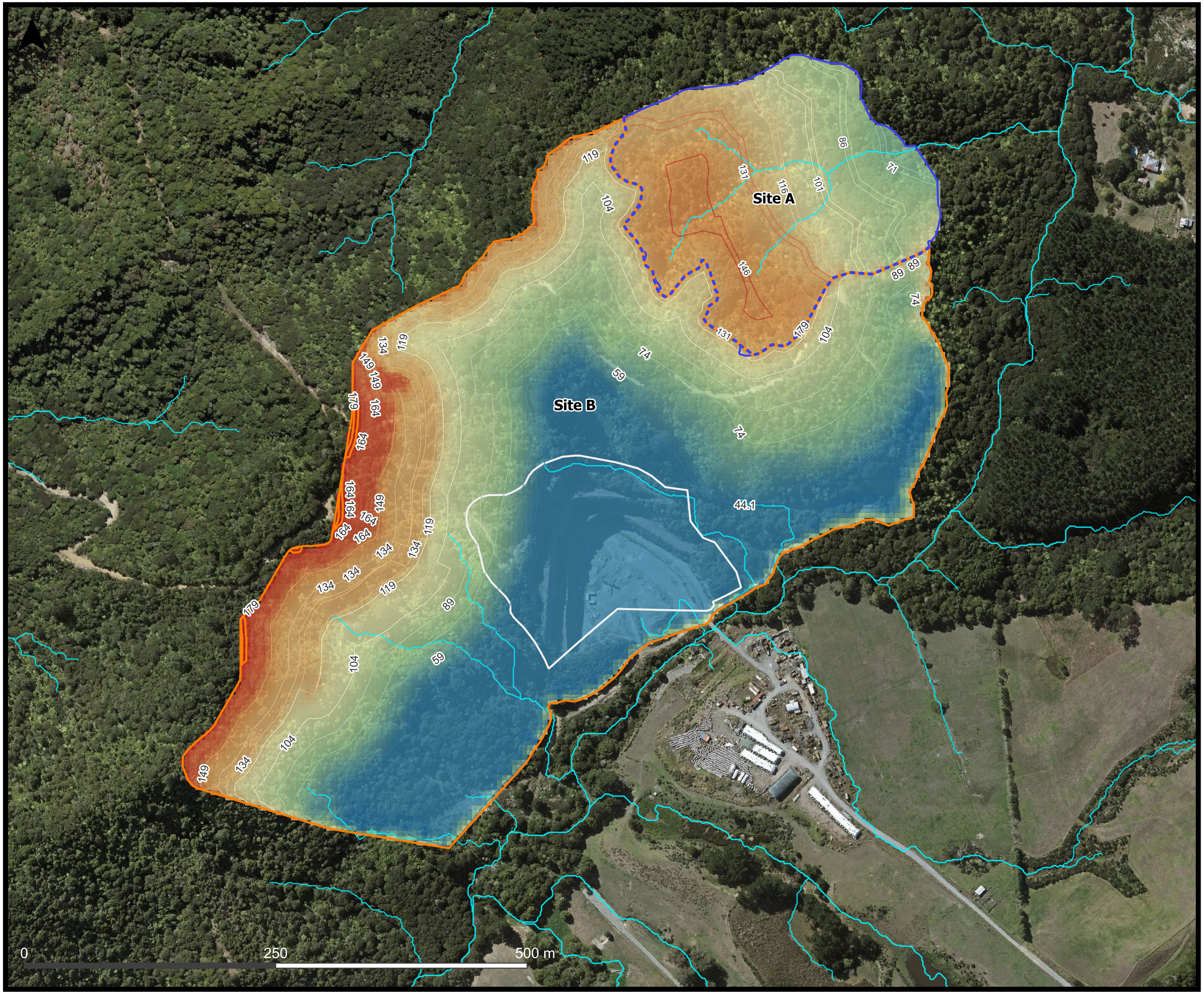

Map Title:
Quarry excavation detail

Project:
Kings Quarry Groundwater Model

Client:
Semenoff Group Ltd.

Legend

- **Waitoki Catchment (Model boundary)**
- **Streams / rivers**
- **Existing quarry**
- **Site A**
- **Site B**

Final quarry surface elevation (mAMSL)
- **180**
- **40**

Final quarry surface elevation contours (mAMSL)
- **40 - 70**
- **70 - 100**
- **100 - 130**
- **130 - 160**
- **160 - 180**

Data Provenance
Aerial imagery and land parcels from Land Information New Zealand

Drawn by: J Scherberg
01/11/2023

Layout Name
Quarry excavation detail

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Figure 11.

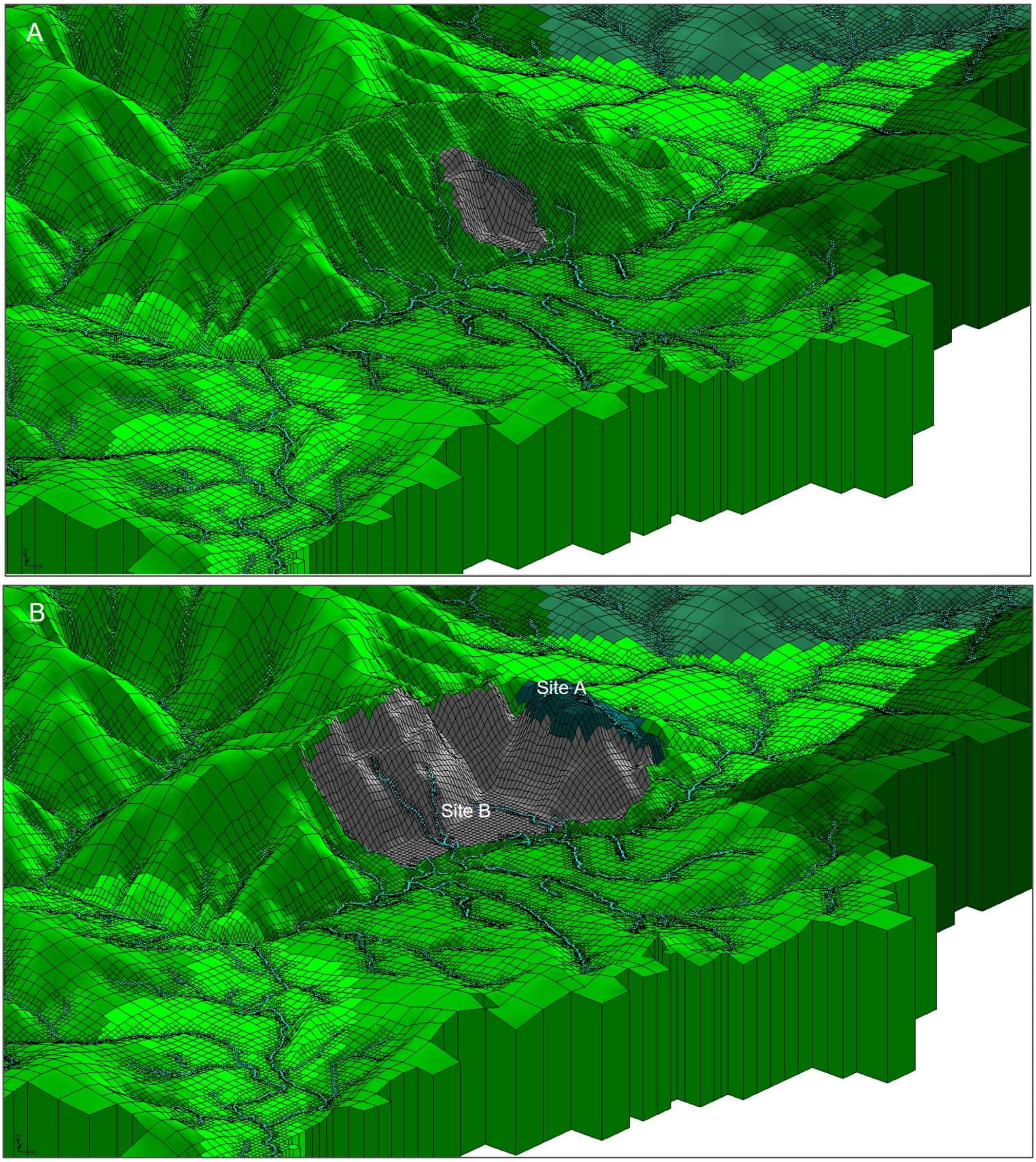


Figure 12. 3-D representation of A) current quarry extent, and B) extent of proposed quarry (Site B) and fill site (Site A) after 45 years of operation.

5. Model Calibration

Model calibration is the process of adjusting the hydraulic parameters and boundary conditions applied in a numerical model, within realistic constraints, to achieve the best possible simulation of measured data. In this case, calibration was based on simulating a combination of groundwater levels and surface water baseflows given the following available measurements:

- SMWBM simulated flow duration curves compared to gauge data collected from the Kaukapapa River at Taylor Road.
- water level measurement taken in bore 947-11255, 150 m east of the existing quarry.
- A single measurement of flow into a drainage pond on the existing quarry.

5.1 Hydraulic Parameters

The geologic units in QMAP (refer **Figure 7**) were used as the basis for defining material boundaries in the model. Hydrogeological parameters were assigned to the materials based on the hydraulic testing reported in PDP (2009). Given that the simulation outputs were deemed realistic, and the lack of data available for detailed calibration, the parameters were not changed from their original vales. The hydrogeological parameters used in the model are shown in **Table 3**.

Table 3. Hydraulic parameters used in groundwater model.

Material	Horizontal k (m/day) [m/sec]	Specific yield (-)
Albany Conglomerate	0.01728 [2.0×10^{-7}]	0.05
Basalt	0.00864 [1.0×10^{-7}]	0.05
Mudstone	0.000864 [1.0×10^{-8}]	0.05
Limestone	0.00311 [3.6×10^{-8}]	0.05
Turbidite	0.000864 [1.0×10^{-8}]	0.05

5.2 Calibration Results

The model was calibrated to steady state conditions using the average daily rate of the groundwater recharge, as determined from the SMWBM analysis. The implication of this method is that the model calibration outputs represent an average condition for groundwater within the Waitoki Catchment. The key results of model calibration are presented in the following sections.

