Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

Assessment of the Risks of Elevated Aluminium in Surface Waters of the Northern Wairoa Catchment

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Cover image credits: Stretches of Wairoa River by Dargaville, Northland. Courtesy - Oblique Photos May 2021.

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Executive Summary

The community in Dargaville is concerned about the health of the Northern Wairoa River. In July 2024, water quality testing by Cannalytic Profiling (an Auckland based water testing laboratory) for the Dargaville Ratepayers and Residents Association, reported high levels of aluminium (Al) in Northern Wairoa River and Dargaville drainage samples (at Dargaville Wharf - 3.253 mg/L, and at Tirarau Street - 1.768 mg/L). Northland Regional Council (NRC) became aware of the test results after receiving a media enquiry on 9 July 2024. A follow-up investigation, sampling and testing of Al undertaken by NRC on 24 July 2024 confirmed high levels of total Al in river water samples at several sites in the vicinity of Dargaville, which warranted further investigation. The results from NRC's 24 July 2024 sampling indicated that elevated concentrations of Al were not confined to the section of the Northern Wairoa River immediately adjacent to Dargaville township as the highest concentrations of total Al (in the water as well as sediment samples) were found 50 metres upstream of Awakino River's confluence with the Northern Wairoa River.

To obtain better context regarding the potential risk of Al contamination in the surface waters of Northern Wairoa catchment, NRC undertook a preliminary investigation by analysing some retrospective heavy metal tests associated with the regionwide State of the Environment (SOE) river monitoring undertaken in 2023 and by undertaking some additional water quality and sediment sampling in the Dargaville area during winter 2024.

It was apparent from the SOE river water quality monitoring data collected between March and June 2023, that the exceptionally high aluminium concentrations (10 – 34 g/m^3) in the Northern Wairoa catchment mostly coincided with high cumulative rainfalls preceding the sampling events and consequent high concentrations of suspended sediment in waterways (indicated by exceptionally high total suspended solids (TSS) of 400-1300 g/m^3). Some of the high Al concentrations also coincided with upstream bank erosion. However, for these high Al concentrations pH levels were always within a range typically found in Northland rivers (i.e. between 6.5 and 8) indicating any risk of aluminium toxicity to be unlikely. It is the acidic pH (around pH 5 or below), and high dissolved organic carbon or DOC (indicator of reducing geology and soil type) that determine Al toxicity which can have harmful effects on aquatic life such as physiological deformities and fish death.

The results from the Kaipara Harbour coastal water quality monitoring sites showed that the dissolved Al concentration was low (below detection limit of <0.1 g/m^3) even for the maximum total Al concentration of 13 g/m^3 at Kaipara Harbour at Wairoa River, indicating most of the aluminium concentration in the harbour to be comprised of particulate Al and very low dissolved Al. Therefore, it is possible that while Al is naturally available in the aquatic environment of Northern Wairoa catchment as well as other parts of Northland due to geology and erosion processes, a bigger proportion of it stays as particulate and therefore not bioavailable. A strong correlation between total Al and sediment (TSS and turbidity) was a clear indication of the naturally occurring process of Al transportation in surface waters of Northland via sediment discharge following heavy storm events.

Although it is suspected that the high Al concentrations in the surface waters of the Northern Wairoa catchment has been the reality for a long time due to naturally occurring processes, it is acknowledged that this report did not investigate the bioaccumulation of Al and its long-term implication on the physiology of aquatic life. According to a recent investigation undertaken by the Ministry for Primary Industries (MPI) on cloudy-eyed snapper caught in the Kaipara Harbour - histological examinations and tests for heavy metals, including Al, and other emerging chemicals were undertaken - have not identified a cause of the condition. Cawthron Institute conducted tests of the affected snapper for common foodborne pathogens and contaminants, including heavy metals, but these tests did not find any cause for concern.

According to SOE monitoring data elevated Al concentrations in Northland rivers, particularly in the Northern Wairoa and Victoria Rivers, are most probably associated with catchment soil chemistry, erosion prone geology and overland flow following heavy rainfall events. It is possible that the freshwater environments of the Northern Wairoa catchment (as well as several other catchments in Northland) have been exposed to Al leaching for a long time due to naturally occurring processes which can also be exacerbated historically by human activities such as clearance of native forests and draining of wetlands. Aluminium in surface waters of the Northern Wairoa catchment is mostly contained in particulate matter and a little amount as dissolved fraction and therefore not necessarily available for bioaccumulation. As extreme weather events such as flash floods, prolonged dry periods, and cyclones are becoming more frequent in Northland due to climate change impacts, erosion, and sediment discharge together with these exceptionally high concentrations of Al will be more common and unavoidable in Northland surface waters.

1. Background

The community in Dargaville is concerned about the health of the Northern Wairoa River. In July 2024, water quality testing by Cannalytic Profiling (an Auckland based water testing laboratory) for the Dargaville Ratepayers and Residents Association, reported high levels of Aluminium (Al) in Northern Wairoa River and Dargaville drainage samples (at Dargaville Wharf - 3.253 mg/L, and at Tirarau Street - 1.768 mg/L). Northland Regional Council (NRC) became aware of the test results after receiving a media enquiry on 9 July 2024. NRC logged the reported high Al levels as an environmental incident and commenced its own investigation. A follow-up Al sampling (24 July 2024) and testing undertaken by the NRC Compliance Monitoring Team confirmed high levels of total Al in river water samples at several sites in the vicinity of Dargaville, which warranted further investigation (Appendices 1a and 1b). The results from NRC's 24 July 2024 sampling indicated that elevated/high concentrations of Al were not confined to the section of the Northern Wairoa River immediately adjacent to Dargaville township as the highest concentrations of total Al (in the water as well as sediment samples) were found 50 metres upstream of Awakino River's confluence with the Northern Wairoa River. The Dargaville Ratepayers and Residents Association undertook further Al testing around mid-August at 16 locations along the lower reaches of Wairoa River, between Ruawai and the Awakino River confluence. While the Al results in July were still high (with the highest concentration reported in the Wairoa River 50 m upstream of the Awakino River confluence), the results in August returned to ranges typically found in rivers (<1 mg/L).

Initially, members of the Dargaville community suspected the source of Al contamination was the Dargaville Wastewater Treatment Plant (WWTP) or other human sources including a historic brick manufacturing site. There was also speculation that the high Al levels were the cause of the so-called "Zombie fish" that were being caught by fishers in the Kaipara Harbour at the time. However, without sampling protocol details for the initially reported results such as exact sampling locations, sampling time, sampling environment and laboratory analysis procedure it was difficult to answer the key questions regarding Al contamination risk to aquatic life and its concentration fluctuation in the watercourses of Northern Wairoa catchment from the results. It was also unclear whether the Al results were associated with total or dissolved fraction of the metal sampled which (together with other water quality factors) is important to know in order to assess the possible effects of aluminium contamination on aquatic life.

To obtain better context regarding the potential risk of Al contamination in the Northern Wairoa River, NRC undertook a preliminary investigation by looking at some retrospective heavy metal tests associated with the regionwide State of the Environment (SOE) River monitoring undertaken in 2023 and by undertaking some additional water quality and sediment sampling in the Dargaville area during winter 2024. This report aims to synthesise the findings from this preliminary NRC investigation and other expert opinions regarding the possible risk of Al contamination in the Northern Wairoa catchment.

2. Aluminium in aquatic environment

Aluminium is one of the most abundant metals found in earth's crust. The erosion and weathering of subsurface earth materials (e.g., soil, rocks, minerals) which allow sediment deposition along rivers, estuaries, and coastal waters, are main natural sources of Al in aquatic environments. It can also be abundantly released by human activities associated with industrial processes (e.g., manufacturing processes using Al, wastewater effluents, sludges from water treatment plants, solid waste, mining). It is to be noted that Al is also widely used in consumer products such as antacids, food additives, cookware, anti-perspirants, and cosmetics. Al can persist in both marine and freshwater environments in various dissolved and precipitated forms, as well as inorganic and organic forms (Driscoll and Schecher WD 1990; Gensemer & Playle 1999; Botté et al. 2021).

International studies show that the dissolved Al concentrations in freshwater environments could reach up to 0.928 mg/L (Wang et al. 2013) in rivers and 3.7 mg/L in lakes (Takatsu et al. 2000). Elevated dissolved Al concentrations in these freshwater locations were either related to industrial pollution, like in the Weihe River (China) running through the biggest city in northwestern China (Wang et al. 2013) or acidic waters of volcanic origin, like in two Japanese lakes - Lake Usoriko (pH = 3.0–3.6) and the Lake Inawashiroko (pH = 5.1–5.2) (Takatsu et al. 2000).

3. Bioavailability and toxicity of aluminium

Aluminium solubility in aquatic systems is dependent on several water quality factors, particularly on pH, dissolved organic carbon or DOC (indicates humic condition), and temperature. Al becomes more soluble, and bioavailable under low as well as high pH (i.e., pH<5.5 and pH>9) as found by previous studies (Driscoll and Schecher WD 1990; Gensemer & Playle 1999; Santore et al. 2017) and therefore its toxicity increases.

Increased temperature may increase the Al toxicity by affecting its solubility and chemical compound formation and therefore the toxicity might be even higher in tropical climates than temperate climates (van Dam et al. 2018, Poléo et al. 1991, Gensemer & Playle 1999). As Al is a gill toxicant to fish causing respiratory effects, fish are generally more sensitive to Al than aquatic invertebrates (Gensemer & Playle 1999).

Decrease in soil pH increases the mobilisation of Al from soil to aquatic environments (Driscoll and Schecher WD 1990). Therefore, catchments dominated with acidic soil types (i.e. with low soil pH) have higher risk of aluminium leaching into waterways as a naturally occurring process. For example, fish kills can occur naturally in northern Australia when acidic, Al-rich water enters the mixing zones of billabongs at the end of some dry seasons (Brown et al. 1983). Exceptionally high Al is also possible in acidic freshwater environments of predominantly volcanic origin such as Lake Usoriko where the native Japanese dace fish (*Tribolodon hakonensis*) was adapted to this environment with lower uptake of Al (Takatsu et al. 2000).

