SLR Consulting Australia Pty Ltd

Review of Hydrogeological Report

Factual Report

April 2020

Table of contents

Table index

Appendices

1. Introduction

1.1 Background information

Vista Gold owns the mining lease for the Mt Todd Gold Mine located approximately 60 km South East of Pine Creek and 56 km North East of Katherine in the Northern Territory. Vista Gold proposes to re-open and operate the Mt Todd Gold Mine.

The Mt Todd Gold Mine ceased mining operations in July 2000 with the last mining of the pit occurring in the 1990s.

A range of mining infrastructure remains on site, including:

- Tailing Storage Facility (TSF)
- Waste Rock Dump
- Waste Rock Dump Water Retention Pond
- Raw Water Supply Reservoir
- Runoff Retention Ponds
- Heap Leach Pad
- Low-Grade Ore Stockpile
- Various other processing facilities in various states of repair

The water balance model was developed by Tetra Tech in the United States of America in 2012 for Vista Gold as part of the pre-feasibility study for the Mt Todd Gold Mine.

Vista Gold has engaged SLR Consulting Australia Pty Ltd (SLR) to update the Water Management Plan (WMP) for the Mt Todd Gold Mine. As part of the update, the Department of Primary Industry and Resources (DPIR) has requested more detail on the review of the water balance model which was undertaken by GHD in 2017 as part of the Mt Todd Gold Mine Management Plan Project.

1.2 Purpose of this report

This report formally documents the independent review, completed by GHD, and subsequent amendments of the Hydrogeological Report on the Water Balance Model, completed in April 2017 by Tetra Tech, for the Mt. Todd Gold Mine.

This report will be used to inform the preparation of the updated Water Management Plan for the Mt Todd Gold Mine by SLR.

1.3 Scope and limitations

The scope is to produce a short factual report summarising the following:

- Findings from an independent review of documentation and correspondence in relation to the Tetra Tech hydrogeological report on the water balance model for the Mt Todd Gold Mine, and
- The points from the meeting between GHD, Tetra Tech and Vista Gold, which occurred in May 2017, to discuss the review and the required amendments to the report which were subsequently undertaken by Tetra Tech.

1.3.1 Disclaimer

This report: has been prepared by GHD for SLR Consulting Australia Pty Ltd and may only be used and relied on by SLR Consulting Australia Pty Ltd for the purpose agreed between GHD and the SLR Consulting Australia Pty Ltd as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than SLR Consulting Australia Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section(s) 1.4. of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by SLR Consulting Australia Pty Ltd and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has not been involved in the preparation of the Mt Todd Gold Mine Water Management Plan and has had no contribution to, or review of the Mt Todd Gold Mine Water Management Plan other than in the Review of Hydrogeological Report – Factual Report. GHD shall not be liable to any person for any error in, omission from, or false or misleading statement in, any other part of the Mt Todd Gold Mine Water Management Plan.

1.4 Assumptions

The following assumptions have been made based on the available information at the time this report was produced.

- The Water Balance Model has not been significantly revised or updated other than the addition and recalibration of the model based on minor input data such as routinely recorded seasonal data, since the time when the 2017 review was undertaken.
- The proposed mine plans including life of mine and the closure plan have not changed considerably from the plans used for the preparation of the water balance model and hydrogeological report in 2017.
- That the hydrogeological report was finalised prior to the copy supplied by SLR to GHD dated October 2019 (supplied as Appendix K to the Preliminary Feasibility Study Technical report)

2. Hydrogeological report on water balance model

Tetra Tech was engaged by Vista Gold to develop a water balance model and produce a report documenting the development of the water balance model as part of the Pre-Feasibility Study completed for the Mt Todd Gold Mine site.

Work undertaken on the water balance model was initially started in 2012, with the report on the water balance model completed in June 2013.

The purpose of the model is to develop a tool to simulate hydrogeological conditions associated with the different phases of operations that will occur at the Mt Todd Gold Mine site. These three phases are the present (steady state phase) conditions, active mining (mining phase), and post-mining (post-closure phase) conditions.

It should be acknowledged that, due to this being a brownfield/disturbed site, the present conditions do not represent natural background conditions.

In 2017, Vista Gold engaged GHD to prepare a Mine Management Plan (MMP) and the associated Environmental Management Plans (EMPs), including an updated Water Management Plan (WMP). As part of the development of the WMP the water balance model and the adjoining Hydrogeological report required review.

Vista Gold again engaged Tetra Tech to review and update the model and the hydrogeological report to incorporate the site data recorded since the initial development of the model. This work was completed in April 2017.

The above information sets the context for the independent review outcomes detailed in Section 3 below.

3. Independent review of model and report

Following the review and update of the water balance model and hydrogeological report, Vista Gold provided GHD with both the model and the report on 27th April 2017.

GHD staff as part of the development and updating of the WMP for the site completed a review of the water balance model and the hydrogeological report, the review was completed and a marked up copy of the report with proposed changes and questions was provided back to Vista Gold on the 8th May 2017.

Following this review Vista Gold arranged a conference call meeting between Vista Gold, GHD and Tetra Tech on the 9th May 2017 to discuss the review and address the questions raised in the review.

Tetra Tech reviewed the comments in the report and updated the report and model based on these comments and the discussion/s during the meeting between Vista Gold, GHD and Tetra Tech.

Tetra Tech provided Vista Gold and GHD with the revised report on 26th May 2017, the changes to the report from the review were assessed by GHD with approval of the changes and acceptance for the report to be finalised provided to Vista Gold and Tetra Tech on 1st June 2017.

The comments generated by the independent review of the model and report which were provided to Vista Gold and Tetra Tech for resolution and the amendments/responses to the comments is included in Appendix A for reference.

The email correspondence in relation to the independent review between Vista Gold, Tetra Tech and GHD is included in Appendix B.

The timing of the review process is summarised in Table 1.

Table 1 Review timeline

Date	Action	Company
27-Apr-2017	Hydrogeological Report completed and provided to Vista Gold and GHD	Tetra Tech
8-May-2017	Hydrogeological Report review completed and marked up copy provided to Vista Gold and Tetra Tech	GHD
9-May-2017	Conference call Meeting between Vista Gold, GHD and Tetra Tech to discuss report review	Vista Gold, GHD and Tetra Tech
26-May-2017	Revised report based on review comments and meeting discussions provide to Vista Gold and GHD.	Tetra Tech
1-Jun-2017	Revised report review completed and acceptance of revision provided to Vista Gold and Tetra Tech	GHD

4. Conclusion

An independent review was undertaken on the water balance model and the associated hydrogeological report produced by Tetra Tech as part of the Mt Todd Mine Management Plan project completed by GHD on behalf of Vista Gold in 2017.

The comments and queries arising from this review were provided back to both Vista Gold and Tetra Tech. A meeting between Vista Gold, GHD and Tetra Tech was held following this review to discuss the outcomes of the review.

The hydrogeological report was revised to address the comments and queries from the review, with the revised report supplied to Vista Gold and GHD.

A follow up review of the revised report was completed and the notice of acceptance of the revised report was communicated to Vista gold and Tetra Tech on 1st June 2017, with the report finalised subsequent to this communication.

Appendices

Appendix A – Review Comments and Responses

Report to:

VISTA GOLD CORP.

7961 Shaffer Parkway, Suite 5, Littleton, CO 80127
Phone: (720-981-1185)

Vista Gold Australia Pty Ltd

Mt Todd Gold Project
Hydrogeology
Northern Territory, Australia

PROJECT NO. 114-910547

DATE: JUNE 2013
REVISED: ~~APRIL~~MAY 2017

TETRA TECH
350 Indiana Street, Suite 500, Golden, CO 80401
Phone: 303-217-5700 Fax: 303-217-5705

TETRA TECH

VISTA GOLD

Report to:

VISTA GOLD CORP.

VISTA GOLD

Vista Gold Australia Pty Ltd

Mt Todd Gold Project
Hydrogeology
Northern Territory, Australia

DATE: ~~APRIL~~ MAY 2017

Prepared by	Keith S. Thompson	Date	~~April 21~~May 25, 2017
Reviewed by	Guy Roemer	Date	~~April 21~~May 25, 2017
Authorised by	Vicki Scharnhorst	Date	~~April 21~~May 25, 2017

TETRA TECH

350 Indiana Street, Suite 500, Golden, CO 80401

Phone: 303-217-5700 Fax: 303-217-5705

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

EXECUTIVE SUMMARY

Vista Gold Australia Pty Ltd (Vista Gold) proposes to re-establish and operate the Mt Todd Gold Mine, located 55 km north of Katherine, NT. This report discusses the hydrogeological aspects of the proposed mine site development.

The existing data were reviewed to identify data gaps. As a result, seven additional monitoring bores were drilled, eighteen additional short-term pumping tests were completed, and additional water levels and geochemical samples were collected. Further, a preliminary regional groundwater flow model was developed and calibrated. These data and tools were used to assess the potential impacts of the proposed mine development on groundwater resources.

Commented [TM1]: This I the work carried out back in 2012. What about reviewing and updating the model with data obtained since then?

Commented [CS2R1]: Vista Gold requested that we complete this report as a stand-alone report and not an update.

Alluvial deposits are limited to small-scale deposits in and around the creeks and river beds. Bedrock in the mine area consists of the Burrell Creek and Tollis Formations, which are locally subject to contact metamorphism (hornfelsed) by the Cullen Batholith. Where such contact metamorphism has occurred, the rock is relatively impermeable. The Batman Pit is located in metamorphosed (hornfelsed) rock; hence, there is typically expected to be very little groundwater recharge or discharge through the walls of the pit. East of Batman Pit, the rock becomes less metamorphosed and has a higher hydraulic conductivity. The approximate location, geometry and extent of the transition zone can be estimated from drilling and hydraulic testing performed over the last ~~25~~ 29 years of investigation in the Project area.

Commented [TM3]: Overall, but should be noted that at times or in certain locations notable discharge/recharge could occur due to fracturing and faulting present within the bedrock.

Commented [CS4R3]: See edits.

Commented [TM5]: 25 changed to 29

Commented [CS6R5]: Agreed.

Groundwater chemistry data indicate that leakage from some of the existing surface water impoundments at the mine site has resulted in localised groundwater contamination. New water-retaining structures such as the proposed TSF2 ~~will be~~is designed to limit leakage to the underlying groundwater system~~. Groundwater bores currently discharging contaminated groundwater to surface should be modified to prevent discharge or rehabilitated prior to the proposed mine site development~~.

Commented [TM7]: Has this design taken place? If so, this requires changing

Commented [TK8R7]: Design exists

Commented [TM9]: From an environmental stand point this should be done ASAP even if the site is not developed.

Commented [TK10R9]: Get more info from Vista Gold.

Groundwater chemistry data have indicated that 'background' or 'boundary' bores have elevated metals (and metalloids) typical of mineralised areas and that local groundwater is not suitable as a potable supply without further treatment. The groundwater chemistry data collected provide background water quality for the proposed mine site development.

Drawdown of the local aquifer associated with the proposed development is not likely to have a significant impact on the local groundwater flows into the Edith River or to neighbouring groundwater supply bores at Werenbun and Leliyn (Edith Falls).

Commented [TM11]: Removed new paragraph starting mid Edith

Commented [CS12R11]: Agreed.

The proposed Batman Pit deepening and enlargement are likely to result in a terminal sink pit lake with a water level significantly below the surrounding land surface. The steady state pit lake water level elevation is predicted to be approximately -15 m AHD. This is expected to prevent outward migration of pit lake water into and though the aquifer. Evaporation from the pit lake will cause the dissolved constituents in the water to concentrate over time, forming a brine.

1.0 INTRODUCTION

Vista Gold Australia Pty Ltd (Vista Gold) proposes to re-open and operate the Mt Todd Gold Mine (Project), which is located approximately 55 km north of Katherine, NT (Figure 1-1). The Project area is located in a historical mining district and is a brownfield/disturbed site. It was last mined in the 1990s, and mining operations reportedly ceased in July 2000. Mining infrastructure remaining on-site includes a tailings storage facility, a low-grade ore stockpile, a waste rock dump, waste rock dump retention pond, a heap leach pad, a raw water supply reservoir, runoff retention ponds, and other processing facilities in varying states of repair (Figure 1-2).

This report is intended to:

- identify the current hydrogeological conditions,
- summarise the existing data sets,
- summarise efforts made by Vista Gold and its consultants to fill data gaps,
- set forth a viable conceptual model for the Project area that considers both regional and local geologic and hydrogeologic information,
- describe the current numerical groundwater flow model for the Project area, and
- describe the model-predicted impacts of the mining effort on groundwater resources in the Project area, including extent of drawdown, groundwater inflow rates into the pit, and pit infill rates after mine closure.

The numerical groundwater flow model was used as a tool to simulate hydrogeologic conditions associated with the present (steady state) conditions, active mining (mining phase), and post-mining (post-closure) conditions. It is acknowledged that the present conditions do not represent natural background conditions due to the presence of the existing Batman Pit and mining infrastructure. The model extent is shown on Figure 1-3.

This report also provides background information to be used in assessing the potential for groundwater and surface water impacts from the proposed mining activities and existing infrastructure.

Commented [TM13]: What about the recent review? Any update/change should be included in this report update

Commented [TK14R13]: This was to be a new report, revised from the old, not an "update.".

Commented [TM15]: Update?

Commented [CS16R15]: See prior response.

Commented [TM17]: Was this reviewed as part of the model review?
If it was reviewed and found to still be appropriate then a mention of this should be made.

Commented [CS18R17]: Yes, this was reviewed, but since this is a stand-alone report, we would not state that.

Commented [TM19]: Isn't this what is said to be covered in this report in the last dot point above?

Commented [CS20R19]: The prior bullet discussed model results; this sentence discusses the background information we used to develop the model.

Figure 1-1: Project Location

Figure 1-2: Facility Layout

Figure 1-3: Model Extents

2.0 PROJECT DESCRIPTION

The Mt Todd Gold Project has several proposed aspects that are relevant to hydrogeology:

- deepening of Batman Pit to a final elevation of -340 metres Australian Height Datum (m AHD);
- expansion of the existing waste rock dump (WRD) to a final elevation of approximately 470 m AHD and area of approximately 218 hectares (ha);
- raising the existing tailings storage facility (TSF1) by 18 m to a final elevation of 158 m AHD; and
- creating a new tailings storage facility (TSF2) that will be approximately 55 m in height with an area of 300 ha.

A local clay borrow area is anticipated to be needed, as well. However, preliminary information indicates that the clay borrow area is unlikely to impact hydrogeology significantly, since the local clay deposits are shallow enough that excavation is unlikely to reach groundwater. Hence it is not discussed further in this document.

3.0 LEGISLATIVE FRAMEWORK

Relevant Legislative Framework to the hydrogeology of the project includes:

- Water Act 1992

The *Water Act 1992* covers allocation, use, control, protection and management of NT water resources. Pollution under the Act includes directly or indirectly altering the physical, thermal, chemical, biological or radioactive properties of water so as to render it less fit for a prescribed beneficial use for which it is or may reasonably be used, or to cause a condition which is hazardous or potentially hazardous to public health, safety and welfare and animals, birds, fish or aquatic life or other organisms; or plants.

- Australian Drinking Water Guideline (NHMRC and NRMMC, ~~2004~~2016) and Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, 2000)~~[1]~~

The current water quality guidelines for drinking water (NHMRC and NRMMC, ~~2004~~2016) and irrigation, livestock watering and aquatic ecosystems, Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, 2000) provide a critical framework for regulators, managers and the community (GA, 2011).

The EIS guidelines for the Mt Todd Gold Mine (NRETAS, 2011) also provide the specific framework for this report.

Commented [TM21]: Most recent guidelines published in 2011, as noted in footnote below. Since, there has been an update to these guidelines in 2016.
At least the 2011 guidelines should be referred to here with a note identifying any changes to the results as a result of the new guidelines.

Commented [TM22R21]: Relevant change addressed in section 4.10.2.
Footnote below should specify version 1 of this report used the 2004 guidelines and this report uses the 2011 guidelines, with the difference noted where appropriate.

Commented [CS23R21]: Footnote removed; references updated.

~~[1] Since the draft report, the 2004 ADWG have recently been superseded by the 2011 guidelines. Any changes to the results will be reported separately.~~

4.0 EXISTING ENVIRONMENT

4.1 LOCATION

The site of the Mt Todd mine is about 55 km north of Katherine, NT, as illustrated in Figure 1-1. The Edith River runs from east to west and is located directly south of the site. There are a number of ephemeral creeks that originate in the rocky hills around the site, as shown on Figure 1-2. The creeks within the area shown on Figure 1-2 enter the Edith River or flow into Stow Creek, which enters the Edith River.

Figure 4-1 shows regional topographic features surrounding the Project area. For reference purposes, the numerical model boundary is also indicated on Figure 4-1. The existing Batman Pit lies on the eastern flank of the Yinberrie Hills. The Arnhem Plateau forms uplands several kilometres east of the Project site. Within the Project site, the topography slopes down toward the Edith River in the south and toward Stow and Horseshoe Creeks in the east. The Edith River originates to the east on the Arnhem Plateau, in the Nitmiluk National Park. Stow and Horseshoe Creeks are two of the numerous ephemeral creeks originating on the low rocky ridges surrounding the Project area. Higher areas north of the Project area form a drainage divide between the Edith River to the south and Driffield Creek on the north. Both Driffield Creek and the Edith River ultimately flow westward toward the Ferguson River.

Figure 4-1: Regional Topography

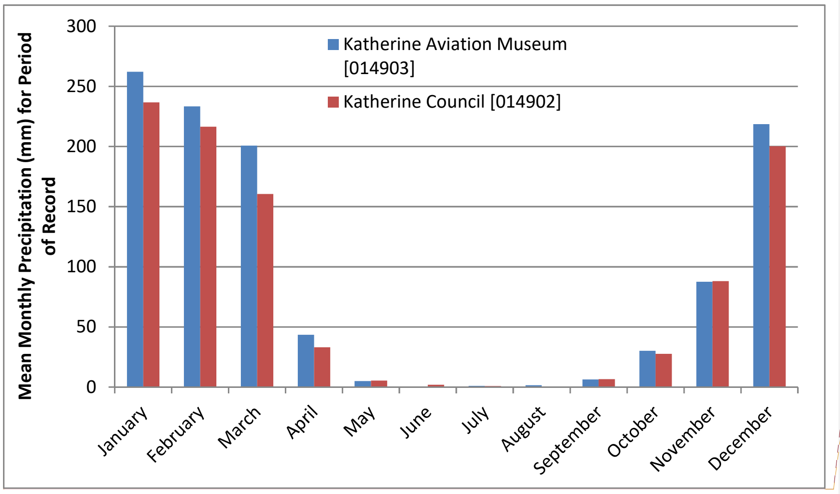
4.2 CLIMATE SUMMARY

4.2.1 PRECIPITATION

Precipitation data in the region are available from the Australian Government Bureau of Meteorology (BOM) for the Katherine Council (BOM Station No. 014902) starting in 1873 and the Katherine Aviation Museum (BOM Station No. 014903) starting in 1943 (BOM, 2017). Mean monthly precipitation for those stations is shown in Figure 4-2. The mean annual precipitation for these periods of record are 971.2 mm at the Katherine Council station (1873 to 2017) and 1142 mm at the Katherine Aviation Museum station (1943-2017). Precipitation varies seasonally, with little precipitation during the dry period from May through September and more frequent, larger precipitation events from October through April. The larger events are typically associated with tropical cyclones.

Commented [TM24]: 1141.8 mm

Commented [CS25R24]: Rounded to 1142.



Commented [TM26]: Is it necessary to include Katherine council weather station? This station is no longer used. The aviation museum is also no longer used having been replaced by the Katherine country club weather station in 2012.

Commented [CS27R26]: The Katherine Council and Katharine Aviation Museum stations are both still in use and have a longer period of record.

Figure 4-2: Mean Monthly Rainfall in Katherine Area, 1873-2017

Precipitation data are available for the Project site from a period of record that includes 1993-2006 and 2008-2017. The mean monthly precipitation at the site for that period of record is shown in Figure 4-3. For comparison, the figure includes data from the Katherine Aviation Museum station for the same period of record. The average annual precipitation measured at the site is 1276 mm; that is slightly higher than the average annual precipitation of 1123 mm at the Katherine Aviation Museum station during the same period (1993-2006 and 2008-2017). In calculating the monthly averages, daily data that were missing for one site were omitted for both sites.

Commented [TM28]: Where is this data? Only the recent data since the installation of a weather in October 2011 has been provided separately

Commented [TK29R28]: We received the referenced data from Vista Gold, and the data are in the project record.

Commented [TM30]: Need to confirm this figure

Commented [TK31R30]: I'm pretty sure this was QC'd and okay.

Commented [CS32R30]: Confirmed.

Commented [TM33]: Different to the rainfall level above.

Commented [TK34R33]: Yes, the values are for different time frames. CLARIFY IN REPORT.

Commented [CS35R33]: See added text noting the dates to which the values apply.

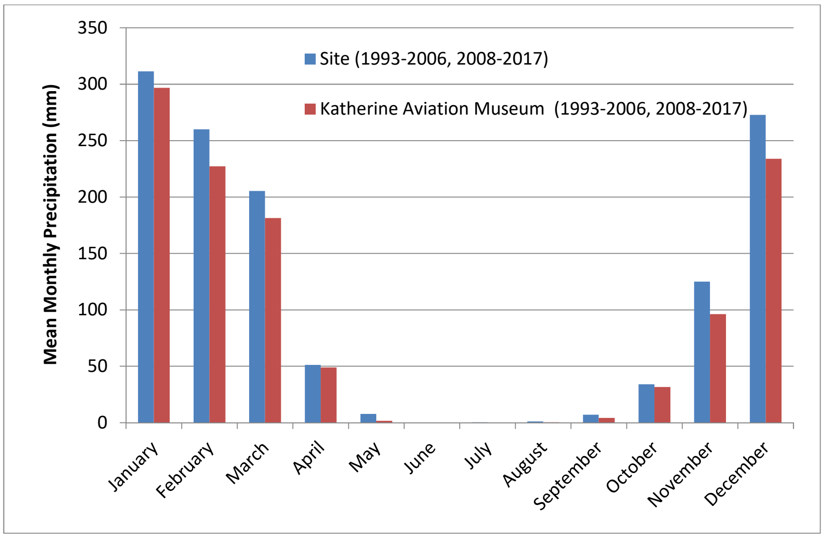


Figure 4-3: Mean Monthly Rainfall at Project Site and Katherine Area, 1993 to 2017

The GA-CSIRO (2013) MapConnect website provided point estimates of average annual precipitation at two locations within the Project site (1057 mm and 1044 mm) and the BOM (2017) website provided a point estimate at a location along the Edith River within a few kilometres southeast of the Project site (1244 mm).

4.2.2 TEMPERATURE

BOM (2017) data for the Katherine Council station (014902) indicate mean monthly maximum temperatures ranging from 29.9°C in June to 38.0° in November. Reported mean monthly minimum temperatures there ranged from 13.2°C in July to 24.7°C in November. The period of record for the temperature data is 1937 to 1985. The Tindall Raaf station (014932) is located about 15 km from the Katherine Council station and has data from 1985 to 2017. The mean monthly maximum temperatures during that recent time period ranged from 30.0°C in June to 37.6° in October, and the mean monthly minimum temperatures ranged from 13.6°C in July to 25.0° in November.

