KSL
Kōmanawa Solutions Ltd



Barrytown Mineral Sand Operation

Water Management,

Monitoring and Mitigation Plan

REV 2

17/04/2023

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Date	Report no	Issue notes
27/02/2023	Z22004_2 Rev 0	Preliminary draft
10/03/2022	Z22004_2 Rev 1	Draft 1 following feedback
17/04/2023	Z22004_2 Rev 2	Draft 2 following feedback

Limitations

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1. INTRODUCTION

1.1. Background

Tiga Minerals and Metals proposes to develop mineral sand extraction facilities in the Barrytown area of the West Coast region. A preliminary Water Management Plan has been developed to support a resource consent application for the site.

The proposed mineral extraction will comprise an excavator feeding a mineral processing plant. The proposed extraction area covers 41 ha of pastoral farmland between Deverys Creek and Canoe Creek with a maximum excavation depth in the order of 9 m.

Groundwater inflows to the excavation will be discharged back to local waterbodies and to groundwater recharge wells and/or trenches.

Several farm drains which convey runoff and seepages from the humps and hollows through the working area will be diverted to avoid mixing clean water with mine-affected water while the mine pit traverses the site.

Water will also be taken from the mine excavation inflows and from Canoe Creek for mineral processing.

A management plan is required to set out how these activities will be managed to avoid adverse effects on the local hydrological environment and to provide a basis for develop of operating procedures on the site.

1.2. Report purpose and scope

This report comprises two main components: a Water Management Plan (WMP) and a Monitoring and Mitigation Plan (MMP).

The purpose of the WMP is to define water management objectives and principles and present a management process which gives effect to these.

The purpose of the MMP is to provide details of the monitoring that will be undertaken to determine whether the WMP objectives are being met and to set out the actions that will be undertaken if monitoring results signal the potential for hydrological impacts to occur.

The scope of work is:

- Describe the aspects of the proposed activity which could cause hydrological effects.
- Define water management and monitoring and mitigation objectives.
- Define water quality action thresholds and the activities that will be undertaken if the action thresholds are exceeded.

A separate Erosion and Sediment Control Plan (ESCP) has been developed and hence stormwater management and sediment control fall outside the scope of this document. The WMP and ESCP are closely related, however, and hence this document should be read in conjunction with the ESCP. Sediment monitoring is included within the monitoring section of this document.

2. DESCRIPTION OF ACTIVITY

The resource consent application (TPRL, 2023) for the proposed operation provides the following description of the activity:

The proposed mining activity will involve the removal and preserving of topsoil, excavation of mineral sands by an excavator, which will be pumped to the onsite processing plant. Specifically:

1. Topsoil, approximately 0.2- 0.6m thick, and overburden will be removed and preserved (stockpiled) for rehabilitation using an 85 tonne excavator, and 40 tonne articulated trucks. This area will be approximately 0.5 ha. Once in mining sequence, topsoil will be removed ahead of mining and placed straight onto rehabilitated ground behind the mining pit.
2. The sand ore will be mined via excavator and deposited onto a mining bench of approximately 1 ha in area. The ore will then be picked up by front end loader directly to the in-pit mining hopper. The slurry will pass through a trommel and desliming circuit before being pumped to the Wet Concentrator Plant (Processing Plant).
3. Reject large material from the trommel and slimes (small particles such as clay, mixed with water) will be returned to the mine pit.
4. Mining will occur at a faster rate (approximately 350 tonnes per hour of sand ore) than processing (approximately 165 tonnes per hour), and the excess ore will be stored at the processing plant and used overnight to ensure the processing plant can run 24/7.
5. Excavated material will be processed at the Processing Plant to extract the Heavy Mineral Concentrate (HMC). Heavy minerals will be separated from the ore using a water and gravity circuit, drained of excess moisture and stored at the Processing Plant in a farm implement building with a concrete floor.
6. Un-mineralised sands will be pumped back to the pit cavity, which will be progressively filled as the mine pit progresses. Pumped tailings will be spread across an approximate 1 hectare area of the mining void. Tailings are dewatered and discharged to the mining void via cyclone. The tailings will be allowed to naturally beach out (spread out). The cyclone will be moved as required to distribute the tailings as necessary. Tailings will be levelled and contoured with the use of excavators and bulldozers ready to receive the pre stripped overburden and soil. The mining void will be progressively rehabilitated as the mining void advances. Vegetative cover (sowing of grass) is established, and the area is removed from the disturbed area once stabilised.

3. ROLES AND RESPONSIBILITIES

3.1. Project Manager

- Responsible for the implementation and enforcement of this plan.
- Authorise any personnel to perform any duties of this plan and ensure that they are competent to complete their duties.
- Ensure that the consent conditions related to water management of the site are complied with

- Inform a Compliance Officer of the Consent Authority immediately if a breach of Consent Condition(s) takes place, or when they believe that a breach may take place.
- Approve any 'permits to work' prior to starting tasks if required (or delegate authority)

3.2. Mine Manager

- Ensure that all personnel that enter the mining operation areas comply with this plan
- Ensure that all pre-start inspections and checklists are being completed
- Ensure all personnel operating any vehicles have been deemed competent, hold a current and appropriate permit or are under the escort of a person who holds a current and appropriate permit
- Ensure any changes to this plan are communicated to all relevant personnel when they occur

4. CONSENT CONDITIONS

4.1. Index to relevant conditions

Table 1 summarises the proposed consent conditions and provides cross references to the sections of this document which give effect to the proposed conditions.

Table 1 Consent conditions and plan cross references

Condition	Report section
24.2 - Annual updates of WMP	8.1
25.1 - 25.3 - Minewater treatment and discharge	7.6
25.5 - Diversion of clean water away from workings	See ESCP
26.1 - Daily inspections of water treatment facility	See ESCP
26.2 - Monitoring schedule	7.3
26.3, 26.4 - Water quality limits	7.6
26.5, 26.5 - Monitoring personnel and procedures	3.1
26.7 - Annual reporting requirements	8
29.1 – Management of excavation inflow effects	7.4 - 7.5
30.1 – 30.8 – Management of Canoe Creek water take	6.2

5. POTENTIAL EFFECTS

5.1. Overview

The Barrytown Mineral Sands Mine Hydrological Impact Assessment (KSL, 2023) describes the activities for which water management controls may be required as follows:

1. Interception of surface drains and overland flow paths to prevent inflows of clean surface water to the excavation.
2. Potential water quality impacts associated with discharge of groundwater and stormwater from the excavation and backfilling area to local surface water bodies.
3. Potential groundwater level declines due to pumping of water from the mine excavation and the associated effects on local surface water bodies.

Management of runoff diversions to avoid adverse effects associated with erosion and sediment discharges is discussed in the ESCP. The scope of this WMP for runoff management is limited to site rehabilitation to re-establish the main pre-mining catchment areas for the Northern Boundary Drain and Collins Creek/Canoe Creek Lagoon. Similarly, the actions that will be taken to manage elevated sediment concentrations in water pumped from the mining excavation and management of runoff from the rehabilitation areas are described in the ESCP and are not discussed further in this document.

5.2. Water quality effects

Potential water quality effects principally relate to dissolved metals and phosphorus which are naturally present in the groundwater which will be pumped from sumps in the mine excavation. It is possible that dissolved metals could also be mobilised because of the mechanical processes of mineral separation and sand and slimes deposition during backfilling of the worked excavation. An increase in the discharge of these metals and phosphorus to surface waters could have an adverse impact on downstream aquatic life. A management, monitoring and mitigation process is required to ensure that this does not occur.

5.3. Water quantity effects

Pumping of groundwater inflows to the mine excavation will be required to facilitate the mineral sand extraction operations below the water table. Modelling results presented in the Hydrological Impact Assessment (KSL, 2023) indicate that groundwater inflow to and pumping from the excavation has the potential to deplete Collins Creek and cause water level declines in Canoe Creek Lagoon, Rusty Pond, the wetlands to the north and to a lesser extent the springs to the south of the site, if appropriate water management is not implemented.

Taking up to 63 L/s from Canoe Creek is not expected to cause adverse effects.

6. WATER MANAGEMENT PLAN

6.1. Water Management Plan goals

6.1.1. Operating condition goals

Groundwater management will be undertaken to create the working conditions required for mineral sand extraction below the water table whilst avoiding adverse hydrological effects.

