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MACRAES PHASE III PROJECT

WATER MANAGEMENT SUMMARY REPORT

Submitted to:
Oceana Gold (New Zealand) Limited

REPORT

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ABBREVIATIONS

ANZECC	Australian and New Zealand Environment and Conservation Council
CIL	Cyanide in Leach
CTI	Concentrate Tailings Impoundment
EGL	Engineering Geology Limited
FTI	Flotation Tailings Impoundment
HIRDS	High Intensity Rainfall Design System
IDF	Intensity, duration and frequency
IPCC	Intergovernmental Panel on Climate Change
MAM	Mean Annual Minimum flow
MGP	Macraes Gold Project
MoH	New Zealand Ministry of Health
MTG	Maori Tommy Gully
MTI	Mixed Tailings Impoundment
NBWR	North Branch Waikouaiti River
NZDWS	New Zealand Drinking Water Standard
ORC	Otago Regional Council
RGP	Reefton Gold Project
RL	Relative level, in this case metres above mean sea level
SPI	Southern Pit Tailings Impoundment
SP10	Southern Pit Tailings Impoundment SP10, currently incorporated in SP11
SP11	Southern Pit Tailings Impoundment SP11
TSF	Tailings storage facility
TTTSF	Top Tipperary Tailings Storage Facility
WAD	Weak acid dissociable – used with reference to cyanide
WRS	Waste rock stack

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1.0 INTRODUCTION

1.1 Background

Oceana Gold (New Zealand) Limited (OceanaGold) operates the Macraes Gold Project (MGP) located in east Otago, approximately 25 km west of Palmerston (Figure 1). The MGP consists of a series of opencast pits and an underground mine supported by ore processing facilities, waste storage areas and water management systems (Figure 2).

OceanaGold has an ongoing program of exploration drilling, ore reserves review and mine design optimisation. Consequently, operational pit designs are regularly updated. The performance of existing waste storage facilities and the requirement for additional waste storage capacity is also regularly reviewed. As the result of a recent review of ore reserves, OceanaGold has concluded that mining operations at the Macraes Gold Project can be extended until 2020 through opencast mining of additional ore reserves. These reserves include:

- Reserves located to the east of the existing Frasers Pit, to be accessed through expanding Frasers Pit.
- Reserves located to the east of the Round Hill Pit, which can be accessed through reclamation of tailings from within the current SP11 tailings storage facility (SP11) and removal of waste rock fill that has previously been stored in Round Hill Pit.
- Reserves located to the east of Innes Mills Pit, to be accessed through removal of the waste rock previously stored in Innes Mills Pit and expanding the pit.

The proposed open pit expansions are termed the Frasers Stage VI, Roundhill Extension, Southern Pit and Innes Mills Stage V.

New waste rock stacks (WRS's) and extensions to existing rock stacks are planned, increasing the total consented tonnage from 850 Mt to 1,180 Mt. A new WRS is planned substantially extending the existing Back Road WRS to the east of the Round Hill/Southern Pit locations. Frasers East and Frasers West WRS's will be expanded and a new linking rock stack between these two called Frasers South WRS and a further one to the north of Frasers East WRS called Frasers North WRS will be constructed.

As a result of recent reviews, OceanaGold has determined that additional tailings storage capacity is necessary to support Phase III mining operations at the site. OceanaGold is planning to decommission both of the current tailings storage facilities (TSF's) by mid 2012 and commence using a new TSF. At this point it is likely that both existing TSF's will have remaining resource consent life, however in review of OceanaGold's new mining schedule and the pro's and con's of various options it is a more effective alternative to switch to the new facility prior to utilisation of all of the consented capacity in the existing TSF's.

A major component of Macraes Phase III involves the need to create the new TSF. A number of options have been investigated with the selected option being located in the very upper reaches of the Tipperary catchment (Figure 3). The reclaimed tailings from SP11 are to be relocated to the existing Mixed Tailings Impoundment (MTI) and the new Top Tipperary tailings storage facility (TTTSF).

OceanaGold is seeking to obtain resource consents covering:

- The construction, operation and closure of the TTTSF
- The construction and rehabilitation of the planned additional WRS's
- The expansion and closure of the existing open pits

Figure 1: Site location map.

Figure 2: Site layout map.

Figure 3: Macraes Phase III staged development plan.

Golder Associates (NZ) Limited (Golder) has been retained by OceanaGold to undertake evaluations covering:

- The mine water management system at the MGP
- Contaminant losses from the site, including from the existing and proposed opencast pits, WRS's, TSF's and other operational areas of the mine
- The effects of these contaminant losses on water quality in the natural water bodies downstream from the MGP
- The effects of these losses on the long term water quality in the proposed pit lakes
- Options for the mitigation of potential effects on downstream water quality

The outcomes of these evaluations are to be used in support of an Assessment of Environmental Effects[1].

1.2 Scope

The purpose of this report is to summarise and integrate the information presented in technical reports produced by Golder to evaluate aspects of water management and effects of the Macraes Phase III Project on water quality downstream from the MGP. The detailed technical assessments produced by Golder in support of the Macraes Phase III Project include:

- Report R003 – Tipperary Creek hydrological monitoring (Golder 2011a)
- Report R004 – TTTSF groundwater modelling (Golder 2011b)
- Report R005 – TSF geochemical assessment (Golder 2011c)
- Report R006 – site wide groundwater modelling (Golder 2011d)
- Report R008 – site wide surface water modelling (Golder 2012e)
- Report R009 – mitigation options (Golder 2011f)
- Report R012 – water quality database review (Golder 2011g)
- Report R014 – Golden Point Pit seepage assessment (Golder 2011h)
- Report R016 – TSF drainage rate review (Golder 2011i)

This report summarises the projected hydrological effects of the planned Macraes Phase III Project, including changes in water quality. Potential ecological effects on creeks and rivers are discussed in a report prepared by Ryder Consulting Limited.

1.3 Project Description

The project description for Macraes Operations – Macraes Phase III is provided in the AEE. The following provides a brief summary of the key components relating to water management:

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[1] This report is subject to Golder's standard report limitations, which are presented in Appendix A.

- A new TSF, called the Top Tipperary Tailings Storage Facility (TTTSF) will be constructed in the upper Tipperary Creek catchment.
- Tailings will be reclaimed from within the current Southern Pit 11 TSF (SP11) and relocated to the existing Mixed Tailings Impoundment (MTI) and the new TTTSF.
- New rock stacks and extensions to existing rock stacks will be constructed. A new Back Road waste rock stack (WRS) is planned, substantially extending the existing Back Road WRS to the east of the Round Hill/Southern Pit locations. Frasers East WRS will be expanded to the north (Frasers North WRS) and a new linking rock stack between Frasers West and Frasers East called Frasers South WRS will be constructed.
- Expanded pit stages on existing pits will be Frasers Stage VI, Round Hill-Southern Pit and Innes Mills Stage V.
- The down dip (North Easterly) development of Frasers Underground mine will be continued.
- Surface water on the expanded mining infrastructure will be managed with diversions and new silt control ponds.
- The revised closure plan will now comprise two lakes formed from the pit excavations.

The location, extent and staging for Macraes Phase III Project for the key components are presented in Figure 3.

1.4 Report Structure

In addition to this introductory section, this mine water management summary report contains the following sections:

- Section 2 provides a summary of the climate at Macraes Flat including adopted design rainfall intensities for the design of water management infrastructure.
- Section 3 provides a summary of the receiving environment hydrology.
- Section 4 provides a summary of observed receiving water quality at the site and projected mine water quality for the site.
- Section 5 provides a summary of the modelling undertaken to evaluate contaminant transport within the MGP groundwater system from existing and proposed TSF’s and WRS’s to receiving water bodies. Included in this section is a summary of the evaluation of TSF drainage system discharges during the operational period of the mine and post-closure.
- Section 6 provides a summary of the surface water modelling undertaken to simulate the mine water management system and the characteristics of the receiving water environment. This section contains projections for the development of pit lakes at the site. This section also contains a summary of projected water quality in the pit lakes and in surface water bodies downstream from the MGP. An assessment of the effects of the MGP on future availability of water to downstream users is also presented.
- Section 7 provides a summary of options available for the mitigation of effects to downstream water quality.
- Section 8 provides a summary of the proposed monitoring program to be instigated at the site to monitor the effects of the Macraes Phase III Project on groundwater and surface water quality.

- Section 9 presents the conclusions reached from the studies summarised in this report.
- Section 10 provides a list of the documents referenced in this report.

2.0 CLIMATE

2.1 Regional Climate Overview

New Zealand lies in the mid-latitude zone of westerly winds, in the path of a succession of anticyclones, which move eastwards (Metservice 2010). The presence of the Southern Alps, extending the length of the South Island, has a major effect on the climate of the Otago region, as does the ocean, and produces distinct climatic contrasts from west to east. In inland Otago areas, just east of the mountains, the climate appears to be more continental in character than coastal areas where there is a more noticeable marine influence.

The distribution of rainfall is mainly controlled by mountain features and the highest rainfalls occur where the mountains are exposed to the direct sweep of the westerly and north-westerly winds. The MGP lies to the east of the main ranges and is therefore a dry area with extended periods of little or no rain. The climate at the MGP is however moderated to some degree by the ocean, which makes it significantly cooler than inland regions further north (Te Ara 2010).

2.2 Rainfall

2.2.1 Site rainfall overview

Rainfall at the MGP is monitored at three locations. The Deepdell and Golden Point monitoring stations have been installed specifically for climate monitoring at the MGP, while the Glendale monitoring station is part of the national climate monitoring network. Details on the locations and operation of these climate monitoring stations are presented in Appendix B.

Rainfall records from the three monitoring stations generally correlate well with Glendale and Golden Point rain gauges receiving on average similar rainfall totals. The Deepdell monitoring station receives the least rainfall out of the three, possibly due to the differences in elevation between the stations. Monthly rainfall statistics for the three rainfall stations are presented in Appendix B.

Rainfall at the MGP is slightly seasonal, with the greatest rainfall occurring during the summer months of December and January. Throughout the remainder of the year the rainfall is relatively constant. The Glendale and Golden Point sites receive average annual rainfall of approximately 628 mm and 659 mm, respectively. The Deepdell site receives an average of approximately 518 mm rainfall annually (Appendix B).

2.2.2 Design rainfall events

Short duration rainfall in the context of this report is that rainfall that falls in less than a 24 hour period. Intensity, duration and frequency (IDF) tables have been generated from Hilltop Software’s Hydro application. Short duration IDF tables were calculated for the Deepdell and Golden Point rain gauges for event durations greater than 20 minutes and one hour, respectively (refer Appendix B). Data from the Glendale rain gauge was not analysed for short duration events as this is a daily manual gauge.

In general, the short duration rainfall analyses for the Deepdell and Golden Point data generated by the High Intensity Rainfall Design System (HIRDS) from NIWA are comparable. HIRDS tends to indicate greater rainfall depths and this reflects the nature of HIRDS, being a conservative design tool. However, this conservatism is not reflected for all rainfall durations and frequencies.

Long duration rainfall in the context of this report is rainfall that falls over periods greater than 24 hours. As for short duration rainfall, IDF tables have been generated from Hilltop Software's Hydro application using the same statistical distribution.

The IDF tables for the Glendale, Deepdell and Golden Point rain gauges for durations of 24, 48 and 72 hours are presented in Appendix B. In general, the long duration rainfall analyses for Glendale, Deepdell and Golden Point are comparable while HIRDS tends to indicate higher rainfall depths for given durations.

For design purposes the most conservative approach should be taken and therefore the greatest rainfall amount for a given duration or frequency from each table in Appendix B would be generally adopted. This applies for both short and long duration events.

2.2.3 Climate change

The Intergovernmental Panel on Climate Change (IPCC) observed that increased average atmospheric temperatures are likely due to anthropogenic greenhouse gas emissions (Mullen et al. 2008). This warming has the potential to alter the climate regime, increasing temperatures and therefore rainfall, across regions of New Zealand.

The Ministry for the Environment has produced tables of projected changes in seasonal and annual mean temperature for regions of New Zealand. The projections for Otago are summarised in Table 1. Recommended percentage adjustment factors to apply for extreme rainfall events, based on a 1 degree Celsius increase of warming, are also presented in Appendix B.

Table 1: Projected changes in annual mean temperature in the Otago region.

Range of Predictions (1)	From 1990 to 2040 (2)	From 1990 to 2090 (2)
Lower limit temperature change	0.1	0.8
Average temperature change	0.9	2.0
Upper limit temperature change	1.9	4.6

Note: 1) All values presented in °C
2) Projected changes from the Ministry for the Environment Climate Change Effects and Impacts Assessment (Mullen et al. 2008).

OceanaGold indicates that the Macraes Phase III Project has a projected mine life of at least 9 years. Due to the relatively short projected mine life the climate change projections for the period 1990 to 2040 are appropriate for surface water management design purposes. Applying the average temperature change factor relevant to the expected design life provides a conservative approach to further design and risk evaluation at the MGP site. Adjustment factors based on the projected temperature changes from Table 1 for the 1990 to 2040 period are summarised in Appendix B.

2.2.4 Adopted rainfall intensity for Macraes site

The adopted rainfall depths for the Macraes site follow a conservative approach for design purposes. The highest rainfall depth for the corresponding return interval and duration was adopted from each rainfall source (Glendale, Golden Point, Deepdell Creek and HIRDS) and has been collated into Table 2. These adopted rainfall depths can by adjusted for climate change using the factors presented in Appendix B.

Table 2: Summary rainfall depth, frequency and duration table for the MGP.