Stream Flow

As previously mentioned, the SMWBM was used to determine the groundwater recharge inputs into the model. The SMWBM was calibrated to simulate Kaukapapa River flow measured at the Taylor Road gauge maintained by Auckland Council, located approximately 4 km downstream from the confluence with the Waitoki Stream. It was assumed, for modelling purposes, that flow generation in the Waitoki Catchment is consistent with flow generation for the Kaukapakapa River in terms of flow per unit of catchment area (or specific discharge) based on the similar soils and geologic materials occurring across the catchment.

The focus for calibration was on simulating the low-flow portion of the hydrograph in particular because low-flow conditions are generally of greatest concern for groundwater effects analysis. A flow-duration curve, showing the measured and simulated probability of stream flow exceeding a given rate is shown in **Figure 13**. It is evident that the simulation performed quite well for the 30% of flows that were below 145 L/s and for the 15% of flows above 2,100 L/s. The SMWBM generally undersimulated flows between the 30th to 85th percentile range.

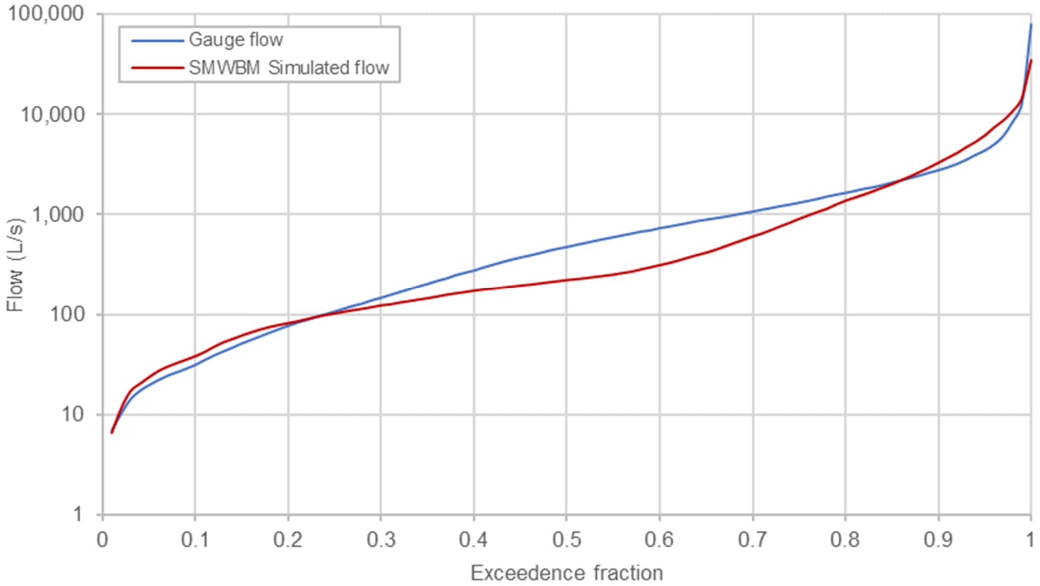
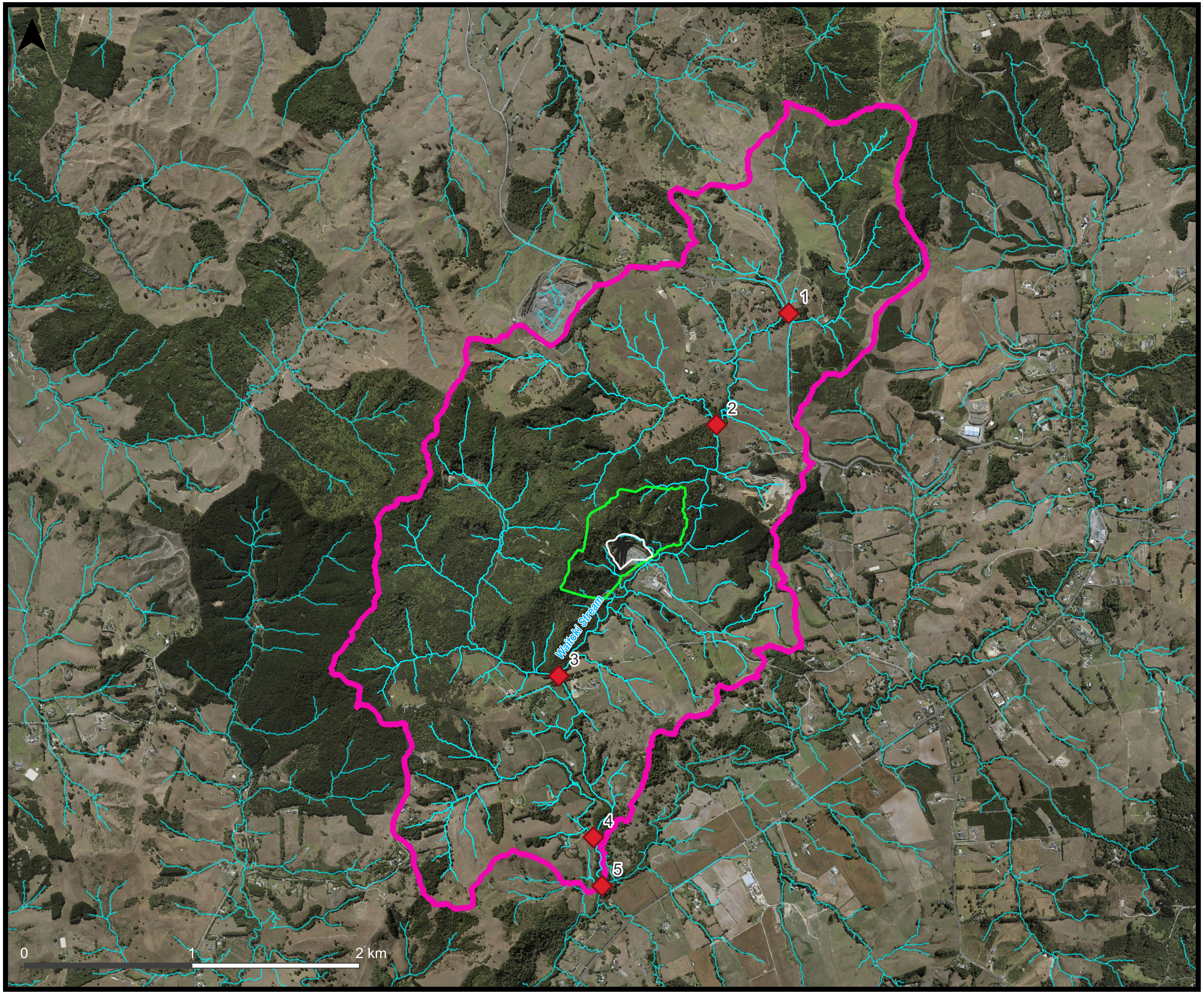


Figure 13. Flow duration curve showing measured and simulated flow for the Kaukapakapa River at Taylor Road.

A second assessment was conducted to verify that the simulated flow aligned with the mean annual low-flow (MALF) estimates as provided on NZ River Maps available through NIWA[3]. Five locations on the Waitoki Stream were selected as reference points, numbered from the uppermost location to the mouth of the stream that corresponds to the model outlet (**Figure 14**). MALF was considered to be a good reference for stream flow because it is generally representative of a baseflow condition which is what is simulated by the model.

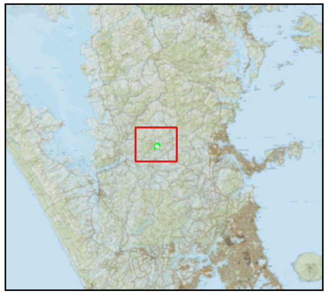
[3] https://shiny.niwa.co.nz/nzrivermaps/



Map Title:
Surface flow reference points

Project:
Kings Quarry Groundwater Model

Client:
Semenoff Group Ltd.



Legend

Waitoki Catchment (Model boundary)
Existing quarry
Proposed quarry
Streams / rivers
Stream flow reference points

Data Provenance
Aerial imagery and land parcels from Land Information New Zealand

Drawn by: J Scherberg
01/11/2023

Layout Name
Surface flow points

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Figure 14.

Table 4 shows the estimated MALF on NZ River Maps relative to the MALF calculated from simulation results. The model simulated results are consistent with the two upstream locations, but progressively become greater than the three downstream locations. This may be related to MALF being calculated for a 7-day period whereas model results represent monthly averages and are therefore less sensitive to annual low flow events (while perhaps the opposite could be said about more extreme drought events). On the whole, model results aligned well with the corresponding MALF predictions.

Table 4. Comparison of NZ River Maps and model simulated MALF at select locations.

Reference Point	MALF (L/s)	
	NZ River Maps	Baseline Model
1	3.01	2.83
2	5.26	5.37
3	10.17	12.95
4	12.28	16.05
5	12.64	16.19

Groundwater level

Two groundwater level measurements were used as general calibration points. These were the Farm Bore (Auckland Council ID 947_11255) and the CMW Geosciences bore. Both bores are labelled in **Figure 9**. Simulated water levels at both bores were within a few m of the measured water levels as shown in **Table 5**. Given that only a single measurement was available for each bore and these measurements were likely taken directly after drilling, the discrepancy was not considered to be significant for the purpose of this analysis.

Table 5. Measured and simulated groundwater levels.