The toxicity of Al to marine and freshwater species can be caused by both dissolved and particulate (precipitated and colloidal) aluminium (Angel et al. 2016; Golding et al. 2015; US EPA 2018; van Dam et al. 2018). According to the ANZECC guidelines (2000)[1] the dissolved aluminium measurement (operationally defined as measurement from samples passing through a 0.45-micron filter) of a water

[1] Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000). Aluminium in freshwater and marine water. Toxicant default guideline values for protecting aquatic ecosystems. https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/toxicants/aluminium-2000

sample is recommended for comparison with the default guideline values (DGVs). This is to ensure that non-bioavailable, mineralised forms of aluminium are not included in the measurement and will only measure the fraction that is more easily absorbed by aquatic organisms.

> The ANZECC guideline value for Al toxicity with 95% species protection in slightly to moderately impacted freshwater environments is 0.055mg/L, which has moderate reliability. However, it is to be noted that Al is generally more toxic over the pH range 4.4 to 5.4, with a maximum toxicity occurring around pH 5.0 to 5.2 (Schofield & Trojnar 1980, Parent & Campbell 1994). It is also to be noted that there is no guideline value for total Al.

4. Catchment context of Northern Wairoa

The Northern Wairoa is the largest river in Northland which ultimately drains into the Kaipara Harbour. It has a catchment area of approximately 4,500 km^2 which covers almost one-third of the region. The main tributaries of this river, from north-east to south-west direction, are - Waiotu River, Whakapara River, Mangahahuru Stream, Mangere Stream, Waipao Stream, Kaiku River, Mangakahia River, Opouteke River, Tangowahine Stream, Awakino River, Kaihu River, and Manganui River. The Waiotu and Whakapara Rivers join in the northern part of the Hikurangi Swamp (south of State Highway 1 between Whangārei and Kawakawa) to form the Wairua River. The Wairua River eventually meets with the Mangakahia River to form the Wairoa River just north of Tangiteroria. The Kaikou and Opouteke Rivers are the two major tributaries of the Mangakahia River draining a mix of plantation forestry and sheep and beef farming land-use with some remnants of mature native vegetation in the upper catchments. Further south the Manganui River along the fringes of Mareretu Forest eventually join the Wairoa River to the east of Dargaville. Another major tributary the Kaihu River, which originates in the Tutamoe Range to the west of Trounson Kauri Park, joins the Wairoa River to the west of Dargaville, while Tangowahine Stream joins the Wairoa River just south of Kirikopuni.

The catchment land-use of Northern Wairoa is predominantly developed agricultural pasture (45% of the total catchment area) with plantation forestry (particularly Kaikou, Mangakahia, Kaihu and Opouteke Rivers) and pockets of mature native forest (about 30% of the total catchment area) in the headwater catchments. The upper catchments of Northern Wairoa River are partially dominated by volcanic geology as well as erosion prone lands with soil creep, slips, and mass wasting. In the lowland floodplain the tributary streams are dominated by sandy/silty substrates of alluvial origin unlike the headwaters in the northern and eastern part where riverbeds have a mix of rocky and sandy materials. The catchment receives high annual rainfall relative to other lowland environments and overland flow is a key contaminant pathway particularly for sediment and sediment bound nutrients and microbes. Sediment, *E. coli* (indicator of microbes) and phosphorus are the main water quality issues in this catchment.

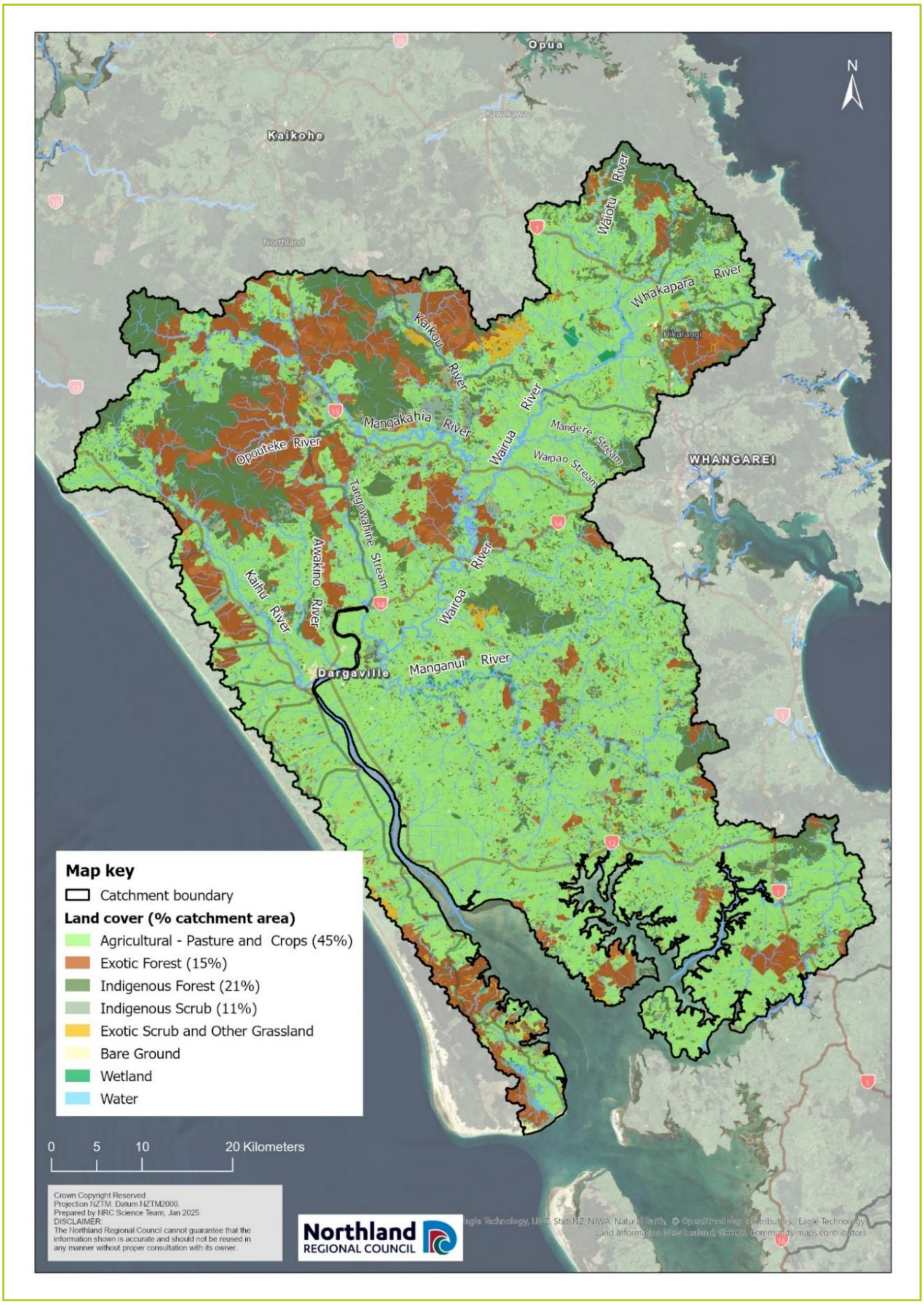


Figure 1. Map showing the land cover types and river network across the Northern Wairoa catchment.

5. Findings from NRC monitoring data

5.1 Monitoring locations

Historic water quality results for total Al were requested from Watercare Laboratory, which were associated with monthly SOE river water quality monitoring across the Northland region between March and June 2023. They were able to be retrospectively retrieved from the Watercare database for the entire regional monitoring network of SOE river water quality including 14 rivers in Northern Wairoa Freshwater Management Unit/catchment and 7 pristine rivers with natural state (NRC's reference SOE sites). Amongst 14 river sites in the Northern Wairoa catchment, dissolved Al was tested at three sites between August 2023 and August 2024 (Table 1, Figure 2), which were not concurrent with available results for total Al at these sites and therefore could not be associated. However, dissolved, and total Al were simultaneously monitored at seven coastal SOE water quality sites in the Kaipara Harbour in August and October 2024 (Table 1, Figure 2).

Table 1. List of SOE monitoring sites in Northern Wairoa Freshwater Management Unit with the available aluminium results.

NRC Site ID	Site Name	SOE network type	Aluminium test type (monitoring period)
109021	Hakaru at Topuni	River	Total Al (March – June 2023)
102256	Kaihu at Gorge	River	
100237	Mangahahuru at Main Road	River	
101038	Mangakahia at Titoki	River	
109096	**Mangakahia at Twin Bridges**	River	Total Al (March – June 2023); Dissolved Al (August 2023 – August 2024)
102257	Manganui at Mititai Road	River	Total Al (March – June 2023)
101625	Mangere at Knight Road	River	
329989	Northern Wairoa at Pukehuia Road	River	
102258	Opouteke at Suspension Bridge	River	
330531	Paparoa Stream at Paparoa Oakleigh Road	River	
322490	**Tangowahine at Tangowahine Valley Road**	River	Total Al (March – June 2023); Dissolved Al (August 2023 – August 2024)
102248	**Waiotu at SH1**	River	
108941	Waipao at Draffin Road	River	Total Al (March – June 2023)
101753	Wairua at Purua	River	
109665	Kaipara Harbour at Wahiwaka Creek	Coastal	Total and Dissolved Al (August, October 2024)
109666	Kaipara Harbour at Te Hoanga Point	Coastal	
109668	Kaipara Harbour at Te Kopua	Coastal	
109669	Kaipara Harbour at Kapua Point	Coastal	
109670	Kaipara Harbour at Burgess Island	Coastal	

NRC Site ID	Site Name	SOE network type	Aluminium test type (monitoring period)
109671	Kaipara Harbour at Five Fathom Channel	Coastal	
318293	Kaipara Harbour at Wairoa River	Coastal	

