Strata Geoscience

Macraes Mine Phase 4 Fast Track Application

A step-change in water management

Frasers Tailings Storage – Macraes Mine, Feb 2026

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1 Introduction

Macraes Mine, New Zealands largest mine, seeks to gain consent for its next phase of operations. This involves extensions to all current operational areas including mine pits, waste rock stacks, tailings storage facilities and under ground operations. Strata Geoscience Ltd has completed project management and peer review of water management consultancy work to support the Macraes Mine Phase 4 Fast Track Application (MP4FTA).

Several disciplines and expert teams are involved in this work programme;

- Aquatic ecology, led by Viridis Ltd. The scope of work for aqutic ecology is to deliver a first principles assessment of environmental values around the Macraes Mine and an appropriate standardised compliance regime.
- Geochemistry, led by Mine Waste Management Ltd. The scope of work for geochemistry is to complete geochemical hazards assessment for the parts of the mine, deliver waste rock seepage quality assessments and complete projections of pit water chemistry during filling and spilling.
- Water treatment studies completed by Process Flow Ltd. The scope of work related to water treatment was to identify best options for water treatment of Macraes water (waste rock and tailings seepage) to deliver water quality better than compliance criteria.
- Surface and groundwater modelling by GHD Ltd. The scope of this work was to build a surface and groundwater model incorporating as much data as is available from site to provide prediction of surface water impacts downstream of the mine should MP4 proceed including infrastructure investments.
- Groundwater and Geotech support by WGA Ltd. The scope of work for this included identification of storage options for brine should a reverse osmosis plant be constructed, and provide information of capping of waste rock stacks.

This report does not provide a complete summary of all work completed within these scopes of work. The reports that support MP4FTA water management are well written and details should be relatively easy to find as required. Instead, this report presents an overview of the approach taken and where the results of this work have led. As this work programme commenced, it was not clear exactly what the outcomes would be for the aquatic ecological assessment, what the impacts of MP4 activities would have on downstream water quality, or what water management options might be required to deliver acceptable downstream water quality.

The outcome for MP4FTA workstream is that aquatic ecosystem values should be protected to a 95% species protection level through a compliance regime that utilises trigger values set to protect chronic toxicity. This system supports management intervention to deliver improved water quality where trigger values are exceeded before non-compliance occurs. It includes trigger value concentrations up to about an order of magnitude lower than previous compliance concentrations for Macraes Mine criteria and additional water quality parameters to be tested related to compliance. With the proposed system, Macraes Mine will invest in three major water management infrastructure improvements for the site, water treatment, improved seepage capture and augmentation dams. This infrastructure provide scope for improved active management of water quality downstream of the mine site.

A surface and ground water assessment has been completed that delivers a probabilistic model including climate, climate change, surface hydrology and groundwater hydrogeology in a manner that is faithful to measured data and relatively objective. The model includes the water management infrastructure related to active management of mine water quality. There are some aspects where data is not available with respect to surface water quality that require assumptions to be made in the model and these have been made in a conservative manner. In addition, the model incorporates site specific geochemical studies throughout the mine site to deliver seepage quality and pit lake water quality so that the impact of the additional mining activity on water quality can be assessed. The geochemical dataset used for short term (operational and closure phase work) is adequate and objective, however the dataset for long term planning is conservative in the absence of data that enable prediction of changes in mine site geochemistry over time.

2 Methods

This environmental geochemistry review was completed through management of water quality consultant workstreams and by desktop review of documents at draft stage and on completion. Several site visits to the mine were completed for familiarisation with the site and to collect additional data from databases or reports. No geochemical studies, interpretations or additional samples were collected by Strata Geoscience.

All technical work that was completed within the scope of this review was completed by five service providers

- Viridis Ltd
- Mine Waste Management Ltd
- GHD Ltd
- Process Flow Ltd
- WGA Ltd

There are two primary objectives for this work:

1. To provide an independent review of how the aquatic environment should be protected downstream of the mine. Consultants were asked to build a compliance regime from first principles and provide updated assessment methods and concentrations limits for environmental protection downstream of the Macraes Mine.

2. To identify surface water collection, treatment and management systems for the site that will achieve protection of the downstream aquatic environment and represent this in a probabilistic model. The probabilistic model must accurately represent natural environmental conditions and inputs as well as mine related impacts on surface water chemistry so that an assessment of whether the proposed operation can operate within the environmental protection regime can be made. This requires several secondary workstreams including:
    - Completion of geochemical testing, interpretation and modelling to quantify the dissolved components that will be mobilised by mining operations.
    - Development of a mass balanced framework for water at the mine site including all inputs from climate and natural catchments, sources of dissolved components and sinks or discharge point for dissolved components.
    - Identification and testing (chemical and desktop) of water treatment processes to removed dissolved components from mine influenced water.
    - Development of a groundwater model for the site and understanding the interactions between groundwater and surface water, especially with respect to filling of mine voids (open pits or underground workings) with surface water or residues from water treatment.

In addition, once the surface water model has been completed, the outputs of the model can be assessed in the manner of an assessment of environmental effects.

2.1 Report Structure

This report is a synthesis report demonstrating the step-change in water compliance systems at the Macreas Mine for the MP4FTA. The step-change has two primary components and these will be used as the structure of the report.

1. To identify and propose compliance criteria that are suitable for protection of aquatic ecosystems downstream of Macraes Mine for the next mining period and continuing into the future.