Bore	Groundwater Level (mAMSL)	
	Measured	Simulated
CMW Geosciences	37.5	38.35
Farm Bore	47	43.8

Quarry Drainage

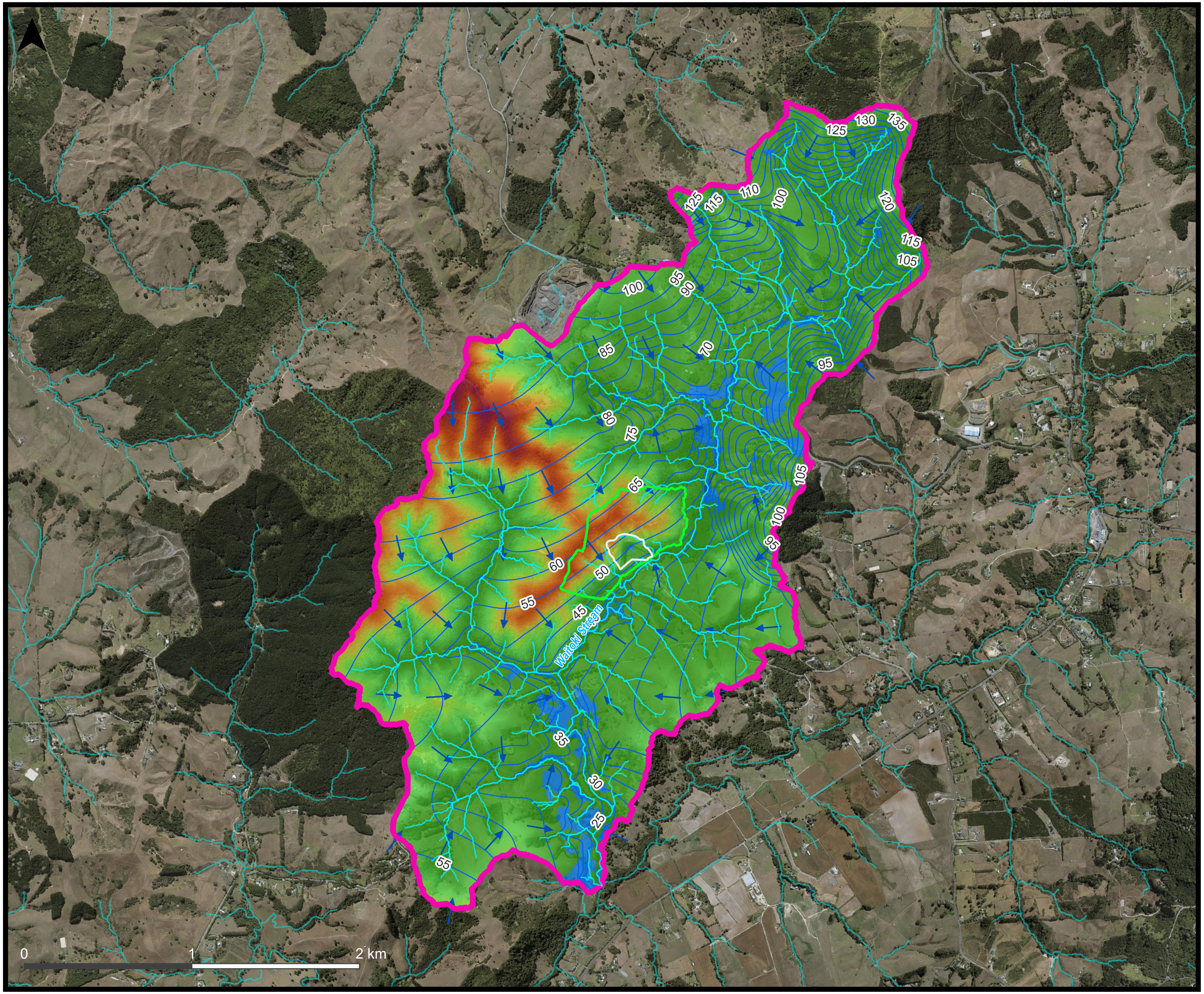
As currently configured, there is a pipe draining water seeping from the quarry headwall into a small pond facility. This flow rate was measured by quarry staff on 25 September 2023, and found to be flowing at rate of 0.20 L/s (17.3 m^3/day) which is roughly the same as a household tap. It is assumed that the source of this water is the immediate area contributing to the quarry face. A drain boundary was applied in the model at the quarry base elevation. Simulated flow into this drain was 0.19 L/s (16.1 m^3/day).

It is acknowledged that this calibration is to a single flow measurement, however the result is taken as a signal that the model is predicting reasonable drainage flow rates for the quarry area and can be used for high-level assessment.

Piezometric Surface

The piezometric surface (water table), depth to groundwater, and general groundwater flow direction determined from the numerical model analysis is presented in **Figure 15**. The figure shows that the water table is over 150 m below surface at the high ridgelines and generally under 10 m in the stream valleys, discharging into surface streams, with adjacent areas where groundwater is at or near the land surface symbolised by the shaded blue areas. Groundwater flow generally follows the topography converging into the stream network.

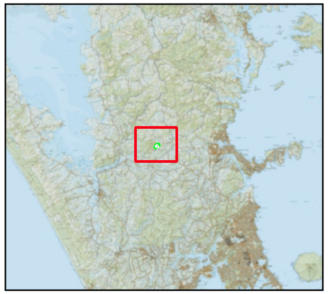
The groundwater elevation in the northern portion of the model is relatively high and shallow where the underlying geology is low permeability turbidite and mudstone. The water table to the northwest of the quarry, where more permeable Albany Conglomerate prevails, corresponds to a comparatively lower water table that is far deeper beneath the land surface.



Map Title:
Simulated water table - average conditions

Project:
Kings Quarry Groundwater Model

Client:
Semenoff Group Ltd.



Legend

- **Waitoki Catchment (Model boundary)**
- **Streams / rivers**
- **Existing quarry**
- **Proposed quarry**
- **Water table elevation contours (mAMSL)**
- **Groundwater flow direction**

Depth to groundwater (m)
160
0

Data Provenance
Aerial imagery and land parcels from Land Information New Zealand

Drawn by: J Scherberg
30/10/2023

Layout Name
Steady state water table

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Figure 15.

5.2.1 Transient Simulation

The calibrated steady state model was converted to a 52-year transient model and simulated using historical rainfall from the period 1972 through August 2023. Groundwater recharge from the SMWBM was compiled into monthly average data which was used as the input for the model to be run using monthly stress periods.

Simulated hydrographs showing the relative groundwater levels at selected reference locations are shown in **Figure 16**. The reference locations were selected to show both the relative groundwater level at various locations within the catchment, and the variability of water levels at different locations.

It is evident that groundwater elevation is correlated to the surface elevation, as shown in the upper left plot. However, the lower right plot shows the simulated groundwater elevations for the entire model run normalised for direct comparison. The topographically higher points (locations 1 through 3) have greater variability in terms of annual fluctuation and long-term changes. The lower points (locations 4 and 5) are less variable as they are controlled by the river level.

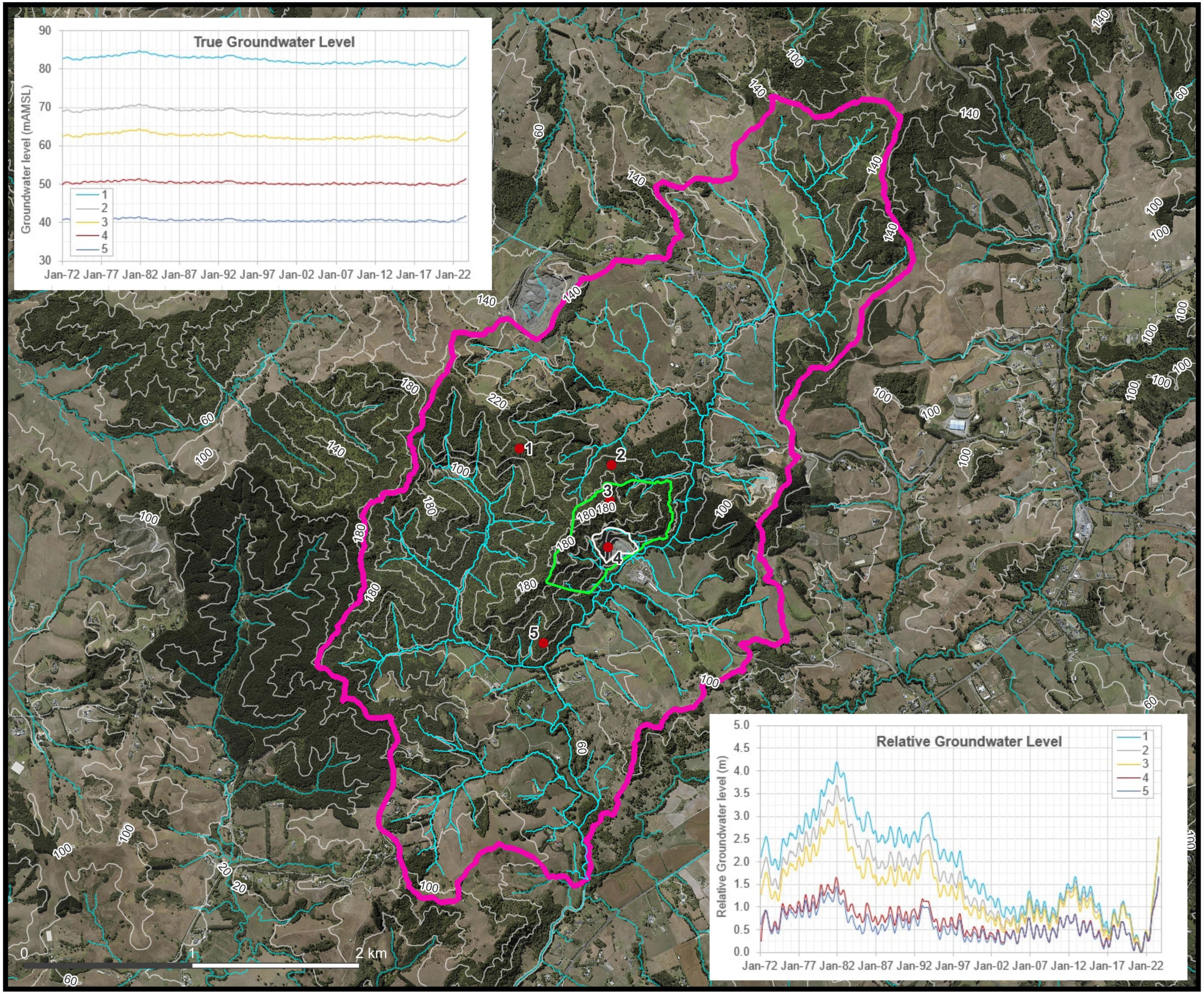
It can be noted that Point 3 is on the existing quarry wall and that Point 4 is on the quarry floor. The implication is that groundwater drainage is likely to fluctuate more where the excavation intersects the water table in relatively higher elevation areas.