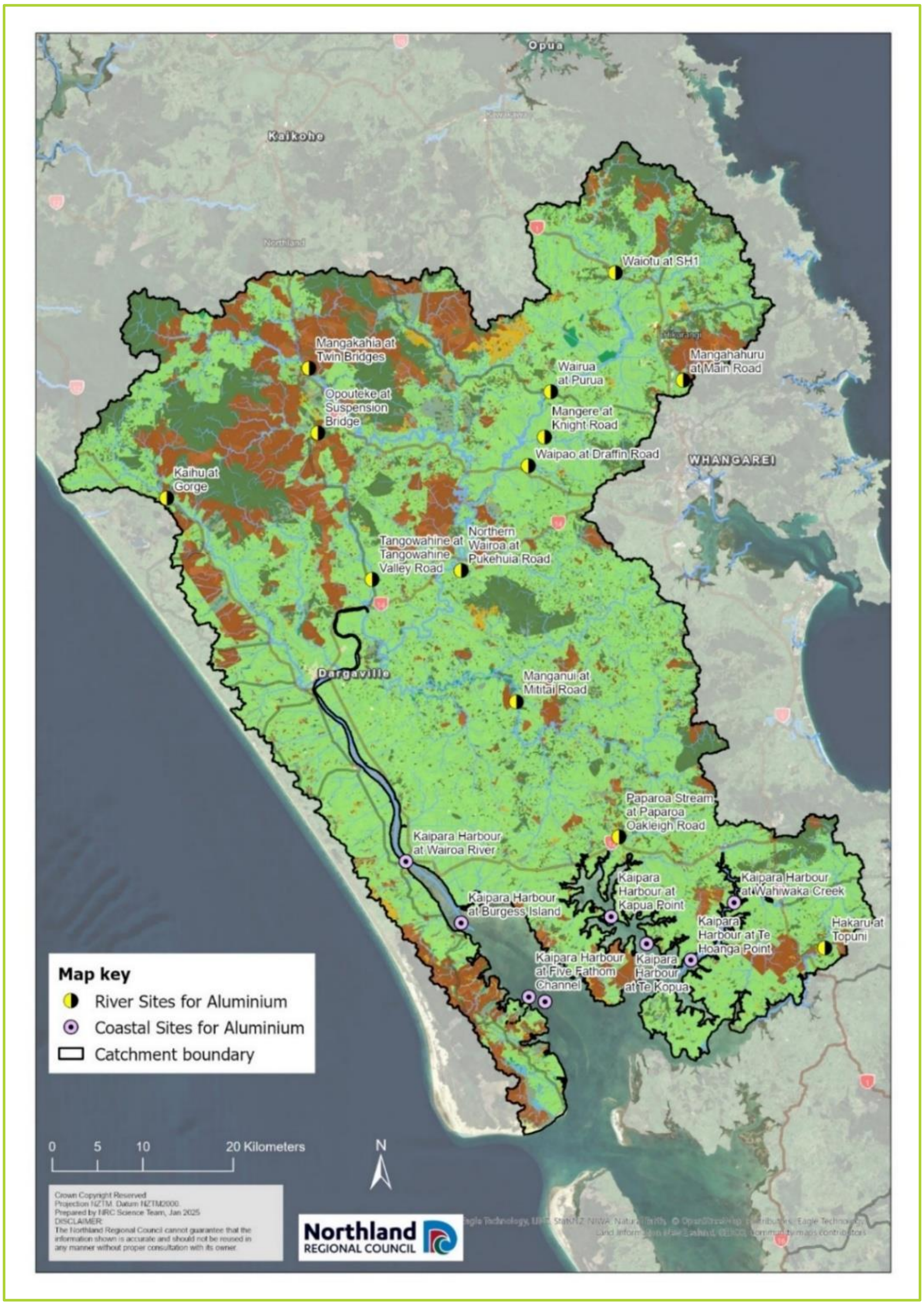


Figure 2. Map showing the locations of SOE monitoring sites (river and coastal) in the Northern Wairoa catchment with available aluminium results.

5.2 Results

As mentioned above, the total Al was determined by analysing the unfiltered samples, while dissolved Al was determined by analysing the sample after filtering through a 0.45 µm filter, which indicates the fraction more easily absorbed by aquatic life (i.e. bioavailable).

The median concentration (i.e. at least 50% of the samples) of total Al across the SOE river monitoring sites in the Northern Wairoa catchment was 0.33 g/m^3, which was almost similar to SOE river sites in the rest of Northland, however slightly higher than that observed in some pristine rivers in forested catchments (Table 2). The 95th percentile concentration (i.e. 5% of the samples with high values) of total Al in the catchment's rivers was 16.4 g/m^3 which was much higher than that observed in the rest of the region (2.2 g/m^3) and in pristine rivers (0.59 g/m^3). While there were no noticeable differences between rivers in the Northern Wairoa catchment, rest of Northland and pristine catchments, while looking at the minimum concentration of total Al, the maximum concentration was much higher in the Northern Wairoa catchment (34 g/m^3 - Tangowahine Stream at Tangowahine Valley Road) compared to rest of Northland (e.g. 9.9 g/m^3 - Victoria River at Victoria Valley Road) and pristine rivers (1.2 g/m^3 - Pukenui at Kanehiana Drive).

The median concentration of dissolved Al for rivers in the Northern Wairoa catchment was 0.047 mg/L which was slightly lower than the ANZECC guideline value for Al toxicity (0.055 mg/L or g/m^3 for 95% species protection in moderately impacted waterways). On the other hand, the 95th percentile concentration of dissolved Al (0.162 g/m^3) in the catchment's rivers was higher than the ANZECC guideline value for Al toxicity (Table 2). 46% of the dissolved Al results were above the ANZECC guideline value for Al toxicity, half of which were associated with high rainfall events (>10mm cumulative rainfall in preceding 48hrs) and consequent sediment discharges. It was not possible to compare these results with rivers in the rest of the region and pristine catchments, as well as associate the dissolved organic fractions (DOC) with total Al concentrations at the same sites, as that data was not available for river monitoring sites.

Table 2. Summary of total aluminium (March – June 2023) and dissolved aluminium (August 2023 – August 2024) in Northern Wairoa catchment comparing that to monitoring sites in rest of the region and pristine catchments.

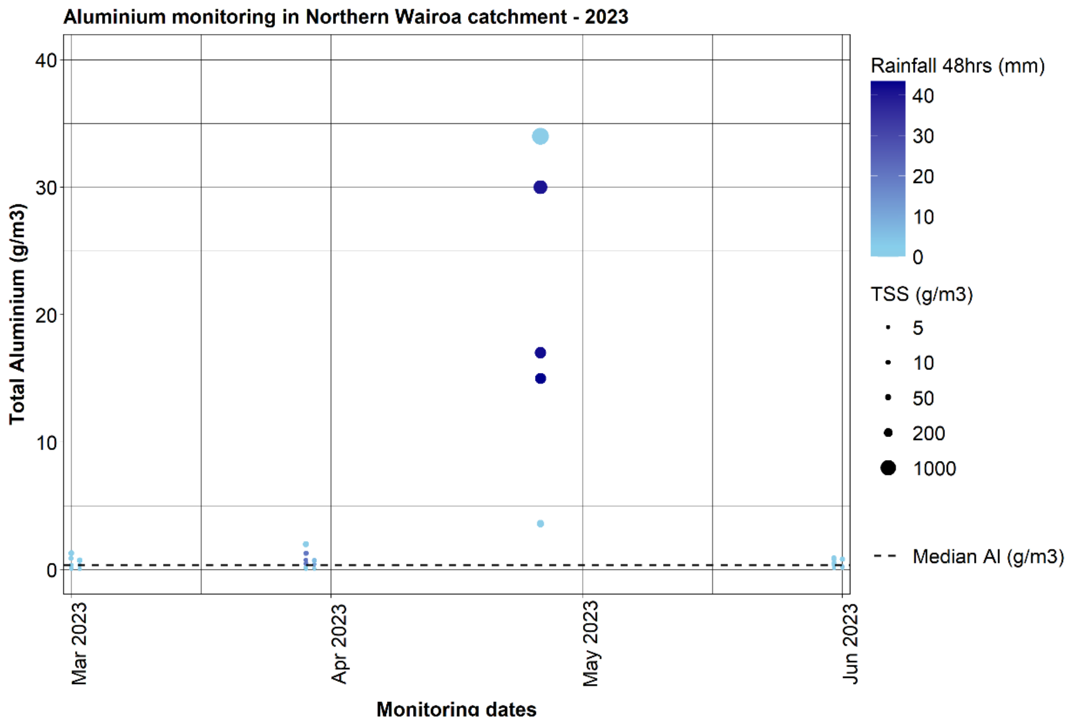
	Total Al (g/m^3)			Dissolved Al (g/m^3)		
	Northern Wairoa (n = 47)	Rest of Northland (n = 115)	Pristine rivers (n = 22)	Northern Wairoa (n = 47)	Rest of Northland	Pristine rivers
Median (50% of the samples)	0.33	0.32	0.23	0.047	No data	No data
95th percentile (5% of the samples with high values)	16.4	2.2	0.59	0.162		
Minimum	0.054	0.03	0.05	0.003		
Maximum	34	9.9	1.2	0.170		

Higher values (>95th percentile concentrations) of total Al concentration were mostly associated with elevated total suspended solids (TSS), and turbidity (NTU) due to sediment discharges from preceding high rainfall events, which was observed not only in Northern Wairoa catchment but also in rivers elsewhere in the region (Table 3, Figure 3). However, for all these exceptionally high Al concentrations, pH levels were found to be within normal range (6.5 - 8 neutral and non-acidic) indicating low risk of Al toxicity to aquatic life (Table 3). The Figure 5 shows a range of maximum concentrations for total Al that was observed at the SOE river and coastal monitoring sites in Northern Wairoa catchment.