Commented [TM36]: What about the recent temperature data from the aviation museum?
Also only January 1985 was recorded

Commented [TK37R36]: UPDATE IF POSSIBLE

Commented [CS38R36]: There is nothing after 1985. The Tindal Raaf station is the only one nearby that still collects temperature data, and it only has from 1985 to 2017. See additions to text.

Commented [TM39R36]: Katherine Aviation Museum started recording temperature data consistently from 1989 until late 2011 and then the Katherine Country Club started from 2012 until present.

4.2.3 POTENTIAL EVAPOTRANSPIRATION

Potential evaporation from a water body in the full sun is very high in the Project area. Based on the GA-CSIRO website (2013), potential evapotranspiration would be expected to average around 2385 mm/yr in the Project site vicinity, more than double the precipitation. More recent data from the BOM (2017) indicate an average of about 2050 mm/yr.

Evapotranspiration is related to vegetation density and type, among other factors. Areas with greater vegetative density (numerous trees and in some cases green grasses) were observed primarily around ephemeral and perennial streams and water bodies. Aerial photography and anecdotal observations of increased alluvial thickness near streams indicated that the vegetation in drainages is likely taking advantage of the water availability and better soil.

Pan evaporation has been measured at the Project site since 1993; however, data collected between approximately 2007 and 2014 are not considered reliable due to the location of the pan evaporation station and surrounding infrastructure. Three additional pan evaporation ~~locations~~ stations were installed in October 2014 and provide data through ~~February~~ May 2017. Average annual pan evaporation from these stations in 2015 and 2016 ranged from ~~2446~~ 2485 mm to ~~2638~~ 2659 mm and averaged ~~2526~~ 2565 mm; this recent annual average compares well with the historic average annual estimate of 2582 mm based on 1993-2006 pan evaporation data.

Commented [TM40]: Need to confirm these levels

Commented [RG41R40]: Updated with new evaporation file provided by Vista Gold.

4.2.4 NET RECHARGE

Typically, recharge would be expected to vary with factors such as slope, ground cover, vegetation, and soil type. The GA-CSIRO (2013) website estimated groundwater recharge using their Method of Last Resort (MOLR) recharge calculation. The MOLR recharge incorporates the influence of generalised soil type, generalised vegetation type, and annual rainfall. The Project area was categorised as having a tenosol soil type and perennial vegetation. The average estimated MOLR recharge for the Project area was 13.8 mm/yr based on the average of 14 data points in the Project area, with an uncertainty range of 0.70 to 272.66 mm/yr. However, better estimates of recharge can often be obtained via model calibration.

Although the site receives over a metre of precipitation on a yearly basis, anecdotal evidence from both Vista Gold and Tetra Tech field personnel indicates that most precipitation does not infiltrate into the ground. Rather, it runs off (often as sheet flow) into the nearest drainage. The vegetation density across most of the Project area is low enough that it does not impede the flow of water into the drainages. The drainages quickly fill to flood stage and drain to the nearest river. Based on observations related to the occurrence of vegetation with respect to surface water bodies, recharge is best conceptualized as net recharge, which includes the effects of water removal via evapotranspiration.

4.3 GEOLOGICAL SETTING

Information regarding the geological setting at Mt Todd was obtained from the Edith River Region 1:100,000 Geology (Needham et al., 1989) and Katherine 1:250,000 Geology (Sweet et al., 1994) and its explanatory notes (Kruse et al., 1994). Figure 4-4 is a generalised geologic cross-section through the mine area. Brief descriptions of the units encountered near the Project area are shown below.

- **Alluvial deposits** (Cenozoic) occur as small-scale deposits in creeks and river beds and on low-lying areas adjacent to the Edith River.

- **Kombolgie Formation** (Paleoproterozoic) is a massive sandstone that forms the Arnhem Plateau east of the site and overlies the Edith River Group.
- **Edith River Group** (Paleoproterozoic) includes the Plum Tree Creek Volcanics and the Phillips Creek Sandstone.
- **Cullen Batholith** (Paleoproterozoic) units include the Yenberrie Leucogranite, Driffield Granite, and Tennysons Leucogranite. The Cullen Batholith underlies the entire project area at depth, and its intrusion resulted in the metamorphism of the older Finniss River Group formations and the uplift of the Yinberrie Hills just west of the mine site.
- **Finniss River Group** (Paleoproterozoic) formations comprise much of the bedrock in the Project area and are folded and fractured metasediments with a fairly thick weathered zone at the surface. The Finniss River Group includes the Burrell Creek Formation and the Tollis Formation, both of which contain greywacke, phyllite, slate, and siltstone lithologies. These formations have experienced significant contact metamorphism due to the intrusion of the Cullen Batholith units.

In this report, the Burrell Creek and Tollis Formations are grouped together due to their similarity both geologically and hydrogeologically and are referred to as BCTF. Figure 4-5 provides a generalized geologic map of the area, modified from the 1:250,000 map (Sweet et al., 1994). The numerical model boundary has been marked on it for reference purposes.

Figure 4-4: Generalised Geologic Cross-section

Figure 4-5: Generalised Geologic Map

4.4 HYDROGEOLOGICAL SETTING

4.4.1 PROTECTED BENEFICIAL USES

In 1999 the Katherine Area groundwater, which includes the Project area groundwater, was declared to have beneficial uses of raw water for drinking water, raw water for agriculture, and raw water for industrial purposes (NRETAS, 1999). The surface water in the Edith River and its tributaries in the Project area has a declared beneficial use for aquatic ecosystem protection (NRETAS, 1997).

4.4.2 GROUNDWATER RESOURCE UTILISATION

The Northern Territory Department of Environment and Natural Resources NR MAPS website (NTDENR, 2017) indicated the presence of five groundwater bores within about 10 km of the Project site, not counting the bores installed for camp and mining water supply at the Project site in the past (Appendix A). These five bores, of which four are indicated to be production wells, are shown in Table 4-1. One bore at the mine site, BW6P (RN026131), is currently used for groundwater production.

Table 4-1: Bores on Neighbouring Properties (NTDENR, 2017)

Bore name	Owner	Usage	Bore report number	Depth to water (m)	Date of water level	Bore depth (m)	Screen depth
Edith Falls	Conservation Commission	Production	RN024418	5.7	19/7/1986	45	33 to 45
1/93	Werrenbun Outstation	Production	RN028738	11.6	2/9/1993	55.5	50 to 52
Edith Falls Site A	Transport Land Works	Not used	RN032152	9.4	20/5/1999	50	abandoned
Edith Falls Site B	Transport Land Works	Production	RN032153	9.6	20/5/1999	50	37 to 43.5
Jawoyn Aboriginal Land Trust	Parks and Wildlife John King	Production	RN036978	5	9/3/2010	49	41 to 43

4.4.3 BACKGROUND HYDROGEOLOGY

Existing reports and ~~recent~~ field work by Vista Gold's consultants were used to evaluate the hydrogeological setting. Primary sources of information included:

- Draft EIS Appendix K (GHD, 2012) and associated field efforts by GHD. These field efforts included water level collection and collation, groundwater sampling, photographs, and bore installation and testing.

Commented [TM42]: Recent?
All reports are from 2012 or older.
Only work by Vista Gold Staff is recent.

Commented [CS43R42]: See edit.

- Field efforts by Vista Gold on-site personnel. These included raw surface water and weather data collection and a physical bore inventory (Vista Gold, 2011 and 2017).
- NT government online resources. These included weather and climate data, boring logs and records, water levels, beneficial water use determinations, and other similar information.
- Rockwater Consulting reports (1988, 1989, and 1994). These reports contained original boring logs and aquifer test records.
- Power and Water Authority hydrogeologic evaluation (1989). This report included qualitative descriptions of the hydrogeologic features of the local formations and helped provide a conceptual framework.

This information was used to develop a conceptual groundwater flow model and then a numerical groundwater flow model. The numerical groundwater flow model was used to assess the potential hydrogeological impacts of the proposed Mt Todd Gold Project.

4.4.4 Conceptual Groundwater Flow Model

The conceptual model of groundwater flow is a fractured rock aquifer with a thick weathered zone. In general, flow in the aquifer is away from recharge areas and toward groundwater discharge areas. For the most part, streams in the area act as the discharge points, and topographic highs and anthropogenic surface water impoundments act as recharge areas. Thus, groundwater flow is generally toward the local streams and drainages where the groundwater can discharge into the drainage, and the potentiometric surface generally follows topography. Thus, water originating in the vicinity of the mine and its infrastructure would be expected to migrate offsite, likely as discharge into surface water.

The path groundwater follows through the Project area is influenced by the regional groundwater gradient and the hydraulic conductivity of the materials in the area. The local flow direction is influenced by differences in recharge, local topography, and local hydraulic conductivity. In addition, any project-related pumping will influence the local flow direction.

The regional groundwater gradient in the Project vicinity is toward the southwest. The groundwater flow direction generally follows topography. Regionally, topography slopes away from the Arnhem Plateau in the Nitmiluk National Park. The Edith River has its source in the Arnhem Plateau and flows generally west-southwest toward the Ferguson River. Regional groundwater flow follows the same trend~~, generally moving toward the west-southwest~~. Local features such as surface water impoundments are not expected to have a regional effect.

The primary fractured rock unit through which groundwater flow occurs in the Project area is the BCTF. Where the BCTF has been contact-metamorphosed by the local intrusions of the Cullen Batholith units, it is relatively impermeable. The Batman Pit is located in metamorphosed (hornfelsed) BCTF; hence, there is expected to be very little groundwater recharge or discharge through the walls of the pit. East of Batman Pit, the BCTF becomes less metamorphosed and has a higher hydraulic conductivity. The approximate location, geometry and extent of the transition zone can be estimated from drilling and hydraulic testing performed over the last ~~25~~29 years of investigation in the Project area. Some of the

Commented [TM44]: Repetition occurs, requires restructuring.

Commented [TK45R44]: OK as is.

Commented [TM46]: Repetition of first sentence.

Commented [CS47R46]: See revision.

Commented [TM48]: Changed 25 to 29

Commented [CS49R48]: Agreed.

surface water impoundments, such as TSF1 and the Raw Water Supply Reservoir, are located in the less-metamorphosed area of the BCTF and act as recharge features. In addition, acidic and metalliferous drainage (AMD) from TSF1 appears to be seeping through and under the embankment to discharge at the surface.

The weathering profile is hydrogeologically significant in the Project area. Based on examination of numerous boring logs, the top 3 metres (m) of material is generally completely weathered, very highly fractured, or unconsolidated. Alluvium often extends somewhat deeper than 3 m below streambeds. Weathering of the bedrock is generally observed down to about 25 to 30 m below land surface (bls). In borehole logs, weathering is often associated with increased fracturing, infilling of fractures with clay or mineralization, or oxidation. The degree of weathering decreases with depth.

The alluvium and uppermost weathered portion of bedrock have the potential to transmit significant water, especially during rain events. However, they are generally unsaturated except in the immediate vicinity of the local streams and surface water bodies. Also, the infilling and mineralization along fractures in the weathered zone above 30 m depth has the potential to cause a decrease in their transmissivity. Thus, the primary flow zone was observed by prior hydrogeologists to be approximately 30-70 m below the land surface in the BCTF (Rockwater, 1988 and 1989).

4.4.5 HYDROLOGY

The natural hydrology of the Project site is dominated by the Edith River and its tributaries. The Edith River is considered ~~to be~~ a perennial stream. The Edith River stream gauge has had recorded measurable flow approximately 70 percent of the time. During dry years, the river bed has been observed to go dry; however, even when the surface flow is not measurable, there is subsurface flow through the underlying alluvium. The denser vegetation along the Edith River appears to require either perennial surface water or subsurface flow in the alluvial deposits. The creeks feeding the Edith River are clearly ephemeral in nature.

Commented [TM50]: Removed “to be”

Commented [CS51R50]: Agreed.

Another aspect of hydrology in the Project area is the presence of anthropogenic water retention facilities. Of the anthropogenic water retention facilities, several are potentially significant. These are labelled on Figure 1-2 and described briefly below.

- *Batman Pit* – The existing Batman Pit (also called RP3) partially filled with water subsequent to mine closure in 2000. By late 2004, water had reached an elevation of approximately 75 m AHD, based on available photographs (NT Department of Mines and Energy, 2013). The vast majority of the water accumulation is believed to be due to rainfall within the pit and its catchment area. In addition, since 2005 Batman Pit has been used for temporary storage and treatment of ~~acid~~Acidic and Metalliferous~~ rock~~ D~~d~~rainage (~~ARD~~AMD) (MWH, 2006). In the past, it has received water from RP1 and several other water retention areas at the mine site as needed. In-situ treatment of the Batman Pit water has been conducted by use of limestone and quicklime (Vista Gold, 2016) since late 2012, with the goal of producing water that can be discharged at rates that continue to protect the quality of the Edith River. Current site conditions route water such that the Batman Pit receives primarily fresh water (Vista Gold, 2016). Batman Pit is a potential source of groundwater recharge, but the low hydraulic

Commented [TM52]: Can this be changed to Acidic and Metalliferous Drainage (AMD)?

Commented [CS53R52]: Revised.

conductivity of the rock limits interaction between groundwater and the pit waters. During mining, the pit will be dewatered and deepened and will act as a groundwater sink.

- *TSF1* – The original tailings storage facility (TSF1, also called RP7) contains a significant depth of water. During mine operation, it received drainage from the waste rock dump (WRD). It was also used from approximately 2000 to 2006 to receive water from the W~~w~~aste R~~r~~ock D~~d~~ump water retention pond (RP1), until that water was redirected to the Batman Pit (MWH, 2006). In addition, TSF1 receives inflow from rainfall on its surface. TSF1 has an underdrain system; however, the underdrain system was deactivated at some point after mining ceased in 2000. Seepage from TSF1 occurs through and/or beneath the embankment (via the historic bed of Horseshoe Creek), based on field observations, geophysical survey results, and surface and groundwater quality data (Earth Systems, 2012). In addition, TSF1 allows some water to infiltrate through its base directly into bedrock (Earth Systems, 2012). TSF1 acts as a groundwater recharge source and is expected to do so during the first five years of mine operations, when it will received tailings, and for some time afterward as it drains following the redirection of the tailings to the proposed new tailings storage facility (TSF2). Ultimately, when the tailings have drained after TSF1 closure, TSF1 is expected to cease being a groundwater recharge source.
- *RP1* – The W~~w~~aste R~~r~~ock D~~d~~ump water retention pond (RP1) receives runoff from the catchment that drains the WRD. Some of the runoff is AM~~R~~D from the WRD, which is ~~used to be~~ pumped to TSF1 during ~~mine operation~~this closure period. Currently, excess water from RP1 is not pumped back to Batman Pit. RP1 is not lined and is a source of groundwater recharge.
- *Raw Water Supply Reservoir* – The Raw Water Supply Reservoir resulted from damming of a tributary of Horseshoe Creek northeast of TSF1. It is used to supply mine water needs and acts as a source of groundwater recharge.
- *Golf and Tollis Pits* – Former mining activities resulted in the Golf and Tollis Pits, which both contain small pit lakes. These pits are located north of Batman Pit and directly west of TSF1. Water levels are within 5 m of ground surface and appear to decant after high rainfall (GHD, 2012). These historic mine pits may act as a minor source of groundwater recharge.

Other ponds at the mine facility are lined and/or quite small, so they are not expected to have a significant effect on the local hydrogeology. The new proposed tailings storage facility (TSF2) will be lined and is not expected to contribute to groundwater either as a recharge or discharge point. However, I~~I~~t will~~, however~~, eliminate the occurrence of natural recharge in the area.

Commented [TM54]: "Water" included here to maintain consistency

Commented [CS55R54]: Agreed.

Commented [TM56]: Via the natural creek bed/s of horseshoe creek before diversion and construction of TSF1, as shown in Earth Systems (2012)

Commented [CS57R56]: Revised.

Commented [TM58]: Changed ARD to AMD

Commented [CS59R58]: Changed to AMD.

Commented [TM60]: This no longer the case according to the Batman Pit description above.
Is it transferred to RP7 again now?

Commented [TK61R60]: Ask Vista Gold. CHANGED PER JOHN

Commented [CS62R60]: See edits per Vista Gold.

Commented [TM63]: Reordered wording here.

Commented [CS64R63]: Agreed.

4.5 Groundwater Monitoring Infrastructure

Extensive groundwater pumping and monitoring infrastructure is present in the Project area. The bores were installed during a number of field efforts over the course of many years. These bores and field efforts included:

- Camp bore BP70, Mt Todd No. 1, Camp Water Supply, and Pacific Camp Bore (locations approximate).

- BW1 to BW31P (Rockwater 1988, 1989, and 1994). This installation effort focussed on obtaining adequate water resources for mine development. The bores were installed in the BCTF and encountered primarily greywacke, hornfelsed greywacke, siltstone, and shale. The bores were airlifted, and many were subjected to pumping tests.
- TDMB#1 to TDMB#6 (Knight Pièsold, 1996), each consisting of a shallow and deep bore. Five of the pairs were located by Earth Systems (2012) and GHD (2012), renamed TDMBD1, TDMBS1, and TDMB1S & D to TDMB4S & D, and re-surveyed. Construction logs were provided, but no lithologic logs were available for these bores.
- MB1 to MB7. No information could be located for these bores.
- WD1 to WD2. No information could be located for these bores; they are reportedly submerged under RP1 (GHD, 2012).
- Piezometers 1A through 1D, 2A through 2E, 3A, 4A, 5A, 6A, and 7A (Earth Systems, 2012). These were installed and subjected to hydraulic testing as part of a detailed assessment of TSF1 by Earth Systems (2012).
- SW4MB01, TSF2MB01, TSF2MB02, BPMB01, BPMB02, WDMB01 and WDMB02 (GHD, 2012). These bores were installed and tested by GHD (2012).

Figure 4-6 illustrates the locations of these bores, and Table 4-2 provides completion information. Some historic bores could not be located and ~~are presumed to be abandoned;~~ their locations were approximated based on existing documentation. Appendix B provides the available borehole logs, and Appendix C provides the aquifer test data.

Commented [TM65]: Removed

Commented [CS66R65]: Agreed.

In addition to measuring water levels in the monitoring bores, regular monitoring of water in several of the surface water bodies and impoundments has been performed. In some cases, these measurements can be used to provide insight into the groundwater elevation and quality.

Where monitoring bore logs were lacking sufficient detail, field crews (GHD, 2012) used a downhole camera (AusLog MightyCam) to investigate the bore. These surveys revealed that there was considerable variability in bore construction approaches. Earth Systems (2012), GHD (2012), and Knight Pièsold (1996) typically utilised machine-slotted screens, filter pack, and bentonite or cement seals. The other bores were typically constructed using coarse grinder-ground vertical slots and no filter pack. The collar seals were also missing in some cases, such as the MB series and some BW bores.

A number of monitoring bores were installed by GHD (2012). These bores were installed for the following groundwater elevation monitoring purposes:

- BPMB01 and BPMB02 – Monitoring of the current and proposed Batman Pit highwall water levels and interaction with the proposed waste dump.
- WDMB02 and WDMB02 – Monitoring of the RP1 and waste rock dump area.
- TSF2MB01 and TSF2MB02 – Monitoring of the interactions between the proposed TSF2 location and the nearby surface water features (raw water supply reservoir and Stow Creek).
- SW4MB01 – Monitoring groundwater adjacent to the Edith River.

These bores were installed in locations outside the footprints of nearby existing and proposed infrastructure. The primary purpose was to monitor groundwater elevations, not water chemistry. Of the bores shown on Figure 4-6, BPMB01, BPMB02, TSF2MB01, TSF2MB02, SW4MB01, BW29, BW17, BW18, and BW6 can all be considered boundary bores. However, as the proposed Project develops, additional monitoring bores may be necessary, and the boundary bores may serve other purposes.

