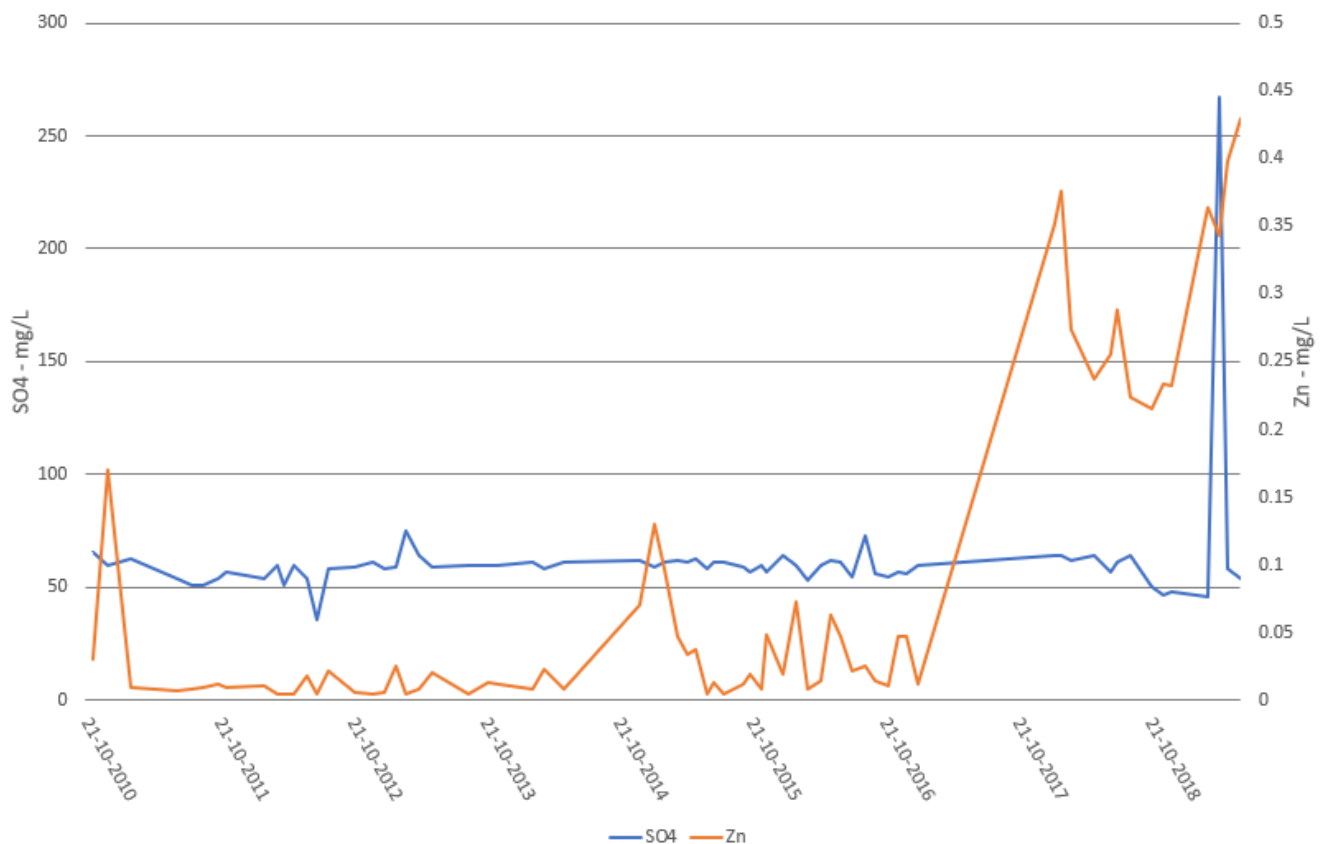


Figure 120 Sulfate (mg/L) and zinc (mg/L) development at W45B4

9.3.9 Far West bores

As an addition to the West 45 bores, 5 supplementary deep bores were installed during 2017/2018 to monitor the impacts of the Far West dewatering on potentially surrounding aquifers (**Figure 14 in Appendix C**). Contrary to the West 45 bores, the Far West bores were not intended to monitor the draw-down within the deposit, but rather focus on the impacts of the dewatering on the unmineralized surrounding rock. Bores FWMB1 to FWMB3 were constructed to a depth of 100m with water being allowed to enter the casing between 32m and 51.5m depth. Bores FWMB4 and FWMB5 were constructed to 50m with water being allowed to enter between 17m and 29m respectively. The groundwater level results for all Far West bores (with the exception of FWMB2, which is located close to bore V1) suggest that the bores are generally not impacted by the dewatering efforts of the Far West deposit (**Figure 121**). Similarly, hydrogeochemical changes are not observed. Yet, the groundwater composition of the five Far West bores differs greatly.

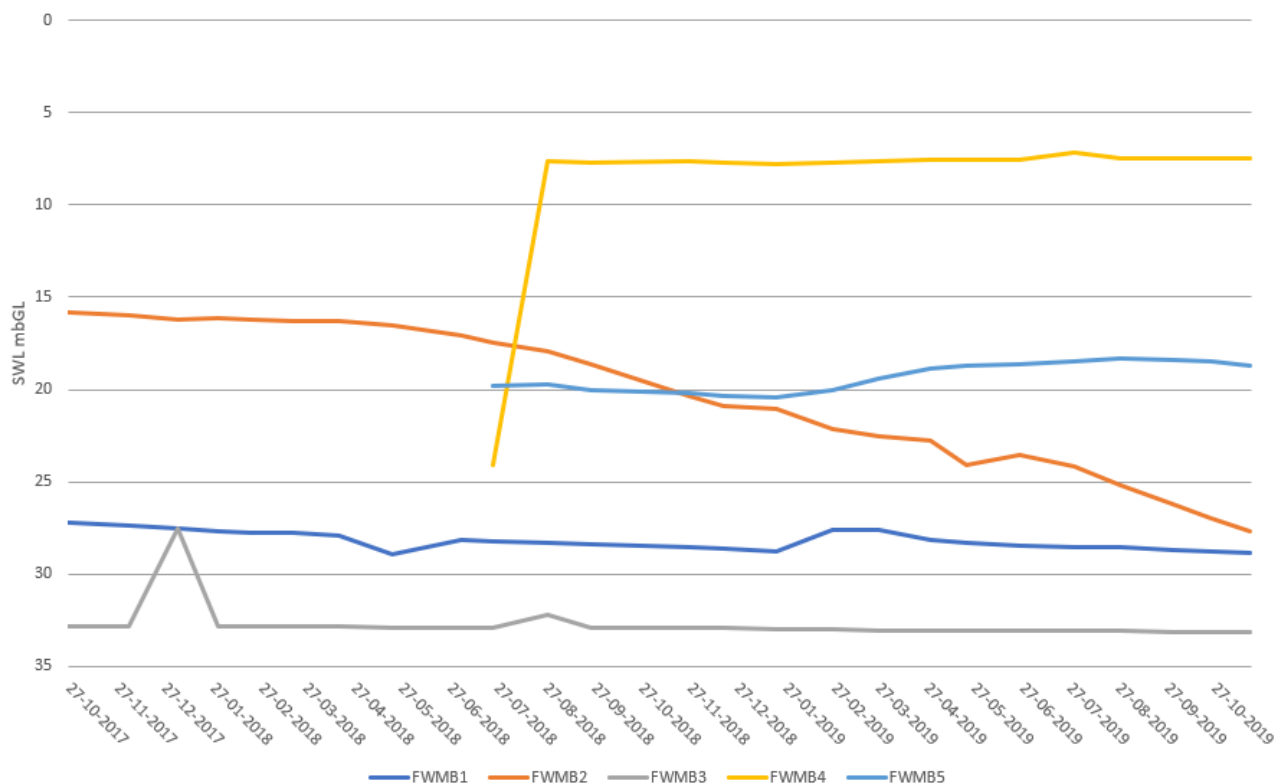


Figure 121 Groundwater level behaviour (m bGL) of the Far West monitoring bores since installation to July 2019

9.3.10 FWMB1 and FWMB3

Bores FWMB1 and FWMB3 display low sulfate (<25mg/L) and chloride (<300mg/L) concentrations. Based on the low sulfate concentrations it can be concluded that FWMB1 and FWMB3 are not impacted by the mining operations at Thalanga.

9.3.11 FWMB2

FWMB2 is located about 120m north of V1. Bore V1 has previously been identified as being impacted by the dewatering of the Far West deposit (refer to **8.4.1**). Yet, during the short period of monitoring, FWMB2 did not experience significant changes in groundwater composition (**Figure 122**, **Figure 123** and **Figure 124**). The groundwater composition at FWMB2 is comparable to the last measurements recorded from V1 before the bore went dry (**Table 14**).

Table 14 Comparison of EC (µS/cm) , sulfate (mg/L), calcium (mg/L) and magnesium (mg/L) from FWMB3 and average from the last three measurements at V1

	EC	SO4	Ca	Mg
Average last 3 measurements from V1	5,886 µS/cm	454 mg/L	264 mg/L	235 mg/L
Average FWMB2 since January 2018	6,330 µS/cm	323 mg/L	277 mg/L	242 mg/L

The similarity between groundwater from FWMB2 and the last measurements from V1 seems to confirm the previous conclusion (refer to **8.4.1**) that groundwater composition at V1 was transiently influenced by “natural” groundwater entering the bore from the north. Additional support comes from the fact that initial EC measurements during bore drilling and in the first few months after, recorded EC values which are closer to seepage from the TSF (see **8.4.1**). Reason for the initially higher EC is likely the diffuse nature of seepage from the TSF (Section **9.3.3.9**). Capillary action could have resulted in TSF seepage being present at FWMB2; however, due to low hydraulic conductivity of the seepage impacted layer, recharge to the bore is slower than recharge by “natural” groundwater. Hence, the EC of about 6,000 μ S/cm and sulfate around 300mg/L is likely to represent the remnants of underground backfill in the natural groundwater in the area.

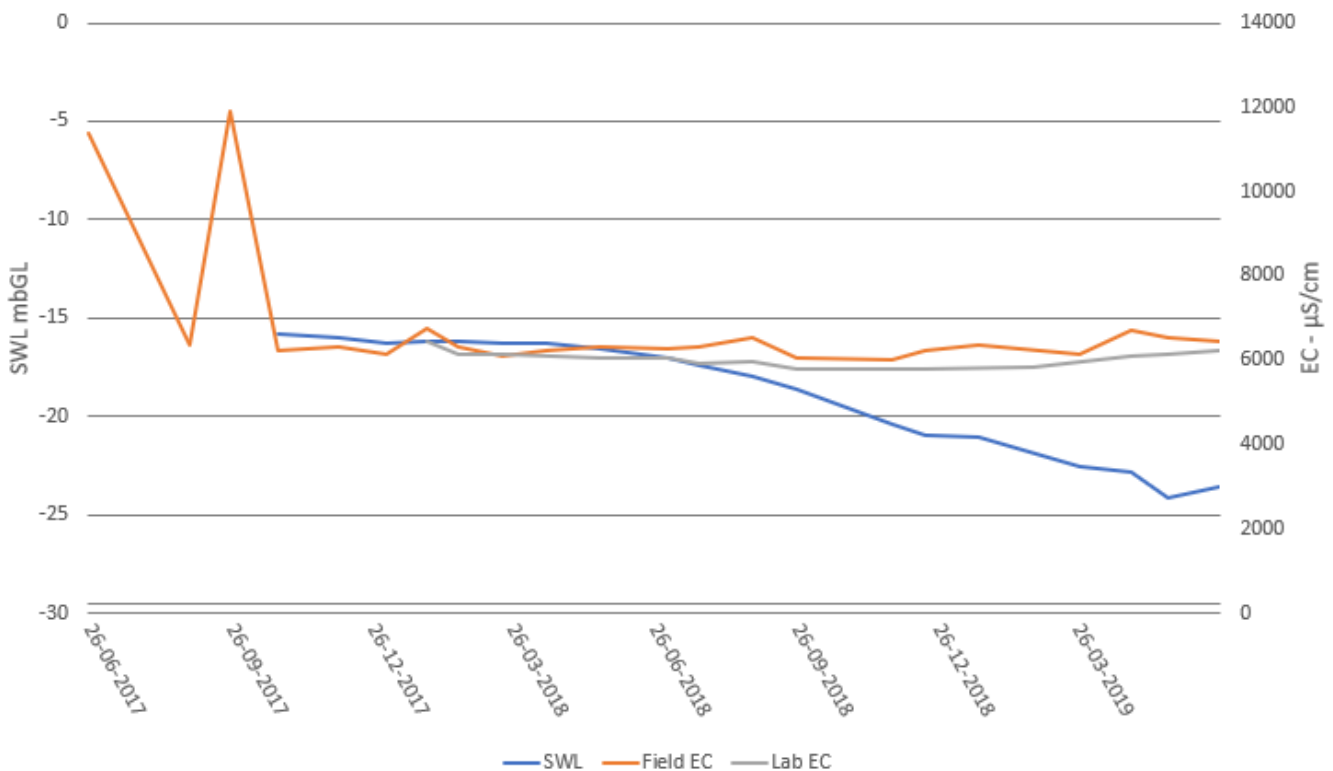


Figure 122 Development of SWL (m bGL), Field EC (μ S/cm) and Laboratory EC (μ S/cm) at FWMB2 since installation in 2017

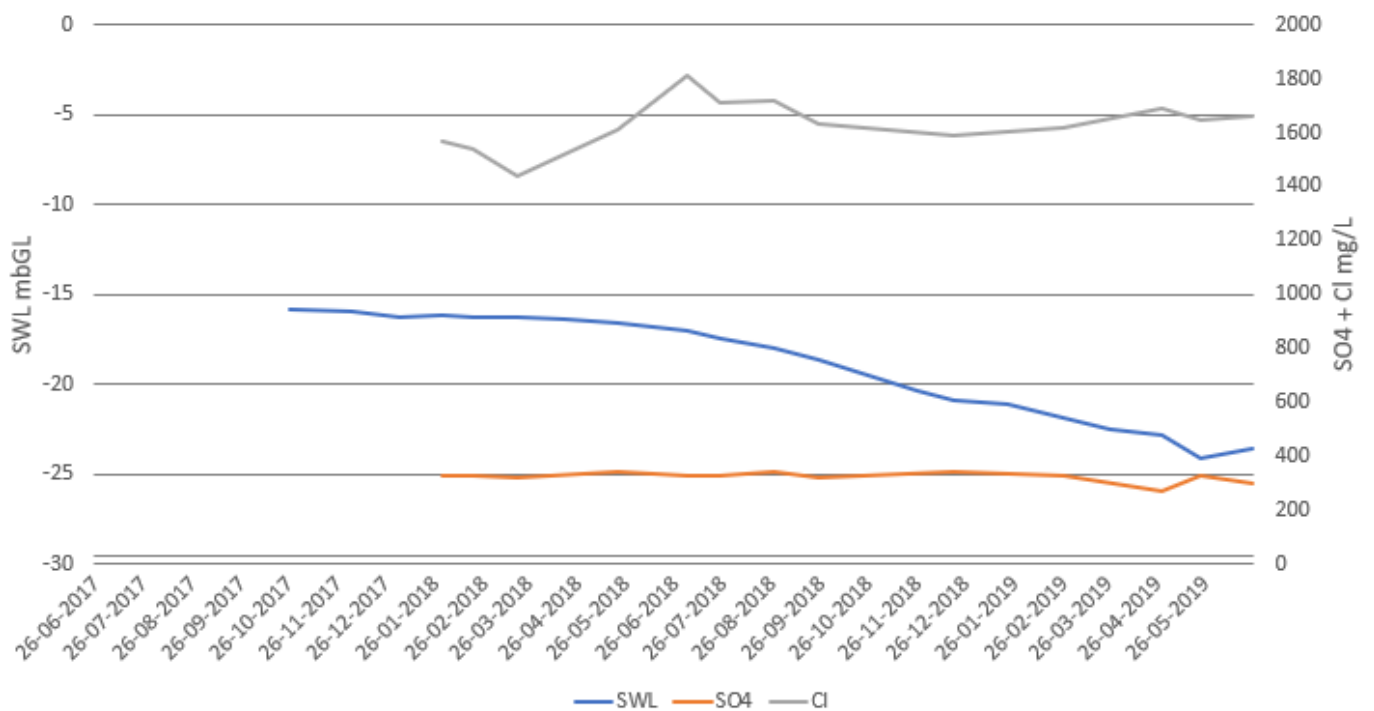


Figure 123 Development of SWL (m bGL), sulfate (mg/L) and chloride (mg/L) at FWMB2 since installation in 2017

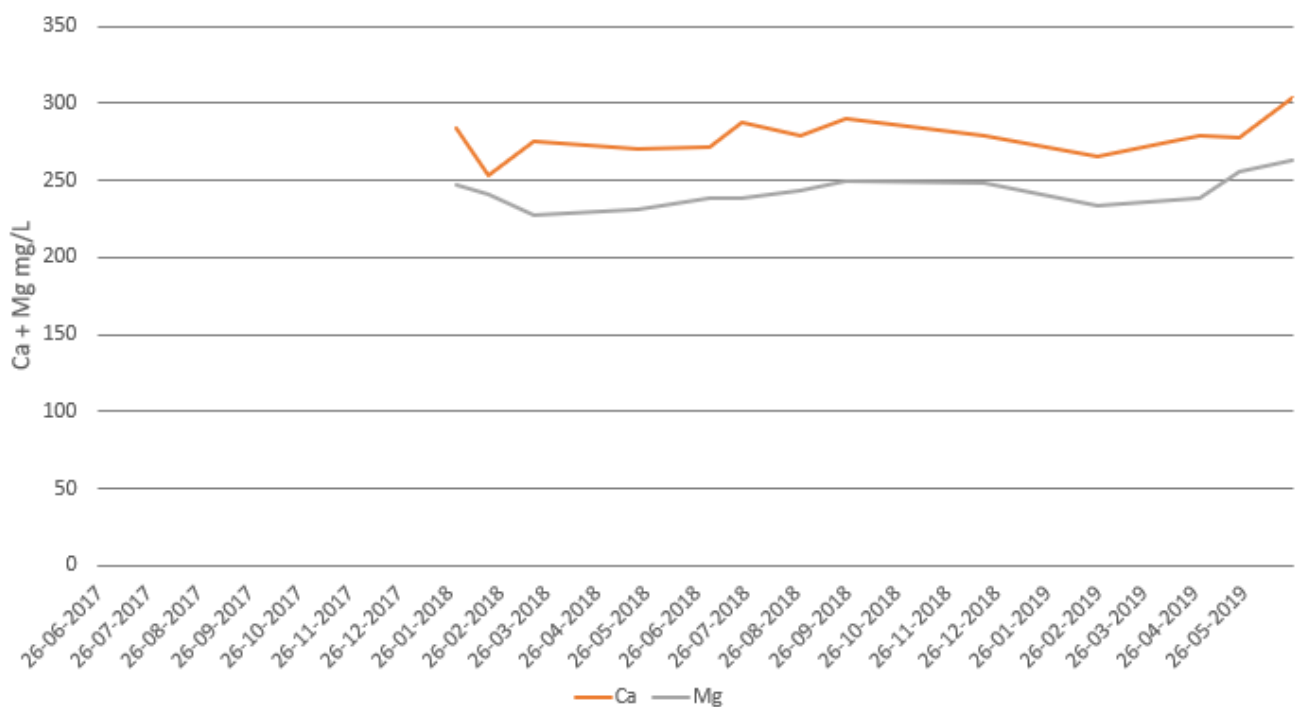


Figure 124 Development of calcium (mg/L) and magnesium (mg/L) at FWMB2 since 2018

9.3.12 FWMB4

The short groundwater chemistry record from FWMB4 shows high EC ($\sim 13,000 \mu\text{S}/\text{cm}$) (Figure 125), moderately high sulfate ($\sim 900 \text{mg}/\text{L}$) combined with high chloride ($\sim 4,000 \text{mg}/\text{L}$) (Figure 126). Noticeable water inflow into the bore during drilling occurred first from a relatively shallow depths of 19 m and initial EC during drilling recorded about $13,000 \mu\text{S}/\text{cm}$ and subsequent measurements continue to show these high EC values. Following the scenario for V1 and FWMB2, groundwater at FWMB4 appears to be impacted by TSF seepage. Compared to

TSF monitoring bores A3 (

Figure 55) and TH4 (Figure 60) groundwater at FWMB4 has a very similar EC but lower sulfate concentrations. As discussed earlier (Sections 9.3.3.9.1 and 9.3.3.9.2) retention along the groundwater flow path could reduce groundwater concentrations. One additional factor will be the relatively shallow depth of the groundwater table at FWMB4. Capillary action combined with greater evapotranspiration effects due to the shallow groundwater tables will promote greater groundwater solute concentrations.