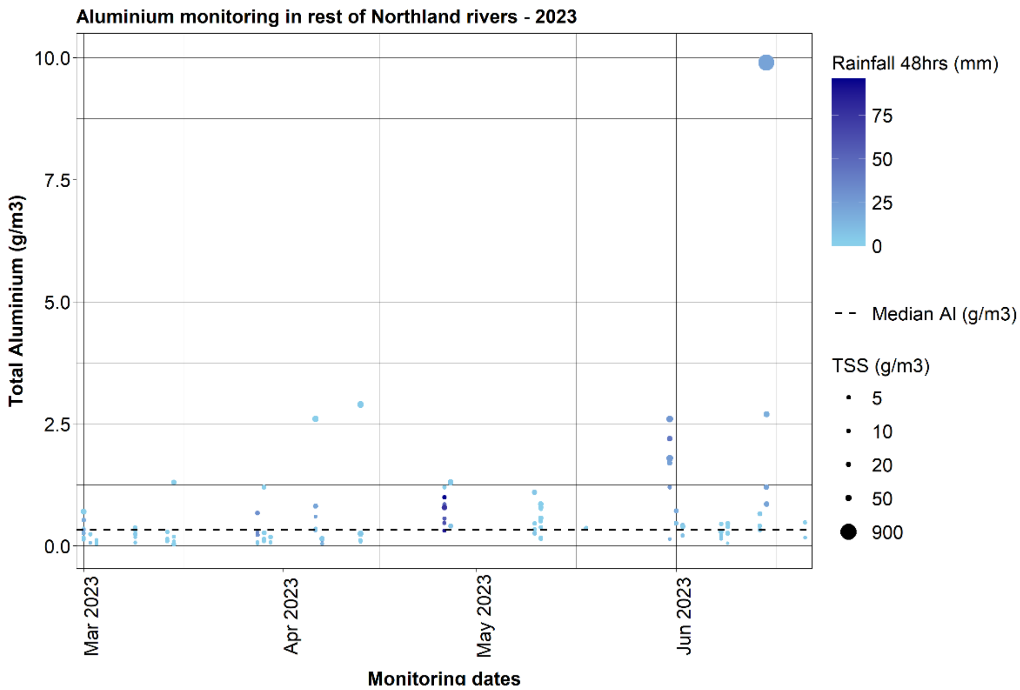
Table 3. Some elevated total Al results associated with high total suspended solids (TSS) and turbidity (Turb) at the SOE river sites in the Northern Wairoa catchment and elsewhere in Northland.

Site name	Catchments	Sampling date	Total Al (g/m^3)	TSS (g/m^3)	Turb (NTU)	pH
Victoria at Victoria Valley Road	Awanui	19/04/2023	2.9	56.8	25	7.6
Victoria at Victoria Valley Road	Awanui	21/06/2023	***9.9***	***920***	***850***	7.3
Ahuroa at Braigh Flats	Bream Bay	12/04/2023	2.6	46.5	55	6.9
Wairoa Stream at Ahipara	Herekino-Whāngāpē	21/06/2023	2.7	36	37	6.6
Mangakahia at Titoki	Northern Wairoa	9/05/2023	***15***	***428***	***240***	6.78
Mangakahia at Twin Bridges	Northern Wairoa	9/05/2023	***17***	***452***	***210***	7.18
Opouteke at Suspension Bridge	Northern Wairoa	9/05/2023	***30***	***764***	***300***	6.93
Tangowahine at Tangowahine Valley Road	Northern Wairoa	9/05/2023	***34***	***1320***	***700***	6.92
Hatea at A H Reed Park	Whangārei	6/06/2023	2.2	26.8	37	7.3
Raumanga at Bernard Street	Whangārei	6/06/2023	2.6	62.8	50	7.4
Waiarohia at Second Avenue	Whangārei	6/06/2023	2.2	25.6	34	7.1

Note: values in ***italic*** indicate exceptionally high results observed during some monitoring events.



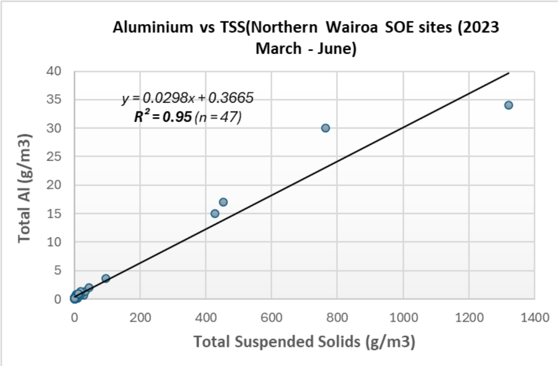
(a)



(b)

Figure 3. Plots of aluminium results (round dots) in Northern Wairoa (plot a), and in rest of Northland (plot b) between March and June 2023. Bigger dots represent high sediment concentrations (TSS) while darker blue dots indicate high rainfall events in preceding 48hrs. Horizontal hashed line indicates median concentration of total Al (0.33 g/m^3).

Total Al was found to have strong correlations with TSS (R^2 = 0.95) and turbidity (R^2 = 0.90) for river monitoring sites in Northern Wairoa, while these relationships were still moderately strong (R^2 of 0.77 and 0.70 respectively) for rest of the region (Figure 4).



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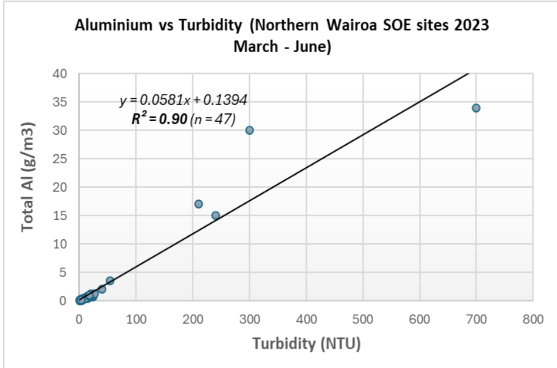

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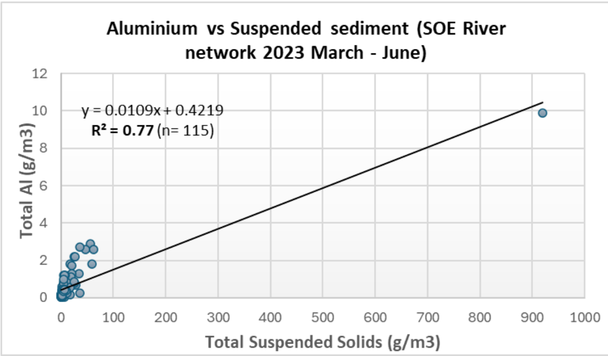

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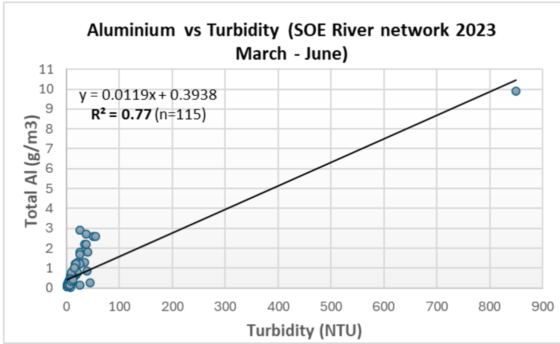

(d)

Figure 4. Scatter plots (round dots) of total Al results showing strong correlations with TSS and Turbidity in Northern Wairoa (plot a, b) as well as in rest of the region (plot c, d).

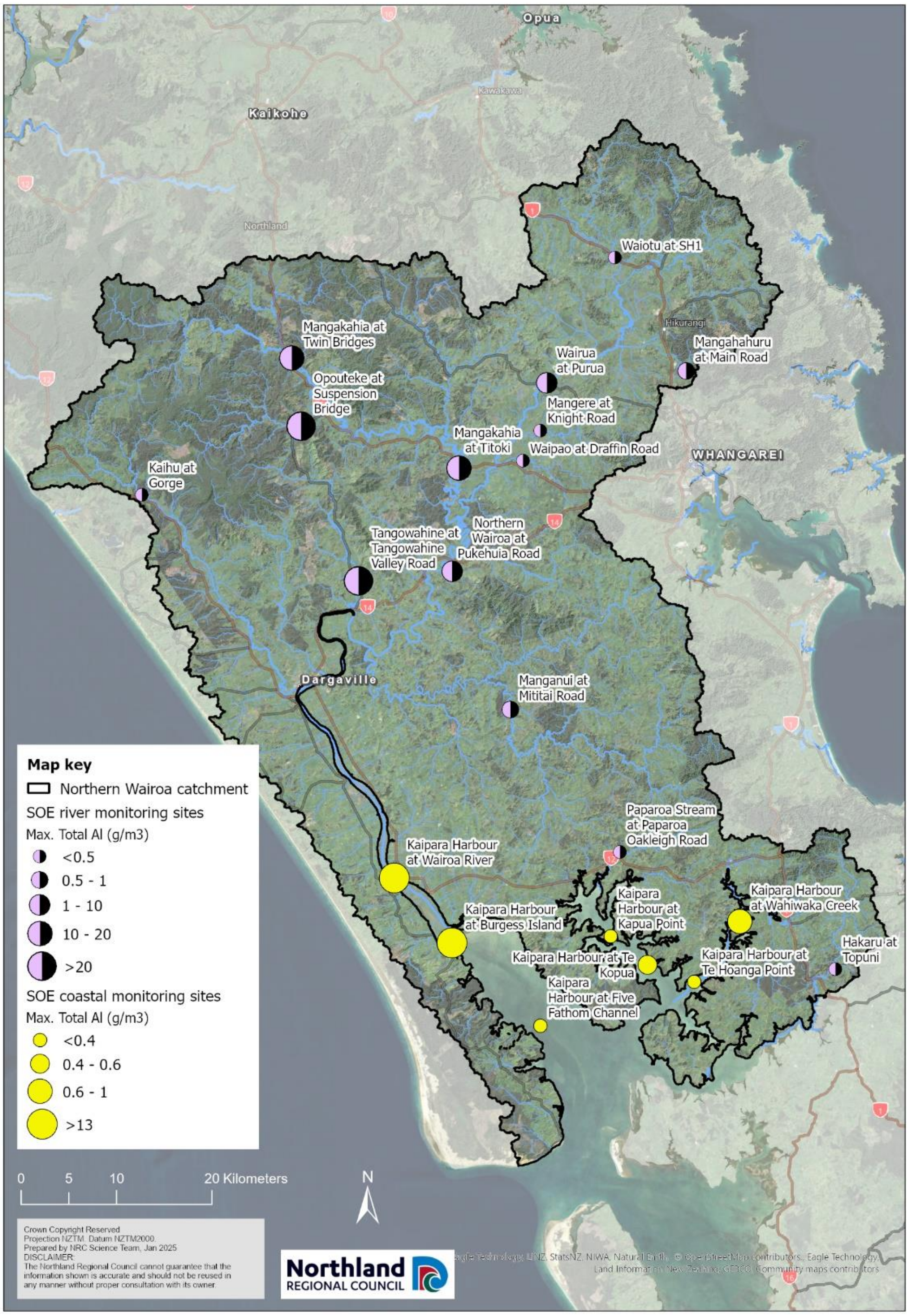

Figure 5. Map showing a range of maximum concentrations for total Al observed across the SOE monitoring network (river and coastal) in the Northern Wairoa catchment. The graduated symbols of site locations are based on maximum concentrations of total Al.