Figure 4-6: Bore Location Map

Table 4-2: Bore Completion Details

Bore Name	Year Installed	Easting (MGA Zone 53)	Northing (MGA Zone 53)	Top of Casing (mAHD)	Ground Surface Elevation (mAHD)	Top of Screen (m)	Bottom of Screen (m)	Status
1A	2010	189607.13	8436467.74	137.28	134.34	1.0	6.5	Current
1B	2010	189673.26	8436470.28	137.20	136.20	1.0	9.0	Current
1C	2010	189740.32	8436473.11	138.17	136.97	1.0	10.0	Current
1D	2010	189841.63	8436628.22	128.00	127.20	1.0	14.9	Current
2A	2010	189241.08	8435674.09	136.95	134.50	1.0	7.0	Current
2B	2010	189259.61	8435632.57	136.95	136.00	1.0	7.3	Current
2C	2010	189277.82	8435591.47	137.45	136.29	0.5	6.8	Current
2D	2010	189320.14	8435537.66	130.36	129.56	1.0	16.0	Current
2E	2010	189349.77	8435444.04	128.36	127.61	3.0	13.0	Current
3A	2010	189509.34	8435553.44	125.59		1.0	15.0	Current
4A	2010	189780.33	8436857.25	132.15	131.45	1.0	14.7	Current
5A	2011	188688.31	8435792.01	136.24	135.35	2.0	25.0	Current
6A	2011	188613.48	8436035.41	137.91	137.09	2.7	25.0	Current
7A	2011	188949.92	8436702.93	138.31	137.26	2.7	25.3	Current
BPMB01	2011	186675.18	8435148.08	171.64		48.8	93.8	Current
BPMB02	2011	187012.31	8434374.82	145.67		27.3	150.0	Current
BW1	1988	*188330.70*	*8434897.20*			27.8	63.8	Historic
BW1P	1988	188331.70	8434907.20	127.56		26.0	62.6	Current
BW2	1988	*188205.20*	*8435506.39*			40.7	76.7	Historic
BW2P	1988	*188210.20*	*8435496.39*	*135.25*		34.9	70.9	Historic
BW5	1988	187506.72	8435612.50	142.88		41.4	65.4	Current
BW6	1988	188895.03	8433966.36	121.27		28.1	70.1	Current
BW6P	1988	188893.02	8433988.37	121.54		28.0	70.0	Current
BW8	1988	*188775.00*	*8434574.00*			1.2	37.2	Historic
BW8P	1988	188788.00	8434591.00	*127.40*		28.6	58.6	Current
BW9	1988	*188721.20*	*8435160.39*			34.6	64.6	Historic
BW10	1988	*188430.61*	*8434214.14*			33.0	69.0	Historic
BW10P	1988	188452.61	8434219.14	123.30		29.9	70.0	Current
BW14	1989	188332.11	8436901.13	146.21		43.4	79.4	Current
BW15	1989	*189114.10*	*8437299.39*	135.22		25.2	65.2	Historic
BW15P	1989	*189118.90*	*8437294.59*	135.10		28.9	58.9	Historic
BW16	1989	*189337.30*	*8437902.49*	136.07		37.9	73.9	Historic
BW16P	1989	*189341.50*	*8437895.69*	137.33		41.1	65.1	Historic
BW17	1989	188334.49	8439215.98	142.33		31.2	67.2	Current
BW17P	1989	188326.27	8439214.79	141.85		22.5	58.5	Current
BW18	1989	189859.60	8439226.40	140.69		25.9	67.9	Current
BW18P	1989	189861.87	8439232.41	140.64		22.8	52.8	Current
BW19	1989	189008.51	8438106.61	138.33		19.3	61.3	Current
BW19P	1989	188997.13	8438108.58	138.45		28.8	58.8	Current
BW20	1989	*188813.80*	*8436904.59*	138.95		25.1	61.1	Historic
BW21	1989	188680.38	8438755.03	139.35		20.0	50.0	Current
BW22P		*188990.50*	*8436139.69*	128.94		14.5	44.5	Historic
Pacific Camp Bore	1989	*188987.10*	*8436136.39*			30.0	48.0	Historic
BW23	1994	189485.51	8438551.79	141.49		32.5	68.5	Current
BW23P	1994	189484.65	8438548.43	141.36		24.7	60.7	Current
BW24	1994	189975.41	8438588.01	145.13		56.7	80.7	Current

Bore Name	Year Installed	Easting (MGA Zone 53)	Northing (MGA Zone 53)	Top of Casing (mAHD)	Ground Surface Elevation (mAHD)	Top of Screen (m)	Bottom of Screen (m)	Status
BW24P		189978.98	8438586.33	145.16		30.5	72.5	Current
BW25	1994	189991.45	8438281.57	145.36		43.6	67.6	Current*
BW25P	1994	189992.46	8438278.19	145.52		24.1	60.1	Current*
BW27P	1994	*188952.70*	*8432434.29*	*114.28*		21.6	54.5	Historic
BW28	1994	*188649.70*	*8432231.29*			2.0	32.0	Historic
BW28P	1994	*188654.70*	*8432231.29*	*111.58*		22.7	52.7	Historic
BW29	1994	188306.79	8431781.47	112.80		0.2	30.2	Current
BW29P	1994	188306.84	8431788.96	112.90		17.8	59.8	Current
BW30P	1994	*187049.90*	*8434667.39*	*153.69*		0.0	49.6	Historic
BW31P	1994	*187893.70*	*8435429.29*	*130.96*		22.3	47.8	Historic
BP70		*187308.00*	*8435000.00*		*149.63*		60.0	Historic
Camp Water Supply		*190228.00*	*8439164.70*					Historic
MB1		188099.52	8434470.27	131.06		40.0	49.0	Current
MB3		189156.48	8434622.84		*123.07*	*3.1*	*28.1*	Current
MB4		189468.86	8434893.87	129.57		38.1	49.7	Current
MB5		189426.03	8435306.61	123.08		5.0	25.0	Current
MB6S		187714.26	8432257.42		*113.07*	*1.6*	*6.6*	Current
MB6D		187852.63	8432281.28		*112.05*	*5.0*	*29.0*	Current
MB7S		187855.29	8432280.52	113.48		1.1	6.1	Current
MB7D		187847.29	8432275.68		*112.03*	*5.0*	*29.0*	Current
Mt Todd No 1		*189628.00*	*8439664.70*					Historic
SW4MB01	2011	186784.00	8431544.00	111.64	109.00	7.5	28.5	Current
TDMB1S	1995	189383.16	8435346.94	124.56	124.04	1.0	7.0	Current
TDMB1D	1995	189381.37	8435351.57	124.77	124.16	15.0	25.0	Current
TDMB2S	1995	189882.01	8435544.06	124.07	123.51	1.0	4.0	Current
TDMB2D	1995	189887.91	8435549.06	123.87	123.51	1.0	11.5	Current
TDMB3S	1995	189941.53	8436310.49	125.24	124.71	1.0	7.0	Current
TDMB3D	1995	189937.18	8436307.72	125.32	124.86	8.0	19.4	Current
TDMB4S	1995	189497.63	8437339.71	132.03	131.87	1.0	7.0	Current
TDMB4D	1995	189499.17	8437336.88	132.44	131.77	19.0	27.0	Current
TDMBS1	1995	188665.10	8437099.17	143.21		1.0	7.0	Current
TDMBD1	1995	188670.07	8437099.54	143.17		12.5	33.0	Current
TSF2MB01	2011	191239.44	8436060.05	138.77		16.9	41.0	Current
TSF2MB02	2011	191608.56	8435084.26	141.36		18.3	42.3	Current
WDMB01	2011	187284.96	8432583.78	124.16		15.7	39.7	Current
WDMB02	2011	188152.00	8433261.00	125.74		16.0	40.0	Current

*Note: * indicates the bore was physically located in 2012, but not during 2016 (Vista Gold, 2016)*

Red italicised numbers are estimated values.

4.6 Temporal Groundwater Level Monitoring

Although numerous bores were installed for pumping and monitoring purposes in the Project area, a relatively limited data set of groundwater elevations is available from the historical documentation. However, field personnel from Vista Gold's consultants regularly collected manual water levels in numerous bores throughout the Project area between late 2010 and the end of 2011, and Vista Gold has continued to collect manual measurements and provided additional data sets for model calibration. The historical and current water level data set was collated and annotated by GHD and provided to Tetra Tech (GHD, October 30, 2012). In addition, automatic water level logging equipment (downhole transducers) was installed in 12 bores, and the data were downloaded quarterly. The instrumented bores were:

- BW5, BW6, BW17P, BW19P, BW29;
- MB1;
- SW4MB01;
- WDMB01, WDMB02;
- TSF2MB02; and
- BPMB01, BPMB02.

Appendix D provides the data sets collected and tabulated between 2010 and 2016. Appendix E provides temporal plots of the available manual and transducer data for bores that were measured at least once between 2010 and 2011 and at least twice since installation. Appendix E also provides plots of manual water level measurements collected from Batman Pit (RP3), TSF1 (RP7), and the ~~w~~Waste ~~r~~Rock ~~d~~Dump water retention pond (RP1) by Vista Gold personnel.

Groundwater elevation data have been plotted for one dry season monitoring event and one wet season monitoring event. Figure 4-7 provides a potentiometric surface map for the November to December 2010 monitoring event, which is at the end of the dry season (low water levels). Figure 4-8 provides a potentiometric surface map for the May 2011 monitoring event, which was taken after the wet season (high water levels). When generating the potentiometric surface maps, all water levels were assumed to represent the ~~uppermost~~ uppermost saturated unit. This assumption is supported by the observation that, when pairs of shallow and deep monitoring bores were present, the measured groundwater elevations in each of the two bores were similar.

More recent water level measurements collected after 2011 were also evaluated.~~, and the potentiometric surfaces were similar to those provided as Figures 4-7 and 4-8.~~ Figures 4-9 and 4-10 show the potentiometric surface maps for the January (wet season) and August 2015 (dry season) monitoring events, respectively. These 2015 potentiometric surfaces are similar to those provided as Figures 4-7 and 4-8.

Commented [TM67]: Are additional data sets the Data logger readings as mentioned below?
Does this additional data include to pond level records?

Commented [TK68R67]: No data logger data were provided.

Commented [CS69R67]: We requested this data, but the Mt Todd personnel have since confirmed that it is not being collected.

Commented [TM70]: Do the bore have data loggers installed in them?
As mentioned if the data is not being downloaded, the first question the regulator will ask is WHY NOT?
Either an explanation why they are not read/downloaded should be included or the section should be removed altogether.

Commented [BM71]: Until 2014 when we transitioned to seasonal (2 x a year)

Commented [TK72R71]: Are transducers present in any bores now? If so, are the data downloaded and stored in the database? We have not received these data if they are available. ASK BRENT.
BRENT TO CONFIRM VIE EMAIL FROM US

Commented [CS73R71]: See above. Brent was able to confirm that no additional data are available.

Commented [TM74]: The new potentiometric surface maps should be included.

Commented [TK75R74]: More recent potentiometric surface maps were constructed, but the patterns did not differ in any significant way from the earlier ones.

Commented [RG76R74]: New maps added.

Figure 4-7: Groundwater Elevation, November-December 2010

Figure 4-8: Groundwater Elevation, May 2011

Figure 4-9: Groundwater Elevation, January 2015

Figure 4-10: Groundwater Elevation, August 2015

4.7 Groundwater Observations

Groundwater elevations across the Project area vary significantly between wet and dry seasons (Figure 4-7 ~~and~~ through ~~Figure 4-8~~Figure 4-8). However, the overall flow directions remain fairly constant throughout the year. Generally, groundwater flow on the site is from the north to the south toward the Edith River. Groundwater discharge to the Edith River and its tributaries is expected, since groundwater elevations are higher than the adjacent creek and river bed elevations. The expected regional groundwater flow direction from the Arnhem Escarpment in the east to the Daly River in the west was not observed at the mine site. However, a regional east to west flow direction is believed to be present based on the topography and the fact that the Edith River (which appears to act as a groundwater discharge point) flows from east to west.

4.7.1 Influence of Surface Water Impoundments

Based on the groundwater elevation data, TSF1, RP1, and the raw water supply reservoir all appear to function as flow-through features. In other words, groundwater elevations are higher on one side of the impoundment than on the other~~,~~ and surface water elevations within the impoundment fall between the elevations up gradient and down gradient of the impoundment. As would be expected, all three of these surface water impoundments interact with groundwater. Seepage evaluations of these impoundments ~~are in progress but not yet complete~~~~will be~~have been completed as part of the prefeasibility study ~~f~~For ~~final design phases of~~ the project.

Groundwater elevations around TSF1, RP1, and the raw water supply reservoir are higher than pre-mining levels due to recharge from the surface water impoundments. The higher groundwater elevations cause the~~In fact,~~ artesian conditions ~~are~~ observed occasionally or consistently in bores 3A, BW6, TDMB4S, and TDMB4D immediately down gradient of TSF1, and in bores MB6S, MB6D, MB7S, and MB7D~~, which are~~ immediately down gradient of RP1. ~~The water levels in TSF1 and RP1 are significantly higher than the ground surface down gradient of the dam structures. The groundwater elevations equilibrate with those higher water levels, resulting in artesian conditions down gradient of the dam structures.~~

Figure 4-11 (GHD, 2012) illustrates the effects of such conditions. Water chemistry in monitoring bores and Horseshoe Creek (Earth Systems, 2012) also supports this hypothesis.

Commented [TM77]: Hasn't this study already been completed?

Commented [CS78R77]: See revisions.

Figure 4-11: Example of Dry Season Discharge (July 28, 2011) from the MB7 and MB6 Bores

4.7.2 INFLUENCE OF BATMAN PIT

Active water management (including pumping into the Batman Pit) ~~has~~ occurred between 2005 and 2014~~since at least 2005~~. Anecdotal information (Vista Gold, Rozelle, pers. comm., August 31, 201~~2~~) indicates that groundwater inflow was a relatively minor component of the pit water, both during and after mine operation. However, no actual water levels were measured between mine closure in 2000 and the time when Vista Gold commenced measuring water levels. A number of photographs have been obtained (NT Department of Mines and Energy, 2013) that allow estimation of approximate water levels in the pit. Combined with the site survey information, these photographs provide snapshots of water levels in the pit at various times (Table 4-3). Prior to about 2005, the pit water levels represent primarily rainfall, with a minor contribution from groundwater inflow. After 2005, Batman Pit was also used for storage of water from other impoundments at the mine. In-situ treatment of the Batman Pit water has been conducted by use of limestone and quicklime (Vista Gold, 2016) since late 2012, with the goal of producing water that can be discharged at rates that continue to protect the quality of the Edith River. Current site conditions route water such that the Batman Pit receives primarily fresh water (Vista Gold, 2016).

Commented [TM79]: Water is no longer pumped into Batman Pit (as indicated below).
Consider including the period water was pumped into Batman Pit (e.g. 2005 – 2009?).

Commented [TK80R79]: Confirm with Vista Gold. Revise as needed.

Commented [RG81R79]: See edits.

Table 4-3: Water Levels from Anecdotal Observations and Survey

Information or Photo Source	Date	Estimated Pit Lake Elevation (m AHD)	Notes
Date of mine closure	July 2000	40	Bottom of pit
Photograph (www.nt.gov.au/d/mttodd)	April 2003	70	Estimated to within ±2 m
	October 2004	75	Estimated to within ±2 m
	May 2006	95	Pumping into pit had begun. Elevation estimated to within ±1 m
	June 2007	110	Continued pumping
Vista Gold data	November 2009	130	Water level maintenance
	September 2010	130	Water level maintenance
	October 2011	133	Water level maintenance
	September 2012	139	Water treatment and water level maintenance
	September 2013	140	Water treatment and water level maintenance
	September 2014	143	Water treatment and water level maintenance
	August 2015	138	Water treatment and water level maintenance

Batman Pit is poorly connected to groundwater, based on a comparison of water surface elevations in the pit to groundwater elevations measured in nearby bores BPMB01, BPMB02, and BW5. Between November 2010 and December 2011, water levels in Batman Pit were consistently between 130 and 134 m AHD. By contrast, groundwater elevations in BPMB01, BPMB02, and BW5 were between 135 and 151 m AHD, once the water levels equilibrated after well installation. Thus, Batman Pit historically appears to have had consistently lower water levels than the nearby bores, despite the pit having received water pumped to it.

The lower water levels in Batman Pit are likely due to a combination of evaporation, very low rates of groundwater inflow from surrounding bedrock, and management of the Batman Pit water levels by Vista Gold staff. If the Batman Pit were well connected to the groundwater system via high-conductivity fracture systems and had lower water levels than the surrounding area, it would be expected to serve as a groundwater sink, and the water levels measured in the surrounding bores would be expected to decrease in response to the low levels in Batman Pit. Conversely, if water were to be continuously pumped into Batman Pit to raise its water level above the surrounding groundwater elevation, then some minor water seepage out of the pit through fractures in the pit walls would be expected to occur~~;~~ ~~however, this situation has not been observed~~.

Commented [TM82]: Unable to be observed as pit water levels have not been raised above the surrounding groundwater elevations.

Commented [RG83R82]: Noted.

4.7.3 INFLUENCE OF EDITH RIVER AND TRIBUTARIES

Anecdotal evidence provided by field personnel of Vista Gold and its consultants has suggested that during the wet season, high flows occur in the both the ephemeral creeks and the Edith River. To clarify the behaviour of the Edith River and its tributaries at the mine site, Vista Gold's consultant GHD documented specific observations about the creeks and streams during several site visits (GHD, 2012):

- In May 2011, GHD saw evidence to suggest that the Edith River had flooded far above its banks during the wet season, and that the ephemeral creeks had also been subject to high flows. Stow Creek, the diversion drain to the east of the tailings storage facility, and Horseshoe Creek still had observable surface flows. Batman Creek and the ephemeral creeks north of the mine area had ceased flowing by GHD's May 2011 visit, although large refuge pools still remained.

- In July and August 2011, GHD observed that surface water pools remained in Batman Creek and the ephemeral creeks north of the mine area, but that Stow Creek had no surface water flow. The eastern diversion drain and Horseshoe Creek still had minor surface water flow. GHD's photograph of the flow in the eastern diversion drain is provided as Figure 4-12. Also, Horseshoe Creek pools remained full, and the groundwater elevations in adjacent bores were near the ground surface. GHD observed significant groundwater seeps down gradient of the eastern and southern walls of the tailings dams, and the seeps appeared to be providing the flow in Horseshoe Creek. Figure 4-13 and Figure 4-14 are two of GHD's site photographs that illustrate the observed seeps.

- In all GHD's site visits during 2011, groundwater elevations measured in the bores adjacent to natural drainages reportedly appeared to be similar to the water level elevations observed in surface water pools in the natural drainages. The field observations described above indicate that there is a large amount of surface runoff during the wet season. Anecdotally, Vista Gold personnel have indicated that significant underflow occurs through the top few metres of soil and weathered material. The underflow reportedly discharges into the natural drainages. In this scenario, the natural drainages would serve almost wholly as groundwater discharge points, with few losing reaches compared to gaining reaches.

Figure 4-12: Eastern Diversion Drain on August 2, 2011

Figure 4-13: Seepage on the Southern Side of TSF1 on August 2, 2011

Figure 4-14: Seepage on the Eastern Side of TSF1 on August 2, 2011

4.8 AQUIFER PROPERTIES

Aquifer properties were ascertained from airlift yield tests and aquifer testing. Airlift yield tests are routinely performed when drilling water bores for investigation and supply purposes. Airlift yields were available for all the BW series bores and for the most recent bores (GHD, 2012). These data are presented graphically in Figure 4-15 as a frequency histogram. All airlift values were from the Burrell Creek and Tollis Formations.

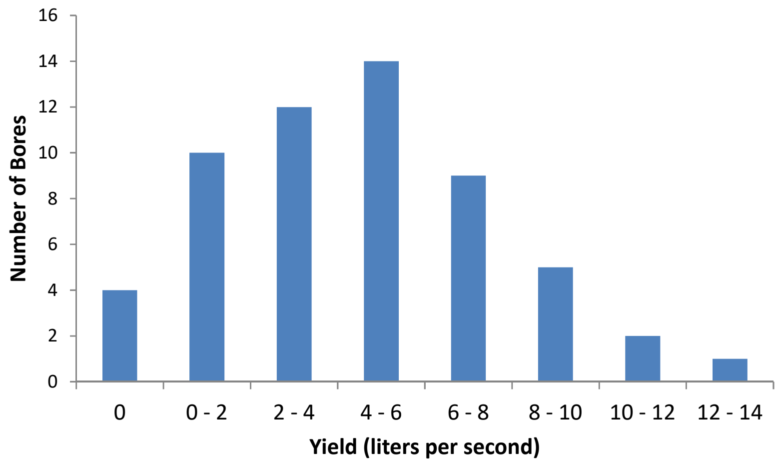


Figure 4-15: Airlift Yields, Burrell Creek and Tollis Formations

In the vicinity of Batman Pit, BCTF has been metamorphosed (hornfelsed). The tested bores nearest to Batman Pit are BW3, BW4, BW5, BW13, BW30P, BPMB01, and BPMB02. Of these bores, all but BW30P had airlift yields below 1 L/s, and three were actually dry during drilling. The anomalously low yields support the concept that the hornfelsed BCTF has very low hydraulic conductivity.

In addition to airlift yield tests, numerous pumping and slug tests have been performed over the last ~~25~~ 29 years to determine aquifer properties. These aquifer tests include:

- eleven pumping tests from the Mt Todd site (Rockwater, 1988 and 1989) in the BCTF;
- two publically available pumping tests on registered bores within the region (NRETAS, 2013) which tested the Plum Tree Creek Volcanics at Edith Falls and the BCTF at Werenbun;
- eighteen pumping tests in the BCTF (GHD, 2012); and
- two slug injection tests (Golder, 2011).

4.8.1 PUMPING TESTS

A summary of the test results is provided as Table 4-4, and plots of the pumping tests are provided in Appendix C. Older aquifer tests (Rockwater, 1988 and 1989), and the most recent aquifer tests (NRETAS, 2013) were generally 24 or 48 hour tests, and the analyses provided were completed by the entity that performed the tests. The ~~most recent 18~~2012 pumping tests of 18 bores (GHD, 2012) were incorporated into the geochemical sampling program. Pumping continued for 30 minutes or the point at which the water levels were approaching top of the pump. Water level recoveries were monitored until water levels had again reached the pre-pumping level or for a maximum of 30 minutes. Flow rates and water levels during the tests were monitored by GHD field personnel manually and with automated logging devices.

Where pumping tests involved both pumping and observation bores, it was possible to estimate the storage coefficient (storativity). The 2012 pumping tests were analysed by GHD using AQTESOLV Pro 4.5 to apply the Cooper-Jacob (Cooper and Jacob, 1964) and Theis (1935) methods. The Cooper-Jacob method is implemented in AQTESOLV using the Birsoy and Summers (1980) method to allow for variable pumping rates.

Table 4-4: Summary of Pumping Tests

Pumped bore (Observation Bore)	Pumping Duration (hours)	Transmissivity (m^2/day)	Storativity (dimension-less)	Reference
BW1P (BW1)	48	9	1.40E-03	Rockwater, 1988
BW2P (BW2)	48	84.5	3.80E-09	Rockwater, 1988
BW5	0.5	0.7		GHD, 2012
BW5	0.5	0.85		GHD, 2012
BW6P (BW6)	48	30.5	1.30E-05	Rockwater, 1988
BW6P (BW6)	48	35	2.50E-03	GHD, 2012
BW6P (BW6)	1	100	5.80E-04	GHD, 2012
BW8P (BW8)	48	20.3	1.50E-03	Rockwater, 1988
BW10P (BW10)	48	14.8	9.60E-07	Rockwater, 1988
BW15P (BW15)	48	73	3.00E-03	Rockwater, 1989
BW16P (BW16)	48	32	6.00E-04	Rockwater, 1989
BW17P	0.5	18		GHD, 2012
BW17P (BW17)	48	18		Rockwater, 1989
BW18P (BW18)	48	40		Rockwater, 1989
BW19P (BW19)	48	6		Rockwater, 1989
BW29P	0.5	16		GHD, 2012
WDMB01	0.5	20		GHD, 2012
WDMB02	0.5	5.3		GHD, 2012
SW4MB01	0.5	32		GHD, 2012
MB1	0.5	120		GHD, 2012
MB3	0.5	36		GHD, 2012
MB4	0.5	0.1		GHD, 2012
MB4	0.5	0.09		GHD, 2012
MB5	0.5	8.2		GHD, 2012
MB6S	0.5	0.64		GHD, 2012
MB7S	0.5	0.12		GHD, 2012
TDMB1D	0.5	0.21		GHD, 2012
TDMB2D	0.5	0.12		GHD, 2012
TDMB4D	0.5	1.6		GHD, 2012
RN028738	24	7.2		NRETAS, 2013
RN032153	24	12.7		NRETAS, 2013; transmissivity value is average of pumping and recovery values

4.8.2 SLUG TESTS

Slug tests were performed where the rock mass permeability was too low for sustained pumping tests. ~~A total of f~~Four slug tests were conducted at four bores in altered BCTF in the

Commented [TM84]: Wording, consider revising.

Commented [TM85R84]: "Four slug tests were conducted on four bores"

Commented [RG86R84]: See text edits

Batman Pit area (Golder, 2011 and GHD, 2012). Table 4-5 summarizes the results of the slug testing.

Table 4-5: Slug Test Results

Borehole	Hydraulic Conductivity (m/day)	Tested Interval (mBGL)	Lithology
VB11-006a	4.80E-07	105 - 600	Altered BCTF
VB11-007	4.80E-06	13 - 487	
BPMB01	2.90E-04	43 - 175	
BPMB02	5.60E-05	24.75 - 150	

4.9 Groundwater Velocities

Example groundwater flow velocities for the current groundwater conditions have been calculated based on the transmissivity values presented above, assumed effective porosity values based on literature, groundwater elevations and distances (Table 4-6). The transmissivity was converted to hydraulic conductivity by dividing by the saturated thickness (this assumes the flow zone is the entire saturated thickness and that the saturated thickness extends from the water table to the bottom of the screen in the particular bore). The geometric mean of the hydraulic conductivity between the two points was then calculated, and this value was used in the velocity calculations. Velocity was calculated using the Darcy velocity calculation:

$$V = [(\partial h/\partial l) \times K] / \rho_e$$

Where:

- V=Groundwater flow velocity (m/d).
- $\partial h/\partial l$= Hydraulic gradient.
- K = Hydraulic conductivity (m/d).
- ρ_e = Effective porosity, which is the porosity within the aquifer open to groundwater flow, and is generally a value between the specific yield and total porosity.