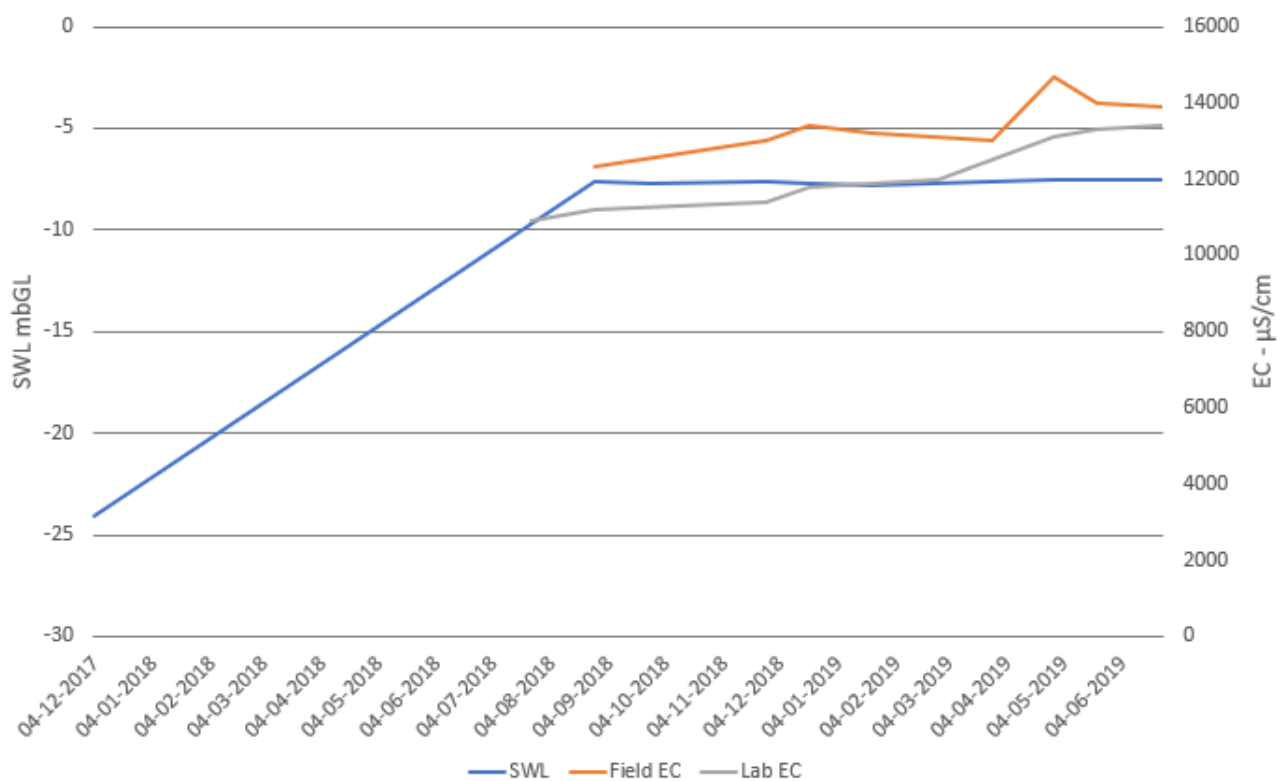


Figure 125 Development of SWL (m bGL), Field EC ($\mu\text{S}/\text{cm}$) and Laboratory EC ($\mu\text{S}/\text{cm}$) at FWMB4 since installation in 2017

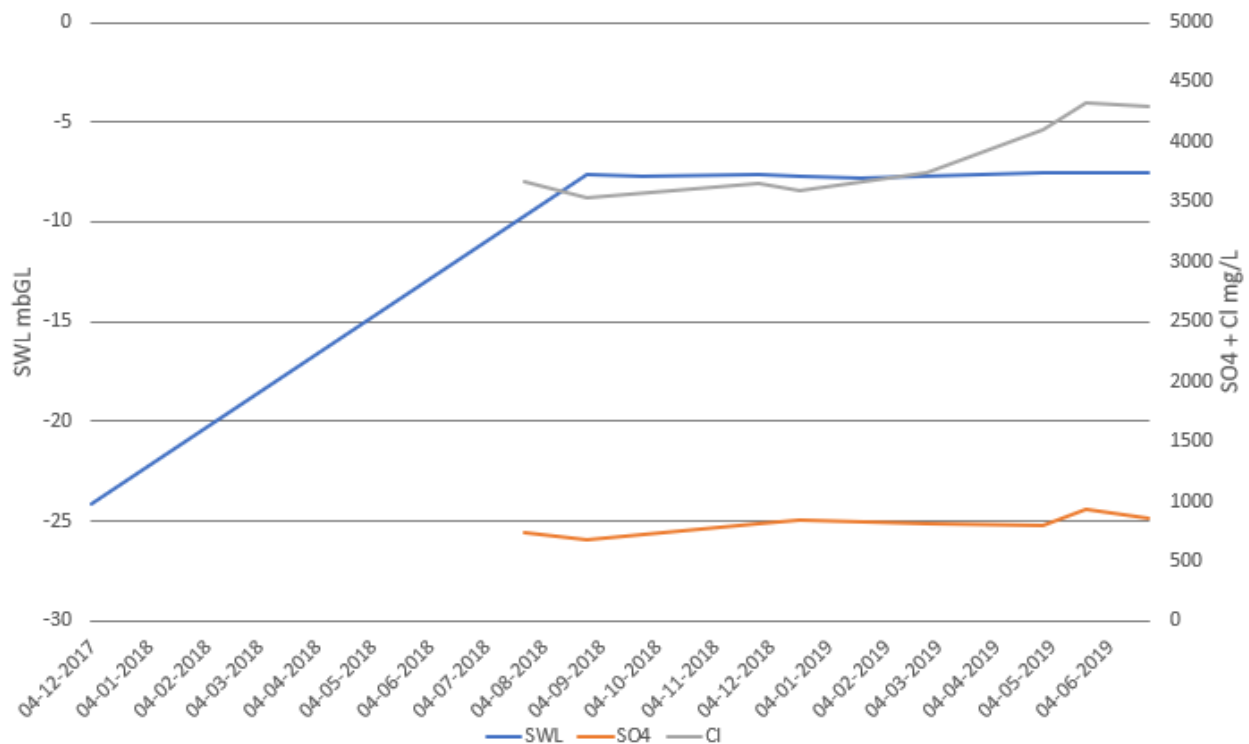


Figure 126 Development of SWL (m bGL), sulfate (mg/L) and chloride (mg/L) at FWMB4 since installation in 2017

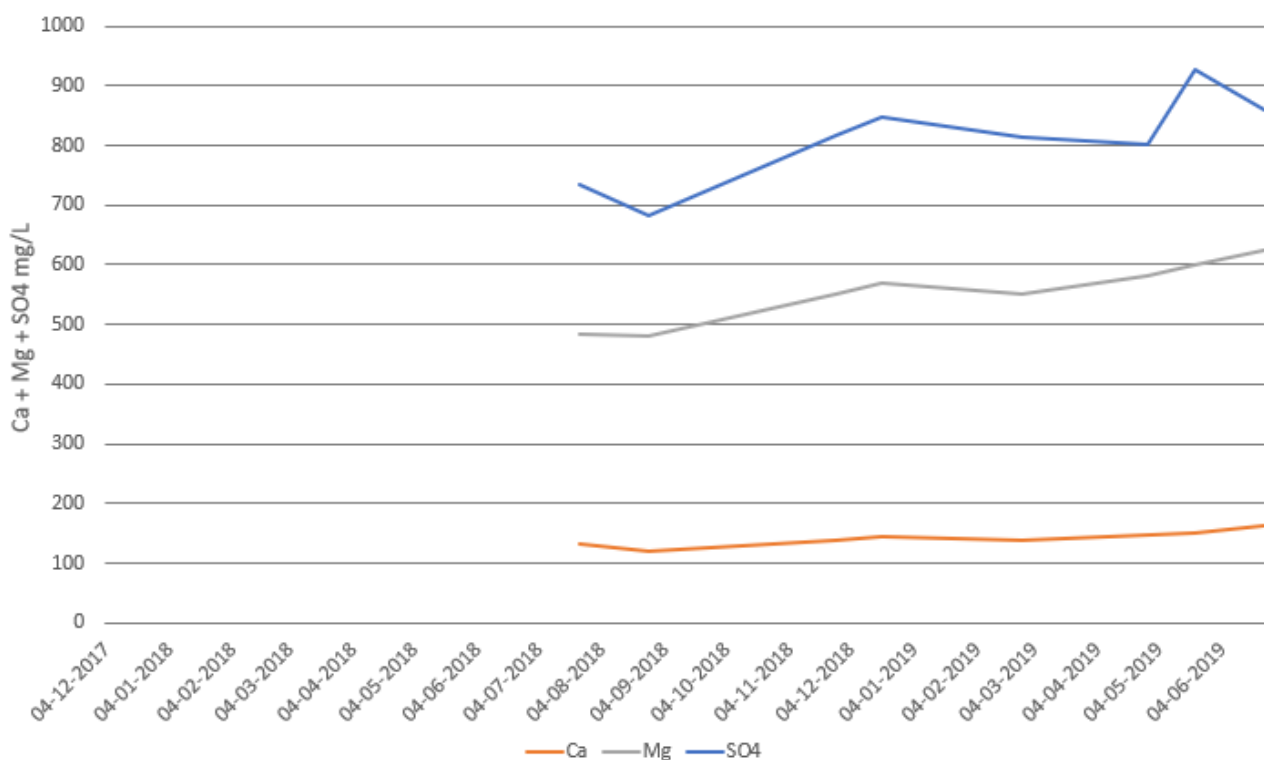


Figure 127 Development of calcium (mg/L), magnesium (mg/L) and sulfate (mg/L) at FWMB4 since 2018

9.3.13 FWMB5

Bore FWMB5 has been drilled to 50 m, with first groundwater intercept at 30m. The bore is located about 100m to the west of the “Wetland” area, which previously was the location of the acid generating Western WRD – in 1998 relocated into the Central Thalanga Pit. FWMB5 exhibits high EC and sulphate concentrations similar to FWMB4 and FWMB2; however, due to the distance and separation by the ore body, FWMB5 is unlikely to be impacted by TSF seepage. FWMB5 also does not appear to be impacted by the underground tailings backfill. Despite the underground being actively dewatered during the short groundwater monitoring period at FWMB5, groundwater levels at the bore increased by 1.2 m between January and April 2019 (**Figure 128**). The increase likely associated with the significant rainfall event that occurred in February 2019. Slightly delayed to the water level increase occurred an increase in zinc, copper and chloride, while sulfate concentrations decreased (**Figure 128**). Zinc and copper concentrations at FWMB5 have been significantly higher than at the other Far West monitoring bores (**Figure 129** and **Figure 130**). The reason for the higher zinc and copper concentrations is likely the slightly lower pH of the groundwater at FWMB5 (**Figure 131**). The lower pH possibly being a legacy issue associated with the former acid generating western WRD. Despite the Western WRD having been removed into the open pit, secondary acid generating salts (AGS), the solid manifestation of acid mine drainage, may be persistent in the strata below or around the waste rock dump footprint. Upon hydration, these AGS will convert back into acid, potentially releasing metals into the groundwater.

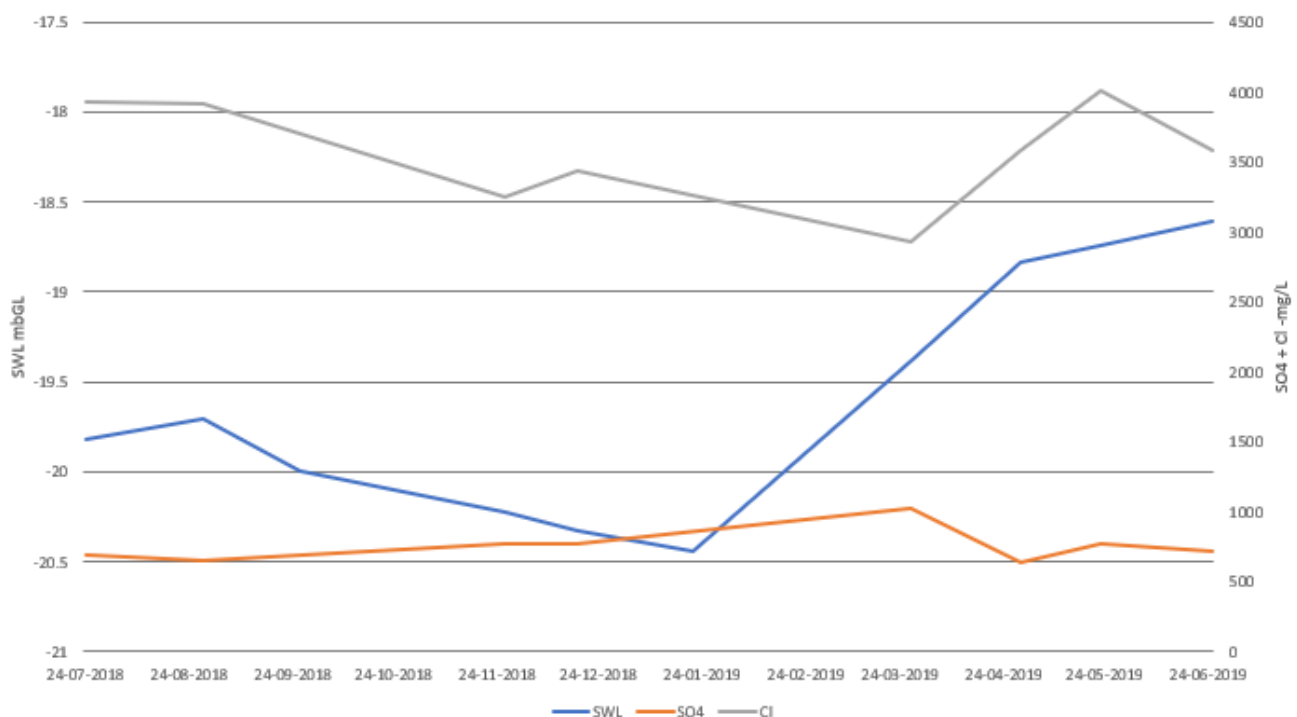


Figure 128 Development of SWL, chloride and sulfate at FWMB5 between July 2018 and June 2019

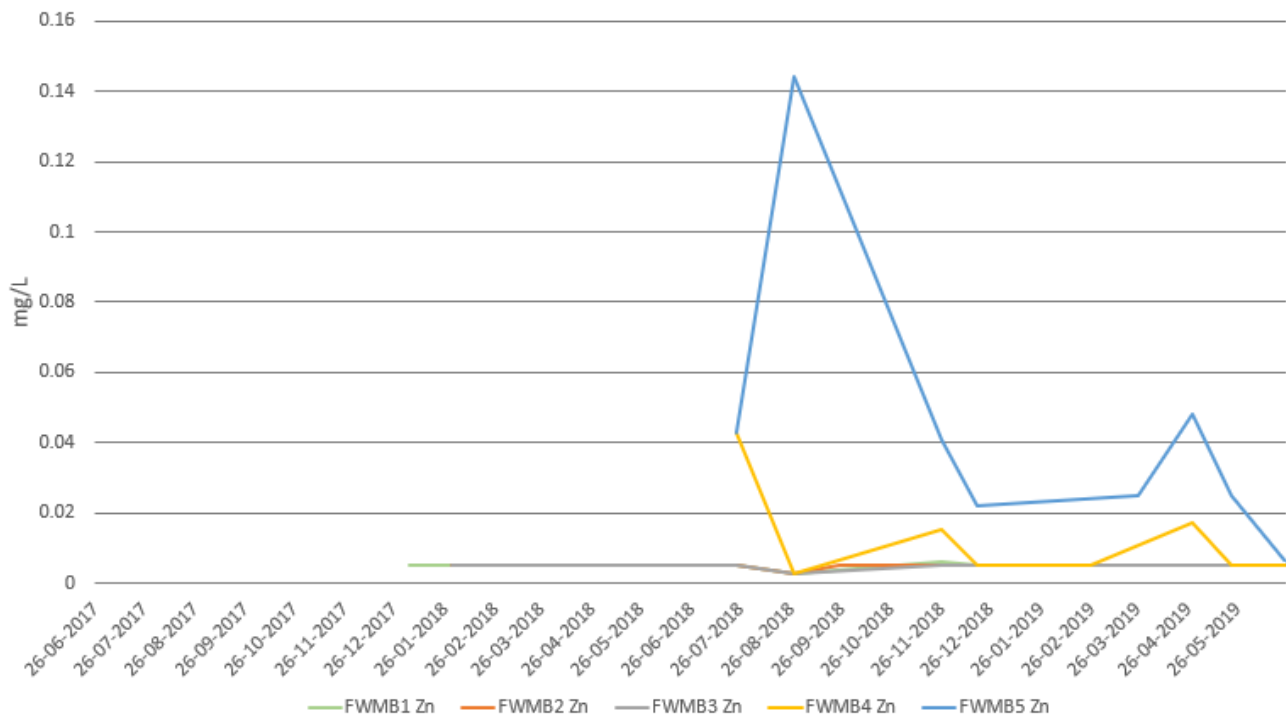


Figure 129 Development of dissolved zinc concentrations (mg/L) in the Far West monitoring bores

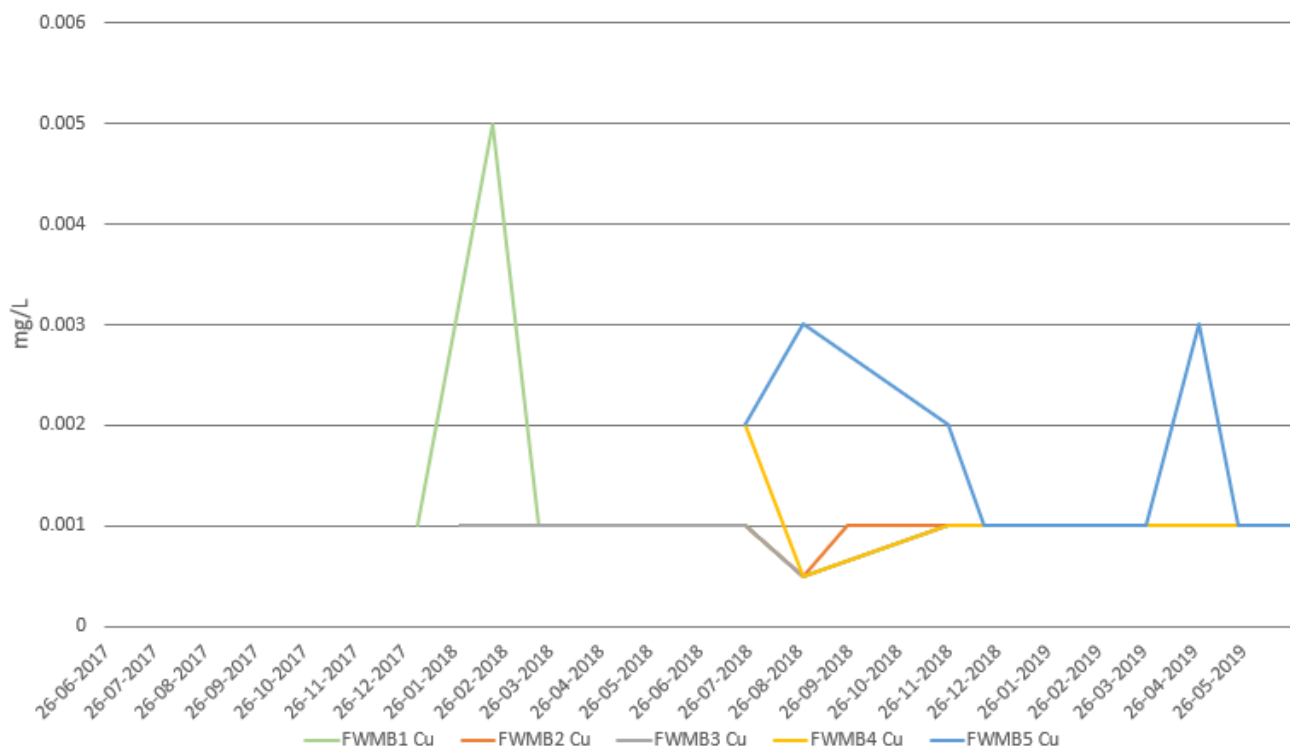


Figure 130 Development of dissolved copper concentrations (mg/L) in the Far West monitoring bores

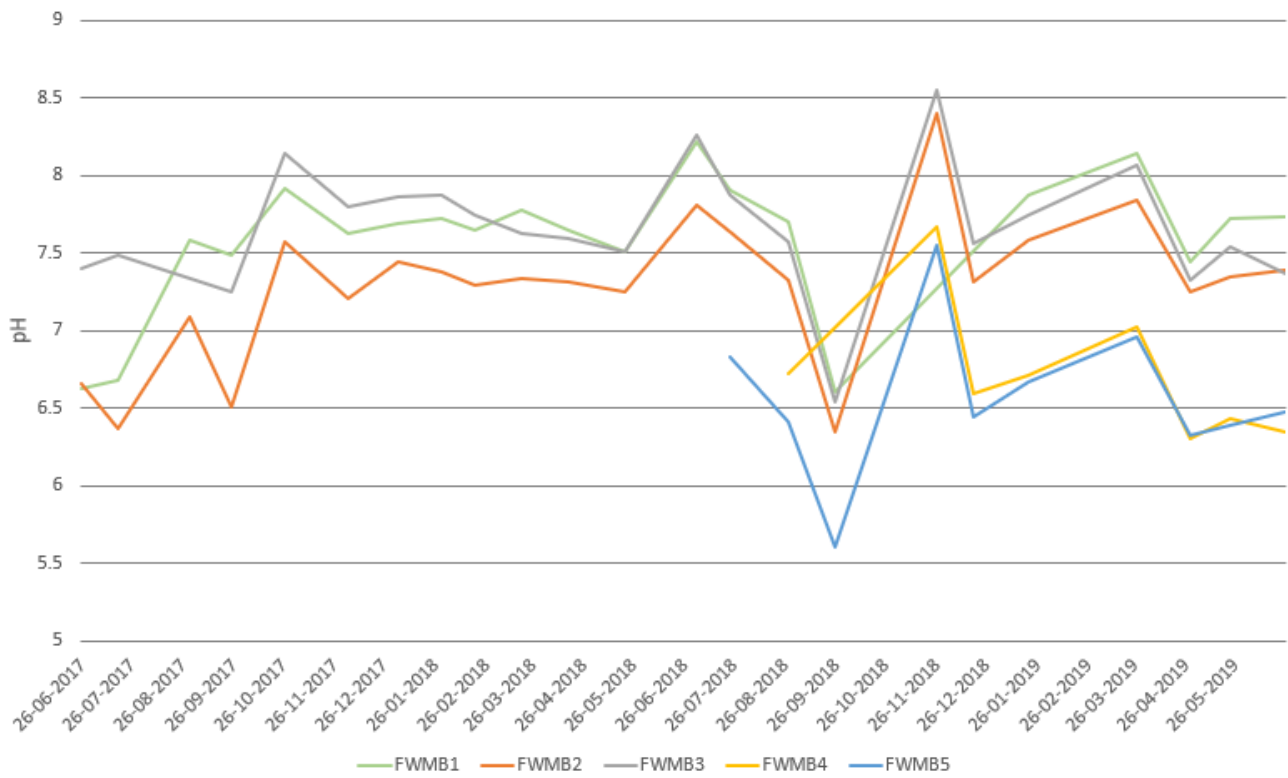


Figure 131 Development of Field pH in the Far West monitoring bores

10 Summary of groundwater contamination issues and remediation options

Due to the extended time of mining operations at Thalanga and the induced hydrogeological changes, the impacts of seepage at the site have varied over time. The changes in groundwater levels associated with the dewatering and backfilling of the underground workings in particular, have produced temporal reversals of groundwater flow gradients within the bedrock environment, the weathered material above.

10.1 Tailings dams

The operation of tailings dams generally had a greater influence on shallow aquifer sections. The shift of tailings deposition towards the east of the TSF and the care and maintenance period between 2012 and 2016 had some impact on the groundwater chemistry and groundwater levels. For example periods of no tailings deposition during the care and maintenance period resulted in some reduction in groundwater levels in bores A3 and TH4 but not in TH5 (

Figure 62). The hydrogeochemical situation, particularly metal concentrations, at TH4 as compared to A3 and TH5 (**Section 9.3.3.6**) highlights the two primary mechanisms of seepage movement:

- Movement dominated by capillary action.
- Movement facilitated by fractured rock.

Groundwater movement primarily through capillary action (bore TH5) involves significant contact between the fluid and the aquifer strata. The shallow strata around the Thalanga TSF consist of clays and oxidised materials. Besides clay having a low hydraulic conductivity, both materials have substantial cation exchange capacities. Low hydraulic conductivity combined with the high cation exchange capacity results in the reduction of metal cations (Cd, Cu, Pb, Zn) along the groundwater flow path.