2. To identify the changes that are required at site to deliver acceptable performance with respect to the proposed compliance regime and provide a realistic water balance model reflecting the site should MP4 proceed.

This report does not summarise all datasets used to deliver the model. There are significant geochemical and water treatment work programmes that have been completed to provide certainty and information for the water balance model. The reports provided along with MP4FTA are well written and provide summaries of the information underpinning assumptions in the model and used to build the model. In general, the mathematical relationships within the model are well constructed and the measured datasets used to support the model are adequate.

There are some areas where data are not currently available, and so conservative assumptions are used to enable the model to function. This report will highlight where conservative assumptions have been made and will identify links between some of the varied datasets that have been collected and how they are applied in the model.

2.2 Limitations

Strata Geoscience Ltd provides expert geochemical consultancy service and completes expert level consultancy on natural surface water environments and mine impacts on surface water environments. The scope of work covered in this document also includes aquatic ecology, hydrogeology and chemical water treatment. Strata Geoscience has sufficient expertise and understanding of these disciplines to complete project management and technical review of these workstreams. Additional technical review of aquatic ecology, hydrogeology and chemical water treatment has been completed by OGL staff and contractors.

This peer review report assumes that analysis information are represented accurately in reports contributing to the MP4FTA. No systematic audit of laboratory reports compared to data used in reports has been completed. Where there has been a reason to check laboratory data in appendices throughout the review, no inconsistencies between report content and appendices have been identified.

Values reflecting geochemical data in tables in the reports have had a cursory review and calculations supporting derived values have not been systematically checked. However, the geochemistry of Macraes Mine wastes are relatively well understood and have been the subject of reports, conference papers and peer reviewed publications. Strata Geoscience is familiar with the literature that is publicly available and has completed occasional work on the Macraes site over the last 15 years. It is likely that major errors or omissions would have been detected during the work programme completed by Strata Geoscience.

This document is designed to deliver a plain English summary of reports of technical studies that are completed with a view to ensuring best practice management of water quality risk related to planned operations at Macraes.

In this summary, the approach that has been taken to surface and groundwater modelling for the MP4FTA will be briefly reviewed, explanation of key assumptions and interpretations that have been made within the data will be provided. The modelling process for MP4FTA makes several conservative assumptions where there is insufficient data or information to provide certainty for more realistic interpretations.

3 Proposed Compliance Criteria

3.1 Introduction

Oceana Gold Ltd (New Zealand) Limited selected Viridis Limited (Viridis) to complete a first principles approach to update and standardise compliance criteria for the Macraes Mine site. The key factors that were assessed by Viridis include.

1. An assessment of environmental condition and ecological values of the receiving environments, including natural background conditions, historical mining influences and other land uses within the catchments surrounding the Macreas Mine site. This process was completed to determine the appropriate level of ecological protection to apply for monitoring and compliance downstream of the Macraes Mine operations.
2. Identification of sites where water quality monitoring should take place and water quality parameters that should be included in the compliance regime based on monitoring datasets from the mine and new geochemical datasets for MP4FTA.
3. Assessment of an appropriate compliance regime that considers factors such as:
    - Identification of constituents relevant to mine-related activities that may affect receiving-water quality, including constituents associated with chronic or acute toxicity.
    - A trigger and response process vs single exceedance non compliance process.
        - If appropriate, identify the frequency selected for trigger value exceedance that signifies non-compliance.
    - Appropriateness of modifying factors for trigger values and compliance.
4. Concentration values for trigger limits or compliance limits of dissolved components based on relevant guideline values.
5. Other factors such as
    - Historic mining impacts,
    - Sites where drinking water , stock water or irrigation use of water downstream of the mine might occur,
    - Naturally elevated concentrations through weathering of mineralised areas, and
    - Algal growth.

3.2 Selected regime

The recommended regime (Viridis 2026) delivers changes in the process, number of analytes, and concentrations at which compliance is assessed for the Macraes Mine site compared to the current regime. The key driver of the change for the compliance regime at the Macraes Mine operation is recognition that the aquatic ecosystems surrounding the mine are relatively unimpacted and therefore, the target that the Macraes operation should seek achieve is 95% protection of aquatic ecosystems (Viridis 2026).

The proposed monitoring regime largely uses the monitoring sites that have been established during previous and current compliance monitoring regimes because these sites adequately capture the downstream impact of previous as well as planned operations. The proposed monitoring regime standardises the analytes used for compliance assessment across all monitoring sites, whereas under current consent conditions the number of analytes used for compliance assessment are not uniform at the monitoring sites. Two inorganic components are added to all monitoring sites within the compliance regime, boron and nickel, reflecting assessment of geochemical and monitoring datasets collected for MP4FTA. One nutrient component, soluble inorganic nitrogen (SIN, nitrate, nitrite + ammonia) is added for measurement at all monitoring sites. Several other components that were elevated in geochemical assessments were tested against monitoring data to see if there was justification for inclusion in the monitoring regime at Macreas Mine (Viridis, 2026).