6.1.2. Hydrological effect goals

The specific goals associated with avoiding hydrological effects are:

I. The pre-mining median rate of discharge from the springs used for domestic and stock water supply on the Langridge property to the south is not reduced.
II. The pre-mining median water level in the wetlands on the Langridge property to the north are not reduced.
III. The pre-mining median water levels in the former dredge pond "Rusty Lagoon" to the north are not reduced.
IV. The rate of water inflow to Canoe Creek Lagoon is not reduced by more than 10% of the Collins Creek Mean Annual Low Flow (MALF).
V. The flow in Collins Creek is not reduced by more than 10% of the MALF.
VI. The median groundwater level in the Northern Boundary Drain is not reduced.
VII. The quality of water discharged to receiving waters will not cause adverse impacts on stream ecology and visual clarity.
VIII. The rate of take of water from Canoe Creek is not greater than 10% of the MALF.
IX. Potential adverse ecological impacts associated with discharge of naturally present toxic metals and phosphorus in downgradient surface waters are avoided.
X. The pre-mining surface drainage patterns are restored such that the catchments areas for the Northern Boundary Drain and Canoe Creek Lagoon are not changed significantly.
XI. The contouring and surface drainage installed during mine rehabilitation does not increase the rate of groundwater drainage at the site.

6.2. Water management objectives

The water management goals will be achieved via the following actions:

A. The groundwater level in the pit will be managed via sump pumping so that excavator plant located on benches in the pit remain above the water table.
B. Pumping of groundwater will be minimised by excavation of saturated material from below the water table within the pit down to the maximum reach depth of the excavator as far as practically possible. Saturated material will be temporarily stored on the excavation bench to allow for natural drainage of entrained groundwater.

C. Water pumped from the pit will be conveyed to a treatment system for removal of particulate matter. Treated water will be recharged back to the aquifer via infiltration trenches and/or wells to achieve the hydrological effect management goals above.

D. The quality of any groundwater recharge water that could enter surface water will be monitored to confirm that it meets standards which are consistent with Hydrological effects goal VII above.

E. Detailed design information for the water management system shall be issued to WCRC for review and comment at least 16 weeks prior to the start of mining operations. Design information will include design drawings of the infiltration trenches and basin.

F. The rate of take of water from Canoe Creek will be monitored in accordance with the Resource Management (Measurement and Reporting of Water Takes) Regulations and the pumping rate will be restricted to 63 L/s.

G. The Canoe Creek intake will either comprise an infiltration gallery or will a direct take. In the case of the later the intake will be installed with a fish screen which will be maintained to ensure, as far as practicable, that eels, fish and fry are prevented from passing through the intake or being trapped against the screen.

H. The rehabilitated mine area will be contoured to re-establish the pre-mining catchment areas, avoid depletion of surface water body flows and water levels and to reduce the potential for transport of nutrients to surface waterways.

6.3. Water management concept design

6.3.1. Overview

Figure 1 illustrates the main features of the water management system which will be installed to deliver the objectives above. The key features comprise:

1. Pumping of groundwater inflows from the mine excavation and conveyance of stormwater from disturbed land to the water treatment system (Ponds 1- 4) during mining for removal of sediment, phosphorus and iron precipitate coupled with hardness adjustment if required to avoid any potential toxicity effects associated with naturally occurring metals.
2. Implementation of a discharge location hierarchy for treated water in Pond 4 (see below) coupled with monitoring of groundwater levels around the site boundary during mining to identify and respond to any areas of groundwater level decline due to groundwater pumping from the excavation.
3. Conveyance of clean water to infiltration/recharge trenches (see Figure 2) constructed along the northern and southwestern site boundaries. Pumping rates will be adjusted as required to maintain groundwater levels at or above the pre-mining median elevation and to support maintenance of pre-mining flows in Collins Creek.
4. Augmentation of water quantity in Collins Creek, Canoe Creek Lagoon, Northern Boundary Drain and Rusty Lagoon (via Northern Boundary Drain) with water drawn from Canoe Creek if required to maintain pre-mining conditions.

6.3.2. Pit water pumping and treatment

The proposed water treatment system comprises three main components: 1) conveyance of mine-influenced water to the treatment train; 2) treatment of water to remove sediment, dissolved iron, and phosphorus; and 3) adjustment of hardness where required to manage the potential toxicity effects of naturally occurring metals in the local groundwater.

Mine water conveyance

The conveyance of stormwater from disturbed areas of the site to the treatment train is described in the ESCP. Sumps will be dug in the active excavation area of the mine pit and installed with pumps to transfer influent groundwater and stormwater to the treatment train via pumping and the Central Drain.

Suspended sediment, dissolved iron, and phosphorus removal

The water treatment system, which has been designed to remove suspended sediment from stormwater runoff from the disturbed areas of the site and the stormwater and groundwater from the mining excavation, comprises a four-pond treatment train with the addition of flocculants as required to achieve the maximum practically achievable rate of sediment removal. Aeration is also provided to promote dissolved iron precipitation (see below). Iron oxyhydroxide precipitates and other flocculants, such as alum, are also proven agents for the removal of phosphorus, which is elevated in some of the groundwater samples bore (viz., PZ-08, PZ-15).

Dissolved iron concentrations in groundwater inflows to the pit are expected to be elevated and may require some treatment to avoid accumulation of iron precipitates at the points of discharge from the treatment train. Aeration is the most cost effective and commonly used method to oxidise ferrous iron, which then forms a precipitate (iron oxyhydroxide) which can be removed via settling ponds and/or filtration. Iron oxyhydroxide formation also facilitates the removal of metals/metalloids, such as cadmium and arsenic, as well as phosphorus, via adsorption and precipitation. The central drain will be installed with rock check dams and waterfalls to increase the dissolved oxygen content of water and promote iron oxyhydroxide precipitation in Pond 3 and Pond 4. The ponds will be closely managed to remove iron oxyhydroxide sludge and settled sediment as required to maximise the performance of the treatment system. Full details are provided in the ESCP.

Hardness adjustment

The Barrytown Sand Mine Stream Ecological Effects Assessment report[1] explains the relationship between the toxicity of certain metals and metalloids and water hardness. Toxicity effects are lower in harder water and hence hardness adjustment is commonly used where the background water hardness is not high enough to avoid potential toxicity impacts on aquatic ecology. Also, the addition of hardness using lime facilitates some removal of phosphorus via the formation of calcium phosphate and related insoluble salts. Hardness adjustment will be implemented via either installation of limestone rip rap or rock dams in the Central Drain or lime dosing of water pumped from the mine void to achieve, as a minimum, the hardness

[1] EcoLogical Solutions 2023. Barrytown Sand Mine Stream Ecological Effects Assessment report

levels described in Table 4. A detailed design for the water treatment system will be provided in an updated version of the WMMP to be issued to WCRC at least 16 weeks prior to excavation of mineral sands from below the water table.

6.3.3. Pond 4 discharge hierarchy

The goal for discharge of water from Pond 4 is to return groundwater inflows from the mine excavation and stormwater runoff from disturbed land to the water bodies to which they discharge pre-mining, as far as practically possible, whilst meeting the appropriate water quality standards. This can be achieved via the following hierarchical objectives.

1. Recharging as much of the groundwater inflows to the pit back to the adjacent mineral sand deposits as practically possible via a system of infiltration tranches along the northern and south-western site boundaries.
2. Discharging excess groundwater inflows and stormwater directly to those surface water bodies which currently receive this water via pumping and overflow from Pond 4.
3. Infiltrating as much of the excess water which does not meet the water quality criteria as practically possible to the Canoe Creek Infiltration Basin.
4. Conveying overflows from the infiltration basin via overland flow to the riverbed at the mouth of Canoe Creek.

These discharge systems are described in detail below.

6.3.4. Mine boundary infiltration system

Design features

The proposed infiltration system comprises a compartmented infiltration trench installed along the western, northern, and southern site boundaries as per the schematic diagram in Figure 2. The key features of the infiltration trench design are as follows:

- The infiltration trench is excavated through the lower permeability overburden deposits to intercept the top of the mineral sand stratum (generally at 1 – 2.5 m depth).
- The trench is segregated into 75[2] m lengths via trench breakers/dams. The breakers extend 0.5 m above the top elevation of the filter sand (see below). The above ground extension of the breaker is fitted with an outlet valve/gate immediately above the top of the filter sand.
- Geotextile is fitted along the trench walls to prevent sediment ingress from the overburden.
- A perforated backwash pipe is installed in the base of the trench with an inflow pipe installed to the ground surface.
- The trench is backfilled with locally sourced river gravel aggregate.