The hydrographs in **Figure 16** also indicate the long term range in groundwater level oscillations, and highlight just how wet the last two years have been, with a significant increase in groundwater level experienced. This is also evidence in the cumulative departure profile provided in **Figure 3**.

From the model calculated water balance, recharge accounts for all inflow and discharge into surface streams (i.e. baseflow) account for all outflow, both averaging approximately 1,550 m^3/day (17.9 L/s). Seasonal changes in groundwater level are shown as changes in aquifer storage. **Table 6** provides range of inflow and outflow as determined from the model water budget.

Table 6. Simulated mass balance - water budget summary.

	Inflows (m^3/day)		Outflows (m^3/day)	
Metric	**Recharge**	**Storage in**	**Drains**	**Storage out**
Minimum	8	0	1149	0
Maximum	4785	1470	2360	2590
Average	1553	348	1540	361



Map Title:
Groundwaer level reference locations

Project:
Kings Quarry Groundwater Model

Client:
Semenoff Group Ltd.

Legend
- **Waitoki Catchment (Model boundary)**
- **Streams / rivers**
- **Elevation contours (mAMSL)**
- **Proposed quarry**
- **Existing quarry**
- **Water level reference points**

Data Provenance
Aerial imagery and land parcels from Land Information New Zealand

Drawn by: J Scherberg
01/11/2023

Layout Name
Water level reference points

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Figure 16.

6. Predictive Simulations

The overall objectives of the work were to quantify the effects of quarry excavation on the local groundwater system. To achieve this the model was setup in transient mode using the same climate and recharge conditions that were applied in the transient model. The transient simulation described in **Section 5.2.1** effectively became the 'Baseline Model' for comparison with the quarry development scenario.

This analysis comprises the following:

- Evaluation of the depth and extent of drawdown resulting from pit excavations;
- Estimation of the rate and volume of groundwater seepage into excavation areas; and
- Assessment of potential impacts on streams and a nearby wetland.

6.1 Model Scenarios

Two model scenarios were developed:

1. Baseline model: applies historic climate data and existing topography (i.e. the quarry remains in its present state through the simulation). Equal to the transient simulation described above.

2. Excavation model: quarry excavation in the Site A and Site B progresses in accordance with the information provided by Aggretech.

The initial condition for groundwater storage in the transient simulations was set equal to conditions in the calibrated steady state model. Both versions of the simulation used the 1972-2023 groundwater recharge data set from the SMWBM, hence the dates referred to in the Excavation Model analysis are effectively a 'what if' scenario, where 1972 is equivalent to Year 1 of the quarry development sequence. This approach enabled a realistic climate data series with a range of conditions to be applied and direct comparison of results to conditions from the calibrated 'Baseline Model'.

6.2 Environmental Effects

The model results will be presented as a time series where conditions can be compared between the two scenarios to assess the effects of the proposed excavation.

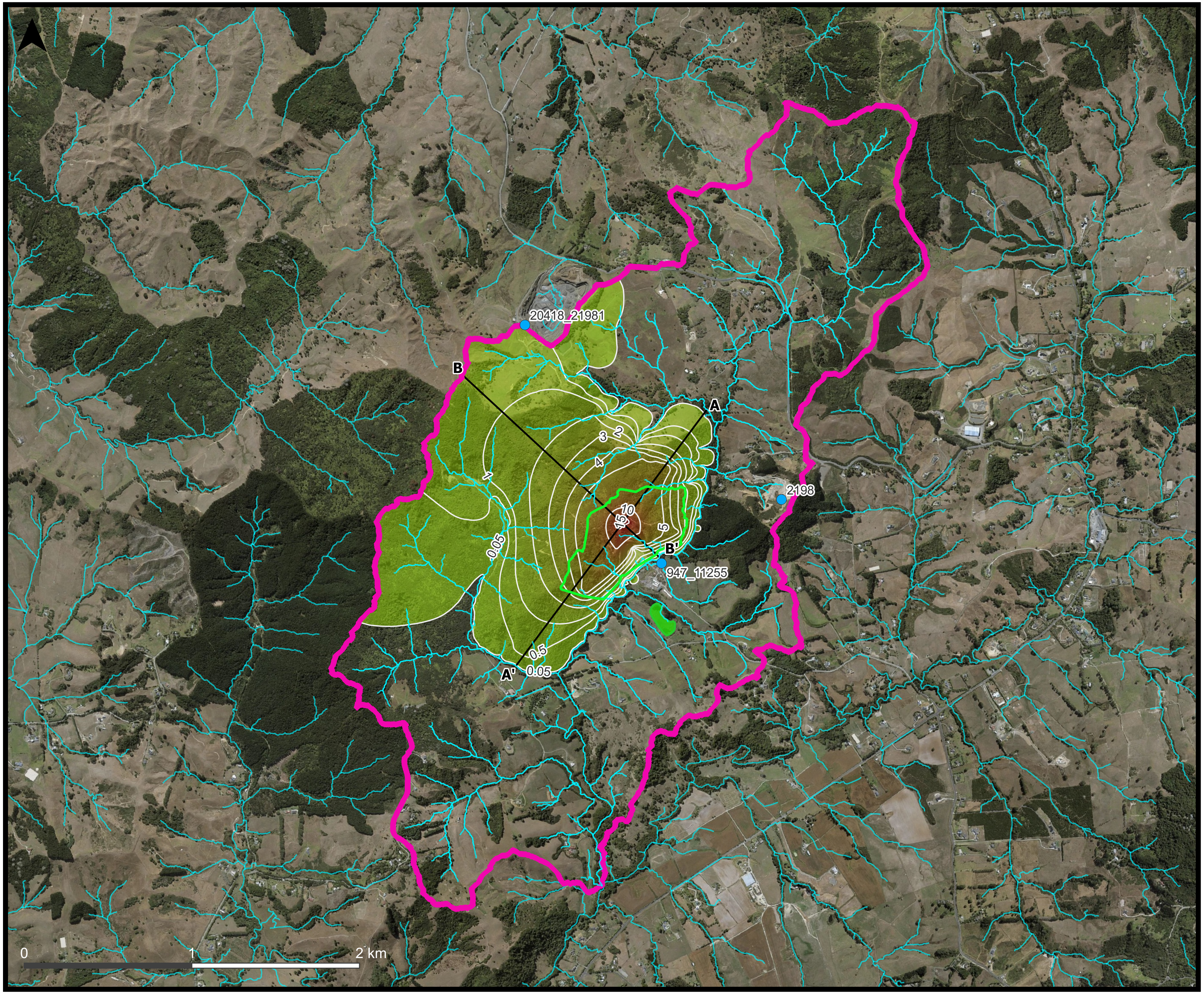
6.2.1 Drawdown

Drawdown reflects the reduction in groundwater pressure at a given location resulting from dewatering that occurs as the quarry excavation falls below the water table.

The maximum drawdown is considered to occur at the end of the model run. Drawdown at this time is exacerbated by the high water levels in 2023, which are expressed in the Baseline Model and limited by the quarry drainage in the Excavation Model. **Figure 17** shows drawdown contours across the model area at the end of the simulation period. Maximum drawdown is approximately 17.0 m and occurs in the middle of the proposed excavation area. The area that is affected by drawdown is constrained by the Waitoki Stream to the east of the quarry, and tributaries flowing into the stream to the north and south of the quarry, respectively.

The maximum extent of the 1 m drawdown contour is under 1 km from the middle of the excavation area and does not extend close to any groundwater users. Groundwater level and land surface elevation with and without the excavation are shown across a northeast-southwest transect in **Figure 18** and across a northwest-southeast transect in **Figure 19** (refer to **Figure 17** for transect locations).

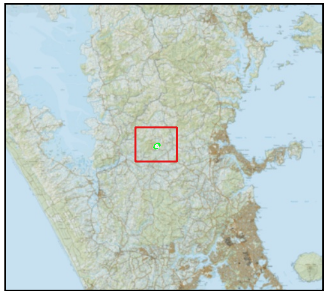
Transect A-A' (**Figure 18**) runs between the Waitoki Stream tributaries the effectively constrain drawdown effects from the excavation, as is evident in the plot. Transect B-B' runs from the top of the ridge above the quarry, showing the extent of upgradient drawdown, to the Waitoki Stream where the water level controlled by the stream bed elevation. This demonstrates that the quarry design strategy of not excavating below the stream level is effective in limiting drawdown and stream dewatering effects.



Map Title:
Groundwater drawdown

Project:
Kings Quarry Groundwater Model

Client:
Semenoff Group Ltd.



Legend

- **Waitoki Catchment (Model boundary)**
- **Streams / rivers**
- **Proposed quarry**
- **Wetland**
- **Bores**
- **Drawdown contours (m)**

Groundwater drawdown (m)

- **17**
- **0.05**
- **Analysis transects**

Data Provenance
Aerial imagery and land parcels from Land Information New Zealand

Drawn by: J Scherberg
01/11/2023

Layout Name
Drawdown

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Figure 17.