Duration	**Annual Recurrence Intervals in years (ARI's)**					
	2	**5**	**10**	**20**	**50**	**100**
10 minutes	3.9	5.3	6.7	8.3	11.3	14.1
30 minutes	8.4	11.6	15	19.1	25.8	32.3
1 hours	10.9	15	19.1	24.7	34.9	45.6
2 hours	16	22.3	27.9	34.9	46.6	57.8
6 hours	31	42.4	52.5	64.7	85.2	104.8
12 hours	47	63.5	78.1	95.4	124.1	151.5
24 hours	71.5	95.3	115.7	139.8	179.1	215.6
48 hours	80.5	107.3	130.4	157.5	201.7	243
72 hours	86.2	114.9	139.6	168.7	216	260

2.3 Evaporation

Evaporation data is available for the MGP site using an onsite open evaporation pan located near the MTI. Penman potential evapotranspiration and open water evaporation data is available for climate stations located at Palmerston, approximately 25 km east from the MGP, and at Middlemarch approximately 31 km from the MGP (Table 3).

Table 3: Summary of evaporation monitoring stations.

Station Name	**Location (NZMS 260)**	**Elevation (mRL)**	**Distance from MGP (km)**	**Current recording authority**	**Date begins**	**Date ends**
Macraes Open Pan	I42 089 343	530	0	OceanaGold	1992	Ongoing
Palmerston	J43 312 233	21	25	NIWA	13/07/1986	Ongoing
Middlemarch	H43 861 172	213	31	NIWA	01/09/2000	Ongoing

Annual evaporation data from the Palmerston, Middlemarch and MGP climate stations is summarised in Appendix B. The average annual evaporation from Palmerston, Middlemarch and MGP are 723 mm, 1,090 mm and 988 mm, respectively. The average monthly evaporation results for the three climate stations are summarised in Table 4.

It is likely that the Middlemarch station is more representative of the MGP site as they are both located inland and their elevations are more closely aligned than that of the Palmerston station. This similarity is also evident in the relative annual totals.

Table 4: Average monthly evaporation at the Macraes Phase III (MPIII) site, Palmerston and Middlemarch.

Station (1,2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Palmerston	92	78	76	44	36	31	30	41	52	68	78	88
Middlemarch	145	115	112	76	52	45	40	56	93	101	124	135
MGP (3)	161	117	117	65	46	25	42	51	76	125	135	141

Notes:
1) Monthly statistics based on complete months only. All evaporation values presented in mm.
2) Palmerston and Middlemarch stations are open water data. MGP station record is for open pan data.
3) MGP data based on 1992 – 2000 data only.

2.4 Climate Summary

Generally rainfall data for the MGP site is of reasonable quality; however a number of gaps do exist in each of the Glendale, Golden Point and Deepdell datasets. The Glendale and Golden Point monitoring stations experience similar annual rainfall totals, while Deepdell experiences relatively less rainfall, probably due to its lower elevation and location in the valley of Deepdell Creek.

On average between 518 mm and 659 mm of rainfall has been recorded annually at the three rainfall monitoring stations at the MGP. Glendale is regarded as the highest quality of data and the annual average rainfall totals for this site of 628 mm is adopted as the site average rainfall.

Generally, monthly rainfall totals are highest during summer months (December and January). Average monthly rainfall is relatively constant throughout May to September.

Design rainfall is provided by IDF tables generated for the Glendale, Golden Point and Deepdell sites. HIRDS design tables have also been provided, including corrections for projected climate change (Table 1). It is recommended that a conservative approach based on the calculated rainfall depth, frequency and return periods (Table 2) be adopted for design purposes. The climate change scenario adopted should reflect the lifespan of the structure being designed.

Open pan evaporation is collected on-site using an evaporation pan operated by OceanaGold. Additionally, evaporation data from monitoring stations at Palmerston and Middlemarch is available however these stations are located some distance from the project site. Annual evaporation totals indicate the Middlemarch data is more representative of the MGP site however the records for monthly evaporation do not correlate as well as would be expected.

3.0 HYDROLOGY

3.1 Introduction

The MGP footprint, including the new operational areas of the Macraes Phase III Project, is encompassed within the headwaters of two major watercourses and their tributaries (Figure 4). These watercourses are:

- The south west draining North Branch Waikouaiti River (NBWR), including the Murphys Creek tributary. The southwestern third of the MGP footprint intersects the combined catchment of this drainage system.

- The south east draining Shag River, which receives the flows from Deepdell Creek, Tipperary Creek (via McCormicks Creek) and Cranky Jims Creek. The Deepdell Creek catchment intersects the northern half of the MGP area. The combined catchments of Tipperary Creek and Cranky Jims Creek cover the southeastern third of the MGP area, including the proposed TTTSF.

Figure 4: Macraes Gold Project natural drainage systems.

The topography of the Macraes Flat area is that of an ancient erosional surface, or peneplain. This peneplain has been bisected by Deepdell Creek, the NBWR, Tipperary Creek and Murphys Creek.

Deepdell Creek and its tributaries, including Maori Tommy Gully (MTG), Battery Creek and Northern Gully, are deeply incised into the peneplain surface, with steep valley slopes and a narrow or no alluvial terrace at the base of each gully. Tributary streams generally have steep gradients. The upper reaches of many of the steep tributary gullies have developed along lines of structural weakness in the basement schist.

The NBWR upstream from Macraes Flat has, in contrast, created a broad shallow valley. Through deposition of sediment in the valley bottom alluvial flats have developed up to 500 m wide that form a continuous feature between Glendale Station and Macraes Flat. The headwaters of Tipperary Creek around Glendale Station and the headwaters of Murphys Creek are both characterised by relatively gentle valley slopes. Neither of these creeks has however developed broad alluvial flats.

Mining operations since 1990 have created a series of opencast pits along the line of the Hyde Macraes Shear Zone (HMSZ). These opencast pits in combination with associated TSF’s, waste rock stacks (WRS’s), water supply and silt ponds have strongly influenced the drainage pattern within the footprint of the MGP.

The MGP is located in a hydrologically deficient area, where mean annual evaporation exceeds mean annual rainfall. The hydrological regime follows that of much of New Zealand with a low flow period in mid to late summer (February – March) and relatively high average flows during winter (July – August). Flows from the main drainage systems intersecting the MGP are characterised by periods of steady low base-flow with large short duration fresh events. All of the drainage systems intersecting the MGP area appear to be ephemeral, with flows ceasing during occasional long dry summers.

To assess hydrology in the vicinity of the MGP area, specific yields have been generated based on previous work and on recent hydrological monitoring. A number of hydrological recording sites have operated periodically in streams and rivers in the vicinity of the MGP. These specifically include the Deepdell Creek recorder at Golden Point Weir and a newly established recorder in the Tipperary Creek, named Rock Weir (Golder 2011a). Flow monitoring stations are also present on the North Branch Waikouaiti River (NBWR) at Cloverdowns and on the Shag River at Dunback, The Grange, Craig Road and Switchback.

Low flow hydrology is particularly important in the context of this report and the evaluation of effects on the receiving environment water quality. High flows are important for detailed design only, which is outside the scope of this report. Consequently the focus of this receiving environment analysis is on the median to low flows in watercourses downstream from the site. An estimate of compliance point hydrology can be calculated from low flow and specific yield data derived from the long term monitoring sites.

Water level and flow datasets for the Shag River at The Grange and the NBWR have been supplied by the Otago Regional Council (ORC). The Deepdell dataset has been supplied by BCL following an audit in late 2010 (BCL 2010). Summary statistics for the Deepdell Creek, Shag River and NBWR monitoring stations are presented in Appendix C. The short Tipperary Creek dataset has been collected by Golder. Summary statistics for the Tipperary Creek monitoring station are presented in the monitoring site documentation by Golder (2011a).

3.2 Deepdell Creek

A water level recorder was installed on Deepdell Creek close to the Golden Point Road ford and commissioned in late 1985. Golder understands this monitoring station was originally operated by the ORC. The site was de-commissioned in 1989. A flow monitoring weir subsequently installed at Golden Point Weir (site number 72627) on Deepdell Creek has operated from 1990 through to present. The Deepdell Creek catchment upstream of the weir is 40.8 km^2.

The Deepdell Creek flow record derived from the recorded stage data has been analysed for the full data period (1985 – 2010). Instantaneous and daily average flow statistics for the Golden Point Weir are summarised in Table 5. The flow duration curve for Deepdell Creek is presented in Appendix C and the low flow section of the curve in Figure 5.

Table 5: Deepdell Creek instantaneous and daily flow statistics.

Format [(1)]	Min	Max	Mean	Std. dev.	L.Q. [(2)]	Median	U.Q. [(2)]
Instantaneous	0	72,056	99.1	562.5	9.1	30.0	89.0
Daily average flow[(3)]	0	20,168	96.0	405.5	9.4	30.6	91.2

Notes:
1) All values presented in L/s.
2) L.Q. Lower quartile; U.Q. Upper quartile.
3) Flows calculated based on midnight to midnight for the monitoring period July 1985 – May 2010.

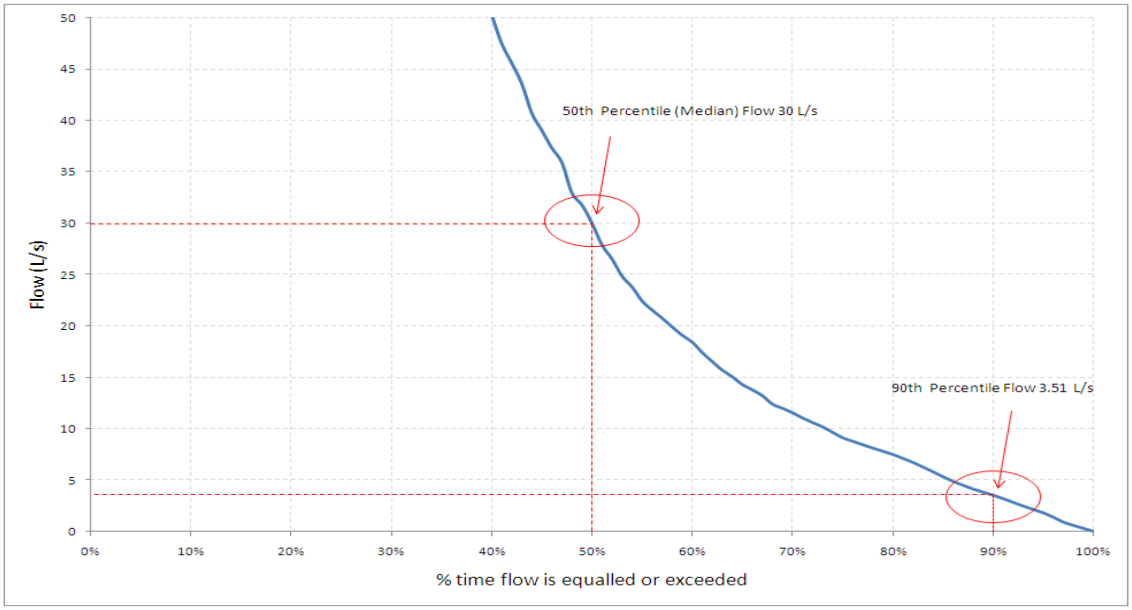

Figure 5: Deepdell Creek flow duration curve for low flow (expanded, linear scale).

Daily mean flow at Golden Point weir is approximately 96 L/s (2.35 L/s/ km^2) with a much lower median flow of 30.6 L/s (0.75 L/s/ km^2). Flow in Deepdell Creek is dominated by periods of relatively low flow with a large number of short duration fresh and flood events. Flow records indicate Deepdell Creek has ceased to flow on a number of occasions through the summers of 1998, 1999, 2004, 2007 and 2009.

Statistics on low flow percentiles and daily average low flow data for Deepdell Creek at Golden Point weir for the monitoring period 1990 to 2010 are summarised in Table 6. The analysis covers a recording period of 23 years, including years that had missing records outside the dry summer months of January to March.

A further low flow analysis using Hilltop Hydro ‘Event’ to fit a statistical distribution to the ranked low flow data was also undertaken. The probability statistics generated from this analysis indicate:

- For 1 day average flows, the analysis found that annually (2.33 years) around 1 L/s (0.02 L/s/km^2) could be expected, every 5 years 0.1 L/s (0.002 L/s/km^2) could be expected and every 8 years the daily average flow at the weir would be zero.

- For 7 day average flows, the analysis found that annually (2.33 years) around 1.7 L/s (0.04L/s/km^2) could be expected, every 5 years 0.3 L/s (0.007 L/s/km^2) could be expected and every 9 years the daily average flow at the weir would be zero.

The monthly average flow data for all complete months at Golden Point Weir is presented in Appendix C.

Table 6: Low flow statistics for Deepdell Creek at Golden Point Weir.

Statistic	Flow (L/s)	Specific discharge (L/s/km^2)
98th percentile	0.58	0.014
95th percentile	1.81	0.044
90th percentile	3.51	0.086
85th percentile	5.31	0.130
80th percentile	7.48	0.183
Mean annual minimum (MAM) (1 day)	2.95	0.072
Mean annual minimum (MAM) (7 day)	3.95	0.097

3.3 Tipperary Creek and McCormicks Creek

Tipperary Creek forms part of the upper catchment of McCormicks Creek, a major tributary of the Shag River. The confluence of McCormicks Creek with the Shag River is located 1 to 2 km south of the town of Dunback. Measured from the Shag River confluence, McCormicks Creek has a total catchment area of approximately 42 km^2.

A temporary water level monitoring station was installed on the upper Tipperary Creek at a natural rock weir in May 2010. Tipperary Creek upstream from a proposed monitoring station, TC01, has a catchment area of approximately 3.9 km^2 and contains an uncapped flowing artesian bore which discharges to the upper reaches of the creek. The monitoring site is still operational and water level data up to 17 February 2011 has been analysed for this report.