The Al results from the coastal water quality monitoring in Kaipara Harbour (14 samples) between August and October 2024 showed a median concentration of 0.37 g/m^3 total Al, and a 95th percentile concentration of 6.76 g/m^3 (mg/L) with the maximum concentration of 13 g/m^3 observed at Kaipara Harbour at Wairoa River site (Figure 5). However, all the results for associated dissolved Al at these coastal sites were below laboratory detection limit (<0.1 g/m^3) even for the sample with maximum total Al concentration of 13 g/m^3. The maximum concentration of total Al at Kaipara Harbour at the Wairoa River site also coincided with elevated TSS (240 g/m^3) and turbidity (260 FNU) reading.

5.3 Discussion

It was apparent from the SOE river water quality monitoring data collected between March and June 2023, that some of the exceptionally high results of aluminium concentrations (10 – 34 g/m^3) in the Northern Wairoa catchment, as well as Victoria at Victoria Valley Road (Awanui River catchments in Far North), mostly coincided with high cumulative rainfalls preceding the sampling events and consequent high concentrations of suspended sediment in waterways (indicated by exceptionally high TSS of 400-1300 g/m^3). Some of the high Al concentrations also coincided with upstream bank erosion, such as 9.9 g/m^3 total Al concentration at Victoria River at Victoria Valley Road in June 2023. However, for these high Al concentrations pH levels were within a range typically observed in Northland rivers (i.e. between 6.5 and 8) indicating any risk of aluminium toxicity to be unlikely. It is the acidic pH (around pH 5 or below), and high dissolved organic carbon or DOC (indicator of reducing geology and soil type) that determines Al toxicity which can have harmful effects on aquatic life such as physiological deformities and fish death.

The results from the Kaipara Harbour coastal water quality monitoring sites showed that the dissolved Al concentration was as low (below detection limit of <0.1 g/m^3) even for the maximum total Al concentration of 13 g/m^3 at Kaipara Harbour at Wairoa River, indicating most of the aluminium concentration in the harbour is comprised of particulate Al and very low dissolved Al. Therefore, it is possible that while Al is naturally available in the aquatic environment of Northern Wairoa catchment as well as other parts of Northland due to geology and erosion processes, a bigger proportion of it stays as particulate and therefore not bioavailable. A strong correlation between total Al and sediment (TSS and turbidity) was a clear indication of the naturally occurring process of Al transportation in surface waters of Northland via sediment discharge following heavy storm events. Surprisingly, the median concentrations of total Al, even in Northland's pristine catchments (0.23 g/m^3), was not much lower than Northern Wairoa catchment (0.33 g/m^3), indicating the influence of geology prone to mass wasting even in upstream forested and pristine catchments.

According to Land & Water Science' Physiographic model[2] elevated Al concentrations in Northland's soil and water are expected in those catchments with high overland flow risk (as percentage of effective rainfall) and poorly drained geology dominated with mudstone, sandstone, and peat. According to soil specialist Bob Cathcart "*The streams with high levels of Al are those I would expect from the soil types in those catchments. The particular soil types that will be generating the greatest volumes of Al are within one soil suite (a family of soils from the same or very similar parent material). They are the moderately to strongly leached Awapuku, Waimatenui, Mangonui and Awarua soils of the Te Kie Suite. The sediment will certainly be causing turbidity as it has a very high proportion of colloidal clay. One of the features of these soils that once the thin topsoil is lost, you have high Al and high clay subsoil exposed*" (Cathcart B, pers comm).

[2] https://landscapedna.org/maps/physiographic-environments/family/

Although it is suspected that the high Al concentrations in the surface waters of the Northern Wairoa catchment has been the reality for a long time due to naturally occurring processes, it is acknowledged that this report did not investigate the bioaccumulation of Al and its long-term implication on the physiology of aquatic life. According to a recent investigation undertaken by the Ministry for Primary Industries (MPI) on cloudy-eyed snapper[3] caught in the Kaipara Harbour - histological examinations and tests for heavy metals, including aluminium, and other emerging chemicals were undertaken - have not identified a cause of the condition. Cawthron Institute conducted tests of the affected snapper for common foodborne pathogens and contaminants, including heavy metals, but these tests did not find any cause for concern.

[3] https://www.mpi.govt.nz/fishing-aquaculture/recreational-fishing/information-on-popular-fish-in-nz/snapper-status-and-information/cloudy-eyed-snapper-from-kaipara-harbour-and-other-areas

6. Conclusion and recommendations

According to SOE monitoring data elevated aluminium concentrations in Northland rivers, particularly in the Northern Wairoa and Victoria Rivers, are most probably associated with catchment soil chemistry, erosion prone geology and overland flow following heavy rainfall events. It is possible that the freshwater environments of the Northern Wairoa catchment (as well as several other catchments in Northland) have been exposed to aluminium leaching for a long time due to naturally occurring processes which can also be exacerbated historically by human activities such as clearance of native forests and draining of wetlands. Aluminium in surface waters of the Northern Wairoa catchment is mostly contained in particulate matter and a little amount as dissolved fraction and therefore not necessarily available for bioaccumulation. As the extreme weather events such as flash floods, prolonged dry periods, and cyclones are becoming more frequent in Northland due to climate change impacts, erosion, and sediment discharge together with these exceptionally high concentrations of aluminium will be more common and unavoidable in Northland surface waters.

It is recommended to:

- Undertake further simultaneous testing of total and dissolved Al (together with pH and DOC) at some of the SOE sites with high total Al concentration in Northern Wairoa and Victoria Rivers and compare them to results in at least two pristine rivers in the Waipoua catchment.

- Investigate in future the bioaccumulation of Al by freshwater fish and aquatic invertebrates (e.g., freshwater mussels) in those catchments with elevated Al concentrations. However, this is difficult to assess without undertaking biopsy of muscle tissues from live samples (e.g., longfin and/or shortfin tuna, kākahi) which are normally undertaken by the MPI. We have not seen any such information available on the MPI website during the publication of this report.

- Careful consenting process for land-use activities (including any earthworks and forestry operation) in those catchments with high risks of aluminium leaching (due to conducive soil chemistry) to prevent further exposure of these areas to erosion and mass wasting. Having said that, it is noted that only commercial forestry operations that do not comply with the National Environmental Standards for Commercial Forestry (NES-CF)[4] permitted activity conditions potentially require consents from the regional council. It is also to be acknowledged that NRC already require erosion and sediment control management plans (ESCP) for any consented earthwork activities. These ESCPs would potentially mitigate/avoid any accidental discharge of sediment and sediment bound contaminants (including Al) to nearabout surface waters from unstable bare surfaces.

- Promote and enable more retirement and revegetation of highly erodible areas in the Northern Wairoa catchment undertaken by NRC's Land Management Team to prevent further land-based erosion and consequent discharge of sediment bound contaminants (including Al).

[4] https://environment.govt.nz/acts-and-regulations/regulations/national-environmental-standards-for-commercial-forestry/

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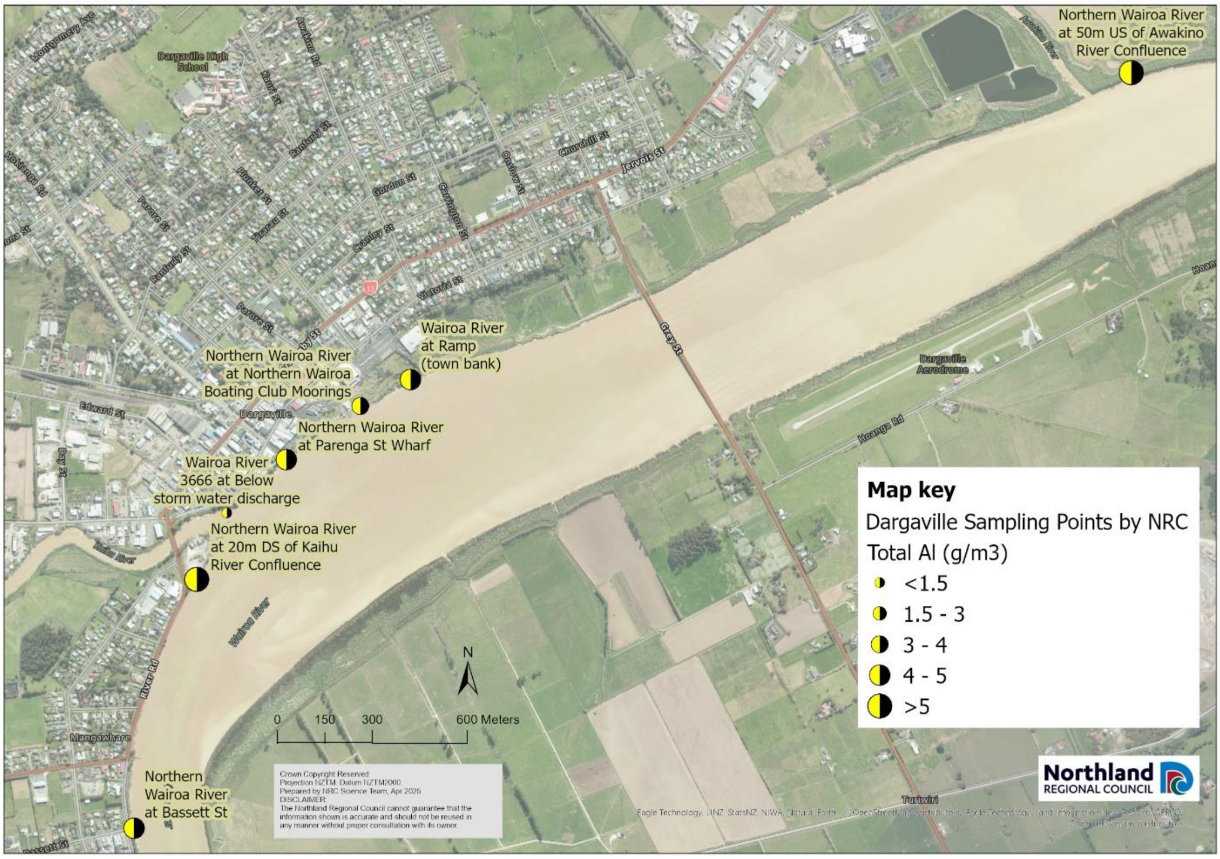
Appendices

Appendix 1a. Results of the NRC Compliance Monitoring Team's sampling and testing for total aluminium in the Northern Wairoa River adjacent to Dargaville. Results highlighted in light blue indicate water samples and those highlighted in light grey indicate sediment samples.

