

Low Flow Gauging Status Report for the Whangārei Harbour, Upper Wairua and Kaihu Catchments



Compiled by

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Abbreviations

7d-MALF	7 day Mean Annual Low Flow
ADCP	Acoustic Doppler Current Profilers
L/s	litres per second
LCDB5	Land Cover Database version 5
MALF	Mean Annual Low Flow
NIWA	National Institute of Water and Atmospheric Research
NPS-FM	National Policy Statement for Freshwater Management
NRC	Northland Regional Council
PRPN	Proposed Regional Plan for Northland
RWQN	Regional Water Quality Network
SOE	State of the Environment
WAT	Water Allocation Tool

TABLE OF CONTENTS

Abbreviations	3
Executive summary	6
1. Introduction	7
Background	7
Scope of the report	7
Objectives.....	7
2. Study area	8
3. Data collection	9
Methodology.....	9
Low flow gauging period	9
4. Results.....	10
Whangārei Harbour catchment	10
Flow trends	10
Impacts of water takes.....	10
Preliminary assessment of low flow coherence for between donor and receiver sites.....	13
Evaluation of observed low flows against Waugh regional estimates across geological settings....	18
Upper Wairua catchment	20
Flow trends	20
Impacts of water takes.....	22
Preliminary assessment of low flow coherence for between donor and receiver sites.....	22
Evaluation of observed low flows against Waugh regional estimates across geological settings....	27
Kaihu catchment	28
Flow trends	28
Impacts of water takes.....	28
Preliminary assessment of low flow coherence for between donor and receiver sites.....	31
Evaluation of observed low flows against Waugh regional estimates across geological settings....	32
5. Assumptions and limitations.....	34
6. Conclusions	35
7. Recommendations.....	36
7. References.....	37
Appendices	38

List of figures

Figure 1: Status of the low flows in the Whangārei Harbour catchment (2023/2024).....	11
Figure 2: Status of the low flows in the Whangārei Harbour catchment (March 2025).....	12
Figure 3: Kohinui at Crisp Road – Ngunguru at Dugmores Rock sites low flow relationship	16
Figure 4: Waikaraka at Straight End – Ngunguru at Dugmores Rock sites low flow relationship	17
Figure 5: Rukuwai at Taraunui Road Bridge – Ngunguru at Dugmores Rock sites low flow relationship	18
Figure 6: Status of the low flows in the Upper Wairua catchment (April 2024)	21
Figure 7: Kaiikanui at Pigs Head Road – Ngunguru at Dugmores Rock sites low flow relationship	27
Figure 8: Status of the low flows in the Kaihu catchment (March 2025)	30
Figure 9: Waipoua at SH12 – Mangatu at Mudfords flow correlation	32

List of Tables

Table 1: Catchment coverage of the targeted low-flow gauging programme since 2016/2017	8
Table 2: Gauging sites that are influenced by water takes in the Whangārei Harbour catchment	10
Table 3: Assessment of the low-flow correlation appropriateness for selected ungauged sites in the Whangārei Harbour catchment	14
Table 4: Summary of zero-flow observations at low-flow gauging sites in the Whangārei Harbour catchment	14
Table 5: Donor and receiver sites selected for preliminary correlation analysis in the Whangārei Harbour Catchment	15
Table 6: Comparison of low-flow gauging-derived specific discharge ranges with Waugh regional minimum-flow estimates across selected geological settings	19
Table 7: Gauging sites that are influenced by water takes in the Upper Wairua catchment.....	22
Table 8: Assessment of the low-flow correlation readiness for selected ungauged sites in the Upper Wairua catchment.....	24
Table 9: Donor and receiver sites considered for preliminary correlation analysis	26
Table 10: Comparison of low-flow gauging-derived specific discharge with Waugh regional minimum-flow estimates across selected geological settings	28
Table 11: Gauging sites that are influenced by water takes in the Kaihu catchment	29
Table 12: Assessment of the low-flow correlation appropriateness for selected ungauged sites in the Kaihu catchment	31
Table 13: Donor and receiver sites considered for preliminary correlation analysis	31
Table 14: Comparison of low-flow gauging-derived specific discharge with Waugh regional minimum-flow estimates across selected geological settings	33

List of Appendices

Appendix 1: Low flow gauging results for the Whangārei Harbour Catchment	38
Appendix 2 : Low flow gauging results for the Upper Wairua Catchment.....	43
Appendix 3: Low flow gauging results for the Kaihu Catchment	47
Appendix 4: Selected site photos from low flow gaugings	48

Executive summary

The Northland Region is characterised by a large number of small and relatively short rivers and streams, with approximately 1,700 individual source-to-sea catchments. Due to the scale and spatial complexity of the river network, it is not feasible to maintain flow monitoring sites across all catchments. Consequently, the setting of minimum flows and water allocation limits in the region has historically relied on modelled data. The regional flow recorder network has significantly improved the understanding of hydrological behaviour in gauged catchments; however, targeted low-flow gauging remains an important component of the monitoring programme to improve understanding of flows in ungauged catchments and support drought response, compliance assessment, and water resource management.

This report presents the collection, analysis, and interpretation of low-flow gauging data from selected sites within the Whangārei Harbour, Upper Wairua, and Kaihu catchments for the 2023/2024 and 2024/2025 summer seasons, supplemented by historic gaugings from the same sites to provide additional temporal context. Preliminary correlation analyses were undertaken to assess the potential for using donor–receiver relationships to refine low flow estimates at ungauged sites. In addition, the potential of assessing specific discharge estimates derived from low flow gaugings against Waugh (1970) minimum flow estimates to provide a regional hydrogeological context was explored.

Some of the key findings from the low flow gauging investigations are:

- Low-flow gaugings across the Whangārei Harbour, Upper Wairua, and Kaihu catchments confirmed generally low stream flows consistent with prolonged dry seasonal conditions.
- Hydrological coherence is site-specific, not uniform across catchments.
- Current monitoring data are insufficient to support robust predictive correlation.
- Correlation analyses demonstrate potential but require more data before application for flow estimation.
- Limited low-flow gauging data restricts robust comparison with Waugh regional estimates, highlighting the need for additional measurements to improve confidence.
- Some catchments are either fully characterised by high-yielding aquifers or have such aquifers in their headwaters, both of which contribute to sustained moderate to high stream flows.
- Water abstraction and groundwater depletion may influence flows at some sites, particularly in the Upper Wairua catchment.

Some of the key recommendations include:

- Increase low-flow gaugings per site to over 10 to improve statistical robustness of analyses and support more reliable low-flow estimation.
- Prioritise sites with moderate to strong correlation potential for continued monitoring to strengthen donor–receiver relationships.
- Apply correlation-based methods alongside geology-based approaches (e.g. Waugh) to combine regional context with site-specific variability.
- Use Waugh estimates as a baseline for comparison, not as standalone predictors at reach scale.
- Investigate rainfall–runoff modelling as a complementary tool for low flow refinement, particularly where data are sparse or correlations are weak.

1. Introduction

Background

Water resource regulators, planners, and managers often encounter challenges when trying to understand and estimate flows in ungauged catchments, in areas lacking continuous monitoring, or during dry periods such as droughts. In many instances, the interaction between groundwater and surface water is not well understood, particularly when assessing groundwater contribution to streamflow under low-flow or dry conditions. These uncertainties highlight the need for hydrological or scientific investigations, like low-flow gauging, to improve the understanding and address low flow estimation challenges within water resource systems.

In 2016, the Natural Resources Science and Hydrology teams at Northland Regional Council (NRC) initiated a targeted low-flow gauging programme as part of the wider regional low-flow monitoring effort. Targeted low flow gauging has been undertaken during the 2016/2017, 2018/2019, 2019/2020, 2023/2024, and 2024/2025 water years.

Scope of the report

This report presents the collection, analysis, and interpretation of low-flow gauging data from selected sites within the Whangārei Harbour, Upper Wairua, and Kaihu catchments. The assessment integrates low-flow gaugings undertaken during the 2023/2024 and 2024/2025 summer seasons with historic low-flow gaugings undertaken at the same sites. The report focuses on characterising streamflow behaviour during summer low-flow conditions and explores the use of correlation and geology for estimating low flows in ungauged catchments and refining modelled low flows. These include correlation-based approaches and using the Waugh geology method.

Objectives

The primary objectives of the low flow gauging programme are as follows:

- To improve the understanding of low-flow behaviour in ungauged catchments.
- To reduce uncertainty in modelled low-flow estimates to improve confidence in water allocation estimates
- To validate yield estimates derived using the Waugh geology based method.
- To support extrapolation of correlated low-flow relationships to physiographically similar ungauged catchments across the region.