A rating curve is currently being developed for the site and a temporary rating has been established (Golder 2011a) and used to calculate flow at the site. The calculated flow record indicates that under natural conditions (i.e., removing the discharge from the uncapped artesian bore) Tipperary Creek at the rock weir is expected to be ephemeral with the natural creek expected to have dried on a number of occasions between November 2010 and February 2011.

Median naturalised daily flows for the monitored period was 4 L/s (1.0 L/s/km^2) while a mean naturalised daily flow was 18 L/s (4.68 L/s/km^2).

3.4 North Branch Waikouaiti River and Murphys Creek

The NBWR receives run-off from the southwestern area of the MGP, including the Murphys Creek catchment. An historical flow monitoring station called Cloverdowns (site number 731040) was commissioned on the river in late December 1976 and collected data up until late February 1987. This station was located just below the NBWR confluence with Murphys Creek and had a catchment area of around 75.7 km^2.

The NBWR flow record at Cloverdowns, derived from the recorded stage data, has been analysed for the full data period (1976 – 1987). The daily average mean flow at Cloverdowns was approximately 475 L/s (6.3 L/s/ km^2), with the median flow of 150 L/s (2.0 L/s/ km^2) being considerably lower (Table 7). The flow duration curve for Deepdell Creek is presented in Appendix C and the low flow section of the curve in Figure 6.

Table 7: NBWR at Cloverdowns daily average flow statistics.

Measurement [1]	Min	Max	Mean	Std dev	L.Q. [2]	Median	U.Q. [2]
Flow	3.4	47,650	475.0	1,542	57.1	150.0	454.3

Notes: 1) All values presented in L/s.
2) L.Q. Lower quartile; U.Q. Upper quartile.

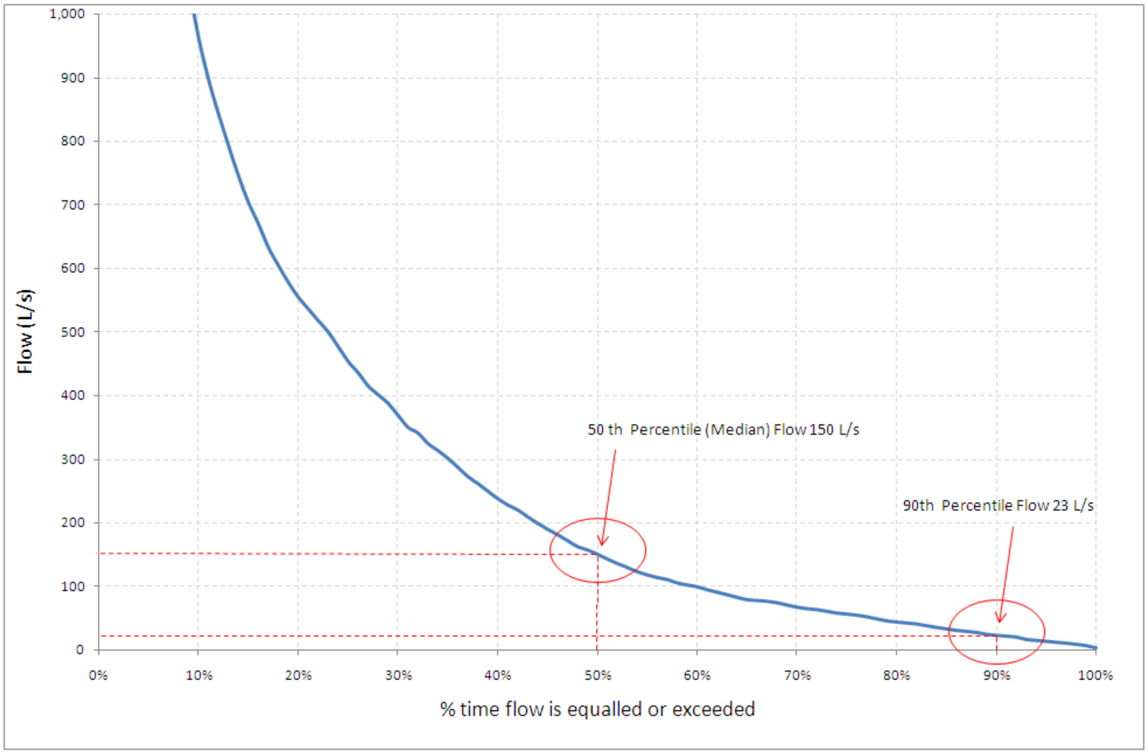

Figure 6: NBWR flow duration curve for low flow (expanded, linear scale).

The 1 day and 7 day low flow values were calculated as the average of the lowest 1 day and 7 day moving means run over the dataset each year. This was undertaken using Hilltop Hydro v5.78. Using this method, if only complete years (years with no missing records throughout the year) were assessed only 2 years of data would be analysed. For this reason the results were re-analysed and years were included that had missing record outside the dry summer months of January to March. The change resulted in the analysis of 9 years of data. Low percentile flows and daily average low flow data from the NBWR at Cloverdowns for the monitoring period 1976 to 1987 are summarised in Table 8. Monthly average flow data for all complete months at Cloverdowns on the NBWR are presented in Appendix C.

3.5 Shag River

The Shag River drains a large catchment, of which the Deepdell Creek and McCormicks Creek are major tributaries. The Shag River has several current and historical hydrological monitoring stations on it including, The Grange, Dunback Domain, Craig Road, and Switchback Road sites. A number of spot gaugings have also been undertaken at Loop Rd. The Grange dataset has been analysed as this site is still operational and has the longest flow record available. It is also close to the two proposed compliance monitoring sites on the Shag River (Loop Rd and McCormicks Creek).

The Grange site (site number 72603) is located on the Shag River at the small town of Waynes Town, off State Highway 85. The site has operated since October 1989 and is currently operational. The Shag River at The Grange has a catchment area of around 319 km^2.

The Grange flow record derived from the recorded stage data has been analysed for the full data period (1989 – 2010). The flow statistics are summarised in Table 9. These include instantaneous and daily average flow statistics for the Shag River site at The Grange. The flow duration curve is presented in Appendix C and the low flow section of the curve in Figure 7.

Table 8: Flow percentiles and low flow data for NBWR.

Statistic	**Flow (L/s)**	**Specific discharge (L/s/km^2)**
98th Percentile	9.1	0.120
95th Percentile	13.7	0.181
90th Percentile	23.2	0.306
85th Percentile	33.2	0.439
80th Percentile	44.1	0.583
Mean annual minimum (MAM) (1 day)	17.2	0.227
Mean annual minimum (MAM) (7 day)	22.9	0.303

Table 9: Shag River at the Grange instantaneous and daily average flow statistics.

Measurement (1)	**Min**	**Max**	**Mean**	**Std Dev**	**L.Q.** (2)	**Median**	**U.Q.** (2)
Instantaneous flow	0.019	427.8	1.6	8.0	0.28	0.56	1.18
Daily average flow (3)	0.021	231.2	1.6	7.2	0.28	0.57	1.19

Notes:
1) All values presented in L/s
2) L.Q. Lower quartile; U.Q. Upper quartile.
3) Flows calculated based on midnight to midnight for the monitoring period 11 October 1989 – 22 June 2010.

The 1 day and 7 day low flow values were calculated as the average of the lowest 1 day and 7 day moving means run over the dataset each year. This was undertaken using Hilltop Hydro v5.78. Using this method, if only complete years (years with no missing records throughout the year) were assessed approximately 7 years of the 20 years of data would not be analysed. For this reason the results were re-analysed and years were included that had missing records outside the dry summer months of January to March. This resulted in the analysis of the full 20 year dataset. Low percentile flows and daily average low flow data from the Shag River at The Grange for the monitoring period 1989 to 2010 are summarised in Table 10.

Table 10: Flow percentiles and low flow data for Shag River.

Statistic	**Flow (L/s)**	**Specific discharge (L/s/km^2)**
98th percentile	65	0.204
95th percentile	101	0.317
90th percentile	152	0.476
85th percentile	195	0.611
80th percentile	233	0.730
Mean annual minimum (MAM) (1 day)	141	0.442
Mean annual minimum (MAM) (7 day)	164	0.514

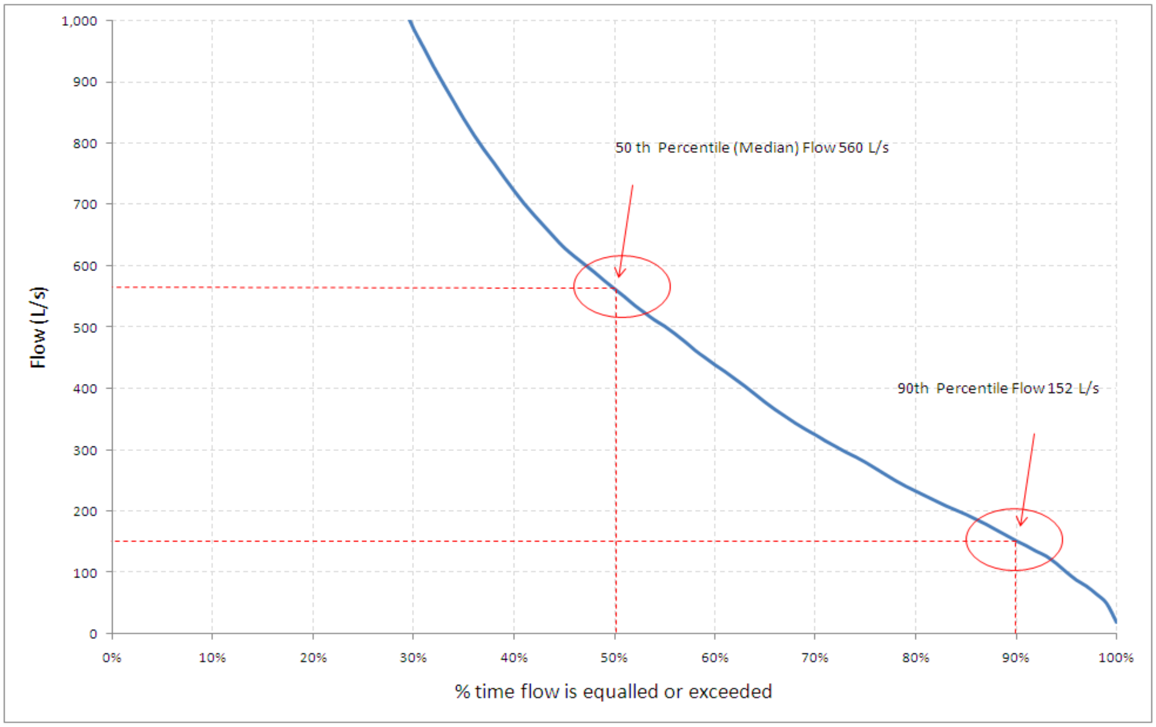

Figure 7: Shag River flow duration curve for low flow (expanded).

3.6 Flows at Water Quality Compliance Sites

Current and proposed water quality compliance monitoring sites are located on each of the main natural watercourses draining the area affected by the Macraes Phase III Project (Figure 4 in main report). These monitoring sites include DC07, DC08 (Deepdell Creek), TC01 (Tipperary Creek), CJ01 (Cranky Jims Creek), NBWRRB, NB03 (NBWR), MC01 (Murphys Creek), Loop Road and McCormicks Creek (Shag River).

An assessment has been undertaken to evaluate the likely low flow regimes at each of these compliance monitoring sites. The assessment has been based on specific discharges calculated at the monitoring sites documented in previous sections.

Flows at the DC07, DC08 monitoring sites have been approximated from the specific discharge statistics from the Golden Point Weir flow record (Appendix C). Flows at monitoring sites TC01 and CJ01 have also been approximated from specific discharge statistics from the Golden Point weir flow record. As previously noted, caution must be applied when using Deepdell Creek to approximate flows in Cranky Jims Creek and Tipperary Creek as long term data is not available to verify this assumption.

Flows at the Loop Road and McCormicks Creek compliance points have been approximated from the specific discharge statistics from The Grange flow record (Appendix C). The Grange monitoring station is located close to both of these compliance monitoring points.

Flows at monitoring sites NBWRRB, NB03 and MC01 have been approximated from specific discharge statistics from the Cloverdowns monitoring station (Appendix C). It is unclear if the compliance points higher in the NBWR catchment are directly comparable to the Cloverdowns site or are more closely aligned with the Deepdell site, which generates smaller low-flow values. For this reason caution is advised when applying Cloverdowns specific discharge values to the compliance sites higher in the catchment.

Based on the specific discharges generated from the flow records from the three monitoring stations documented in Appendix C, likely flow statistics have been generated for each compliance point. A summary of the calculated low flow statistics for each compliance site is presented in Table 11.

Table 11: Calculated compliance point flow statistics and percentiles.

Site	Catchment area	Mean	Median	98th	90th	80th	MAM (1) (1 day)	MAM (1) (7 day)
	km^2	L/s	L/s	L/s	L/s	L/s	L/s	L/s
DC07	51.6	121.4	37.9	0.7	4.4	9.5	3.7	5.0
DC08	56.8	133.6	41.8	0.8	4.9	10.4	4.1	5.5
TC01	6	14.1	4.4	0.1	0.5	1.1	0.4	0.6
CJ01	5.1	12.0	3.8	0.1	0.4	0.9	0.4	0.5
Loop Road	263.3	1,314	465	54	125	192	133	149
McCormicks	345.3	1,723	609	70	164	252	174	196
NBWRRB	3.4	21.3	6.7	0.4	1.0	2.0	0.8	1.0
NBWRRF	27	169.4	53.5	3.3	8.3	15.7	6.1	8.2
MC100	2.6	16.3	5.2	0.3	0.8	1.5	0.6	0.8
NBO3	44.9	281.7	89.0	5.4	13.8	26.2	10.2	13.6
MC01	4.9	30.7	9.7	0.6	1.5	2.9	1.1	1.5

Note: 1) MAM – Mean annual minimum. Calculated as a 1 day and 7 day moving mean run over the entire dataset.