In comparison, groundwater movement facilitated by fractured rock (bores A3 and TH4) occurs at a higher velocity. At the same time the surface area along the flow path is significantly smaller. Combined with the higher velocity and smaller surface areas, these factors result in a significant reduction of contact between the fluid and aquifer material. As a result of the shorter contact times, metal cations (Cd, Cu, Pb, Zn) can remain in solution.

The recent installation of bores A1 and A4 highlights the different aspects of seepage by capillary action. Upon drilling, bore A4 appeared essentially dry while A1 made some water (too small to measure) from very fractured rhyolite at 21m. Prior to reaching full depth (A1-23m and A4-31m), both bores were drilled through 13m to 15m of clay and 4m to 8m of weathered clayey rock. Assuming the TSF as being the source of subsequently measured EC and sulfate concentrations, seepage migration must be through the thick clay layer.

10.2 Underground

The underground workings at Thalanga have undergone a series of hydrogeological changes over the last 30 years, the impact of which are largely restricted to the extends of the ore body, areas connected via underground workings and exploration holes. The exemption may be the induced period of extremely high groundwater tables peaking during 2008 (**Section 9.3.4** and

Figure 76). At the same time, or shortly after these levels peaked, small groundwater chemistry changes were observed in the Campaspe Channel Bores (**Section 9.3.5**) and within the Campaspe Formation itself (**Section 9.3.2**). Considering a potential connection between the underground and the Campaspe Formation, high groundwater levels within the underground must be avoided. At a minimum, groundwater levels within the underground should not be artificially elevated above levels which would encourage flow into the Campaspe Formation. As the depth of the Campaspe Formation varies across the site, the deepest known extent should be applied as the upper groundwater level limit within the ore deposit corridor.

Seepage migration towards the cones of depression caused by the dewatering of the West 45 and Far West deposits resulted in a reversal of groundwater flow directions, most evident with reference to bore V1. The reverse groundwater flow rates introduced by the dewatering are significantly higher than the previous flows introduced by higher site groundwater levels in the underground. For example, the disposal of tailings and process water to the underground increased groundwater levels at V1 by about 25m. The renewed and ongoing dewatering resulted in a subsequent draw down of at least 40m. Hence, the reversal of gradients resulted in greater groundwater flow rates towards the underground workings. With regards to potential contaminant migration, the dewatering and a reversal of groundwater gradients towards the underground is seen as being beneficial in reducing the potential for environmental impact.

From a remediation point of view, the installation of FWMB1 and FWMB3 suggests that there has been no impact on the surrounding natural hard rock groundwater composition outside of the influence of the deposit. Nevertheless, the tailings backfill monitoring bores V1 to V7 and site-wide high water levels during 2008 demonstrate that where the strata associated with the deposit and underground workings has been intersected by drilling, the groundwater impact may migrate, especially if groundwater levels within the underground are artificially elevated. Hence, as mining of the West 45 and Far west deposit at Thalanga concludes, natural flooding of the underground by groundwater should not be accelerated by additional fluid back fill. Natural flooding of the western section of the Thalanga Underground was estimated in 1998 to occur at a rate of about 0.2L/s or about 17m³/day.

Pre-mining groundwater levels were assumed to have been between 20m and 40mbGL and it was calculated that the previous West Workings would take about 50 years to flood (URS, 2002). Once flooding of the underground will reach pre-mining natural groundwater levels, groundwater flow towards the underground will stop. With groundwater levels on the mine site ultimately being in equilibrium with its surroundings groundwater flow gradient will return to pre mining conditions. The bedrock outcrop in the western section of the mining lease will remain the main natural recharge area resulting in seasonally fluctuation in groundwater levels across the site. Contaminant migration will continue to be mitigated by clay and iron oxide/hydroxides along the groundwater flow path, as some form of contaminant retention is evident from the groundwater composition of most bores at Thalanga. However, due to the reduced head conditions, future natural groundwater flow will be considerably slower than experienced during site operation. Hence, contaminant transport from the naturally flooded underground in the future will likely not cause an impact on the surrounding groundwater.

11 Solute transport model

Solute transport models are used to simulate the transport of dissolved constituents in groundwater and predict its impact to the surrounding environment. The potential for mine site contaminants to migrate into the surrounding groundwater environment is governed by hydrogeological factors and geochemical nature of the seepage and the strata along the flow path. Hydrogeological factors include:

- the hydraulic conductivity of the strata; and
- the hydraulic gradient

Combined with ground porosity, distance and cross-sectional area produces groundwater velocity and groundwater flow rate.

The geochemical nature of the seepage and the strata along the flow path involves

- the nature of the contaminants; and
- the mineralogical and geochemical nature of the strata.

The hydraulic conductivity and the impact of the evolving hydraulic gradients has been discussed in **Section 8** of this report. Hydraulic gradients can be calculated by using RL water levels of the potential source areas and groundwater RL levels along the potential groundwater flow path. The hydrogeochemical changes of the groundwater composition can be assessed following the hydraulic gradients, the initial source composition and the groundwater chemistry measured in the downgradient bores. The two main source areas identified in **Section 10** are the TSF area and the underground workings.

11.1 Hydrogeological factors

11.1.1 Hydraulic conductivity values

Table 15 lists the minimum and maximum observed hydraulic conductivities (K min and K max respectively) for the relevant strata.

Table 15 Hydraulic properties used for models

• Strata	• Depth (m)	• K min (m/day)	• K max (m/day)
Deep bedrock	35 – 100	0.0029	0.0221
Bedrock	17 – 30	0.000343	0.122
Weathered bedrock section	2 – 6	0.000125	0.00055
Campaspe Formation	1 – 2	0.0035	0.00675
Surficial strata	0 – 1	0.02	0.075

11.1.2 Hydraulic gradients

To calculate groundwater gradients around the TSF and the underground the following water level locations have been grouped into individual models or transects (transect locations are included in as **Figure 21** in **Appendix C**. Calculated hydraulic gradients are shown in **Table 16**.

11.1.3 Groundwater velocity

Groundwater velocity can be used to assess the potential travel time of contaminants under saturated conditions (i.e. considering advection as the main transport process). Actual groundwater velocity along a hypothetical flow path can be estimated using the following (Fetter, 2001):

$$v_x = \frac{K}{n_e} \frac{dh}{dl}$$

where: v_x is the average linear velocity

n_e is the effective porosity (dimensionless)

dh hydraulic head difference

dl distance between two locations

Assuming that:

Saturated conditions are present

The aquifer properties are homogenous

groundwater flow follows hydraulic gradient

effective porosity is 0.25 (25%) (assumed specifically for the above calculation)

11.1.4 Groundwater flow rate

To assess the potential seepage rates, the groundwater flow rate can be calculated using the following equation:

$$Q = KiA$$

where: Q is the flow rate

K is the hydraulic conductivity

i is equal to dh divided by dl

A is the cross-sectional area of assumed flow.

11.1.5 Hydrogeological conditions TSF

Model transects involving the TSF area included:

Model 1: TSF Cell 1-7, A2 and A1 (new).

Model 2: TSF Cell 1-7 and A1 (old).

Model 3: TSF Cell 1-7 and FWMB4.

Model 4: TSF Cell 1-7, FWMB2 and V1.

Model 5: TSF Cell 9 and TH4.

Model 6: TSF Cell 9 and TH5.

Model 7: TSF Cell 9, A3 and A4.

Groundwater levels within bores FWMB2, V1, TH4, TH5, A3, A4 and A1 have been calculated from surveyed bore heights and measured groundwater levels. Water levels (RL) within the capped TSF cells 1-7 have been estimated based on photographic evidence that shows free water approximately 1m below ground level in TSF cover investigation bores (NRA, 2018). The water level in TSF cell 9 has been estimated based on construction details (Kagara Plan of operations) and Queensland Government contour mapping (Queensland Globe).

Table 16 Hydraulic gradients used for models

• Model #	• Transect	• Hydraulic gradient
1	Cell 1-7 to A2 (old)	0.054
1	A2 (old) to A1 (new)	0.009
2	Cell 1-7 point to A1 (old)	0.127
3	Cell 1-7 point to FWMB4	0.049
4	Cell 1-7 point to FWMB2	0.060
4	FWMB2 to V1	0.119
5	Cell 9 point A to TH4	0.108
6	Cell 9 point B to TH5	0.166
7	Cell 9 point C to A3	0.055
7	A3 to A4	0.055
8	V1 to FWMB2	0.050
9	V6A to C2	0.009
9	C2 to M	0.011

11.1.6 Hydrogeological conditions Underground

Model transects involving the underground workings and tailings backfill included:

Model 8: Underground (V1) and FWMB2.

Model 9: V6A, C2 and M.

Groundwater levels in bores V1 and V6A have been shown to be closely related to water levels in the underground workings. Hence, it is reasonable to utilise groundwater levels in these bores as substitutes for the West underground (V1) and East underground V6A.

11.2 Geochemical and hydrogeochemical factors

As has been shown in the previous sections, changes in groundwater chemistry are strongly influenced by the hydrogeological nature of the strata. The strata of the TSF area is characterised by the presence of thick, low permeability, weathered rock and clay layers. This is reflected by relatively low hydraulic conductivities, which limit groundwater flow velocities. Groundwater associated with the historic underground workings may travel unrestricted through the created underground voids and unrehabilitated exploration holes. Migration away from these voids seems to be limited by the surrounding hard rock strata but may occur along a shallow flow path if groundwater levels are elevated.

At the generally encountered semi neutral groundwater pH, clays and iron oxide/hydroxides are the dominant sinks for cations, including copper lead, zinc and cadmium. The effects of these sinks on the seepage migration and groundwater chemistry has been demonstrated in **Section 9.3.3**.

11.2.1 Changes in groundwater chemistry along the flow path TSF

Tailings dam decant and groundwater chemistry has been available since 1989. As shown in the previous sections, changes in groundwater chemistry away from the source areas are evident mainly as increases in EC and sulfate concentrations. Dissolved metal concentrations are generally too low or too variable to be reliably associated. Hence, sulfate concentrations have been used as general indicator of potential contaminant migration rates. As has been demonstrated in **Section 9.3.3.8**, retention by the natural strata around the TSF is able to reduce metals and metalloids by two orders of magnitude within 120m between the TSF and TH4. Further metal and metalloid migration away from TH4 would continue along a) a lower gradient; and b) a less impacted flow path. Both these factors should result in a virtual halt of metal and metalloid migration downgradient of TH4. Due to the demonstrated retention of metals and metalloids, sulfate, due to its overall greater concentration, is the only chemical indicator for the determination of contaminant migration rates around the TSF area.

11.2.2 Changes in water chemistry along the flow path Underground

Water chemistry of the underground backfill monitoring bores has been recorded since 2003. The different characteristics of the bores have been discussed in **Section 9.3.4**. Due to the absence of direct measurements at the western section of the underground, Bore V1 has been deemed representative for this area, whereas bore V6A is thought representative of the East underground workings. Like the TSF monitoring bores, groundwater in V1 and V6A is generally low in metal and metalloid concentrations.

One must consider that the underground backfill monitoring bores were only installed in the vicinity, but not within the underground workings. Hence, low metal and metalloid concentrations are either the result of retention while the water travels to the bores, or more likely the result of retention and precipitation reactions since the underground was backfilled. Due to the acid generating nature of the volcanic massive sulphide (VMS) deposit, initial seepage into the freshly mined underground would have been acidic. Subsequent tailings backfill was alkaline, with final backfilling of process water possibly resulting in some additional mixing and dilution. Mixing of acid and alkaline fluids and subsequent dilution will provide the conditions for precipitation of metal and metalloids within the underground. Due to the likely retention and returning anoxic conditions, metals and metalloids are an unreliable indicator for contaminant migration rates from the underground workings.

At the same time, sulfate concentrations (like metals and metalloids) vary greatly over time. Therefore, due to unknown locations of tailings and process water discharge and the preferential flow paths through the mined underground, the additional interpretation of migration rates through the historic underground workings are not possible. Hence migration away from the underground relies solely on measurements from V1 and V6A.

11.3 Data compilation

To assess the actual contaminant migration rates in the groundwater around the Thalanga TSF all available sulfate data for tailings Cell 1-7, Cell 8 and Cell 9 and bores included in **Section 11.1.5** and **Section 11.1.6** was compiled, assessed for obvious errors and compared according to their stated association. Sulfate concentrations within the individual tailings cells and most bores (excluding V1 and V6A) were relatively stable within their respective ranges; therefore, in order to simplify the process of data comparison, sulfate concentrations for each model group were reduced to the 80th percentile (**Figure 132**).

11.4 Results

Each model is presented as cross-sections from

Figure 133 to Figure 141.

Calculations of groundwater velocity along assumed flow paths are provided beside each model cross-section in

Figure 133 to Figure 141. Elevations (mAHD) are shown as the y-axis in each cross-section. The modelled potentiometric surface is shown as dotted blue lines and assumed flow directions and flow paths are indicated by blue arrows. 80th percentile sulfate concentrations for each model group (**Figure 132**) are also presented cross-sections.

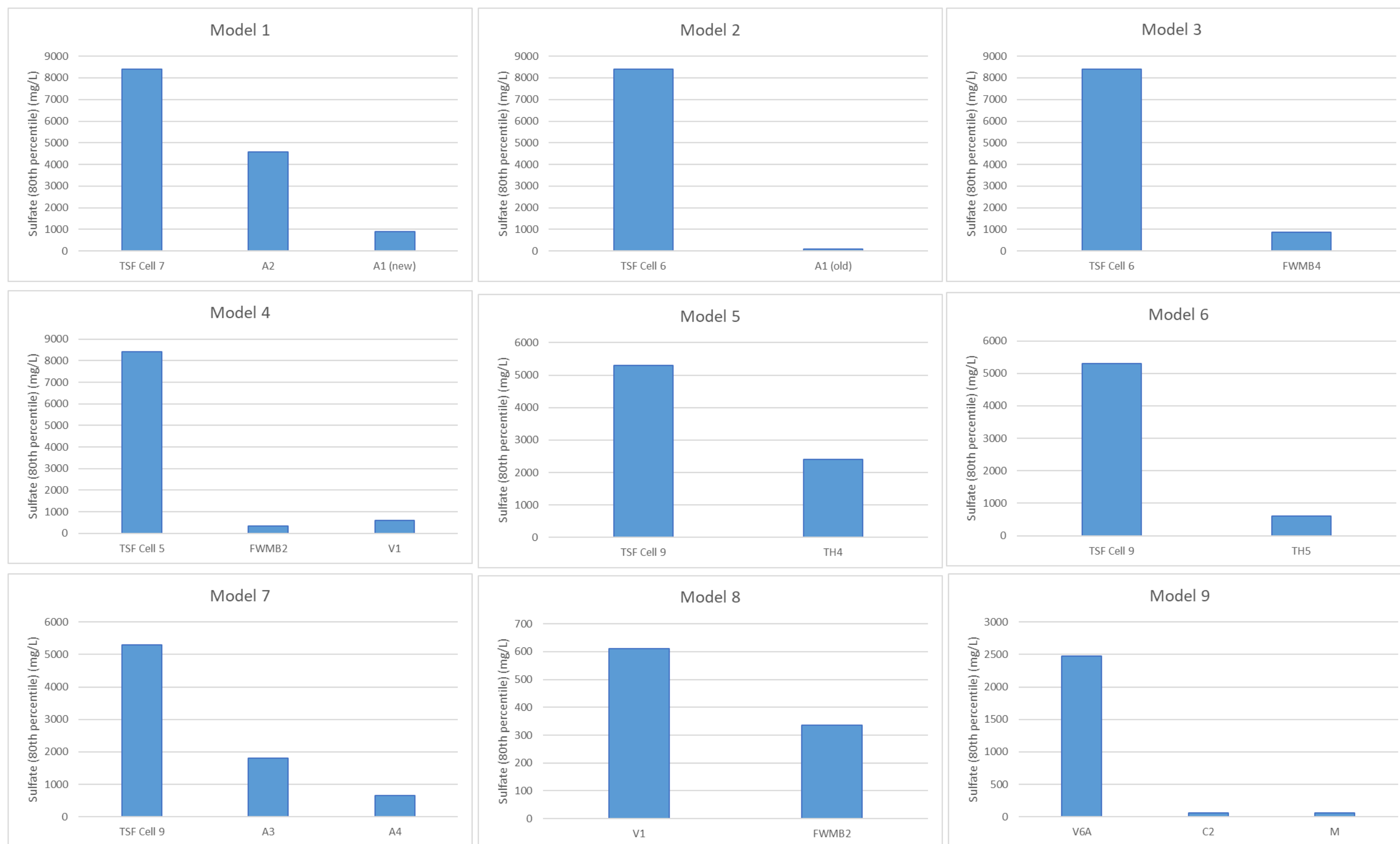


Figure 132 Sulfate 80th percentile concentrations in solute transport model transects

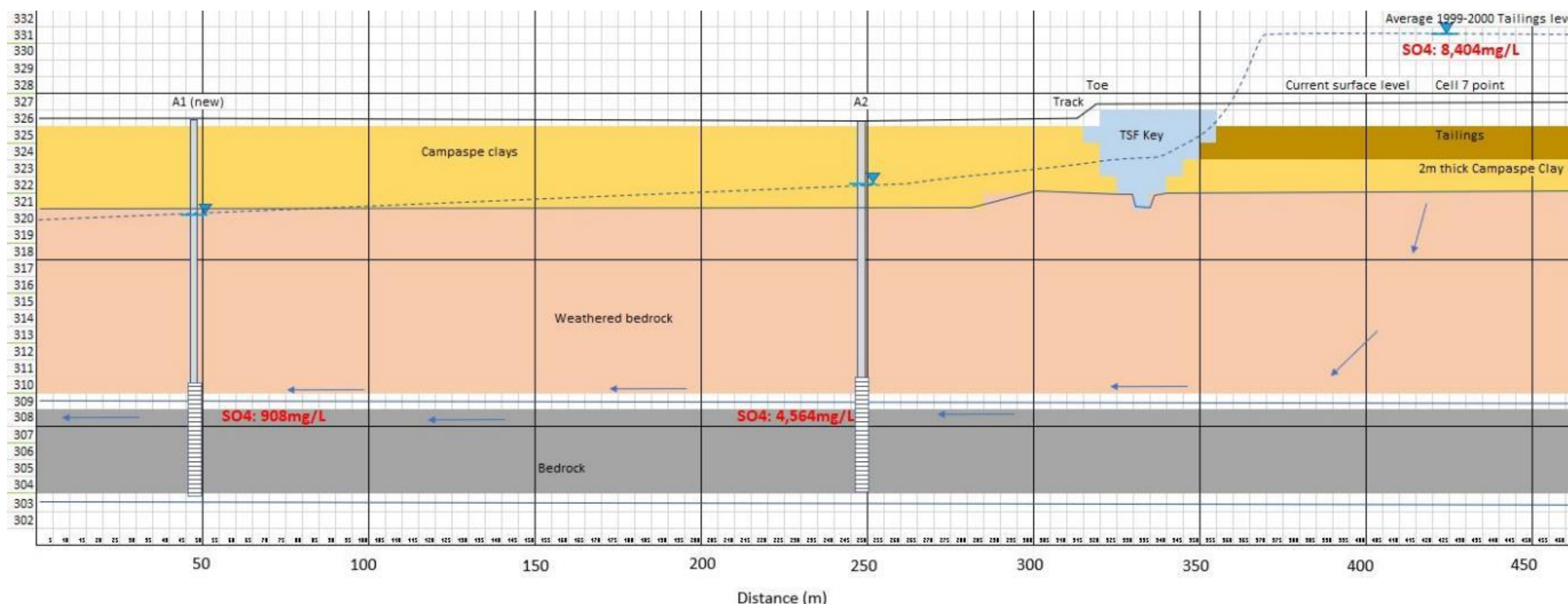


Figure 133 Model 1 cross-section and flow velocity calculations

Model 1

Average water level (1999-2000) for Cell 7 was used=331.7 mASL. Average water level (1999-2000) for A2 (old) was used=322.24 mASL. Average water level (2017-2019) for A1 (new) was used=320.455 mASL.

Hydraulic gradient (Cell 7 point to A2) using distance of 175 m=0.054. Hydraulic gradient (A2 to A1 new) using distance of 200 m=0.009.

Vertical infiltration: Used a conservative hydraulic conductivity (K) for Campaspe Formation (1-2m) maximum=0.075 m/day. It would take 0.34 years to infiltrate through 2 m of Campaspe Formation at a velocity of 0.0162 m/day. Used a conservative K for weathered bedrock of 0.06128 m/day. It would take 2.5 years to infiltrate through 12 m of weathered bedrock at a velocity of 0.013 m/day. Total infiltration time=2.82 years.

Horizontal flow in weathered bedrock: Used a conservative hydraulic conductivity (K) for weathered bedrock (maximum)=0.06128 m/day. Flow velocity (Cell 7 point to A2)=0.013 m/day. Travelling at this velocity, water from Cell 7 would take 21.7 years to reach A2.

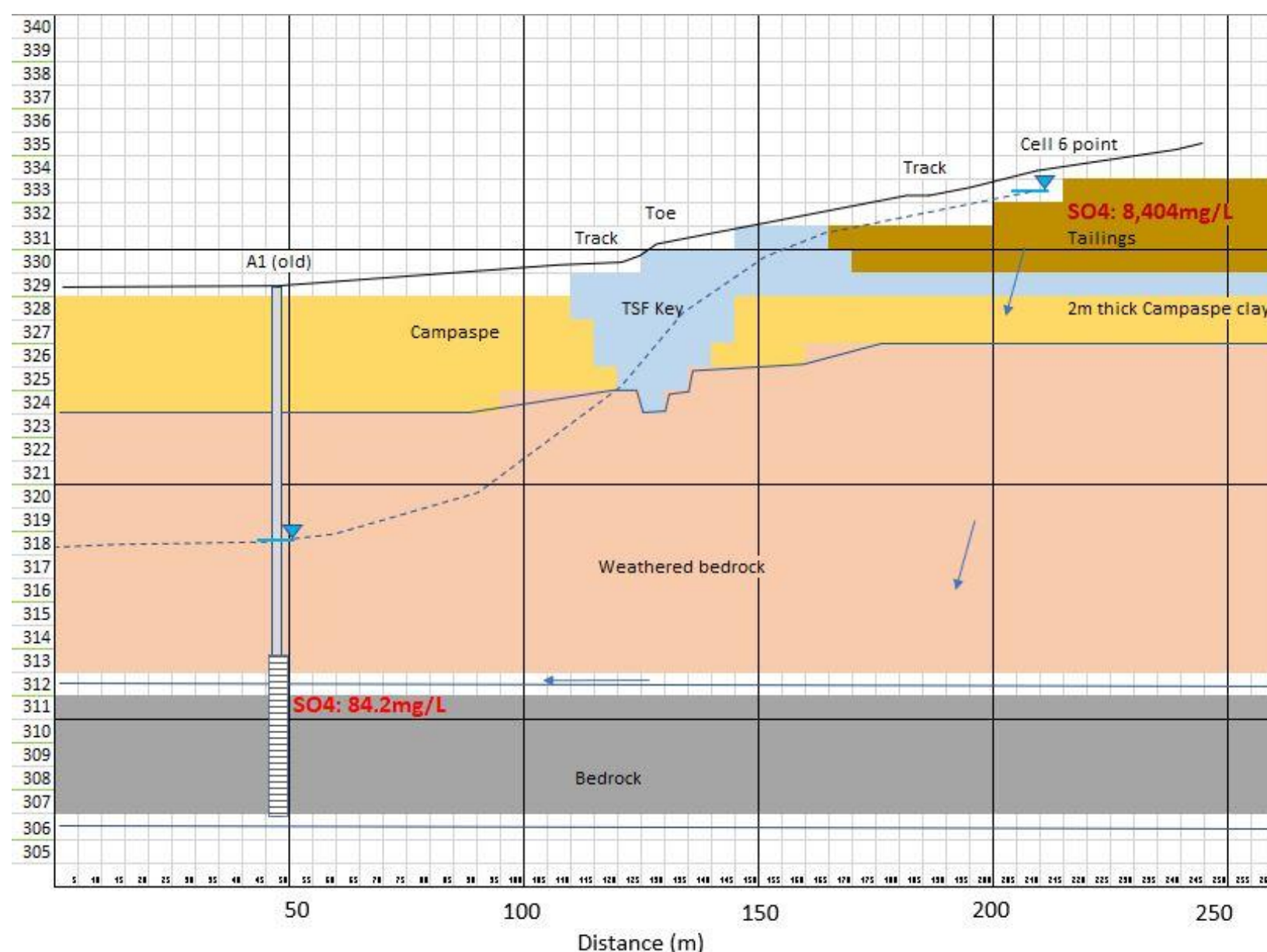
Flow velocity (A2 to A1 new)=0.0022 m/day. Travelling at this velocity, water from A2 would take 130.4 years to reach A1 (new).