In achieving the primary objectives of the low-flow gauging programme, the specific objectives of this assessment are as follows:

- To present and analyse low-flow gauging data collected from selected sites within the Whangārei Harbour, Upper Wairua, and Kaihu catchments during the 2023/2024 and 2024/2025 summer gauging seasons.

- To assess the suitability of both current and historic (pre 2023/2024) low-flow gaugings at selected sites in meeting the objectives of the overall low-flow gauging programme and supporting low-flow characterisation.
- To undertake preliminary correlation analysis between ungauged (receiver) sites and physiographically similar flow recorder (donor) sites to evaluate hydrological coherence and the potential for correlation-based low-flow estimation.
- To examine the influence of geology on low-flow behaviour and its applicability in estimating low flows across different catchment types.
- To provide recommendations for future monitoring, data collection, and analytical approaches, including opportunities to strengthen correlation analyses and incorporate complementary methods such as rainfall–runoff modelling.

2. Study area

The targeted low-flow gauging programme was initiated with a pilot study in the Whangārei Harbour catchment in the 2016/2017 water year. In subsequent years, the programme was expanded to include additional catchments, primarily in response to drought-related initiatives and an increasing demand for improved low-flow information. Prior to the establishment of this programme, low-flow gaugings had been undertaken at selected sites across the region, typically in response to prolonged dry periods or drought conditions. Table 1 summarises the catchment coverage of the targeted low-flow gauging programme over time.

Table 1: Catchment coverage of the targeted low-flow gauging programme since 2016/2017

Water year	Catchment						
	Whangārei Harbour	Upper Wairua	Ōtaika	Waitangi	Ruakaka	Waipu	Kaihu
2016/2017	X						
2018/2019	X *			X *			
2019/2020	X	X	X	X	X	X	
2020/2021			X				
2023/2024	X	X					
2024/2025	X						X

* 2 low flow gauging runs

3. Data collection

Methodology

Some of the key procedures used in the low flow gauging are as follows:

- Low flow gauging sites were selected using a combination of historical gauging locations, catchment mapping, and local hydrological knowledge held by NRC staff.
- Health and safety considerations informed final site selection, with gaugings undertaken only at river reaches that were safely accessible and suitable for accurate flow measurement under prevailing low flow conditions.
- Gaugings were undertaken under stable or slowly receding (recession) low flow conditions to ensure that measured flows were representative of prevailing hydrological conditions and not significantly influenced by short-term rainfall-runoff responses. Where practical, gauging was undertaken when flows at telemetered flow recorder sites within the catchment were approximately at or below the 7d-MALF.
- Selected cross-sections were generally characterised by laminar or near-laminar flow conditions, with little or no vegetation present on the channel bed or banks. Where flows were too low to allow accurate measurement, temporary channel constriction was undertaken to raise the water stage and enable accurate gauging. A minimum stabilisation period of five minutes was observed prior to flow measurement.
- Gauging methods and equipment were selected based on site-specific conditions and flow characteristics. Methods used included portable V-notch weirs, StreamPro Acoustic Doppler Current Profilers (ADCP), FlowTracker devices, volumetric (bucket) measurements, and, where necessary, visual flow estimation.
- Field data including date, time, and flow, were recorded on site at the time of gauging.

Low flow gauging period

Low-flow gauging was undertaken in the Whangārei Harbour catchment between 25 and 28 March 2024, and in the Upper Wairua catchment between 3 and 5 April 2024 during the 2023/2024 summer season. Subsequent low-flow gaugings were undertaken in the Whangārei Harbour catchment between 18 and 21 March 2025, and in the Kaihu catchment between 24 and 26 March 2025. Historic low-flow gauging data measured at the same sites, where available, were retrieved from the Hilltop database and incorporated into the analysis to support correlation with gauged sites and the broader low flow gauging programme.

4. Results

Whangārei Harbour catchment

Flow trends

A total of 42 low-flow gauging sites were assessed within the Whangārei Harbour catchment. Stream flows across the catchment were generally low, as is typical during the summer low-flow period. The status of low-flow conditions observed during the 2023/2024 and 2024/2025 summer seasons is presented in Figures 1 and 2, respectively.

Most low-flow gauging sites within the Whangārei Harbour catchment are located on separate streams due to the small size of contributing catchments, which limits the ability to establish upstream–downstream flow relationships. The only sites located on the same stream are the Takahiwai Dam outfall and Takahiwai at Carr Quarry Road. However, these sites are unsuitable for upstream–downstream flow analysis due to the presence of the dam outfall, which is an artificial structure that restricts downstream flow, as shown in the site photograph provided in Appendix 4. At the time of the gauging, there was no water flowing over the spillway although the dam was almost at full capacity. Additionally, there is no maintenance flow released downstream of the reservoir.

Impacts of water takes

Most of the low flow gauging sites in the Whangarei Harbour catchment are not affected by consented takes. However, permitted activity takes for domestic supply, stock drinking water, and dairy shed washdown purposes occur in some parts of the catchment. As many permitted activity takes are not registered with the Council, such water takes are based on estimates. The following low flow gauging sites are located downstream of water take points and therefore gauged flows may be influenced by water takes when they are being exercised.

Table 2: Gauging sites that are influenced by water takes in the Whangārei Harbour catchment

Gauging Site	Upstream consent(s)	Sum of consented takes (L/s)	Potential impacts
Taihu at Pines Golf Club	AUT.001772.01.03	0.58	Low
Hatea at Whareora Road	AUT.007398.01.02	104.17	High
Ōtaika at Kay	Several	135	High
Waiarohia at Lovers Lane	AUT.001725.02.02	36	Moderate

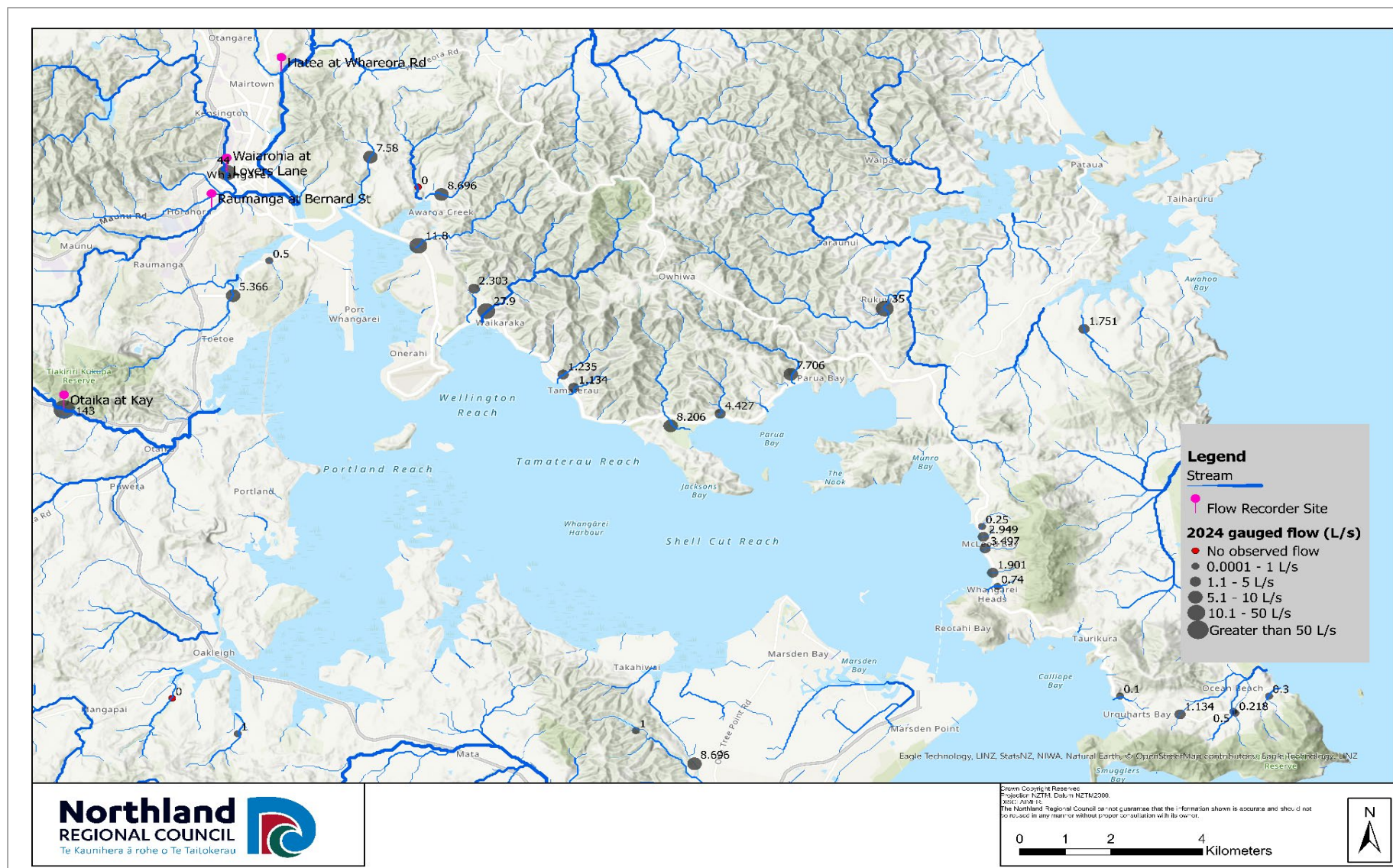


Figure 1: Status of the low flows in the Whangārei Harbour catchment (2023/2024)