3.7 Flood Analysis

3.7.1 Introduction

High flow flood data is available for the Golden Point Weir, The Grange and Cloverdowns monitoring stations. Only the Deepdell Creek and Shag River records have been analysed, as the NBWR is likely to be less reliable due to the shorter monitoring period.

Based on historical information and work undertaken in GCNZ (1988), runoff coefficients were calculated for Deepdell Creek for a number of storm events. These were calculated as proportion of storm rainfall reporting as runoff. Three storms were analysed (25-25 February 1986, 10-13 August 1986 and 10-13 March 1987). The flood coefficients for each storm respectively were 0.17, 0.69 and 0.31.

3.7.2 Deepdell Creek

For the current project the full Deepdell Creek dataset from 1985 to 2010 was analysed for flood events using Hilltop Hydro v5.78. The highest gauged flow of approximately 0.947 m^3/s was recorded on 30 Jul 2007, during an event that peaked at approximately 72 m^3/s (1,761 L/s/km^2). A number of smaller high flow events have also occurred including:

- 36 m^3/s (880 L/s/km^2) on 22 December 1993
- 34 m^3/s (827 L/s/km^2) on 27 July 1994
- 39 m^3/s (705 L/s/km^2) on 26 April 2006
- 24 m^3/s (588 L/s/km^2) on 13 March 1986.

The return periods of floods in the Deepdell Creek (Table 12) have been calculated using a fitted distribution. A number of distributions were analysed with the Pearson Type III approximating floods. Flood data was analysed based on hydrological years (July through June) using a 12 month data partition.

Table 12: Predicted floods and return periods based on fitted distribution in Deepdell Creek.

Return period (years)	Peak flow (m^3/s)	Specific discharge ($L/s/km^2$)
2.3	8.4	207
5	21.3	522
10	34.5	845
20	48.4	1,187
50	67.6	1,658
100	82.5	2,023

3.7.3 Shag River

The full Shag River dataset was analysed for flood events using Hilltop Hydro v5.78. The return periods of floods in the Shag River have been calculated using a fitted distribution. A number of distributions were analysed with the Pearson Type III distribution for selected approximating floods in the Shag River at The Grange (Appendix C).

Flood data was analysed based as hydrological years (July through June) with a 12 month data partition. Table 13 presents the estimated flood flows for selected return periods. The highest instantaneous flow recorded in the Shag River at the Grange was around 420 m^3/s on 22 December 1993.

Table 13: Predicted floods and return periods based on fitted distribution in Shag River.

Return Period (years)	Peak Flow (m^3/s)	Specific discharge ($L/s/km^2$)
2.3	99	311
5	192	601
10	273	856
20	353	1,106
50	457	1,432
100	535	1,677

4.0 WATER QUALITY

4.1 Introduction

As part of an ongoing environmental monitoring program at the MGP, water quality sampling has been undertaken at various locations within the site footprint and in waterways upstream and downstream from the active mine areas since 1991. These sampling sites include both surface water (Figure 9) and groundwater monitoring locations. The data is used for consent compliance monitoring, early detection of potential issues and general site characterisation purposes. The cumulative results of this monitoring program forms the basis for water quality projections used for groundwater and surface water models of the MGP site. This site specific data provides information on water quality trends, potentially stable water quality characteristics and data for comparing to laboratory analysis results. A summary of water quality information from selected sampling locations is provided in an environmental water quality review for the MGP (Golder 2011g).

Figure 8: Surface water monitoring points.

4.2 Mine Water Quality

4.2.1 Tailings water

At the MGP site, two types of tailings are produced: flotation tailings and concentrate tailings.

Flotation tailings are produced through the initial separation of high gold content minerals from the low gold content ore by a flotation process. Low gold ore is processed through a froth flotation cycle and the resulting waste material is referred to as flotation tailings. High gold concentrate produced from the flotation circuit is processed by pressure oxidation and multiple cyanide leaches, with the resulting waste product referred to as concentrate tailings.

Over the past 20 years, a number of operational changes have occurred that have influenced the quality of the decant pond water. These changes include:

- The introduction of a pressure oxidation stage to ore processing at the plant in 1999
- An increase to full plant capacity in 2006
- The introduction of Reefton Gold Project (RGP) concentrate to the plant in 2007
- Ongoing optimisation of the gold extraction processes

Prior to 1993 two tailings storage areas were operational. These areas consisted of:

- The Concentrate Tailings Impoundment (CTI), where tailings from the concentrate process stream were stored.
- The larger Flotation Tailings Impoundment (FTI), where tailings from the flotation process stream were stored

Following 1993 the two tailings streams were combined. Since 1993 they have been mixed with a short period of separation in 1998/99, immediately prior to implementation of pressure oxidation. Since then the mixed tailings have been stored in the Mixed Tailings Impoundment (MTI, formerly the FTI) and the Southern Pit Impoundment (SPI). Tailings stored in the CTI have been excavated and processed. The storage space that was made available has since been incorporated in the MTI.

Sampling of TSF decant water has been undertaken on a regular basis since the start of operations at the MGP. The analysis results are summarised in the water quality review for the site (Golder 2011g).

Assessment of the geochemistry of tailings from MGP and RGP ore indicates the differences in decant water quality generated by processing the two tailings are not substantial (Golder 2011a). Tailings decant water quality is more strongly controlled by the quality of the water used in the process plant than by the nature of the ore being processed at any particular time. Tailings decant water quality data from the past 10 years of operation, since the implementation of pressure oxidation at the MGP process plant, has been used to generate projected decant water quality for the site (Table 14).

The use of cyanide in the MGP process plant has decreased as a result of plant optimisation. During the past two years cyanide_{WAD} concentrations detected in decant water have been substantially lower than earlier periods. OceanaGold does not expect the use of cyanide to increase from current levels. Consequently the projected cyanide_{WAD} concentrations for tailings water have been based on water quality records from the past two years.

After tailings are deposited in a TSF, the suspended tailings solids settle out of the slurry and a decant pond forms from the accumulating water. As the tailings mass increases in thickness, settlement of the tailings results in further water being forced upward out of the tailings mass to the decant pond. Below the immediate surface of the unconsolidated tailings, the seepage of pore water is primarily downward toward the TSF drainage systems as well as into the underlying bedrock (Golder 2011d).

The quality of tailings pore water, as represented by TSF drain discharge water, differs from that of decant water. Complex hydrogeochemical interactions take place within the surface and more consolidated subsurface tailings solids. Tailings pore water quality changes due to dissolution and precipitation reactions. In addition, the pore water becomes deoxygenated with depth and reducing conditions dominate in the tailings mass. The key processes involved include the overall seepage time, the tailings geochemistry and the redox environment in the tailings mass (Golder 2011c).

The projected tailings water quality for the site is summarised in Table 14. As the closure plan for the site includes the removal of tailings decant water prior to rehabilitation of the TSF's, decant water quality projections are only appropriate for the operational period of the mine.

Table 14: Projected leachate water quality from mine wastes.

Parameter (1)	**Tailings decant**	**Tailings pore water seepage**		**Waste rock seepage**
		Operational	**Post-closure**	
Arsenic	3.4	5.38	1	0.007
Sulphate	5,650	2,769	2,260	2,500
$\text{Cyanide}_{\text{WAD}}$	0.47	0.47	0.35	0
Copper	0.64	0.02	0.02	0.0027
Iron	590	31	21	1
Lead	0.01	0.01	0.013	0.00021
Zinc	0.035	0.02	0.009	0.035
Sodium	585	498	416	62
Potassium	125	46	17	13
Calcium	680	411	410	470
Magnesium	420	245	200	390
Chloride	54	107	111	11

Notes: 1) All units in g/m^3. Refer to Golder reports (2011d, 2011e) for derivation of water quality projections.

Mineralogical investigation of the tailings samples detected no sulphide minerals in samples of current tailings. Calcite, siderite and gypsum were identified. Acid base accounting and net acid generation testing was conducted to determine the acid generation potential of the tailings samples. The static test results indicate that the tailings samples are unlikely to generate acidic leachate, confirming previous investigation outcomes (Golder 2011c).

Laboratory test results indicate that the leaching of tailings with rainwater is likely to generate discharge water quality considerably better than that recorded from most of the TSF drainage systems (Golder 2011c). This may be explained by the fact that the tailings above these drains are being leached with decant water with elevated concentrations of parameters such as arsenic and sulphate. Some TSF drains however have discharges that are in good agreement with laboratory data.

As the tailings decant water is oversaturated in sulphate, gypsum and potentially other salts are being precipitated and settle with the tailings solids during the operational period of the TSF. Infiltrating rainwater would leach these salts for a considerable period following TSF closure. Eventually these soluble salts would be leached away and contaminant concentrations in the drain discharges would decline to the level indicated by leach tests of tailings samples. These long term leachate concentrations are expected to be considerably lower than those indicated from analysis of the drainage records from most of the MTI and SPI drain discharges.

For modelling purposes it has been assumed that post-closure seepage from the TSF's would reflect the range of drainage water quality measured on site from the MTI and SPI (Golder 2011c). No improvement in the drainage water quality has been incorporated in the models simulating the post-closure management period of the mine (Table 14).

4.2.2 Waste rock seepage

Two underdrains were installed in Northern Gully prior to construction of the Northern Gully WRS. The discharge water from these drains (Golder 2011g) is considered to be the most reliable indicator of waste rock seepage water quality available for the MGP site (Table 14).

Water samples have also been collected from locations which are significantly affected by seepage water from waste rock stacks. These locations include Frasers West and Murphy's Creek silt ponds and groundwater monitoring wells located down-gradient from the Frasers West WRS. The water quality data from these sites indicates that concentrations of sulphate and other major ions are increasing towards those measured in drainage water from the Northern Gully underdrains. These trends support the use of Northern Gully drainage water quality as a proxy for waste rock seepage.

4.2.3 Run-off water quality

In addition to the waste storage areas at the MGP site, there are areas considered to be impacted by mining activity and areas classed as non-impacted. Areas classed as impacted include pits, ore processing areas, mine roadways, unrehabilitated WRS's and rehabilitated tailings surfaces. The non-impacted areas are considered to be areas within the mine site that are still in a natural state but may be influenced by mining through mine dust, etc, and rehabilitated WRS's.

Impacted and non-impacted areas are characterised by different run-off water quality (Table 15). The data used to evaluate run-off water quality is primarily from sampling and analysis of pit wall run-off and pit sump water (Golder 2011g).

Table 15: Mine site run-off water quality.

	Non-impacted areas	Impacted areas
Arsenic	0.021	0.1
Sulphate	125	201
Cyanide $_{WAD}$	0.001	0.001
Copper	0.001	0.002
Iron	0.05	0.135
Lead	0.0001	0.001
Zinc	0.005	0.005
Sodium	15	28
Potassium	3	4
Calcium	46	63
Magnesium	26	34
Chloride	6	13

Note: All units in g/m^3. Refer to Golder report (2011e) for derivation of water quality projections.

4.3 Background Stream Water Quality

Water quality data from compliance and baseline surface water quality monitoring programs are available dating back to the start of MGP operations. Different catchments intersecting or potentially influenced by discharges from the MGP are characterised by different water quality (Table 16). The dataset used to evaluate background water quality in the case of the NBWR and Murphys Creek has included some sulphate data indicating existing influence from mining operations. The elevated background sulphate is however not considered to have a significant effect on model projections.

Table 16: Background surface water quality in catchments influenced by the MGP.

Parameter (1)	**Catchments**			
	Deepdell/Shag	**Tipperary/McCormicks/ Cranky Jims**	**NBWR/Murphy's**	**NBWR downstream (2)**
Arsenic	0.0015	0.005	0.007	0.0058
Sulphate	4	4	47	58
Cyanide $_{\text{WAD}}$	0.003	0.005	0.005	0.002
Copper	0.0011	0.002	0.001	0.002
Iron	0.2	0.5	0.1	0.18
Lead	0.0001	0.001	0.001	0.001
Zinc	0.005	0.005	0.005	0.004
Sodium	11	11	13	12
Potassium	1	2	2	1.6
Calcium	13	10	36	24
Magnesium	4	4	12	11
Chloride	11	11	10	12

Note: 1) All units of g/m^3. Refer to Golder report (2011e) for derivation of background water quality.
2) Area downstream from Ross Ford.

4.4 MGP Water Quality Compliance Criteria

4.4.1 Surface water

The development of the MGP over time has resulted in a range of compliance points related to different sections of the mine. In some cases these compliance points are now unnecessary or will become unnecessary if the proposed compliance monitoring regime outlined in Table 17 is approved.

The proposed changes in surface water quality compliance points are recommended for the following reasons:

- A shift of the Deepdell Creek compliance point from DC07 to DC08 as run-off and groundwater seepage from the proposed Back Road WRS would enter Deepdell Creek downstream from DC07.
- New compliance points on Tipperary Creek and Cranky Jims Creek to monitor surface water quality effects in these creeks from the proposed TTTSF.
- A new compliance point on the Shag River downstream from the confluence with McCormicks Creek, to monitor water quality effects from the MGP above consented water abstractions on the Shag River. The existing Loop Road compliance point on the Shag River is retained as there is a consented water take from the Shag River between Loop Road and the McCormicks Creek confluence.