Hydraulic conductivity values were based on testing presented in Appendix C, and water table elevations were based on the data collected on September 27, 2011. The groundwater flow velocity calculations do not take into account local changes in geology between the points calculated.

Table 4-6: Example Darcy Velocities

Point 1	Point 2	Date	Hydraulic Conductivity (m/day)	Effective Porosity	Groundwater Elevation 1 (m AHD)	Groundwater Elevation 2 (m AHD)	Distance (m)	Hydraulic Gradient	Velocity (m/day)
BW5	MB1	2013-03-12	0.19	0.01	137.27~~132.94~~	126.51~~125.35~~	1525	0.~~005~~0071	0.~~14~~13
BPMB02	WDMB02	2013-24-04	0.0029	0.01	141.59~~136.98~~	123.26~~132.94~~	1675	0.~~002~~4011	0.~~0027~~0032

Commented [TM87]: What about reviewing this using the recent water level data?

Commented [BM88R87]: There is data in the excel files including 2016 wet season

Commented [TK89R87]: As noted in 1st paragraph, these are example GW velocities.

Commented [RG90R87]: Updated table with most recent data from each bore pair. Velocities were comparable to the 2011 data.

Formatted Table

MB1	BW6	2011-27-09	1.4	0.01	124.78~~125.35~~	119.75~~120.03~~	920	0.~~0058~~0055	0.~~76~~77
BW17P	BW19P	2013-02-12	0.2	0.01	138.35~~141.00~~	131.61~~133.14~~	1310	0.~~0060~~0051	0.~~11~~10

4.10 Water Sampling

Water sampling performed in 2011 provided baseline ~~geochemistry~~ water quality values for groundwater in the region and adjacent to mine features, and water quality monitoring has continued on a routine quarterly or semi-annual schedule to the present.

4.10.1 Groundwater Chemistry Monitoring Program

Water sampling performed in 2011 provided baseline water quality values for groundwater in the region and adjacent to mine features. Water analyses assisted in supporting conceptual hydrogeological model development by confirming groundwater flow directions and providing support for hypotheses.

Commented [TM91]: Why was this changed when it wasn't changed above?

Commented [RG92R91]: Text changed in previous paragraph to be consistent with this paragraph.

Baseline groundwater chemistry and water level monitoring was undertaken between April 2011 and September 2011. Quarterly monitoring was undertaken by Envirotech Monitoring for Vista Gold at Mt Todd at the following bores:

- TDMB1S, TDMB1D, TDMB2S, TDMB2D, TDMBD1, and TDMB3D;
- MB1, MB3, MB4, MB7S, and MB7D;
- BW17P.
- BW5, BW6, BW19P, and BW29P;
- TDMB4S and TDMB4D;
- SW4MB01;
- WDMB01 and WDMB02; and
- TSF2MB01 and TSF2MB02.

The following parameters were measured:

- TDS, pH, and electrical conductivity (EC);
- Cyanide Total, Cyanide WAD, Cyanide Free, and Cyanide Cl Amenable;
- Hg;
- NO_2, NO_3, NH_3, Total N TKN, Total P;
- dissolved trace metals ICP-MS scan (Tl, Bi, Cd, U, Ag, Be, Co, Mo , Pb, Th, As, Cr, Sb, Se, Sn, V, Ba, Cu, Li, Mn, Ni, Sr, Ti, Zn, Fe, Al, and B); and
- major cations and anions (sulphate, chloride, bicarbonate, carbonate, sodium, potassium, calcium, and magnesium).

Groundwater chemistry monitoring has continued quarterly or semi-annually since the baseline data was collected in 2011. The baseline locations and the parameters included in the 2011 monitoring are part of the current monitoring program.

4.10.1.1. Groundwater Chemistry Analyses

Initial ~~G~~groundwater chemistry analyses were undertaken to assist in the development of conceptual hydrogeological models and identifying groundwater flow paths, rather than as a true contamination assessment of the groundwater system at Mt Todd. The groundwater analyses provide context as background or baseline groundwater concentrations for the proposed development. Results prevent wrongly attributing later-identified contamination that may be present due to historical activities or natural mineralisation to the proposed operations. Subsequently, ~~G~~groundwater analyses ~~should~~ continued to be undertaken and these baseline levels used as a reference point. Groundwater analyses were completed quarterly until 2014 and seasonally thereafter.

Commented [TM93]: Initial analysis?

Commented [TM94R93]: Can this be changed to: "Initial groundwater chemistry analyses"

Commented [CS95R93]: Agreed.

Commented [TM96]: This is happening quarterly as noted above

Commented [BM97R96]: Changed from 2014 to seasonally

Commented [CS98R96]: See revisions.

4.10.1.2. Groundwater Sampling Methodology

Water sampling was undertaken in general accordance with AS/NZS 5667.11:1998 : *Water quality - Sampling - Guidance on sampling of groundwaters* and aimed at ensuring that all environmental samples are collected using a set of uniform and systematic methods. Key requirements of these procedures (GHD, 2012) were as follows:

- staff with appropriate experience and training conducted the field work;
- decontamination procedures: including the use of new disposable gloves for the collection of each sample, decontamination of the sampling equipment between each sampling location (using DECON 90) and the use of dedicated sampling containers provided by the laboratory;
- calibration procedures: all field monitoring equipment was appropriately calibrated;
- sample identification procedures: samples were immediately transferred to sample containers of appropriate composition and with the appropriate preservatives for the required laboratory analyses. All sample containers were clearly labelled with a sample number, sample location, sample depth, sample date and sampler's initials. The sample containers were then transferred to a cool box for sample preservation prior to and during shipment to the testing laboratory;
- Chain of custody information requirements: a chain-of-custody and analysis request form was completed and forwarded to the testing laboratory; and
- Field notes were collected during the fieldwork (i.e. field logs noting the outcomes of field activities, deviations from the SFOP, and site conditions at the time of sampling).

4.10.1.3. Field Quality Control Samples

The field quality control program (GHD, 2012) included the collection and analysis of the following:

Blind duplicates: Comprised a single sample that was divided into two separate sampling containers. Both samples were sent anonymously to the project laboratory (MGT Labmark). Blind duplicates provide an indication of the analytical precision of the laboratory but are inherently influenced by other factors such as sampling techniques and sample media heterogeneity. Blind duplicate samples should return relative percent differences (RPDs) within the Australian Standard AS4482.1 acceptance criteria of 30 to 50 percent.

Split duplicates: Identical to a blind duplicate, except that the primary sample was sent to the project laboratory and the duplicate was sent to the secondary 'check' laboratory (ALS). Split duplicate samples should return RPDs within the Australian Standard AS4482.1 acceptance criteria of 30 to 50 percent.

4.10.2 Baseline Groundwater Chemistry Results

The baseline groundwater chemistry analysies undertaken as part of the GHD study are provided in Appendix F. A summary of these (and historical) analyses results is also provided in Appendix F. As a reference point, the groundwaters are compared to:

- ANZECC & ARMCANZ (2000) guidelines for freshwater aquatic ecosystems at the 95 percent of species protection level (FAE95%),
- ~~guidelines~~Guidelines for long term irrigation values (LTV),
- ~~guidelines~~Guidelines for livestock watering and
- Australian Drinking Water Guidelines (NHMRC & NRMMC, ~~2004~~2016) ~~(Appendix F Summary)~~.

The only variation in the 2011 Australian Drinking Water gGuidelines versus the 2004 guidelines that is relevant to the analyses was a change in the arsenic guideline from 7 micrograms per litre (µg/L) to 10 µg/L. This affects the reporting of only one sample in one event MB5 (February 2011). The subsequent updates to the 2011 guidelines did not affect the reporting of any samples. Groundwater at Mt Todd is not intended for such uses, and the guidelines are used to provide a reference point only. Groundwaters do discharge into surface waters used for such purposes (Vista Gold, 2016). ~~The effect of groundwater on surface waters is addressed in the surface water component of the EIS.~~

4.10.3 Groundwater Types

Groundwater major ion concentrations were plotted on Piper trilinear diagrams[2], to compare key groundwater types (

[2] A piper diagram plots the relative proportions of the concentrations of the major anions and cations as milliequivalents per litre, which are a function of the concentration and electrical charge of the ion.

Formatted: Bulleted + Level: 1 + Aligned at: 0.63 cm + Indent at: 1.27 cm

Commented [TM99]: This is the result of the Australian Drinking Water Guideline update.

Commented [RG100R99]: Noted

Commented [TM101]: Requires updating to reflect current management activities (e.g. water management plan)?

Commented [RG102R101]: Reference to water management plan added.

Commented [TM103]: Have these concentrations changed since the initial water quality analysis?

Commented [RG104R103]: Major ion chemistry has been pretty stable since 2011.

Table 4-7) at Mt Todd (~~Figure 4-14~~Figure 4-16). The groundwaters were grouped into three types: magnesium sulphate (circled in orange); mixed-cation bicarbonate (circled in blue)~~;~~ and an intermediate group of mixed-cation sulphate + bicarbonate (circled in green). Bores plotted in the magnesium sulphate group were in most cases adjacent to the anthropogenic water retaining structures, suggesting this was the source of the elevated sulphate. BW19P plotted in the sulphate group, and TSF2MB01 and BW6P plotted in the intermediate group. These relatively high sulphate readings (considering their locations) may be associated with historical mining.

Table 4-7: Groundwater Types

Magnesium Sulphate Groundwaters	Mixed Cation Bicarbonate Groundwaters	Intermediate Groundwaters
MB6D	SW4MB01	TSF2MB01
MB6S	WDMB01	BW6P
MB7D	TSF2MB02	MB5
MB7S	WDMB02	TDMBD1
TDMB1D	BPMB02	
TDMB2S	TDMB3D	
TDMB2D	TDMB4D	
BW19P	BW17P	
MB3	BW5	
TDMB3S	BW29P	
	MB1	
	MB4	

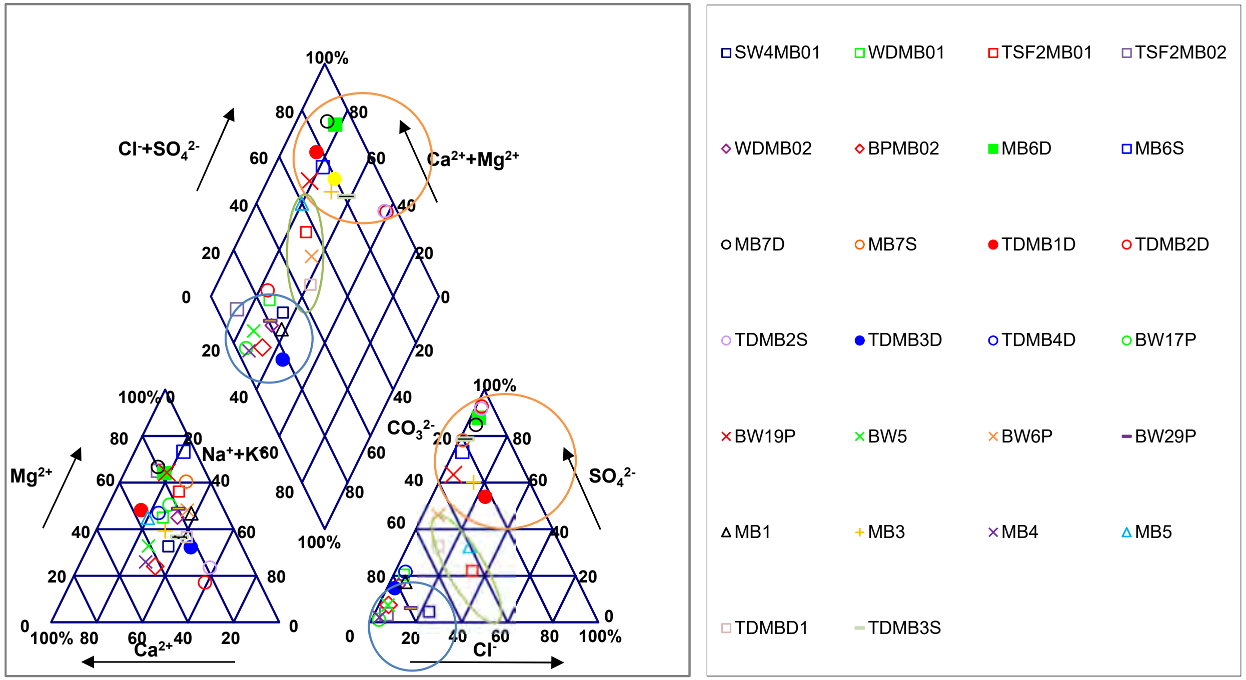


Figure 4-16: Piper Plot for Mt Todd Baseline Groundwater Samples (2011 data).

4.10.4 Groundwater Chemistry Discussion

The presence of elevated levels of toxicants and major ions in bores down-gradient from water retaining structures supports the conceptual models developed for the site. Elevated levels of toxicants were observed in most bores, even those designed to be background or boundary bores. Existing elevated toxicants across the site included:

- metals and metalloids: arsenic, cobalt, lead, iron, manganese, zinc, copper, aluminium, chromium, and molybdenum; and
- inorganics: chloride, cyanide (total), and sulphate.

Background water in the Mt Todd area may have elevated toxicants due to:

(i) natural background levels associated with the area containing significant natural mineralisation;
(ii) historical prospecting and small scale workings distributed over the region, disturbing sulphide mineralisation; and
(iii) features associated to the existing Mt Todd mine. Generally, background bores are bicarbonate type; however, the example of TSF2MB01 was slightly outside of the background group, having a slightly lower proportion of bicarbonate.

Waters contaminated with ~~acid rock and metalliferous drainage (AMDARD/ML)~~AMD and process water are present in the surface water retaining features at Mt Todd, including, but not limited to:

- the tailings storage facility (TSF1) (Earth Systems, 2012);
- the heap leach pad;
- the LGO stockpile;
- the process plant;
- open cut mine pits;
- the waste rock dump; and
- the ~~w~~Waste ~~r~~Rock ~~d~~Dump water retention pond.

The detailed chemistry of these features is beyond the scope of this document. It is recognised that these existing features present potential sources of groundwater contamination through AMD~~ARD~~.~~/ML.~~

The fact that ‘background’ or ‘boundary’ bores exceed the Australian drinking water guidelines (NHMRC & NRMMC, ~~2004~~2016) demonstrates that the existing groundwater at Mt Todd is not suitable as a reliable source of potable water without treatment.

Commented [TM105]: Should be just Acidic and Metalliferous Drainage (AMD)
What does the ML refer to?

Commented [CS106R105]: Revised.

Commented [TM107]: Water included to maintain consistency through report

Commented [RG108R107]: Noted.

Commented [TM109]: Should remain as AMD

Commented [CS110R109]: Agreed.

Commented [TM111]: Change to the 2011 guidelines

Commented [RG112R111]: See edits.

4.11 Groundwater Demand

Groundwater will be extracted as part of the proposed pit dewatering. External pit dewatering using dewatering bores is unlikely to be viable or necessary due to the relatively low flow rates generally observed in the hornfelsed BCTF. In-pit groundwater extraction is expected to be performed using sumps. The groundwater removed from the proposed pit is likely to be acidic and contain elevated concentrations of metals or other contaminants and therefore should be assumed ~~to be~~ unfit for raw or potable water supply without additional treatment.

The demand for groundwater for potable and raw water use has not been estimated as part of this study. Rather, this study assumes that any needed potable and raw water will be obtained from surface water bodies (i.e. the raw water supply reservoir). Although BW6P is currently in use as a raw water supply, this water and the water from other existing pumping bores is considered, due ~~too~~to elevated ~~in~~ toxicant concentrations, unsuitable for use as potable water without treatment. Even the bores considered background for the purpose of this study have elevated concentrations of toxicants. For example, the detected arsenic levels often significantly exceed Australian drinking water guidelines of 0.01 milligram per litre (NHMRC, 2011). Nearly all the Project area bores exceed this guideline for arsenic.

4.12 Surface Water Flows

Flow data ~~were~~ is publicly available from the Northern Territor~~iesy~~ Government (NTG) water data portal NT.GOV.AU for the Edith River below the mine site, at *Edith River at Dam Site* 5 km upstream from the Stuart Highway (station G8140152). The data have been collated by Vista Gold and its consultants regularly. Surface water flows in the Edith at this site averaged about 5 m^3/s (cubic meters per second) since the 1960's, but the average is about 7.6 m^3/s since January 1995. Flows peaked at approximately 1150 m^3/s after a significant rainfall event in December 2011 while the GHD study was ongoing. Edith River surface water flows were observed to be of similar scale both at the mine and down gradient of the mine during the dry season. It appears that, at least during the dry season, most surface water flow in the Edith River near the mine site originates in the Arnhem Escarpment. Only a minor component would be expected to be from discharge of groundwater associated with the mine site. However, no groundwater flow or discharge data have been obtained to support this observation.

Available data regarding Edith River flow rates were used in conjunction with precipitation and catchment areas to determine the approximate percentage of precipitation that becomes runoff into the streams. Based on the NTG water data portal (NTG, 2017), the catchment area of the Edith River gauging station G8140152 is 673 km^2. The precipitation is approximately 1.2 m/yr. These values were used to calculate the total precipitation on the watershed. The total precipitation was then divided by the number of days in a year to get an average precipitation volume per day. This was compared to the average flow of the Edith River at the gauging station, resulting in an estimate of about 35 percent of precipitation entering the Edith River as runoff.

Commented [TM113]: "To be" removed

Commented [RG114R113]: Noted.

Commented [TM115]: What about the current data from the telemetry network monitoring the Edith River flow to determine if discharging can occur?

Commented [BM116R115]: Flow data is available from 2012 to today (SW4)
This data is in the MMP water balance for the relative year and the excel spreadsheets sent to Tetra Tech.

Commented [RG117R115]: See edits.

5.0 GROUNDWATER MODELLING

As part of the assessment and permitting process for the Mt Todd Project, a regional numerical groundwater flow model was constructed. The model simulated the groundwater conditions existing prior to Vista Gold's acquisition of the site, the mining activities proposed by Vista Gold, and the groundwater conditions following closure of the mining operations. This section describes the development, calibration and operation of the model.

Commented [TM118]: What about the review/update of this model with the recent data collected since its development?

Commented [TK119R118]: See earlier comment responses.

5.1 GROUNDWATER MODEL OBJECTIVES

The primary objectives of the groundwater flow modelling were to:

- provide estimates of the amount of groundwater inflow to the enlarged and deepened Batman Pit during the proposed mining and thereby facilitate optimal design of groundwater dewatering systems for the mine;
- predict the effects of mine dewatering and mine water management operations on groundwater levels and surface water flows;
- predict post-mining pit lake formation and pit-lake water balance; and
- estimate post-mining changes in groundwater levels and surface water flows.

5.2 GROUNDWATER MODEL SCALE

The groundwater model domain consisted of a rectangular area extending approximately 15.4 km north to south and approximately 16.9 km east to west, with the Mt Todd Project area approximately ~~centered~~centred within the domain (Figure 1-3). Simulation of a regional area limits the resolution of the model grid, which in turn limits the resolution and accuracy of the model simulations. Hydrogeologic features smaller than the grid resolution are typically not simulated, and geometries and distributions are approximate. Small-magnitude flows, small water-level changes, and steep hydraulic gradients are therefore difficult for a regional model to replicate.

The regional-scale groundwater modelling was not intended to model site features such as the raw water supply reservoir, the existing tailings storage facility (TSF1), the waste rock dump (WRD), and the waste rock dump water retention pond (RP1) on a scale that would accurately predict seepage rates from the facilities and the associated impacts. Although those features were included in the regional groundwater flow model, their impacts were simulated in a more generalised fashion. As o~~O~~ther separate studies, such as seepage modelling, are completed, the results can be incorporated into the groundwater model.~~have been or are being conducted to assess the seepage rates and impacts associated with those facilities~~.

Commented [TM120]: "Water" inserted to maintain consistency across report

Commented [RG121R120]: Noted

The overall modelling approach was to construct groundwater flow models to simulate steady-state pre-mining conditions, transient mine development and dewatering, and transient post-mining conditions. The steady-state pre-mining conditions were based on historical water level, stream-flow, and hydraulic property data. The flow model was first calibrated to the steady-state water level data, forming the basis for the subsequent transient flow models. The steady-state calibrated model was then converted to a transient model and further calibrated to water-level changes observed at the monitoring bores during the aquifer testing conducted at bores BW1P, BW2P, BW6P, BW8P, BW10P, BW16P, BW17P, BW18P, and BW19P (Rockwater, 1988 and 1989). The calibrated transient model was used as the basis for mining and post-mining phase models. The mining-phase transient model simulated the initial pump-out and the step-wise mining and dewatering of the Batman Pit during the approximately 14-year operational period. The open-pit mine dewatering was simulated with drain cells, which remove water from the model when water levels reach the specified elevation of the drain. The post-mining phase used the LAK2 package (Council, 1999) to simulate pit lake development from the refilling of the pit with groundwater, precipitation and runoff following the end of dewatering.

Commented [TM122]: Has model recalibration been completed using the expanded water level data?

Commented [TK123R122]: Yes.

5.3 Groundwater Model Conceptualization

The components of the groundwater flow models that remained consistent in each model are discussed in this section. The model code, domain, grid, and hydrogeologic framework are the same for each model version. Initial recharge, stream flow, and external model boundaries were also simulated in the same manner in each model version. Elements specific to the pre-mining steady-state model, mining-phase model, and post-mining phase model are discussed in subsequent sections.

5.3.1 Model Code Selection

The hydrogeologic conditions to be simulated posed several numerical challenges because ~~of~~ of the following;

1) ~~1)~~ steep hydraulic gradients that would occur during dewatering of a mine pit excavated into low-permeability rocks to a depth of approximately 500 metres,
2) ~~2)~~ potentially unsaturated or partially-saturated conditions that could occur beneath seepage sources such as TSF1, and
3) ~~3)~~ the potential re-saturation of areas near the Batman Pit after they had been dewatered by mining activities.

Formatted: Numbered + Level: 1 + Numbering Style: 1, 2, 3, … + Start at: 1 + Alignment: Left + Aligned at: 0.63 cm + Indent at: 1.27 cm

The groundwater flow model was implemented using the MODFLOW-SURFACT finite-difference code (Version 4; HydroGeoLogic, 2011). MODFLOW-SURFACT was selected over the traditional MODFLOW code due to its improved simulation of variably~~-~~ saturated flow and re-saturation of dewatered model cells, the improved and computationally more efficient Pre-conditioned Conjugate Gradient solver (PCG5), and the adaptive ~~time-stepping~~time stepping and output (ATO) package that reduces simulation time. The graphical user interface Groundwater Vistas (Version 6.~~29~~96, Build 1; Environmental Simulations, Inc., ~~2011~~2017) was used in model construction.