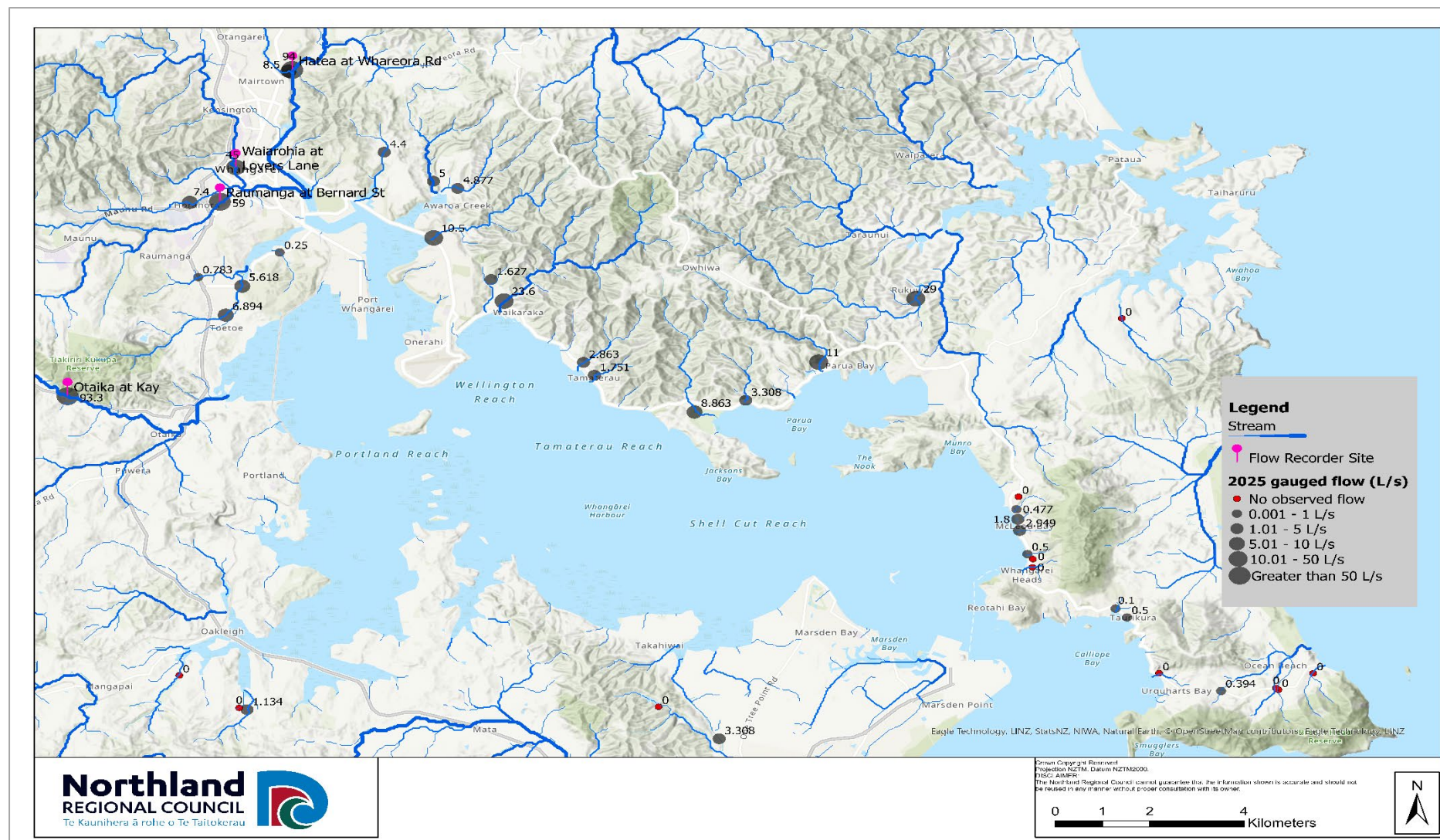


Figure 2: Status of the low flows in the Whangārei Harbour catchment (March 2025)

Preliminary assessment of low flow coherence for between donor and receiver sites

A preliminary correlation analysis was undertaken to evaluate potential linear relationships between a sample of low-flow measurements at ungauged/receiver sites and concurrent flows at physiographically similar donor/gauged sites.

The following guiding principles, as outlined by Griffiths and McKerchar (2015) were applied to support sound flow correlation analysis:

- A minimum of 10 concurrent low-flow gauging runs should be undertaken to improve statistical robustness and reduce uncertainty.
- Gaugings should be undertaken during the recession limb of the hydrograph, typically at least four days after a rainfall event, to minimise the influence of event-driven flow.
- Gaugings should be undertaken when flows at the donor site are below the median flow. For predictive purposes, it is ideal that several donor-site flows are below the 7d-MALF.
- Naturalised stream flows should be used to ensure that correlations reflect hydrological behaviour rather than the effects of abstraction or regulation.

For most sites, the available datasets comprise a limited number of paired observations, which constrains statistical confidence. Given the limitation, the correlation analysis is exploratory and intended to basically assess low flow coherence and relative hydrological behaviour between paired sites rather than to derive definitive predictive relationships.

A summary of selected gauging sites for the Whangārei Harbour catchment, and their appropriateness for correlation analysis is presented in Tables 3 and 4.

Table 3: Assessment of the low-flow correlation appropriateness for selected ungauged sites in the Whangārei Harbour catchment

Gauging site	Total number of low-flow gaugings	Total number of usable low-flow gaugings	Range of gauged flows (L/s)	Correlation appropriateness	Limiting factors
McLeods Bay Trib at Dudin Weir	19	19	2.16 – 3.59	moderate	no gauged site with matching hydrogeology
Limeburners Creek Trib at Kioreroa Rd	6	2	0 – 0.50	low	zero flows (4 runs); limited gaugings
Awaroa Trib at Jacksons	5	5	1.30 – 8.73	moderate	limited number of gaugings
Ocean Beach Trib at Bottom Car Park	6	2	0 – 0.3	not suitable	zero flows (4 runs); limited gaugings
Ocean Beach Trib at 427 Ocean Beach Road	6	5	0 – 1.13	low	limited number of gaugings; zero flow
Ocean Beach Trib at 274 Ocean Beach Road	5	2	0 – 0.218	not suitable	zero flows (3 runs); limited gaugings
Ocean Beach Trib at 276 Ocean Beach Road	6	1	0 – 0.5	not suitable	zero flows (5 runs); limited gaugings
Waimahanga at Riverside Drive	7	7	6.20 – 23.36	moderate	limited number of gaugings
Waioneone Creek at Abbey Caves Road	7	7	1.00 – 11.00	moderate	limited number of gaugings
McLeods Bay Trib at Kemps House	7	7	0.67 – 2.95	moderate	limited number of gaugings
Rukuwai Stream at Taiharuru Road	7	7	19.96 – 58.00	moderate	limited number of gaugings
Te Waiiti at Rewarewa Road Bridge	16	8	2.38 – 102	low	old gaugings (from early 1980's); some gaugings were done in winter
Waikaraka at Straight End (Old Orange Tree Site)	7	7	14.18 – 40.32	moderate	limited number of gaugings
Kohinui Stream at Crisp Road	7	7	8.00 – 15.42	moderate	limited number of gaugings
McLeods Bay Trib at Batting North	15	8	0 – 17.00	low	zero flows (7 runs)

Table 4: Summary of zero-flow observations at low-flow gauging sites in the Whangārei Harbour catchment

Site group	Total number of gaugings	Number of zero-flow recorded	Dominant geology	Interpretation
Ocean Beach streams (4 gauging sites)	23	13	melange	naturally intermittent streams
Urquharts Bay tributaries	6	2	melange	limited baseflow contribution
McLeods Bay Trib at Batting North	15	7	mud and volcanic breccia	naturally intermittent streams
Limeburners Creek Trib at Kioreroa Road	6	4	sandstone	naturally intermittent stream

Consequently, correlation testing was undertaken for a representative sample of three paired sites in the Whangārei Harbour catchment to provide an initial indication of potential relationships as shown in Table 5.