The criteria that define compliance at Macraes Mine have been changed in the proposed monitoring regime and the concentrations at which compliance and non-compliance is determined has decreased for nearly all parameters by up to about an order of magnitude. The are two reasons for these changes;

1. The literature from which guideline values have been selected has been updated and modernised. In general, the current guidelines indicate that ecological impacts occur at lower concentrations than were assumed when previous compliance regimes were established at Macraes Mine.
2. The process of assessing toxicity has changed, previously an acute model of ecosystem toxicity was used to establish compliance and so a single exceedance of a threshold value resulted in non-compliance. The proposed regime uses a chronic model of ecosystem toxicity to establish compliance which means non-compliance is established by multiple exceedances of trigger values in a fixed period of time. Acute toxicity values are retained for Zn and Cu recognising that short duration increases in the concentration of these components should also be considered as non-compliant.
    - The chronic model enables the operator to identify sites where an elevated concentration of a monitored parameter exceeds a relatively low threshold and deploy measures for environmental improvement.
    - Non-compliance under this occurs with more than two exceedances of trigger concentrations in any 12 month rolling period where the increase is attributable to mine activities.

Many of the concentration values in the new chronic toxicity based compliance regime have modifying factors where published literature on the toxicity of particular elements demonstrates that that toxicity varies depending on the concentrations of other dissolved species. Typically, these factors include hardness (dissolved calcium and magnesium), pH, chloride, and dissolved organic carbon. All modelling of surface water exceedance of trigger values and non-compliance is assessed against modified concentrations using modelled concentrations of the modifying factors. The concentrations of modifying factors are derived from source terms in the surface and groundwater model in a similar manner to other components.

There are some exceptions to the criteria that define compliance above. Parts of the catchments downstream of Macraes Mine are used for drinking water and irrigation and monitoring sites in these areas have additional criteria that must be met for compliance. The additional criteria are based on health-related concentration limits and aesthetic concentration limits. Health limits are treated in an acute toxicity manner, so a single exceedance is considered non-compliant whereas aesthetic limits are treated as trigger values similarly to those described above.

In addition to toxicity through elevated concentration of dissolved components, periphyton growth leading to eutrophication is recognised as a risk downstream of the mine site. A separate compliance regime based on the concentration of soluble inorganic nitrogen (SIN) species (nitrate, nitrite and ammonia) is used to trigger assessment of periphyton that might cause or increase the risk of eutrophication. These assessments could lead directly to management actions, for example, if the stream has recently had some natural high flow events, it is likely that periphyton build up will be minimal. However, if the stream is in a period of prolonged low flow, periphyton could be abundant and a flushing flow of water through the catchment could be deployed to prevent eutrophication.

3.3 Summary – a Step Change in monitoring

Adoption of a first principles to setting new conditions for Macraes Mine operations during MP4 is the key driver of Step Change at the mine. Delivering compliance with the new regime drives significant investment in improved water management infrastructure and significant changes in data collection to ensure that the improved infrastructure deliver maximum environmental benefit.

Overall, the proposed compliance regime is a large change for the Macraes Mine site aimed at replacement of outdated compliance practices and adoption of standardised new best practice approaches. The proposed new regime delivers improved environmental protection downstream of the mine as well as protection for other water users in the catchment. Significant factors include:

1. An increased number of compliance related parameters.
2. Significantly lower concentrations for most compliance related components compared to previous compliance limits.
3. The introduction of trigger values with compliance assessed on a frequency of exceedance basis for most parameters rather than single exceedance non-compliance. This provides incentive for improved performance monitoring at the site and opportunities for management intervention to deliver environmental benefit before compliance issues occur.
4. Overlay of ecological protection limits with health-related drinking water concentration limits applied assessed on a single exceedance non-compliance basis to protect users downstream of the mine.

4 Surface and ground water modelling

4.1 Introduction

4.1.1 Modelling processes

Surface and groundwater models are a common feature of mining related resource developments. They are completed during consenting to deliver predictions of future conditions throughout proposed operations, rehabilitation, decommissioning and into closure. Models developed for this purpose can often also be used during operations to run water management scenarios for mixing, treatment or distribution of different water types. Typically to complete these kind of models, different types of modelling packages are used with inputs and outputs going back and forth between software platforms to deliver user defined outputs.

Modelling requires that a conceptual framework is developed by expert scientists and engineers to represent real environmental conditions and the proposed mine infrastructure. The model is a simplification of the real environmental conditions and relies on four types of inputs or information:

1. Measured data.
   a. There are many types of measured data including but not limited to, rainfall, evaporation, concentrations, flows, permeability and more.
2. Mathematical functions representing natural and anthropogenic processes.
   a. There are many types of mathematical functions used to represent processes such as mixing, dilution, flow rates, exchange between surface and groundwater, removal of components through water treatment and others.
3. Statistical relationships to project or predict trends in the absence of data
   a. Statistical trend data are used for diverse purposes to arrive at appropriate representations of the real world including but not limited to, climate variability, climate change, geochemical means/medina values, geochemical trends, permeability, probabilistic data distributions to represent variability modelling inputs or outcomes.
4. Interpretations and assumptions made by experts
   a. Where data, mathematical functions or statistical relationships cannot be obtained or developed, experts make interpretations or assumptions. Often these relate to trends with time, or adoption of values to appropriately represent a data distribution, or simplification of complex processes such as vadose zone hydrogeology to averaged values such as net percolation. Interpretations and assumptions have the potential to make models conservative or optimistic and should be tested and refined as real-world datasets are collected.

Once developed, models should be calibrated against measured data or continually tested and refined as new data is collected. However, the model remains an approximation of a complex real-world environment and the application or interpretation of modelled outputs must be made with care.