Commented [TM124]: The graphical user interface Groundwater Vistas (Version 6.29, Build 1; Environmental Simulations, Inc., 2011) was used in model construction, whereas model review/update was completed using Groundwater Vistas (version 6.96, Build 1; Environmental Simulations, Inc., 2017)

Commented [TK125R124]: Not relevant to report intent.

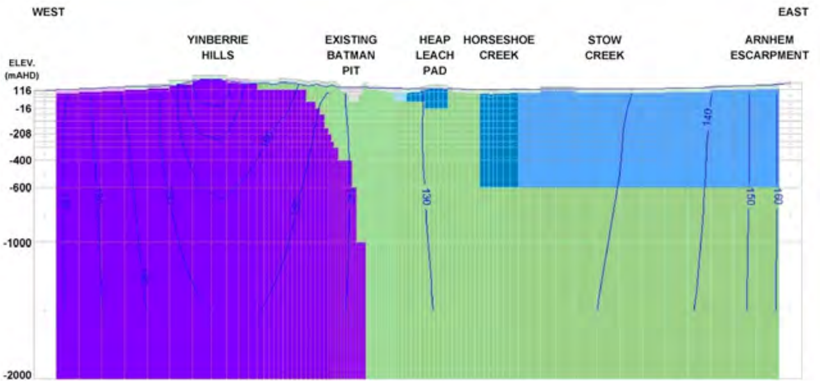
5.3.2 MODEL DOMAIN AND GRID

The model domain shown in Figure 1-3 was selected ~~so as~~ to encompass an area sufficiently large that the hydraulic effects of the proposed project would not extend to the edges of the domain. Natural hydrologic boundaries such as major divides, major streams, lakes, and similar features are normally preferred for bounding the active area of the model within the model domain. However, in this case, such features were far outside the project area, and their incorporation into the model would have resulted in a model domain that extended well beyond the area for which water~~-~~ level data and other model-constraining data were available. The model domain extended from the vicinity of Driffield Creek ~~on~~ in the north to slightly south of the Edith River and from approximately Leliyn (Edith Falls) ~~on~~ in the east to the Edith River at Stuart Highway ~~on~~ in the west.

The finite-difference model grid consisted of 111 rows, 96 columns, and 15 layers, producing ~~a total of~~ 159,840 model cells in total. Of those, 159,792 model cells were active. The total area included in the model grid was approximately 260,826,508 m^2 (26,082.65 ha). The model cell horizontal dimensions were 50 m by 50 m in the area encompassing the existing Batman Pit and the proposed enlargement of the pit. The horizontal cell dimensions gradually increased outside that area to a maximum of 500 m by 500 m at the corners of the domain. Figure 5-1 shows the model grid, and Figure 5-2 provides an example cross-section through the model grid.

Vertical discretization of the model grid was based on the hydrogeological characteristics of the area and the proposed mine plans. The top of the uppermost layer represented the land surface. The uppermost layer itself was 3 m thick and represented the highly~~-~~ weathered, higher-permeability regolith and alluvial fill along ephemeral drainages and the Edith River. The second layer was 24 m thick and was designed to allow representation of the upper weathered portion of the bedrock. The thicknesses of model layers 3 and 4 were variable to accommodate the topographic difference between the land surface and the horizontal bottom of layer 4 at a constant elevation of 32 m AHD. The model layers below layer 4 were horizontal, and each was of a constant thickness. Layers 5 through 11 were each 48 m thick, twice the design height of the proposed Batman Pit benches, to facilitate simulation of the mining progression. Layers 12 through 15 increased progressively in thickness, such that the bottom of the model was at an elevation of -2000 m AHD. Table 5-1 summarizes the model layering.

Figure 5-1: Model Grid



Vertical Exaggeration = 3X

Figure 5-2: Example Cross-Section Through Model Grid Along Row 73

Table 5-1: Model Layering

Model Layer	Bottom Elevation (mAHD)	Thickness (m)	Description
Layer 1	variable	3	3 metres below ground surface
Layer 2	variable	usually 24	24 metres below Layer 1, but the bottom was no lower than 104 mAHD in the vicinity of Batman Pit
Layer 3	variable	usually 24	24 metres below Layer 2, but trimmed so it was never below 80 mAHD in the vicinity of Batman Pit and never above 120 mAHD elsewhere
Layer 4	32	variable	The layer bottom was flat at 32 mAHD
Layer 5	-16	48	Layers 5-11 had flat top and bottom and were 48 m thick to facilitate simulation of pit dewatering
Layer 6	-64	48	
Layer 7	-112	48	
Layer 8	-160	48	
Layer 9	-208	48	
Layer 10	-256	48	
Layer 11	-304	48	
Layer 12	-400	96	Layers 12-15 below proposed pit were progressively thicker to reduce the possibility of drawdown propagation to the model bottom
Layer 13	-600	200	
Layer 14	-1000	400	
Layer 15	-2000	1000	

5.3.3 Model Recharge

Recharge in the model was simulated as net recharge, or recharge minus evapotranspiration. Initial estimates of net recharge were calculated from seasonal volumetric changes in aquifer storage; these initial recharge estimates were adjusted as part of model calibration. In the upland areas where vegetation is generally sparse, the modelled recharge rate was set at 0.74 mm/yr (in the units of metres and days used in the model, 2.03e-006 m/d). Along the larger drainages, where vegetation is generally ~~more dense~~denser and evapotranspiration rates consequently greater, the net recharge rate was set at 0.365 mm/yr (1.00e-006 m/d). Figure 5-3 illustrates the distribution of net recharge in the model.

Commented [TM126]: How were these value determined? As recharge in sparsely vegetated area is one of the parameters with the largest influence on the steady state model, this needs to be clearly defined and checked for accuracy

Commented [CS127R126]: See edits.

Figure 5-3: Net Recharge Zones

5.3.4 Model Boundary Conditions

Model boundary conditions included MODFLOW no-flow boundaries, MODFLOW general head boundaries, MODFLOW stream boundaries, and MODFLOW horizontal flow barrier boundaries. MODFLOW drain boundaries and lake boundaries were utilised in the predictive modelling but not during calibration; therefore, these latter boundaries are discussed in the report sections regarding the mining and post-mining models. A summary of the MODFLOW model packages used to represent discrete features in the groundwater model is presented in Table 5-2 and Figure 5-4.

Table 5-2: Summary of MODFLOW Packages

Feature	MODFLOW Package	Layer	Model
Creeks	Stream-Flow Routing	1	Steady state calibration and transient
Edith River	Stream-Flow Routing	1	Steady state calibration and transient
Existing Batman Pit	General Head	1 to 4	Steady state calibration
Existing Batman Pit	Lake	1 to 4	Transient mining (during pit pump-out only)
Proposed Batman Pit	Drains	1 to 12	Transient mining
Proposed Batman Pit	Lake	1 to 12	Transient post-mining
Raw Water Supply Reservoir	General Head	1	Steady state calibration and transient
Tailings Storage Facility 1	General Head	1	Steady state calibration and transient mining
Waste Rock Dump Retention Pond	General Head	1	Steady state calibration and transient

5.3.4.1. No-Flow Cells

Inactive, or no-flow, cells were utilised for layers 1 and 2 in the area north of Driffield Creek near the northern edge of the model. This area is on the north side of the hydraulic boundary that was assumed to be formed by Driffield Creek. These 48 cells were the only no-flow cells in the model. Figure 5-4 illustrates the location of these cells.

Figure 5-4: Model Boundary Conditions

5.3.4.2. General Head Boundaries

MODFLOW general head boundaries were used to circumscribe the model domain and to simulate anthropogenic water sources at the Project site. Figure 5-4 illustrates the location of the general head boundaries.

General ~~head~~Head boundaries were placed in layers 2 through 15 around the perimeter of the model domain. General ~~head~~Head boundaries in perimeter positions allow flow into or out of the model domain, depending on whether the head in the cell is less than or greater than the head assigned to the boundary. The flow rate is proportional to the conductance assigned to the boundary and the head difference between the cell and the boundary. The heads assigned to the model domain perimeter general head boundaries varied along the perimeter. The assigned head at each location was the potentiometric surface elevation estimated at the location, and that head was assigned to the general head boundaries in all of the model layers at that point. The northern general head boundary represents water elevations in Driffield Creek.

Anthropogenic water sources at the Project site, including TSF1, the raw water supply reservoir, the Golf and Tollis pits, and the Waste Rock Dump water retention pond, were simulated with general head boundaries. Additionally, the existing Batman Pit was simulated with general head boundary cells during model calibration. Heads assigned to these water sources were based on the average elevation of the water surface in each source.~~:~~ 136 m AHD for TSF1, 134 m for the raw water supply reservoir, 137 and 138 m AHD for the Golf and Tollis pits, respectively, 119 m AHD for the WRD retention pond, and 133 m AHD for the existing Batman Pit.

Commented [TM128]: Changed for consistency throughout report

5.3.4.3. Stream Boundaries

The Edith River, Stow Creek, Horseshoe Creek, Batman Creek and the larger tributaries to those drainages were simulated as streams, using the MODFLOW-2000 Streamflow-Routing (SFR1) package (Prudic et al., 2004). The SFR1 package allows simulation of interactions between surface water and groundwater, including both groundwater discharge into a stream and seepage from the stream into the groundwater system. Input required for the SRF1 package includes ~~stream bed~~streambed elevations, ~~stream bed~~streambed characteristics, stream routing connections, stream segment lengths, and stream inflows and outflows or diversions. Figure 5-4 illustrates the locations of the streams in the model.

~~Stream bed~~Streambed elevations were taken from topographic information obtained from the DEM. Stream routing connections and segment lengths were determined from aerial photography. The initial stream inflows into the model domain were considered ~~to be~~ zero for all of the ephemeral drainages in the area, as they normally carry significant flows only in response to runoff from precipitation events. Each stream segment was assigned runoff inflows based on the catchment area. As mentioned earlier, an estimated 35 percent of precipitation becomes runoff. This value was used to calculate the amount of runoff (as a daily average) to each stream segment based on its catchment area. The most upstream reach of the Edith River was assigned an incoming flow rate equal to 35 percent of the average daily precipitation on the catchments of the Edith River east of the model boundaries. No outflows or diversions were simulated, as there are none ~~are~~ known in the area.

5.3.4.4. Horizontal Flow Barrier Boundaries

The dam forming the north, east and south sides of TSF1 was simulated using the MODFLOW Horizontal-Flow-Barrier (HFB) package. The package is used to simulate thin, vertical low-permeability features that impede the horizontal flow of groundwater. Conceptually, the barrier is situated between pairs of adjacent cells in the finite-difference model grid. The barrier boundaries were assigned to the upper two model layers and given a thickness (width) of one metre and a hydraulic conductivity of 0.0001 m/d. This conceptually represents the clay core of the earthen dam. Figure 5-4 shows the location of the horizontal flow boundary associated with TSF1.

5.3.5 Aquifer Properties

The Cenozoic surficial sediments and highly weathered regolith at ground surface have the highest horizontal hydraulic conductivity of the modelled geologic units, ranging up to 5 m/d based on transmissivity values (Table 4-4) and logged unit thicknesses. In the sediments, this may be due in part to large interconnected pores observed during geotechnical investigations. In the case of highly weathered regolith, the higher conductivities are due to widening of fractures and, in some cases, spalling. The sediments below the streams and streambeds are primarily comprised of silts, clays, and some sand. The unconsolidated material elsewhere is primarily highly weathered regolith, which may be gravel, cobbles, clay, silt, and sand.

> **Commented [TM129]:** Where did this value come from?
>
> **Commented [TK130R129]:** T values from Table 4-4 and borehole logs for b. ADD THIS IN PARENTHESIS
>
> **Commented [CS131R129]:** Revised.

The granite and hornfelsed BCTF have the lowest horizontal hydraulic conductivity, in the range of $1x10^{-5}$ m/d (Table 4-5). Granite has little to no primary porosity, and unweathered granite has very few open or interconnected fractures. The hornfelsed BCTF has recrystallized such that almost all of the original primary porosity is gone, and there are very few open or interconnected fractures. Thus, these two units form ~~fairly~~ effective barriers to groundwater flow.

> **Commented [TM132]:** Where did this value come from? The hydraulic conductivity values derived from aquifer testing results are different to this value.
> Refer Table 4-5
>
> **Commented [TK133R132]:** Geomean of values in Table 4-5 is 1.4e-05 m/d. ADD REFERENCE TO TABLE 4-5
>
> **Commented [CS134R132]:** Revised.

The less-metamorphosed BCTF has some primary porosity due to starting out as sedimentary rock. In addition, both bedding-plane fractures and deformation-related fractures occur in the BCTF. Thus, compared to the granite and hornfelsed BCTF, the less-metamorphosed BCTF has significantly higher hydraulic conductivity, in the range of $1x10^{-1}$ m/d based on transmissivity values (Table 4-4) and logged unit thickness. The type of rock varies somewhat from location to locations and includes greywacke, phyllite, slate, siltstone, and similar lithologies. In addition, the degree of fracturing varies with location and with depth. Thus, the hydraulic conductivity would also be expected, ~~to~~ potentially, to vary quite a bit between locations.

> **Commented [TM135]:** Where did this value come from? The hydraulic conductivity values derived from aquifer testing results are different to this value.
> Refer Table 4-5
>
> **Commented [TK136R135]:** T values from Table 4-4 and borehole logs for b. ADD REFERENCE
>
> **Commented [CS137R135]:** Revised.

The weathered granite has significantly higher hydraulic conductivity than fresh granite, simply due to the addition of secondary porosity. The weathered BCTF, however, has been observed to have significant infilling of fractures by clay and iron oxide materials, which actually results in a lowering of the hydraulic conductivity. Thus, interestingly, the most productive portions of the BCTF were observed to be in the interval located 30-70 m below land surface (Rockwater, 1988 and 1989).

The model was used to calibrate hydraulic conductivity (K) values for each zone. Table 5-3 shows the calibrated hydraulic conductivities for each modelled K zone. Appendix G provides plots of the spatial distribution of hydraulic conductivity zones for each model layer.

Table 5-3: Calibrated Hydraulic Conductivity and Storage Coefficient Values

Model Zone Name	Horizontal Hydraulic Conductivity (m/day)	Vertical Hydraulic Conductivity (m/day)	Storage Coefficients	Description
Unconsolidated	5	0.5	Ss = 1e-5 Sy = 0.1	Alluvial material in streambeds
	2	0.2		Completely weathered bedrock
Weathered Granite	0.001	0.001	Ss = 1e-5 Sy = 0.1	Weathered Cullen Batholith material
Granite	0.00001	0.00001	Ss = 1e-5 Sy = 0.02	Cullen Batholith members (Yenberrie Leucogranite, Driffield Granite, and Tennysons Leucogranite)
Weathered Volcanics	0.001	0.001	Ss = 1e-5 Sy = 0.1	Weathered Plum Tree Creek Volcanics
Volcanics	0.0001	0.0001	Ss = 1e-5 Sy = 0.02	Plum Tree Creek Volcanics
Weathered Burrell Creek and Tollis Formation (BCTF)	0.0606	0.0606	Ss = 1e-5 Sy = 0.1	Weathered BCTF up to approximately 27 metres below land surface
BCTF - North	0.13	0.13	Ss = 1e-5 Sy = 0.02	BCTF in the northern portion of the model
BCTF - Central	0.25	0.25	Ss = 1e-5 Sy = 0.02	BCTF in the central model area, primarily under and near TSF1
BCTF - South	0.17	0.17	Ss = 2e-5 Sy = 0.02	BCTF in the southern portion of the model
BCTF - Altered	0.00001	0.00001	Ss = 1e-5 Sy = 0.02	Hornfelsed BCTF
BCTF - Transition	0.019	0.019	Ss = 3e-6 Sy = 0.02	Transition between hornfelsed BCTF and less-metamorphosed BCTF
Sandstone	0.1	0.01	Ss = 1e-5 Sy = 0.1	Phillips Creek Sandstone

Note: Ss = specific storage, Sy = specific yield

As shown in Table 5-3, the metamorphic and igneous rocks were assigned equal hydraulic conductivity in the vertical and horizontal directions. This is because there was no evidence to support a systematic vertical anisotropy. For the unconsolidated materials, a higher horizontal conductivity was selected because the primary flow in the unconsolidated materials has been observed to be horizontal rather than vertical. Further, sedimentary deposition of clays would result in decreased vertical conductivity.

The calibrated storage coefficients from the model are also shown in Table 5-3. In general, specific yield should be in the same range as porosity. For unconsolidated, weathered, and sandstone materials, specific yield was assigned a value of 0.1 due to the presence of significant primary porosity. For igneous and metamorphic materials with little to no primary porosity, specific yield was assigned a value of 0.02, which is roughly analogous to 2 percent porosity due to fractures.

Specific storage, based on aquifer test results reported in Table 4-4, ranged from about 1e-3 to 1e-6. In the calibrated model, specific storage ranged from 2e-5 to 3e-6. This range is consistent with the aquifer test results.

Commented [TM138]: What about the specific storage values between 1e-3 to 2e-5?
The calibrated range is only the lowest 2% of the range calculated from testing results.

Commented [TK139R138]: The Ss value falls within reported range and was a parameter included in and adjusted during calibration. That the calibrated values are in the lower part of the large range is not a negative consideration.

5.3.6 CALIBRATION DATA SETS

The groundwater model was calibrated to both steady state and transient calibration data sets. For the steady state model, the average groundwater elevations measured between 2011 and 2016 were used. These calibration data are illustrated in Figure 5-5 as an average potentiometric surface.

Figure 5-5: Steady-State Calibration Data

The transient model was calibrated to aquifer testing conducted at bores BW1P, BW2P, BW6P, BW8P, BW10P, BW16P, BW17P, BW18P, and BW19P (Rockwater, 1988 and 1989). The observation bore data were used, since data from the pumped bore also include the effects of bore inefficiency. Pumped bores in general are not 100 percent efficient, and as a result, there is more drawdown within the bore than would be expected given the formation hydraulic properties. To eliminate this source of error, only observation bore data were used for calibration. If an aquifer test did not have an observation bore, then the test was not used as part of the transient model calibration.

Commented [TM140]: What about the other aquifer testing results?

Commented [TK141R140]: These had observation well data available, so were the most appropriate and representative.

The model was calibrated to the steady state hydraulic head data and transient drawdown data using a combination of manual calibration and automated calibration using the PEST software package as a tool (Doherty, 2016). After an initial calibration using steady-state data only, the steady state and transient models were calibrated simultaneously. This process ensured that changes in the steady state model were automatically represented in the transient model, and vice versa. The calibrated transient model became the basis for subsequent predictive modelling.

5.3.7 *Steady State Calibration Results*

The steady state model was calibrated to within 10 percent of the observed head values. Table 5-4 provides the numerical calibration statistics for the steady state model. In the table, “residual” refers to the actual measured hydraulic head in metres minus the simulated (modelled) hydraulic head in metres. Thus, a negative residual means that the model predicted a higher hydraulic head than was observed, and a positive residual means that the model predicted a lower hydraulic head than was observed.

Table 5-4: Steady State Calibration Statistics

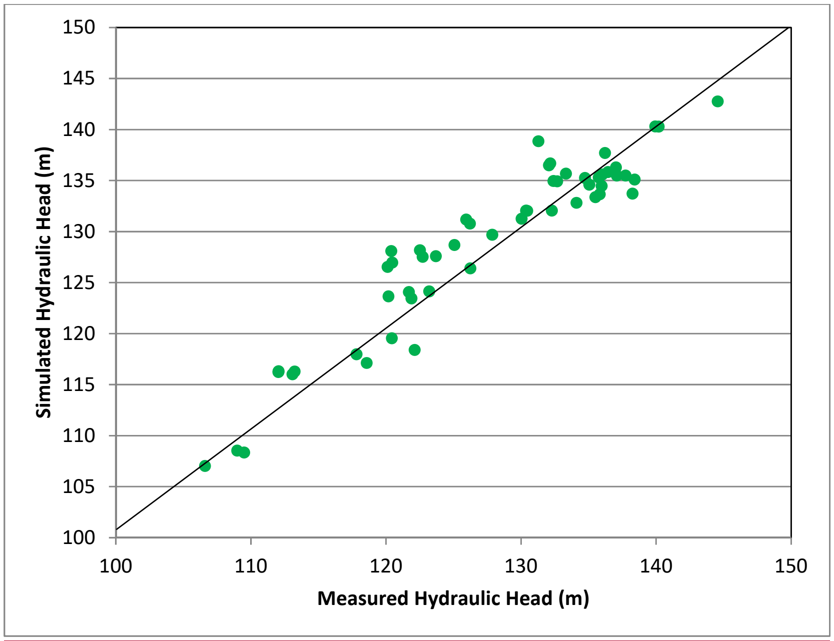
Statistic	Value
Residual Mean (m)	-1.~~69~~36
Absolute Residual Mean (m)	2.~~3664~~51
Root-Mean-Square (RMS) (m)	~~2.93~~3.~~34~~20
Standard Deviation (m)	2.~~60~~8~~8~~9
Minimum Residual (m)	-~~7.50~~7.72~~8.00~~
Maximum Residual (m)	4.53~~3.55~~80
Range of Observations (m)	37.95~~34.1201~~
Scaled RMS (%)	8.4~~9.8.6~~
Scaled Standard Deviation (%)	7.6~~8.57.6~~
Abs. Res. Mean/Range (%)	~~7.8~~6.6~~6.9~~

In a well-calibrated model, the residual mean and absolute residual mean should be as close to zero as possible. The negative residual mean indicates that the model is slightly biased toward over-predicting the hydraulic heads. The overall calibration can be assessed using the scaled RMS, scaled standard deviation, and absolute residual mean/range. Generally, these statistics should all be less than 10 percent in a well-calibrated model. This criterion was met, indicating that the Mt Todd steady state model is acceptably calibrated in a numerical sense.

Commented [TM142]: The model does meet the criteria to indicate acceptable calibration, but as the calibration statistics have increased from those produced by the original model calibration indicates model parameters may require adjustment

Commented [TK143R142]: The model meets acceptable calibration criteria. No further adjustment is required.

Figure 5-6 is a plot of the measured hydraulic head against the model-simulated hydraulic head. In a perfectly-calibrated model, all the points would plot directly on the one-to-one line. A well-calibrated model will have some scatter but not a lot. The Mt Todd model has some scatter, with a slight bias to over-predicting the heads as discussed above. However, overall the calibration is considered acceptable.


