19. Hydrogeology

The Hydrogeology Assessment Report presents an assessment of the potential effects of the construction and operation of the Project on the existing groundwater regime. The Hydrogeology team assessed the potential effects on groundwater by field investigations including drilling, lithological logging, installation of monitoring wells and aquifer testing, and through the development of a regional 3-dimensional steady state groundwater model calibrated to water level monitoring data.

The Hydrogeology Assessment Report provides a detailed description of the existing groundwater environment in the Project area and the methodology used to model and determine effects. The following is a summary of the issues and potential effects identified in the Report.

This summary and the Report subsequently inform the recommended mitigation contained in Section 28 and will inform the Project conditions.

19.1 Existing groundwater environment

Several hydrogeological regimes are found within the Project area and are strongly influenced by the underlying geological units. The regional hydrogeology is described in Section 4.3.4 of this AEE.

19.1.1 Groundwater levels and quality

Borehole records obtained by the Hydrogeology team from Auckland Council indicate a total of 112 boreholes drilled within a 2 km radius of the indicative alignment. The Hydrogeology team obtained water levels from 44 of these boreholes, for which depth to groundwater ranged from 1 m to 132 m below ground level (BGL), with a median depth of 8 m BGL.

The groundwater quality of the Waitemata Aquifers can be broadly divided into shallow groundwater and deeper groundwater. Shallow groundwaters (<200 m depth) commonly have a high total hardness/total alkalinity ratio[117], and are hard calcium carbonate waters with near-neutral pH, high total iron (>1.0 g/m^3), and silica concentrations greater than 40 g/m^3[118]. In comparison, deeper groundwaters commonly have a low total hardness/total alkalinity ratio, and are soft sodium bicarbonate waters with pH >8.5, low total iron (<0.2 g/m^3) and silica concentrations of less than 40 g/m^3.

19.1.2 Groundwater abstraction and use

There are two main clusters of boreholes in the Project area, namely at Pūhoi and Warkworth. These boreholes primarily tap the Waitemata Group and have been drilled mainly for either domestic or stock water supply or as observation piezometers. Borehole depths range from 6 m to 305 m BGL, with an average depth of 135 m BGL.

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[117] Total hardness is a measure of total concentration of calcium and magnesium while total alkalinity is a measure of the total concentration of carbonate and bicarbonate anions.

[118] Refer Section 3.10 of the Hydrogeology Assessment Report.

Table 19-1 summarises information for the 11 existing groundwater consents in the Pūhoi and Mahurangi catchments. The majority of the yields are low to very low. However, the exception is the recently obtained Watercare Services Ltd municipal supply abstraction in Warkworth, which is consented to abstract groundwater at a rate of up to 50 L/s (4,320 m^3/day). This bore is extremely high yielding, having intersected a highly fractured zone associated with a local fault. As such, the Watercare bore is considered atypical for the rock type and region.

Table 19-1: Existing groundwater consents

Consent No	Name	Allocation (m^3/day) [L/s]	Bore Depth (mBGL)	Expiry Date	Purpose
21606	Buckley	100 [1.2]	168	31/05/2015	Irrigation Market Garden
22840	Morton-Jones	40 [0.46]	305	31/05/2014	Community Supply
23056	Lawson Investments Ltd	40 [0.46]	15	01/05/2015	Irrigation Market Garden
31071	Warwick Rhodes Contractors Ltd	80 [0.93]	Unknown	31/05/2015	Potable Supply
34117	Summerset Villages Ltd	60 [0.69]	180	31/12/2029	Potable Supply
34119	Stockyard Holdings Ltd	60 [0.69]	180	31/12/2029	Potable Supply
35264	Watercare Services Ltd	4,320 [50.0]	200	03/04/2045	Municipal
35620	Atlas Concrete Ltd	80 [0.93]	160.5	31/05/2029	Industrial
36585	Bio Marine Properties Ltd	100 [1.2]	Unknown	31/05/2029	Industrial
38170	Pūhoi Valley Cheese	130 [1.5]	Up to 4 bores	31/05/2025	Industrial
40713	Southern Paprika Ltd	500 [5.8]	60	31/05/2029	Irrigation

The Hydrogeology Assessment Report does not specifically identify groundwater takes less than or equal to 20 m^3/day. Such takes can be undertaken as permitted activities, provided they are not within the High Use Aquifer Management Zone[119]. However, the Report is not influenced by the groundwater takes that are less than 20m^3/day.

[119] Defined and mapped in the ARP:ALW, not within the Project area.

19.1.3 Groundwater / surface water interaction

Potential changes in groundwater levels or flows may affect surface water features such as streams/rivers, springs/seeps, ponds, wetlands and drains. A desktop survey of aerial photos and maps identified approximately 45 such features within 2 km of the indicative alignment that could potentially be affected.