4.1.2 Modelling for Macraes MP4FTA

The MP4FTA surface and groundwater assessment develops a probabilistic model for the Macraes Mine site that incorporates climate, natural catchment hydrology, hydrogeology, site specific geochemical conditions as well as mining activities and infrastructure. The climate information, natural catchment hydrology and hydrogeology datasets are reflected in the surface and groundwater assessment model in an objective manner. The interpretation of geochemical data is completed in a manner that adequately reflects the measured data and is extrapolated in a consistent manner to MP4 changes. In the absence of data, conservative geochemical assumptions are made. The mine infrastructure changes that have been made for MP4 are integrated into the model, and treated in a stochastic manner, however this infrastructure creates many active management opportunities.

The model includes nodes that represent downstream water quality compliance sites and is iterated through of a range of scenarios representing variability of the mine site and its surroundings to assess the influence of the mine on downstream water quality. In this manner, the likelihood of the mine site operating within the new compliance regime can be assessed.

There are two fundamental aspects to this kind of model;

1. Mass balance of water. All water in the system is accounted for through either liquid surface water flow, evaporation, evapotranspiration, storage in pits, ponds or aquifers, quantified losses, groundwater and discharge.
2. The chemistry of the water is quantified and mass balanced. Within the surface and groundwater model, dilution, mixing, separation or evaporative concentration can readily be calculated. Geochemical processes that influence water quality such as weathering, dissolution, adsorption and precipitation are completed outside of the surface and groundwater. Numerical representations of these processes can be added to the model if required.

The software that has been selected includes

1. Groundwater modelling was completed using a block modelling and MODFLOW code (GHD, 2026).
2. Surface Water modelling was completed using a probabalistic modelling package Goldsim (GHD, 2026).
3. Geochemical modelling is completed in PhreeqC, sometimes with python scripted processes to enable multiple runs or iterations and in spreadsheets (MWM, 2026).

4.2 Mine Infrastructure

4.2.1 Current infrastructure for water management

The current Macraes Mine infrastructure includes several types of water management infrastructure

1. Silt ponds and drains for sediment control.
2. Sumps to provide capture points for seepage from tailings and waste rock stacks.
3. Pump back systems from some of these points to recirculate mine influenced water into the mine water management system.
4. Water management infrastructure to enable dewatering of pits and underground operations
5. Process water circuit including TSF.
6. Top up water conveyance and storage from the Taieri River.

Tailings underdrainage seepage is all managed through pump systems and returned to the process water circuit form Top Tipperary, Mixed Tails and Southern Pit Impoundment. Waste rock seepage water pump back is available from three seepage collection points.

1. Northern Gully silt pond,
2. Murphys silt pond, and
3. Sump B/Maori Tommy silt pond.

The current infrastructure for pump back of waste rock stack seepage water is generally applied to relatively dry site conditions where the seepage might make up a more significant proportion of stream water flows compared to relatively wet conditions.

4.2.2 MP4FTA infrastructure

The step change in compliance regime drives a parallel step change in water management infrastructure to deliver improved water quality to the downstream environment. Key elements of this improved infrastructure include a water treatment plant, diffuse seepage capture drains and improved point source capture, as well as flow augmentation dams. Each of these infrastructure features provides opportunity to actively manage seepage or clean water on the site to deliver improved environmental outcomes downstream.

<u>Water treatment plant</u>

The step change in the downstream water compliance regime requires that dissolved components are removed from discharges and retained at the mine site. Water treatment is the only way this can be accomplished. Several water treatment processes have been investigated and a base case system has been selected for incorporation into the Surface and Groundwater Assessment (GHD, 2026) model.

The water treatment process is separated into two phases of treatment, a pretreatment process that removes arsenic and other trace elements and a main treatment phase which targets removal of sulphate (Process Flow, 2026) which is one of the key components downstream that might exceed trigger values.

For the main treatment phase, either reverse osmosis (RO) or ettringite precipitation provide acceptable treated water quality with respect to sulphate, and other components. Reverse osmosis was assessed through a desktop study of Macraes specific water quality by an established supplier of

RO systems. The ettringite precipitation process was assessed by benchtop testing completed through Process Flow Ltd.

Options for the pretreatment phase include either lime addition or ferric chloride dosing. The lime dosing method has been tested by benchtop testing (Process Flow 2026) and the ferric chloride dosing method has not been investigated at this stage by water engineers. However, OGL has experience with water treatment by ferric chloride dosing into the Globe Progress Mine pit lake at their Reefton site and have summarised the effectiveness of this work (MWM 2026).

The base case model that is incorporated into the surface and groundwater assessment includes lime dosing pretreatment followed by reverse osmosis main treatment system. This leads to a brine waste stream that will be managed on site through deposition into disused underground working (WGS 2026).

Based on the water treatment work completed, either combination of pretreatment and main treatment methods will deliver acceptable water quality with concentrations of key components low enough to dilute surface waters relative to trigger values (Viridis, 2026). Water treatment delivers a decrease of dissolved components exported from the mine site to the downstream environment, and also provides clean water that can dilute fugitive seepage that remains uncaptured. Water treatment methodologies will have additional study with final selection of the full-scale plant to be made after additional investigations and pilot trials have been completed.

Diffuse seepage capture drains and improved point source capture

A plan to install seepage capture drains at the toe of waste rock stacks has been developed based on the knowledge of seepage pathways and performance monitoring data collected between the mine footprint and current compliance sites. The plan includes emplacement of trenches at the toe of waste rock stacks with sumps and pumps installed in natural low areas to retrieve seepage water that would otherwise report to streams. Currently all diffuse seepage water is fugitive from site and it discharges into small streams upstream of compliance points. Key areas where these drains will be emplaced are around the Frasers West and Coronation North waste rock stacks. Seepage collected in the sumps will be pumped to water treatment or maintained in the mine water management system until the water treatment plant is functional.