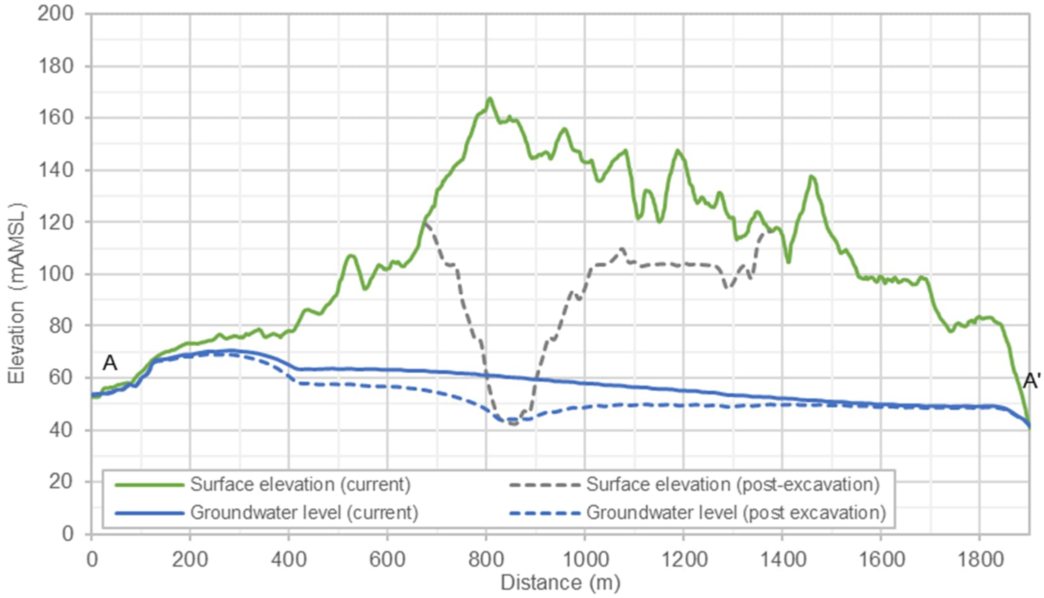


Figure 18. Water table elevation across Transect A-A'

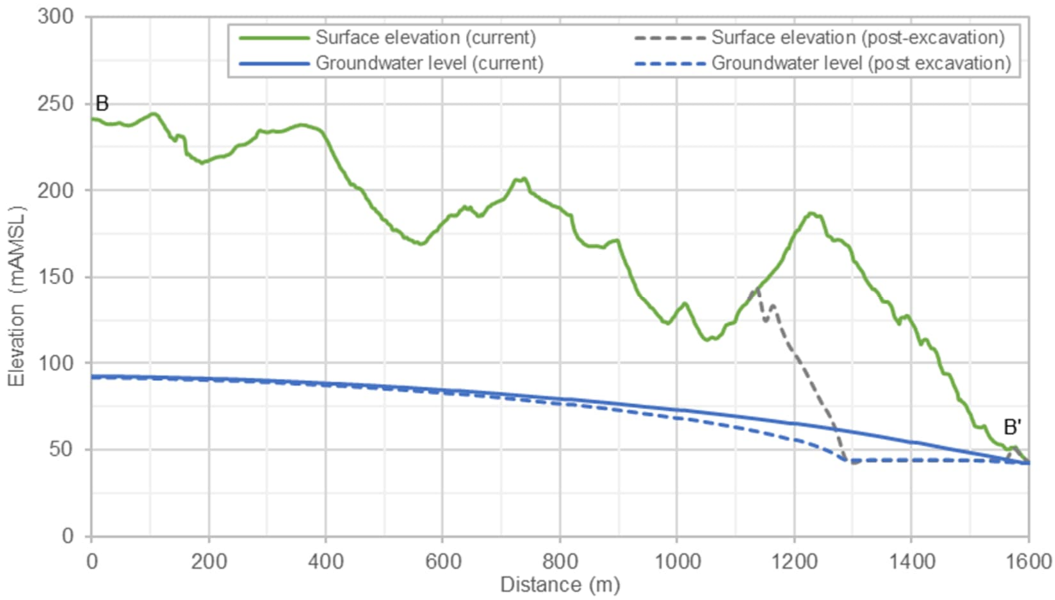


Figure 19. Water table elevation across Transect B-B'

6.2.2 Neighbouring Bore Interference Effects

Three water bores within 2 km of the excavation area were identified, as stated in **Section 2.7.1** (Bore 2198 was noted as being dry at the time of drilling). All of these bores are outside of the 0.05 m maximum drawdown contour and are therefore considered to have negligible effects from the proposed excavation.

The closest of these bores is the Farm Bore at 70 Pebble Brook Road (947-11255) which is drilled into the same aquifer that will be intersected by the proposed quarry expansion and has been demonstrated to have a 20 m drawdown at a pumping rate of 20 m^3/day. This level of drawdown has potential to draw the groundwater level below the Waitoki stream, thereby bypassing the hydraulic barrier it represents under normal conditions and posing a risk that the bore could draw water contaminated by chemicals leached from the quarry.

Quarry operations will include the construction and maintenance of a storage pond where water produced by quarry operations will be collected. This pond will be monitored for water quality. The proposed Water Quality Programme Consent Conditions offered by the Applicant require that the pond is monitored for the presence of chemicals from explosive materials (including blasting derivatives) used in the quarry. If these are detected it will trigger further actions including:

- testing of the Waitoki Stream and the Farm Bore;
- providing an alternative stock water supply should those sources also exceed the trigger levels; and
- daily testing until levels recede to below the trigger level.

The proposed Water Quality Baseline and Ongoing Monitoring Consent Conditions offered by the Applicant requires the establishment of baseline water quality for the Waitoki Stream and Farm Bore prior to the proposed consent being exercised. It is noted that excavation over the first year of quarry operations will not reach a level that will affect stream flows, and therefore flow data from this period can be taken as a baseline condition. Future management practices such as setting appropriate trigger levels to initiate a response (ie stock water supply mitigation) to any effects that may occur can be developed in relation to the baseline data.

Given the limited drawdown, low bore production rate (20 m^3/day), and the hydraulic flow barrier of the stream under most conditions, it is considered highly unlikely that bore production or water quality will be affected by the quarry. These considerations indicate a low risk of contamination affecting any current groundwater users and preclude the need for a new monitoring bore, as monitoring of the storage pond will ultimately be a more effective means of recognising and avoiding any contamination originating from the quarry.

In the event of an adverse effect on bore production or water quality being detected, mitigation measures are set out in the Mitigation Plan items t within the proposed Groundwater Diversion Permit Conditions.

6.2.3 Stream Baseflow

All stream flow predictions from the groundwater model apply only to baseflow, the portion of flow that is due to groundwater discharge where streams intersect the water table. Flow generated from surface runoff and shallow flow within the soil profile is not simulated in a groundwater model hence flow predictions are more representative of observed flow during low flow periods and less so during high flow periods.

Waitoki Stream

Waitoki Stream baseflow over the simulation period for both the Baseline and Excavation Models is shown in **Figure 20**, ranging from approximately 12 to over 25 L/s with a sharp spike in 2023 on account of the record rainfall.

Baseflow depletion resulting from quarry excavation was calculated as the difference between the flow in the two simulations and remained around 0.3 L/s for the first 40 years of the simulation, then increasing as a greater portion of the excavation reached a level where it intersected the groundwater table. As flow increased in the final year of the simulation (refer **Figure 3**), baseflow depletion also increased to approximately 2.0 L/s during high flow conditions. In terms of percentage of baseflow, the peak depletion rate is 10.1 % and occurs during the drought conditions of May 2020.

As stated in **Section 5**, MALF for the Waitoki Stream is estimated to be 12.6 L/s, which is slightly over simulated by the model. The baseflow depletion that is predicted to occur during the peak low-flow conditions mentioned above is 1.3 L/s, amounting to 10.3% of MALF.

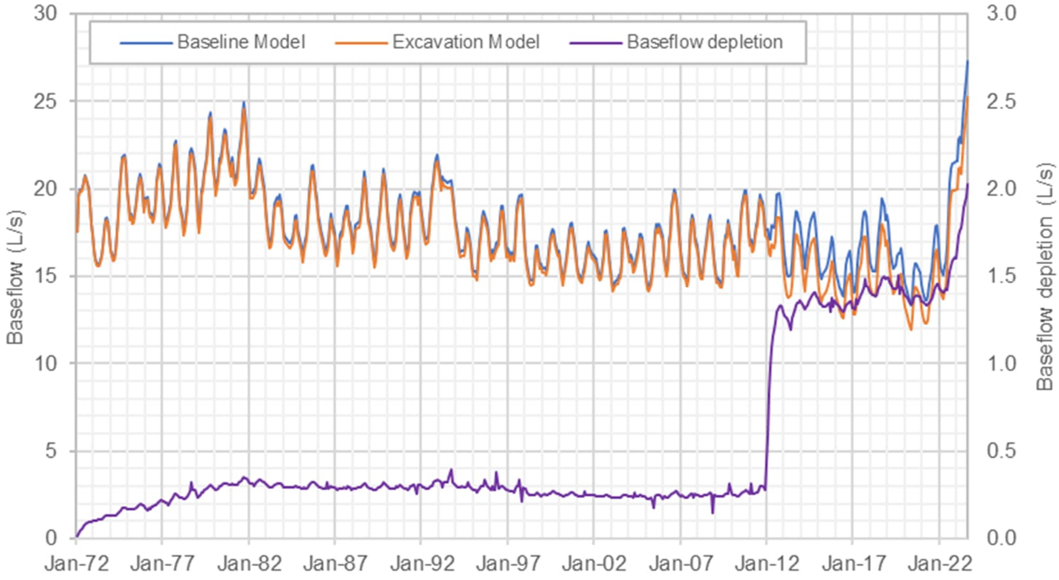


Figure 20. Simulated baseflow and baseflow depletion in Waitoki Stream.