In areas underlain by the Waitemata Group or Northern Allochthon materials, groundwater typically emerges in the form of seeps at the base of slopes, and springs along geological boundaries. Some of these springs and seeps feed small streams, many of which are ephemeral.

In areas where alluvium has infilled the valleys, groundwater is responsible for the baseflow in the larger streams and rivers. Baseflow also feeds wetlands such as those found north of Carran Road in the vicinity of Warkworth.

19.2 Assessment methodology

The Hydrogeology team undertook a Project field investigation programme February and May 2013 to obtain site-specific geological and hydrogeological data. The scope of the investigation included:

- Drilling of 28 boreholes;
- Geotechnical testing in the boreholes;
- Installation of piezometers for recording groundwater levels;
- Monitoring of groundwater levels; and
- Aquifer hydraulic testing, including rising and falling head tests, and packer (lugeon) testing.

The details and locations of the boreholes are shown in Appendix A of the Hydrogeology Assessment Report.

19.2.1 Geological drilling

The ground conditions encountered during investigations typically comprise of Pakiri Formation with alluvium and colluvium deposits observed in low lying regions and valleys. The Hydrogeology team identified Northland Allochthon in the Schedewys Hill area and near the Moirs Hill Road area. The team constructed a geological long section and cross sections through specific areas along the alignment using the collected information.

19.2.2 Groundwater levels and flow measurement

Piezometers installed in 25 of the drilled boreholes provided information on static water levels. In summary, depth to groundwater is typically shallower, being close to the surface, and absolute groundwater level is typically lower in the valleys where infill alluvium is present. In the upland areas typically comprising Waitemata Group materials, groundwater levels are higher, albeit deeper (ie greater distance from the ground surface).

Groundwater levels in the alluvial deposits are shallow (typically between 0.17 m and 0.9 m BGL) and relatively sensitive to rainfall events and higher stream flows. These factors suggest that the alluvium deposits are directly connected to surface processes. Piezometer results indicate an upward flow potential in valley floor locations, though this is likely influenced by very dry conditions during the investigation period.

Groundwater levels in the Waitemata group are deeper (typically between 3.8 m BGL and 39.93 m BGL) and have shown little variation over time and little response to rainfall events.

A model developed for the Project shows that groundwater predominantly flows through the alignment from the west to the east. However, south of Moirs Hill Road between Ch. 57000 and Ch. 58000, groundwater is flowing southward and crossing the alignment from the eastern side.

19.3 Assessment of hydrogeological effects

The impact of the Project on groundwater will largely arise from deep excavations. Excavations below the water table can impact on the natural groundwater regime in the following ways:

- **Drawdown** – Groundwater drawdown and associated ground settlement may have the potential to impact on existing structures and services.
- **Surface water resources** – Reduction in groundwater levels may affect stream baseflow regimes, and alter present inflows and outflows from springs, streams, rivers, ponds and wetlands.
- **Groundwater quantity and quality** – Reduction in groundwater quantity (yield) and possible changes to water quality at existing abstraction bores through the alteration of groundwater flow patterns.
- **Migration of existing contaminants** – Potential to spread contaminants residing in areas of past landfilling and/or contaminated sites through groundwater drawdown in these areas.

19.3.1 Groundwater drawdown

The Hydrogeology team assessed drawdown for each of the proposed cuts with a calibrated numerical groundwater model. The extent of groundwater drawdown from the cuts on the indicative alignment is shown in Figure 19-1, which indicates that drawdown is very localised to the cut alignment. Although the maximum extent of drawdown extends to 700m from the centre of the indicative alignment, drawdown of any great significance (ie 5m or greater) is typically constrained to within 160m of the indicative alignment.

There are only two existing consented abstraction bores and the calculated drawdown profile. The maximum drawdown impact simulated in these bores is only 0.5m. Both these bores are over 150 m deep and hence the hydrogeologists consider this level of impact to be minor.

Groundwater drawdown has the potential to induce ground settlement in soft compressible sediments, such as alluvium and highly weathered rock or clay. The cuts that will induce groundwater drawdown are mainly located in Waitemata Group materials that display very low compressibility potential. Groundwater drawdown is typically localised to within the Waitemata Group materials, and hence the Hydrogeology team do not expect measureable settlement.