In addition, to the diffuse source capture infrastructure, improved point source capture and pump systems will be installed at point source seepage discharges. This will include seepage sites at Golden Bar and Coronation, Coronation North and Trimbles areas as well as improvements at additional sites in the Central part of the mine. The engineering works that are required for interception of diffuse seepage and improved collection of point sources are compatible with installation of toe bund infrastructure that will diminish oxygen ingress into the current waste rock stacks and assist with water management. Where appropriate this infrastructure will be installed to improve long term outcomes for the mine site with respect to oxidation of sulphide minerals in waste rock stacks.

All captured seepage will be treated and returned to the environment with a final water quality having concentration levels that provide diluent for downstream environments compared to trigger levels. The commitment to develop and build seepage capture infrastructure is another significant step change for the Macraes Mine site.

With the base case model, seepage capture is currently modelled probabilistically and there is a synchronised process of seepage return to catchments with treatment residues (brine) removed. The modelled water quality for treated water that is returned matches treated water quality concentrations and removal rates (Process Flow, 2026).

<u>Flow Augmentation Dams</u>

Currently two sites are proposed for large dams to enable flow augmentation to:

- supplement flow in Deepdell Creek if there is flow loss caused by mining related de-watering,
- supplement low flow periods when un captured seepage might make up a larger proportion flow, and
- provide fresher flows for management of periphyton.

These dams have been proposed and consented previously and will be constructed during MP4. The wildlife clearance, construction and filling of these structures is expected to take about 4-6 years depending on influent flows.

In the base case model, the discharge regime for these dams is linked to flow data in the receiving environments. When flows in the receiving environment decrease to values that are assessed to be minimum values for ecological health, the augmentation dams automatically discharge within their consented flow parameters. Under this scenario, the Camp Creek Dam is able to deliver adequate water volumes throughout all modelled conditions and the Coal Creek Dam is able to deliver sufficient apart from in exceptionally dry circumstances.

The current model is probabilistic with respect to augmentation dam operations and there are many unmodelled scenarios for pro-active management of the augmentation dam infrastructure that could see more efficient use of water. There are additional un-modelled options to use these Dams (and other water storage infrastructure on site) to store excess treated water. If this water is stored on site, additional management options are available to site operators with respect to discharge of treated water on site to dilute seepage that remains uncaptured.

4.3 Selected datasets that support surface and ground water assessment

4.3.1 Rock Geochemistry

A baseline geochemical dataset has been collected for the MP4FTA to test if the rocks that will be mined during MP4 will have similar geochemical characteristics to those that have been mined in previously. This involves collection of samples from drill core for geochemical test work that identifies if the rock is acid forming or acid neutralising and leach tests that are used to identify dissolved components that might mobilised by water if mining proceeds. The approaches taken for this assessment sit within a framework of internationally recognised test methods, sample densities and interpretation processes.

Key outcomes from this dataset are that

1. Rock that is mined during MP4 is similar to those previously mined and therefore the waste rock and tailings that will be generated by MP4 are similar to those previously generated. Seepages from wastes can be expected to be consistent with previous data and interpretations.
2. Acid mine drainage (AMD) will not occur, however neutral and metalliferous drainage (NMD) will occur. Nitrogen species will be present from leaching of explosives residue.
3. Dissolved components that are enriched in the leachate from geo-environmental testing have been checked against historical multi element site water monitoring analysis and have been incorporated into the compliance regime where appropriate (Viridis, 2026).

In general, the geology of the Macraes deposit is relatively uniform and the environmental geochemistry of the rock is also relatively uniform. The data compiled for rock geochemistry are appropriate and are interpreted objectively, they demonstrate relatively unchanged geochemical conditions on the mine site during MP4.

4.3.2 Geochemical data for waste rock seepages

Statistical relationships have been developed that describe the concentrations of dissolved components in mine influenced water from waste rock stacks (WRS). These relationships recognise that the average height of the WRS is a primary driver of the concentrations of dissolved components in waste rock seepage. Sulphate concentration and seepage chemistry is used as the primary indicator of geochemical processes that take place within the waste rock dump and when combined with waste rock geochemistry, a conceptual model of processes that take place in waste rock stacks at Macraes Mine can be developed.

- The weathering processes in WRS take place in a relatively oxic environment.
- Oxygen is available to oxidise sulphide minerals and the high acid neutralising capacity of the schist prevents formation of acid.
- Iron that is released during sulphide oxidation mostly precipitates as ferrihydrite (or a similar mineral) within the WRS and adsorbs much of the arsenic that is abundant in the sulphide minerals at the Macraes deposit and possibly other trace elements.
- This process delivers a sulphate rich and relatively trace element poor WRS seepage.
- Nitrate and other N-species in waste rock primarily come from explosive residue and will flush through the waste material unlike other components that come from weathering.

These interpretations are made based on waste rock geochemistry and seepage geochemistry data and adequately explain most aspects of current seepage water quality, although there is some variation in trace element geochemistry in seepages that are not fully explained by current geochemical WRS conceptual model (above).