Total time it would take for water from Cell 1-7 point to reach A1 (new) in weathered bedrock=2.82 + 21.7 + 130.4 years = 154.92 years.

Horizontal flow in fresh bedrock: Used a conservative hydraulic conductivity (K) for fresh bedrock (maximum)=0.122m/day. Flow velocity (Cell 1-7 point to A2)=0.026 m/day. Travelling at this velocity, water from Cell 1-7 would take 10.9 years to reach A2.

Flow velocity (A2 to A1 new)=0.0044 m/day. Travelling at this velocity, water from A2 would take 65.5 years to reach A1 (new).

Total time it would take for water from Cell 7 point to reach A1 (new) in fresh bedrock=2.82 + 10.9 + 65.5 years = 79.22 years.



Model 2

An average of depths to moisture in Cell 6 investigated by NRA (2011) was used=335.6 mAHD. Average water level (1999-2000) for A1 (old) was used=318.44 mAHD.

Hydraulic gradient (Cell 6 point to A1 (old) using distance of 135 m=0.127.

It was assumed that groundwater flow could occur in both weathered bedrock and fresh bedrock.

Vertical infiltration: Used a conservative hydraulic conductivity (K) for Campaspe Formation (1-2m) maximum=0.075 m/day. It would take 0.14 years to infiltrate through 2 m of Campaspe Formation at a velocity of 0.0381 m/day. Used a conservative K for weathered bedrock of 0.06128 m/day. It would take 1.23 years to infiltrate through 14 m of weathered bedrock at a velocity of 0.03 m/day. Total infiltration time=1.38 years.

Horizontal flow in weathered bedrock: Used a conservative hydraulic conductivity (K) for weathered bedrock (maximum)=0.06128 m/day. Flow velocity (Cell 6 point to A1 old)=0.031 m/day. Travelling at this velocity, water from Cell 6 would take 9.2 years to reach A1 (old).

Total time it would take water from Cell 6 point to reach A1 (old) in weathered bedrock=1.38 + 9.2 years=10.62 years.

Horizontal flow in fresh bedrock: Used a conservative hydraulic conductivity (K) for fresh bedrock (maximum)=0.122m/day. Flow velocity (Cell 6 point to A1 old)=0.062 m/day. Travelling at this velocity, water from Cell 6 would take 4.6 years to reach A1 (old).

Total time it would take for water from Cell 6 point to reach A1 (old) in fresh bedrock=1.38 + 4.64 years=6.02 years.

Figure 134 Model 2 cross-section and flow velocity calculations

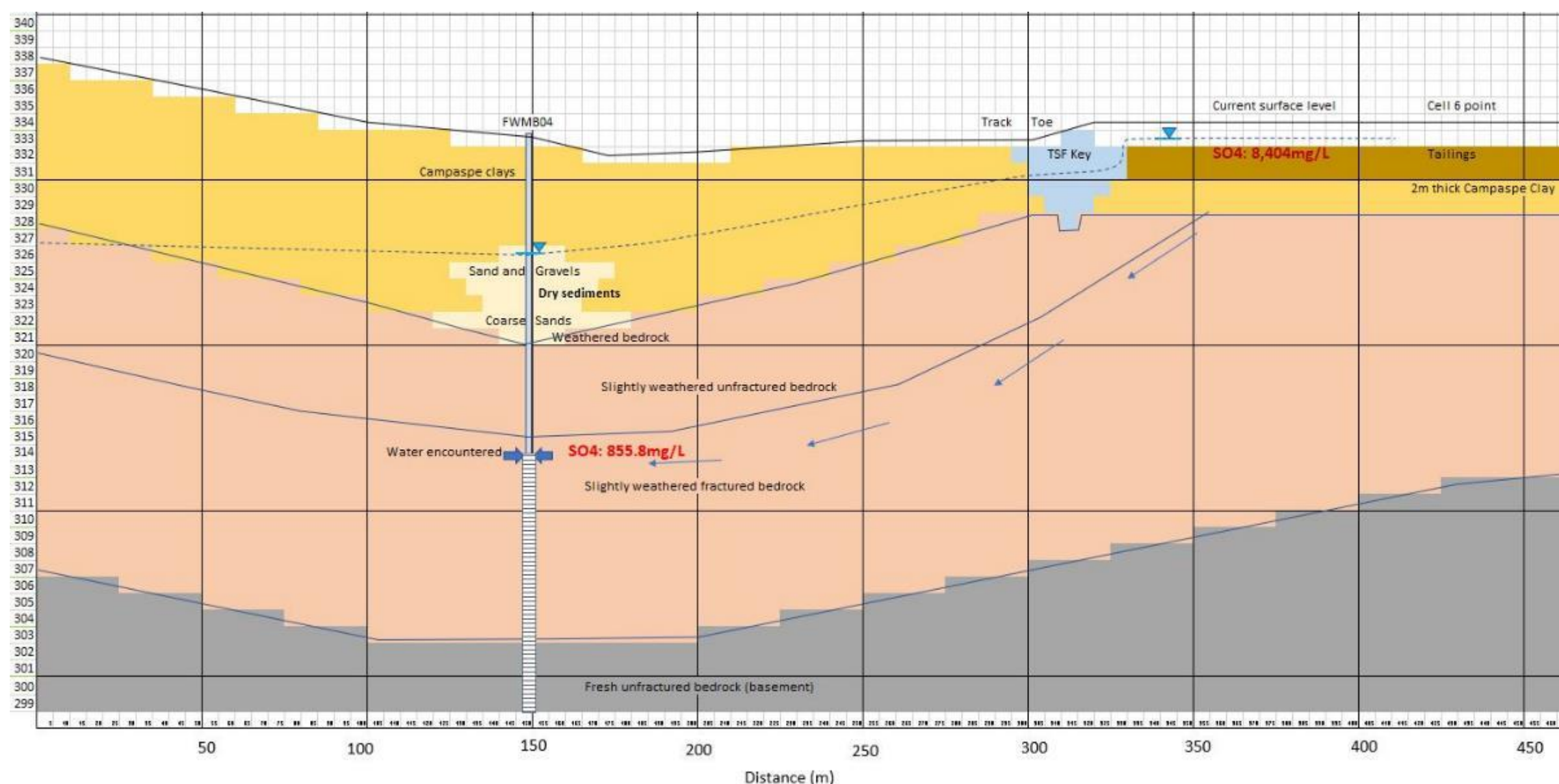


Figure 135 Model 3 cross-section and flow velocity calculations

Model 3

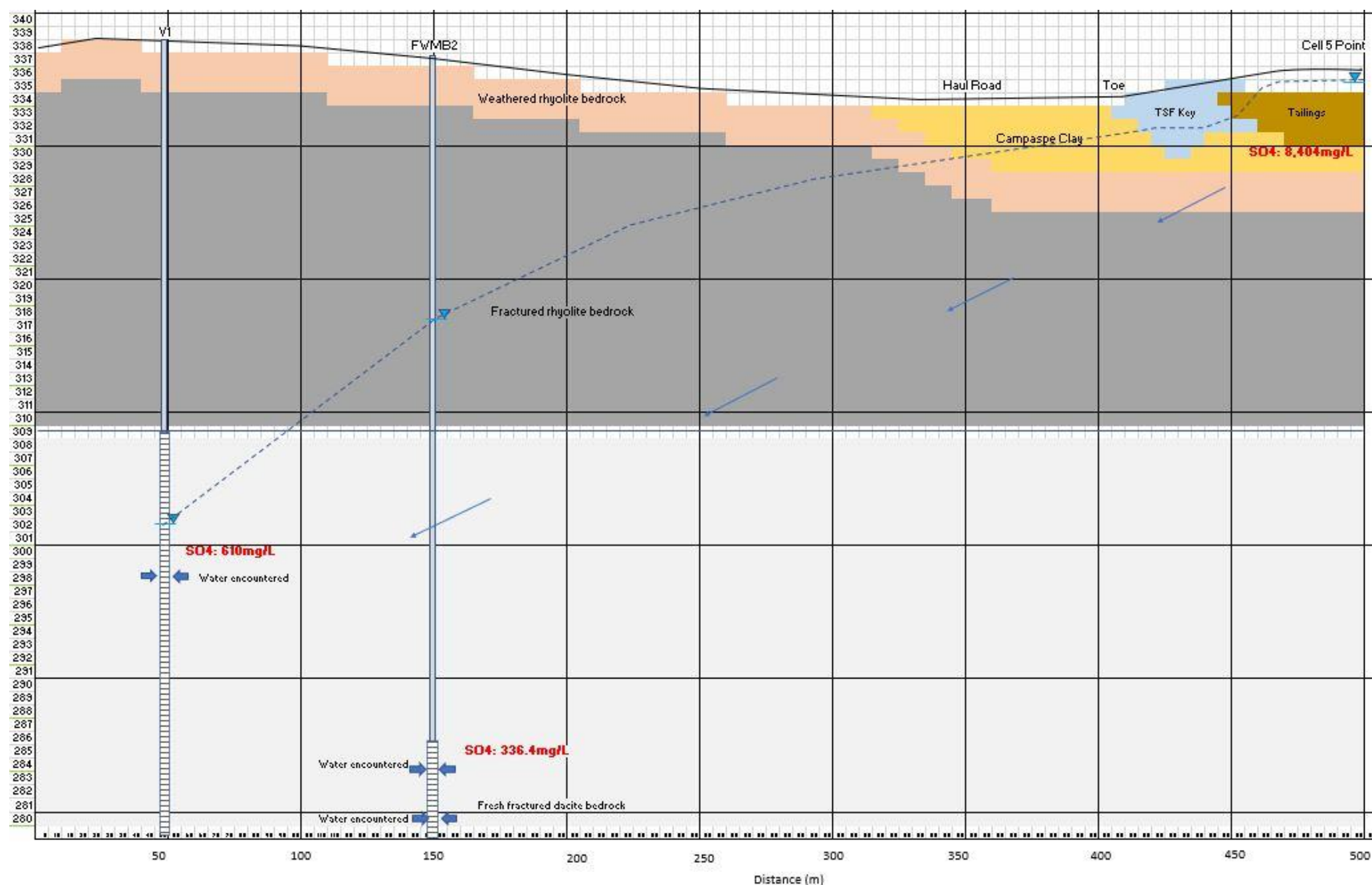
An average of depths to moisture in Cell 6 investigated by NRA (2011) was used=335.6 mAHD. Average water level (2018-2019) for FWMB4 was used=326.061 mAHD.

Hydraulic gradient (Cell 6 point to FWMB4 using distance of 195 m=0.049.

Vertical infiltration: Used a conservative hydraulic conductivity (K) for Campaspe Formation (1-2m) maximum=0.075 m/day. It would take 0.37 years to infiltrate through 2 m of Campaspe Formation at a velocity of 0.0147 m/day. Total infiltration time=0.37 years.

Horizontal flow in weathered bedrock: Used a conservative hydraulic conductivity (K) for weathered bedrock 17-30m (maximum)=0.122 m/day. Flow velocity (Cell 6 point to FWMB4)=0.0239 m/day. Travelling at this velocity, water from Cell 6 would take 22.97 years to reach FWMB4.

Total time it would take water from Cell 6 point to FWMB4 in weathered bedrock=0.37 + 22.97 years=23.34 years.



Model 4

An average of depths to moisture in Cell 5 investigated by NRA (2011) was used=335.55 mASD. Average water level (2018-2019) for FWMB2 was used=317.476 mASD. Average water level (2018-2019) for V1 was used=301.945.

Hydraulic gradient (Cell 5 point to FWMB2) using distance of 300 m=0.060. Hydraulic gradient (FWMB2 to V1) using distance of 130 m=0.119.

Vertical infiltration: Used a conservative hydraulic conductivity (K) for Campaspe Formation (1-2m) maximum=0.075 m/day and assumed higher hydraulic gradient near Cell 5 of 0.08. It would take 0.23 years to infiltrate through 2 m of Campaspe Formation at a velocity of 0.024 m/day and 0.42 years to infiltrate through 3m of weathered bedrock at a velocity of 0.019 m/day. Total infiltration time=0.65 years.

Horizontal flow in fresh bedrock: Used a conservative hydraulic conductivity (K) for fresh bedrock (maximum)=0.122m/day. Flow velocity (Cell 5 point to FWMB2)=0.02928 m/day. Travelling at this velocity, water from Cell 5 would take 32.97 years to reach FWMB2.

Flow velocity (FWMB2 to V1)=0.058 m/day. Travelling at this velocity, water from FWMB2 would take 4.7 years to reach V1.

Total time it would take for water from Cell 5 point to reach V1) in fresh bedrock=0.65 + 32.97 + 4.7 years=38.34 years.

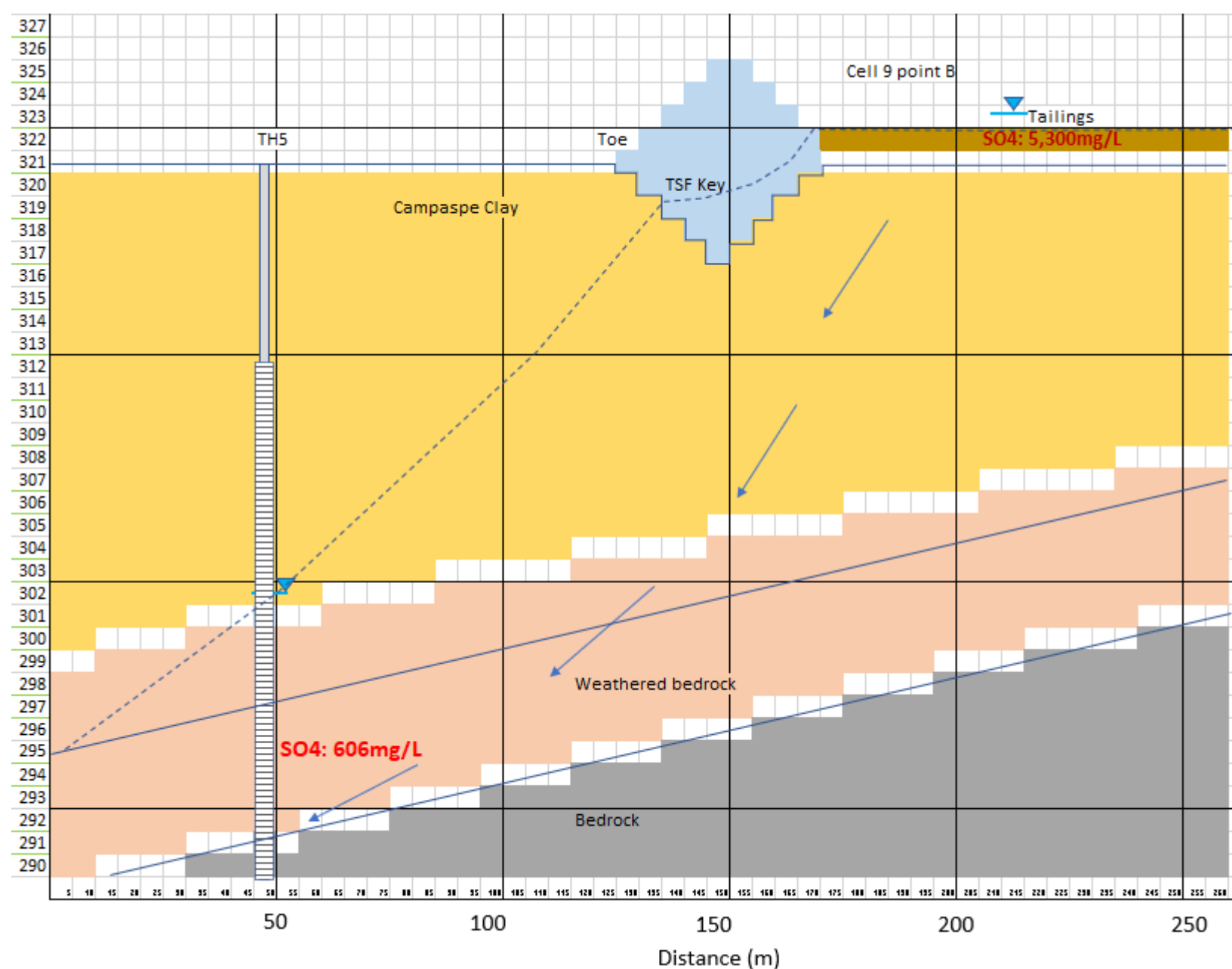
Figure 136 Model 4 cross-section and flow velocity calculations

Water level in Cell 9 was estimated using Plan of Operations design and Queensland Globe elevation estimate=323 mAHD. Average water level (2008-2019) for TH4 was used=306.813 mAHD.

Vertical infiltration: Used a conservative hydraulic conductivity (K) for Campaspe Formation (1-2m) maximum=0.075 m/day. It would take 0.42 years to infiltrate through 2 m of Campaspe Formation at a velocity of 0.0381 m/day. Used a conservative K for weathered bedrock of 0.06128 m/day. It would take 0.52 years to infiltrate through 14 m of weathered bedrock at a velocity of 0.03 m/day. Total infiltration time=0.94 years.

Total time it would take water from Cell 9 point A to reach TH4 in fresh bedrock=0.94 + 7.84 years=8.78 years.

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Model 6

Water level in Cell 9 was estimated using Plan of Operations design and Queensland Globe elevation estimate=323 mAH. Average water level (2008-2019) for TH5 was used=302.308 mAH.

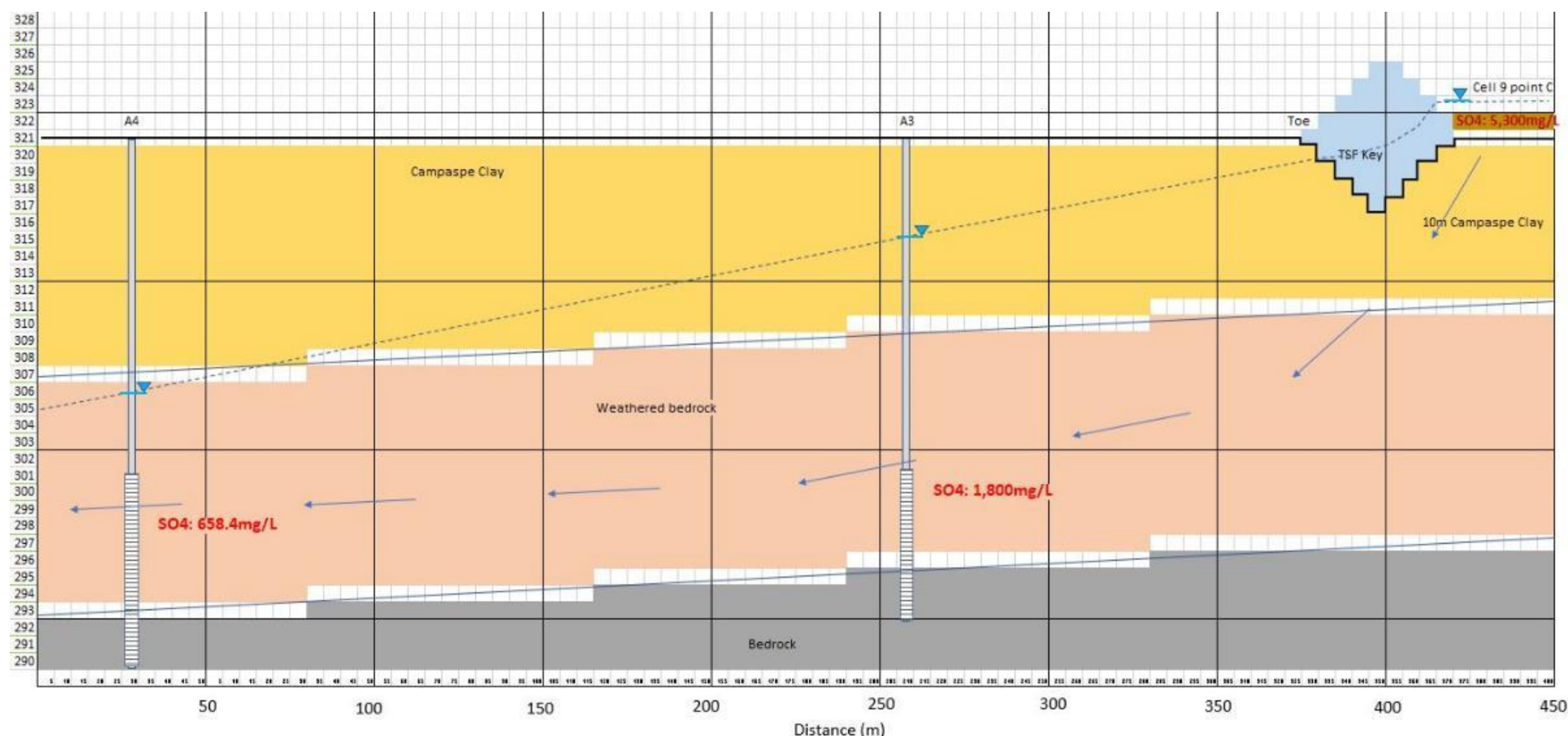
Hydraulic gradient (Cell 9 point B to TH5) using distance of 125 m=0.166.