Simulated Hydraulic Head (m)
Measured Hydraulic Head (m)
150
145
140
135
130
125
120
115
110
105
100
100
110
120
130
140
150

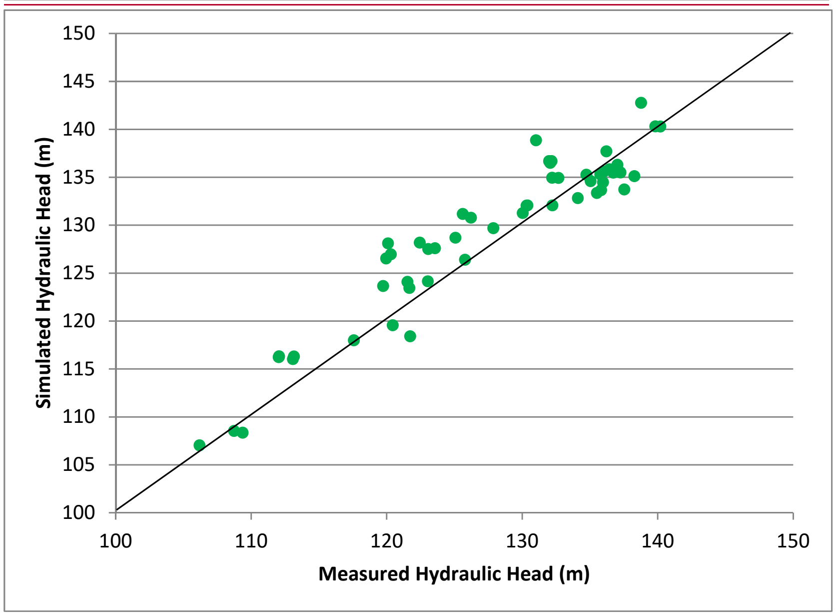

Simulated Hydraulic Head (m)
Measured Hydraulic Head (m)
150
145
140
135
130
125
120
115
110
105
100
100
110
120
130
140
150

Figure 5-6: Measured vs. Simulated Hydraulic Head Data

The spatial distribution of the steady state model residuals is shown on Figure 5-7. Ideally, the positive and negative residuals should be distributed randomly across the map. In the Mt Todd model, this is generally true, indicating a well-calibrated model. In general, the positive residuals are interspersed ~~fairly~~ randomly between the negative residuals, and the large residuals are interspersed ~~fairly~~ randomly amongst the small ones. As mentioned earlier, there is a slight bias toward over-predicting head. The negative residuals (over-predicting head) tend to fall near surface water features, indicating that possibly the conductances of the surface water features ~~are~~ require additional refinement. This is to be expected, since an exhaustive evaluation of the streambed and impoundment bottom conductances was not performed as part of this study.

In addition to the hydraulic head data, one average ~~s~~Stream ~~f~~Flow data point was used to assess how well the stream flow was simulated. The data point was the stream gauge on the Edith River. While this single data point is not considered to be part of the steady state residuals, the simulated steady state stream flow of 683,700 m^3/day at the Edith River gauge was within about 10 percent of the average stream flow in the Edith River ~~between 1994 and 2012~~over time (663,000 m^3/day), according to the ~~NRETAS~~ NTG water data portal ~~online data tool~~ (~~2012~~2017). ~~Also~~In addition, the Edith River simulated steady-state stage was about 0.5 metres, which is similar to the average measured gauge height (0.5 metres) over time.

Table 5-5 provides a summary of the steady state model water balance. The negligible error in the model water balance indicates that a numerically stable solution was reached. In keeping with the site conceptual model that most recharge either evaporates or becomes runoff, recharge formed a very minor part of the water balance. Most of the groundwater flows occurred through the general head boundaries, which represented the permanent surface water impoundments and flow through the subsurface geologic formations.

Table 5-5: Steady State Groundwater Model Water Balance Output (m^3/day)

Package	In (source)	Out (sink)
Recharge	478.4	0.0
Streams	917~~5.2~~6.6~~24143.3~~	2386~~4~~6.8~~36415.3~~
General heads	191115.~~6~~7~~190854.9~~	176903.3~~179060.1~~
Total flow	2007~~69~~70.~~2~~7~~215476.6~~	2007~~68~~70.1~~215475.3~~
In - Out	~~1.1~~0.6 (m3/day)~~1.3 (m^3/day)~~	
Difference	0.00 %	

Commented [TM144]: What is the average measured stream flow?

Commented [BM145]: This should be updated to include 2017 data

Commented [CS146R145]: Updated; note that years with no data were not included.

Commented [TM147]: What is the average measured gauge height?

Commented [CS148R147]: Updated.

Figure 5-7: Steady State Model Residuals

5.3.8 *Transient Calibration Results*

The transient model was calibrated to measured drawdown during aquifer pumping tests. The modelled drawdown was within 10 percent of the measured drawdown. Figure 5-8 compares the measured to the simulated drawdowns for the aquifer pumping tests that were part of the transient calibration.

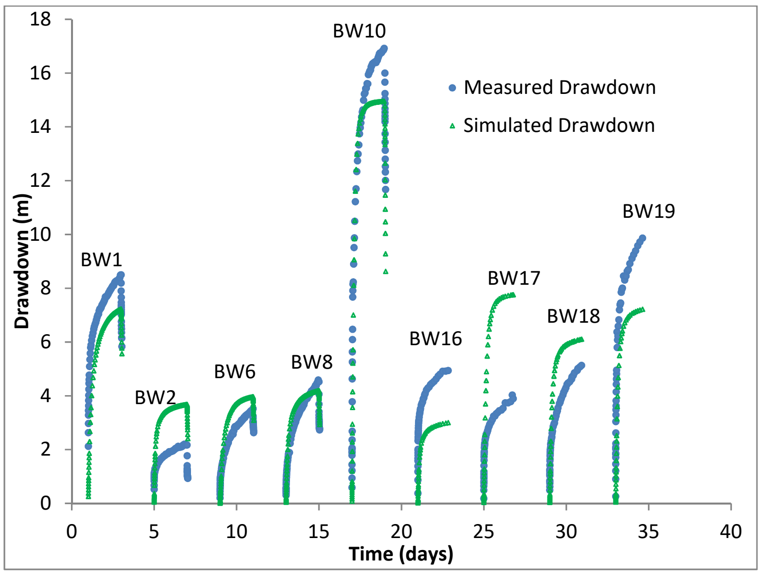


Figure 5-8: Transient Model Calibration – Measured vs. Simulated Drawdowns

Figure 5-8 shows that visually the transient model is capable of simulating the drawdowns associated with aquifer testing in various parts of the Project area. The matches could be improved in some cases, particularly BW16 and BW17. However, overall the matches to drawdown data collected from the monitoring bores were reasonable.

Table 5-6 provides the transient calibration statistics calculated from all of the modelled aquifer tests. The residual mean was quite close to zero, indicating that the model did not significantly over- or under-predict drawdown. The absolute residual mean was 1.~~17~~2 m, indicating an overall reasonable match to the magnitude of drawdown. The scaled RMS, scaled standard deviation, and absolute residual mean divided by range were all less than 10 percent, indicating a well-calibrated match to transient drawdown data.

Commented [TM149]: While the new result is quite close to zero, it is almost 3 times the result from the original calibration.

Commented [CS150R149]: Noted.

Commented [TM151]: Table states 1.2 m for the absolute residual mean

Commented [CS152R151]: Agreed.

Commented [TM153]: The change in these statistics is obviously due to the change in the steady state model calibration as no new drawdown data was used. Thus again indicating the steady state model requires adjustment.

Commented [TK154R153]: See previous response. Model calibration meets criteria.

Table 5-6: Transient Calibration Statistics

Statistic	Value
Residual Mean (m)	0.148
Absolute Residual Mean (m)	1.20
Root-Mean-Square (RMS) (m)	1.47
Standard Deviation (m)	1.47
Minimum Residual (m)	-4.19
Maximum Residual (m)	3.22
Range of Observations (m)	16.74
Scaled RMS (%)	8.9
Scaled Standard Deviation (%)	8.8
Abs. Res. Mean/Range (%)	7.2

5.3.9 CALIBRATION SENSITIVITY EVALUATION

A sensitivity analysis was performed to determine which model parameters had the most influence on the model calibration. Parameters evaluated were hydraulic conductivity in the horizontal and vertical directions, recharge, specific storage, specific yield, and stream-bed conductivity. Each parameter was doubled, the model was re-run, and calibration statistics were calculated. Then each parameter was halved, the model was re-run, and calibration statistics were re-calculated.

The parameters with the largest effect on steady state model calibration were net recharge in the less-vegetated areas, the vertical and horizontal hydraulic conductivity in the weathered BCTF, and the vertical conductivity in the hornfelsed BCTF. These parameters govern the amount of recharge and its ability to infiltrate into the subsurface, which are major drivers in the morphology of the potentiometric surface. Thus, the potentiometric head calibration was very sensitive to these parameters.

The parameters with the largest effect on transient model calibration were the vertical and horizontal hydraulic conductivity and specific storage of the various BCTF zones in which the pumped bores were located. These parameters affect the water availability and drawdown propagation in the vicinity of each of the pumped bores. Therefore, the calibration to pumping test drawdown data was most affected by the hydraulic properties of the BCTF zones containing the pumped wells.

Commented [TM155]: The accuracy of the values used for these parameters needs to be reviewed.

Commented [TK156R155]: N/A

Commented [TM157]: The accuracy of the values used for these parameters needs to be reviewed.

Commented [CS158R157]: N/A per conference call.

Commented [TM159]: The values in the model where only the lowest 2% of the range calculated from the aquifer testing results, therefore these values should be reviewed.

Commented [TK160R159]: That the calibrated values are in the lower part of the large range is not a negative consideration. Further review is not warranted.

5.3.10 TRANSIENT PREDICTIVE MODEL DEVELOPMENT

Two transient predictive models were developed: one to simulate the mining period and one to simulate the post-mining period. The steady-state heads calculated by the calibrated model were used as the starting heads for the mining model, and the transient heads calculated by the mining model for the end of the mining period were used as the starting heads for the post-mining model.

5.3.10.1. PREDICTIVE SIMULATION – MINING PHASE

The mining-phase predictive model was divided into 34 transient stress periods of 182.625 days each, preceded by a single stress period of 0.001 day. During the first stress period, no anthropogenic stresses were applied to the model. The following six stress periods (2 through 7) simulated the period prior to the start of mining, during which the accumulated water in the existing Batman Pit would be removed by pumping from the pit. Stress periods 8 through 35 simulated the 14 years of proposed active mining of the Batman Pit.

Commented [TM161]: Is this still the case?

Commented [TK162R161]: Yes.

Because the pit pump-out would occur over a period of approximately three years, the MODFLOW LAK3 package (Merritt and Konikow, 2000) was selected as the most appropriate means for simulation of the interaction of the pit lake and the groundwater system during the pit pump-out period. The Lake package is capable of simulating precipitation falling onto the lake water surface, runoff into the lake from the surrounding catchment area, evaporation from the lake surface, addition of water to the lake from sources such as stream inflow or pumped inflow, and removal of water from the lake by stream outflow or pumping. Lake cells were assigned at the same locations within model grid layers 1 through 4 as had been occupied by the general head boundary cells used to simulate the existing Batman Pit during model calibration.

Commented [TM163]: This is no longer the case as three years of pumping have already occurred and the pit water level has only been reduced by 25% of capacity, with the current pit level at approximately 70% of capacity.

Commented [TK164R163]: This is a different issue; the three years is part of the mine plan that was integrated into the model.

Precipitation onto the lake water surface was at the average annual rate of 1157 mm (0.003167 m/d), based on ~~historical~~ recent precipitation data from the average of the gauges at the Project site since October 2012. An average annual rate of evaporation from the lake surface was calculated using the average annual pan evaporation rate of 2637 mm for the Project work shop site pan since October 2014 and a coefficient of 0.78 for conversion of the pan evaporation rate to a lake evaporation rate. The coefficient was determined by extrapolation of contoured coefficients for Western Australia (Luke et al., 1987). The estimated lake evaporation rate is 2057 mm/yr (0.00563 m/d). Average annual runoff into the pit lake from the surrounding catchment area was estimated using the SCS Curve Number method (USDA, 1996). The applicable equation is:

Commented [TM165]: Section 4.2.1 states the average annual precipitation onsite is 1276 mm.

Commented [TK166R165]: 1157 mm is the average of the on-site gauges since Oct 2012. CLARIFY IN TEXT

Commented [CS167R165]: Done.

Commented [TM168]: Section 4.2.4 states the average annual pan evaporation rate at the different stations ranges from 2446-2638 mm, with an average of 2526 mm over the site.

Commented [TK169R168]: 2637 mm is the average for the shop pan since Oct 2014. CLARIFY IN TEXT

Commented [CS170R168]: Done.

$$Q = (P - I_a)^2 / (P - I_a + S)$$

where:

Q is the runoff (mm);

P is the precipitation in a single precipitation event (mm);

I_a is the initial abstraction (all losses before runoff begins, such as interception by vegetation, water retained in surface depressions, and water lost by evaporation and infiltration) (mm); and

S is the potential maximum retention after runoff begins, in mm, calculated from the runoff curve number (CN) by the equation S = 25.4 * 1000/(CN-10).

Calculation of an average annual runoff of 702 mm was based on a synthetic daily precipitation series stochastically derived for the Project site and a curve number of 95. The catchment area of 161750 m^2 (16.175 ha) outside of the pit was thus estimated to produce an average annual runoff of 161750 m^3 (442.8 m^3/d). By trial and error, it was determined that a withdrawal rate of 15680 m^3/d from the pit was necessary to lower the pit lake water level to the bottom of the pit at elevation 40 m AHD at the end of the pump-out period of three years.

The Batman Pit would be enlarged and deepened over an estimated period of 14 years. Dry working conditions are expected to be maintained in the pit by the construction of inflow collection sumps from which the water would be pumped for use by mining operation or for discharge at the surface. Dewatering of the Batman Pit was simulated in the mining-phase model by using the MODFLOW drain boundary condition. Drain boundaries are useful for simulating the effects of mine dewatering because they remove water from the groundwater system only when head in the drain cell is greater than the elevation of the head specified for the drain cell. The configuration and elevations of the drain cells within the model can be adjusted through time as the mine configuration changes, thereby enabling accurate simulation of the mine progression. The drain configuration in the model represents the mining plan as of February 2013.

Drains were assigned to model layers 1 through 12 based on the layout and scheduling of the proposed enlargement and deepening of the Batman Pit. The deepening and lateral expansion of the pit was simulated by expanding the drain locations within the model grid and lowering the drain elevations over time. A total of 2966 drain cells were used to simulate the mine dewatering. The drain cell locations are shown plan view in Figure 5-9. The vertical progression of mining simulated by the drain cells is shown in cross-section view in Figure 5-10.

Commented [TM171]: This is a large change in runoff, what is the reason for this change? Change in catchment area? Average rainfall and evaporation levels have not changed dramatically,

Commented [TK172R171]: Updated to match water balance model.

Commented [TM173]: Why was this curve number selected?

Commented [TK174R173]: So runoff would match water balance model.

Commented [CS175R173]: For consistency with site water balance model. This curve number indicates a nearly impervious surface.

Commented [TM176]: Is this still the current planned number of years of mining?

Commented [BM177R176]: yes

Commented [TM178]: Is this the current plan?
If not why was this one used?

Commented [TK179R178]: Mine plan unchanged from previously.

Figure 5-9: Drain Cell Locations – Plan View

Figure 5-10: Modelled Mining Sequence Batman Pit

Tailings would be deposited in the existing TSF1 during the initial five years of mining. During that period, the height of the tailings dam would be raised step-wise, and the elevation of the water ponded on the tailings would rise gradually, thus increasing the head within TSF1. This situation was simulated by incrementally raising the head assigned to the general head boundary cells representing TSF1 from 136 m AHD at the start of the mining phase to 157 m AHD by the fifth year. The head was increased 2.1 m per stress period, starting with stress period 8 and ending with stress period 17. The new TSF2 would be placed into service in year 6, and TSF1 would no longer be used. The cessation of use of TSF1 was simulated by turning off the general head boundary cells in that area and thereby allowing the head in the TSF1 area to decline as governed by the hydraulic conductivities of the tailings and adjacent materials. Recharge in the TSF1 area was held constant at the background rate of 2.027e-006 m/d throughout the simulation period. Areas where lined facilities including the heap leach pad and ponds RP2 (low-grade ore stockpile pond) and RP5 (plant runoff pond) were present were assigned a recharge rate of zero. Recharge in the TSF2 area was reduced to zero in year 6, when that facility would be placed into service. The timing of the recharge reduction can be refined when the model is updated to reflect final TSF design plans.

At the start of the mining period, the height of the dam that forms the raw water supply reservoir would be raised by 2 m. To account for this in the model, the head assigned to the general head boundary cells simulating the reservoir was increased by 2 m at the start of the mining period and maintained at that elevation for the remainder of the simulation period.

5.3.10.2. Predictive Simulation – Post-Mining Phase

Predictive simulation of post-mining conditions was completed by modifying the numerical model to account for post-closure pit lake development. The pit lake water balance was simulated with the LAK2 package (Council, 1999). The other anthropogenic sources were simulated in the same way as in the mining-phase model. The post-mining phase was simulated as a single stress period of 1,500 years.

Upon cessation of mining activities and active pit dewatering, the pit would begin to fill with water derived from the inflow of groundwater, precipitation and runoff. The rate at which the pit would fill, and the ultimate depth and stage of the pit lake, would depend on the pit lake water balance, which describes how water flows into and out of the lake. Depending on the relative magnitudes of these flows, a pit lake may form or the pit could remain dry.

Conceptually, the post-closure water balance for the mine pits can be expressed as:

$$\Delta_{\text{pit lake volume}} = I_{\text{precip}} + I_{\text{runoff}} + I_{\text{pit runoff}} + GW_{\text{inflow}} - E_{\text{pit}} - GW_{\text{outflow}}$$

where:

I_{precip} is the inflow from direct precipitation falling on the lake surface;

Commented [TM180]: Where is this value from?

Commented [TK181R180]: Model calibration.

Commented [TM182]: Lining known to be breached

Commented [TK183R182]: TEXT OK

Commented [CS184R182]: OK per conference call

Commented [TM185]: Is this pond lined?
2012-2016 Water Management Plans indicate the contrary.

Commented [TK186R185]: OK as is

Commented [CS187R185]: Per conference call

Commented [TM188]: Wouldn't this reduction have occurred prior to the facility being placed in service?

Commented [TK189R188]:

Commented [CS190R188]: Edited per conference call

Commented [TM191]: This indicates this is either an infinite water source, or little to no use of this water supply (i.e. extraction is =< recharge)

Commented [CS192R191]: Noted.

Commented [TM193]: Why this length of time?

Commented [TM194R193]: A period of 1500 years is used for the pit lake below and 1200 years is used for drawdown and groundwater flow predictions

Commented [TK195R193]: Simulation length was 1500 years; stabilization occurred at 1200 years.

Commented [TM196]: Based on previous modelling work a range for these flows have been determined, so what is the possible pit water levels range based on these flows?

Commented [TK197R196]: This paragraph is a generic description only, outlining the parameters included in the water balance.

I_{runoff} is the inflow from runoff from upgradient drainages (zero in this case, as no runoff into the pit will occur from outside the pit itself);

$I_{pit\ runoff}$ is the inflow from pit wall runoff (the fraction of precipitation falling on the pit walls that ultimately reaches the pit lake);

GW_{inflow} is the groundwater inflow to the pit lake;

E_{pit} is the open-water evaporation from the pit lake surface; and

$GW_{outflow}$ is the outflow of groundwater from the pit lake.

There are two types of pit lakes: terminal-sink and flow-through. A terminal-sink pit lake has no groundwater leaving the pit ($GW_{outflow} = 0$). A flow-through pit has a component of groundwater leaving the pit ($GW_{outflow} > 0$). Evaporation must be greater than the sum of precipitation, runoff, and groundwater inflow for a terminal-sink pit lake to form. In an equilibrated terminal-sink pit lake, the evaporative loss from the pit lake maintains the pit lake water level below the level of the groundwater in the surrounding rocks and forms a drawdown cone around the pit lake, drawing in groundwater from all sides and prohibiting groundwater through-flow.

Due to the steep, roughly cone-shaped walls of the proposed open pit, the surface area of the pit lake would be small initially, but as the lake stage rises, the surface area would increase. The evaporation losses would increase as the surface area increases. The water-surface elevation in the pit lake would stabilize when the evaporation rate from the pit lake equals the sum of the inflow components. The stabilized lake stage would dictate the long-term, steady-state groundwater inflow and drawdown associated with the pit lake.

The LAK2 package was selected to simulate post-mining pit lake formation because it can calculate the transient stage of a pit lake as the lake fills, determining groundwater inflows and outflows across multiple model layers, and is more numerically stable than the LAK3 package. The LAK2 package couples the lake water balance and the groundwater flow model, thereby allowing the lake stage to vary according the hydraulic stresses applied to the aquifer and the lake water budget. The inputs and outputs for the LAK2 package are:

- direct precipitation onto the lake (L/T);
- lake Evaporation (L/T);
- runoff into the pit (L^3/T); and
- conductance values for LAK cells (L/T).

Using the three-dimensional representation of the final configuration of the proposed Batman Pit, model cells adjacent to the exterior of the pit were designated as “lake cells.” The groundwater inflow into the pit would vary depending on heads in the surrounding aquifer cells, lake stage, and cell conductance. The conductance of the lake cells was based on the aquifer material properties and the grid block geometry. The lake cell conductance was set equal to the conductance of the adjacent aquifer material. The bottom of the lake was set to the final pit floor elevation of -340 m AHD. The lake cells for the Batman Pit spanned 13 model layers. The stage-area relationship for the pit lake was generated in the LAK2 package as a function of the area of the simulated lake cells for each model layer, and the stage-volume relationship was generated as a function of lake cell areas for each layer and the layer thicknesses. The stage-volume relationship simulated by the LAK2 package was checked against the elevation-volume relationship of the final pit shell and was found to accurately represent the relationship.

Direct precipitation onto the lake was at the average annual rate of 1157 mm (0.003167 m/d), and the lake evaporation rate was at the annual average rate of 2057 mm/yr (0.005632 m/d), using the same method as described above for the Batman Pit pre-mining pump-out. The LAK2 package calculates the volumetric evaporation rate as a function of lake stage and surface area, thereby allowing evaporation to increase as the pit lake water level rises and the lake occupies more area. However, the volumetric precipitation rate is calculated based on the lake surface area at the maximum possible lake stage. The pit lake at maximum possible stage would occupy the entire pit, so all precipitation falling within the pit (not just on the pit lake water surface) would be included as input into the lake water balance.

Commented [TM198]: Inconsistent with value specified in section 4.2.1

Commented [TK199R198]: See previous response. REVIEW AND CONFIRM

Commented [CS200R198]: 1157 mm is the average of the on-site gauges since Oct 2012.

Commented [TM201]: Accuracy of this value requires confirmation

Commented [TK202R201]: See previous response.

Commented [CS203R201]: 2057 is the same lake evaporation rate described in Section 5.3.10.1.

Precipitation and runoff were input into the LAK2 package and were specified manually as step functions whose values were dependent on lake stage and lake area. Precipitation onto the lake surface was increased over time as the lake surface area increased with rising stage. Runoff was decreased over time as the catchment area between the pit lake and the pit rim decreased with rising pit lake stage. This required an iterative approach wherein the times at which the rate changes occurred were adjusted to ultimately coincide with the times at which the model-calculated evaporation rate changed as the lake stage rose into successively higher layers in the model.

6.0 POTENTIAL IMPACTS

Potential impacts related to the proposed mining activities were identified through comparison of the results of the predictive groundwater flow modelling to the conditions simulated by the steady-state results of the calibrated groundwater flow modelling. The background conditions for purposes of identification of potential impacts were assumed to be those at the start of Vista Gold's tenure, as simulated by the steady-state calibrated model.