Table 5: Donor and receiver sites selected for preliminary correlation analysis in the Whangārei Harbour Catchment

Ungauged / Receiver site	Receiver site catchment area (km ²)	Flow recorder site / donor site	Number of paired gaugings used in preliminary correlation (n)
Waikaraka at Straight End (Old Orange Tree Site)	8.6	Ngunguru at Dugmores Rock	7
Kohinui Stream at Lens Parkers Crisp Road	3.5	Ngunguru at Dugmores Rock	7
Rukuwai Stream at Taraunui Road Bridge	8.3	Ngunguru at Dugmores Rock	7

Kohinui at Crisp Road and Ngunguru at Dugmore's Rock sites preliminary flow correlation

The relationship between concurrent flows at the Ngunguru at Dugmore's Rock flow recorder site and spot-gauged flows at the Kohinui at Crisp Road site is illustrated in Figure 3. Based on the seven paired observations included in this exploratory analysis, approximately 77% of the variability in the observed low-flow measurements at the Kohinui site is explained by the fitted linear relationship with concurrent flows at the Ngunguru donor site ($R^2 = 0.7659$). This indicates a relatively strong positive linear correlation with comparatively limited scatter around the regression line.

The observed relationship indicates a good degree of hydrological coherence between the two sites and suggests potential suitability for correlation-based low-flow estimation. However, given the current limited number of paired gaugings, the relationship should be interpreted as indicative rather than definitive. Additional concurrent low flow gaugings across a broader range of low-flow conditions are required to improve confidence in the robustness and reliability of the correlation.

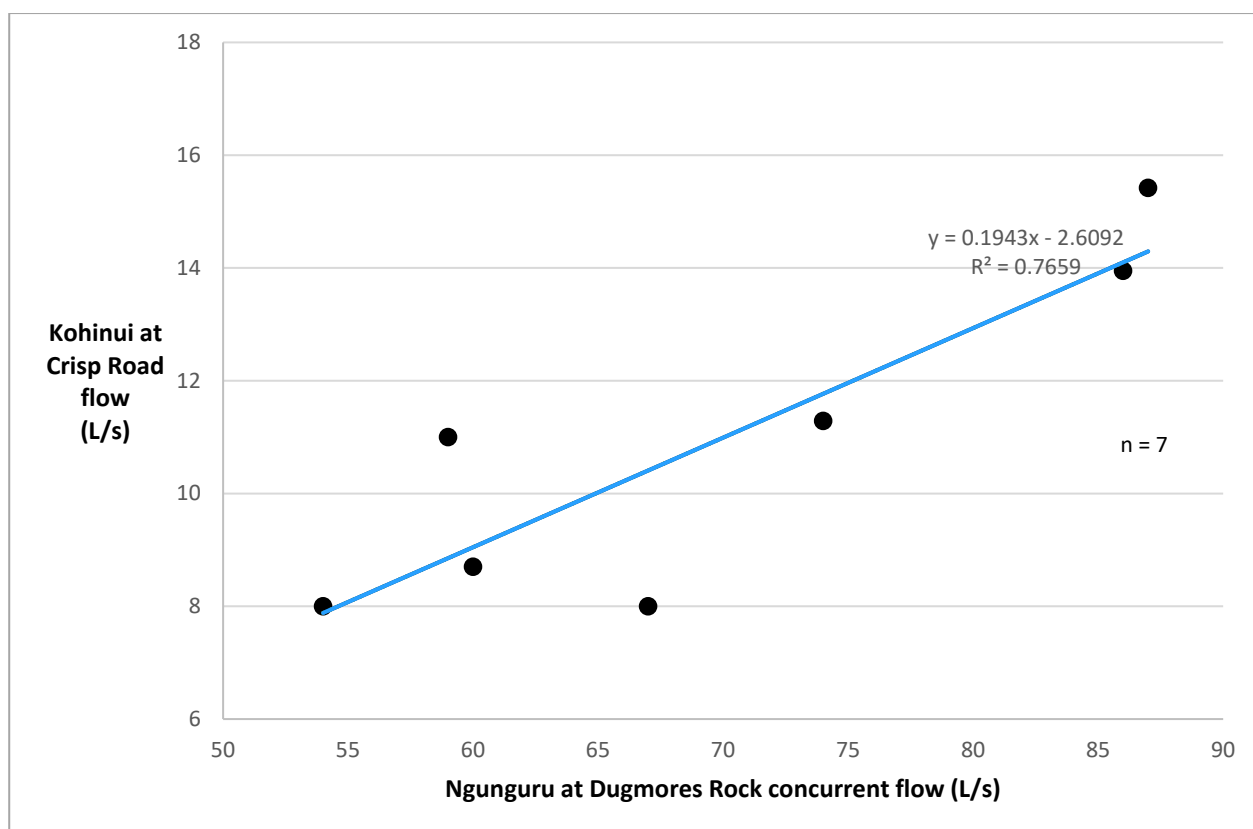


Figure 3: Kohinui at Crisp Road – Ngunguru at Dugmores Rock sites low flow relationship

Waikaraka at Straight End and Ngunguru at Dugmore's Rock flow sites preliminary flow correlation

The relationship between concurrent flows at the Ngunguru at Dugmore's Rock flow recorder site and spot-gauged flows at the Waikaraka at Straight End site is illustrated in Figure 4. Based on the seven paired observations included in this exploratory analysis, approximately 53% of the variability in the observed Waikaraka low-flow measurements is explained by the fitted linear relationship with concurrent flows at the donor site. This represents a moderate positive linear correlation, characterised by considerable scatter around the regression line.

The remaining unexplained variability likely reflects a combination of factors, including the limited number of paired gaugings, differences in local catchment characteristics, and variations in hydrological responses between the two sites, particularly under higher flow conditions. As such, while some degree of flow coherence is evident, the relationship is not sufficiently strong to support predictive low-flow estimation at this stage and should be considered indicative only.

Excluding the higher flow observations (with considerable scatter) from the analysis improved the goodness of fit to $R^2 = 0.88$. This may indicate that the relationship between the two sites becomes more consistent under lower-flow recession conditions. However, this improvement is based on only five paired gaugings and is therefore associated with high uncertainty and limited statistical robustness.

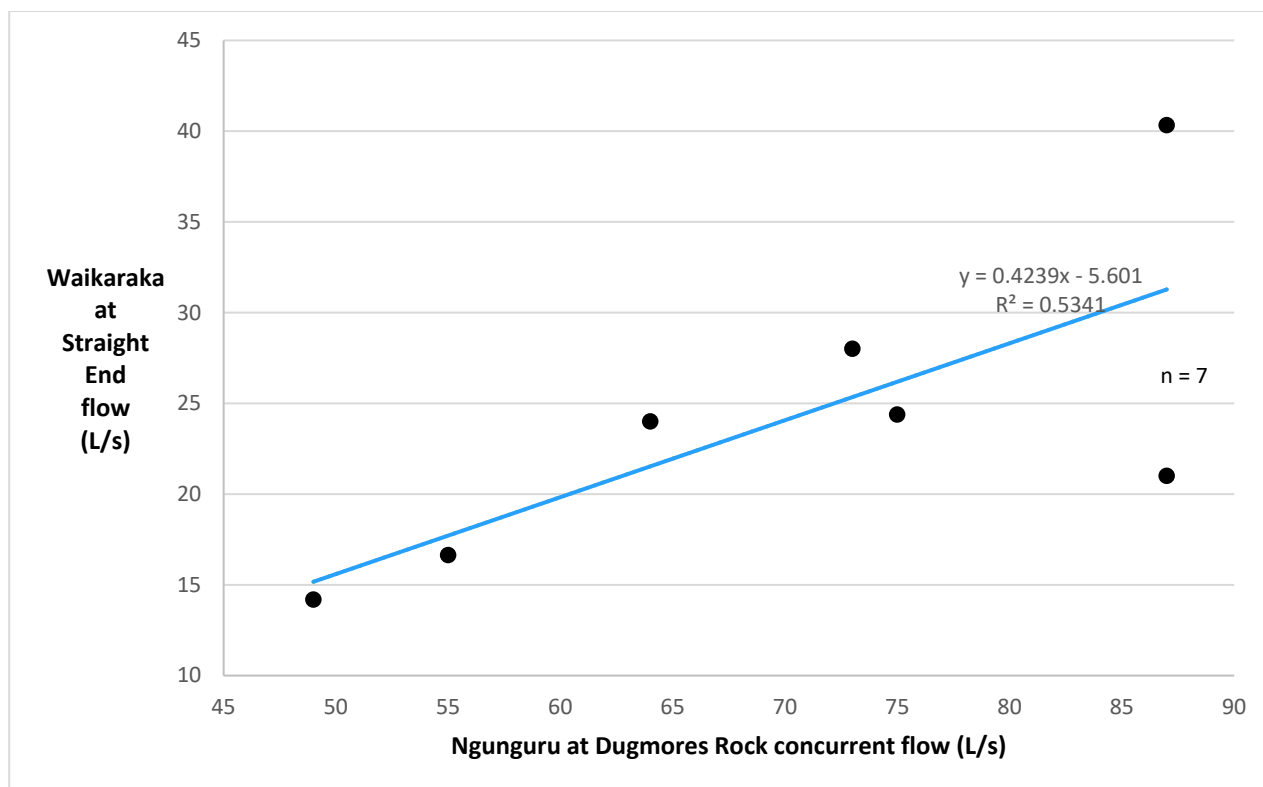


Figure 4: Waikaraka at Straight End – Ngunguru at Dugmores Rock sites low flow relationship