[2] Subject to confirmation/modification at detailed design stage

- A 200 mm layer of filter sand[3] is installed at the surface underlain by geotextile filter fabric.
- The upper part of the trench above the sand layer is battered to create a channel profile with stable side walls, which are vegetated or fitted with geotextile to prevent erosion. Bunding is installed where required to provide a minimum 0.5 m vadose zone between the base of the sand filter and the seasonal high groundwater level and to additionally allow for at least 0.5 m of water stage above the sand filter.
- Water is conveyed into the top of the infiltration trench and flows down the first trench compartment and into the next compartment, with a proportion of the water infiltrating to the underlying mineral sands in each trench compartment.
- The water level in each trench compartment is controlled via the trench shutter outflow valve/gate. The valve can be used to restrict the rate of flow into the next compartment and thereby increase the stage and hence driving head in individual compartments as required to control groundwater levels at the site boundary.
- The trench breakers prevent lateral flow of water between adjacent trench compartments during backwash operations such that backwash water flows upwards through the trench aggregate and sand filter and transports clogging material to the surface. Splitting the trench into compartmented sections supports generation of sufficiently high upward flow velocities through the aggregate and sand filter and filter fabric to mobilise clogging material. An outlet pipe at the lower end of the trench compartment conveys the backwash to land adjacent to the trench, where it either infiltrates to ground or is transported to the Central Drain via overland flow.

Note that the above details are subject to confirmation and amendment at detailed design stage for the purpose of optimising the infiltration capacity of the trench. The capacity of the infiltration system is evaluated in the Hydrological Impact Assessment Report (KSL, 2023).

Infiltration management

The key features of the infiltration trench management are as follows:

Treated water from Pond 4 is pumped to the infiltration trenches under the following priority system:

- To the southern and western trench when mining the area of land within strips 1 to 4 of the mine excavation (see Hydrological Impact Assessment Report, KSL 2023).
- To the South(west)ern trench when mining strips 1 - 4, plus the strip adjacent to Ponds 1 & 2.
- To the Northern trench when mining strips 5 – 9.

Recharge locations and rates will be adjusted based on monitoring data from the site perimeter piezometers. For example, if the monitoring data show groundwater levels starting to fall below the action trigger thresholds (see Section 7.4), additional recharge will be supplied to that stretch of the site boundary. Targeted recharge wells will be installed if the infiltration trench is unable to recharge sufficient water to the groundwater system to maintain groundwater levels within the target range at specific locations. The procedure for this is described in Section 7.5.

[3] Thickness and specification to be defined at detailed design stage

6.3.5. Pond 4 discharge to surface waters

Pond 4 will be constructed with an overland flow path to Canoe Creek Lagoon and a water quality monitoring system as per Section 7.3. The outlet valve will be opened to allow overflow of excess water to the lagoon when water quality meets the discharge water quality standards. Excess water comprises the water that is not recharged to the mine boundary infiltration system.

Water meeting the discharge standards may also be pumped to the Northern Boundary Drain to maintain water levels in the drain, Rusty Lagoon and the adjacent wetland. The trigger for this discharge will be based on water level monitoring in PZ09 as discussed in Section 7.4. Appropriate erosion/scour protection will be installed at the discharge location (see Figure 1).

Additionally, water meeting the discharge standards may also be pumped to Collins Creek to augment flows in the event of depletion due to pumping of groundwater from the mine pit. As above, appropriate erosion/scour protection will be installed at the discharge location (see Figure 1).

6.3.6. Canoe Creek infiltration basin and overland discharge

Any water which does not meet the discharge standards for Collins Creek, Canoe Creek Lagoon and/or the Northern Boundary Drain but does meet the appropriate standard for discharge to Canoe Creek (via the basin) will be conveyed to the Canoe Creek infiltration basin (see Figure 3). The key design features of the basin are as follows:

- The basin will be installed at the location of a former "standoff pad". The standoff pad comprises a ~60 m long x 20 m wide pad surrounded by 1 – 1.5 m bunds. The standoff pad will be reprofiled and the base scraped to create a 100 x 20 m basin on the Canoe Creek river terrace.
- The basin floor will comprise highly transmissive river gravel deposits (see inset photo in Figure 3) with a base elevation 0.5 – 1.0 m above the river stage elevation and hence the expected groundwater elevation.
- Bunding will be installed/reprofiled around the basin to provide for a basin water stage of at least 1 m above the basin floor elevation.
- The infiltration capacity of the basin is expected to be 100 L/s or more (see Hydrological Impact Assessment Report, KSL 2023) during the initial operating period but is likely to reduce over time due to clogging. The basin will be maintained when the infiltration capacity falls below the lesser or 100 L/s or the average weekly discharge to the basin. Maintenance will comprise excavation of fines and clogged river gravel from the base and replacement with clean gravel from the river.
- The western basin end will be installed with an overflow structure to convey any excess water to the overland flow pathway shown in Figure 3. This pathway comprises an existing swale which will be reprofiled as required to create a channel with a minimum capacity of 50 L/s. The channel will terminate on the bank of Canoe Creek, where any overflow water which has not infiltrated to ground will discharge to the Canoe Creek bed. No erosion protection is required at this point of discharge because the channel and riverbank here are highly dynamic and subject to periodic erosion and deposition cycles.

Infiltration trench and groundwater recharge wells installed to base of overburden/ base of mineral sand and underlying gravel deposits respectively. Treated water discharged to trench/wells as required to maintain groundwater levels at key locations on site boundary.

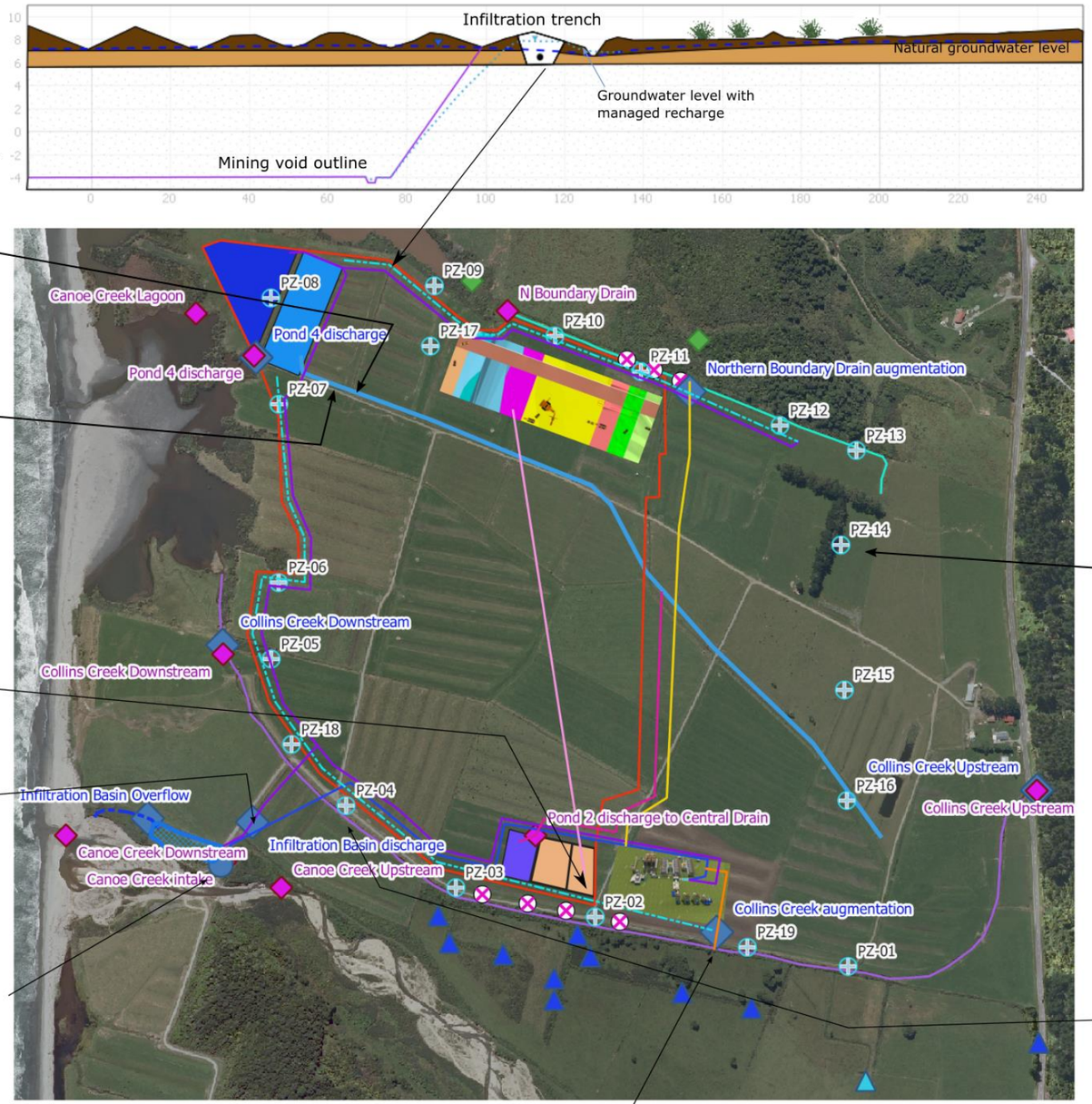
Central drain flows to finishing pond (Pond 3), which overflows into cleanwater facility (Pond 4). Pond 4 water discharged in accordance with Pond 4 Discharge Hierachy