Vertical infiltration: Used a conservative hydraulic conductivity (K) for Campaspe Formation (1-2m) maximum=0.075 m/day. It would take 0.94 years to infiltrate through 17 m of Campaspe Formation at a velocity of 0.0498 m/day. Total infiltration time=0.94 years.

Horizontal flow in weathered bedrock: Used a conservative hydraulic conductivity (K) for bedrock 17-30m (maximum)=0.122 m/day. Flow velocity (Cell 9 point B to TH5)=0.029 m/day. Travelling at this velocity, water from Cell 9 would take 12.16 years to reach TH5.

Total time it would take water from Cell 9 point B to reach TH5 in weathered bedrock=0.94 + 12.16 years=13.1 years.

Figure 138 Model 6 cross-section and flow velocity calculations



Model 7

Water level in Cell 9 was estimated using Plan of Operations design and Queensland Globe elevation estimate=323 mAHD. Average water level (2007-2019) for A3 was used=315.888 mAHD and an average water level (2018-2019) for A4 was used=305.972.

Hydraulic gradient (Cell 9 point C to A3) using distance of 130 m=0.055 and hydraulic gradient (A3 to A4) using distance of 180 m=0.055.

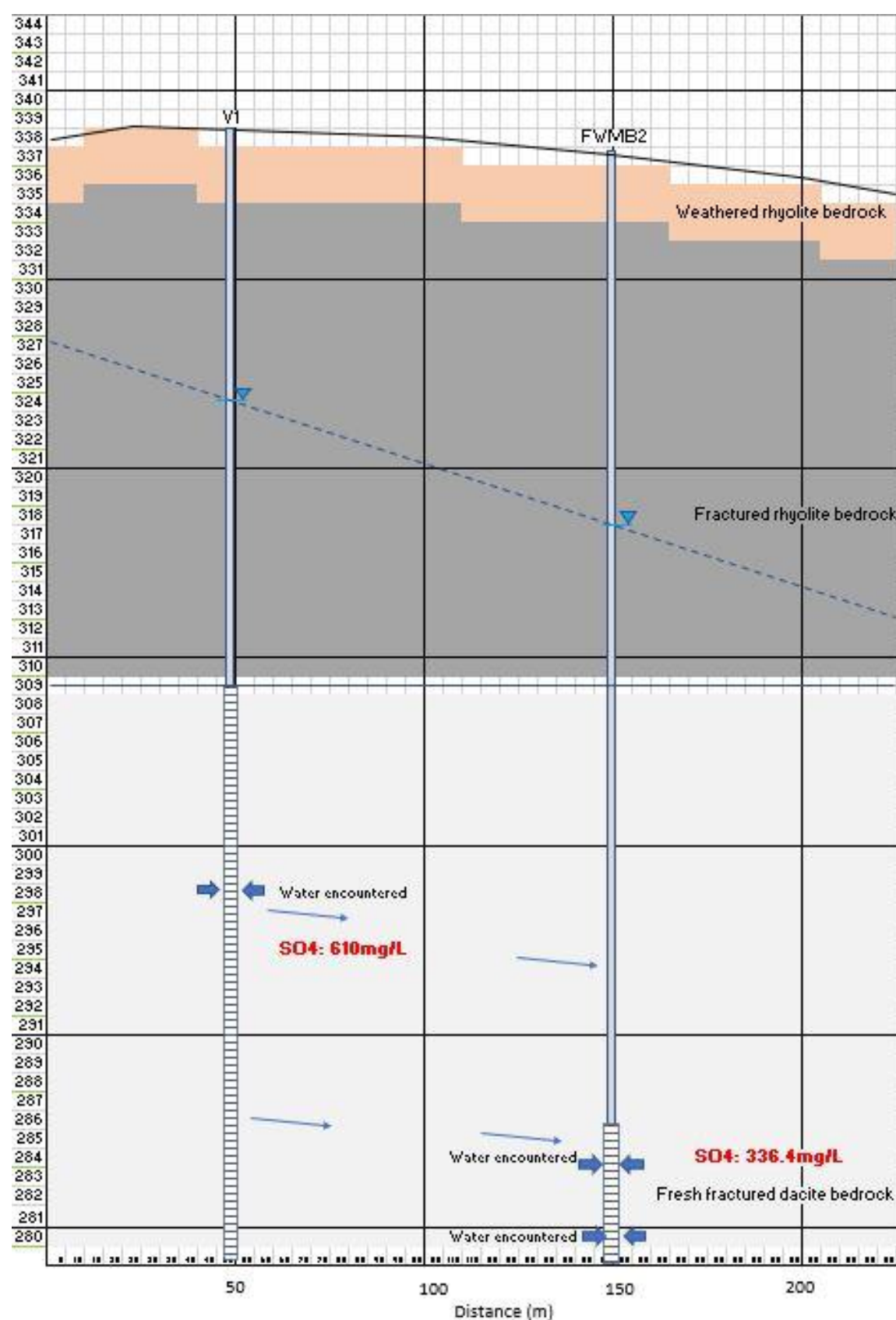
Vertical infiltration: Used a conservative hydraulic conductivity (K) for Campaspe Formation (1-2m) maximum=0.075 m/day. It would take 1.66 years to infiltrate through 10 m of Campaspe Formation at a velocity of 0.0165 m/day. Used a conservative K for bedrock maximum=0.122 m/day. It would take 1.74 years to infiltrate through 9 m of weathered bedrock at a velocity of 0.0268 m/day. Total infiltration time=3.4 years.

Figure 139 Model 7 cross-section and flow velocity calculations

Horizontal flow in weathered bedrock: Used a conservative hydraulic conductivity (K) for weathered bedrock 17-30m (maximum)=0.122 m/day. Flow velocity (Cell 9 point C to A3)=0.0268 m/day. Travelling at this velocity through weathered bedrock, water from Cell 9 would take 16.84 years to reach A3.

Flow velocity (A3 to A4)=0.0268 m/day. Travelling at this velocity through weathered bedrock, water from A3 would take 18.37 years to reach A4.

Total time it would take water from Cell 9 point C to A4 in weathered bedrock=3.39 + 16.84 + 18.37 years=38.61 years.



Model 8

An average water level (2008) for V1 was used=324.017 mASL. V1 was assumed to represent the underground.

Average water level (2018-2019) for FWMB2 was used=317.476.

Hydraulic gradient (V1 to FWMB2) using distance of 130 m=0.050.

Horizontal flow in fresh bedrock: Used a conservative hydraulic conductivity (K) for fresh bedrock (maximum)=0.122m/day. Flow velocity (V1 to FWMB2)=0.0244 m/day. Travelling at this velocity, water from V1 would take 11.35 years to reach FWMB2.

Total travel time for water to travel through fresh bedrock from V1 (representing underground tailings backfill) to FWMB2=11.35 years.

Figure 140 Model 8 cross-section and flow velocity calculations

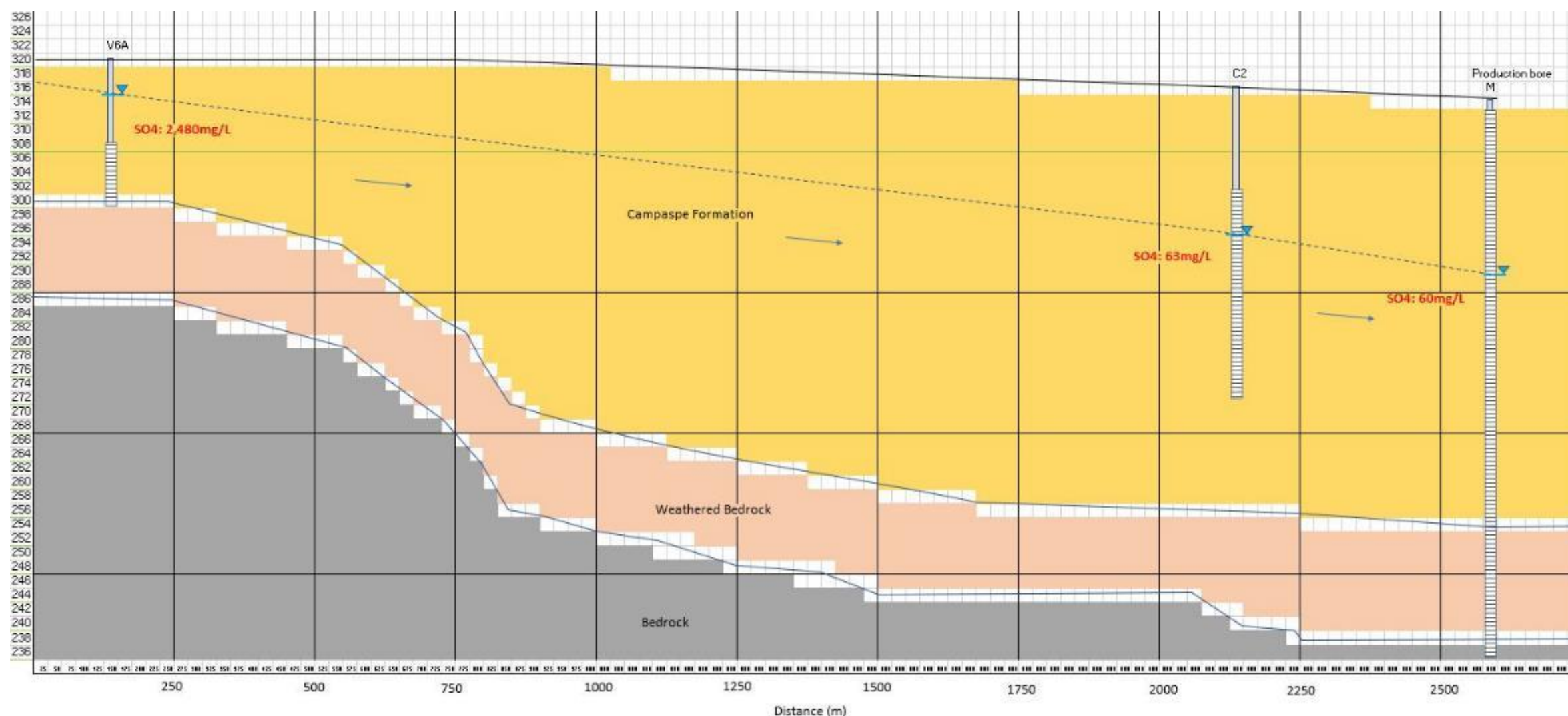


Figure 141 Model 9 cross-section and flow velocity calculations

Model 9

An average water level (2008-2010) for V6A (assumed to represent underground tailings backfill) was used=314.161 mAHD. Average water level (2008-2010) for C2 was used=295.392 mAHD and an average water level (2008-2010) for M was used=290.431.

Hydraulic gradient (V6A to C2) using distance of 1980 m=0.009 and hydraulic gradient (C2 to M) using distance of 470 m=0.011.

Horizontal flow in Campaspe Formation:

GRAVEL: Used a conservative hydraulic conductivity (K) for gravel (maximum from Domenico and Schwartz, 1990)=2592 m/day. Flow velocity (V6A to C2)=93.312 m/day. Travelling at this velocity through Campaspe gravel, water from V6A would take 21 days to reach C2.

Flow velocity (C2 to M)=114.05 m/day. Travelling at this velocity through Campaspe gravel, water from C2 would take 4 days to reach M.

Total time it would take water from V6A to M in Campaspe gravel=21 + 4 days= 25 days.

Coarse sand: Used a conservative hydraulic conductivity (K) for coarse sand (maximum from Domenico and Schwartz, 1990)=518.4 m/day. Flow velocity (V6A to C2)=18.66 m/day. Travelling at this velocity through Campaspe coarse sand, water from V6A would take 107 days to reach C2. Flow velocity (C2 to M)=22.8 m/day. Travelling at this velocity through Campaspe coarse sand, water from C2 would take 20.5 days to reach M. Total time it would take water from V6A to M in Campaspe coarse sand=107 + 20.5 days= 127.5 days.

Fine sand: Used a conservative hydraulic conductivity (K) for fine sand (maximum from Domenico and Schwartz, 1990)=17.28 m/day. Flow velocity (V6A to C2)=0.622 m/day. Travelling at this velocity through Campaspe fine sand, water from V6A would take 8.8 years to reach C2. Flow velocity (C2 to M)=0.76 m/day. Travelling at this velocity through Campaspe fine sand, water from C2 would take 1.7 years to reach M. Total time it would take water from V6A to M in Campaspe coarse sand=8.8 + 1.7 years= 10.5 years.

Sandstone: Used a conservative hydraulic conductivity (K) for sandstone (maximum from Domenico and Schwartz, 1990)=0.5184 m/day. Flow velocity (V6A to C2)=0.0187 m/day. Travelling at this velocity through Campaspe sandstone, water from V6A would take 293 years to reach C2. Flow velocity (C2 to M)=0.0228 m/day. Travelling at this velocity through Campaspe sandstone, water from C2 would take 56.5 years to reach M. Total time it would take water from V6A to M in Campaspe sandstone=293 + 56.5 years= 350 years.

11.5 Discussion and limitations

Modelled groundwater travel times are shown in **Table 17** and range from 21 days to 350 years. A discussion of the results and limitations for each model is provided below.

Table 17 Summary of modelled travel times

Model #	Transect	Travel time	Time unit
1	Cell 1-7 to A2 (old)	13.7 to 24.5	years
1	Cell 1-7 to A1 (new)	79 to 155	years
2	Cell 1-7 point to A1 (old)	6 to 10.6	years
3	Cell 1-7 point to FWMB4	23.3	years
4	Cell 1-7 point to FWMB2	33.5	years
4	Cell 1-7 point to V1	38.3	years
5	Cell 9 point A to TH4	8.8	years
6	Cell 9 point B to TH5	13.1	years
7	Cell 9 point C to A3	20.2	years
7	Cell 9 point C to A4	38.6	years
8	V1 to FWMB2	11.4	years
9	V6A to C2 (gravel)	21	days
9	V6A to M (gravel)	25	days
9	V6A to C2 (coarse sand)	107	days
9	V6A to M (coarse sand)	127.5	days
9	V6A to C2 (fine sand)	8.8	years
9	V6A to M (fine sand)	10.5	years
9	V6A to C2 (sandstone)	293	years
9	V6A to M (sandstone)	350	years

11.5.1 Model 1

Modelled hydrogeological travel time for Model 1 (Cell 1-7 to A2) ranged from 13.7 years to 24.5 years. At present, it is possible for water from Cell 1-7 to have reached A2 by advection as shown by travel times and a sulfate concentration of 4,564mg/L (80th percentile); however, based on the available hydrogeological data, it is highly unlikely that water from Cell 1-7 has reached A1 (new) by advection as it would take 79 to 155 years. These large travel times are attributed to the measured low hydraulic conductivities of weathered and fresh bedrock and the low hydraulic gradient between A2 and A1 (new). Based on the groundwater flow rates, the sulfate concentration of 908 mg/L (80th percentile) should be indicative of natural unimpacted groundwater.

Alternatively, if measured hydraulic conductivity values and calculated groundwater flow rates are disregarded as unreliable, the natural regression of sulfate concentrations by adsorption along the groundwater flow path indicates a 5-fold reduction over 250m between A2 and A1(new). A linear extrapolation of that reduction further away suggests that sulfate concentrations will be on par with pre-TSF (1989) concentrations (~100mg/L) measured at TD4 and TD6 (**Section 9.3.3.1**) within 44.2m from A1(new) (**Figure 142**). Using a more likely exponential reduction would reduce the extent of measurable sulfate anomaly to about background levels (~100mg/L) within 70m of A1(new) (**Figure 143**). The difference between linear regression and exponential (logarithmic) reduction rests within the mathematical assumptions; while linear regression only incorporates the last two data points, exponential reduction includes all three data points and projects a reduction of concentrations over distance. The latter approach is more likely to reflect natural interaction between groundwater and geological materials along the flow path.

Given the uniform geology along the groundwater flow path, cation exchange surfaces would be uniformly distributed over distance. Closer to the TSF, more of these cation exchange surfaces would be occupied by sulfate. With less cation exchange surfaces available, sulfate will migrate. However, as sulfate continues to be bound along the flow path, seepage concentrations of sulfate decrease with distance from the TSF. Consequently, more cation exchange surfaces are available as seepage migrates further away from the TSF. As seepage naturally radiates from its source and more and more cation exchange surfaces become available the reduction of sulfate within the groundwater is exponential with distance. This exponentiality can be clearly observed in groundwater sulfate concentrations around the Thalanga TSF.

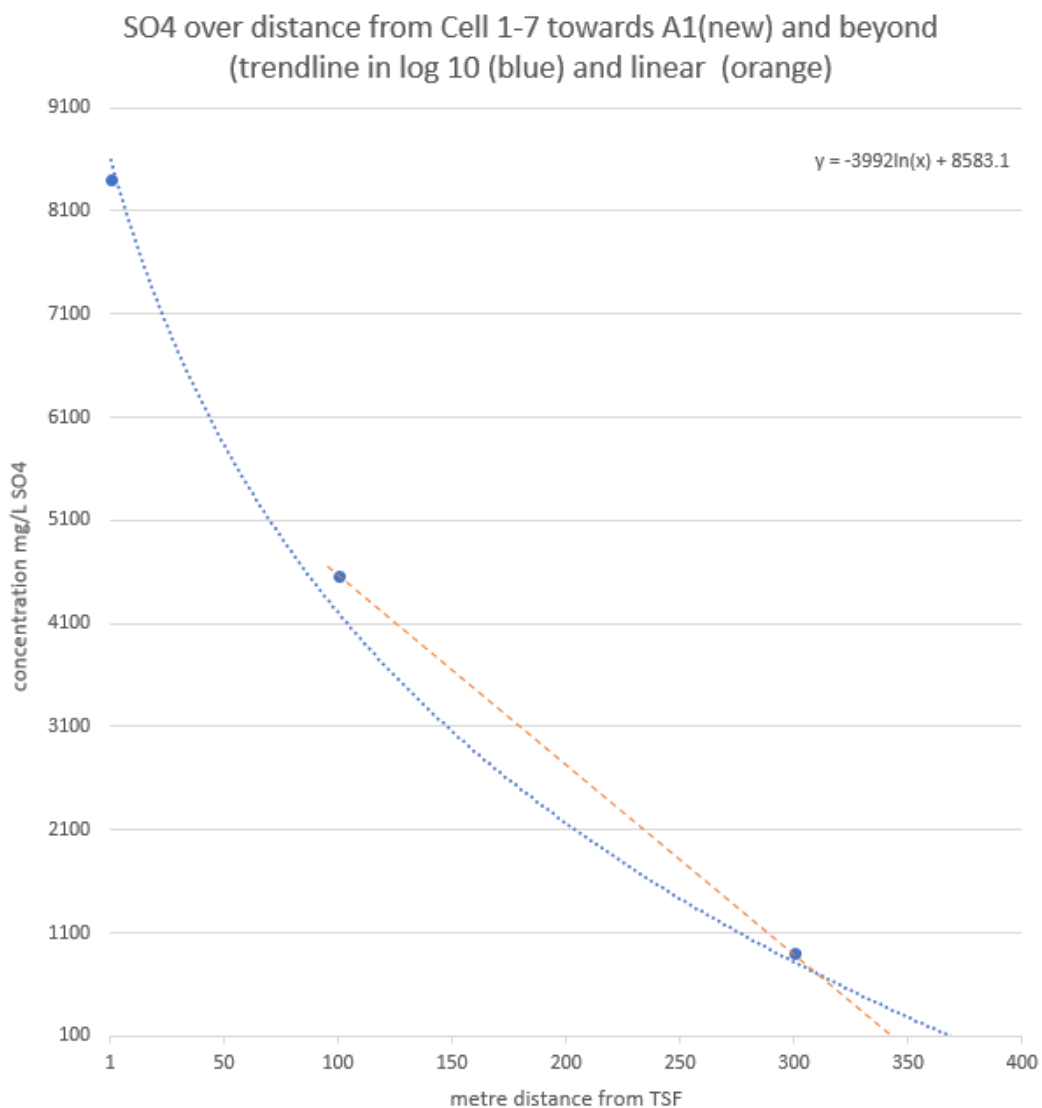


Figure 142 Decline of sulfate concentrations over distance (Model 1). Showing linear concentrations and linear reduction (in orange) and log10 trend reduction (in blue)

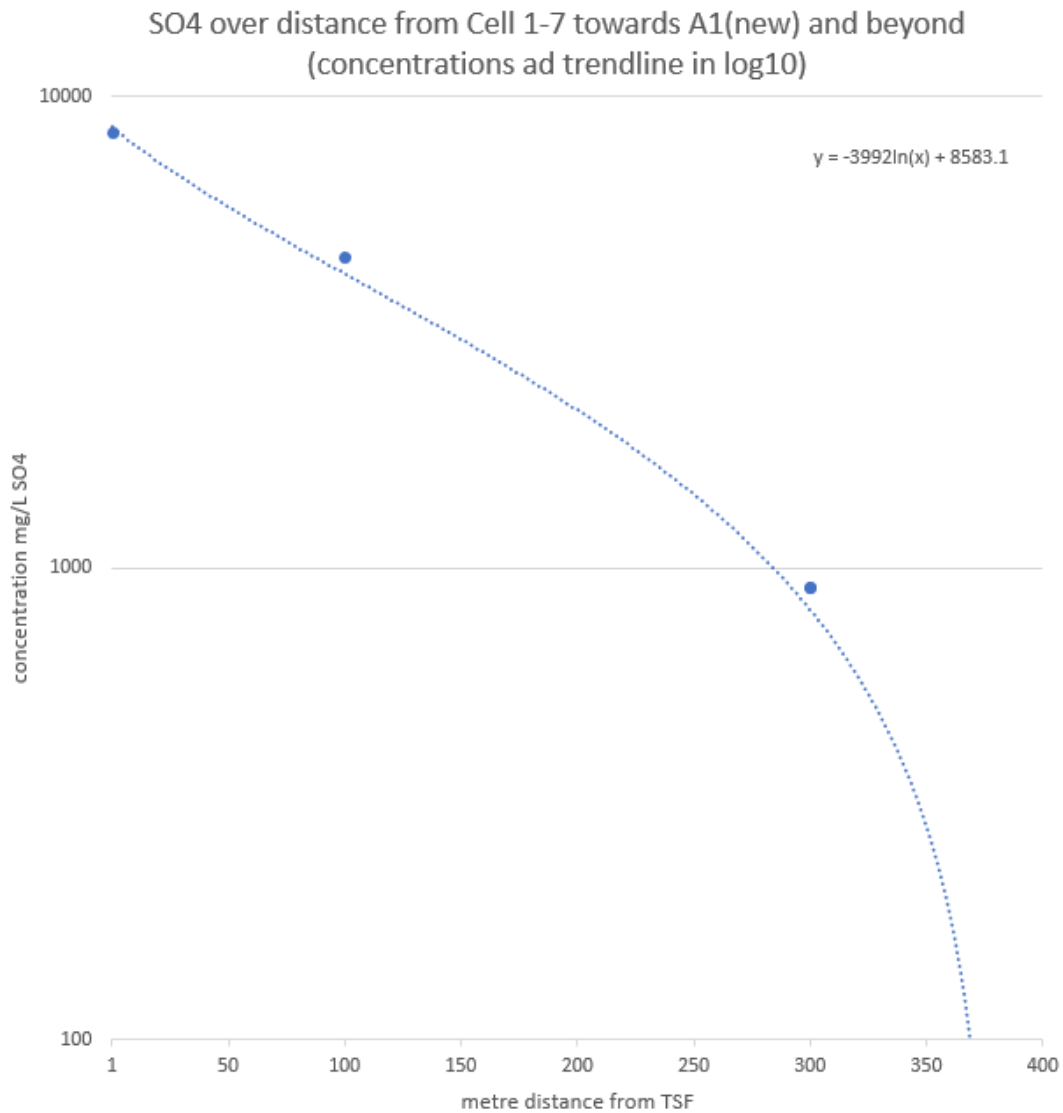


Figure 143 Decline of sulfate concentrations over distance (Model 1). Concentrations and decline trend in log10

11.5.2 Model 2

The modelled travel time for Model 2 (Cell 1-7 to A1 (old)) ranged from 6 to 10.6 years. Hydrogeological measurements suggest that water from Cell 1-7 would have reached A1 old by advection. As this bore has been decommissioned (operational between 1995 and 2003), it is not possible to verify sulfate concentrations at this location. However, a modelled groundwater flow velocity of 0.0311m/day suggests that during the past 20 years, water from Cell 1-7 could have travelled between 211m and 421m after infiltration through the Campaspe Formation and weathered bedrock. Geology, depth and bore construction for A1(old) has been inferred from the geology of A1(new) and depth and typical bore construction of A3. Assuming a groundwater flow direction towards the north-east, it would seem (based on 8 years of low sulfate measurements(

Figure 52)) that TSF seepage bypassed A1(old). However, considering sulfate measurements at A1(new) and FWMB3 (Model 3) this seems unlikely. A more likely explanation for low sulfate measurements at A1(old) would be that the bore was too shallow (more shallow than indicated in **Figure 134**) to intercept any seepage.