Rukuwai at Taraunui Road Bridge and Ngunguru at Dugmore's Rock sites preliminary flow correlation

The scatter plot of concurrent flows between the Ngunguru at Dugmore's Rock flow recorder site and the Rukuwai at Taraunui Road Bridge gauging site indicates a low to moderate positive linear relationship (Figure 5). Based on the seven paired observations included in the analysis, approximately 47% of the variability in the observed spot-gauged flows at the Rukuwai site is explained by the fitted linear relationship with concurrent flows at the Ngunguru donor site ($R^2 = 0.4725$).

The remaining unexplained variability suggests that flow behaviour at the Rukuwai site is only partially represented by the concurrent flows observed at the donor site. This variability is likely influenced by a combination of factors including the limited number of paired gaugings, local catchment characteristics or differences in hydrological responses. While some degree of hydrological coherence is evident, the current relationship should be regarded as preliminary and should not be used for predictive low flow estimation purposes.

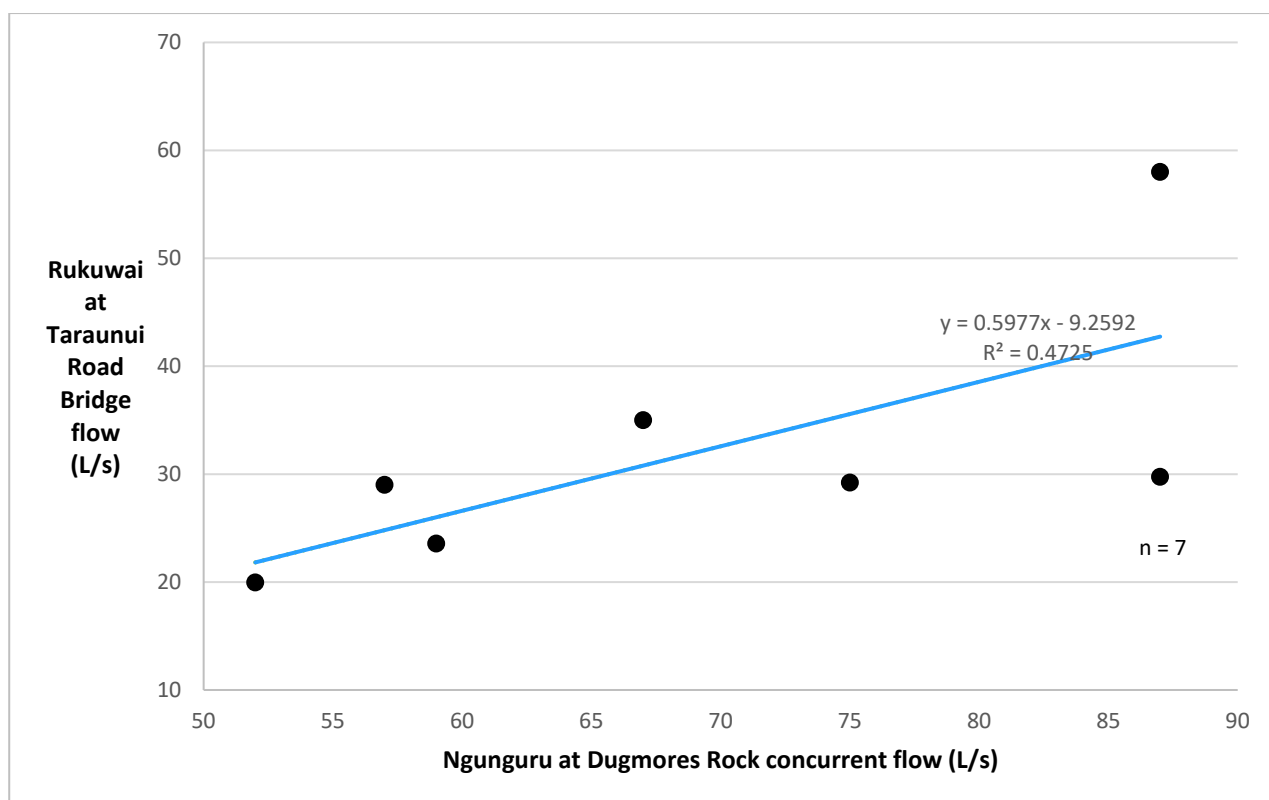


Figure 5: Rukuwai at Taraunui Road Bridge – Ngunguru at Dugmores Rock sites low flow relationship

Evaluation of observed low flows against Waugh regional estimates across geological settings

The gauged low flows for selected sites were assessed against indicative regional minimum flow values reported by Waugh (1970) for similar geological settings. Specific discharge ranges, derived from low-flow gaugings, were used as it normalises for catchment area and enables meaningful comparison and interpretation of flows across catchments of different sizes. This analysis provides contextual insight into whether observed low-flow conditions are broadly consistent with expected hydrogeological behaviour. However, given the limited number of low-flow gaugings currently available, the results should be interpreted as preliminary and as such were just reported as ranges. Once sufficient number of gauges have been attained and low flow statistics of the ungauged sites have been estimated, they can be effectively assessed against the Waugh estimates.

In general, low flows at greywacke sites clustered around the Waugh regional values. This was observed at the Waikaraka, Kohinui, and Rukuwai sites which, despite some slightly lower specific discharge values, were broadly comparable to the Waugh estimates (Table 6). These results suggest that the Waugh regional estimates are generally representative for greywacke-dominated catchments.

In contrast, catchments dominated by volcanic breccia and melange generally have intermittent streams and had lower specific discharge ranges compared to the Waugh estimates (Table 6). Locally elevated specific discharge values observed at two McLeods Bay sites (Dudin Weir and Kemps House) suggest

enhanced groundwater contributions relative to other catchments under similar geological settings. These two sites are the only ones among the six McLeods Bay tributaries that exhibited sustained low flows, with no recorded zero-flow conditions over a monitoring period of at least three years. This indicates the presence of more persistent baseflow at these locations and suggests that these systems are likely perennial. In contrast, the remaining McLeods Bay tributaries displayed intermittent flow behaviour, with zero-flow conditions recorded during some monitoring years, reflecting more limited groundwater storage and baseflow contribution.

Table 6: Comparison of low-flow gauging-derived specific discharge ranges with Waugh regional minimum-flow estimates across selected geological settings

Gauging site	Area (km ²)	Main geology	Number of gaugings (n)	Gauged flows (L/s)	Specific discharge (L/s/km ²)	Waugh regional value (L/s/km ²)
Waikaraka at Straight End (Old Orange Tree Site)	8.6	greywacke (99%)	7	14.2 – 40.3	1.6 – 4.7	3.8
Kohinui Stream at Lens Parkers Crisp Road	3.5	greywacke (96%)	7	8 – 15.4	2.3 – 4.4	3.8
Rukuwai Stream at Taraunui Road Bridge	8.3	greywacke (96%)	7	20 – 58	2.4 – 7	3.8
McLeods Bay Trib at Dudin Weir	0.6	volcanic breccia (90%), melange (6%)	19	2.2 – 3.6	3.6 – 6.0	3.8
McLeods Bay Trib at Kemps House	0.6	volcanic breccia (81%), melange (6%)	7	0.7 – 2.9	1.1 – 4.9	3.8
Ocean Beach Trib at 427 Ocean Beach Road	0.6	melange (50%), volcanic breccia (50%)	6	0 – 1.1	0 – 1.9	3.8
Ocean Beach Trib at 274 Ocean Beach Road	0.7	volcanic breccia (80%), melange, (18%)	5	0 – 0.2	0 – 0.3	3.8
Ocean Beach Trib at 276 Ocean Beach Road	1.0	volcanic breccia (55%), melange (30%), mud (15%)	6	0 – 0.5	0 – 0.5	3.8
Ocean Beach Trib at Bottom Car Park	1.3	volcanic breccia (86%), melange (8%), mud (6%)	6	0 – 0.3	0 – 0.2	3.8

Overall, the comparison indicates that estimated specific discharge values at greywacke-dominated sites are broadly consistent with Waugh regional estimates. However, the limited dataset constrains the robustness of this assessment. As such, additional low-flow gaugings are required to improve confidence in the comparison.