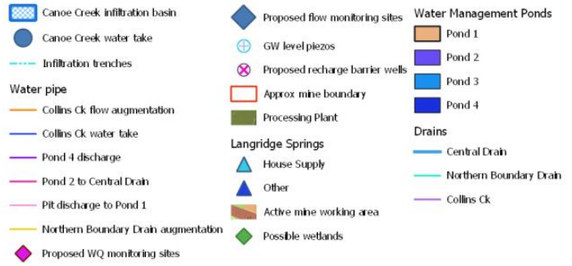
Limestone drain or lime dosing into pond(s) increases hardness of water to avoid potential toxicity of naturally present metals in water pumped from mine pit.

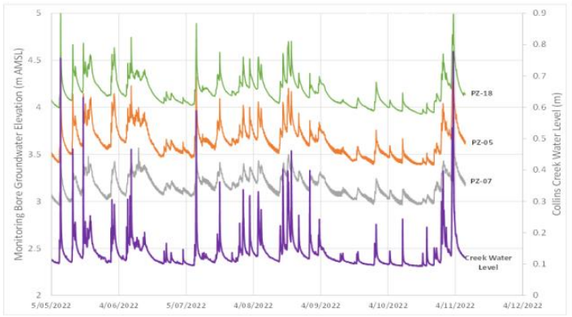
Mining void water and stormwater runoff from process plant area conveyed to Pond 1 and Pond 2. Sediment laden water in Pond 1 forebay treated with flocculant to assist with settlement. Clean water from Pond 2 conveyed to central drain and/or used in the process plant.

Water from pond 4 discharged to infiltration basin with overflow via overland path to Canoe Creek rivermouth

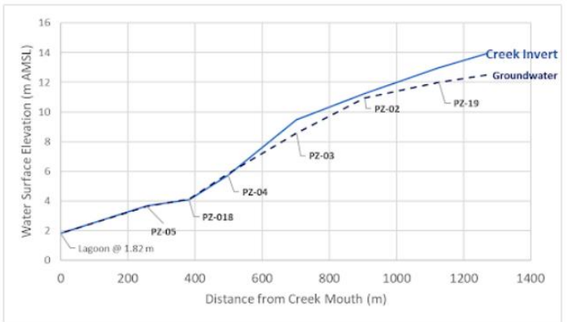
Infiltration gallery or direct water take from Canoe Creek to supply water to processing plant and for augmentation of surface water bodies







Groundwater level monitoring around the site perimeter identifies any potentially significant deviation from natural conditions. Water management actions are undertaken to avoid hydrological impacts.



Collins Creek is perched above the water table upstream of PZ04 and hence flow depletion is only expected to occur downstream of this point.

Collins Creek flow augmentation discharge

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Project: Barrytown Mineral Sands
Title: Water Management Concept 1a
Date: 07/03/2023