In general, this model explains much of the current situation, however, it is not useful in a predictive sense for how seepage will evolve with time. There is potential for the oxidation processes to have developed a large reservoir of soluble to partially soluble salts within the WRSs, in which case, implementation of improved waste rock management practice will have a lag period before it becomes effective to improve seepage quality of pre-existing WRSs. It is also possible that the WRS are continually flushed with respect to soluble and partially soluble salts in which case improved WRS management will have a relatively immediate positive effect on seepage quality.

The current conceptual model for WRS geochemistry is not able to quantify or predict the impact of improved waste rock management on seepage quality for future waste rock stacks. In addition, the current conceptual model is not able to predict the chemical evolution of seepages from the mine site through time and so this leads to conservative interpretations within the surface and groundwater assessment. However, collection of additional datasets to enable these long term predictions has commenced and development of a model for chemical evolution of WRS seepage and the impact of improved management is underway.

Conservatism in waste rock stack seepage

The seepage geochemical signature once established through the statistical relationships related to WRS height maintain this chemistry through time. Currently there is no data at Macraes Mine to enable calculation of decrease in the leaching of mobile components with time and so the conservative position that these seepages will maintain their modelled chemical signature continuously in the long term (~200y) modelling period is made. Although this is unlikely, the rate at which components decline is difficult to estimate and possible rates of decrease could vary through 1-2 orders of magnitude. In addition, there is currently insufficient data to estimate the impact that improved waste rock management will have on seepage water quality. However, at other mine sites improved WRS management delivers measurable decreases in oxygen advection in waste rock and significant improvement in seepage water quality.

4.3.3 Pit Lake Geochemistry

Geochemical models are developed for each pit lake based on the site-specific characteristics for each lake and inputs including but not limited to, WRS seepage, pit wall run off, direct rainfall, overland flows into pits and groundwater inputs/outputs (MWM, 2026). At closure, pit lake filling rates are derived from the surface and groundwater assessment models (GHD, 2026) and chemical signatures and concentrations are assigned for each or the inputs (MWM, 2026).

The evolution of pit lake chemistry through time is developed through a mixing model that represents the relative contributions and concentrations of different inputs. In addition, geochemical modelling is completed to ensure that dissolved components in the pit lake water quality model does not include components that will precipitate and be removed from solution.

The key component that is included in the pit lake filling model that is not included elsewhere in the water quality or the surface and groundwater assessment (GHD 2026) is the pit wall run off geochemistry. The pit wall runoff is based on historic geochemistry data from the filling of the

Golden Bar pit. This pit includes some backfill (now mostly submerged) that would also have contributed components to the pit lake and also includes data from early phases of pit wall run off when it is most likely high concentrations are shed from the pit wall.

Conservatism in pit lake dataset

The pit lake dataset contains embedded conservatism where seepage enters the pit lake either from ex-pit WRS or from in-pit waste rock before it is submerged for reasons outlined above. The concentrations of components in these seepages will decrease with time, but the rate is unknown and so these concentrations are assumed to stay static into the future.

In addition, the pit wall run off data set uses the best available dataset, related to filling of Golden Bar pit. However, this dataset is not perfect because it contains some seepage from waste rock (now mostly submerged) and early flush data from the pit walls. The pit wall run off dataset does not contain sufficient data to calculate decrease with time and so is assumed to be static throughout the modelling period. In reality, concentrations of components derived from pit wall runoff part of the pit lake geochemistry will diminish with time.

4.3.4 Flow data for seepages

Overall, the dataset for seepage flows at Macraes Mine is relatively small, there is data from pump rates at seepage collection points, there are flow measurements made at the time of sample collection for some seeps and there are some continuous monitoring datasets for short periods (several months) at some sites. The seepage flow rate data is a target for improvement at the site during MP4. There is adequate data to demonstrate that the proportion of annual rainfall that reports as seepage can be reduced to a low rate (5-6%) when waste rock stacks are rehabilitated and runoff is encouraged. Active waste rock stacks have a higher proportion of annual rainfall report as seepage (20-30%). These values are used in modelling to predict the seepage rates for different parts and phases of the mine site. Variations in flow rate for different mine seeps with seasonal climate cycles have been measured at some seeps and rainfall driven increase in seepage flows have been measured at some seepage sites. However, there is not sufficient data to provide a predictive model for these seepage flow changes or understand the differences that might occur in such a mode at different seepage locations.

Conservatism in interpretation

The seepage flow variability at the Macraes Mine is represented in the Surface and Groundwater Assessment as a probability distribution ranging between high and low values for waste rock stacks at different stages of completion.

In addition, the flow rates in catchments are stochastic in and derived from mathematical functions for runoff and evapotranspiration processes driven by rainfall variability and climate. In the real world, low seepage rates and low flow rates in the receiving environment are correlated because seepage volumes decrease during dry conditions. However, the details of the relationships between dry conditions and low seepages are not understood well enough to build numerical or statistical relationships.

The probabalisitic Goldsim model randomly assigns seepage flow rates against receiving environment flow rates based on the probability distribution and stochastic data for these components of the model. However, in the real environment, low seepage rates should be somewhat correlated with low environmental flow rates and higher seepage rates should be similarly correlated with high environmental flow rates. This leads to a conservatism in the model where there is an unquantified increase in the chance of high seepage rates coinciding with low environmental flows and increasing the chance of trigger level exceedance in the model compared to the real world.