Upper Wairua catchment

Flow trends

A total of 36 low flow sites were gauged across the Upper Wairua catchment in April 2024. As expected for the summer season, flows were low. Most of the gauging sites are located on the same rivers and streams, allowing for the assessment of upstream and downstream flow relationships. These include sites on the Wairua, Whakapara, Mangere, Waiotu, Waipao, Kaimamaku, Waiariki, and Taotaoroa rivers and streams and their tributaries.

The only stream where the typical incremental flow effect of tributaries was not observed was on the Mangahahuru gauging sites. The reduction in flow at the downstream gauging site amounting to approximately 35 L/s can be attributed to a significant surface water take consent (AUT.004373.04.02) located between the two gauging sites. This occurred despite several small tributaries contributing additional flow to the Mangahahuru stream between the two gauging sites.

The status of low flows for the 2023/2024 summer season is illustrated in Figure 6.

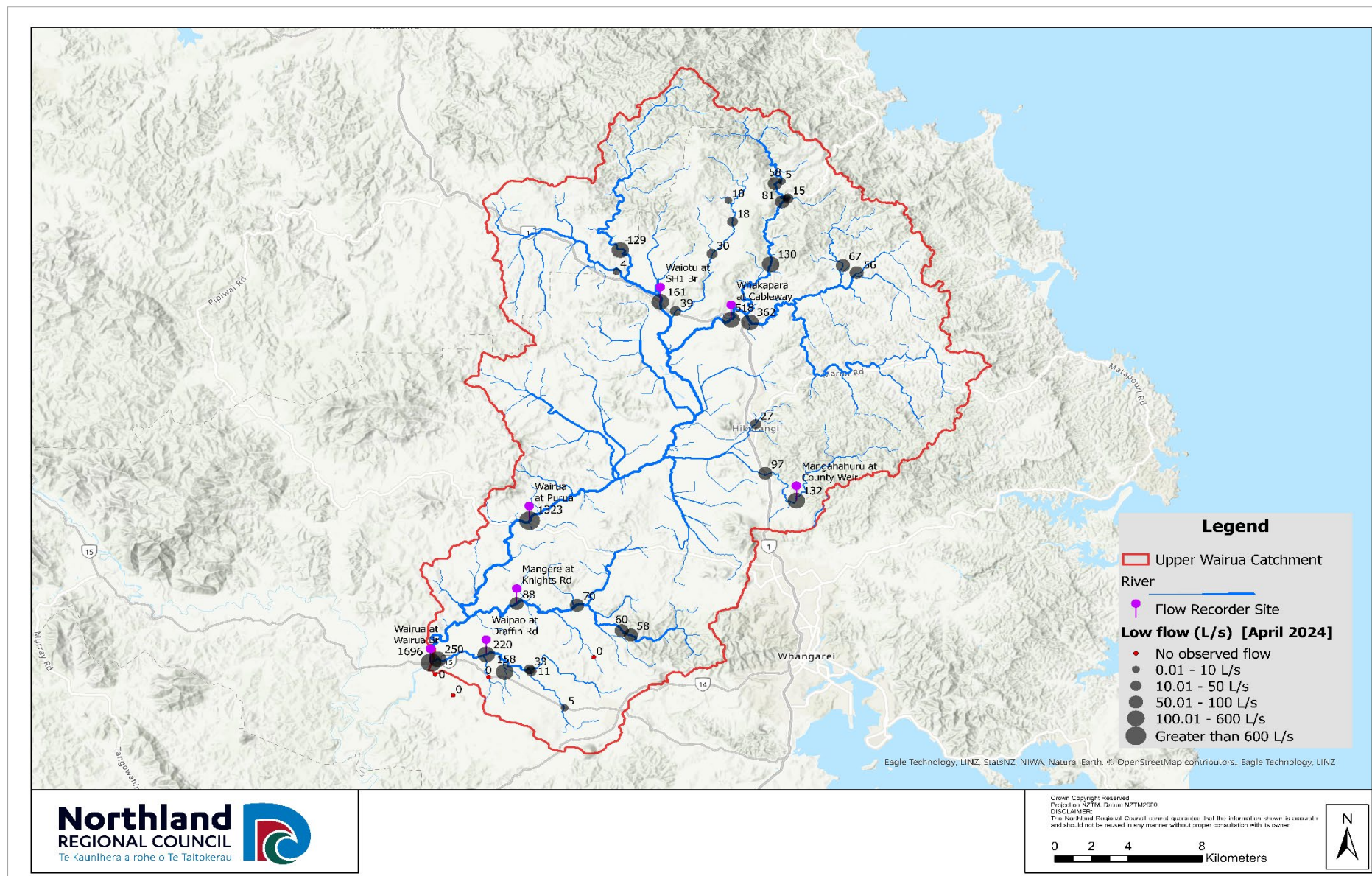


Figure 6: Status of the low flows in the Upper Wairua catchment (April 2024)

Impacts of water takes

The following gauging sites are located downstream of water take points such that the recorded low flows may be influenced when these water takes are being exercised. Gauged flows were also lower than some consent maintenance flow requirements meaning that if such conditions were strictly adhered to, water takes should have been ceased at the time of gauging. However, for the Waipao at Kokopu Road and Wairua at Wairua Bridge sites, the gauged flows were higher than the estimated minimum flows at reach level.

Table 7: Gauging sites that are influenced by water takes in the Upper Wairua catchment

Gauging site	Upstream consent(s)	Sum of consented takes (L/s)	Potential impacts
Waipao at Kokopu Road	AUT.011641.01.03 AUT.043469.01.01 AUT.002960.01.03 AUT.038056.01.01 AUT.031027.01.02 AUT.007172.01.03	184	High
Mangere at Knight Roads	AUT.004965.01.04 AUT.002696.01.03 AUT.004966.02.03	53.5	High
Whakapara at Russell Road Bridge	AUT.042854.01.01 AUT.042873.02.01 AUT.004191.01.04 AUT.042873.02.01	2.53	Low
Mangahahuru at SH1	AUT.004373.04.02 AUT.002184.01.03	91.9	High
Waiariki at SH1	AUT.004964.03.03	66.5	High
Okarika stream	AUT.043556.01.01 AUT.042012.01.01 AUT.041951.01.01	1.83	Low
Wairua at Wairua Bridge	46 consents upstream of gauging site	492	High

Preliminary assessment of low flow coherence for between donor and receiver sites

In the Upper Wairua catchment, a number of gauging sites are located downstream of consents water take points, reaches influenced by impoundments, or in proximity to bores with potential stream depletion effects. These factors can alter the natural hydrological regime and influence observed low flow conditions and therefore should be accounted for in correlation analysis. Where flow naturalisation is undertaken, the use of measured or reported abstraction rates is preferred over consented take limits, as these provide a more representative estimate of actual water use and the resulting degree of hydrological alteration.

A key limitation of the analysis is the availability of actual water use data, which generally extends from the 2015/2016 water year onwards. In contrast, a proportion of the historical low flow gauging data in the Upper Wairua catchment predates this period. This temporal mismatch significantly limits the number of gauging events that can be reasonably naturalised and incorporated into the correlation analysis. Consequently, the preliminary correlation analysis was restricted to sites that are not influenced by water takes, or where any such influences are considered negligible.

A summary of selected gauging sites and their appropriateness with best-practice correlation guidelines is presented in Table 8.