Sample ID = 20244000	**Date Collected**	**24/07/2024**	**Time 14:10**	
Site 100305	**Wairoa River 3666 at Below storm water discharge**			
Measurement	Method		Value	Units
Aluminium Total	Aluminium (Total) by ICP-MS		1.4	g/m3
pH	pH (field meter)		6.81	pH
Salinity (Field)	Salinity		0.08	ppt
Sample ID = 20244002	**Date Collected**	**24/07/2024**	**Time 10:51**	
Site 101727	**Wairoa River at Ramp (town bank)**			
Measurement	Method		Value	Units
Aluminium Total	Aluminium (Total) by ICP-MS		4.2	g/m3
pH	pH (field meter)		7.23	pH
Salinity (Field)	Salinity		0.26	ppt
Sample ID = 20244003	**Date Collected**	**24/07/2024**	**Time 10:50**	
Site 101727	**Wairoa River at Ramp (town bank)**			
Measurement	Method		Value	Units
Aluminium Total Sediment	Aluminium (Recoverable Dry Wt.) by ICP-MS		18000	mg/kg
Sample ID = 20244006	**Date Collected**	**24/07/2024**	**Time 10:21**	
Site 339278	**Northern Wairoa at 50m US of Awakino River Confluence**			
Measurement	Method		Value	Units
Aluminium Total	Aluminium (Total) by ICP-MS		9.1	g/m3
pH	pH (field meter)		7.09	pH
Salinity (Field)	Salinity		0.25	ppt
Temperature	Temperature - YSI		13.1	degC
Sample ID = 20244007	**Date Collected**	**24/07/2024**	**Time 10:20**	
Site 339278	**Northern Wairoa at 50m US of Awakino River Confluence**			
Measurement	Method		Value	Units
Aluminium Total Sediment	Aluminium (Recoverable Dry Wt.) by ICP-MS		20000	mg/kg
Sample ID = 20244008	**Date Collected**	**24/07/2024**	**Time 11:30**	

Site 339279	**Northern Wairoa at Northern Wairoa Boating Club Moorings**			
Measurement	Method		Value	Units
Aluminium Total	Aluminium (Total) by ICP-MS		3.4	g/m3
pH	pH (field meter)		6.94	pH
Salinity (Field)	Salinity		0.07	ppt
Sample ID = 20244009	**Date Collected**	**24/07/2024**	**Time 11:31**	
Site 339279	**Northern Wairoa at Northern Wairoa Boating Club Moorings**			
Measurement	Method		Value	Units
Aluminium Total Sediment	Aluminium (Recoverable Dry Wt.) by ICP-MS		19000	mg/kg
Sample ID = 20244010	**Date Collected**	**24/07/2024**	**Time 11:50**	
Site 339280	**Northern Wairoa at Parenga St Wharf**			
Measurement	Method		Value	Units
Aluminium Total	Aluminium (Total) by ICP-MS		4.2	g/m3
pH	pH (field meter)		6.82	pH
Salinity (Field)	Salinity		0.07	ppt
Sample ID = 20244012	**Date Collected**	**24/07/2024**	**Time 12:20**	
Site 339281	**Northern Wairua at 20m DS of Kaihu River Confluence**			
Measurement	Method		Value	Units
Aluminium Total	Aluminium (Total) by ICP-MS		5.2	g/m3
pH	pH (field meter)		6.94	pH
Salinity (Field)	Salinity		0.07	ppt
Sample ID = 20244014	**Date Collected**	**24/07/2024**	**Time 12:30**	
Site 339282	**Northern Wairoa at Bassett St**			
Measurement	Method		Value	Units
Aluminium Total	Aluminium (Total) by ICP-MS		4.6	g/m3
pH	pH (field meter)		6.87	pH
Salinity (Field)	Salinity		0.08	ppt

Appendix 1b. Map showing the locations of investigation sampling adjacent to Dargaville undertaken by the NRC Compliance Monitoring Team on 24 July 2024. The graduated symbols of sampling points are based on results of total Al concentrations.



Appendix 2. Results of aluminium and other relevant water quality parameters at SOE river monitoring sites in Northern Wairoa catchment measured between March 2023 and August 2024.

Site Name	Sampling Date	Sample ID	Aluminium Dissolved (g/m3)	Aluminium Total (g/m3)	TSS (g/m3)	Turb (NTU)	pH	Rainfall 48hrs (mm)
Hakaru at Topuni	15/03/2023	20231139		0.38	5	8.6	7.63	4.5
Hakaru at Topuni	12/04/2023	20231658		0.4	4	8	7.42	11
Hakaru at Topuni	14/06/2023	20232244		0.27	2.6	7.2	7.41	1.5
Kaihu at Gorge	15/03/2023	20231136		0.088	0.8	1.7	7.62	5.1
Kaihu at Gorge	12/04/2023	20231655		0.12	1	2	7.54	14.3
Kaihu at Gorge	14/06/2023	20232250		0.25	1.6	3.7	7.24	7.8
Mangahahuru at Main Road	14/03/2023	20231129		0.33	2.8	6.8	6.65	1
Mangahahuru at Main Road	11/04/2023	20231648		0.75	4.4	13	6.46	21.3

Site Name	Sampling Date	Sample ID	Aluminium Dissolved (g/m3)	Aluminium Total (g/m3)	TSS (g/m3)	Turb (NTU)	pH	Rainfall 48hrs (mm)
Mangahahuru at Main Road	13/06/2023	20232238		0.33	1.8	6.8	6.88	1
Mangakahia at Titoki	14/03/2023	20231119		0.36	6	8.5	7.45	0.6
Mangakahia at Titoki	11/04/2023	20231646		0.17	3	4.3	7.69	5.1
Mangakahia at Titoki	9/05/2023	20231974		15	428	240	6.78	43.4
Mangakahia at Titoki	13/06/2023	20232236		0.88	13.8	15	0	2.4
Mangakahia at Twin Bridges	14/03/2023	20231118		0.19	3	4.4	8.37	0.6
Mangakahia at Twin Bridges	11/04/2023	20231645		0.073	1.5	2.2	8.3	2.3
Mangakahia at Twin Bridges	9/05/2023	20231973		17	452	210	7.18	41.8
Mangakahia at Twin Bridges	13/06/2023	20232235		0.16	1.4	3.8	8	2.4
Mangakahia at Twin Bridges	15/08/2023	20233903	0.049		3	4.7	7.96	4.8
Mangakahia at Twin Bridges	19/09/2023	20234210	0.027		2.6	3.3	7.95	0
Mangakahia at Twin Bridges	10/10/2023	20234614	0.17		8.8	0	7.56	44.7
Mangakahia at Twin Bridges	14/11/2023	20235010	0.013		1.5	0	8.09	0
Mangakahia at Twin Bridges	12/12/2023	20240264	0.016		2	0	8.4	0
Mangakahia at Twin Bridges	16/01/2024	20240952	0.0051		1.4	0	7.8	7.5
Mangakahia at Twin Bridges	13/02/2024	20241319	*0.0025*		0.9	0	8.49	0
Mangakahia at Twin Bridges	12/03/2024	20241516	*0.0025*		0.4	0	8.42	0
Mangakahia at Twin Bridges	10/04/2024	20241765	*0.0025*		2.4	0	8.48	0.5
Mangakahia at Twin Bridges	29/05/2024	20242108	0.14		19	0	7.37	19
Mangakahia at Twin Bridges	19/06/2024	20243407	0.13		5.8	0	7.41	14
Mangakahia at Twin Bridges	21/08/2024	20243807	0.13		3.2	0	7.84	11
Manganui at Mititai Road	15/03/2023	20235083		0.73	28	24	8.09	2.6
Manganui at Mititai Road	12/04/2023	20231141		0.71	15.2	22	7.38	6.2
Manganui at Mititai Road	14/06/2023	20231660		0.82	19.2	19	7.3	1.5