- The compliance point on the NBWR at Ross Ford (NBWRRF) is considered unnecessary as existing compliance points already exist upstream at Red Bank Road (NBWRRB) and downstream below the confluence with Murphys Creek (NB03). There are no consented or known surface water takes between the compliance points NBWRRB and NB03.
- The existing compliance point MC100 is considered unsuitable for monitoring of water quality effects from the MGP, as there is inadequate space between the Murphy's Creek silt pond and this compliance point to enable water quality mitigation measures (refer Section 7.0). The compliance criteria applicable at MC100 have been shifted downstream to the existing MC01 compliance point. The criteria that are currently applicable at MC01 are also applicable downstream at NB03. As there are no consented or known surface water takes between MC01 and NB03, the transfer of these compliance criteria is considered to be reasonable.

In general the water quality criteria developed for compliance monitoring points immediately downstream from the MGP, including DC08, TC01, CJ01, MC01 and NBWRRB, are based on either stock water guidelines for sulphate or on ANZECC guideline values for soluble metals to protect the aquatic life in the stream. The water quality criteria developed for the further downstream compliance monitoring points are primarily based on New Zealand drinking water standards or the ANZECC guideline values for soluble metals to protect the aquatic life (Table 17).

To date only minor exceedances of the existing surface water quality criteria have been recorded (Golder 2011g). These exceedances are mainly related to dissolve iron. The dissolved iron concentrations detected at some monitoring points, such as MC100 on Murphys Creek, are likely to be derived from waste rock stack seepage. At other compliance monitoring sites the concentrations that exceed the compliance criteria may be natural in origin.

Exceedances of the water quality criteria for trace metals tend to be a consequence of the criteria being hardness dependent. For example, there have been four recorded exceedances of the limit for lead at DC07 on Deepdell Creek. Lead concentrations detected upstream from the MGP on three corresponding monitoring dates were also higher than the downstream compliance limit. On the date of the fourth exceedance no upstream sample was taken (Golder 2011g). These results indicate the exceedances are not related to mining operations and in each case the exceedance was related to changes in water hardness.

Sulphate exceeded the compliance criteria in Deepdell Creek once. This exceedance was a consequence of an oversight in water management at the site leading to mine water discharges from Golden Point Pit through the historical underground workings to Deepdell Creek. These discharges were brought under control once they were identified. Sulphate concentrations in Deepdell Creek have since decreased to levels similar to those recorded prior to the unplanned releases.

4.4.2 Groundwater

Groundwater quality monitoring wells have been installed down-gradient from the TSF's at the MGP. These monitoring wells are designated as internal use, detection and compliance wells. Water quality compliance criteria (Table 18) are only applied to water at monitoring wells designated as compliance wells.

The water quality at the line of compliance wells in MTG, down-gradient from the MTI, has generally been in compliance with the water quality criteria, with the exception of soluble iron. Soluble iron frequently exceeded the compliance limit during the two years following installation of the wells. Concentrations have also started to exceed the compliance limits as the leachate plume from the MTI has reached the compliance wells. The progress of tailings leachate down MTG between the lines of detection and compliance wells is clearly identifiable in graphs of sulphate concentrations in the water (Golder 2011g).

Groundwater quality in the compliance monitoring wells down-gradient from the SPI is considerably more variable than that in the compliance wells in MTG. The variability of the water quality between SPI compliance wells is primarily due to the relative separation of each well from either the Golden Point Pit or the historic Golden Point underground workings.

Table 17: MGP surface water quality compliance criteria.

Compliance Point	**Potential usage**	**pH (unitless)**		**Arsenic**		**Cyanide $_{WAD}$**		**Copper [(6)]**		**Iron**		**Lead[(6)]**		**Zinc[(6)]**		**Sulphate**	
		current	proposed	current	proposed	current	proposed	current	proposed	current	proposed	current	proposed	current	proposed	current	proposed
Deepdell Creek DC07 (1)	Stock watering	6 – 9.5	-	0.15	-	0.1	-	0.009	-	1	-	0.0025	-	0.12	-	1000	-
Deepdell Creek DC08 (1)	Stock watering	-	6 – 9.5	-	0.15	-	0.1	-	0.009	-	1	-	0.0025	-	0.12	-	1000
Shag River at Loop Rd (1)	Drinking	7 – 8 .5	7 – 8 .5	0.01	0.01	0.1	0.1	0.009	0.009	0.2	0.2	0.0025	0.0025	-	0.12	250	250
Shag River at McCormicks	Drinking	-	7 – 8 .5	-	0.01	-	0.1	-	0.009	-	0.2	-	0.0025	-	0.12	-	250
North Branch Waikouaiti River NBWRRB (2)	Stock watering	6 – 9.5	6 – 9.5	0.15	0.15	-	0.1	0.009	0.009	1	1	0.0025	0.0025	0.12	0.12	-	1000
North Branch Waikouaiti River NBWRRF (2, 3)	Stock watering	6 – 9.5	-	0.15	-	-	-	0.0014	-	1	-	0.0025	-	0.12	-	-	-
Murphys Creek MC100 (2, 4) (upstream)	Stock watering	6 – 9.5	-	0.15	-	-	-	0.009	-	1	-	0.0025	-	0.12	-	-	-
Murphys Creek MC01 (2, 4) (downstream)	Stock watering	6 – 9.5	6 – 9.5	0.01	0.15	-	-	0.0014	0.009	1	1	0.0025	0.0025	0.12	0.12	-	1000
North Branch Waikouaiti River NB03 (5)	Drinking	6 – 9.5	6 – 9.5	0.01	0.01	-	-	0.009	0.009	1	1	0.0025	0.0025	0.12	0.12	-	250
Cranky Jim Creek CJ01	Stock watering	-	6 – 9.5	-	0.15	-	0.1	-	0.009	1	1	-	0.0025	-	0.12	-	1000
Tipperary Creek TC01	Stock watering	-	6 – 9.5	-	0.15	-	0.1	-	0.009	1	1	-	0.0025	-	0.12	-	1000
Current Guidelines and Standards																	
ANZECC (2000) stock water	Guideline			0.5		NA		0.5	sheep	NA		0.1		20		1000	
NZDWS (2008)	Guideline or Standard	7 – 8.5	(GV)	0.01	(MAV)	0.08	(MAV total)	2	(MAV)	0.2	(GV)	0.01				250	

Notes: All units g/m^3 unless otherwise stated.

1) Current compliance standards from ORC Resource Consents 2006.304, 2006.305, 2006.307, 2006.308.
2) Current compliance standards from ORC Resource Consents 2006.635, 2003.636, 2003.637, 2003.638, 2004.362, 2005.208, 2005.209, 2005.210, 2007.583.
3) Ross Ford NBWRRF compliance point proposed to revert to monitoring only, in favour of downstream compliance point NB03.
4) MC100 compliance point proposed to revert to monitoring only. Compliance limits currently applicable to MC100 to be applied at MC01.
5) Current compliance standards from ORC Resource Consents 2002.491, 2002.759, 2002.763. NB03 becomes final downstream compliance point on the NBWR for all MGP operations.
6) Metal limits hardness adjusted as per equations 1 to 3 below.

ANZECC (2000) drinking water quality guidelines for livestock.
NZDWS (2008) drinking water standards for human consumption
MoH (2008) drinking water limit equivalent to the maximum acceptable value (MAV) given in MoH (2008); MAV for total cyanide, short term.

Trace metal compliance criteria hardness corrections.

1) Copper (g/m^3) = (0.96exp$^{0.8545[\ln(\text{hardness})] – 1.702}$) / 1000

2) Lead (g/m^3) = (1.46203 – [ln(hardness)(0.145712)]exp$^{1.273[\ln(\text{hardness})] -4.705}$) / 1000

3) Zinc (g/m^3) = (0.986exp$^{0.8473[\ln(\text{hardness})] + 0.884}$) / 1000

Table 18: MGP groundwater quality compliance criteria.

Parameter (1)	Groundwater compliance wells
pH (unitless)	6.0 – 9.5
Arsenic	0.15
$\text{Cyanide}_{\text{WAD}}$	0.10
Iron	1.0
Copper (2)	0.009
Lead (2)	0.0025
Zinc (2)	0.12

Notes: 1) All units in g/m^3 unless otherwise stated.
2) Metal limits hardness adjusted as per equations 1 to 3 provided with Table 17.

5.0 GROUNDWATER MODELLING

5.1 Introduction

Following established practice from the consenting of previous expansions to the TSF capacity at the MGP, groundwater flows and associated contaminant transport across the site have been modelled using 3D models. Two models have been constructed to simulate adjacent areas of the site. One model, termed the site wide model, was constructed to simulate the MGP area within the Deepdell Creek, NBWR and Murphy's Creek catchments (Golder 2011d). The second model was constructed to simulate the proposed TTTSF, including the Tipperary Creek and Cranky Jims Creek catchments (Golder 2011b).

The Visual MODFLOW Pro software package was used to construct and calibrate the groundwater model. Modelling of contaminant mass transport within the groundwater system at the MGP has been undertaken to cover the period from 2010 through to the close of mining operations at the site at the start of 2020 followed by a 150 year post-closure period. Beyond that period, potential changes in the hydrogeological behaviour of the tailings material and climactic conditions are considered to limit the usefulness of predictive modelling.

The site wide model is based directly on existing calibrated groundwater models used to simulate the groundwater system at the site (Kingett Mitchell 2002, 2005). The outcomes from previous models have been accepted by the ORC as part of previous applications by OceanaGold for resource consents. Planned changes to the MGP site simulated using the current model include:

- Ongoing expansion of the Frasers Pit and the reopening of Round Hill/Golden Point and Innes Mills Pits.
- Construction of the Frasers South, Frasers East, Frasers North and Back Road WRS's.
- Closure of the MTI and the SPI, including recovery of the tailings from SP11 and removal of the SP11 embankment.

The Top Tipperary groundwater model was constructed based on the current topography of the catchment and the planned TSF layout provided by OceanaGold. The model primarily incorporates the proposed TTTSF, including drainage systems and embankment layout. The planned Frasers East and Back Road WRS's have been simulated to ensure potential contaminant losses from these areas to the Tipperary Creek catchment were incorporated in the model outcomes. The groundwater model does not however incorporate possible increases in seepage losses to the Golden Point/Round Hill Pit that may result as a consequence of movement of the MTI embankment.

5.2 Model Input Parameters

Hydrogeological parameters applied to the schist bedrock have been based on the calibration outcomes from existing groundwater models of the site (Kingett Mitchell 2005). Hydraulic tests performed on drillholes in the area of the Back Road WRS (Golder 2009) and the TTTSF (Golder 2011b) indicate these parameters are reasonable for the new areas affected by the Macraes Phase III Project. Modelled groundwater quality projections for seepage down the MTG also remain conservative in terms of concentrations. On this basis the parameters applied to previous modelling were retained. Hydrogeological parameters for the simulated TSF's are based on embankment design values (EGL 2000, 2001, 2011) and on tailings grain size analyses (Kingett Mitchell 2005).

Groundwater quality input parameters for the modelling were based on water quality data from the site environmental monitoring program. These parameters include leachate water quality representing TSF decant ponds, TSF drain discharges and WRS seepage (Table 14). The water quality parameters simulated include the major ions, a range of metals, arsenic and cyanide$_{WAD}$. Contaminants are introduced to the groundwater models through defining concentrations for each contaminant applied as recharge water to the WRS and the TSF areas. The contaminant concentrations applied to each TSF change as the TSF shifts from operational to closed. During the post-closure period the contaminant concentrations applied do not change over time.

Contaminant transport for each of the simulated contaminants, with the exception of arsenic, has been undertaken on the basis of conservative transport within the groundwater system. There is therefore no attenuation of contaminants in the groundwater system other than that provided by dilution. Arsenic transport has been modelled based on arsenic (III) being the main form of this element in the tailings seepage water. The adsorption characteristics of arsenic (III) onto loess soils and weathered schist have been derived from testing of rock and soil samples from the site (Golder 2011b) and incorporated in the contaminant transport simulations.

Simulated groundwater recharge rates applied to the TSF's is calibrated to ensure the water table within the tailings is at the tailings surface during the operational period of the mine. The regional groundwater recharge rate has been applied to the rehabilitated WRS's and TSF's at the site.

5.3 Projected Discharges to Natural Watercourses

The maximum simulated contaminant mass load in water discharging to natural water bodies at the Macraes Gold Project occurs after the site has been closed, with the exception of the TSF drainage systems. It requires a considerable period of time for contaminants to be transported through the groundwater system at the site to the receiving water bodies. Simulated groundwater discharge rates at the time of maximum discharge mass load and the associated average sulphate and arsenic concentrations are summarised in Table 19.

Groundwater inflows to the opencast pits at the MGP can be expected to vary depending on the water level of the pit lake. As the water level in a pit rises following closure the groundwater hydraulic gradients toward the pit decrease and the groundwater inflows to the pit also decrease.

At its maximum extent, groundwater inflows to the combined Round Hill/Golden Point pit are calculated to peak at approximately 180 m^3/day. Groundwater inflows to the combined Innes Mills and Frasers pit lake are treated as being connected as they are expected to eventually become combined following closure. Groundwater inflows to the combined pits are calculated to peak at approximately 1,280 m^3/day. These flows would decrease following closure in response to declining flows from SP10 and rising lake water levels.

Table 19: Summary of modelled MGP post-closure groundwater discharges and discharge water quality.