Figure 1 Water management concept

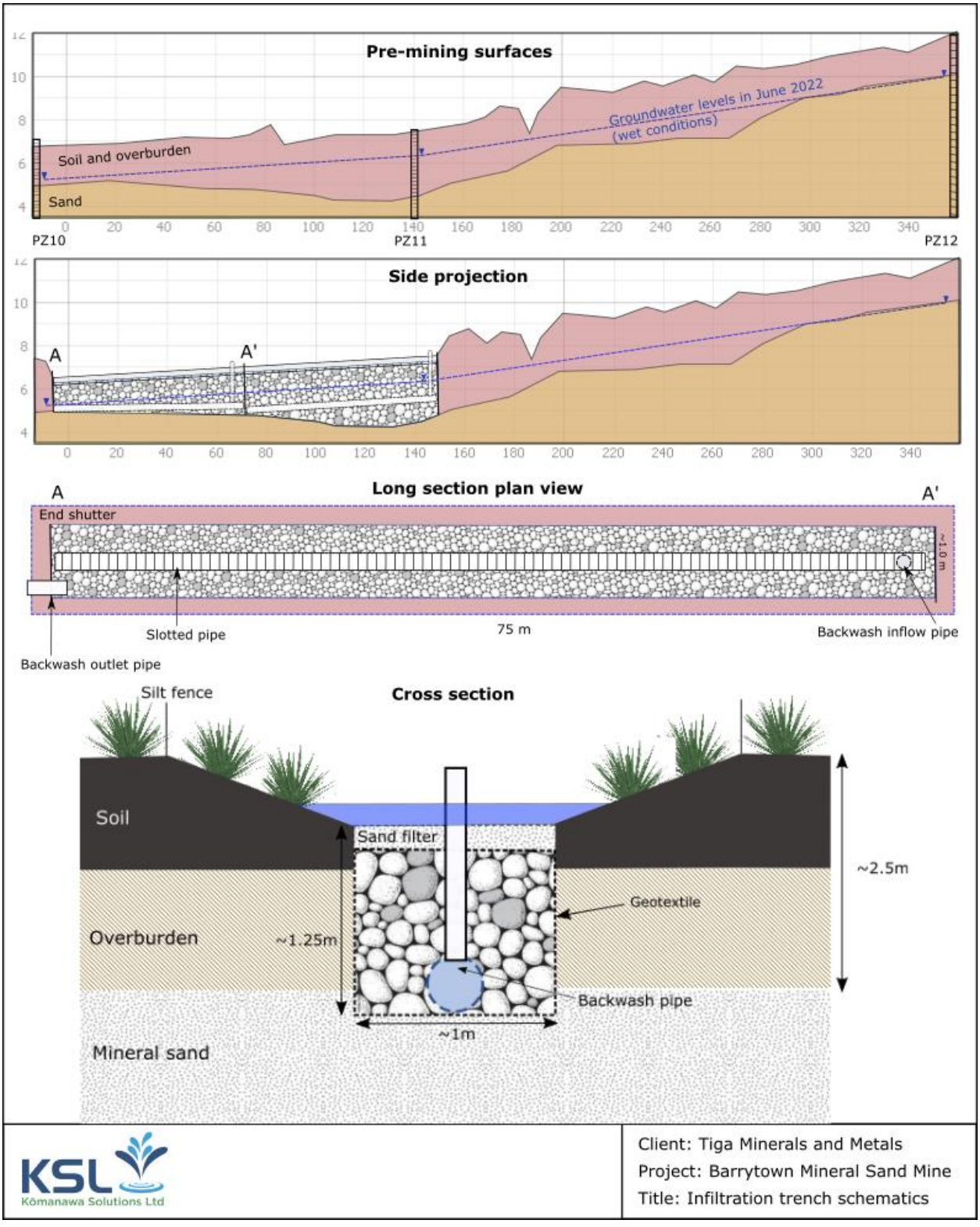

Figure 2 Infiltration trench schematic

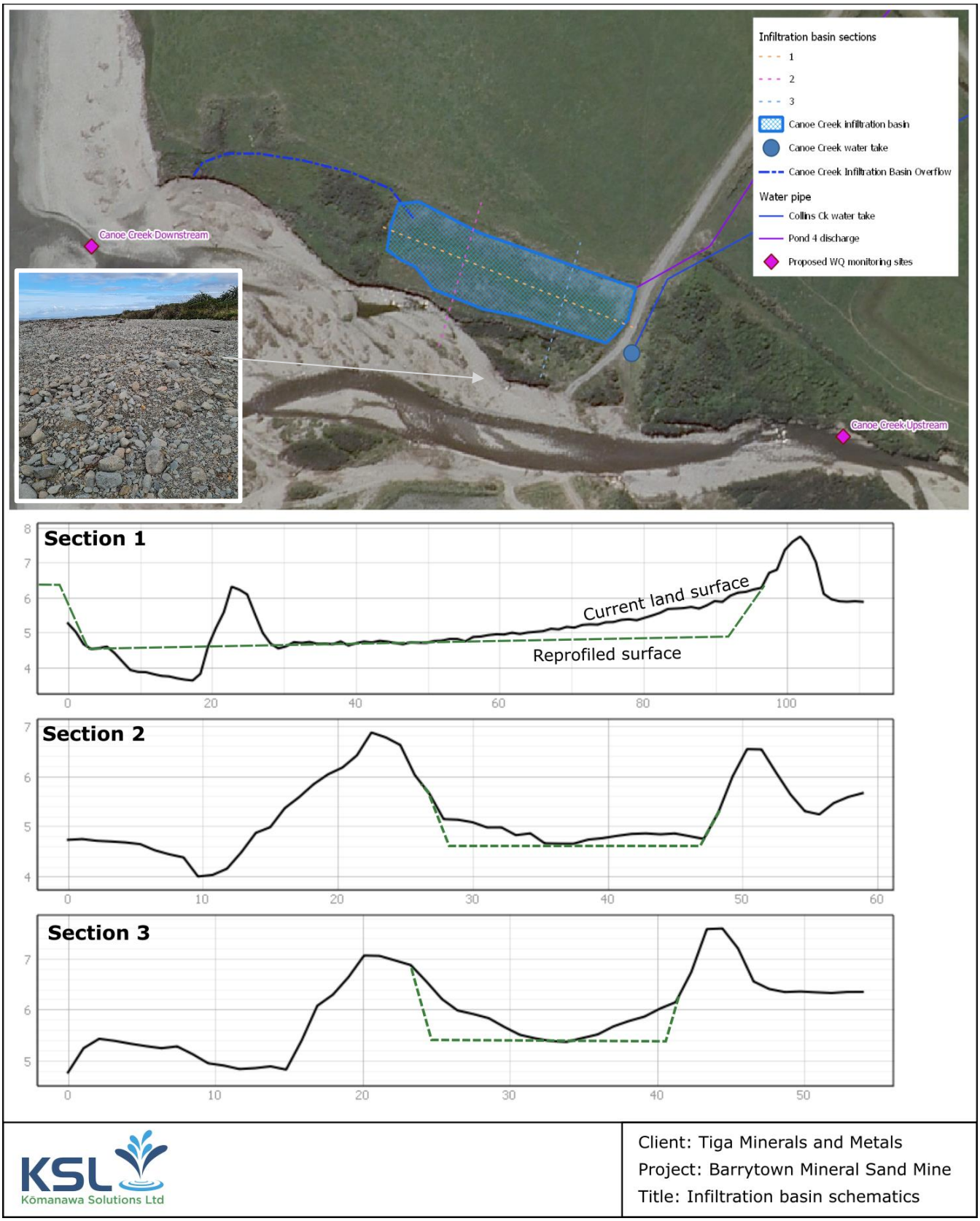

Figure 3 **Canoe Creek infiltration basin schematic**

6.4. Rehabilitation concept

Mapping of current drainage patterns (Figure 4) shows that ~6.5 ha of the proposed mine area drains to the Northern Boundary Drain with the remainder draining to Canoe Creek Lagoon via farm drains, or via the lowest reach of Collins Creek. Drainage patterns from part of the Northern Boundary Drain catchment outside of the mine area but within the disturbed area footprint could also be affected by the proposed activity. The final landform will be contoured to re-establish the existing distribution of drainage such that the catchment area draining to the Northern Boundary Drain does not change by more than 15% (i.e. 1 ha). This recontouring will ensure that the runoff rates to Rusty Lagoon and Canoe Creek Lagoon do not change as a result of mining.

The groundwater[4] and topography cross sections through the proposed mining area in Figure 5 below indicate that the average water table elevation is at or above the base of the hollows in the hump and hollow areas of the site. This suggests that the hump and hollow system could be draining the water table in parts of the site, which reduces the potential for nutrient uptake in the soil profile in the hollows and hence increases the potential rate of nutrient transport to downstream receptors. The final land surface will be recontoured with much lower gradient hump and hollows, with the elevation of the base of the hollows being above the average groundwater level as far as practically possible. This will both improve pasture quality and reduce potential for nutrient discharge to waterways. Material from above the water table to the east of the proposed excavation area, where the seasonal high water table is between 1 m and > 3 m deep, will be excavated and transferred to the mined area to replace the heavy mineral concentrate material removed from the site.

[4] Note that groundwater level data in areas with no piezometers were interpolated are therefore subject to local uncertainty. The groundwater elevations shown in some of the hollows in Figure 5 are higher than is likely to be the case.