4.3.5 Fugitive seepage and groundwater seepage chemistry

Waste rock stack seepage that escapes the diffuse capture drains and improved point source capture system is the main source of mining related dissolved components into the downstream environment. Overall, these sources occur in areas where seepage capture infrastructure is not built or where seepage can migrate under the seepage capture drains. The chemistry of this fugitive seepage water is assumed to be the same as waste rock stack seepage that occurs at the toe of the appropriate WRS (MWM 2026).

Groundwater seepages also occur once pit lakes begin to discharge into the surrounding rock mass. The timing of this relates to complex interplay of relative input volumes and elevation with respect to groundwater levels and recharge after mining. In the model, it is assumed that the time taken for seepage to migrate from the open pits to the surface water is zero. Therefore, as soon as a groundwater plume begins to form it is assumed to be discharging to surface water at down gradient locations. The purpose of this in the model is to ensure that late phase models include both discharge from pits as well as seepage because this is the most likely scenario in these phases of operation.

<u>Conservatism in interpretation</u>

Fugitive seepage that travels through shallow groundwater systems has several concentration attenuation mechanisms.

1. Within the shallow groundwater system and soil system, there are abundant iron oxyhydroxide minerals. These minerals are effective sorbents for trace elements and so it might be expected that trace element concentrations partially attenuate before reaching the surface water environment.
2. Within the root zone and shallow soil zone, there are two processes that could attenuate nitrate and other N-species. Microbial processes of nitrification and de-nitrification can lead to removal of dissolved N species as nitrogen gas. In addition, N-species are nutrients and uptake by plants is also likely.
3. If the shallow seepage is reduced (unlikely) then oxidation might lead to precipitation of components such as dissolved Fe and $Fe(OH)_3$

There is sufficient information to know that these attenuation process occur, however currently there is insufficient data to include attenuation processes in the surface and groundwater assessment. It is assumed that all seepage water quality that intersects streams and rivers has the same chemistry as seepage calculated for each waste rock stack. (MWM 2026).

Groundwater plume modelling also employs conservative assumptions in the absence of adequate measured data. Ground water seepage chemistry reflects pit water chemistry modelling, however attenuation of dissolved concentrations can also take place in shallow groundwater environments. The immediate reporting of pit lake plumes to surface water environments is conservative. It is likely that this process will take several years to decades to deliver dissolved components to the surface water environment. In the real world, seepage concentrations are likely to have decreased with time (noting pit lakes take about 50y to fill up). Therefore, immediate reporting of seepage into downstream environments is likely to over-estimate concentrations in the downstream environment compared to the real-world system.

4.4 Modelled water quality results for Macraes MP4FTA

4.4.1 Modelled water quality results for the Surface and Groundwater Assessment

Key results from the Surface and Groundwater Assessment report are

1. Calibration of the model predictions against measured results.
2. Projections of the model through 5 phases of mine activity and a climate change scenario
    - Operations Phase A (commissioning phase for new water management infrastructure – uses current compliance criteria)
    - Operations Phase B (assumes new water management infrastructure is in place – uses proposed compliance criteria)
    - Closure (site rehabilitated and pit lakes filling)
    - Pit overflow (pit lakes spill to the environment as modelled)
    - Long term (long tern steady state)
    - Long term with climate change (long term steady state with inputs adjusted for climate change)

The split of MP4 operations into Phase A, and 7 years later Phase B, is required to provide time for construction and commissioning of the MP4FTA water management infrastructure including the water treatment plant, improved seepage capture systems and the augmentation dams. The critical path item for construction of the MP4 water management infrastructure delivery of functional augmentation dams, where pre-work is estimated to take 1 year, construction 2 years and filling up to 3 years followed by commissioning work.

The surface and groundwater assessment model is calibrated against measured data from 2020-2026. In general, the model reflects the concentrations and range of data relatively well for most parameters at most sites. There is a general trend of slight conservatism in the modelled data with mean values for most modelled parameters slightly higher than measured mean values. For most parameters, the spread of modelled data is similar to measured data. Where differences between the modelled and measured data have been identified an assessment the impact of the difference with respect to compliance has been completed. In general, few of the differences between modelled and measured data have implications for compliance. Overall, the calibration process gives confidence the model adequately reflects the mine site, and differences between the model and measured data point to areas where further sampling and investigation can be completed during Phase A to ensure adequate operational practise is in place for the transition to the new compliance regime in Phase B.

In addition to the calibration, the stochastic model has been iterated in a probabilistic manner within each of the 5 phases of mining and climate change scenario listed above. The potential for non-compliance at each monitoring site has been tested and the results indicate that some sites have potential to be non-compliant. Potential for non-compliance is spread geographically, chemically and through time, different measured parameters are modelled to be non-compliant at different sites in different phases of mine operations. The model demonstrates that the new compliance regime for the site will be challenging to meet, and the sites identified that have modelled non-compliance provide information that the site can use to develop active management responses.

4.4.2 Active Surface water management

The Surface and Groundwater Assessment is based on a model that is completely stochastic, driven by climate and the surface water flow regime that has been established for the mine site and that is embedded within the model. Overall, this is the most logical approach for a base case model, and this model is able to highlight locations where trigger levels could be exceeded and noncompliance could follow if appropriate actions are not completed. However, the additional infrastructure for water management and treatment that Macraes Mine will put in place for MP4 will provide many ways in which improvement can be made above a stochastic base case model.