11.5.3 Model 3

The calculated seepage travel time for Model 3 (Cell 1-7 to FWMB4) was 23.3 years. Measured sulfate concentrations at FWMB4 are consistent with the calculated groundwater travel times. Like in Model 1, sulfate concentrations show a natural regression over distance. In the case of FWMB4, concentrations experience a 10-fold reduction over approximately 180m distance. Compared to Model 1, the greater reduction in sulfate is likely due to the greater thickness of the Campaspe Formation clays and weathered bedrock. Both Campaspe Formation and weathered bedrock by nature contain significantly greater numbers of adsorption sites. With FWMB4 mainly installed through the weathered bed rock, it shows that migration rates of seepage are significantly reduced. Again, using linear extrapolation, reduction of sulfate concentrations to back ground levels (pre-TSF (1989) concentrations measured at TD4 and TD6 (**Section 9.3.3.1**)) would be achieved within 19m of FWMB4 (**Figure 144**). Using a more likely exponential reduction would reduce the extent of measurable sulfate anomaly to about background (~100mg/L) within about 45m of FWMB4 (**Figure 145**).

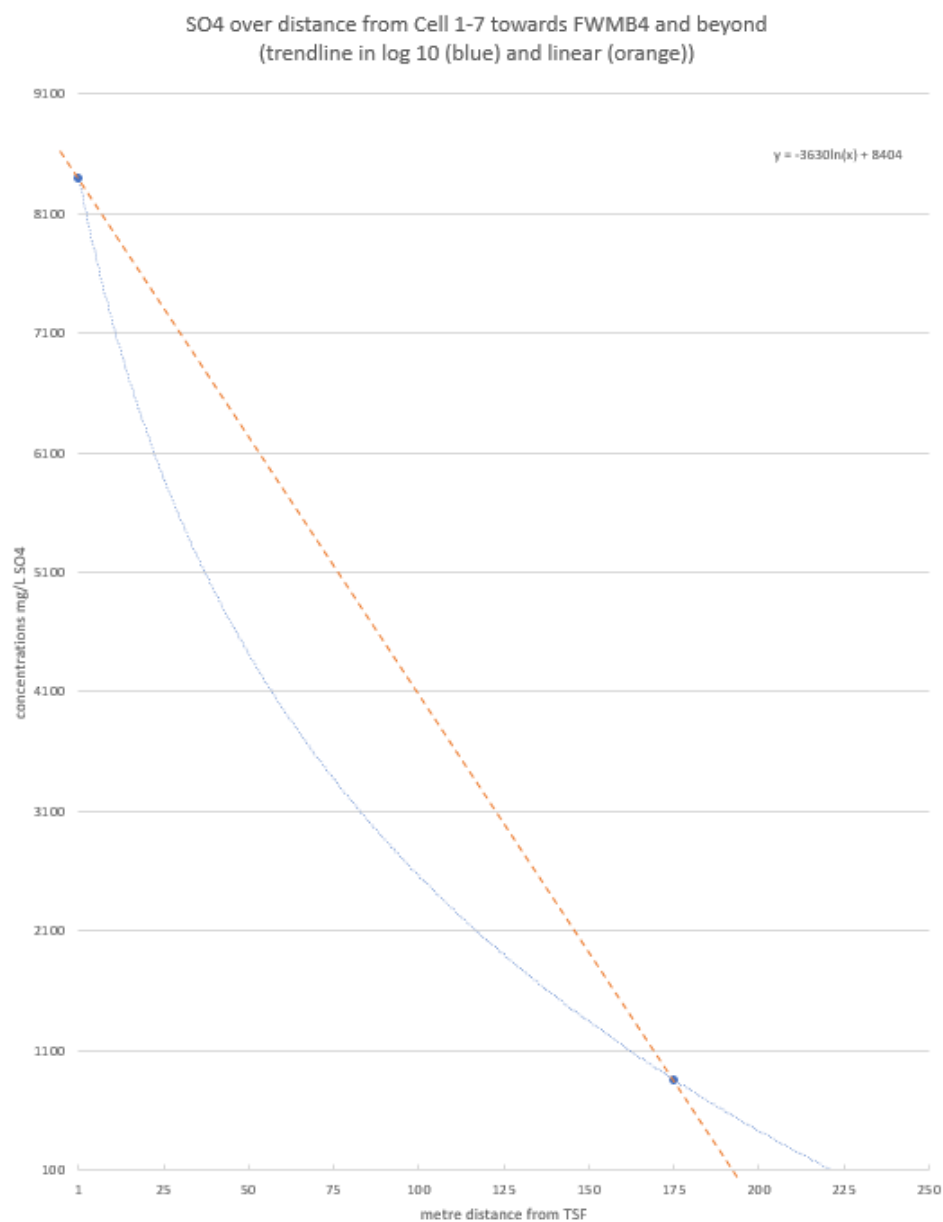


Figure 144 Decline of sulfate concentrations over distance (Model 3). Showing linear concentrations and linear reduction (in orange) and log10 trend reduction (in blue)

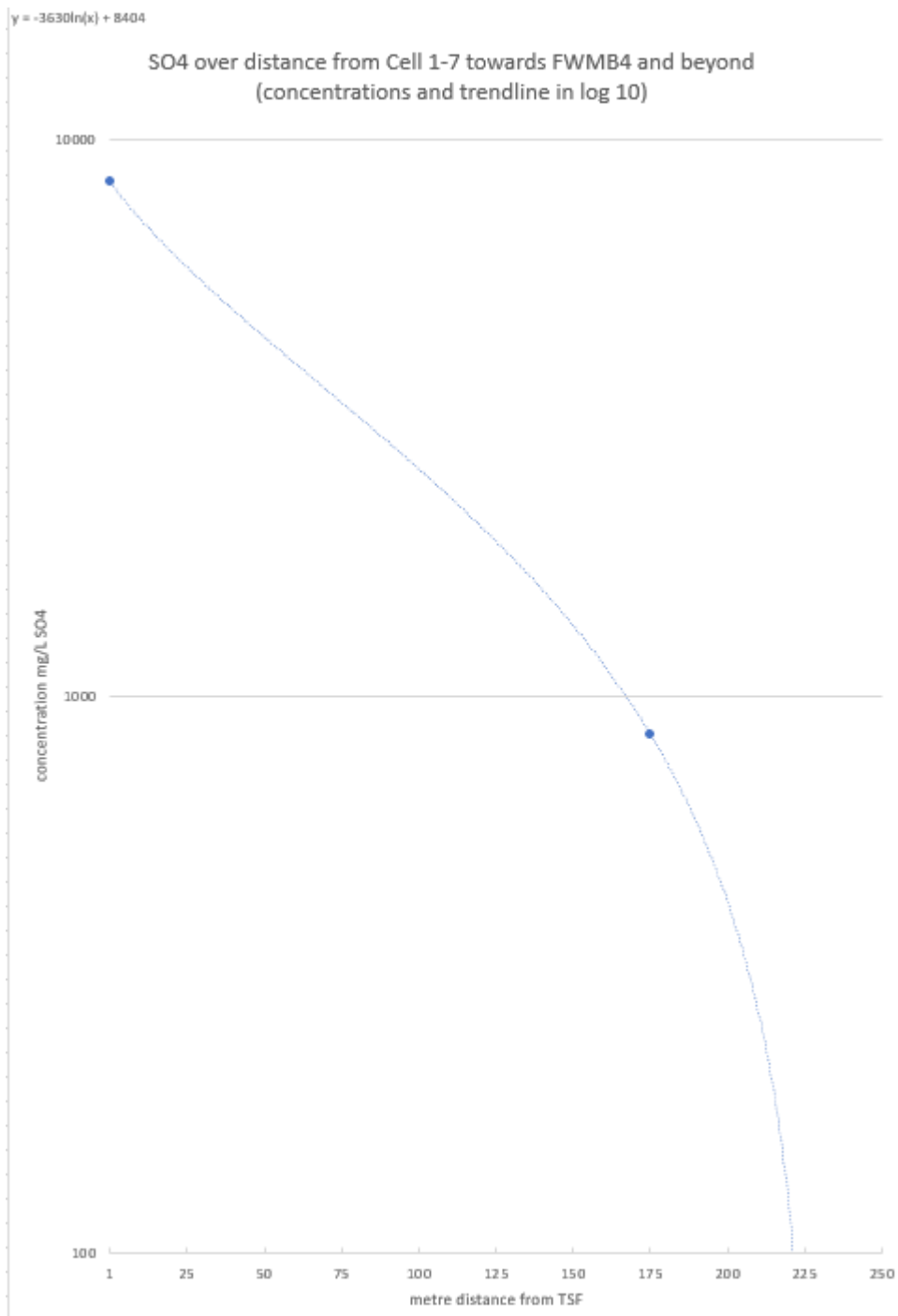


Figure 145 Decline of sulfate concentrations over distance (Model 3). Concentrations and decline trend in log10.

11.5.4 Model 4

Modelled travel time for Model 4 was 33.5 years (Cell 1-7 to FWMB2) and 38.3 years (Cell 1-7 to V1). As cell 1-7 was operational during the 1990s, it seems unlikely that tailings water from Cell 1-7 was able to reach FWMB2 or nearby V1 by advection. However, as discussed in **Section 9.3.4.1**, water quality in V1 has been highly variable due to influences such as dewatering and tailings backfill into underground workings. Eventual impact from tailings seepage (either from underground backfill or TSF seepage) can be observed in sulfate time-series graphs. One of the limitations of Model 4 is the lack of a bore specific hydraulic conductivity and the application of a single hydraulic gradient. To further investigate the possibility of tailings seepage reaching V1, more specific velocities were calculated by breaking down the model into sections (see **Table 18**). The highest gradients were reached during periods of underground dewatering between 1990-2003 and 2018-2019. The 15-year period between 2003 and 2018 was marked by artificially elevated groundwater levels originating from the backfilling of the underground workings. As a result, a conservative total travel distance of 343.6m (not accounting for a reverse in flow direction towards the north due to underground tailings backfill) from Cell 1-7 was calculated. Although this is slightly lower than the actual distance between Cell 1-7 and V1 of approximately 375m, it highlights the likelihood that TSF seepage could migrate to V1 during periods of underground dewatering (provided a high hydraulic conductivity >0.122m/day was used).

Due to underground tailings backfill and subsequent dewatering efforts, the evaluation of trends at FWMB2 is extremely difficult and inherently error prone. Hence, further discussions with regards to sulfate adsorption are not attempted.

Table 18 Additional detailed modelling of V1 flow velocities and distance travelled

Year range	Years	Average V1 water level (mAHD)	Gradient	Velocity (m/day)	Travel distance (m)
1990-2003	13	300.000	0.0827	0.0403	191.4
2003-2008	5	310.000	0.0594	0.0290	52.9
2008-2012	4	318.815	0.0389	0.0190	27.7
2012-2018	6	312.547	0.0535	0.0261	57.2
2018-2019	1	300.914	0.0805	0.0393	14.3
Assumed Cell 1-7 water level: 335.55 mAHD				Total distance (m)	343.6

11.5.5 Model 5

Modelled travel time for Model 5 (Cell 9 to TH4) was 8.8 years. This indicates that TH4 is likely impacted by tailings seepage as discussed in **Section 9.3.3.9.1**. One of the limitations of this model was the lack of an accurate cell 9 tailings water level which could provide a more precise flow velocity rate that can then be used to estimate the potential extent of tailings seepage impact to the east of the TSF (Cell 9). As has been stated before, elevated metal concentrations would suggest that seepage at TH4 is a fast process. The reason for this is likely the relative steep gradient of the Campaspe Formation clay and weathered bedrock. Regardless, the relative fast increase and subsequent reduction in EC (**Figure 60**) and metal concentrations (

Figure 67 and

Figure 69) suggest that concentrations are dependent on water levels within cell 9 and that dispersion and reduction of concentrations in the groundwater system are equally fast. Alternatively, over long periods, higher EC and sulfate concentrations at TH4 (when compared to the East Evaporation pond and Cell 9) suggests that the bore site may have been impacted prior to the construction of Cell 9.

A linear extrapolation of that reduction further away suggests that sulfate concentrations will be on par with pre-TSF (1989) concentrations (~100mg/L) measured at TD4 and TD6 (Section 9.3.3.1) within 99m from TH4 (**Figure 146**). Using a more likely exponential reduction would reduce the extent of measurable sulfate anomaly to about background levels (~100mg/L) within 270m of TH4 (**Figure 147**).

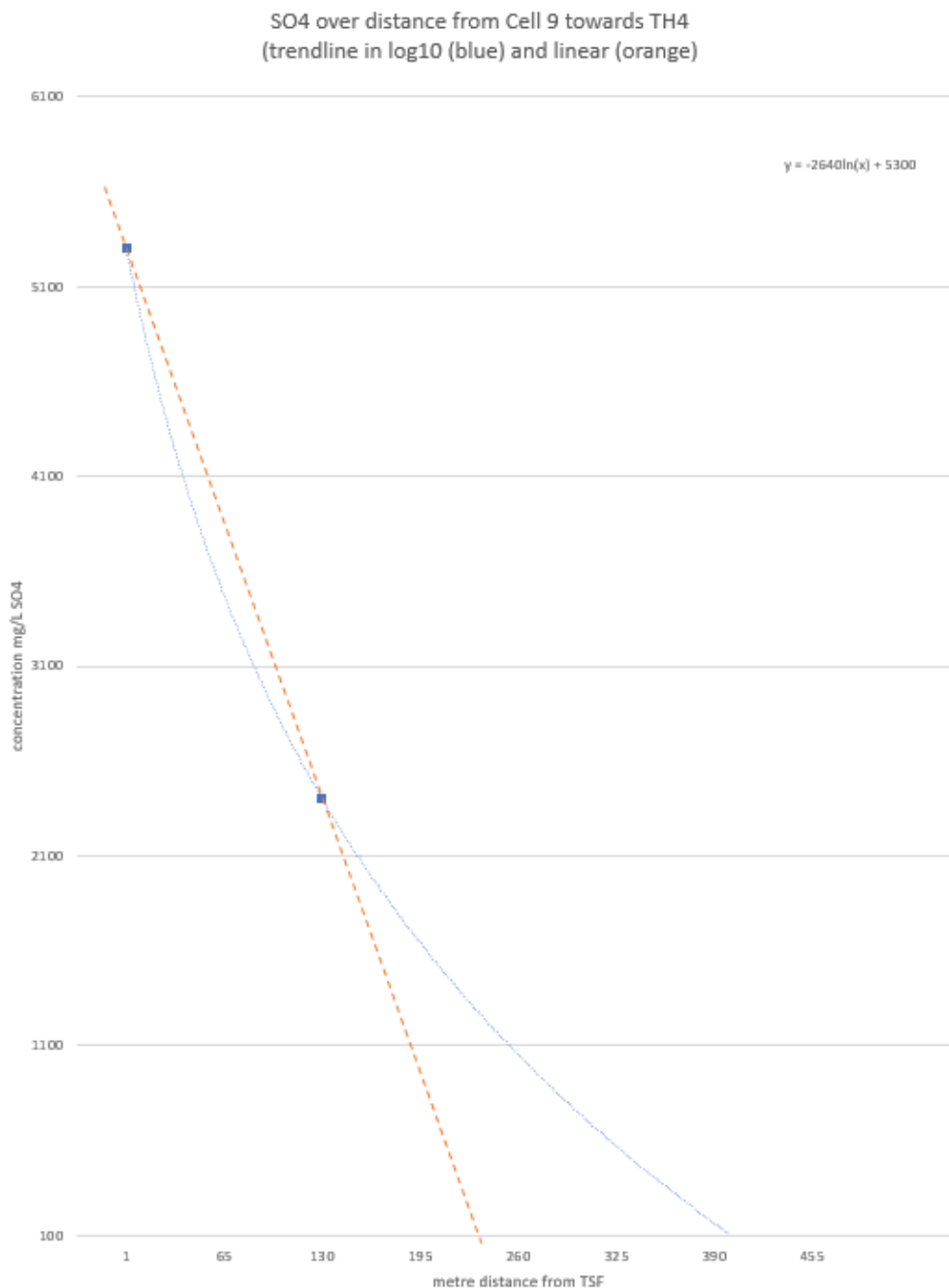


Figure 146 Decline of sulfate concentrations over distance (Model 5). Showing linear concentrations and linear reduction (in orange) and log10 trend reduction (in blue)

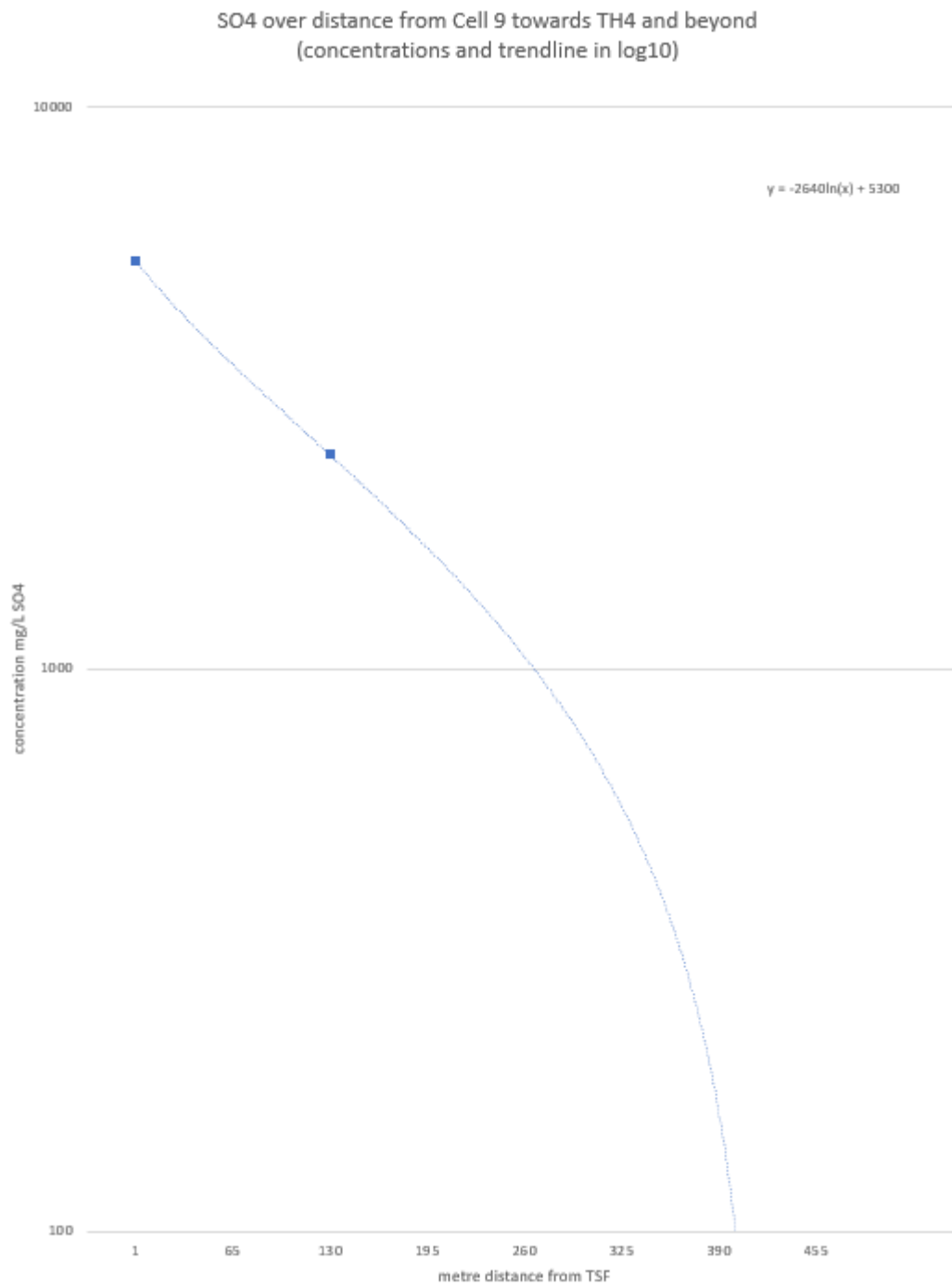


Figure 147 Decline of sulfate concentrations over distance (Model 5). Concentrations and decline trend in log10

11.5.6 Model 6

Modelled travel time for Model 6 (Cell 9 to TH5) was 13.1 years. This indicates that tailings seepage may not have fully reached TH5 by advection at the present time. Alternatively, as discussed in **Section 9.3.3.5**, TH5 may be only partially impacted by seepage at this stage. The bore is screened from 7.5m onwards through the lower section of the Campaspe Formation, the entirety of the weathered bedrock and into the top metre of the hard bedrock below. Located at a similar distance to Cell 9 as TH4 in Model 5, bore TH5 is less likely to have been impacted prior. The only alternative contaminant source, the East Evaporation pond, is located about 630m to the south. With groundwater flow gradients suggesting flow in an easterly direction, impacts of the East Evaporation pond on TH5 are unlikely.