Table 8: Assessment of the low-flow correlation readiness for selected ungauged sites in the Upper Wairua catchment

Gauging site	Total number of low-flow gaugings	Total number of usable low-flow gaugings	Range of gauged flows (L/s)	Correlation appropriateness	Limiting factors
Mangere at Kara Road Bridge	10	10	61 – 102	Moderate to high	Dam upstream; lack of historic water use records
Mangere at Kokopu Road	7	2	80 – 200	Low to moderate	Limited number of gaugings; most gaugings were done in the early 1980's; 3 dams and 1 stream water take upstream; lack of historic water use records
Mangere at Woods Road	7	7	43 – 97	Moderate	Limited number of gaugings; Dam upstream of gauging site
Okoihu at Wharekohe Rd	1	0	0	Low	Limited number of gaugings; zero flow; groundwater take with stream depletion
Kauritutahi at Mangakahia Rd (SH15)	25	1	7 – 137	Low	Limited number of gaugings, 24 gaugings done between 1979 and 1992; non stationarity/catchment change risk; 1 stream take and 1 groundwater take with stream depletion; lack of historic water use records
Waipuakakahua at Tapuhi Road	2	2	4 – 7	Low	Limited number of gaugings
Waiariki at SH1	16	1	39 – 136	Low	Old gaugings (1942; 1982 to 1994); non stationarity/catchment change risk; 3 diversions (2 dams and 1 weir); historic gaugings cannot be naturalised because of lack of historic water use records
Waiariki at Mine Rd	7	1	25 – 134	Low	Limited number of gaugings; old gaugings (1982 to 1989); 3 diversions (2 dams and 1 weir); historic gaugings cannot be naturalised because of no historic water use records
Tapahina at Mangakahia Rd (SH15)	1	0	0	Low	Limited number of gaugings; zero flow
Waipao at Kokopu Rd	2	1	75 – 250	Low	Limited number of gaugings; several surface water takes including significant consented take (180 L/s)
Poroti Springs at Fig Tree	9	9	38 - 186	Moderate to high	3 groundwater takes with stream depletion
Waipao at McBeth Rd	15	1	30 – 220	Low	Most gaugings are old (1979 to 1993); 5 surface water and 1 groundwater takes; historic gaugings cannot be naturalised because of lack of historic water use records

Gauging site	Total number of low-flow gaugings	Total number of usable low-flow gaugings	Range of gauged flows (L/s)	Correlation appropriateness	Limiting factors
Waiotu at Tapuhi Road	8	2	110 - 381	Low	Limited number of gaugings; 6 of the gaugings are old (1982 to 1983); non stationarity/catchment change risk
Waiariki at Rockells Ford	23	1	18 – 312	Low	22 gaugings are old (1993 to 2005); 2 dams immediately upstream of site; historic gaugings cannot be naturalised because of lack of historic water use records
Whakapara at Russell Road Bridge	1	1	362	Low	Limited gaugings; 3 stream water takes upstream
Mangawhero Stream at George St Bridge	1	1	27	Low	Limited gaugings
Mangahahuru at SH1	4	4	103 - 359	Low	Limited number of gaugings; 2 stream water takes; historic gaugings cannot be naturalised because of lack of historic water use records; Mangahahuru catchment mainly under exotic forestry and landuse has been changing with harvesting and replanting
Kaimamaku at Hodgson Rd	2	2	130 – 151	Low	Limited number of gaugings
Kaiikanui at Pigs Heads Rd	9	8	67 – 179	Moderate	Limited number of gaugings; Most gaugings done in the 1980's; one gauging undertaken in winter
Mataroa at Bushby Rd	2	2	56 – 82	Low	Limited number of gaugings

Consequently, correlation testing was undertaken for a sample of one paired site to provide an initial indication of potential flow relationships as shown in Table 9.

Table 9: Donor and receiver sites considered for preliminary correlation analysis

Ungauged site / Receiver catchment	Receiver site catchment area (km ²)	Flow recorder site / donor site	Number of gaugings used in preliminary correlation (n)
Kaiikanui at Pigs Heads Road	15.6	Ngunguru at Dugmores Rock	8

The relationship between concurrent flows at the Ngunguru at Dugmore's Rock flow recorder site and spot-gauged flows at the Kaiikanui at Pigs Heads Road site is illustrated in Figure 7. Based on the eight paired observations included in this exploratory analysis, approximately 95% of the variability in the observed low-flow measurements at the Kaiikanui site is explained by the fitted positive linear relationship with concurrent flows at the Ngunguru donor site ($R^2 = 0.9519$). This indicates a very strong positive linear correlation with limited scatter around the regression line.

The strength of the observed relationship suggests a high degree of low flow coherence between the two sites and indicates strong potential suitability for correlation-based low-flow estimation. The strong correlation may reflect similarities in catchment response characteristics and flow recession behaviour between the two sites. However, given the limited number of paired gaugings and some of the old gaugings used, the relationship should still be interpreted as indicative rather than definitive. It is important to undertake additional low flow gaugings across wider range of low flow conditions to confirm the robustness and long-term reliability of the correlation.

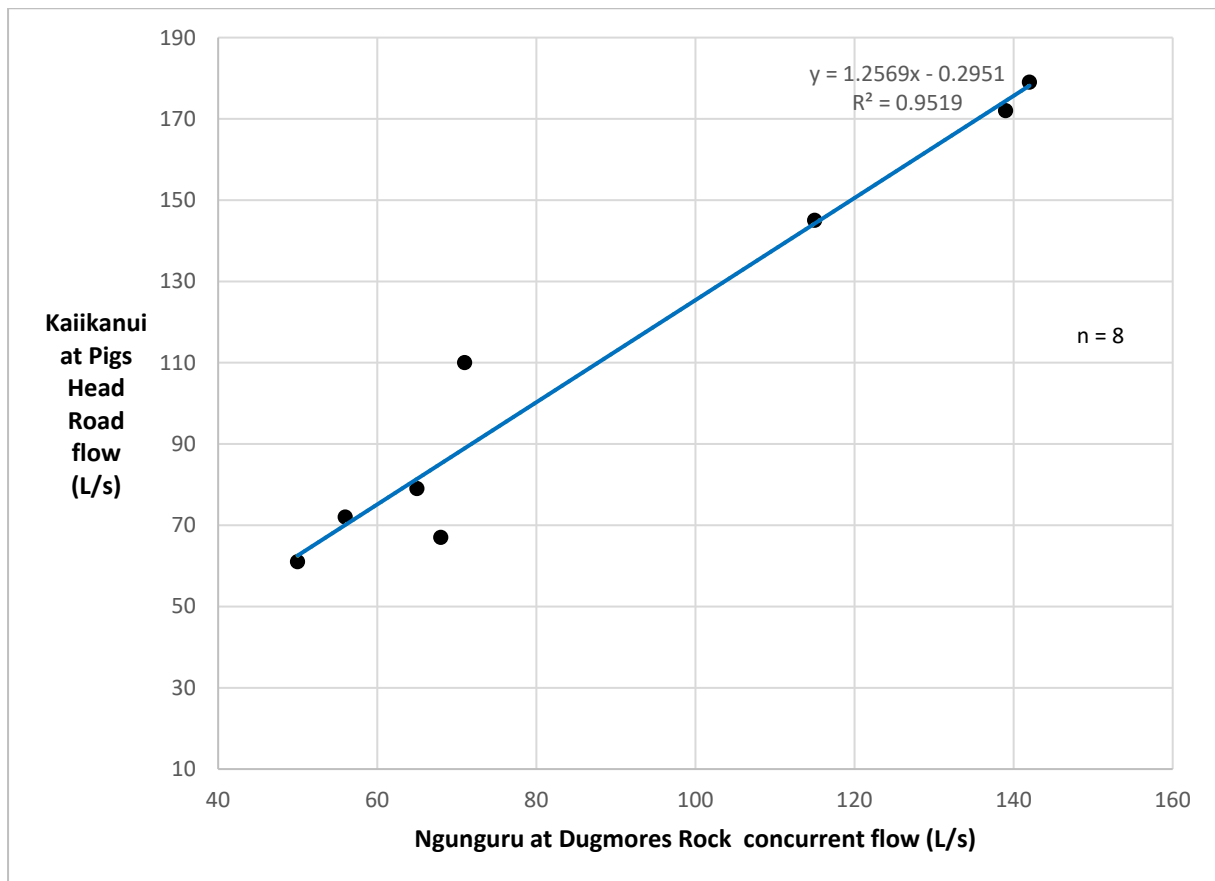


Figure 7: Kaiikanui at Pigs Head Road – Ngunguru at Dugmores Rock sites low flow relationship

Evaluation of observed low flows against Waugh regional estimates across geological settings

Specific discharge values derived from selected low flow gauging sites with minimal upstream water take influences were assessed against the Waugh regional values. Table 10 presents a comparison of estimated specific discharge ranges with the corresponding Waugh regional value across selected geological settings.

In general, most sites exhibit specific discharge ranges that are broadly comparable with the Waugh regional estimate, indicating overall consistency with expected regional low-flow behaviour. However, elevated specific discharge values observed at some sites, such as Mangere at Woods Road, are likely influenced by enhanced groundwater contributions associated with localised basalt aquifer systems. The catchment upstream of the Mangere at Woods Road site originates around the margins of the Matarau, Three Mile Bush, and Maunu North basalt aquifers. These basaltic systems are highly productive and are known to sustain streamflows through spring-fed inputs and groundwater discharge. As a result, catchments influenced by these aquifers tend to exhibit higher baseflow contributions and elevated specific discharge under low-flow conditions.