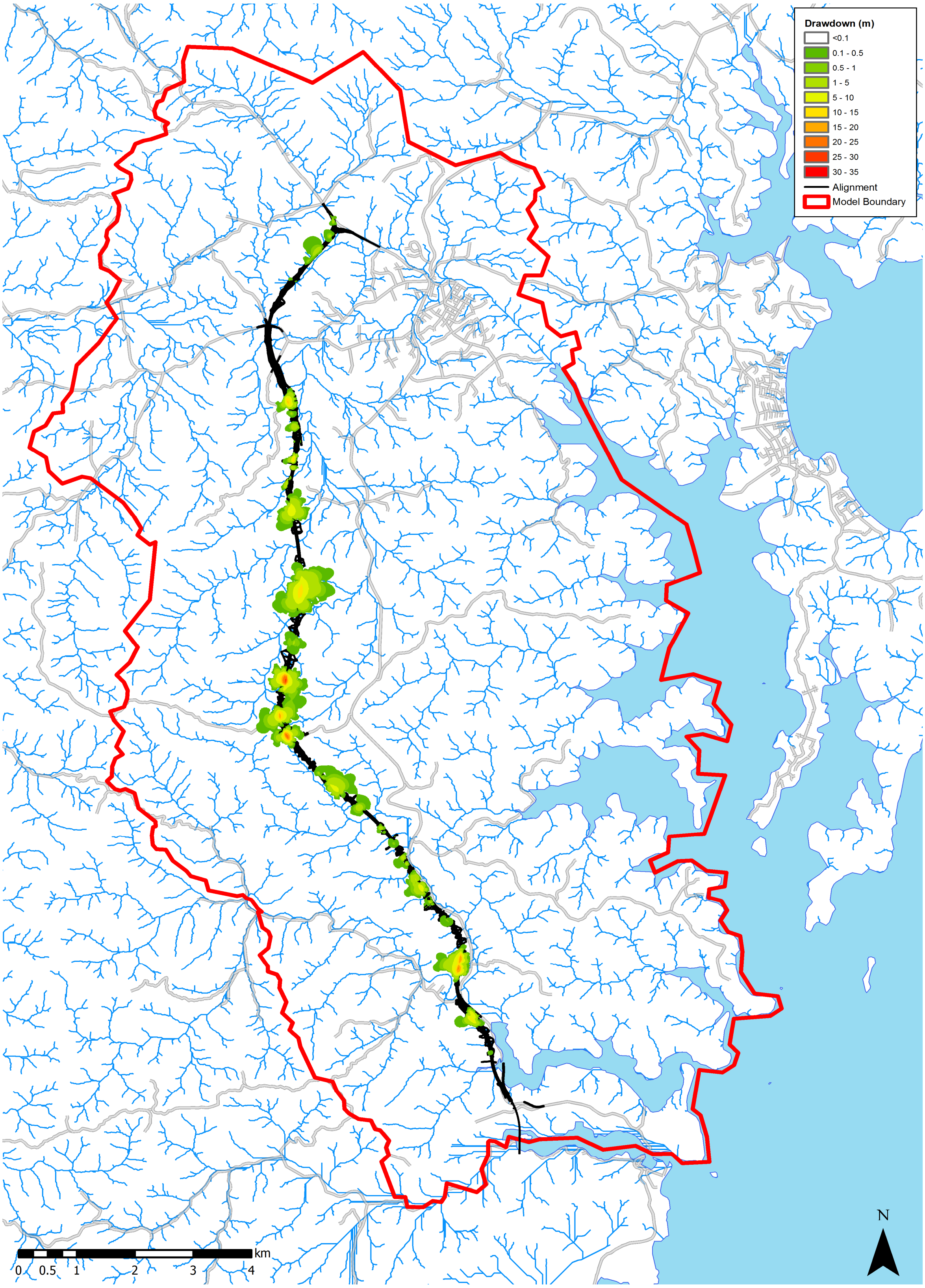

Figure 19-1: Extent of groundwater drawdown from alignment cuts

19.3.2 Impact on neighbouring groundwater users

As noted above, only two of the 112 bores within a 2km radius of the indicative alignment are located within the calculated drawdown profile. Details for these bores are shown in Table 19-2. They are of small diameter and deep, which suggests that the shallow aquifer has very low permeability. Drilling to construct these wells to significant depth was necessary for the Hydrogeology team to gain an acceptable yield.

Table 19-2: Bores located within predicted drawdown profile

AC bore ID	Owner	Purpose	Bore details	Estimated drawdown (m)
828	C Brown	Stock and domestic supply	Diameter: 100 mm Bore Depth: 160 m Casing Depth: 50 m	0.5
22861	Boys to Men Trust	Domestic Supply	Diameter: 100 mm Bore Depth: 200 m Casing Depth: 80 m	< 0.5 (located in cut)

The estimated drawdown for these bores is 0.5m or less. For bore 828, the Hydrogeology team considers this drawdown to be less than minor in terms of the impact on the ability of the bore to supply water for stock and domestic purposes. It is noted that bore 22861 is located in the vicinity of a large cut at Billing Road. This property and bore have been purchased by the NZTA and consequently the groundwater take will cease to be used for a domestic water supply.