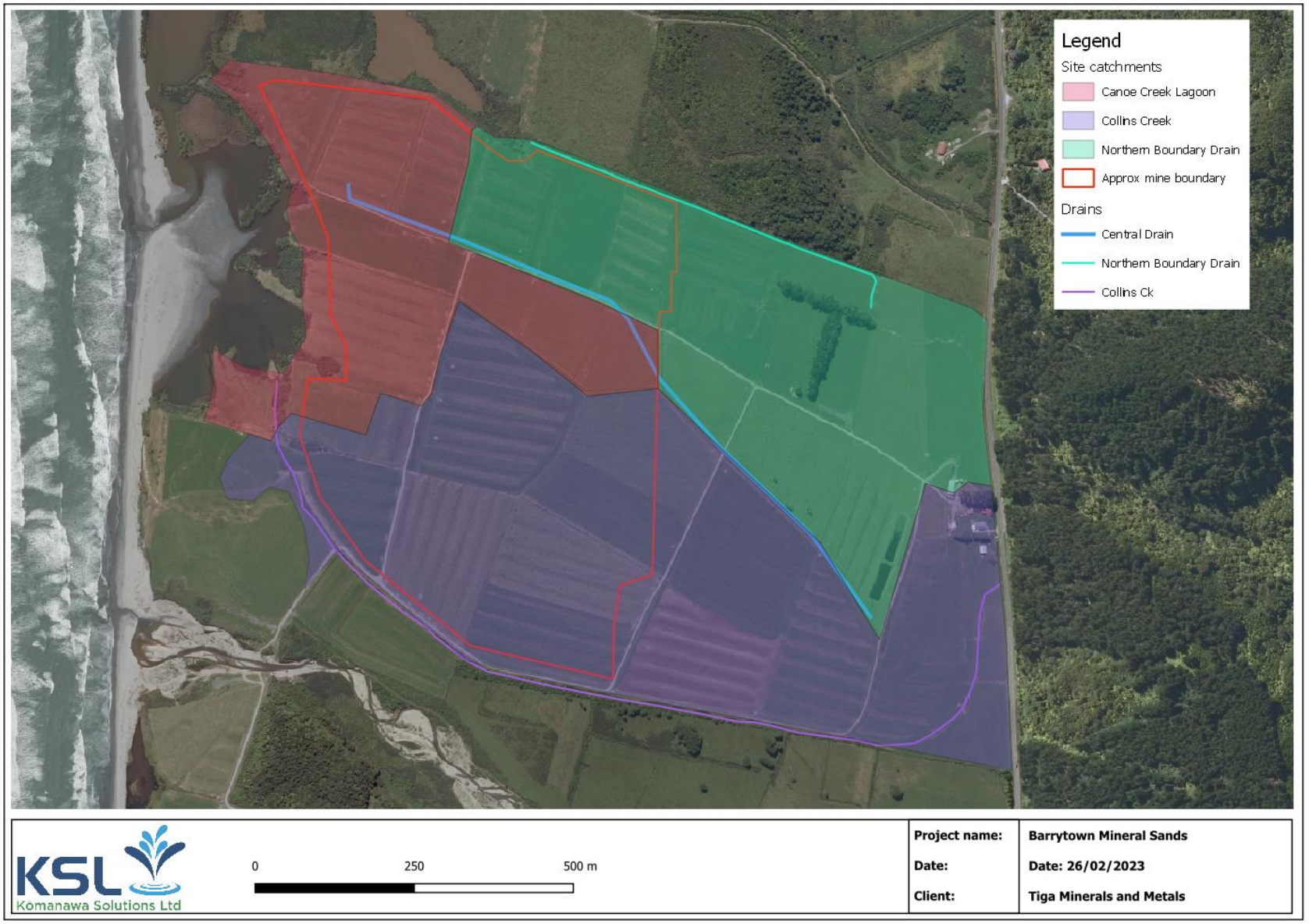

Figure 4 **Pre-mining surface water catchments**

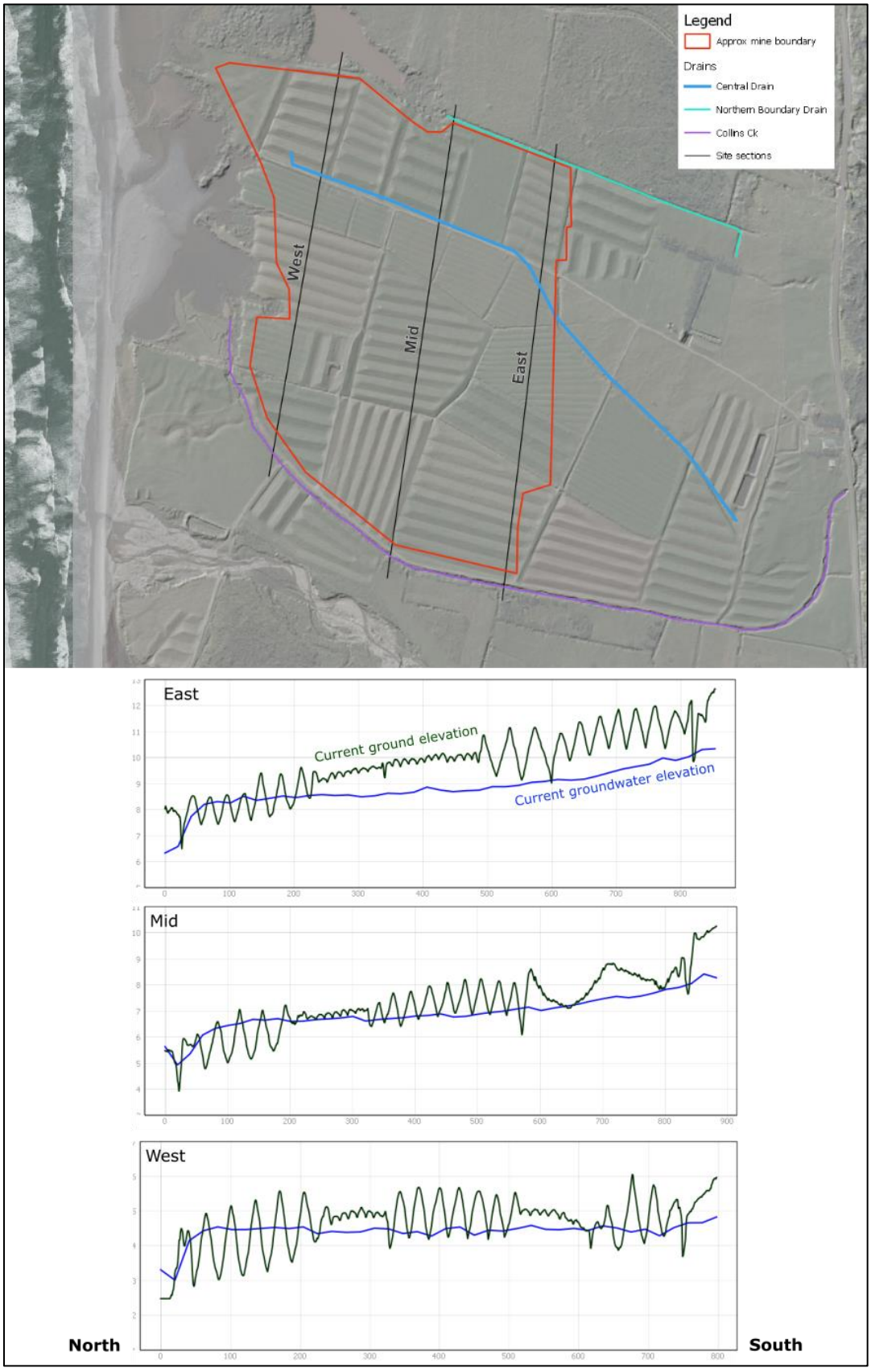

Figure 5 **North – south cross sections through mining area**

7. MONITORING AND MITIGATION PLAN

7.1. Monitoring and Mitigation Plan Objectives

The objectives of the Monitoring and Mitigation Plan (MMP) are as follows:

- Ensure that potential water quality impacts associated with mining activities are identified as quickly and clearly as possible via monitoring.
- Identify actions that will be undertaken to avoid, remedy or mitigate water quality effects through implementation of appropriate actions in a timely manner where required.

These objectives are achieved by:

- Specification of a monitoring programme which can robustly confirm that the water management system is working effectively and identify where adjustments are required to optimise water management and avoid adverse effects.
- Definition of action thresholds and an associated set of activities which can be implemented within a suitable timeframe to achieve the objectives of the WMP.
- Setting out reporting procedures for environmental monitoring data and consent compliance.

7.2. Baseline monitoring

The following baseline monitoring was initiated in May 2022:

1. Monitoring of groundwater levels around the site boundary to define baseline water levels.
2. Monitoring of flows in Collins Creek upstream and downstream of the site to define the natural change in flow between these points.
3. Monitoring of water quality in Collins Creek, Northern Boundary Drain and Canoe Creek Lagoon to define baseline water quality.

Groundwater levels

A groundwater level monitoring network was installed around the site perimeter in April 2022. Groundwater level loggers were installed in a representative sub-set of these wells (PZ01, PZ06, PZ10, PZ12, PZ18) to collect groundwater level data at hourly intervals. Water levels in remaining piezometers are dipped periodically to establish a relationship with the logged piezometers. The groundwater level data collected from this network provide a robust set of baseline data at the site boundaries which can be used to signal the potential for hydrological effects beyond the site boundary when mining operations are underway.

Collins Creek flows

An upstream and downstream flow monitoring site were installed in Collins Creek on 03/05/22. The upstream site location is shown in Figure 1. The downstream site is currently located in the vicinity of PZ18 but will be relocated to the lower site shown in Figure 1 prior to the start of mining because

hydrological modelling undertaken after the initial monitoring site installation identified the potential for stream flow depletion downstream of the lower site.

7.3. Operational monitoring

Operational level and quantity monitoring will include:

1. Groundwater levels around the site boundary
2. Flows in Collins Creek upstream and downstream of the site
3. Discharge rates from Pond 4 to:
    a. Canoe Creek Lagoon
    b. Infiltration trenches
    c. Canoe Creek infiltration basin
    d. Collins Creek flow augmentation
    e. Northern Boundary Drain augmentation
4. Overflow rates from the Canoe Creek infiltration basin
5. Water take rates from Canoe Creek
6. Augmentation discharge rates from Canoe Creek to Collins Creek
7. Augmentation discharge rates from Canoe Creek to the Northern Boundary Drain

Items 1 - 2 will comprise dataloggers with telemetry data transmission and an automated alert system for threshold exceedances (see below). Items 3 - 4 and 6 - 7 may comprise either a datalogger with or without telemetry system or a manual recording system. Items 5 will comprise flow recording via datalogger.

Operational water quality monitoring will include:

- Turbidity monitoring in the Pond 2 discharge to Central Drain
- Water quality, turbidity and sediment monitoring in Collins Creek upstream and downstream of the excavation area
- Water quality, turbidity and sediment monitoring in the lower Northern Boundary Drain
- Water quality, turbidity and sediment monitoring in Canoe Creek Lagoon
- Water quality, turbidity and sediment monitoring in Canoe Creek upstream and downstream of the infiltration basin

Monitoring will be undertaken at or about the locations shown in Figure 6 in accordance with the schedule in Table 2 and Table 3.

Table 2 Monitoring schedule

Monitoring site	Parameters	Minimum frequency
Boundary piezometers	Groundwater levels	Every 6 hours via data logger
Collins Creek upstream and downstream flow sites	Flow	Hourly
Pond 4 discharges to: 1. Canoe Creek Lagoon 2. infiltration trenches 3. Canoe Creek infiltration basin 4. Collins Creek augmentation 5. Northern Boundary Drain augmentation	Daily total flow	Daily
Overflow from the Canoe Creek infiltration basin	Daily total flow	Daily
Canoe Creek water take	Flow	15 minutes
Canoe Creek augmentation discharges to: 1. Collins Creek 2. Northern Boundary Drain	Daily total flow	Daily
Pond 2 discharge to Central Drain	Turbidity	Daily
Collins Creek upstream and downstream water quality sites	Monitoring Suite A Visual clarity	See Monitoring Suite A Weekly
Canoe Creek Lagoon water quality site	Monitoring Suite A Visual clarity	See Monitoring Suite A Weekly
Canoe Creek upstream and downstream water quality sites	Monitoring Suite A Visual clarity	See Monitoring Suite A Weekly
Canoe Creek water take	Turbidity	Daily for direct surface water take, monthly for first 6 months if infiltration gallery take. No further monitoring if max NTU <5, otherwise monthly thereafter
Pond 4 discharge water quality	Turbidity	Daily
Northern Boundary Drain water quality	Monitoring Suite A Visual clarity	See Monitoring Suite A Weekly