Site Name	Sampling Date	Sample ID	Aluminium Dissolved (g/m3)	Aluminium Total (g/m3)	TSS (g/m3)	Turb (NTU)	pH	Rainfall 48hrs (mm)
Mangere at Knight Road	14/03/2023	20232246		0.3	4.4	6.8	7.15	0
Mangere at Knight Road	11/04/2023	20231131		0.25	1.6	6.8	7.18	1.7
Mangere at Knight Road	13/06/2023	20231650		0.41	5	11	6.88	0.6
Northern Wairoa at Pukehuia Road	14/03/2023	20232240		1.3	32	20	7.22	0
Northern Wairoa at Pukehuia Road	11/04/2023	20231115		2	44	40	6.79	0
Northern Wairoa at Pukehuia Road	9/05/2023	20231642		3.6	96	55	6.9	0
Northern Wairoa at Pukehuia Road	13/06/2023	20231970		0.81	11	16	7.29	0
Opouteke at Suspension Bridge	14/03/2023	20232232		0.16	5.4	2.6	7.77	0.6
Opouteke at Suspension Bridge	11/04/2023	20231117		0.17	1.6	2.8	7.76	2.3
Opouteke at Suspension Bridge	9/05/2023	20231644		**30**	764	300	6.93	40.6
Opouteke at Suspension Bridge	13/06/2023	20231972		0.26	1.2	4.4	7.89	2.4
Paparoa Stream at Paparoa Oakleigh Road	15/03/2023	20232234		0.064	3	3.1	7.3	0
Paparoa Stream at Paparoa Oakleigh Road	12/04/2023	20231140		0.087	1.6	3.5	7.36	0
Paparoa Stream at Paparoa Oakleigh Road	14/06/2023	20231659		0.14	2.6	6.3	7.38	0
Tangowahine at Tangowahine Valley Road	14/03/2023	20232245		0.11	8.8	5	7.45	0
Tangowahine at Tangowahine Valley Road	11/04/2023	20231116		0.18	5.4	6.5	7.39	0
Tangowahine at Tangowahine Valley Road	9/05/2023	20231643		**34**	1320	700	6.92	0
Tangowahine at Tangowahine Valley Road	13/06/2023	20231971		0.6	9.2	14	7.23	0

Site Name	Sampling Date	Sample ID	Aluminium Dissolved (g/m3)	Aluminium Total (g/m3)	TSS (g/m3)	Turb (NTU)	pH	Rainfall 48hrs (mm)
Tangowahine at Tangowahine Valley Road	15/08/2023	20232233	0.036		16	14	7.16	0
Tangowahine at Tangowahine Valley Road	19/09/2023	20233901	0.025		29.2	12	7.28	0
Tangowahine at Tangowahine Valley Road	10/10/2023	20234208	0.15		65	0	6.85	0
Tangowahine at Tangowahine Valley Road	14/11/2023	20234612	0.018		16	0	7.43	0
Tangowahine at Tangowahine Valley Road	12/12/2023	20240289	0.024		10	0	7.37	0
Tangowahine at Tangowahine Valley Road	16/01/2024	20240960	0.0092		3.2	0	7.5	0
Tangowahine at Tangowahine Valley Road	13/02/2024	20241317	*0.0025*		2.6	0	7.69	0
Tangowahine at Tangowahine Valley Road	12/03/2024	20241524	0.0073		6.6	0	7.57	0
Tangowahine at Tangowahine Valley Road	10/04/2024	20241773	*0.0025*		6.2	0	7.65	0
Tangowahine at Tangowahine Valley Road	29/05/2024	20242106	0.16		9.4	0	7.05	0
Tangowahine at Tangowahine Valley Road	19/06/2024	20243815	0.091		14	0	6.91	0
Tangowahine at Tangowahine Valley Road	21/08/2024	20235008	0.09		12	0	7.22	0
Waiotu at SH1	14/03/2023	20235081		0.25	4.2	5.3	6.79	0
Waiotu at SH1	11/04/2023	20231128		0.48	5.6	15	6.95	20.9
Waiotu at SH1	13/06/2023	20231647		0.47	8.4	11	6.66	0
Waiotu at SH1	15/08/2023	20232237	0.043		13	22	6.82	4.9
Waiotu at SH1	19/09/2023	20233905	0.062		8	9.7	6.8	0
Waiotu at SH1	10/10/2023	20234212	0.11		18	0	6.44	19.1
Waiotu at SH1	12/11/2023	20234606	0.07		6.2	0	6.74	0
Waiotu at SH1	12/12/2023	20235002	0.065		4	0	7.14	0
Waiotu at SH1	16/01/2024	20240287	0.059		5.8	0	6.83	23.7
Waiotu at SH1	13/02/2024	20240958	0.047		3.4	0	6.71	0

Site Name	Sampling Date	Sample ID	Aluminium Dissolved (g/m3)	Aluminium Total (g/m3)	TSS (g/m3)	Turb (NTU)	pH	Rainfall 48hrs (mm)
Waiotu at SH1	12/03/2024	20241315	0.039		1.6	0	6.77	0
Waiotu at SH1	10/04/2024	20241522	0.032		5.4	0	6.9	5.5
Waiotu at SH1	22/05/2024	20241771	0.097		4.5	0	6.66	63.5
Waiotu at SH1	19/06/2024	20242104	0.084		9.6	0	6.32	10
Waiotu at SH1	16/07/2024	20243813	**0.17**		12	0	6.67	73
Waiotu at SH1	21/08/2024	20235075	0.071		6.2	0	7.03	0.5
Waipao at Draffin Road	14/03/2023	20231132		0.055	1.6	1.7	7.08	0
Waipao at Draffin Road	11/04/2023	20231651		0.054	1.1	1.5	7.11	1.7
Waipao at Draffin Road	13/06/2023	20232241		0.12	1.6	3.6	6.97	0.6
Wairua at Purua	14/03/2023	20231130		0.87	15	18	6.78	0
Wairua at Purua	11/04/2023	20231649		1.3	20	27	6.48	20.3
Wairua at Purua	13/06/2023	20232239		0.91	12	18	6.67	0

Appendix 3. Results of aluminium and other relevant water quality parameters at SOE coastal water quality sites in Kaipara Harbour measured between August and October 2024.

Site Name	Sampling Date	Sample ID	Aluminium Dissolved (g/m3)	Aluminium Total (g/m3)	TSS (g/m3)	Turb (NTU)
Kaipara Harbour at Wahiwaka Creek	22/08/2024	20243820	<0.1	0.43	15	9.7
Kaipara Harbour at Wahiwaka Creek	17/10/2024	20244511	<0.1	0.85	84	18
Kaipara Harbour at Te Hoanga Point	22/08/2024	20243821	<0.1	0.3	10	5.1
Kaipara Harbour at Te Hoanga Point	17/10/2024	20244512	<0.1	0.32	20	6.1
Kaipara Harbour at Te Kopua	22/08/2024	20243822	<0.1	0.31	11	6.3
Kaipara Harbour at Te Kopua	17/10/2024	20244513	<0.1	0.57	18	11
Kaipara Harbour at Kapua Point	22/08/2024	20243823	<0.1	0.29	12	5.5
Kaipara Harbour at Kapua Point	17/10/2024	20244514	<0.1	0.37	19	7.6
Kaipara Harbour at Burgess Island	22/08/2024	20243818	<0.1	<0.1	34	18
Kaipara Harbour at Burgess Island	17/10/2024	20244509	<0.1	1.1	33	20
Kaipara Harbour at Five Fathom Channel	22/08/2024	20243819	<0.1	0.32	15	5.7
Kaipara Harbour at Five Fathom Channel	17/10/2024	20244510	<0.1	0.17	9.8	4
Kaipara Harbour at Wairoa River	22/08/2024	20243817	<0.1	**13**	**240**	**260**
Kaipara Harbour at Wairoa River	17/10/2024	20244508	<0.1	2.6	69	40

Appendix 4. Results of aluminium and other relevant water quality parameters at SOE river monitoring sites in the rest of Northland measured between March and June 2023.

Site Name	Sampling Date	Sample ID	Aluminium Total (g/m3)	TSS (g/m3)	Turb (NTU)	pH	Rainfall 48hrs (mm)
Waiharakeke at Stringers Road	8/03/2023	20231109	0.24	5	11	7.33	1.6
Waiharakeke at Stringers Road	5/04/2023	20231641	0.18	6.8	8.5	7.49	0
Waiharakeke at Stringers Road	3/05/2023	20231964	1.3	34	34	6.74	5.3
Waiharakeke at Stringers Road	7/06/2023	20232226	0.72	15	17	7.24	18.9
Awanui at FNDC	21/03/2023	20231152	0.19	2.8	5.5	7.22	0
Awanui at FNDC	19/04/2023	20231669	0.092	1.6	2.7	7.55	4.4
Awanui at FNDC	17/05/2023	20231997	0.79	14	13	7.21	2.2
Awanui at FNDC	21/06/2023	20232260	1.2	18	24	7.23	22
Utakura River at Lake Omapere outlet bridge	21/03/2023	20231149	0.03	6.8	7.5	6.98	0
Utakura River at Lake Omapere outlet bridge	19/04/2023	20231672	0.25	37	45	8.84	0
Utakura River at Lake Omapere outlet bridge	17/05/2023	20232000	0.15	6	5.9	8.24	0
Utakura River at Lake Omapere outlet bridge	15/06/2023	20232254	0.26	7.6	6.9	7.34	0
Waipapa at Forest Ranger	13/04/2023	20231663	0.05	0.8	1.3	7.91	15.4
Waipapa at Forest Ranger	15/06/2023	20232253	0.053	0.5	1.2	7.64	0
Waitangi at Wakelins	9/03/2023	20231114	0.068	2	2.8	8.1	0
Waitangi at Wakelins	3/04/2023	20231630	0.67	8.8	18	7.62	31.3
Waitangi at Wakelins	17/05/2023	20231969	0.56	15.8	14	7.2	2.6
Waitangi at Wakelins	8/06/2023	20232231	0.42	9	9.9	7.28	10.8
Kaeo at Dip Road	8/03/2023	20231107	0.065	1.2	2	7.11	10.1
Kaeo at Dip Road	5/04/2023	20231639	0.073	3	3.4	7.04	0
Kaeo at Dip Road	3/05/2023	20231962	0.41	11.2	8.5	6.98	8
Kaeo at Dip Road	7/06/2023	20232225	0.46	10.2	9.1	7.26	8.6
Waitangi at Waimate North Road	9/03/2023	20231112	0.12	3.4	2.9	6.7	0