As improved datasets related to seepage flow and surface water flows are developed, then water management options can also be developed to deliver improved outcomes for the environment. For example, it is possible that with additional monitoring data it can be identified that fugitive seepage reporting to a catchment peaks a few days after a significant rainfall event. With this information a planned release of stored treated water, or augmentation dam fill could be designed to prevent elevated concentrations occurring in the downstream environment.

Overall, the operator is investing significantly in infrastructure and data collection that will provide opportunity to deliver targeted and designed responses to variations in water quality that arise from natural processes such as changes in climate or rainfall, or anthropogenic processes such as changes in operations on site. Flexibility to operate this infrastructure in a manner that delivers compliance and provide options or contingency for unforeseen circumstances is required.

5 Summary – a Step Change in water management

The proposed new compliance regime for MP4FTA represents a step change in processes for the Macraes Mine. First principles assessment of the Macraes Mine environment indicates that aquatic ecosystem management should aim to protect 95% of aquatic ecosystem values and organisms. In practice, this requires a decease in the concentrations for compliance of nearly all monitored parameters by up to about an order of magnitude. In addition to the changes to concentrations used to assess compliance, the process to establish non-compliance has also changed. In place of a single exceedance non-compliance process that has operated in the past, the proposed regime uses trigger values and a number of exceedances within a fixed period of time to determine non-compliance.

The change to trigger levels rather than single exceedance non-compliance provide the operator with an opportunity to put in place management options to prevent trigger exceedances turning into non-compliance events.

The surface and ground water assessment delivers a Goldsim probabilistic model that utilises all available data and calibrates reasonably well against measured data. The model incorporates data on climate, surface hydrology and groundwater hydrogeology in an objective manner and provides projections for 5 mine phases relating to operations, closure and long term projections. The model incorporates all changes in the mine plan related to MP4 and incorporates several major investments in mine water management including; water treatment, diffuse seepage capture and improved point source seepage capture as well as flow augmentation dams. These improvements to water management infrastructure are also evidence of a step-change in water management for the site.

The model is completely stochastic, it is driven by climate variability and mine water management infrastructure and are turned on or off in the model automatically by environmental conditions. This model can be used by the operator to identify the potential for different parts of the downstream catchment to have concentrations of dissolved components that exceed trigger concentrations and the probability that these trigger exceedances might become non-compliances.

The stochastic approach provides a sensible and logical base case for environmental assessment however, it is a source of conservatism with respect to exceedance of trigger concentrations and non-compliance. The infrastructure that will be delivered for MP4 provide many opportunities for active management of downstream water quality, especially when combined with improved data related to seepage quality and flow rate variation that will be collected in MP4. Water that is treated will be returned to catchments to preserve essential flows, or otherwise meet compliance limits. However, this water might also be directed to sites where clean diluting flows are required or stored on site for future use. Overall active management of surface water quality at site through this improved infrastructure, rather than relatively passive management (with partial pump back of some three mine seeps) is also a step-change in approaches to water management at the Macraes Mine.

There are several other sources of conservatism in the surface and groundwater assessment model. Three of the larger conservatisms are:

- There is no attenuation of dissolved components for fugitive seepage water. This has been measured but there is insufficient data to integrate this into modelling.
- High and low seepage flow rates are not correlated with high and low receiving environment flow rates. It is known that low seepage flow correlates with low environmental flow but

there is insufficient data to build a statistical relationship for this, so seepage flow is randomised against environmental flow

- Groundwater plumes from pit lakes (once filled in ~50y) are assumed to immediately discharge to surface water once they form on pit lake filling. In reality, this will take years to decades and unquantified attenuation/depletion processes will occur in these catchments reducing the potential for groundwater discharge to cause exceedance or non-compliance.

In general, geochemical data that are incorporated into the model for the operational and short term phases of operation are relatively objective and adequate for the projections that are made. However, the long term geochemical predictions are conservative for three reasons:

- The chemical evolution of water quality with time is not quantified at the site:
  - Changes in seepage chemistry with time from waste rock is poorly understood. It is likely that depletion of dissolved components will occur, however the rates at which this could occur are highly variable and in the absence of data, depletion has not been included in the model.
  - Pit wall run off chemistry is also assumed to be static and is based on a relatively conservative pit wall chemistry model from filling of the Golden Bar pit.
  - Tailings underdrainage water chemistry is also assumed to be static through time. Data from other sites demonstrate that these seepage values reach a peak concentration for dissolved components and then decrease with time.
- The impact of improved WRS management on seepage water quality has not been incorporated. It is known (based on information from other mine sites) that oxygen exclusion can deliver improved seepage quality, however, this can-not be quantified with the current geochemical dataset that is available.
- The pit wall runoff term that is derived from Golden Bar pit includes seepage from now mostly submerged waste rock as well as early flush data from the Golden Bar pit. This is likely to lead to conservatively high dissolved components in the pit wall runoff term.

In summary, the MP4FTA delivers a step-change water management at New Zealands largest mine. This is motivated by an improved environmental monitoring regime that recognises downstream ecosystem values require 95% ecosystem protection. Compliance with this regime demands significant investment in water management infrastructure including water treatment, improved seepage capture and augmentation dams. The new infrastructure provides many opportunities to manage surface water actively especially when combined with improved data on seepage volumes and chemistry. A stochastic model has been developed that shows locations and times when mine water discharges pose risk of exceedance of compliance conditions. This model is useful for highlighting risk but also has some conservatism build in related to surface water flows and distribution of treated water along with some conservatism built into long term geochemical projections.

6 References

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