19.3.3 Stream baseflow reduction

The Hydrogeology team assessed the reduction in groundwater contributions to local streams (stream baseflow reduction) with a calibrated numerical groundwater model that considered the worst case impact on perennial streams crossing or adjacent to the indicative alignment.

Stream baseflows under natural conditions range from a trickle or 15% of a typical garden hose (0.2 L/s) to roughly a third of a fire hydrant (20 L/s), respectively. The modelled reductions in stream baseflows as a result of the Project are shown in Table 19-3.

Table 19-3: Modelled stream baseflow reductions

Stream chainage	Stream order	Baseflow (natural) (L/s)	Baseflow (with cut) (L/s)	Baseflow reduction (L/s)	Percentage decrease (%)
47400	1	0.10	0.10	0.01	6.3
47700	1	0.03	0.02	0.01	46.0
48000	2	0.66	0.62	0.04	5.9
49500	4	2.69	2.69	0.00	0.1

Stream chainage	Stream order	Baseflow (natural) (L/s)	Baseflow (with cut) (L/s)	Baseflow reduction (L/s)	Percentage decrease (%)
50800	1	0.06	0.05	0.01	16.3
52100	4	3.41	3.33	0.08	2.4
54700	4	7.29	7.18	0.11	1.6
55000	1	0.14	0.14	0.00	1.4
55300	2	0.53	0.50	0.03	5.2
56400	2	0.16	0.14	0.01	9.5
56700	2	0.30	0.26	0.04	12.9
58400	2	0.16	0.15	0.01	3.5
60200	3	1.18	1.17	0.00	0.4
61100	2	0.20	0.20	0.00	0.3
61300	1	0.04	0.04	0.00	2.4

The absolute magnitude of reduction in baseflows is from 0.0007L/s to 0.11L/s. Lower order streams (ie smaller streams with less baseflow) are impacted more significantly in terms of stream baseflow reduction (0.3-46.0% of flow) than higher order streams (0.1-2.4% of flow). However, flow in these lower order streams is small and hence the stream is likely to be a perennial wet area rather than a free flowing stream.

Overall, the absolute reduction in flow in these areas is very small and unlikely to be detectable over and above the influence that surface runoff may have. The Hydrogeology team considers the reduction in baseflow from a flow volume perspective to be minor. The consequential influence on the Mahurangi River will be imperceptible. As such, the Hydrogeology team considers that the effects on existing surface water takes from the Mahurangi River will be negligible.

19.3.4 Groundwater quality

Effects on groundwater quality as a result of groundwater disturbance required by the Project may include:

- **Mobilisation of metals** – Change in the redox characteristics within the aquifer at the position of the new 'drawn down' groundwater table resulting in the mobilisation of connate metals from within the aquifer, commonly seen as iron seeps or staining on cut exposures or drainage swales;
- **Turbidity production** – any excavation of aquifer materials to beneath the groundwater table has the potential to increase the turbidity of groundwater;

- **Reduced assimilative capacity** – Reduction in stream baseflow may reduce the assimilative capacity of the streams, exacerbating any water quality issues already occurring in streams; and
- **Shallow aquifer contamination** – Road runoff infiltration of the local groundwater system may contaminate shallow groundwater.

The Hydrogeology team considers the scale of these effects on groundwater quality throughout the Project area to be minor due to the low permeability, and thus very slow infiltration and flow rates of Waitemata Group materials, and the very small volumes of water that will be diverted at the cuts.

It is unlikely that surface discharges of TSS during construction will affect groundwater quality due to the low permeability and low likelihood of runoff infiltrating the groundwater system. However, the Hydrogeology team recommends that stormwater treatment ponds located in elevated areas where there are downward pressure gradients have a clay or synthetic liner with low transmissivity. The team does not consider liners necessary in wetland areas where the flow potential is upwards towards the surface as the risk of surface contamination is low.

19.3.5 Overall effects on groundwater

The Hydrogeology team considers construction and operational impacts of the Project on groundwater to be negligible because of the surface water containment system developed for the Project, the underlying groundwater system being so impermeable and diverted groundwater being re-directed in natural water courses through the surface water drainage system.

19.4 Recommendations and mitigation

Based on the indicative design for the Project, the Hydrogeology team does not consider mitigation or monitoring necessary for groundwater impacts because of the very low likelihood of any significant impacts, the fact that there are no affected parties, and because any diversions are routed through the Project's stormwater system or discharged back into natural watercourses. This conclusion will be confirmed following detailed design of the Project. I support this conclusion.