From a water quality perspective, the seepage into the quarry pit and surface runoff generated on-site will be collected in an on-site storage pond. A water sampling protocol for the storage pond will be enacted in accordance with the proposed Water Quality Programme Consent Conditions.

Establishment of baseline water quality for the Waitoki Stream will be undertaken prior to the proposed consent being exercised, as required under the proposed Water Quality Baseline and Ongoing Monitoring Consent Conditions. It is noted that the low level of effects anticipated on streamflow precludes the need for dissolved oxygen or temperature monitoring from a hydrological perspective.

In the event of a trigger level exceedance being detected in the pond, the proposed Water Quality Programme Consent Conditions stipulate that water quality sampling in the stream be undertaken immediately. In the event of an adverse effect on stream flow or water quality being detected, mitigation measures are set out in the Mitigation Plan items within the proposed Groundwater Diversion Permit Conditions.

Waitoki Tributary Adjacent to Quarry
As stated in **Section 3**, stream headwaters are supported by shallow groundwater and there is a potential for flow reduction in the stream when a portion of the catchment is affected by the quarry.

This is the case for the unnamed tributary flowing along the northern edge of the proposed quarry area. Model analysis indicates that under natural conditions the permanent section of this stream emerges approximately 95 m upstream of the confluence with the Waitoki Stream. With the full quarry excavation as proposed, the model indicates that the permanent section of the stream will emerge approximately 55 m upstream from the confluence, i.e. a 40 m reduction in the length of the permanent flowing stream. The maximum reduction in baseflow in this reach is predicted to be 0.09 L/s.

6.2.4 Wetland Effects

A review of the New Zealand Land Cover Database and the Wetland Management Areas Overlay in the AUP showed one wetland within the Waitoki Catchment, as mentioned in **Section 2.3**. This wetland is located approximately 350 m south of the existing quarry and on the opposite side of the Waitoki Stream. Drawdown from the excavation did not extend to this wetland, as shown in **Figure 17**, because the base of the quarry does not extend below the stream bed.

6.2.5 Settlement Effects

Settlement can occur where compressible material is dewatered. In the quarry area the dewatered material will be removed, therefore settlement cannot occur. The material that may be dewatered because it is outside of the quarry excavation area and within the cone of depression is comprised of Albany Conglomerate, which is effectively non-compressible. The area to the north of the quarry is predicted to have up to 7 m of drawdown which is not a risk for land settlement for this type of material. Further to that point, there is no infrastructure in this area to be affected.

The access road to the south of the quarry is also underlain by Albany Conglomerate and is predicted to have only 1 m of drawdown in the underlying aquifer.

6.3 Quarry Engineering Effects

6.3.1 Groundwater Seepage into Quarry

Predicted groundwater seepage into the quarry over the course of the simulation is presented in **Figure 21**, along with the average depth of the quarry excavation. Seepage into the pits generally declines over the course of the excavation as the surrounding material is dewatered, though spikes can be expected when new material is excavated below the water table.

Over the first 40 years of the simulation, seepage into the quarry is predicted to remain at approximately 0.5 L/s (43 m^3/day). The model results predict that the excavation will intersect a greater portion of the water table during the period between 2012-2017 (40-45 years into the excavation sequence) with a corresponding spike in groundwater drainage into the quarry. **Figure 21** shows that during this time the average excavation depth will increase approximately 6 m and the flow will temporarily increase to 6 L/s (518 m^3/day), and then recede to under 2 L/s (173 m^3/day) as the surrounding area is dewatered over a two to three month time period. The flow is predicted to increase to over 2.5 L/s (216 m^3/day) with the unusually wet conditions that have occurred in 2023.

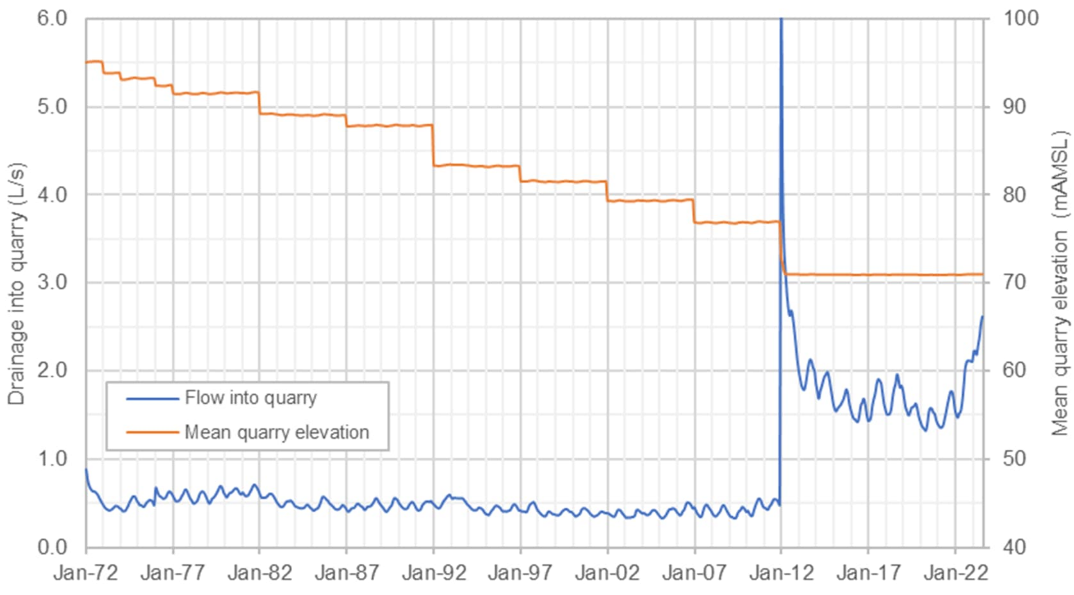


Figure 21. Seepage into the quarry over the course of the excavation.

7. Dust Suppression Analysis

Onsite dust suppression is covered under the erosion and sediment control plan prepared by Air Matters Ltd (2025). The indication is that this will require 1 L/hr for each square m of unpaved road across the site when dust suppression is required. The area of unpaved roads has been calculated to be 6,821 m^2.

For the purpose of this analysis, it is assumed that dust suppression is required 12 hours per day when it is needed at all; i.e. on days with little or no rainfall.

This indicates a total requirement of 81.9 m^3 per day, which is anticipated to only be required between November and April (6 months per year).

As stated in **Section 6.3.1**, the simulated flow into the pit for the first 40 years quarrying is 43.0 m^3/day, with a steep increase occurring after that point when the excavation intersects the water table. This means that a typical day where dust suppression is required will need approximately 1.9 days of flow into the onsite storage pond.

The storage pond is rectangular with sides of 62 x 25 m, and 3 m deep, hence its capacity is 4,650 m^3. Using these numbers, the storage pond can retain up to nearly 57 days of the water requirement for dust suppression. It can be assumed, given that dust suppression is not generally required before November, that each year the dry season will begin with the storage pond at full capacity.

The implication is that a supplemental water source would only be required if there was an extended dry period of approximately two months where dust suppression was required on a daily (or near daily) basis.

8. Auckland Unitary Plan – Chapter E7 Assessment

Chapter E7 of the AUP (2023), which addresses consenting requirements related to 'Taking, using, damming and diversion of water and drilling', was reviewed in relation to the proposed quarry excavation and its effects on groundwater.

From a consenting perspective, the quarry classifies as a groundwater diversion caused by an excavation (refer AUP Table E7.4.1 (A28)) in addition to not meeting permitted activity standards (A20). The activity does not meet the permitted activity standard specified in AUP Section E7.6.1.10 (2) because the quarry is over 1 ha and extends over 6 m in depth. Based on these findings, the proposed quarry expansion is a 'Restricted Discretionary' activity and requires consent.

The matters of discretion upon which consent will be considered are provided in AUP Section E.7.8. The relevant criteria from a groundwater effects perspective are listed in Part 6 of the Section (diversion of groundwater). The primary issues related to the proposed quarry expansion are addressed in **Table 7**.

Consent conditions have been offered by the Applicant in accordance with clause 5(1)(k) of the Fast-track Approvals Act 2024 , which includes reference to two Waitoki Stream flow monitoring sites to be established as part of the monitoring and contingency plan. The recommended monitoring locations are shown as **Appendix B** of this document.

Once the monitoring sites are installed, flow rating curves will need to be established for each site to translate water levels to a corresponding stream depth. The recommended methodology for developing flow rating curves involves undertaking at least three low to medium stream flow measurements and correlating them to continuous flow records from the AC gauge on the Kaukapakapa River, as mentioned in the proposed Waitoki Stream Flow monitoring Condition offered by the applicant.