Table 3 Monitoring Suite A (Q = quarterly sampling, M = monthly sampling)

Dissolved metals	***Others***
Aluminium (Q)	EC (M)

Arsenic (Q)	pH (M)
Boron (Q)	Turbidity (M)
Cadmium (Q)	TSS (M)
Chromium (Q)	Hardness (Q)
Copper (Q)	Sulphate (Q)
Iron (Q)	Amm-N (M)
Nickel (Q)	NO_3-N (M)
Lead (Q)	Dissolved Reactive Phosphorus (M)
Manganese (Q)	
Zinc (Q)	

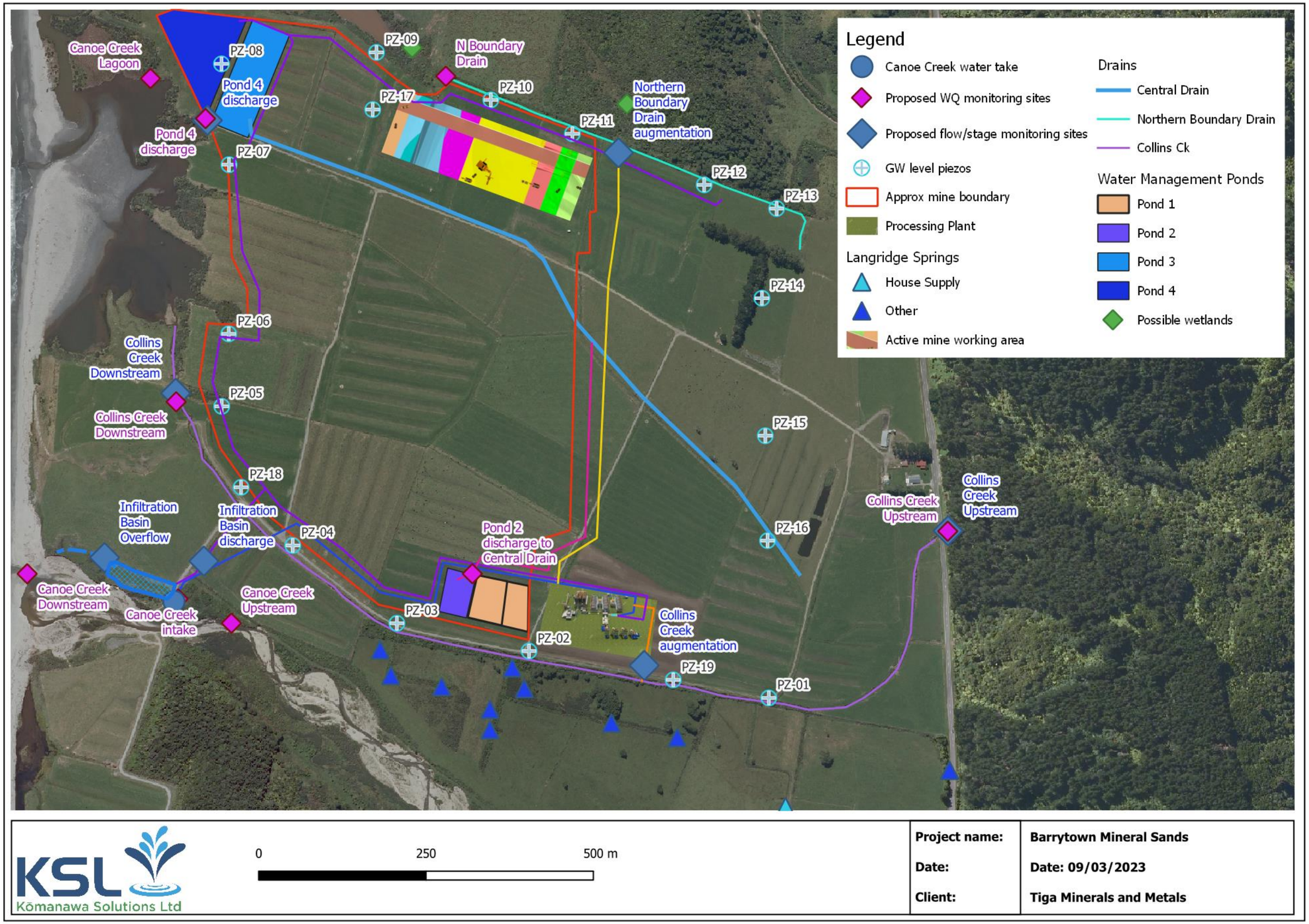

Figure 6 **Proposed monitoring network**

7.4. Water quantity thresholds

Hydrological thresholds are defined below to give effect to the hydrological effect goals presented in Section 6.1.2.

7.4.1. Groundwater level thresholds

Groundwater level data recorded in boundary monitoring piezometers PZ1 - PZ12 and PZ18 - PZ19 for at least 12 months prior to commencement of mineral sand excavations below the water table will be analysed to calculate the median water level in each well. These median values will be defined as action thresholds. The remaining boundary wells will be monitored for information purposes only.

7.4.2. Collins Creek flow threshold

The MALF in Collins Creek is taken to be 16 L/s based on the hydrological model-based statistic presented in Booker and Woods (2014)[5]. The maximum rate of depletion of Collins Creek is therefore 2 L/s (rounding to the nearest L/s in recognition of flow measurement accuracy limitations).

The rate of augmentation of Collins Creek will be equal to the trailing 24-hour average flow in the Collins Creek upstream flow site minus the trailing 24-hour average flow in the Collins Creek downstream flow monitoring site +/- the average difference between these sites defined during a minimum 12 month monitoring period prior to the start of mineral sand excavations minus 2 L/s.

For example:

- The average pre-mining upstream flow is calculated to be 60 L/s and the average downstream flow is 70 L/s. The upstream/downstream flow gain is therefore +10 L/s.
- During mining operations near Collins Creek, the trailing 24-hour average flow in the Collins Creek upstream flow site is found to be 100 L/s and the trailing 24-hour average flow in the Collins Creek downstream flow monitoring site is 60 L/s.
- The augmentation rate in this example is therefore 100 - 60 +10 - 2 = 48 L/s.

7.4.3. Canoe Creek Lagoon stage

Inflows to Canoe Creek lagoon comprise Collins Creek and groundwater seepages from land to the east of the lagoon. Implementations of the action thresholds above for Collins Creek and the piezometers adjacent to the lagoon will therefore protect the water balance of the lagoon. The water level in the lagoon is strongly influenced by the beach profile to the west and is therefore highly dynamic over time

[5] Booker DJ, Woods RA. 2014. Comparing and combining physically-based and empirically-based approaches for estimating the hydrology of ungauged catchments. *Journal of Hydrology* **508**:227-239. See https://shiny.niwa.co.nz/nzrivermaps/

due to wave erosion and deposition. Definition of a pre-mining baseline water level in the lagoon would therefore not provide a suitable effects threshold.

7.5. Water quantity actions

7.5.1. Groundwater level threshold actions

Two action thresholds are defined for boundary monitoring piezometers PZ1 - PZ7, PZ09, PZ10 - PZ12, PZ18 and PZ19: a 7-day rolling average and a 30-day rolling average. The former comprises an operational management trigger, the latter comprises a mitigation action threshold.

If the 7-day rolling average groundwater level in any of the above boundary monitoring piezometers falls below the pre-mining median, water will be discharged to the appropriate sections of infiltration trench to recharge the aquifer in the location of the groundwater level decline. Groundwater levels will be reviewed over the subsequent 48 hours after the management trigger and adjustments made to the rate of recharge until the pre-mining median groundwater level is restored.

If the 30-day rolling average groundwater level in any of the above boundary monitoring piezometers falls below the pre-mining median the following actions shall be undertaken:

- The consent holder shall contact the West Coast Regional Council within five working days with details of the threshold exceedance and the actions that will be undertaken.
- The consent holder may submit a request to WCRC for approval to maintain a lower groundwater level in the well(s) under circumstances where it can be shown (via data from background groundwater monitoring wells located away from the area of influence of the mining operation and within the same hydrological setting) that this would not cause a deviation from the natural background variability. Approval to use any such off-site background monitoring wells must be obtained in writing from WCRC at least 4 weeks prior to the start of mineral sand excavations.
- If approval to maintain a lower groundwater level is not sought or provided, relevant infiltration trench sections will be investigated to determine whether the decline relates to inadequate recharge rates. Remedial actions such as backwashing or excavation and replacement of the trench filter media will be implemented.
    - If:
        - the groundwater level declines are within one or more of piezometers PZ10 - PZS12, PZ01 - PZ03, PZ06, PZ07 or PZ19; and
        - remedial actions have not restored groundwater levels within 20 working days; then
        - pumping from the mine void shall cease until further remedial actions have been implemented. Further remedial actions could include installation of recharge wells or re-engineering of the infiltration trench system.
        - Mine void pumping can recommence when the daily average groundwater level in PZ10 - PZS12, PZ01 - PZ03, PZ06, PZ07 or PZ19 have been restored to the pre-mining median.
    - If:
        - the groundwater level declines are within one or more of piezometers PZ04 , PZ05 or PZ18; and

- remedial actions have not restored groundwater levels within 20 working days
- Flow monitoring data from the upstream and downstream Collins Creek flow monitoring sites shall be reviewed to ensure that depletion rates are less than 10% of MALF. Additional augmentation flows will be supplied to Collins Creek as required.