Receiving Water	Groundwater maximum discharge rate (m^3/day)	Arsenic (g/m^3)	Sulphate (g/m^3)
Deepdell Creek upstream from DC07, including tributaries	730	0.03	590
Deepdell Creek between DC07 and DC08, including tributaries	116	0.05	1,050
Murphys Creek upstream from MC100	180	0.03	380
North Branch Waikouaiti River upstream from NBWRRB	100	0.03	1,050
Tipperary Creek main channel	1,800 (260) (1)	<0.01	10 (2)
Tipperary Creek western tributary	46 (30) (1)	<0.01	190
Cranky Jims Creek	16 (7) (1)	<0.001	600
Round Hill / Golden Point Pits	180 (3)	0.4	860
Frasers / Innes Mills Pits	1,280	0.05	740

Note: 1) Values in brackets are long term post-closure discharge rates.
2) Stretch of creek upstream from proposed Tipperary sump is incorporated in TTTSF drainage discharges. Seepage discharge zone is almost entirely upstream from sump.
3) Does not take into account seepage flows resulting from potential movement of MTI embankment.

5.4 Projected TSF Drainage System Discharges

Drainage discharges from the combined MTI and SPI at closure were simulated to be approximately 1,800 m^3/day. The simulated TSF drainage systems are limited in detail and the drainage systems built into the uphill raises of the MTI and SPI are poorly represented. This lack of detail leads to understatement of drainage flows that may be expected at closure. Monitoring of drainage flows at the site indicates the total flows at closure are more likely to be in the order of 2,500 m^3/day (Golder 2011i).

Simulated MTI and SPI drain discharge rates indicate a decrease in flows of approximately 50% within a period of 10 years following closure. It is, however, likely that this decrease in drain discharges is conservative. An assessment of the rates at which MTI and SPI drain discharges have declined during inactive periods in the past, indicates discharges are likely to decline at a faster rate of between 50% and 90% within two years following closure (Golder 2011i).

It is expected that much of the stored tailings mass would become unsaturated during the 20 years following closure of a TSF. There is, however, considerable uncertainty with respect to the length of time required for the overall groundwater system to reach a steady state flow pattern. This uncertainty is partly due to the inherent variability of the hydrogeologic characteristics of the tailings mass. In addition, dynamic factors such as compaction of both the tailings mass and the underlying soils have not been taken into account in this projection.

Once the groundwater systems within the tailings storage facilities have reached a steady state following closure the contaminant loads in water subsequently lost from the tailings would be associated with the residual moisture content and ongoing recharge from rainfall. Further transport of contaminants from the tailings would mainly occur in response to significant rainfall events. These events would lead to pulses of seepage water travelling downward through the unsaturated tailings to the groundwater table. These pulses, averaged on a long term annual basis, are expected to be equivalent to the natural 32 mm/year groundwater recharge rate for the region.

Discharges to Deepdell Creek have been calculated on a seasonal basis. Tributary creeks considered to fall dry during the summer months due to evaporative losses from the creek beds. This implies no contaminant load from these tributaries during the summer periods.

6.0 SURFACE WATER MODELLING

6.1 Introduction

As part of the environmental assessment of the Macraes Phase III Project a mine water management model has been constructed to simulate dissolved contaminant transport in surface water from the Macraes Gold Project site. This model has been constructed using the GoldSim modelling platform. The model simulates water flows across the Macraes Gold Project site and in downstream catchments, taking into account the planned sequential mining operations at the site. Runoff and surface flows, based on rainfall records from the site, have been calibrated against flow records from monitoring stations on Deepdell Creek and the Shag River (Golder 2011e).

Rainfall projections have been developed using a stochastic rainfall generator and converted into run-off projections using the Australian water balance model. The outcomes of these rainfall and run-off projections have been compared to the historical records. The comparison indicates the projections are very similar to observed hydrological patterns, although minor anomalies are present relating to the exaggeration of rare extreme rainfall events.

Representative water quality characteristics for TSF decant water and drainage water, WRS drainage water and run-off water from disturbed surfaces, rehabilitated surfaces and undisturbed surfaces applied in this model are summarised in Section 4.0. Dissolved parameter concentrations for water quality modelling have been defined as being toward the upper end of the observed range for each parameter, in order to ensure model outcomes for contaminant transport are conservative.

The model generates a water balance for the MGP site, with an associated mass load related to each receiving water catchment. Dilution water together with the appropriate water quality is modelled as being available from the surrounding catchments upstream from each simulated compliance point.

The transport of all contaminants simulated in the mine water management model is done on a conservative basis. Although natural attenuation of some contaminants is expected to occur in natural watercourses within the MGP boundaries, no attenuation processes other than dilution have been incorporated in the model.

6.2 Site Water Management

6.2.1 Operational Period

The mine water management stages of the Macraes Stage III Project are summarised below. These water management stages have been incorporated in the mine water management model (Golder 2011e).

January 2010 to February 2012. Frasers Pit is operational and being actively dewatered. Water levels in Golden Point pit are being actively managed. Water from pit dewatering is either utilised in the processing plant or for dust suppression. Waste rock placement is to Frasers West and Frasers East WRS's. Tailings from the process plant are alternately placed in the MTI and SP11. Seepages from both TSF's are collected by the impoundment drainage systems and returned to the process plant. Make-up water is pumped from the Taieri River. Surface water run-off and groundwater seepage collecting in the Northern Gully and Maori Tommy Gully silt ponds is returned to the process water system.

March 2012 to December 2015: Frasers Pit is operational and being actively dewatered. Water levels in Golden Point pit are being actively managed. Water from pit dewatering is either utilised in the processing plant or for dust suppression. Waste rock placement is to Frasers East, Frasers North and Frasers South WRS. Frasers West WRS is being rehabilitated. Tailings from the process plant are stored in the TTTSF. The MTI, SP10 and SP11 are inactive, are becoming dewatered and seepage drain discharges are declining. Tailings from SP11 are being recovered and dry stacked on the MTI or in the TTTSF. Seepages from the TSF are collected by the impoundment drainage systems and returned to the process plant. Make-up water is pumped from the Taieri River. Surface water run-off and groundwater seepage collecting in the Northern Gully and Maori Tommy Gully silt ponds is returned to the process water system.

January 2016 to December 2017: Round Hill Pit and Frasers Pit are operational. Round Hill pit is being actively dewatered. Water management for Frasers Pit has ceased and a pit lake is starting to develop. Waste rock placement is to Back Road WRS. Frasers East, Frasers North and Frasers South WRS are being rehabilitated. The MTI, SP10 and SP11 are inactive, are becoming dewatered and seepage drain discharges are declining. Seepages from the TSF's are collected by the impoundment drainage systems and returned to the process plant. Make-up water is pumped from the Taieri River. Surface water run-off and groundwater seepage collecting in the Northern Gully and Maori Tommy Gully silt ponds is returned to the process water system.

January 2018 to January 2019: Innes Mills Pit is operational. None of the opencast pits is subject to active water management. Waste rock placement is to Back Road WRS and to the relatively small Frasers South in-pit stack. The MTI, SP10 and SP11 are inactive, are becoming dewatered and seepage drain discharges are declining. Seepages from the TSF's are collected by the impoundment drainage systems and returned to the process plant. Make-up water is pumped from the Taieri River. Surface water run-off and groundwater seepage collecting in the Northern Gully and Maori Tommy Gully silt ponds is returned to the process water system.

To date the water management system at the MGP has operated very well. A very high level of compliance with water quality criteria has been achieved.

6.2.2 Post-Closure Period

January 2019 to December 2169: All mining operations have ceased. Pit lakes are developing in Frasers and Round Hill/Golden Point pits. Rehabilitation of all WRS's is completed. Collected tailings drain discharges are to be initially pumped to Frasers Pit until they can be either passively managed or released to the environment without exceeding consent conditions. Seepage water collecting in the Northern Gully and Maori Tommy Gully silt ponds is released to downstream receiving waters.

The pumping of tailings drainage water to Frasers Pit for a period of up to 20 years following the close of mining operations is a water quality mitigation measure. This measure was however included in the post-closure mine water management plan proposed during the previous consenting process for an expansion of the TSF capacity at the MGP. As such, this is considered to be a "base case" mitigation measure and automatically incorporated in each proposed water quality mitigation scenario summarised in Section 7.0.

6.3 Pit Lake Level Projections

Projections for filling of the Frasers Pit incorporate the filling of the hydraulically linked Innes Mills Pit. These projections indicate the combined lake would not overflow within the 150 year simulation period of the model. The projection for pit lake volume (Golder 2011e) indicates the rate of filling would decrease over time as the evaporative area of the exposed lake surface increases. The rate of rise in the water level in the lake (Figure 9) is much more rapid during the first decade following mine closure than during later decades. This initial rapid rate of water level rise is partially a function of the storage of tailings water in the pit and partially due to the inverted cone shape of the pit.

Projections for filling of the Round Hill Pit incorporate the filling of the connected Golden Point Pit. These projections indicate the pit lake would not overflow within the 150 year simulation period of the model. The projection for pit lake volume (Golder 2011e) indicates the rate of filling would decrease over time as the evaporative area of the exposed lake surface increases. The rate of rise in the water level in the lake (Figure 10) is more rapid during the first decade following mine closure than later. This difference in water level rise is however not as substantial as for the Frasers Pit.

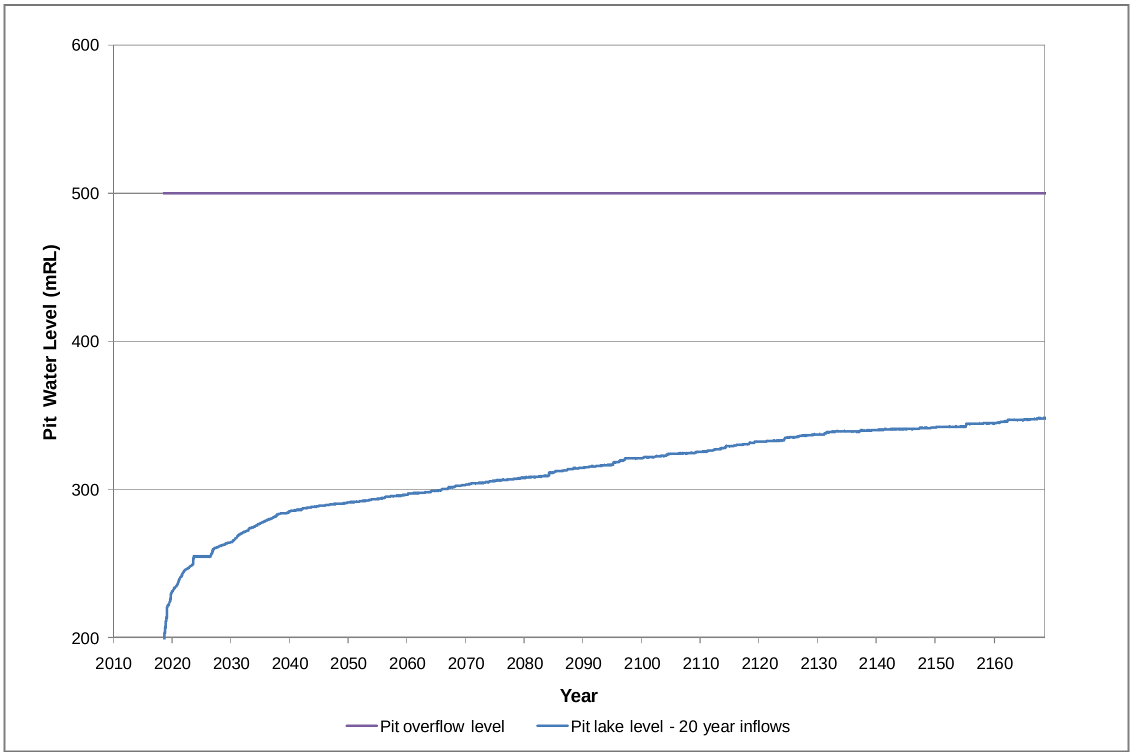

Figure 9: Frasers Pit lake post-closure water level projections.

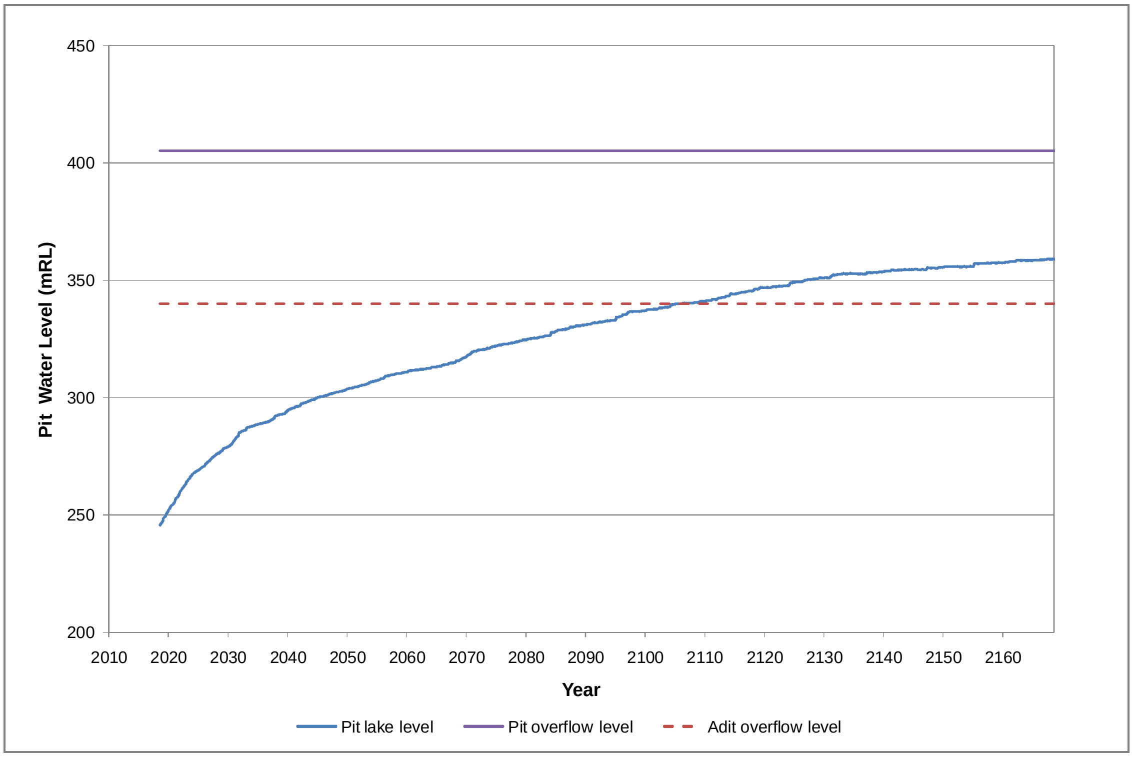

Figure 10: Round Hill Pit lake post-closure water level projections.