Table 7. Review of AUP matters of discretion related to groundwater diversion (refer to AUP E7.8.1 (6) (a))

AUP E7.8.1 (6) (a) Category		**Predicted effect**
i	Base flow in rivers and springs	The maximum baseflow depletion predicted for the Waitoki Stream during low flow conditions is 1.3 L/s, amounting to 10.0% of MALF for the stream (**Section 6.2.3**). The minimum flow requirement for the Waitoki Stream is provided in Table 1 of the AUP Appendix 2: River and stream minimum flow and availability. The stream falls under the category of 'Other rivers and streams', hence the default allocation limit is 30% of MALF and the minimum flow requirement is 85% of MALF. The implication is that the level of effects that may result from the proposed quarry expansion are within the allocation limits and associated baseflow reduction envisaged in the AUP criteria and will not violate minimum flow requirements hence no flow mitigation is recommended. It is also noted that this level of baseflow depletion is not predicted to manifest until 40 years into the excavation sequence. Monitoring both upstream and downstream is recommended to be undertaken to account for the inherent uncertainty in modelling analysis. Although highly unlikely, if any adverse effect on streamflow or water quality is detected, mitigation measures are set out in the Mitigation Plan items within the proposed Groundwater Diversion Permit Conditions.
ii	Wetland water levels and flows	There is one wetland within the Waitoki Catchment and it is not affected (**Section 6.2.4**).
iii	Lake levels	Not relevant (no lakes).
iv	Existing groundwater takes	No other groundwater takes are within the area affected by drawdown, therefore there will be no effects on other groundwater users in terms of bore production. The closest bore is at 70 Pebble Brook Road, situated across the Waitoki Stream which constitutes a hydraulic flow barrier except at times of maximum drawdown within the bore (**Section 6.2.2**). Contaminants reaching the bore is considered highly unlikely due to the low bore production rate of 20 m^3/day and the bore being located across the Waitoki Stream. Water quality monitoring in the quarry storage ponds, required under the proposed Water Quality Programme Consent Conditions, will serve as an early warning system for any potential bore contamination by

AUP E7.8.1 (6) (a) Category		Predicted effect
		triggering immediate testing of the bore if a trigger level breach is detected. If any adverse effect on flow or water quality is detected, mitigation measures are set out in the Mitigation Plan items within the proposed Groundwater Diversion Permit Conditions.
v	Groundwater pressures and saline intrusion	Several nearby bores and piezometers are available to use as potential monitoring sites (refer **Figure 9**). The cone of depression will not extend anywhere close to the coast, hence there will not be any risk of saline intrusion (**Section 6.2.1**).
vi	Ground settlement	In the quarry area the dewatered material will be removed, therefore settlement cannot occur. The surrounding area is comprised of non-compressible Albany Conglomerate and only predicted to have a maximum of 7 m of drawdown which is not enough to cause land settlement in this type of material. In addition, there is no infrastructure in this area to be affected. Land settlement effects are addressed in **Section 6.2.5**.
vii	Surface flooding	The excavation will have a dewatering effect and will not increase flood risk in any area.
viii	Cumulative effects with other groundwater diversions	There are no other groundwater diversions within the area affected by the excavation cone of depression.
ix	Discharge of groundwater containing sediment or contaminants	Addressed in the Erosion and Sediment Control report included with the resource consent application (LDE 2023).
x	Effects on historic heritage sites	Based on a review of the AUP Overlay there are no heritage sites within the Waitoki Catchment. No heritage sites that will be affected.
xi	Terrestrial and freshwater ecosystems and habitat	Ecological effects are being addressed by Bioreasearches Ltd. It is presumed the total baseflow depletion for the entire catchment, generally under 2.0 L/s, will not cause harm to aquatic habitat and is within the allocation limits set forth in the AUP.

The matters set out in E7.8.1(6)(b)-(f) are addressed within the Assessment of Environmental Effects prepared by Barker & Associates Limited.

9. Conclusions

WWLA has completed a groundwater effects analysis as to support an application for fast-track consenting application for the expansion of the Kings Quarry site. This analysis comprised two primary components:

1. Developing a conceptual hydrogeological model of the site from available information.

2. Developing a numerical groundwater model to support the groundwater assessment.

The complete quarrying operation, as proposed, will occur over a 45 year period with the quarry eventually expanding to approximately 29 ha in area. This modelling assessment provided a quantitative analysis of groundwater effects that may result from the proposed quarry excavation comprising the following:

a) An evaluation of the depth and extent of drawdown resulting from pit excavations;

b) An assessment of neighbouring bore interference effects;

c) An assessment of potential depletion effects on streams and wetlands within and adjacent to the proposed quarry area due to dewatering and drawdown;

d) Estimation of the rate and volume of groundwater seepage into the quarry; and

e) An assessment of predicted groundwater effects relative to Auckland Unitary Plan (AUP) criteria for groundwater diversions.

A numerical model was developed in MODFLOW, and calibrated to groundwater elevation at two locations, estimated MALF, and groundwater drainage from the existing quarry. Though limited data was available, all indications are that the model generated realistic outputs and was fit for the purpose of general analysis of groundwater conditions with and without quarry development.

A pair of 52-year transient simulations were run, comparing groundwater conditions and stream baseflow with and without the quarry. The following area the key conclusions with regard to groundwater effects:

- Drawdown outside of the excavation area is limited to 7 m, at a maximum, which occurs directly north of the completed quarry.
- The extent of drawdown is constrained by surrounding streams that control groundwater elevation. This is largely by design as the quarry is designed to not extend vertically below the Waitoki Stream channel to avoid stream depletion.
- Proposed water quality monitoring of an on-site storage pond is recommended as a consent condition. If blast chemicals are detected in excess of trigger levels (to be determined), then further sampling of the Waitoki Stream and nearby farm bore should be undertaken. If adverse effects are detected on either, appropriate mitigation measures should be implemented in accordance with Consent Conditions.
- No bores are within the area affected by drawdown.
- The maximum baseflow depletion across the Waitoki Stream catchment is 2.0 L/s during high-flow conditions. Durrin low flow conditions, when the stream is most sensitive to depletion, the maximum depletion rate is 1.3 L/s, approximately 10% of MALF. These effects are within allocation limits in the AUP and hence considered to be within the accepted criteria.
- There is one wetland in the catchment, but it is outside of the envelope of effects because is on the opposite side of the Waitoki Stream from the quarry.
- There is predicted to be limited groundwater seepage into the quarry (~0.5 L/s) until 40 years into the excavation period when a larger portion of aquifer material is excavated. At this point there is a brief spike to 6.0 L/s, which drops to a more consistent rate of 2-2.5 L/s thereafter.

- AUP criteria indicates that the proposed quarry development is a Restricted Discretionary Activity, hence a consent is required. A review of applicable matters of discretion indicates that there are no major issues related to groundwater effects from the proposal.

In summary, the predicted effects on groundwater and groundwater related features within the Waitoki Catchment are considered to be minor, with no adverse consequences to people or the environment resulting from the proposed quarry excavation.

10. References

Air Matters Limited; (2025). Assessment of the discharge of contaminants into air (dust) from the operation of Kings Quarry. Consultancy report prepared for *King's Quarry Limited*.

Auckland Unitary Plan (AUP) Operative in Part; 2023. (https://unitaryplan.aucklandcouncil.govt.nz/pages/plan/Book.aspx?exhibit=AucklandUnitaryPlan_Print).

Pattle Delamore Partners (PDP); 2008. Groundwater Effects Assessment - Flat Top Quarry Expansion. *Prepared for Winstone Aggregates*.

Grant Fisher Industrial Geology; 2009. Geological Evaluation of Conglomerate Resources, Wainui Quarry. *Prepared for Winstone Aggregates*.

Land Development & Engineering (2023). Kings Quarry Erosion and Sediment Control Report. *Prepared for Kings Quarry Ltd.*

Appendix A. SMWBM Overview

Table 8 provides and high-level description of the parameters used in the SMWBM_VZ and **Figure 22** is a conceptual diagram of the key components of SMWBM_VZ model structure and functionality. The parameters used to calculate groundwater recharge are provided in **Table 9**.

Table 8. SMWBM_VZ parameters.

Parameter	Name	Description
ST (mm)	Maximum soil water content	ST defines the size of the soil moisture store in terms of a depth of water
SL (mm)	Soil moisture content where drainage ceases.	Soil moisture storage capacity below which sub-soil drainage ceases due to soil moisture retention.
FT (mm/day)	Sub-soil drainage rate from soil moisture storage at full capacity	Together with POW, FT (mm/day) controls the rate of percolation to the underlying aquifer system from the soil moisture storage zone. FT is the maximum rate of percolation through the soil zone.
ZMAX (mm/hr)	Maximum infiltration rate	ZMAX and ZMIN are nominal maximum and minimum infiltration rates in mm/hr used by the model to calculate the actual infiltration rate ZACT. ZMAX and ZMIN regulate the volume of water entering soil moisture storage and the resulting surface runoff. ZACT may be greater than ZMAX at the start of a rainfall event. ZACT is usually nearest to ZMAX when soil moisture is nearing maximum capacity.
ZMIN (mm/hr)	Minimum infiltration rate	
POW (>0)	Power of the soil moisture-percolation equation	POW determines the rate at which sub-soil drainage diminishes as the soil moisture content is decreased. POW therefore has significant effect on the seasonal distribution and reliability of drainage and hence baseflow, as well as the total yield from a catchment.
PI (mm)	Interception storage capacity	PI defines the storage capacity of rainfall that that is intercepted by the overhead canopy or vegetation and does not reach the soil zone.
AI (-)	Impervious portion of catchment	AI represents the proportion of the catchment that is impervious and directly linked to drainage pathways.
R (0,1)	Evaporation – soil moisture relationship	Together with the soil moisture storage parameters ST and SL, R governs the evaporative process within the model. Two different relationships are available. The rate of evapotranspiration is estimated using either a linear (0) or power-curve (1) relationship relating evaporation to the soil moisture status of the soil. As the soil moisture capacity approaches, full, evaporation occurs at a near maximum rate based on the mean monthly pan evaporation rate, and as the soil moisture capacity decreases, evaporation decreases according to the predefined function.
DIV (-)	Fraction of excess rainfall allocated directly to pond storage	DIV has values between 0 and 1 and defines the proportion of excess rainfall ponded at the surface due to saturation of the soil zone or rainfall exceeding the soils infiltration capacity to eventually infiltrate the soil, with the remainder (and typically majority) as direct runoff.
TL (days)	Routing coefficient for surface runoff	TL defines the lag of surface water runoff.
GL (days)	Groundwater recession parameter	GL governs the lag in groundwater discharge or baseflow from a catchment.
QOBS (m^3/s)	Initial observed streamflow	QOBS defines the initial volume of water in the stream at the model start period and is used to precondition the soil moisture status.
K_v (m/s)	Vertical hydraulic conductivity at full saturation	K_v defines the vertical hydraulic conductivity of the parent geology type when at full saturation. The Kv value sets the upper limit on the rate of flow in the vadose zone.