Groundwater model output relevant to prediction of potential impacts included:

- calculated groundwater flows to the drains that were used to simulate dewatering of the Batman Pit during the proposed mining operations;
- the calculated water balance of the pit lake that would form in the Batman Pit after the proposed mining operations have ended;
- calculated groundwater levels during and after the proposed mining operations compared to the calculated steady-state groundwater levels; and
- calculated surface-water flow rates during and after the proposed mining operations compared to the calculated steady-state surface-water flows.

The simulation results depicted in the figures and tables that follow are based on the model described herein, which was developed using currently~~-~~ available information on the geologic and hydrogeologic conditions at the Project site and in the region. It is possible that as-yet-unidentified conditions, such as zones of intense fracturing or of low-permeability materials, could be encountered during mining operations. Such conditions could result in mine inflows and mining-related water-level changes that differ from those predicted by the model.

Although the calibrated model reasonably reproduced anecdotal qualitative and semi-quantitative estimates of historical inflows to the existing Batman Pit, no reliable measurements of historical inflows to the existing pit are known to exist, and therefore the model could not be verified against known inflows. Also, because the proposed mining has not yet begun, no quantitative field data regarding groundwater inflows during mining yet exist against which the model results can be compared and the model thus verified. In cases where appropriate field data such as measured mine inflow rates and water-level changes in monitoring wells are available, the results from the calibrated model can be verified against observed data and the model can be adjusted accordingly, thereby reducing uncertainty inherent in predictions made based on the model. Although such verification of the model described herein is expected to be possible in the future, no quantitative verification has been performed, and the model predictions must therefore be considered in light of that qualification.

Commented [TM204]: What about the current discharge of treat water data from Batman Pit, along with measured precipitation and evaporation to determine interactions between the pit water and the groundwater (inflows and/or outflows)

Commented [TK205R204]: The statement stands as is.

Commented [CS206R204]: This refers to inflow data collected during mining, which is significantly different from pumping out surface water inflows. See clarifying text.

Commented [TM207]: Isn't this what this review was meant to do?

Commented [TK208R207]: No.

Commented [CS209R207]: Verification will only be possible after mining begins.

6.1 MINING-PHASE PREDICTIVE GROUNDWATER MODEL RESULTS

Potential impacts related to the proposed mining-phase activities include changes in groundwater levels, groundwater flow directions, and stream flows as a result of pit dewatering and on-site water management. Prediction of groundwater inflow to the pit is a component of impacts prediction that is important to mine planning and management of discharges from pit dewatering. The quality of any discharged groundwater is also of potential significance.

6.1.1 PREDICTED GROUNDWATER INFLOWS TO BATMAN PIT

Estimated groundwater inflows to the Batman Pit during mining are shown graphically in Figure 6-1. Predicted groundwater inflows ranged from a few litres per second at the start of mining to approximately 36 L/s during the final months of mining. Short-term variability of inflows calculated by the model has been smoothed by plotting the inflows as cumulative average values. Although the proposed mining would deepen and laterally expand the pit gradually, the model simulated pit deepening and lateral expansion in a step-wise fashion. By instantaneously lowering the drain cell elevations and/or activating additional drain cells at the start of each stress period, the model simulation represents the pit depth and extent during the entire stress period as the depth and extent planned for the end of the stress period. The instantaneous lowering of drain elevations and increase of the lateral extent typically results in a sudden increase in the calculated inflow at the start of the stress period, followed by a gradual decrease through the remainder of the stress period. The smoothing does not remove such effects, but it provides a better representation of the groundwater inflows that can be expected during the actual gradual deepening of the pit.

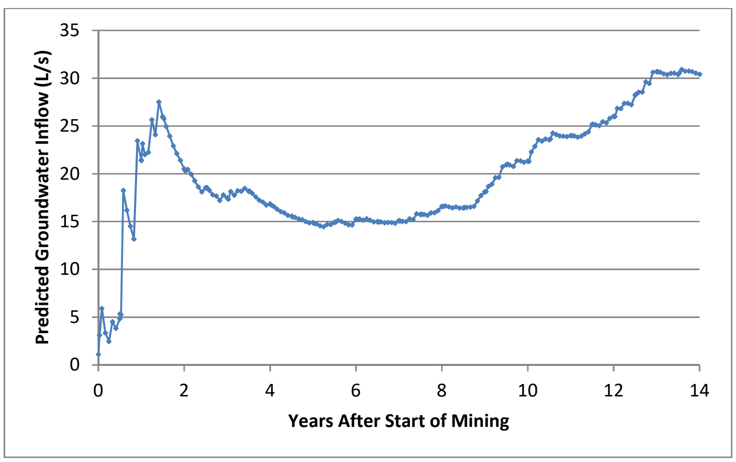


Figure 6-1: Predicted Groundwater Inflows to Batman Pit

6.1.2 Predicted Groundwater Level Changes

The mining-phase simulation also provided estimates of predicted drawdown related to mine dewatering operations. Figure 6-2 shows the predicted water table drawdown at the end of active mining. The drawdown was calculated by subtracting the water table elevation at the end of mining from the steady-state water table elevation. The maximum predicted drawdown at the end of mining was approximately 475 m, the depth of the pit below the initial steady-state water table. Drawdown was predicted to decrease rapidly with distance from the pit, with the 10-m drawdown contour extending only to about the rim of the pit. The contours of the 5-m and 1-m drawdown extents encompass the TSF1 area, primarily because TSF1, an anthropogenic source of seepage to the groundwater system, was simulated with a head of 136 m AHD as the steady-state baseline condition. TSF1 would be removed from service after five years of mining; therefore, it was removed as a seepage source at that point in the simulation, and for the remaining nine year of the mining simulation the water level in that area was allowed to decline. The predicted 1-m drawdown contour extended approximately 300 m northwest and approximately 200 m south of the Batman Pit at the end of the mining period.

Modelled changes in water levels at the locations of several monitoring bores are illustrated on Figure 6-3. Very little water level change was predicted for locations BW17P near the north side of the Project area, SW4MB02 adjacent to the Edith River near the downstream side of the Project area, or WDMB02P near the WRD retention pond. The water level at location BW1P east of Batman Pit and south of TSF1 was predicted to rise while TSF1 is active during the first five years of mining and then decline to about 1.5 m below its initial level by the end of the mining period, after TSF1 has drained for about nine years. Water levels at BPMB01 and BPMB02 near the Batman Pit were predicted to decline in response to pit dewatering during the mining phase.

6.1.3 Predicted Stream Flow Changes

Stream flows were monitored along the Edith River near the confluence with Stow Creek (Edith River SW4 on Figure 6-4) and near the downstream side of the Project area (Edith River SW10) and along the lower reaches of Stow Creek (Stow Creek SW3). Stream flows at all three locations were predicted to increase slightly during the first five years of mining, as the head in TSF1 increased and seepage from TSF1 into the alluvium along Horseshoe Creek likely increased, and then decrease with the decline in heads at TSF1 following its closure. The predicted stream flows at the end of the mining period were reduced from the modelled stream flows at the start of the mining period by 0.1 percent at both locations along the Edith River and by 0.78 percent along Stow Creek.

Figure 6-2: Predicted Water Table Drawdown at End of Mining

Figure 6-3: Predicted Head Changes at Observation Locations

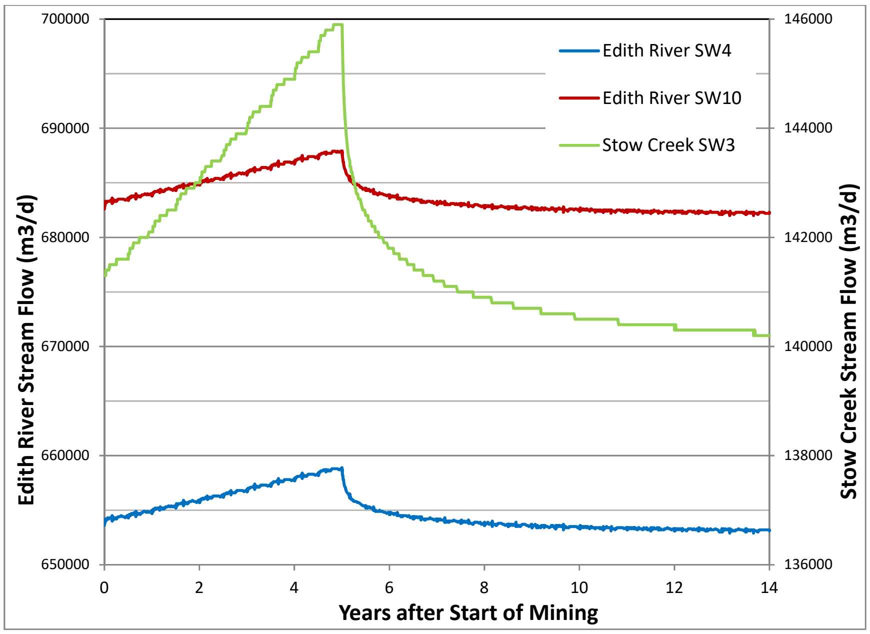


Figure 6-4: Predicted Stream Flows During Mining Phase

6.2 Post-Mining Phase Predictive Groundwater Model Results

Potential impacts in the post-mining period would be related to the changes in hydrogeologic conditions caused by the mining activities, including the deepening and enlargement of the Batman Pit, the increased dam height of the raw water supply reservoir, and construction of the lined TSF2 facility. Potential post-mining impacts could include changes in groundwater levels, groundwater flow directions, and stream flows.

The ~~w~~Waste ~~r~~Rock ~~d~~Dump water retention pond would not change significantly except for a slight decrease in ~~area~~ volume as the waste rock dump is enlarged to the south into the retention pond area. Consequently, no additional impact is anticipated when compared to the baseline condition which included the retention pond. The liners of the heap leach pad, ~~the low-grade ore stockpile retention pond,~~ and the plant runoff pond preclude the infiltration of groundwater recharge in those areas, but because the facilities were present under the baseline conditions, their continued presence would not impart additional change during the post-mining period.

Commented [TM210]: Slight decrease?
Isn't it decreased by approximately 1/3 as it is covered by the WRD?

Commented [CS211R210]: See edits per conference call.

Commented [BM212]: We are replacing the filled volume of this pong with excavation of the remaining footprint to compensate for this

Commented [TM213]: This lining is known to have been breached.

Commented [TM214]: Is this lined?

Commented [CS215R214]: See edits.

6.2.1 Predicted Batman Pit Lake Water Balance

The post-mining groundwater flow model predicted that a pit lake will form in the Batman Pit after mine dewatering ceases. The predicted water balance for the pit lake through the 1,500-year simulation period is shown graphically in Figure 6-5. Runoff into the pit lake, precipitation directly onto the pit lake water surface, and evaporation from the pit lake depend on the percentage of the total pit area occupied by the pit lake water surface at each time step for which output was generated. The step-wise changes in the graphed parameters result from the step-wise change in the pit lake surface area from one model layer to the next.

The simulated pit lake water level rose relatively rapidly following cessation of pit dewatering until the lake stage had recovered about 90 percent of the way to the surrounding groundwater elevation. At that point, the rate of water level increase slowed as the lake surface area became larger. After about 1,~~2~~000 years the pit lake had reached approximate steady-state at an elevation of approximately -15 m AHD, with the water surface covering an area of approximately 602,250 m^2 (60.625 ha). Starting at that time, the modelled water surface elevation fluctuated slightly, which resulted in some lake cells alternately being flooded or dry. This produced the fluctuations in evaporation rates evident in Figure 6-5 at times beyond about 1,~~2~~000 years.

Commented [TM216]: A 500 year simulation period is stated above in section 5.3.10.2

Commented [TK217R216]: 1,500 years simulation period

Commented [TM218]: Looking at the graph in figure 6-5, it appears that steady state occurs after approximately 1000 years

Commented [TK219R218]: Graph does appear that way. We will check the tabulated data.

Commented [CS220R218]: Agreed.

Commented [TM221]: This appears to begin at approximately at 1000 years.

Commented [CS222R221]: Agreed.

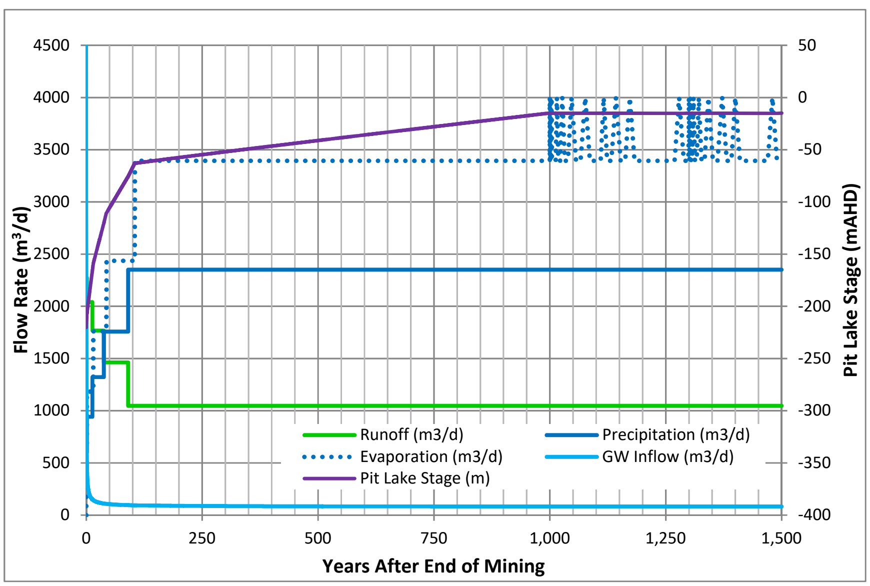


Figure 6-5: Predicted Batman Pit Lake Water Balance

The model predicted that the post-mining pit lake would be a terminal sink, with net evaporation from the lake exceeding the contributions from precipitation and runoff into the lake. The net loss from the high evaporation rate would be balanced by influx of groundwater into the lake. The components of the pit lake water balance at the end of the post-mining simulation are summarized in Table 6-1. Precipitation accounted for nearly two-thirds of the predicted lake inflow, runoff from the pit walls approximately one-third, and groundwater inflow accounted for only a small part of the predicted inflow. The only predicted outflow from the pit lake was through evaporation. The mass balance at the end of the simulation was within 2 percent.

Table 6-1: Summary of Pit Lake Water Balance at End of Simulation

Inflows	Average Rate (m3/d)	Percent of Total Inflow or Outflow
Direct Precipitation	2350.5	67.5%
Groundwater Inflow	82.6	2.3%
Pit Wall Runoff	1047.0	30.2%
Total Inflow	3480.1	
Outflows		
Evaporation	3393.9	100.0%
Groundwater Outflow	0.0	0.0%
Total Outflow	3393.9	
Inflow - Outflow	86.3	
Percent discrepancy	-2.0%	

6.2.2 *Predicted Post-Mining Groundwater Elevations and Groundwater Level Changes*

The model predicted that the post-mining pit lake would comprise a terminal sink. The net evaporative loss from the pit lake would result in an inflow of approximately 83 m^3/d of groundwater to the pit lake. Because evaporation from the lake surface would occur as long as the pit lake exists, the pit lake would constitute a long-term hydraulic sink that would draw groundwater toward and into the pit lake from the surrounding area. Figure 6-6 shows the predicted water table elevation contours 1,000 years after the end of mining. The inferred directions of groundwater flow are also illustrated on the figure. Groundwater is predicted to enter the pit from all sides. A groundwater divide is predicted to form south and southeast of the pit, separating groundwater flow toward the pit from groundwater flow toward Stow Creek and the Edith River.

As the water level in the pit lake recovers toward the predicted equilibrium elevation of -15 m AHD, the drawdown cone of depression around the pit lake would become shallower but continue to expand laterally as it equilibrates with the groundwater inflow induced by the evaporative loss from the pit lake. The area predicted to be affected by 1 m or more of drawdown within the 1,000 year post-mining simulation period was limited to a portion of the mine lease area. The predicted 1 m drawdown contours for 10, 50, 100 and 1,000 years after the end of mining are shown on Figure 6-7.

The 1 m drawdown contour was predicted to extend on the northeast side to just west of Horseshoe Creek, where drawdown would be limited by seepage from the reservoir, and on the north to approximately 1500 m north of TSF1. In those directions, the extent of the area affected by 1 m or more of drawdown remained relatively stable throughout the post-mining simulation period. In the areas north, west and south from the Batman Pit, the 1 m drawdown contour migrated laterally outward, ultimately reaching distances of approximately 2000 m from the pit rim.

Figure 6-6: Predicted Water Table Elevation 1000 Years After End of Mining

Figure 6-7: Predicted 1-M Drawdown Distributions at 10, 50, 100 and 1000 Years After End of Mining

6.2.3 Predicted Stream Flow Changes

Stream flow during the post-mining simulation was monitored at the same two locations along the Edith River and the same location along Stow Creek as were monitored during the mining-phase simulation. For comparison, both the mining and post-mining flows are included in Figure 6-8. Flows for the Edith River locations are shown on the left-hand vertical axis, whilst those for Stow Creek are shown on the right-hand axis. The post-mining flows remained relatively steady. A decrease of 0.14 percent was predicted to occur at both locations along the Edith River, and a decrease of 0.89 percent was predicted to occur at the location along Stow Creek.

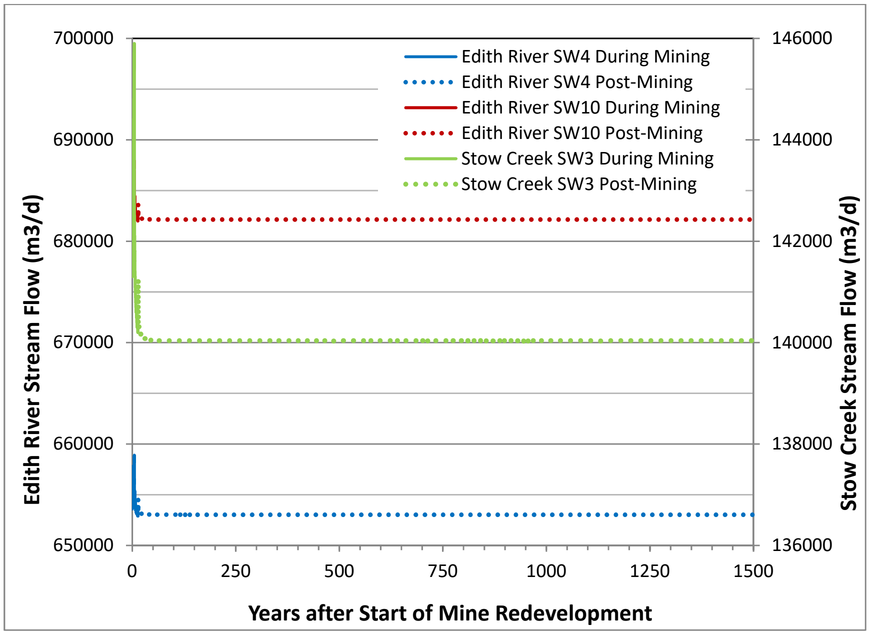


Figure 6-8: Predicted Stream Flows During and After Mining – Edith River and Stow Creek

6.2.4 Model Limitations

The regional-scale flow models used to simulate the groundwater system have limitations due to the simplifications necessary to represent complex natural systems. Flow model grid size and available data constrain the resolution and accuracy of the predictions. Estimation of approximate magnitudes and timing of groundwater system changes is possible with regional scale predictive flow models. Small changes in water levels and stream flows are inherently difficult for a regional model to accurately simulate, but the predictions are useful for assessing the potential range of impacts.

In general, monitoring of groundwater inflow to underground and open pit mines in low-permeability rocks with relatively low fracture density and connectivity has shown that fractures can initially yield substantial rates of inflow that decrease rapidly over time. The degree to which this occurs depends on how well connected the fracture network is over large areas. The equivalent porous media (EPM) conceptual flow model assumes that the fracture network is connected enough to be simulated as a porous media at the regional scale. This conceptual model has been shown to be applicable on a regional scale. However, as the scale becomes more local, small-scale fracturing and geologic structures play an increasingly significant role in groundwater inflow to mines, and the EPM assumption can become less appropriate. The inflows predicted by this model are therefore averages that do not account for extreme high or low flows due to faults, fractures or other local-scale geologic features not included in the models. However, on a regional scale, changes to the hydrogeologic and groundwater system can be adequately simulated with the flow model.

The groundwater inflows to the open pit mine during mining and post-mining are quantified by simulating the mine dewatering operations, and the effects of these hydraulic stresses on the system are quantified by predicting the water-level drawdowns, changes in surface water flows, and pit-lake development and water balances. Some of these changes are small relative to the model scale, which limits the resolution of the predictions.

Groundwater inflows to the open pit and post-mining pit lake may differ from what was simulated. The necessary simplifying assumptions required to simulate the system as an equivalent porous media prevent simulation of the small-scale faults and fractures that could impact the groundwater inflows. Also, there has not been significant hydrogeologic characterization of regional faults, shear zones, or other structural geologic features, so their potential effect on mine pit and pit lake inflows (either as conduits or barriers) could not be simulated.

The models are also constructed based on present-day conditions, but natural and possibly anthropogenic changes can be expected over the simulation period. No attempt has been made to simulate possible future changes that could alter the groundwater system. As predictive simulations extend further in time, the potential error associated with the predictions increases. These factors limit the precision and accuracy of the model predictions. However, the results presented here represent Tetra Tech’s best estimate of groundwater system changes associated with the proposed Project.

Although the model is designed to represent the overall hydrogeological system on a regional scale, little information is known about hydraulic properties on a regional scale (outside those areas drilled and tested). Consequently, the model relies on assumptions at the regional level to greater extent than locally.

7.0 MANAGEMENT MEASURES

Potential management measures to limit the groundwater impacts due to the proposed mining project include:

- any bores that do not meet the minimum construction requirements for water bores in Australia (LWBC, 2003) should be decommissioned or rehabilitated in accordance with the methods in the guidelines;
- lift works on the existing TSF should not be undertaken until all bores in the vicinity are rehabilitated;
- any exploration drill holes that may act as conduits interacting with mine features should be considered for rehabilitation;
- groundwater extracted from the proposed Batman Pit during operation (and other pit water) should, if necessary, be treated to ~~the same level as other site water prior to~~levels suitable to allow discharge from site;
- all potential contaminants brought onto site (i.e., fuel, explosives, process reagents, etc.) should be itemised, and plans should be developed for their management;
- the new tailings storage facility should be designed, constructed and rehabilitated in a manner that will minimise oxidisation of sulphides and leakage of any liquor or leachate;
- the existing tailings storage facility, heap leach pad and associated infrastructure should be rehabilitated to either significantly reduce seepage or improve seepage water quality;
- the new waste rock dump should be constructed in a manner such that it will not result in significant changes to the local groundwater regime or the development of AMD (and potentially in such a manner that it limits AMD occurring in the existing waste rock dump);
- monitoring should be continued or implemented to ensure that the groundwater impacts are not greater than those predicted by these works; and
- validating, refining, updating and improving the groundwater model should be ~~continued~~ conducted periodically ~~(at least on an annual basis)~~ then used to confirm closure scenario assumptions and be used to aid closure management decisions.