The simulation of water level change in the Round Hill pit lake was undertaken on the assumption that there would be no seepage losses from the pit lake through historical gold mine adits and underground workings located beneath the schist ridge separating Golden Point Pit from Deepdell Creek. These workings have not been mapped in detail, however, their general layout, elevations and seepage discharge points are known. Three levels of mine workings have been identified from mapping undertaken by OceanaGold. These underground workings were exposed in the Golden Point Pit wall and have some connection to mine portals opening onto the valley slope above Deepdell Creek.

The hydraulic connectivity of the upper levels of underground workings has not been tested. The lowest of these workings is however a demonstrated hydraulic connection between Golden Point Pit and Deepdell Creek valley. Underground workings that were exposed in the pit wall during mining operations have subsequently been buried with fill deposited in the pit.

Experience from past mine water discharges through the historic underground workings indicates the filling of a pit lake to the level of these workings would result in unacceptably large discharge flows to Deepdell Creek. At present these discharges have been minimised through pumping mine water from inside the pit to the process plant. A number of passive management options to reduce the discharge of seepage water from the proposed pit lake through the underground workings to Deepdell Creek have been considered by OceanaGold (Golder 2011h).

Seepage models have been constructed to investigate potential discharge flow rates through the Golden Point adits. These models indicate that a groundwater level within the waste rock in Golden Point Pit of 347 mRL, which is approximately equivalent to elevations of water in the pit sump on occasion since 2007, would result in a discharge flow of approximately 400 m^3/day through the workings. This discharge rate is toward the upper limit of flows observed from the workings during the same period. The simulations also indicate that a further increase in water level within the pit would simply lead to increased discharges through the underground workings.

The models indicate that installing a low permeability liner the present northern face of the pit and keyed against into the underlying schist could reduce seepage flows through the underground workings by a factor of about 4. However, the calculated discharge flows still became unacceptably high as the simulated water level in the lake was increased.

The most effective scenario at limiting discharge flows from Golden Point Pit was to completely seal the underground workings, thereby limiting water losses from the pit to general groundwater seepage. If this could be achieved, the seepage flows from Golden Point Pit could decrease to less than 100 m^3/day. The total discharge flows from Golden Point Pit are completely dominated by flows through the underground workings under each modelled scenario where the workings have not been sealed (Golder 2011h).

If the underground workings are not sealed or potential flows through these workings not minimised by some means, the pit lake water level within Round Hill Pit is unlikely to rise much above the level of the lowest workings. Sealing the adits should result in the lake surface rising until the lake inflows are balanced by evaporation and seepage losses through the intact rock barrier.

6.4 Unmitigated Water Quality Projections

The outcomes of the site wide surface water modelling program (Golder 2011e) identify locations where mitigation measures may be necessary in order to ensure the MGP continues to operate within the current and proposed consent compliance limits. The GoldSim modelling outcomes indicate mitigation measures are likely to be necessary to ensure the MGP continues to meet consent water quality compliance limits at most of the sites listed in Table 20.

The simulation of water quality using the GoldSim model has been performed based on the assumption that contaminants are conservatively transported in surface waters. For a number of the simulated parameters, including metals, metalloids and cyanide$_{WAD}$ this is unlikely to be the case (Golder 2011e). For example, the outcomes from past investigations in southern New Zealand have indicated arsenic is attenuated not only in soils but also in the stream environment (Craw et al. 2000; Haffert & Craw 2008). Most metals and metalloids, including iron, are likely to be attenuated through adsorption and precipitation reactions.

Table 20: Summarised un-mitigated and un-attenuated exceedances of proposed consent water quality limits.

Monitoring site	Parameter $^{(1,2)}$				
	Arsenic	**Copper**	**Cyanide_{WAD}**	**Iron**	**Sulphate**
DC08	(YES)	NO	(YES)	(YES)	YES
TC01	(YES)	NO	NO	(YES)	YES
Shag at Loop Road	(YES)	NO	NO	(YES)	YES
Shag at McCormicks	(YES)	NO	NO	(YES)	YES
NBWR Red Bank	(YES)	NO	NO	(YES)	YES
MC01	(YES)	NO	NO	(YES)	YES
NB03	(YES)	NO	NO	(YES)	YES
CJ01	NO	NO	NO	YES	NO

Notes: 1) Other parameters for these sites are projected to remain within compliance limits.

2) Simulated exceedances presented in brackets are unlikely to eventuate. The in-built conservatism of the model and the lack of simulated natural attenuation processes leads to exceedances being indicated.

A preliminary assessment of the hydrochemical stability of the simulated water quality in Deepdell Creek at DC08 has been performed. The assessment is preliminary and indicative only in that the water quality in Deepdell Creek can be expected to change daily. The outcomes (Golder 2011e) indicate the major ions, including calcium, potassium, magnesium and sulphate, are effectively conservatively transported in surface water at the concentrations simulated by GoldSim at DC08. In contrast, the hydrochemical assessment indicated reductions in iron concentration were at least two orders of magnitude, based on the precipitation of Ferrihydrite ($Fe(OH)_3$). A similar reduction in the concentration of lead was indicated and the decrease in arsenic concentration was at least one order of magnitude. Copper, zinc and cyanide_{WAD} showed effectively no change in concentration, although breakdown rates for the latter were not incorporated in this assessment.

Due to the conservatism of the mine water management model, the projected compliance exceedances for arsenic and cyanide_{WAD} are unlikely to occur. Both are subject to geochemical reactions, precipitation, adsorption or breakdown in the natural environment. This attenuation has not been incorporated in the surface water model. Dissolved iron is also unlikely to present an issue at the compliance points, due to its capacity to rapidly oxidise and subsequently precipitate. Mitigation measures may however be required to minimise any possible issues of iron flocculants and discolouration of stream beds close to the TSF's.

Pit water quality following closure of the MGP varies over time in response to:

- The shift in land use surrounding the pits, from operational areas to rehabilitated surfaces.
- The baseline post-closure water management measure applied to the TSF's, where drain discharges and captured seepage water is pumped to Frasers Pit for up to 20 years following closure.

These factors result in the initial water quality in the pit lakes being poor. As the pit lakes fill and the dilution water from rainfall gradually forms a larger component of the accumulated lake water, the water quality improves. Eventually, the simulated water quality in both Frasers Pit lake and the Golden Point/Round Hill pit lake improves to the extent that both lakes would meet ANZECC stock water guidelines for sulphate and dissolved metals/metalloids. The guideline values for stock water are not necessarily appropriate for the pit lakes as stock access is to be restricted and it is not clear that either pit lake would eventually overflow to a natural receiving water body.

Golder understands there is to be no unauthorised access to the pits following closure of the mine. This includes the provision of fencing to prevent stock access. In addition, the water balances calculated for the two pits indicates they will not overflow within a 150 year period following closure. On that basis, the only potential for unmanaged water losses from the pit lakes is through the historical underground workings at the northern end of Golden Point Pit. Golder understands these workings are to be sealed to minimise the risk of excessive seepage losses through these workings.

Taking into consideration the in-built conservatism of the model and natural processes that will likely attenuate arsenic and iron, the simulated exceedances of compliance criteria that are unlikely to eventuate have also been identified in Table 20. Monitoring is recommended for all bracketed parameters listed in Table 20 to confirm the expected conservatism of the model. Mitigation should be considered with respect to the parameters in Table 20 that are not bracketed due to the greater potential for exceedances at proposed surface water compliance monitoring locations.

The primary water quality issue identified with respect to the MGP is the need to manage sulphate concentrations in receiving surface water bodies. As sulphate is conservatively transported in water, it does not become naturally attenuated except through dilution. Sulphate concentrations at all of the proposed compliance monitoring sites, except the site on Cranky Jims Creek, are likely to eventually exceed the relevant compliance limits on a seasonal basis. Mitigation measures are therefore considered necessary to ensure water quality on all of the creeks intersecting the MGP site, and in the Shag River, meet the proposed consent compliance criteria.

The monitoring of water quality trends at some compliance points indicate that non-compliance with proposed sulphate criteria is likely to occur within the operational period of the mine unless mitigation measures are instigated. The modelling indicates that significant non-compliance during the operational period of the mine is unlikely to occur in Deepdell Creek, the Shag River and Tipperary Creek provided existing mine water management measures are continued and extended to the TTTSF.

6.5 Catchment Water Availability

Mining operations change topography, groundwater levels and drainage properties within and surrounding the mine site. As such, the MGP operations have the potential to alter surface water and groundwater flow paths and catchments, thereby changing flows in watercourses downstream of the mining operations. Generally, any observed changes in flow (i.e., pre-mining compared with post-mining) would decrease as you move downstream from the mining activity, with the largest effects occurring within or immediately downstream of the mining activities.

The small currently planned changes in catchment areas, when compared to the larger overall catchments, are expected to have no discernable effect on flow rates in either river at the compliance points. Most changes in flow are expected to be very minor and within the generally accepted uncertainty of between 5% and 10% accuracy normally associated with flow measurements.

The exception to this expectation of minor to non-detectable changes would be the flows in the Tipperary catchment. Tipperary Creek is to temporarily lose a considerable fraction of its catchment upstream from the TC01 water quality compliance monitoring site. At present the catchment area upstream from TC01 is approximately 6.0 km^2. Construction and operation of the TTTSF would reduce this catchment by approximately 2.5 km^2, leaving a consequent catchment of approximately 3.5 km^2.

The assessment of flows for Tipperary Creek has been based on flow records from the Golden Point Weir monitoring site on Deepdell Creek. A flow monitoring site was established on Tipperary Creek in May 2010, but the flow record is as yet too short to use for this assessment. From the data recorded to date it is expected that the upper reaches of the creek are ephemeral (Golder 2011a).

The outcomes of the assessment indicate the estimated median flows in Tipperary Creek at TC01 would decrease from about 4.4 L/s under current conditions to about 2.6 L/s during the operational period of the

TTTSF. There is considerable uncertainty with respect to the relative reductions in flows during low flow periods. This uncertainty is partly due to:

- Differences in the flow patterns between Deepdell Creek and Tipperary Creek.
- The effects of evaporation and evapo-transpiration of water from the creek beds.
- The limited number of low flow measurements that have been undertaken in Deepdell Creek and Tipperary Creek.

Following closure and rehabilitation of the TTTSF, it is expected that run-off from the rehabilitated surfaces would again be released to Tipperary Creek, provided the water quality criteria proposed for TC01 are met. At that time effectively the full catchment upstream from TC01 would be re-established and flows in Tipperary Creek should recover to rates similar to those currently being recorded.

Establishment of a water reservoir on Camp Creek in the Deepdell Creek catchment (refer Section 7.0) is not expected to have a substantial effect on flows in Deepdell Creek (Golder 2011f). It is calculated that the filling time for the reservoir, if it is constructed, could be up to 8 years. During this period a small residual flow could be released to Camp Creek for ecological protection purposes. After the dam is filled the ongoing releases of water for base flow augmentation would change the pattern of flows in Deepdell Creek, however the actual downstream availability of water should be very similar to the current situation.

7.0 WATER QUALITY MITIGATION

The effectiveness of a variety of water quality mitigation options has been assessed at screening and initial simulation levels, taking into account the practicality of implementation of these options (Golder 2011f). The results indicate that one mitigation approach is not suitable to resolve all projected water quality issues in the receiving water bodies around the MGP. Water quality in receiving water bodies around the site will need to be managed through the application of a suite of mitigation measures.

The proposed mitigation strategy involves the use of standard adaptive management approaches. The strategy is based on meeting the receiving environment criteria for water quality and not fixing proposed management and mitigation options. This approach sets the receiving environment criteria and assesses compliance projected to be achieved by a range of options but also assesses options against economic and technical feasibility considerations. Following the assessment of options, a range of measures considered appropriate has been adopted for implementation, subject to adaptive management changes following ongoing monitoring, investigation and bench scale studies and testing of treatment technologies.

The most appropriate mitigation measures that may apply to managing the water quality at compliance points on the Shag River, Deepdell Creek and Tipperary Creek during the operational period of the mine are based primarily on returning all captured discharges from TSF and WRS areas to the mine water management system. This is effectively what is occurring at present. The effectiveness of this management scenario has been demonstrated through results from the site environmental monitoring program, where non-compliance events have been minimal. A suite of measures has been identified that is considered appropriate to manage projected water quality issues associated with the Macraes Phase III Project and also the wider Macraes Gold Project. These measures include:

- Ongoing monitoring to confirm outcomes of surface water modelling and water quality assessments.
- Ongoing pumping of TSF discharges to the process water system (this is considered part of operations and is technically not a mitigation measure).