➢ If:

- the groundwater level decline is in piezometers PZ09; and
- remedial actions have not restored groundwater levels within 20 working days; then
- pumping from the mine void shall cease until further remedial actions have been implemented. Further remedial actions could include additional flow augmentation of Northern Boundary Drain, installation of local recharge wells and/or re-engineering of the infiltration trench system.
- Mine void pumping can recommence when the daily average groundwater level in PZ09 has been restored to the pre-mining median.

7.5.2. Collins Creek flow threshold

If the Collins Creek flow threshold is breached the following actions will be undertaken:

- The consent holder shall contact the West Coast Regional Council within five working days with details of the threshold exceedance and the actions that will be undertaken.
- The flow monitoring sites will be inspected and a manual flow gauging undertaken to confirm the flows if the accuracy of the flow monitoring rates is uncertain.
- The rate of flow augmentation will be increased until the upstream-downstream flow difference falls within the required range.

7.6. Water quality thresholds and actions

7.6.1. Water quality action thresholds

Metals and metalloids

Action thresholds for metals and metalloids measured in accordance with the operational monitoring programme in receiving waters at the Collins Creek Downstream, Canoe Creek Lagoon. N Boundary Drain and Canoe Creek Downstream water quality monitoring sites shown in Figure 6 are provided in Table 4.

Table 4 Water quality action thresholds - metals and metalloids

Parameter	Threshold mg/L	Dependency	Reference
Aluminium	0.62[B]	Hardness, pH, Dissolved Organic Carbon	USEPA (2018)
Arsenic	0.013	As arsenic (V)	ANZECC (2000)[c]
Boron	0.94	NA	ANZECC (2018)[c]
Cadmium	0.0002[D]	Hardness	ANZECC (2000)[c]

Parameter	Threshold mg/L	Dependency	Reference
Chromium	0.0033[D]	Hardness, as chromium (III)	ANZECC (2000)[c]
Copper	0.0039[E]	Hardness, pH, Dissolved Organic Carbon	USEPA (2007)
Iron	1.0	As total fraction	USEPA (1986)
Lead	0.0034[D]	Hardness	ANZECC (2000)[c]
Manganese	1.9	NA	ANZECC (2000)[c]
Nickel	0.011[D]	Hardness	ANZECC (2000)[c]
Zinc	0.008[D]	Hardness	ANZECC (2000)[c]

[A] dissolved fraction, unless stated

[B] at hardness = 25 g/m^3, pH = 7.0, Dissolved Organic Carbon = 1.0 g/m^3

[C] 95%-ile trigger value

[D] at hardness = 30 g/m^3

[E] at hardness = 25 g/m^3, pH = 7.0, Dissolved Organic Carbon = 2.0 g/m^3

Turbidity, suspended sediment and visual clarity

Action thresholds for turbidity and suspended sediment and clarity are provided in Table 5.

Table 5 Water quality action thresholds - turbidity, total suspended solids, clarity, and dissolved reactive phosphorus

Parameter	Threshold	Notes
Total Suspended Solids	15 mg/L	In discharges to Collins Creek, Northern Boundary Drain or to the overland flow path to Canoe Creek Lagoon.
Turbidity	15 NTU	In discharges to Collins Creek, Northern Boundary Drain or to the overland flow path to Canoe Creek Lagoon.
Visual clarity	Conspicuous visual change Relevant NPS-FM (2020) attribute state for visual clarity	In the receiving water bodies above based on visual inspection at the upstream and downstream monitoring sites (see Figure 6). No change in the attribute states of the receiving surface water bodies, as an annual median and a 95%-ile, versus the baseline states. See note below.
Dissolved Reactive Phosphorus (DRP)	Relevant NPS-FM (2020) attribute state	No change in the attribute states of the receiving surface water bodies, as an annual median and a 95%-ile, versus the baseline states. See note below.

Notes:

The attribute state for visual clarity and DRP shall be either *a) defined via at least 12 months of baseline monitoring in Collins Creek, Northern Boundary Drain, Canoe Creek and Canoe Creek Lagoon; or b) assumed to be of pristine water quality (A Band*). *In the case of a), the monitoring data and attribute state assessment shall be submitted to WCRC for approval at least 4 weeks prior to the start of mining operations*

The Canoe Creek Lagoon upstream observation location shall be upstream of the Collins Creek inflow and the inflow from the Pond 4 discharge, but may change over time, given the dynamic nature of the lagoon. The Northern Drain upstream site shall be the lowest point in the stream which is a) upstream of any discharge and b) at which visible flow is occurring on the day of the observation.

7.6.2. Water quality threshold exceedance actions

The following actions shall be undertaken in the event of a water quality threshold exceedance:

- The consent holder shall notify WCRC within 5 working days.
- In the case of an exceedance within the surface water monitoring sites, the water quality data from upstream monitoring sites and the downstream monitoring sites shall be compared to determine whether it is related to natural water quality.
- The consent holder shall provide a toxicant management plan (see below) to the Regional Council. The plan will employs the effects management hierarchy to ensure the adverse effects of the discharge on aquatic life are reduced to no more than minor.

If a toxicant management plan is developed in response to a threshold level exceedance, the plan shall include the following as a minimum:

a) The actions to be taken to avoid, minimise, remedy, offset or compensate for more than minor effects.
b) The timeline in which the actions identified through (a) above will be implemented.
c) The consent holder shall implement the actions identified through Condition (a) in accordance with timeline in Condition (b).

8. ANALYSIS, REPORTING AND IMPROVEMENT PROCEDURES

8.1. Plan updates

The WMP should be updated on an annual basis. Key components of the WMP to be defined for the year ahead include:

- The proposed mine area for that year.
- A description of all site activities with the potential to cause hydrological impacts.
- The water management actions that will be implemented to avoid hydrological effects.

- Audit checklists.
- An organisational chart showing staff and contractor positions and responsibilities for plan implementation.
- Relevant training and induction procedures and schedules.

The water management plan and associated procedures should be updated to improve water management practices and reduce the potential for adverse hydrological impacts in the following circumstances:

- Ongoing actions or management changes are implemented in response to breaching of any of the action thresholds.
- The hydrological monitoring system is not performing as intended (e.g. due to lack of flow in a surface water monitoring site or insufficient information being gathered to identify the cause of any water quantity or quality issues)
- A pollution incident or one or more near-misses occur which could have resulted in water quality or quantity impacts, and new procedures have been identified to reduce future risk.
- Improvement opportunities identified through the data review and analysis procedures.

8.2. Annual reporting

An annual monitoring report will be prepared by a suitably qualified and experienced person and submitted to WCRC for review. The report will include:

1. A summary of the monitoring undertaken over the preceding 12 months. The summary will:
    a. Reference the specific consent conditions under which the monitoring has been undertaken to show how the conditions have been complied with.
    b. Provide tables, graphs and summary data of the water quality, flow and water level monitoring.
2. Discussion and evaluation of the monitoring data in relation to the relevant consent conditions including a summary of compliance with conditions.
3. A summary of the actions that have been undertaken in response to any action thresholds.
4. Records of the inspections/monitoring undertaken to verify that the mine operation has not caused any of the following effects within any receiving waterbody measured at or beyond 100 metres from any discharge:
    a. Any conspicuous oil or grease films, scums or foams, or floatable or suspended materials,
    b. Any conspicuous change in the colour or visual clarity,
    c. Any emission of an objectionable odour,
    d. Any significant adverse effects on aquatic life, or
    e. The rendering of fresh water unsuitable for consumption by farm animals.

END

APPENDIX A. WATER MANAGEMENT AND MONITORING PROCEDURES

To be completed at least 8 weeks prior to start of mining

APPENDIX B. HAZARDOUS SUBSTANCES ENVIRONMENTAL MANAGEMENT PROCEDURES

To be completed at least 8 weeks prior to start of mining