A linear extrapolation of that reduction further away suggests that sulfate concentrations will be on par with pre-TSF (1989) concentrations (~100mg/L) measured at TD4 and TD6 (Section **9.3.3.1**) within 13.5m from TH5 (**Figure 148**). Using a more likely exponential reduction would reduce the extend of measurable sulfate anomaly to about background (~100mg/L) within 32m of TH5 (**Figure 149**).

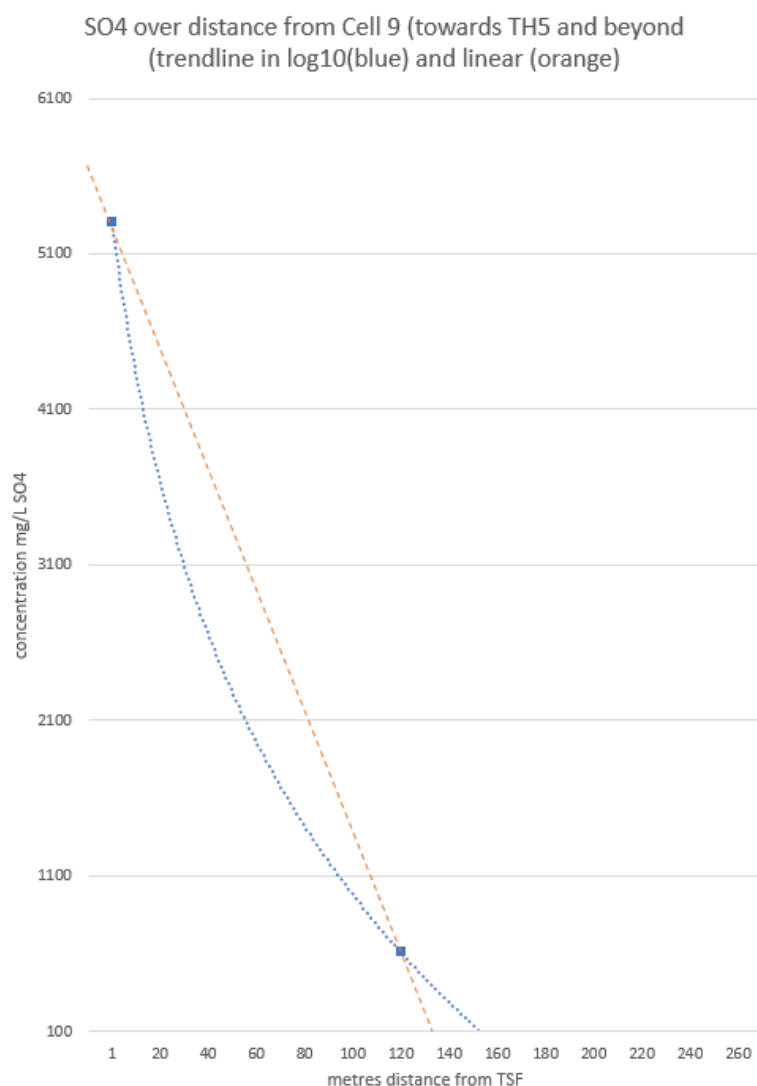


Figure 148 Decline of sulfate concentrations over distance (Model 6). Showing linear concentrations and linear reduction (in orange) and log10 trend reduction (in blue)

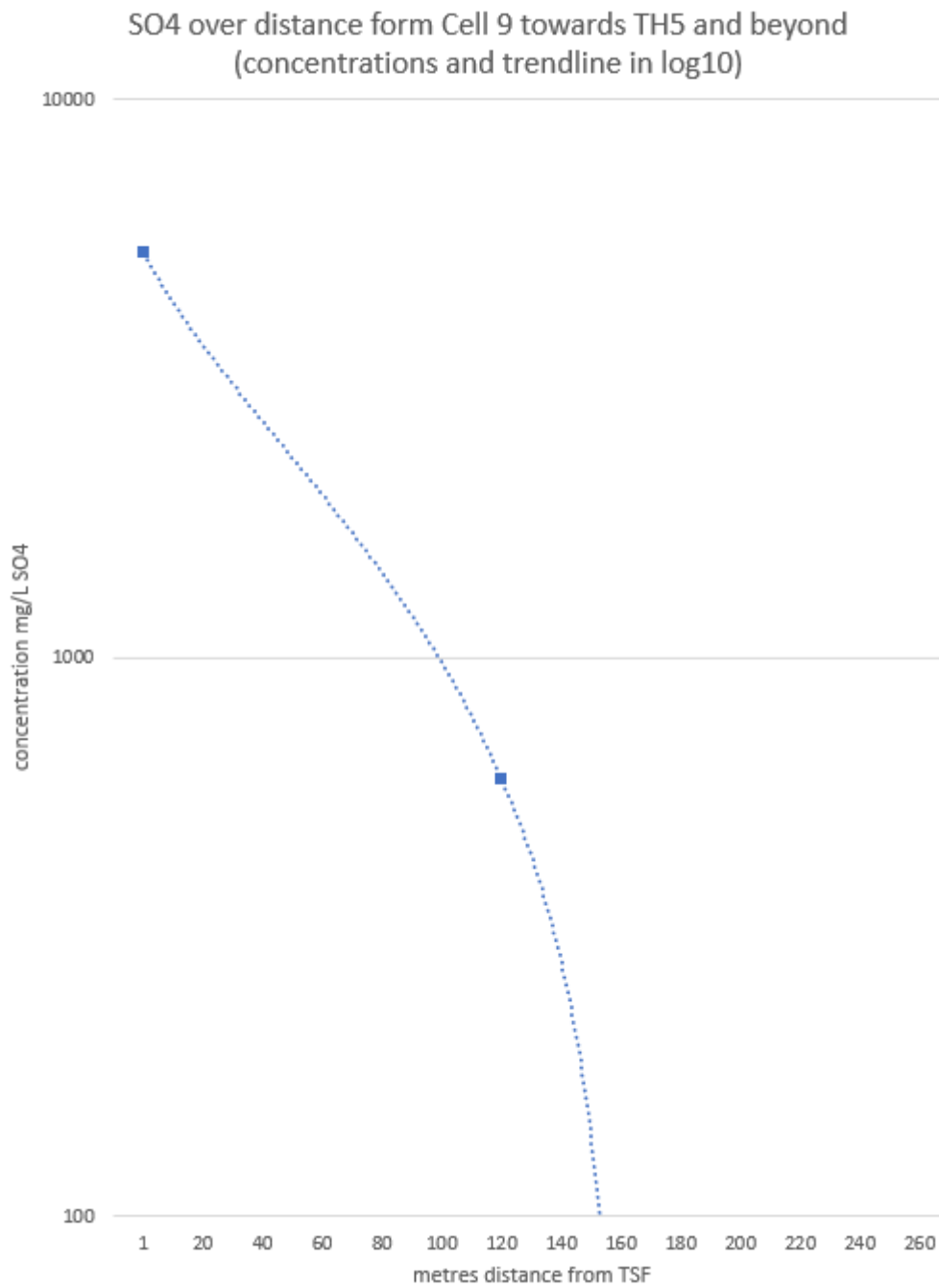


Figure 149 Decline of sulfate concentrations over distance (Model 6). Concentrations and decline trend in log10

11.5.7 Model 7

Model 7 assumed a groundwater flow from Cell 9 over A3 to A4. Modelled groundwater travel time for Model 7 was 20.2 years (Cell 9 to A3) and 38.6 years (Cell 9 to A4). The results of sulfate seepage flow calculations from Cell 9 to A4 are shown in **Figure 150** and **Figure 151**. What can be seen is that, unlike previous calculations, the results for the Cell 9 towards A4 significantly diverge from the log10 trends. The latter an indication that seepage must originate from a different source.

It appears unlikely that A3 and A4 are impacted by tailings seepage originating from Cell 9 as the operation of this cell only started around 2008. A more likely source of impact on A3 is tailings seepage from Cell 1/7, which became operational in 1998, or one of the earlier cells dating back to the 1990s. Historical groundwater records for A3 show that the bore has previously been impacted by seepage from Cell 1-7, hence a more direct flow and different starting concentrations were incorporated into the sulfate migration model. Therefore, a decrease in sulfate concentration from Cell 1-7 (8,404mg/L) to 1800mg/L at A3 and 658mg/L at A4 represents a 92% reduction of groundwater sulfate concentrations over approximately 180m distance.

A linear extrapolation of that reduction further away suggests that sulfate concentrations will be on par with pre-TSF (1989) concentrations (~100mg/L) measured at TD4 and TD6 (Section **9.3.3.1**) within about 30m from A4 (**Figure 152**). Using a more likely exponential reduction would reduce the extent of measurable sulfate anomaly to about background (~100mg/L) within 35m of A4 (**Figure 153**).

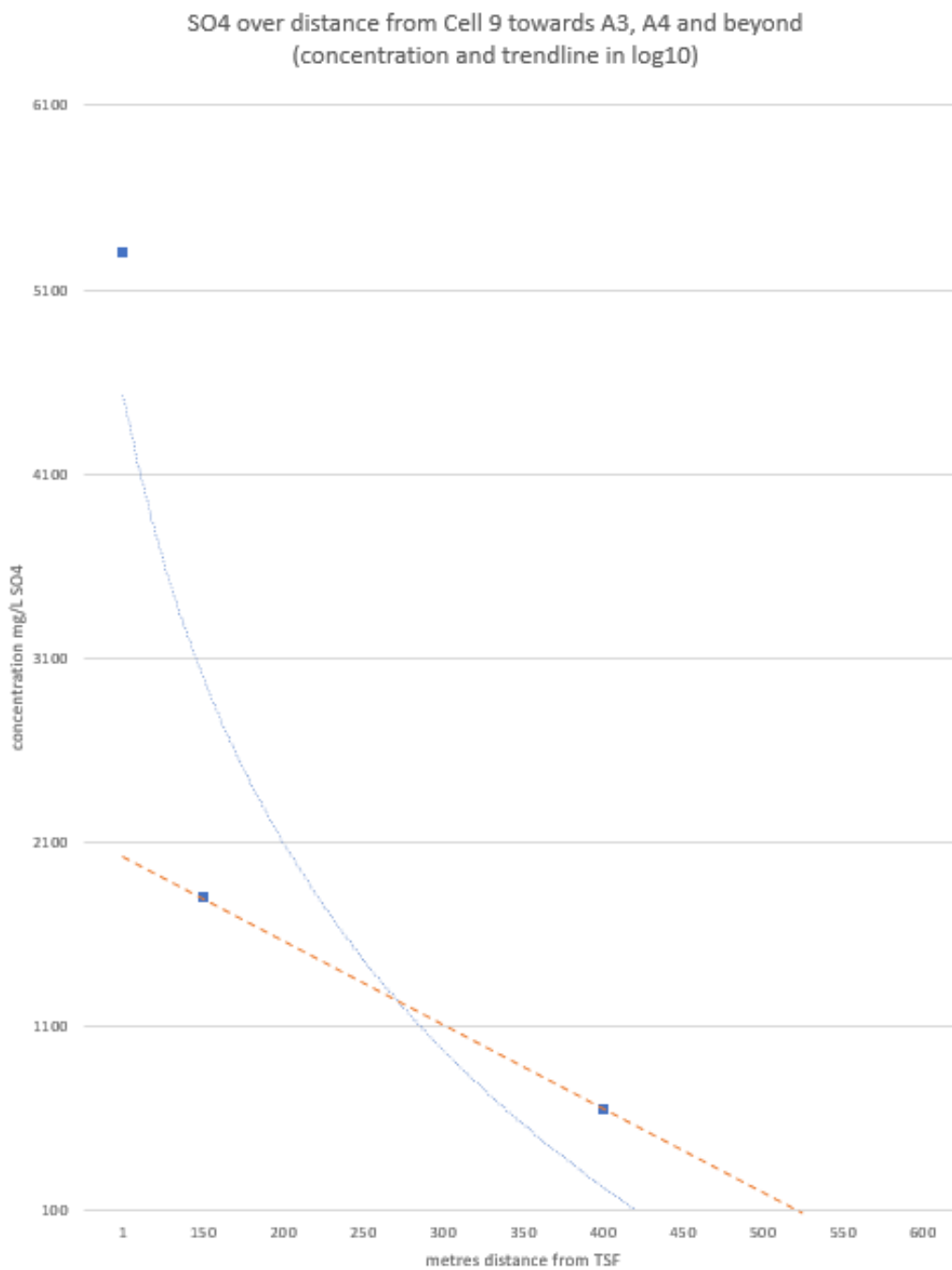


Figure 150 Decline of sulfate concentrations over distance (Cell 9 over A3 to A4, Model 7). Showing linear concentrations and linear reduction (in orange) and log10 trend reduction (in blue)

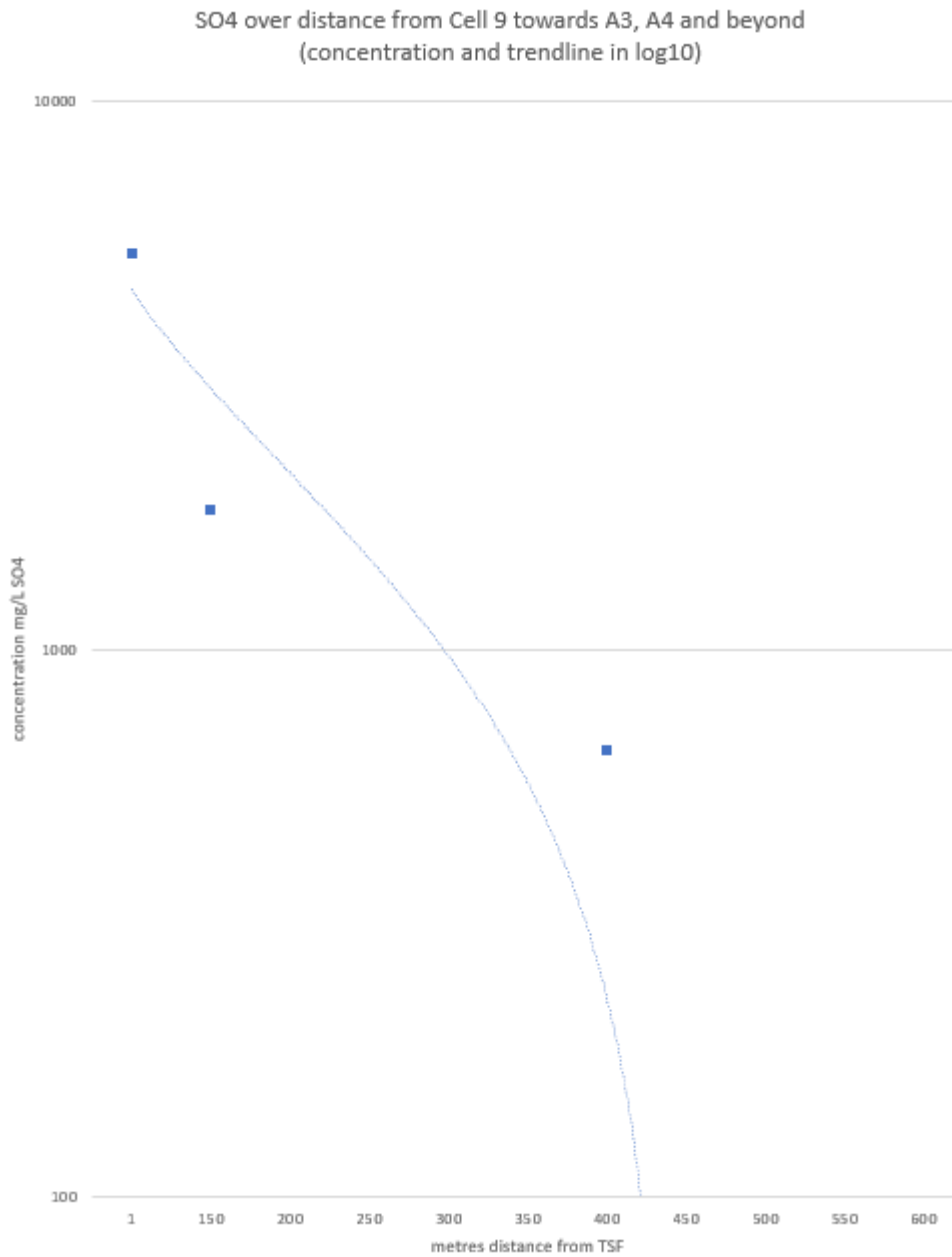


Figure 151 Decline of sulfate concentrations over distance (Cell 9 over A3 to A4, Model 7). Concentrations and decline trend in log10

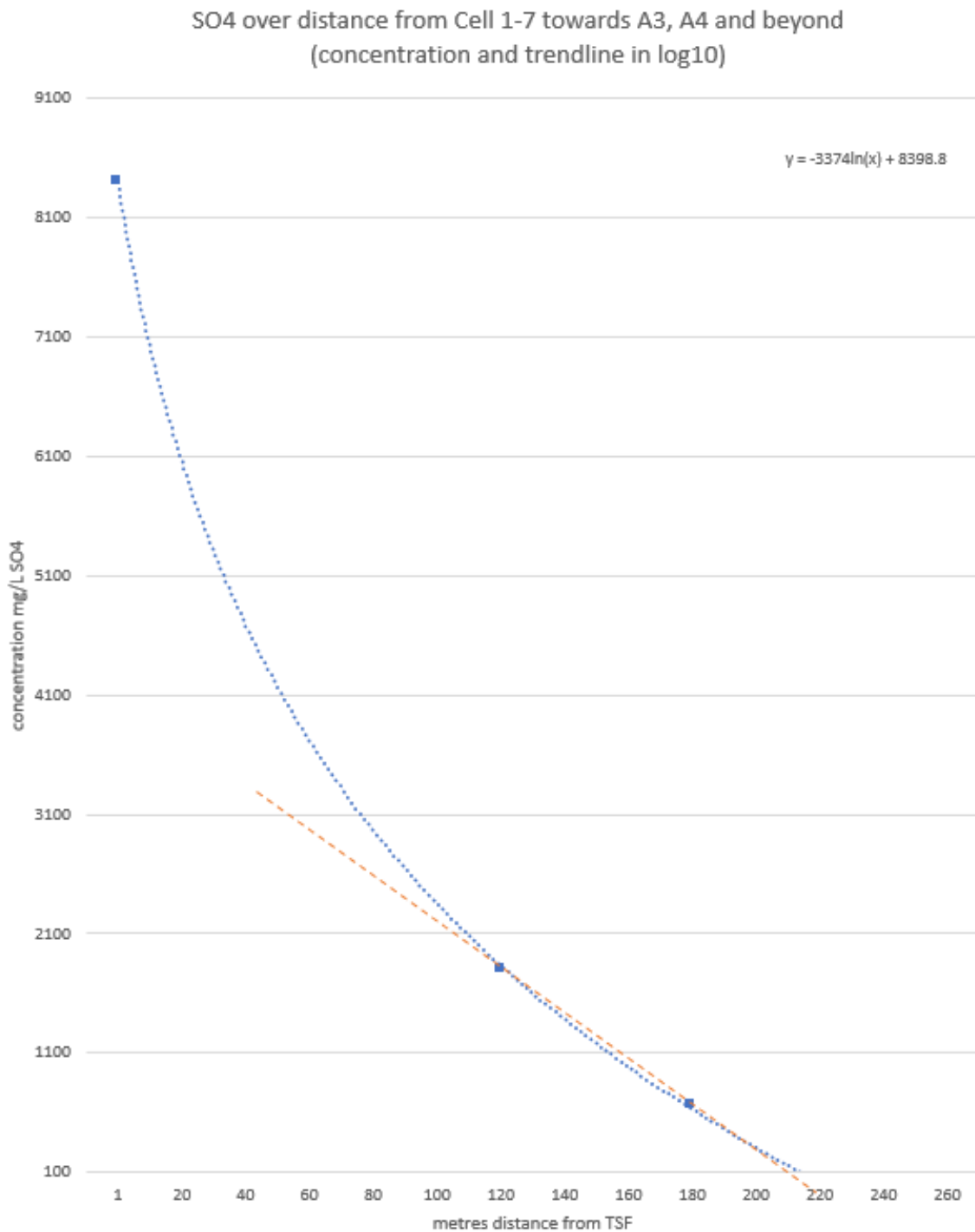


Figure 152 Decline of sulfate concentrations over distance (Cell 1-7 over A3 to A4, Model 7). Showing linear concentrations and linear reduction (in orange) and log10 trend reduction (in blue)

$$y = -3374 \ln(x) + 8398.8$$

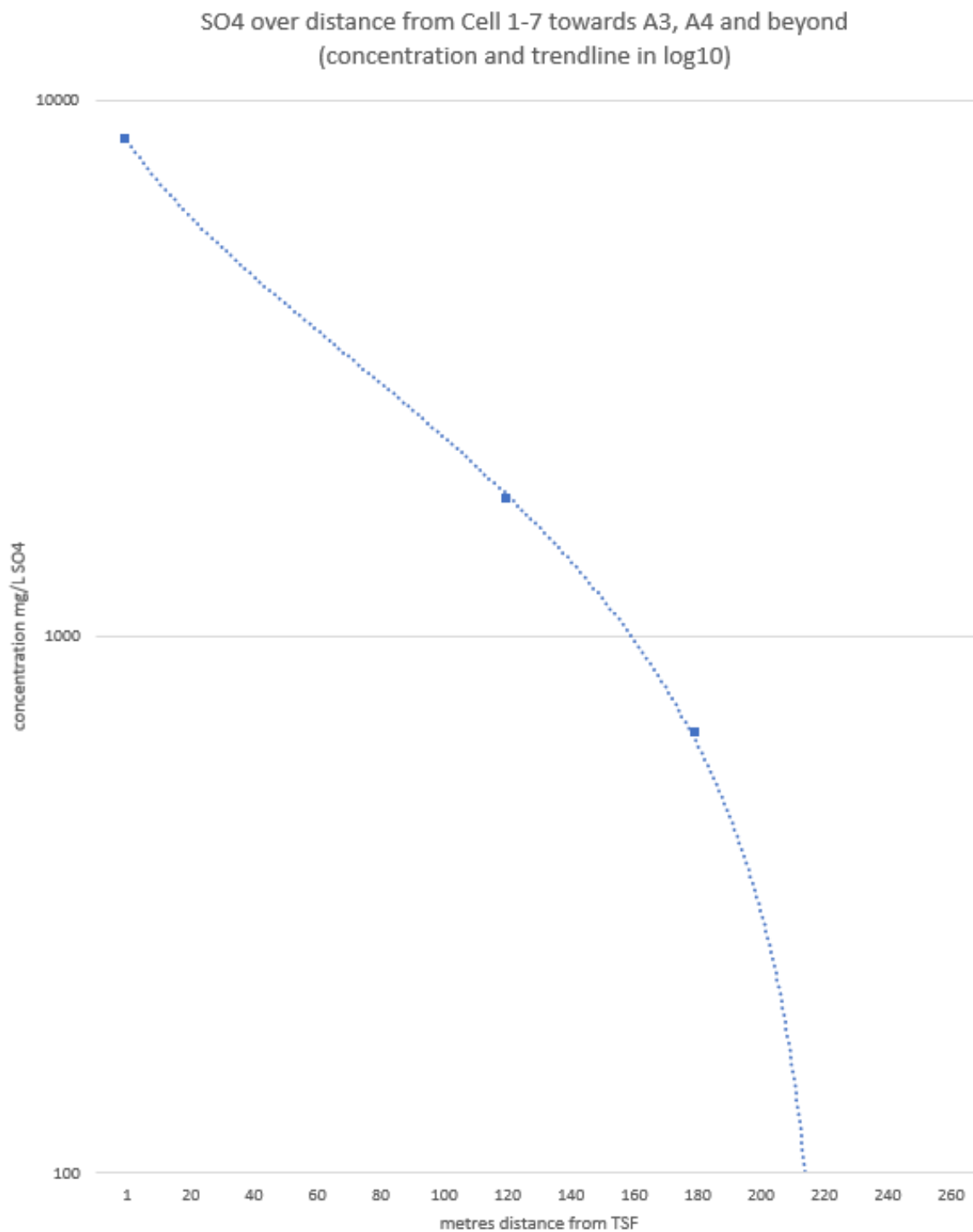


Figure 153 Decline of sulfate concentrations over distance (Cell 1-7 over A3 o A4, Model 7). Concentrations and decline trend in log10

11.5.8 Model 8

Modelled travel time for Model 8 was 11.4 years (V1 associated with underground tailings backfill to FWMB2 (9.3.4.1)). There is a possibility that FWMB2 has been impacted to an extent by underground tailings backfill. Similar to Model 4, this model is likely to have oversimplified the hydrogeological situation. This is due to the fact that multiple sources of water are involved and water levels being highly variable in the past. The screened intervals of V1 and FWMB2 are also installed at relatively different depths. Additionally, monitoring data for FWMB2 is limited to 2018-2019. Similar to V1, due to the number of sources involved, a calculation of sulfate migration rates between V1 and FWMB2 is not possible.