The most appropriate measures identified to date to manage water quality at compliance points on the NBWR and Murphys Creek during mine operations are also based on returning captured discharges from

Frasers West WRS and the proposed Frasers South WRS areas to the mine water management system. These specifically include:

- Ongoing monitoring to confirm outcomes of surface water modelling and water quality assessments.
- Construction of drains to intercept shallow groundwater down-gradient from the Frasers West WRS in the NBWR catchment and pumping the collected water back to the mine water management system, and
- Construction of a drain to intercept shallow groundwater around the southern side of the proposed Frasers South WRS and pumping the collected water back to the mine water management system.

A suite of measures has been identified that is considered appropriate to manage projected water quality issues associated with the Macraes Phase III Project and also the wider Macraes Gold Project following closure of the site. These measures include:

- Pumping of TSF discharges to Frasers Pit for up to 20 years following closure of each facility to allow discharge flow rates to decrease to the point where other passive mitigation measures (specified below) could be instigated. Once effective passive mitigation measures have been instigated, pumping of TSF discharges to Frasers Pit would cease.
- Installation of an aerobic passive treatment system in or close to Maori Tommy Gully to remove up to 90% of the arsenic and iron from the MTI drainage water.
- Removal of Maori Tommy Gully silt dam.
- Construction of a fresh water dam on Camp Creek to provide a base flow to Deepdell Creek to manage and effectively mitigate sulphate concentrations in Deepdell Creek and in the Shag River as far as the confluence with McCormicks Creek. If necessary, seasonal or flow matched discharges of water may be provided from the proposed Camp Creek dam to effectively mitigate the sulphate concentrations in the Shag River. The actual discharge regime needed to effectively mitigate for the MGP discharges should be determined on an adaptive management basis once monitoring improves our understanding of what concentrations of contaminants and discharge flows from the TSF's eventually need to be managed.
- Passive injection of drainage water from the TTTSF to the Frasers underground mine. This measure would enable compliance with water quality criteria in Tipperary Creek and assist in compliance with the criteria applicable on the Shag River at McCormicks on a long term basis.
- Continued operation of interception drains for shallow groundwater down-gradient from the Frasers West WRS in the NBWR catchment with discharges to Frasers Pit, and
- Continued operation of an interception drain around the southern side of the proposed Frasers South WRS with discharge to the existing backfill in the southern end of Frasers Pit.
- If management or mitigation of iron, arsenic and cyanide$_{\mathrm{WAD}}$ concentrations in the Frasers Pit lake is required, this could be achieved through the construction of aerobic passive treatment systems to remove arsenic, iron and cyanide$_{\mathrm{WAD}}$ from water pumped to this lake or injected into the underground workings. The same measure could potentially be applied to manage seepage discharges to the Round Hill pit lake. Although this measure is not necessary to enable compliance with water quality criteria downstream from the MGP, it would lead to improvement in the water quality in the pit lake over the short to medium terms.

Mine water models incorporating simulations of these individual mitigation measures have been carried out and the outcomes documented (Golder 2011f). The outcomes of these simulations indicate that application of these mitigation measures listed above should enable OceanaGold to continue to operate the MGP through to the end of mine life and in the post-closure phase within the proposed compliance criteria.

The permanent injection of TTTSF drain discharge water to the Frasers Underground mine is expected to result in an increase in the long term concentrations of sulphate in the Frasers Pit lake. If this mitigation measure was not implemented it could be expected that the concentrations of sulphate in the pit lake would over time decrease to below the ANZECC stock drinking water guideline. Ongoing injection of the TTTSF drain discharges to the underground mine, is likely to result in the sulphate concentrations in the pit lake not meeting the ANZECC guideline. The water quality outcomes of modelled mitigation options are reported as the 99th percentile concentration rather than the maximum projected concentration (Golder 2011f). Use of the 99th percentile does not imply the water quality is likely to exceed compliance limits 1% of the time. The 99th percentile is considered an “effectively mitigated” outcome for the simulations, taking into account model and sampling limitations. On this basis, occasional simulated exceedances of the sulphate compliance limits in the Shag River in the post-closure phase are considered to be unrealistic as both the groundwater and surface water models incorporate a range of conservative assumptions including the incorporation of high percentile contaminant concentrations as model input concentrations.

The proposed approach to water quality effects management is one scenario which is considered likely to be effective and therefore provide confidence to project stakeholders. A water management plan for Macraes Phase III would involve ongoing monitoring at critical monitoring and compliance points, which will be used to confirm projected trends in water chemistry including the expected model conservatism. During design of the post-closure water management plan, further consideration and refinement of the measures proposed is expected to be undertaken.

This combination of mitigation measures is not the only combination of measures identified that would enable long term compliance with the proposed water quality limits. It would be possible to use other combinations of measures to meet the proposed downstream water quality compliance criteria. Golder therefore recommends that any consent conditions should only relate to the required water quality outcomes rather than the methods by which they are to be achieved.

Further mitigation measures have been identified that hold promise for improving the quality of drainage discharges from TSF’s at the site during the operational period of the mine. These measures include:

- Improvement of process water quality through changes instigated at the process plant to capture and separate contaminants.
- Purging the SPI and MTI tailings with clean water obtained from a clean water dam constructed in the Deepdell Creek catchment during the rehabilitation process.
- Periodic discharge of TSF drainage water during high flow periods in Deepdell Creek.

These scenarios have not been fully investigated at this stage and have therefore not been incorporated in the currently proposed suite of water quality mitigation measures.

8.0 PROPOSED MONITORING

8.1 Groundwater

It is expected that monitoring wells will be required to be installed around the TTTSF for groundwater sampling purposes. As is the practice elsewhere at the MGP, detection wells may be installed to enable monitoring expected contaminant plumes sourced from the TTTSF, evaluation of contaminant attenuation rates and confirm expectations of contaminant mass loads to receiving waters. Compliance wells may be installed close to the receiving water bodies to confirm that contaminant losses to creeks are within acceptable limits.

In terms of the primary contaminant discharge routes it is expected that detection wells would be installed in Tipperary Creek upstream from the proposed Tipperary Sump. The sump is expected to be the collection point for groundwater discharges to the main Tipperary Creek channel and possibly the discharge flows from the TTTSF drainage systems. Compliance wells are proposed to be installed downstream from the Tipperary Sump to verify that contaminant losses from the TTTSF are mainly discharging to the valley upstream from the sump and can thereby be collected.

Detection and compliance wells may also be installed down-gradient from the TTTSF embankment where it overlooks the western tributary of Tipperary Creek and Cranky Jims Creek. These wells would be used to verify the nature of the contaminant plumes in each of these directions. In the case of Cranky Jims Creek, detection wells should also be installed in the highly fractures zones of the Macraes Fault Zone to enable monitoring of any seepage losses along this structural feature.

Monitoring of groundwater pressures along the catchment divide between the Tipperary and Deepdell Creeks may be undertake to monitor the position of the hydraulic catchment divide during and immediately following the operational period of the TTTSF. This monitoring would provide data to verify that contaminants from the TTTSF are not transported in the direction of Deepdell Creek.

Monitoring wells may be installed down-gradient from the Back Road WRS to confirm contaminant attenuation rates in this area. It is not considered necessary to install compliance wells in this area.

Water quality criteria suitable for compliance monitoring in groundwater are summarised in Section 4.4.2. It is not considered necessary to add to or change this standard set of parameters for groundwater compliance monitoring purposes for the Macraes Phase III Project.

8.2 Surface Water

Surface water compliance monitoring at the MGP site is currently undertaken on a monthly basis. It is proposed that this monitoring frequency is continued and applied at new proposed monitoring locations. Proposed changes to the surface water compliance monitoring locations have been summarised in Section 4.4.1, together with the reasons for the changes. The proposed surface water compliance monitoring locations for the MGP are presented in Figure 11.

9.0 CONCLUSIONS

The extension of OceanaGold's MGP which includes new and expanded pits and WRS's, a new TSF, and the development of two pit lakes at closure, has been assessed by Golder in terms of overall mine water management and the potential for effects on the long term water quality in area surface water bodies.

Surface water modelling was undertaken to simulate the mine water management system and the characteristics of the receiving water environment. The modelling included projections of water quality in surface water bodies downstream from the MGP and projections of water level and water quality for the development of pit lakes at the site. An assessment of the effects of the MGP on future availability of water to downstream users was also undertaken.

The surface water model inputs were supported by a series of assessments including hydrogeological modelling, geochemical assessments, water quality trend analyses, hydrological monitoring and assessments.

Results indicate that the primary water quality issue identified with respect to the MGP is the need to manage sulphate concentrations in receiving surface water bodies. As sulphate is conservatively transported in water, it does not become naturally attenuated except through dilution. Sulphate concentrations at all of the proposed compliance monitoring sites, except the site on Cranky Jims Creek, are likely to eventually exceed the relevant compliance limits on a seasonal basis. Mitigation measures are therefore considered necessary to ensure water quality on all of the creeks intersecting the MGP site, and in the Shag River, meet the proposed consent compliance criteria.

Figure 11: Proposed surface water compliance sites.

Due to the conservatism of the mine water management model, the projected compliance exceedances for arsenic and cyanide$_{WAD}$ are unlikely to occur. Both are subject to geochemical reactions, precipitation, adsorption or breakdown in the natural environment. This attenuation has not been incorporated in the surface water model. Dissolved iron is also unlikely to present an issue at the compliance points, due to its capacity to rapidly oxidise and subsequently precipitate. Mitigation measures may however be required to minimise any possible issues of iron flocculants and discolouration of stream beds close to the TSF's.

Following initial poor water quality in the pit lakes, the assessment has concluded dilution which occurs as pit lake levels rise from rainfall gradually improves lake water quality to within the compliance limits applicable at Deepdell Creek for sulphate and dissolved metals. Golder understands there is to be no unauthorised access to the pits following closure of the mine. On that basis, the only potential for unmanaged water losses from the pit lakes is through the historical underground workings at the northern end of Golden Point Pit. Golder understands these workings are to be sealed to minimise the risk of excessive seepage losses through these workings.

Mitigation measures to address issues with sulphate and to also reduce concentrations of arsenic and other non-conservatively transported parameters are proposed to be applied during operational and post-closure stages. A suite of mitigation measures has been identified which can be practically adapted to site management during the mine life and to the relatively inactive post-closure conditions. These mitigation measures, applied at appropriate times depending on the mine stage, include:

- Ongoing monitoring to confirm model projections and assess effects.
- Ongoing pumping of TSF discharges to the process water system during the operational period of the mine.
- Construction of interception drains for shallow groundwater down-gradient from the Frasers West WRS in the NBWR catchment and pumping the collected water back to the mine water management system.
- Construction of an interception drain around the southern side of the proposed Frasers South WRS and pumping the collected water back to the mine water management system.
- Pumping of TSF discharges to Frasers Pit following cessation of mine operations for up to 20 years following closure of each facility to allow discharge flow rates to decrease to the point where other passive mitigation measures (specified below) could be instigated.
- Construction of a fresh water dam on Camp Creek to provide a base flow to Deepdell Creek to manage and effectively mitigate sulphate concentrations in Deepdell Creek and in the Shag River as far as the confluence with McCormicks Creek. If necessary, seasonal or flow matched discharges of water may be provided from the proposed Camp Creek dam to effectively mitigate the sulphate concentrations in the Shag River. The actual discharge regime needed to effectively mitigate for the MGP discharges should be determined on an adaptive management basis once monitoring improves our understanding of what concentrations of contaminants and discharge flows from the TSF's eventually need to be managed.
- Installation of an aerobic passive treatment system in or close to Maori Tommy Gully to remove up to 90% of the arsenic and iron from the MTI drainage water during post closure stage.
- Removal of Maori Tommy Gully silt dam.
- Passive injection of drainage water from the TTTSF to the Frasers underground mine. This measure would enable compliance with water quality criteria in Tipperary Creek and assist in compliance with the criteria applicable on the Shag River at McCormicks on a long term basis.
- Construction of passive water aeration systems and aerobic wetlands to reduce the concentrations of iron and arsenic in TSF water to be discharged to Frasers Pit or Round Hill Pit. Although this measure

is not strictly necessary to enable compliance with water quality criteria downstream from the MGP, it would lead to improvement in the water quality in the pit lakes over the short to medium terms.

Mining operations change topography, groundwater levels and drainage properties within and surrounding the mine site. As such, the MGP operations have the potential to alter surface water and groundwater flow paths and catchments, thereby changing flows in watercourses downstream of the mining operations. In general, the currently planned changes in catchment areas are small, when compared to the larger overall catchments and are expected to have no discernable effect on flow rates in either river (i.e. Shag and NBWR) at the compliance points. Most changes in flow are expected to be very minor and within the generally accepted uncertainty of between 5% and 10% accuracy normally associated with flow measurements.

The exception includes the time limited effects to the Tipperary Creek flows which are anticipated to occur during operations periods due to construction of the TTTSF, Rehabilitated surfaces on the TTTSF at closure should provide catchment to return flows to those similar to current conditions.

Establishment of a water reservoir on Camp Creek in the Deepdell Creek catchment is not expected to have a substantial effect on flows in Deepdell Creek. During the dam filling period a small residual flow could be released to Camp Creek for ecological protection purposes. After the dam is filled the ongoing releases of water at approximately 10 L/s for base flow augmentation would change the pattern of flows in Deepdell Creek, however the actual downstream availability of water should be very similar to the current situation.

Water management for the Macraes Phase III project can be undertaken to minimise and mitigate for projected contaminant losses and hydrological effects associated with the proposed expansion elements.

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Report Signature Page

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APPENDIX A

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APPENDIX B

Macraes Gold Project climate summary

APPENDIX C

Natural watercourse hydrological data

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