Parameter	Name	Description
VGn (-)	van Genuchten constant soil type	VGn is a text book value used to define the relationship between soil moisture status and hydraulic conductivity of soil. It is used to determine the actual vertical hydraulic conductivity, which reduces as the soil dries.
n_s (-)	Soil zone porosity	n_s defines the porosity of the soil zone.
n_{vz} (-)	Vadose zone porosity	n_{vz} defines the porosity of the vadose zone and is therefore determined from an understanding of the parent geology material.
D (m)	Thickness of vadose zone (depth to water table)	D defines the thickness or the depth of the vadose zone.
GW_OnOff (True/False)	Groundwater on or off Selection	This feature of the SMWBM allows you to turn off the groundwater component of a sub-catchment so it does not report back to the river. This feature is useful when integrating with groundwater models.
AA, BB	Coefficients for rainfall disaggregation.	Used to determine the rainfall event duration and pattern. Default values usually suffice.

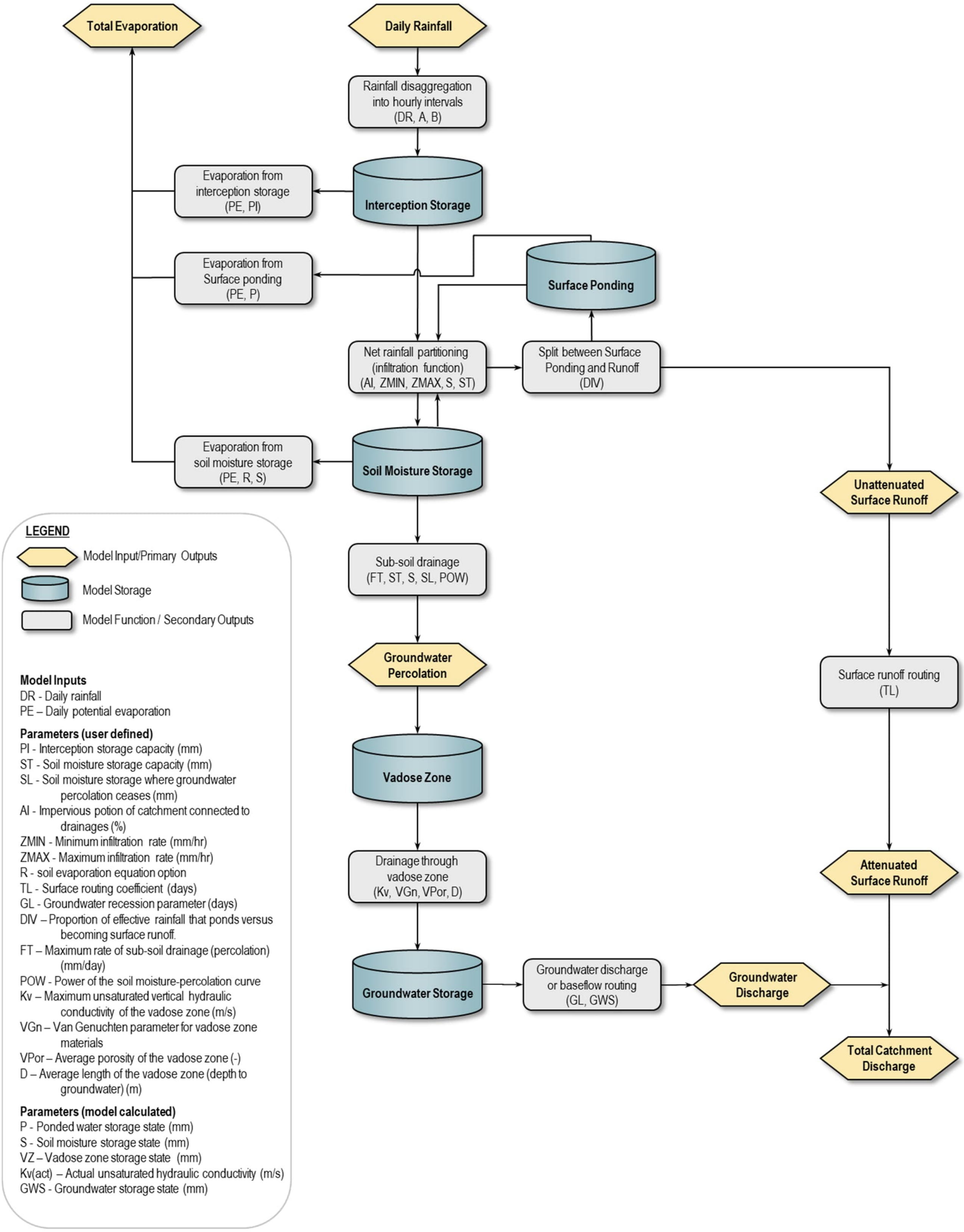


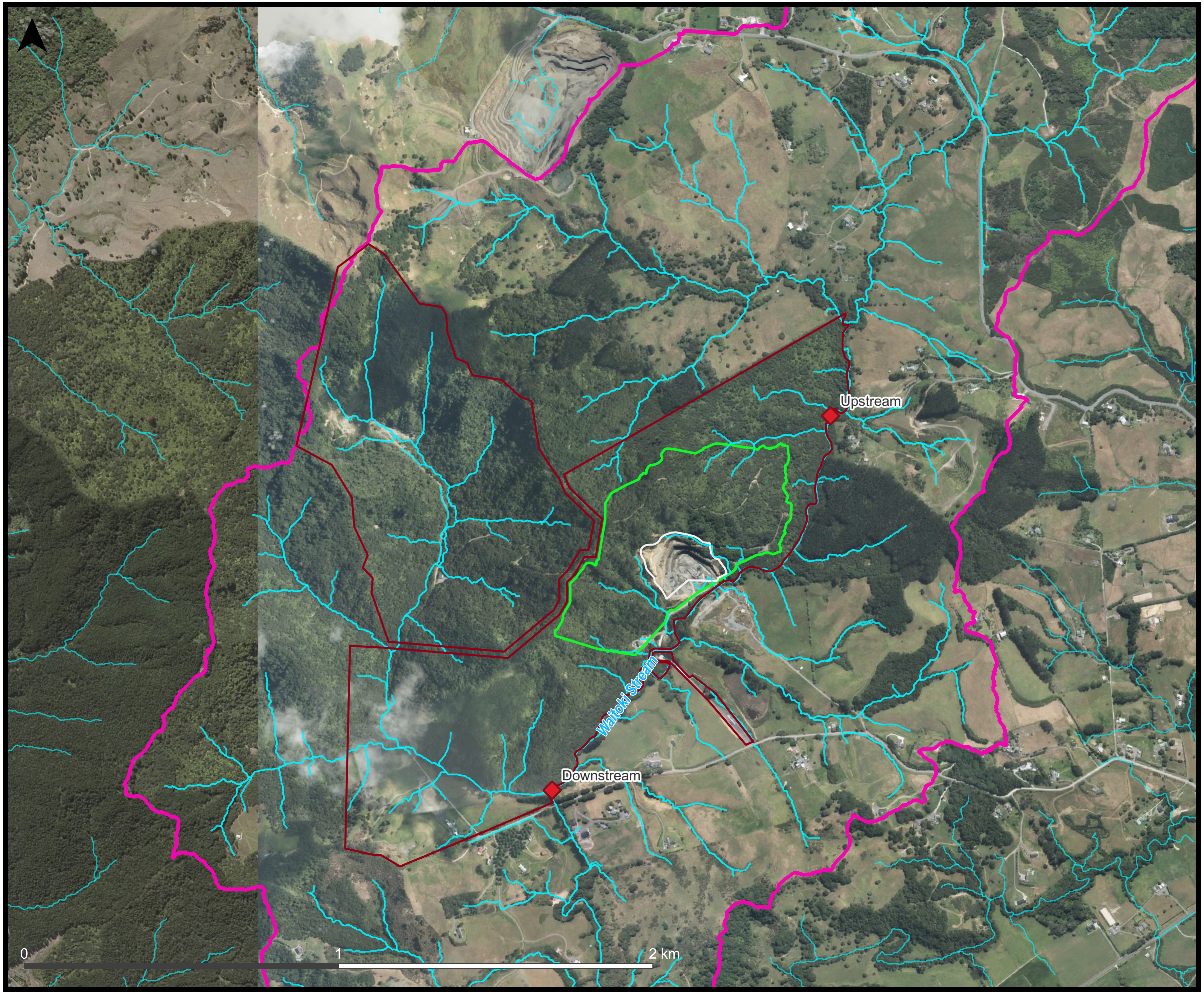
Figure 22. Flow diagram of the SMWBM_VZ structure and parameters.

Table 9. Parameters applied for SMWBM model for Kaukapakapa @ Taylors Road Catchment.

Area (km^2)	ST	Zmax	FT	POW	PI	AI	DIV	TL	QOBS	SL	AA	BB
61.9	310	1.5	0.7	1	2.0	0.2	0	1	43330	0	0.216	0.22

Appendix B. Recommended Flow Monitoring Location

The establishment of two flow monitoring sites in the Waitoki Stream are recommended as part of the Monitoring and Contingency Plan. The recommended downstream location is downgradient from the quarry near the southern end of the Kings Quarry property (NZTM 1739172 5947243) and the recommended upstream location is approximately 160 m north of the northern edge of the proposed quarry (NZTM 1740060 5948465) as shown in **Figure 23**.



Map Title:
Recommended Waitoki Stream monitoring location

Project:
Kings Quarry Groundwater Model

Client:
Semenoff Group Ltd.

Legend

- **Waitoki Catchment (Model boundary)**
- **Property boundary**
- **Existing quarry**
- **Proposed quarry**
- **Streams / rivers**
- **Recommended stream monitoring location**

Data Provenance
Aerial imagery and land parcels from Land Information New Zealand

Drawn by: J Scherberg
11/03/2025

Layout Name
Recommended Stream Monitoring site

WILLIAMSON WATER & LAND ADVISORY

Figure 23.