This ongoing monitoring should include:

- the monitoring of groundwater levels (and usage) on neighbouring properties (Edith Falls and Werenbun) and the subsequent development of a series of trigger values to monitor and manage any drawdown or contamination impact resulting from the proposed development;
- the geochemical monitoring ~~of a limited set~~ of key groundwater bores (including those deemed 'background' or 'boundary' bores) should be continued on a quarterly basis;
- water retention structures and dumps should have specific groundwater monitoring infrastructure installed ~~(in addition to those installed throughout 2011)~~;

Commented [TM223]: Should be treated to levels suitable to allow discharge from site.
Though based on the current operation plan the site will be a zero discharge site.

Commented [CS224R223]: Agreed.

Commented [TM225]: At least, if not prevent

Commented [TM226]: Has this been happening since the model was first developed in 2013?
If not, why?

Commented [TK227R226]: This is too frequently. It should be more like every 5 years, starting after mining starts.

Commented [TM228]: Why a limited set? Isn't the determination of key groundwater bore the limiting factor here? No a limited number of key bores, this could prevent the early detection of issues relating to groundwater contamination

Commented [CS229R228]: See edit.

Commented [TM230]: What about those installed in 2012?

Commented [CS231R230]: See edit.

- site water balance data, including pumping, rainfall and stream flows, should be maintained in a suitable format; and
- water levels should continue to be monitored on a ~~quarterly~~seasonal basis in ~~all~~ groundwater monitoring bores on site.

Commented [BM232]: Seasonal, not quarterly
Commented [CS233R232]: Agreed.
Commented [TM234]: Why isn't this already being done?
Commented [CS235R234]: See revision.

8.0 REFERENCES

ANZECC & ARMCANZ, 2000, Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ).

National Health and Medical Research Council, 2011. National Water Quality Management Strategy - Australian Drinking Water Guidelines 6.

Bureau of Meteorology (BOM), 2017. Website accessed on April 13, 2017: http://www.bom.gov.au/climate/data/index.shtml, station number 14062 (Edith Falls Ridge).

Birsoy, Y.K. and W.K. Summers, 1980, Determination Of Aquifer Parameters From Step Tests And Intermittent Pumping, Ground Water, vol. 18, no. 2, pp. 137-146.

Cooper, H.H. and C.E. Jacob, 1946, A Generalized Graphical Method For Evaluating Formation Constants And Summarizing Well Field History, Am. Geophys. Union Trans., vol. 27, pp. 526-534.

Council, G. W. , 1999. A Lake Package for MODFLOW (LAK2). Documentation and User's Manual, Version 2.2. HSI GeoTrans, A Tetra Tech Company, June 1999. 132 pp.

Doherty, J., 2016. PEST: Model-Independent Parameter Estimation, version 13, Watermark Numerical Computing.

Earth Systems, 2012. Assessment of Potential Acidity Generation and Migration from the Mount Todd Tailings Storage Facility, prepared for Vista Gold Australia Pty. Ltd. July.

Environmental Simulations, Inc., 2011. Guide to Using Groundwater Vistas, Version 6, 221 pages.

GA, 2011, Geoscience Australia, Governance, Standards and Guidelines www.ga gov.au/groundwater.html accessed online 2011.

GA-CSIRO, 2013, MapConnect http://mapconnect.ga.gov.au/MapConnect/ Average Annual Rainfall Dataset for Recharge Discharge Project Catalogue Number: 71645, Release Date : 5 May 2011, GIS Dataset–National.

Golder, 2011, Batman Pit Geotechnical Investigations Hydrogeological Testing Program Vista Gold Mt Todd Gold Project.

GHD, 2012. Mt Todd Gold Project Draft Environmental Impact Statement, Appendix K, Hydrogeology.

GHD, October 30, 2012. Memo from Lee Evans re: Borehole Data Release.

HydroGeoLogic, Inc., 2011. MODFLOW-SURFACT Software (Version 4.0). Herndon, Virginia.

Knight Pièsold, 1996. Tailings Storage Facility Manual, Mt Todd Gold Mine, Volume 2 Stage 1 Construction Report. October.

Kruse, P.D., Pillinger, D.M., Sweet, I.P., Pieters, P.E., Crick, I.H., 1994, Katherine 1:250 000 geological map. Second Edition, Australian Geological Survey Organisation, 1v, map.

Kruse, P.D., Pillinger, D.M., Sweet, I.P., Pieters, P.E., Crick, I.H., 1994, Katherine 1:250 000 geological map. Second Edition, Australian Geological Survey Organisation, 1v, SD53-9 1:250000 Geological Map Series Explanatory Notes.

Luke, G.J., Burke, K.L., and O'Brien, T.M., 1987. Evaporation Data for Western Australia. Western Australia Department of Agriculture Resource Management Technical Reeport No. 65.

Merritt, M.L., and Konikow, L.F., 2000. Documentation of a Computer Program to Simulate Lake-Aquifer Interaction Using the MDOFLOW Ground-Water Flow Model and the MOC3D Solute Transport Model. U.S. Geological Survey Water-Resources Investigations Report 00-4167.

MWH, 2006. Mt Todd Environmental Management Services – Report 1: Environmental Assessment. Prepared for Vista Gold Corp. December 2006.

NHMRC & NRMMC ~~2004~~2016. Australian Drinking Water Guidelines 6, 2011, Version 3.3. National Health and Medical Research Council and the Natural Resource Management Ministerial Council, Canberra.

Needham, R.S.; Stuart-Smith, P.G.; Bagas, L.; Whitehead, G.; Multer, C.A.; and C. Amri, 1989. Geology of the Edith River Region (1:100 000 scale map), Bureau of Mineral Resources, Canberra.

Northern Territory Department of Mines and Energy, 2013. Department of Mines and Energy – Mount Todd Batman Pit Water Levels, 2003-2008. Accessed April 23, 2013: http://www.nt.gov.au/d/mttodd/index.cfm?newscat1=&newscat2=&header=Site%20Photos%20-%20Batman%20Pitt.

NRETAS, 1997. Declaration of Beneficial Uses – Edith River Surface Water. Declaration published June 11, 1997 in Northern Territory Government Gazette No. G23. Map prepared in November 1999; obtained online on May 6, 2013 from searching the website: http://www.lrm.nt.gov.au.

NRETAS, 1999. Declaration of Beneficial Uses and Quality Standards of Groundwater – Katherine Area. Declaration published June 9, 1999. Map obtained online on May 6, 2013 from searching the website: http://www.lrm.nt.gov.au.

NRETAS, 2011. Draft Guidelines for the Preparation of an Environmental Impact Statement, Mt Todd Gold Project, Katherine Region, NT, Vista Gold Australia Pty Ltd, September 2011.

NRETAS, 2012. Reports for Telemetered Gauging Station, accessed December 2012: http://www.nt.gov.au/nreta/naturalresources/water/surfacewater/telemeteredsites/description.jsp?Site_Id=g8140152

Commented [TM236]: Needs to be updated to the 2011 guidelines which were updated in 2016

Commented [TK237R236]: Fix this

Commented [CS238R236]: See edit.

NTDENR, 2017. Northern Territory Department of Natural Resources Maps NT web application, accessed April 20, 2017: http://nrmaps.nt.gov.au/.

NTG, 2017. Northern Territory Government water data portal, accessed April 19, 2017. https://nt.gov.au/environment/water/water-data-portal.

Power and Water Authority, 1989. Hydrogeology of the Pine Creek Mining Region Explanatory Notes for 1:250000 Scale Map R J McGowan Northern Territory of Australia. Conservation and Natural Resources Group, Department of Infrastructure, Planning and Environment, Northern Territory of Australia.

Prudic, D.E., Konikow, L.F., and Banta, E.E., 2004. A New Streamflow-Routing (SFR1) Package to Simulate Stream-Aquifer Interaction with MODFLOW-2000. U.S. Geological Survey Open-File Report 2004-1042.

Rockwater Consultant Hydrogeologists, 1988. Groundwater Drilling and Testing, Batman Water Supply, Mt Todd, NT, prepared for Billiton Australia Gold Pty Ltd. December.

Rockwater Consultant Hydrogeologists, 1989. Groundwater Drilling and Testing Report – Stage II, Water Supply for Batman Gold Deposit, Mount Todd, NT, prepared for Billiton Australia Gold Pty Ltd. June.

Rockwater Proprietary Ltd., 1994. Bore Water Supply Expansion Programme, Bore Completion Report, Mt Todd Gold Mine, prepared for Zapopan NL, August.

Sweet, L.P.; Pieters, P.E.; and I.H. Crick, 1994. Katherine Second Edition (1:250 000 scale geological map). Australian Geological Survey Organisation, Canberra.

Theis CV, 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground water storage. Trans Am Geophys Union Part 2, 16:519–524.

United States Department of Agriculture (USDA). 1996. Urban Hydrology for Small Watersheds. United States Department of Agriculture Natural Resources Conservation Services Conservation Engineering Division Technical Release 55, June 1996. http://www.hydrocad.net/pdf/TR-55%20Manual.pdf

Vista Gold Australia Pty Ltd, ~~2011~~2016. ~~Mt Todd Water Management Plan 2011/2012, Revision 1~~Mining Management Plan 2016 – Water Management Plan, Mount Todd Gold Project.

Vista Gold Australia Pty Ltd, 2016. Mining Management Plan 2016, Mount Todd Gold Project.

Commented [TM239]: Why not the 2016 Water Management Plan?

Commented [RG240R239]: See edits.

APPENDIX A:
KEY BORES ON NEIGHBOURING PROPERTIES

APPENDIX B:
BOREHOLE LOGS

APPENDIX C:
AQUIFER TEST DATA

TETRA TECH

APPENDIX D:
WATER LEVELS COLLECTED, 2010 - 2016

TETRA TECH

APPENDIX E:
TEMPORAL WATER LEVEL PLOTS

TETRA TECH

APPENDIX F:
WATER ANALYSES

APPENDIX G: MODELLED HYDRAULIC CONDUCTIVITY DISTRIBUTIONS

TETRA TECH

APPENDIX H:
DRAIN CELLS TABULATION

Appendix B – Email Correspondence

From: John Ross
To: Jill Woodworth; Tim Murphy
Cc: Nicole Conroy
Subject: Latest Tetratech work
Date: Thursday, 27 April 2017 3:20:09 PM

Hi all, Brent has sent me through some stuff from Tetratech. I have placed this information into a new folder inside the Section 6 folder of the MMP. Hyperlink below.

G:\43\22632\Tech\MMP Document\Section 6\Latest from Tetratech

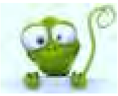
Cheers

John Ross

Senior Environmental Scientist

Celebrating 60 years in the Territory

GHD
T: + 61 8 8982 0117 | V: 430117 | M: 0474 141 096 John.Ross@ghd.com
Level 7, 24 Mitchell St, Darwin, Northern Territory, 0800 Australia | http://www.ghd.com/
Water | Energy & Resources | Environment | Property & Buildings | Transportation



From: Brent Murdoch
To: Jill Woodworth; Nicole Conroy
Subject: Mt Todd Water Model
Date: Monday, 8 May 2017 12:48:45 PM
Attachments: image001.png

Hi,

Below is a link to the current GoldSim water model for Mt Todd;

ftps://Ghd@darwin.mttodd.com.au/GHD/Hydrogology%20Data/GoldSim%20Model%20Ver%2011%20100

This will enable us to look at the predictive flows for each year.

I have updated it with the actual rainfall to date.

Regards

Brent Murdoch
Director & General Manager Australia

Vista Gold Australia Pty Ltd.

T: +61 8 8941 9105
F: +61 8 8992 9011
M: +61 488 100 314 Australia
Sat: +61 404 805 563
M: +1 720 4272 324 USA
Skype brent.murdoch
E: bmurdoch@mttodd.com.au

Level 1, 43 Cavenagh Centre, Cavenagh Street, Darwin
GPO Box 3449, Darwin NT 0801

www.mttodd.com.au

From:	Tim Murphy
To:	Brent Murdoch (InTouch)
Subject:	Tetra Tech Mt Todd Hydro Report Review
Date:	Tuesday, 9 May 2017 7:38:28 AM
Attachments:	17 04 23 Tetra Tech Mt Todd Hydro Update for MMP 114311285_VistaGoldMtTo.._TM Review.docx

Brent,

Please find attached the reviewed Tetra Tech Mt Todd Hydro Report (with comments/mark-ups) on the modelling review.

Regards

Tim Murphy
Hydrogeologist
GHD
T: +61 8 8982 0101 | V: 430 101 | M: +61 499 056 068 | E: tim.murphy@ghd.com
Level 7, 24 Mitchell Street, Darwin NT 0810 Australia | www.ghd.com

From:	Brent Murdoch
To:	John Ross
Cc:	Jill Woodworth; Nicole Conroy
Subject:	FW: 114-910547 | Mt Todd - Hydrogeology Report (Revisions from May 9, 2017)
Date:	Friday, 26 May 2017 11:00:43 AM
Attachments:	image001.png Appendix F Chem Output table december 2011 resave.zip 2017-05-25 with comments on Draft and with Tt responses(FINAL DRAFT).docx

Hi John,

This has just come thought from Denver for our consideration

Regards

Brent Murdoch
Director & General Manager Australia

Vista Gold Australia Pty Ltd.

T: +61 8 8941 9105
F: +61 8 8992 9011
M: +61 488 100 314 Australia
Sat: +61 404 805 563
M: +1 720 4272 324 USA
Skype brent.murdoch
E: bmurdoch@mttodd.com.au

Level 1, 43 Cavenagh Centre, Cavenagh Street, Darwin
GPO Box 3449, Darwin NT 0801

www.mttodd.com.au

From: Scharnhorst, Vicki [mailto:Vicki.Scharnhorst@tetratech.com]
Sent: Friday, 26 May 2017 9:44 AM
To: Brent Murdoch <bmurdoch@mttodd.com.au>; John Rozelle <jwrozelle@vistagold.com>
Cc: Keith Thompson <keith.thompson@tetratech.com>; Cadle, Sonya <Sonya.Cadle@tetratech.com>; Hudson, Amy <Amy.Hudson@tetratech.com>; Roemer, Guy <Guy.Roemer@tetratech.com>
Subject: 114-910547 | Mt Todd - Hydrogeology Report (Revisions from May 9, 2017)

Brent and John:

Per our conference call (May 9, 2017), this represents a final draft markup version of the text with the new edits highlighted, and prior edits accepted.   We believe that Tetra Tech's edits adequately reflect the changes requested by Vista Gold and GHD; however, we will wait for confirmation before turning the document into a final, signed off version. We've left the comments in the document as well, for ease of review. Upon confirmation that the changes are acceptable and no additional edits are needed, we will finalize the text, remove comments, and produce a full PDF version of the entire report, including appendices and figures.

Please note we have also attached the original 2012 summary table from **Appendix F**. We have updated all the Appendix F graphs; however, this 2012 summary table has embedded macros and programming. GHD originated the file and likely has easy access to the program referenced. We suggest that GHD update this summary table to include the new data as, when we open it, there is a macro for another program. It appears that it may be readily produced from a GHD database, and if so, this will save time. Please advise.

As always, we look forward to meeting to discuss any remaining comments and/or compilation of the final document. We look forward to hearing from you soon.

Regards,
Vicki
Vicki J. Scharnhorst, P.E., LEED AP
Direct: 720.881.5812 | Cell: 303.324.7322
Main: 303.217.5700 | 877.855.2655 | Fax 303.217.5705

Tetra Tech | complex world, CLEAR SOLUTIONS
350 Indiana Street, Suite 500 | Golden, CO 80401 | www.tetratech.com

From:	Tim Murphy
To:	Brent Murdoch (InTouch)
Subject:	Review of Final Draft Hydrogeology report
Date:	Thursday, 1 June 2017 9:30:49 AM
Attachments:	2017-05-25_with comments on Draft and with Tt responses(FINAL_DRAFT)_TM_review.docx

Brent,

Attached is my review of the final draft of the hydrogeology report.
Only two things;

The recent temperature data (post 1985). Tetra Tech have referred to Tindal RAAF base for this data, whereas the Katherine Aviation Museum and then the Katherine Country Club have records for the majority of this period and are only 1-2 Km from the Katherine Council weather station.

The data loggers. As yourself and site staff confirmed there has been no data downloaded from these, as the loggers are mentioned an explanation on why they are not monitored/downloaded should be included. If there are not loggers installed then the reference to them should be removed altogether.

Other than the items raised above, the report is ok to be finalised.

If you have any questions please contact me.

Regards

Tim Murphy
Hydrogeologist
GHD
T: +61 8 8982 0101 | V: 430 101 | M: +61 499 056 068 | E: tim.murphy@ghd.com
Level 7, 24 Mitchell Street, Darwin NT 0810 Australia | www.ghd.com

Appendix C – Curriculum Vitae

Curriculum Vitae

Tim Murphy

Hydrogeologist

Qualification: Bachelor of Engineering Technology (Environmental)

Connected: IAH, ALGA

Located: Darwin, Northern Territory

Relevance to project: Tim is a Hydrogeologist within the Environment Group in the GHD Darwin Office.

Tim has 12 years' experience in groundwater bore drilling and installations, monitoring and sampling of groundwater and geotechnical bores and sampling of soil, sediment and surface water, interpretation and reporting of results, as well as sub-contractor supervision.

Hydrogeologist

EPL Groundwater Monitoring | Darwin Turf Club | Jan 2020 | NT

Conducting groundwater monitoring and reporting for compliance with an Environmental Protection Licence.

Confidential Project | Jan 2019 | NT

Conducting PFAS sampling of Biota, Sediment and Groundwater

Remote Community Groundwater Monitoring | Power and Water Corporation | Nov 2018 | NT

Conducting end of dry season groundwater level monitoring across 10 remote communities

Downloading datalogger data and replacing failed dataloggers

Training of the communities Essential Services Officers to take groundwater level readings

Wagait Tip Detailed Site Investigation | Department of Planning Infrastructure and Logistics (DPIL) | 2018 – 2019 | Wagait, NT

Conducting landfill investigation

Supervision of sub-contractors

Test pitting supervision

Soil and groundwater sampling

DCARM | Department of Defence (DoD) | 2017 – 2020 | NT DoD sites

Defence Sites:

- Bradshaw Field Training Area
- Defence Establishment Berrimah
- Defence Establishment Howard Springs South
- Kangaroo Flats Training Area
- Larrakeyah Defence Precinct (including HMAS Coonawarra)
- Mount Bundy Training Area
- RAAF Base Darwin
- RAAF Base Tindal
- Robertson Barracks

Conducting contaminated sites investigation across multiple sites, including the interpretation and reporting of results

Supervision of sub-contractors

Soil bore and monitoring well drilling, sampling and installation and test pitting supervision

Soil, sediment, vapour, surface water and groundwater sampling

Yulara Landfill Services | Voyages Indigenous Tourism Australia | Jan 2020 | Yulara, NT

Conducting landfill and contaminated site annual monitoring

Soil gas, landfill surface-gas emissions and building gas accumulation monitoring and groundwater and leachate monitoring and sampling

Interpretation and reporting of results

Epenarra Environmental Investigations | Power and Water Corporation | Mar – Oct 2018 | Epenarra, NT

Conducting contaminated site investigation and interpretation and reporting of results

Supervision of sub-contractors

Soil bore and monitoring well drilling, sampling (soil and groundwater) and installation

Katherine Town Council WMF | Katherine Town Council | Dec 2017 – Aug 2019 | Katherine, NT

Conducting landfill investigation and interpretation and reporting of results

Supervision of test pitting and groundwater monitoring bore drilling and installation and groundwater sampling

Groundwater Management Plan | New Hope | Feb 2017 – Jul 2018 | Burton, QLD

Supervision of groundwater monitoring bore drilling and installation.

Monitoring groundwater levels in existing monitoring wells (manual and data logger).

Rehabilitation Plan and Financial Assurance Review | Capricorn Copper | Sep 2017 – Dec 2019 | Gunpowder, QLD

Supervision of test pitting, soil and groundwater monitoring bore drilling and installation.

Soil sampling and Insitu permeability testing

DOI Adelaide River Bridge NT CP Testing 2017 | DPIL | Nov 2017 | Wak Wak, NT

Cathodic Protection condition performance monitoring for the Adelaide River Bridge on the Arnhem Highway

New Water Source Investigation | Power and Water Corporation| Oct – Dec 2017 | Pirlangimpi, NT

Review of existing bores and aquifer testing results.

Aquifer property analysis of pump/recovery tests and slug testing results using AQTESOLV Pro for input into drawdown interference model to determine sustainable flow rates for remote community water supply.

Milingimbi Long Term Water Study | Power and Water Corporation | Apr – Oct 2017 | Milingimbi, NT

Desktop Hydrogeological study to inform the long-term water supply options study.

Groundwater Investigation | CORE Exploration | May – Aug 2017 | Cox Peninsula, NT

Designing groundwater monitoring network including the locating of bores, bore design, bore installation and bore development and interpreting /analysing results and reporting

Supervision of sub-contractors

Sampling of groundwater bores and installation of data loggers in the groundwater monitoring bores

PSD Water Quality Monitoring | CO2 Australia| Jan – Mar 2017 | Legune, NT

Water quality sampling of surface water bodies via helicopter (due to remote location of site) for an Environmental Impact Assessment

Curriculum Vitae

Hydrogeologist/Technical Officer

AGL Loy Yang | Mar 2008 – Dec 2016 | Traralgon, Victoria

Design, Management and Operation of the depressurisation and aquifer monitoring networks, the locating of bores, bore design, and bore performance assessment

Installation and monitoring of groundwater, geotechnical and extensometer bores

Supervision of sub-contractors

Groundwater sampling via low flow pump, waterra and bailer and from operating depressurisation pump bores

Interpretation and reporting of results in mine depressurisation including WRL and pressure contour modelling using Minescape

Pumping and recovery testing of new depressurisation bores and slug testing of potential bores to determine suitability and analysis of results, using AQTESOLV Pro.

Technical Officer

Shenhua | Jan 2020 | Gunnedah, NSW

Multi piezo (Standpipe and Vibrating Wire) installation for stability/aquifer monitoring

Supervision of sub-contractors

Centennial Coal | Jan 2020 | Mandalong South, NSW

Multi piezo installation for stability/aquifer monitoring

Supervision of sub-contractors

Referee

Name. Keith Stacy
Position. Chief operating Officer
Company. Darwin Turf Club
Project. Darwin Turf Club Environmental Monitoring
Phone. (08) 8923 4222
Mobile. 0417 892 468
Email. kstacy@darwinturfclub.org.au

Key areas of experience

- Management and designing of groundwater monitoring and depressurisation networks
- Groundwater monitoring bore and soil bore drilling and installations
- Groundwater monitoring and aquifer testing
- Soil, sediment, surface water and groundwater sampling
- Interpretation and reporting of results
- Sub-contractor supervision

GHD

Level 7, 24 Mitchell Street
Darwin NT 0800
T: 61 8 8982 0100   F: 61 8 8981 1075   E: drwmail@ghd.com

12530403-16277-1/12530403-REP_Review Of Hydrogological Report - Factual Report.Docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	T. Murphy	C. Sylianteng		C. Sylianteng		20/04/2020

www.ghd.com