11.5.9 Model 9

A range of different aquifer materials were used in the model to attain a range of travel times for Model 9 due to the lack of hydraulic conductivity data for the Campaspe Formation (other than at shallow intervals, i.e. 0-2m depths). **Table 19** lists the results for different aquifer properties for gravel, coarse sand, fine sand and sandstone.

Table 19 Calculated travel times for different materials

Material	K (m/day)	Travel time V6A to C2	Travel time V6A to M
Gravel	2592	21 days	25 days
Coarse sand	518.4	107 days	128 days
Fine sand	17.28	8.8 years	10.5 years
Sandstone	0.5184	293 years	350 years

As no trends in sulfate or other impacts have yet been detected in C2 or M since monitoring began, gravel, coarse sand and fine sand were deemed unsuitable (too permeable). It is therefore (in the interim) more appropriate to take a range between fine sand and sandstone as the potential travel time between the modelled sites, i.e. 8.8-293 years (V6A to C2) and 10.5-350 years (C2 to M).

As with some of the other models, the limitation in this model is the uncertainty of the hydraulic conductivity. Even with a field-measured hydraulic conductivity at V6A, C2 and M, there would still be a high level of spatial uncertainty due to natural heterogeneity in the Campaspe Formation and the lack of monitoring bores between V6A and C2. High clay content, as that found in palaeochannel / borefield bores such as L, M, O, P etc., could impede groundwater flow from the mine and prevent contaminant transport.

Similarly, the thickness and clayey nature of the Campaspe Formation and the weathered bedrock would reduce the extent of seepage migration. However, the respective sulfate concentrations at C2 and production bore M are considered representative for the Campaspe Formation at these locations.

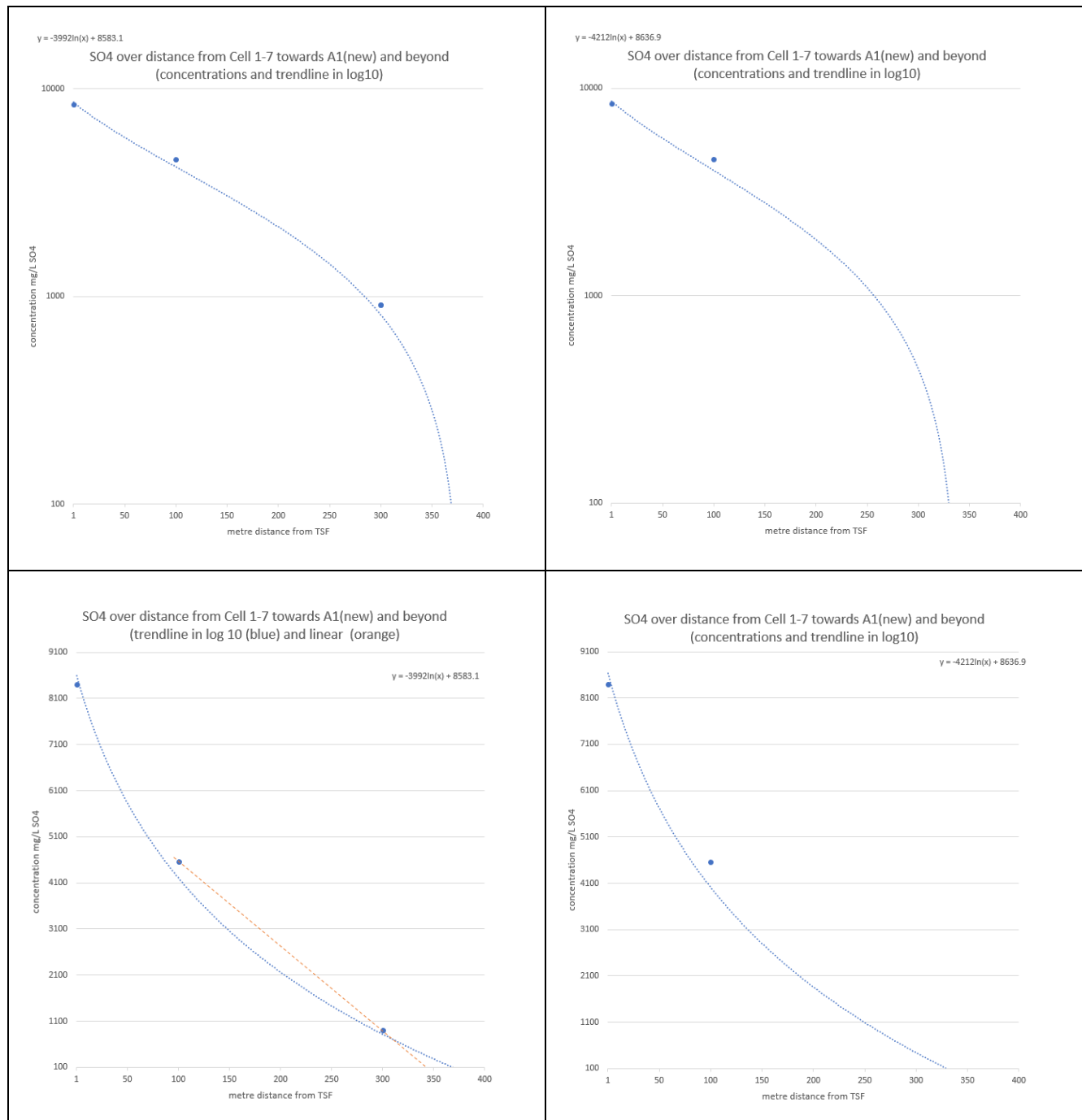
11.6 Sensitivity Analysis

To determine the validity and error of the calculated migration distances, the three-point models (Model 1 and Model 7 (Cell1-7)) were re-run using only two-point data configurations. As a smaller number of points will increase the uncertainty of the model output and a two-point re-run will allow for an estimation of that uncertainty.

11.6.1 Model 1

The comparison between the three-point model outcome and the modified two-point data configuration is shown in **Table 20**. The two-point data configuration in log10 and linear format suggest that background groundwater concentrations are reached at about 330m from Cell 1-7 as opposed to about 370m calculated with the three-point models, which represents a negative 10.8% deviation from the three-point model.

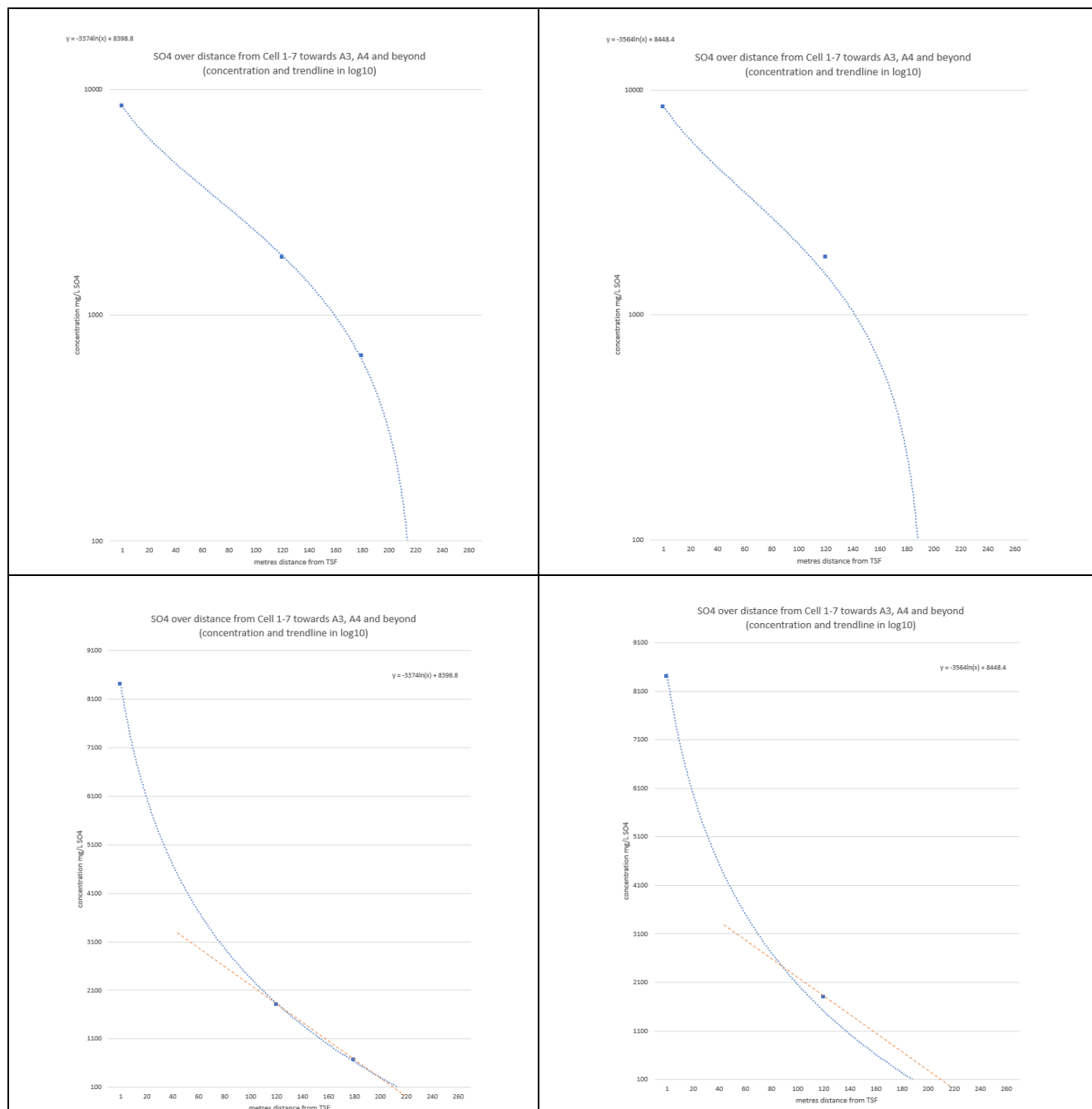
Table 20 Comparison between three-point model (left) and two-point data (right) for Model 1



11.6.2 Model 7 (Cell1-7)

The comparison between the tree-point model outcome and the modified two-point data configuration is shown in **Table 21**. The two-point data configuration in log10 and linear format suggest that background groundwater concentrations are reached at about 190m from Cell 1-7 as opposed to about 215m calculated with the three-point models, which represents a negative 11.6% deviation from the three-point model.

Table 21 Comparison between three-point model (left) and two-point data (right) for Model 7



11.6.3 Discussion

The outcome of the sensitivity analysis suggests a relatively small error potential of approximately negative 11% at a 33% reduction of available data (reduction from three to two data points). With regards to the outcomes of calculated two point models (Model 3(**Figure 149**), Model 5(**Figure 145**) and Model 6(**Figure 147**)), additional data points are likely to increase the predicted migration distance from their sources by approximately 25m, 40m and 15m respectively.

12 Summary

The results of the Environmental Evaluation of the Thalanga mine site identified historical underground backfill of tailings and excess process water discharge into mine voids as the most significant impact on the groundwater situation. The impacts are most prominent along the strike of the ore deposit and the underground workings. Past migration was aided by the interconnection of mine workings and the presence of potentially unrehabilitated and open exploration drill holes. Generally confined to the immediate vicinity of the mine workings and the mining lease, potential for migration of contaminants only exist along a bed rock corridor filled with Campaspe Formation sediments along the eastern section of the mine site. Groundwater level and quality records suggest that migration of contaminants along that bedrock channel has occurred during a period of artificially elevated groundwater levels in 2008 and 2009. Since then, dewatering of the Vomacka Pit, and subsequently the West 45 and Far West underground, has resulted in a reduction in groundwater levels on the mine site. As a result, the groundwater quality within the Campaspe Formation channel appears to be improving.

The impact of tailings seepage is generally localised and restricted to the vicinity of the TSF area. Migration is generally slow, controlled by the low hydraulic conductivity of the strata, low hydraulic head conditions and the adsorption of potential contaminants to clays and secondary iron minerals.

The results of the dewatering of the West 45 and Far West underground demonstrates the limited hydraulic conductivity of the ore deposit to its surrounds. Bores within the country rock- outside of the ore zone- do not experience groundwater level changes, while bores in the immediate vicinity- connected to the orebody- are dewatered. Current dewatering is seen as being beneficial with regards to potential seepage migration. As the situation at V1 and FWMB2 shows, low groundwater levels in the underground induce migration of contaminants towards the centre of the mine site and reduce potential for outward migration.

13 Recommendations

13.1 TSF seepage

To determine the natural state of the groundwater in the vicinity of the TSF, the drilling of two additional monitoring bores approximately 500m to the north and northwest of the TSF is recommended. Bores should be drilled through the shallow alluvium of the Campaspe Formation into the underlying bedrock. 500m to the east of the TSF the hard rock strata is overlain by about 40m of Campaspe Formation, which will not be representative of the natural state of the groundwater encountered by the TSF monitoring bores. Until the natural background composition of groundwater around the TSF has been established, the currently existing bores A3, TH5 and TH4 must be assumed impacted. Constantly exceeding EA trigger and contaminant limits for EC and sulfate, these bores could be removed from EA.

From a remediation perspective, seepage movement via capillary action is slow but diffuse, which limits its extent but also makes it difficult to effectively remediate within that extent. The example of A1 and A4 can help in visualising the problem. While groundwater at A1 and A4 appears impacted, recharge to these bores is very limited. Hence, conventional effective pumping back of seepage is not possible. Such pumping would have to rely on water levels to recover in order to be pumped out intermittently. The recovery of groundwater levels however is not desirable as this will allow potential seepage to migrate. Therefore, keeping groundwater levels low is the only effective solution to prevent migration past the pump back bores. Lowering of water tables for seepage interception will lead to an increase in hydraulic gradients, which may increase seepage migration towards the bores. Hence, the installation of pump back bores must in time be followed by effective capping of the final TSF structure to prevent recharge to the seepage source material. Only if the driving force of seepage migration (e.g. oversaturation of the TSF) is mediated can the effects of groundwater contamination be reduced, and groundwater will eventually return to its natural pre-mining state.

One way of reducing groundwater levels is the installation of a seepage interception pump back network (**Figure 154**). Such pump back network installation should be suitable for the depths and flow rates encountered around the Thalanga TSF.



Figure 154 Schematic outline of potential pumping back system at Thalanga, incorporating existing bores

Bores A3, TH5 and TH4 should be converted into pump back bores. The pump back system could be supplemented by four additional pump back bores installed along the linage of the system (**Figure 155**). The newly installed bores A1 and A4 have only been sampled for a short time period, hence further monitoring is necessary. In light of previous groundwater development at A1 (old) (

Figure 52) seepage from the TSF appears to have been reduced following the capping of TSF cells 3 to 6 in 1999/2000. Considering this, the newly installed bore A1 may also see an improvement in groundwater quality in the future. Alternatively, as the example of A1(old) shows, the capping of Cell 1/7, Cell 8 and Cell 9 would very likely reduce the need pump back bores.



Figure 155 Potential pump back bores alongside the existing TSF monitoring bores

13.1.1 Cost Estimate

Costings for a potential seepage interception system involves the drilling of six additional 18m deep monitoring bores and the instalment of the pumping and pipeline infrastructure. A detailed cost estimate has not been prepared at this stage, but potential expenditure has been estimated at approximately \$300,000.-.

Costings for a cover system for Cell1/7, Cell 8 and Cell 9 would be considerably higher. However, such capping would likely eliminate the need for a pump back system.

13.2 Underground Seepage

With regards to impacts of the underground, current operations resulted in a reduction of groundwater levels across the western side of the deposit. Groundwater levels along the eastern side of the deposit appear to have returned close to pre-mining equilibrium levels. Yet, the impact of previous high groundwater levels remains somewhat inconclusive. While some evidence for Campaspe Formation groundwater deterioration exists following the period of high groundwater tables in 2008, the bores reporting this deterioration are some distance from the mine site and not in the centre of the identified bed rock flow channel. Considering the above, a bore more specifically monitoring the depth of the identified bedrock channel leading towards the Campaspe Formation borefield would be beneficial in identifying potential seepage migration from the mine site in the future. It is hence recommended to install such bore at UTM 55K 373390mE and 7750700mS (**Figure 156**). This location represents the deepest section of the bedrock channel that underlies the Campaspe Formation, leading from the mine site towards the east (**Figure 12 in Appendix C**).

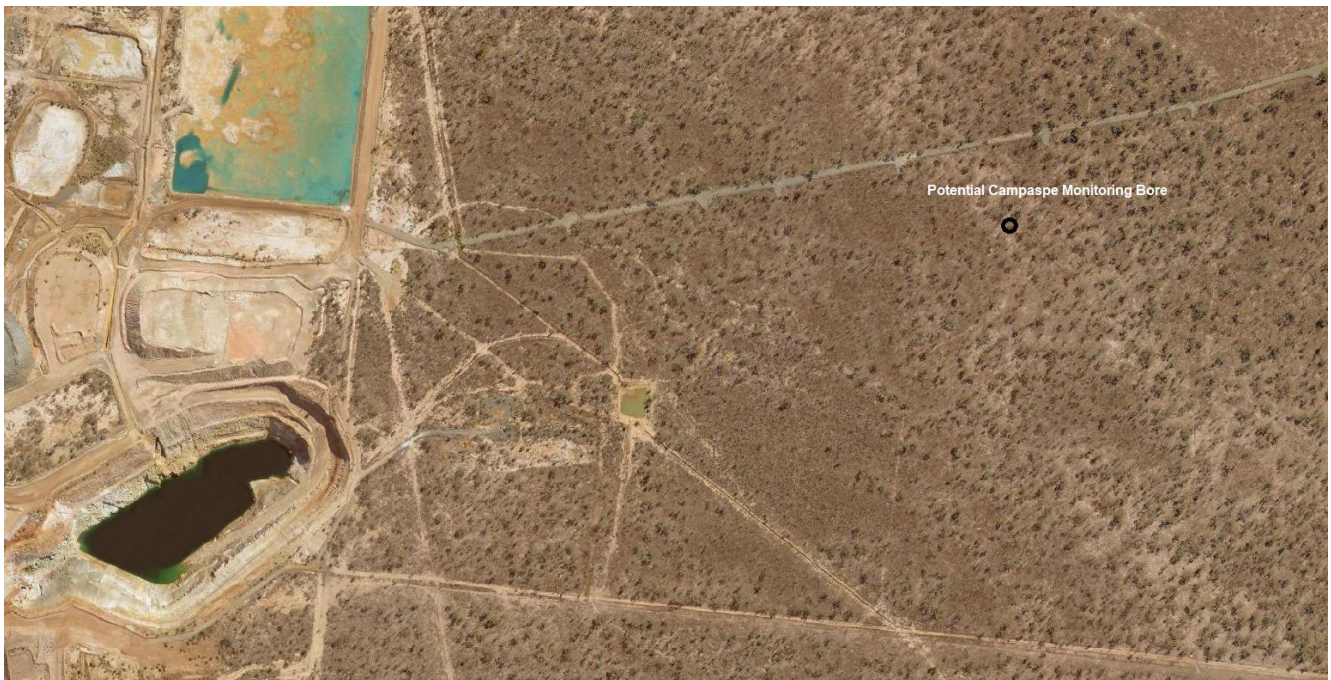


Figure 156 Location of potential Campaspe Formation paleo channel monitoring bore

13.2.1 Cost Estimate

The cost for one additional 70m deep monitoring bore within the centre of the Campaspe Bed channel has been estimated at \$25,000.-.

13.3 Review of Trigger Values

Eleven of the twenty-two current EA bores were installed to monitor either the rising water levels in the close vicinity of the historic underground (V1 to V7a/b (old)) or the progress of dewatering activities close to the West 45 underground (W45B1 to W45B4). These bores were purposefully installed to monitor groundwater levels within the ore-zone and not to monitor the impacts on the groundwater quality. Hence, changes in groundwater quality in these bores cannot be used as an indicator of environmental impacts on the surrounding environment. Their current use as impacted site bores and, in the case of V1, reference bore is not appropriate. With this in mind, trigger values and contaminant limits for these bores should be revised to reflect their initial purpose and location.

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APPENDIX A

Notice to conduct an Environmental Evaluation

APPENDIX B

Environmental Evaluation Design Document

APPENDIX C

Historical Aerial Photos and Figures of the Thalanga site

APPENDIX D

Map of Thalanga mine infrastructure

APPENDIX E

Geological cross sections through the Thalanga deposit

APPENDIX F

Groundwater levels of the Campaspe Formation monitoring bores 1995 – 2003

APPENDIX G

Campaspe monitoring bores SWL 1995-2003

APPENDIX H

Thalanga Central Pit dewatering records

APPENDIX I

Bore Logs

APPENDIX J

Old tailings dam bore chemistry results

APPENDIX K

Boxplots

APPENDIX L

Timeseries Graphs

APPENDIX M

Statistical Summary Table

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