Site Name	Sampling Date	Sample ID	Aluminium Total (g/m3)	TSS (g/m3)	Turb (NTU)	pH	Rainfall 48hrs (mm)
Waitangi at Waimate North Road	3/04/2023	20231628	0.23	4	4.6	6.72	31.3
Waitangi at Waimate North Road	17/05/2023	20231967	0.86	23.2	16	6.51	2.6
Waitangi at Waimate North Road	8/06/2023	20232229	0.4	11.6	8.2	6.59	10.8
Waipoua at SH12	15/03/2023	20231135	0.18	1.1	2.5	7.47	5.1
Waipoua at SH12	12/04/2023	20231654	0.32	2.2	4.3	7.3	13.7
Waipoua at SH12	14/06/2023	20232249	0.18	0.8	2.3	7.18	8.3
Ruakaka at Flyger Road	15/03/2023	20231137	0.32	6.5	9.8	7.3	1.5
Ruakaka at Flyger Road	12/04/2023	20231656	0.35	4.4	9.2	7.2	6.4
Ruakaka at Flyger Road	14/06/2023	20232242	0.29	6.8	11	7.2	0
Punakitere at Taheke	13/04/2023	20231661	0.12	1.2	3	7.51	24.3
Punakitere at Taheke	15/06/2023	20232251	0.39	4	7.9	0	0
Victoria at Victoria Valley Road	21/03/2023	20231151	1.3	20.8	21	7.21	0
Victoria at Victoria Valley Road	19/04/2023	20231668	2.9	56.8	25	7.55	4.4
Victoria at Victoria Valley Road	17/05/2023	20231996	0.51	6.8	9.4	7.27	2.2
Victoria at Victoria Valley Road	21/06/2023	20232259	9.9	920	850	7.31	22
Hatea at Whangarei Falls	7/03/2023	20231101	0.53	6.4	13	7.09	19
Hatea at Whangarei Falls	4/04/2023	20231633	0.14	1.9	4.7	7.51	0
Hatea at Whangarei Falls	2/05/2023	20231956	0.85	5.6	13	6.61	49.7
Hatea at Whangarei Falls	6/06/2023	20232219	1.8	18.2	26	6.98	42.6
Utakura at Okaka Road	13/04/2023	20231662	0.15	18.4	26	7.49	5.5
Utakura at Okaka Road	15/06/2023	20232252	0.46	14.8	8.9	6.94	0
Waiarohia at Second Avenue	7/03/2023	20231106	0.17	3.6	4.2	7.41	2.6
Waiarohia at Second Avenue	4/04/2023	20231638	0.14	5.4	3.9	7.57	0
Waiarohia at Second Avenue	2/05/2023	20231961	0.8	12	15	7.02	42.8

Site Name	Sampling Date	Sample ID	Aluminium Total (g/m3)	TSS (g/m3)	Turb (NTU)	pH	Rainfall 48hrs (mm)
Waiarohia at Second Avenue	6/06/2023	20232224	2.2	25.6	34	7.11	28
Oruru at Oruru Road	20/03/2023	20231146	0.29	4.8	7.3	7.33	0
Oruru at Oruru Road	16/05/2023	20231994	1.1	20	20	7.03	6.5
Oruru at Oruru Road	20/06/2023	20232257	0.66	11	17	7.25	5.5
Waimamaku at SH12	15/03/2023	20231133	0.073	0.9	1.2	7.57	4.8
Waimamaku at SH12	12/04/2023	20231652	0.82	11	11	7	21.4
Waimamaku at SH12	14/06/2023	20232247	0.15	1.6	3	7.41	5.8
Otaika at Otaika Valley Road	7/03/2023	20231104	0.7	28	16	7.1	0.5
Otaika at Otaika Valley Road	4/04/2023	20231636	0.11	1.4	3.4	7.43	0
Otaika at Otaika Valley Road	2/05/2023	20231959	0.79	26	21	6.77	76.5
Otaika at Otaika Valley Road	6/06/2023	20232222	1.8	59.2	40	6.96	25.3
Ngunguru at Coalhill Lane	7/03/2023	20231102	0.26	2.2	4.5	7.13	16.3
Ngunguru at Coalhill Lane	4/04/2023	20231634	1.2	7.8	26	6.9	0
Ngunguru at Coalhill Lane	2/05/2023	20231957	1.2	5.8	17	6.41	0
Ngunguru at Coalhill Lane	6/06/2023	20232220	1.7	20.6	26	6.99	23.3
Waiaruhe at Puketona	9/03/2023	20231113	0.1	3	3.2	7.06	2.1
Waiaruhe at Puketona	3/04/2023	20231629	0.27	3.4	6	6.97	34.2
Waiaruhe at Puketona	17/05/2023	20231968	0.57	18	14	6.83	1.1
Waiaruhe at Puketona	8/06/2023	20232230	0.4	10.4	9.5	6.9	3.3
Oruaiti at Windust Road	20/03/2023	20231148	0.096	2	3.5	7.27	0
Oruaiti at Windust Road	16/05/2023	20231992	0.26	4	6.8	7.16	6.5
Oruaiti at Windust Road	20/06/2023	20232255	0.33	4	8.3	7.33	5.5
Raumanga at Bernard Street	7/03/2023	20231105	0.14	2.8	4.2	7.61	2.6
Raumanga at Bernard Street	4/04/2023	20231637	0.097	1.8	2.6	8.22	0
Raumanga at Bernard Street	2/05/2023	20231960	0.56	5.6	10	7.4	55.4

Site Name	Sampling Date	Sample ID	Aluminium Total (g/m3)	TSS (g/m3)	Turb (NTU)	pH	Rainfall 48hrs (mm)
Raumanga at Bernard Street	6/06/2023	20232223	2.6	62.8	50	7.42	27.9
Pukenui at Kanehiana Drive	7/03/2023	20231099	0.36	1.6	8.1	7.17	2.6
Pukenui at Kanehiana Drive	4/04/2023	20231631	0.11	1.5	4.6	7.22	0
Pukenui at Kanehiana Drive	2/05/2023	20231954	0.47	3.2	9.1	6.95	62.9
Pukenui at Kanehiana Drive	6/06/2023	20232217	1.2	6.2	18	7.07	27.8
Tapapa at SH1	21/03/2023	20231150	0.085	1.6	1.8	7.87	0
Tapapa at SH1	19/04/2023	20231671	0.25	4.5	2.5	7.99	6.2
Tapapa at SH1	17/05/2023	20231999	0.38	4.6	4.5	7.8	1.2
Tapapa at SH1	27/06/2023	20233770	0.17	1	3.5	7.83	5.8
Wairau at SH12	15/03/2023	20231134	0.24	4.4	3.2	6.79	4.8
Wairau at SH12	12/04/2023	20231653	0.6	1.6	7.1	6.46	22.4
Wairau at SH12	14/06/2023	20232248	0.22	0.8	2.5	6.99	5.2
Punaruku at Russell Road	7/03/2023	20231100	0.13	1.8	2.3	6.78	4.8
Punaruku at Russell Road	4/04/2023	20231632	0.27	10.9	5.5	6.81	0
Punaruku at Russell Road	2/05/2023	20231955	0.31	2.9	5.2	6.62	88.7
Punaruku at Russell Road	6/06/2023	20232218	0.14	1.4	2.1	6.91	15.2
Takou River at Below Ford	24/05/2023	20233428	0.37	3.8	7.1	6.92	0
Takou River at Below Ford	27/06/2023	20233523	0.48	2.8	7.6	6.99	0
Ahuroa at Braigh Flats	15/03/2023	20231138	0.37	9.5	8.5	7	0
Ahuroa at Braigh Flats	12/04/2023	20231657	2.6	46.5	55	6.85	0
Ahuroa at Braigh Flats	14/06/2023	20232243	0.45	6.6	10	6.99	0
Waipapa at Doonside Road	9/03/2023	20231110	0.043	1.6	1.2	6.41	0
Waipapa at Doonside Road	3/04/2023	20231626	0.053	1.4	1	6.28	0
Waipapa at Doonside Road	17/05/2023	20231965	0.17	2	3.1	6.06	0
Waipapa at Doonside Road	8/06/2023	20232227	0.39	2.6	6.7	6.25	0
Waitiki Stream at Te Paki	21/06/2023	20233471	0.86	26	39	6.83	21.9
Wairoa Stream at Ahipara	21/03/2023	20231153	0.095	0.8	1.9	6.98	1.6

Site Name	Sampling Date	Sample ID	Aluminium Total (g/m3)	TSS (g/m3)	Turb (NTU)	pH	Rainfall 48hrs (mm)
Wairoa Stream at Ahipara	19/04/2023	20231670	0.12	1.9	1.8	7.17	1.8
Wairoa Stream at Ahipara	17/05/2023	20231998	0.76	4.8	9.4	6.47	2
Wairoa Stream at Ahipara	21/06/2023	20232261	2.7	36	37	6.63	17.2
Peria at Honeymoon Valley US Dutton Rd	20/03/2023	20231147	0.098	0.7	2.4	7.67	0
Peria at Honeymoon Valley US Dutton Rd	16/05/2023	20231995	0.46	6	7.7	7.5	2.7
Kerikeri at Golf View Road	9/03/2023	20231111	0.058	1	1.9	6.81	1.1
Kerikeri at Golf View Road	3/04/2023	20231627	0.072	2.4	1	6.7	5
Kerikeri at Golf View Road	17/05/2023	20231966	0.16	1.4	2.5	6.6	1.7
Kerikeri at Golf View Road	8/06/2023	20232228	0.21	2.4	3.4	6.82	8.9
Hatea at A H Reed Park	7/03/2023	20231103	0.33	3.2	7.6	7.62	19
Hatea at A H Reed Park	4/04/2023	20231635	0.15	1.6	3.7	7.8	0
Hatea at A H Reed Park	2/05/2023	20231958	1	5.4	15	7.2	96.2
Hatea at A H Reed Park	6/06/2023	20232221	2.2	26.8	37	7.26	42.1
Toatoa Stream at Parapara-Toatoa Road	20/03/2023	20231145	0.14	2.5	5.5	7.51	0
Toatoa Stream at Parapara-Toatoa Road	16/05/2023	20231993	0.34	6	9.4	7.26	0
Toatoa Stream at Parapara-Toatoa Road	20/06/2023	20232256	0.41	7.6	12	7.48	0

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