However, the interpretation of these results is constrained by the limited number of low-flow gaugings available for each site ($n = 2-8$). The restricted dataset reduces statistical robustness and may not fully represent long-term low-flow conditions.

Table 10: Comparison of low-flow gauging-derived specific discharge with Waugh regional minimum-flow estimates across selected geological settings

Site	Area (km ²)	Geology	Number of gaugings (n)	Gauged flows (L/s)	Specific discharge (L/s/km ²)	Waugh regional value (L/s/km ²)
Mangere at Woods Road	15.6	greywacke (75%); basalt (13%); melange (6%)	7	43 - 97	2.8 - 6.2	3.8
Waiotu at Tapuhi Road	46.5	greywacke (72%); (basalt (10%))	8	110 - 381	2.4 - 8.2	3.8
Kaimamaku at Hodgson Road	37.5	greywacke (69%); basalt (25%)	2	130 - 151	3.5 - 4	3.8
Kaiikanui at Pigs Heads Road	15.6	greywacke (91%); mud (7%)	8	67 - 179	4.3 - 11.5	3.8
Mataroa at Bushby Road	19.6	greywacke (79%); mud (19%)	2	56 - 82	2.9 - 4.2	3.8

Overall, while the comparison suggests general alignment between observed and regional estimates at several sites, additional low-flow gaugings are required to improve dataset representativeness and enable a more robust and defensible evaluation of specific discharge relative to Waugh regional estimates.

Kaihu catchment

Flow trends

Low flows were observed throughout the catchment, consistent with typical summer season conditions. Gauged low flows within the Kaihu catchment were mostly consistent with upstream and downstream flow patterns. Upstream gauging sites recorded lower flows than downstream sites along the main stem, confirming the contribution of tributary inflows as shown in Figure 8.

Impacts of water takes

There are four low flow sites within the catchment that showed evidence of flow reduction due to water abstraction. This is based on the fact that the downstream gauged flow was lower than the upstream flow. For the Kaihu at Rotu site, one of the gaugings revealed gauged flow below the consent maintenance flow condition suggesting water takes may have contributed to the low flow.

Table 11: Gauging sites that are influenced by water takes in the Kaihu catchment

Gauging Site	Upstream consent(s)	Sum of consented takes (L/s)	Potential impacts
Waima at Burkes (Lambers)	AUT.043558.01.01	0.57	Low
Waima at Trounson Park Road (Top 10)	AUT.043558.01.01 AUT.007642.01.03 AUT.004318.03.02	26.45	Moderate
Kaihu at Rotu	AUT.008134.01.03 AUT.008367.01.03 AUT.008361.01.04 AUT.004653.03.03 AUT.030845.01.01 AUT.007642.01.03 AUT.043558.01.01	182.73	High
Waiparataniwha at Ford 1 Waiparataniwha at Ford 2 Waiparataniwha at Ford 3	AUT.030845.01.01	51.55	High

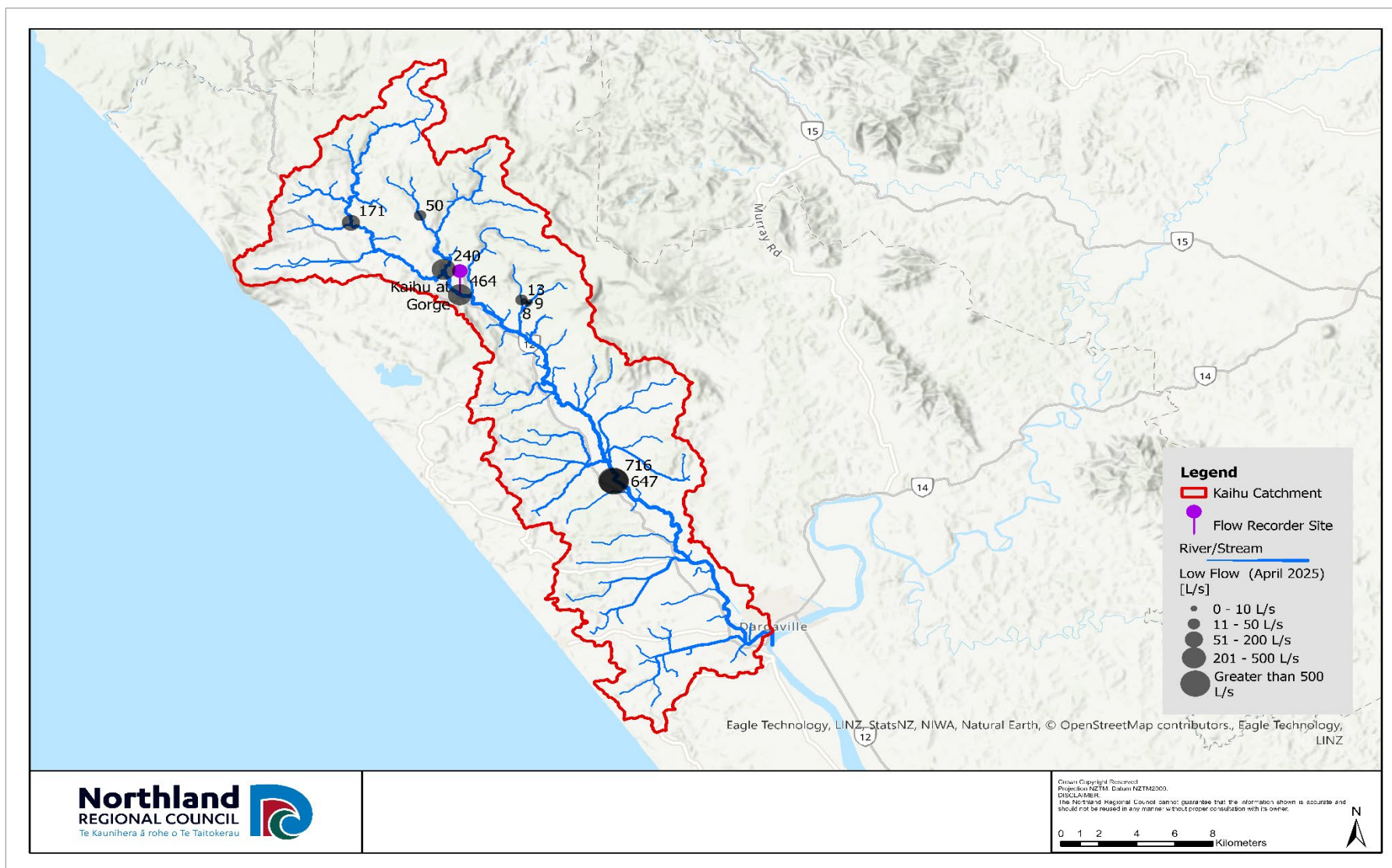


Figure 8: Status of the low flows in the Kaihu catchment (March 2025)

Preliminary assessment of low flow coherence for between donor and receiver sites

A preliminary correlation analysis was undertaken to evaluate potential linear relationships between a sample of low-flow measurements at ungauged site and concurrent flows at a physiographically similar donor flow recorder site in the neighbouring Waipoua Catchment. A summary of selected gauging sites and their conformity with best-practice correlation guidelines is presented in Tables 12 and 13.

Table 12: Assessment of the low-flow correlation appropriateness for selected ungauged sites in the Kaihu catchment

Gauging site	Total number of low-flow gaugings	Total number of usable low-flow gaugings	Range of gauged flows (L/s)	Correlation appropriateness	Limiting factors
Waima at Burkes (Lambars)	3	3	171 – 480	Low	Limited number of gaugings
Mangatu at Milicich (Mudfords)	5	4	50 – 81	Low	Limited number of gaugings; one gauging was when flow at the Waipoua site was above the median

Consequently, correlation testing was undertaken for a sample of one paired site to provide an initial indication of potential relationships as shown in Table 13.

Table 13: Donor and receiver sites considered for preliminary correlation analysis

Ungauged site / Receiver catchment	Receiver site catchment area (km ²)	Flow recorder site / donor site	Number of gaugings used in preliminary correlation (n)
Mangatu at Milicich (Mudfords)	6.9	Waipoua at SH12	4

The relationship between concurrent flows at the Waipoua at SH12 flow recorder site and spot-gauged flows at the Mangatu at Mudfords site is illustrated in Figure 9. The relationship between observed low-flow measurements at the Mangatu site and concurrent flows at the Waipoua donor site indicates a moderate positive linear correlation, with moderate scatter around the regression line. However, this relationship is based on a very limited number of paired observations and is therefore subject to substantial uncertainty. As such, it should be regarded as indicative of some degree of low-flow hydrological coherence between the two sites, rather than a robust predictive relationship. Additional low-flow gaugings spanning a wider range of conditions are required to improve confidence in the correlation and its suitability for low-flow estimation.

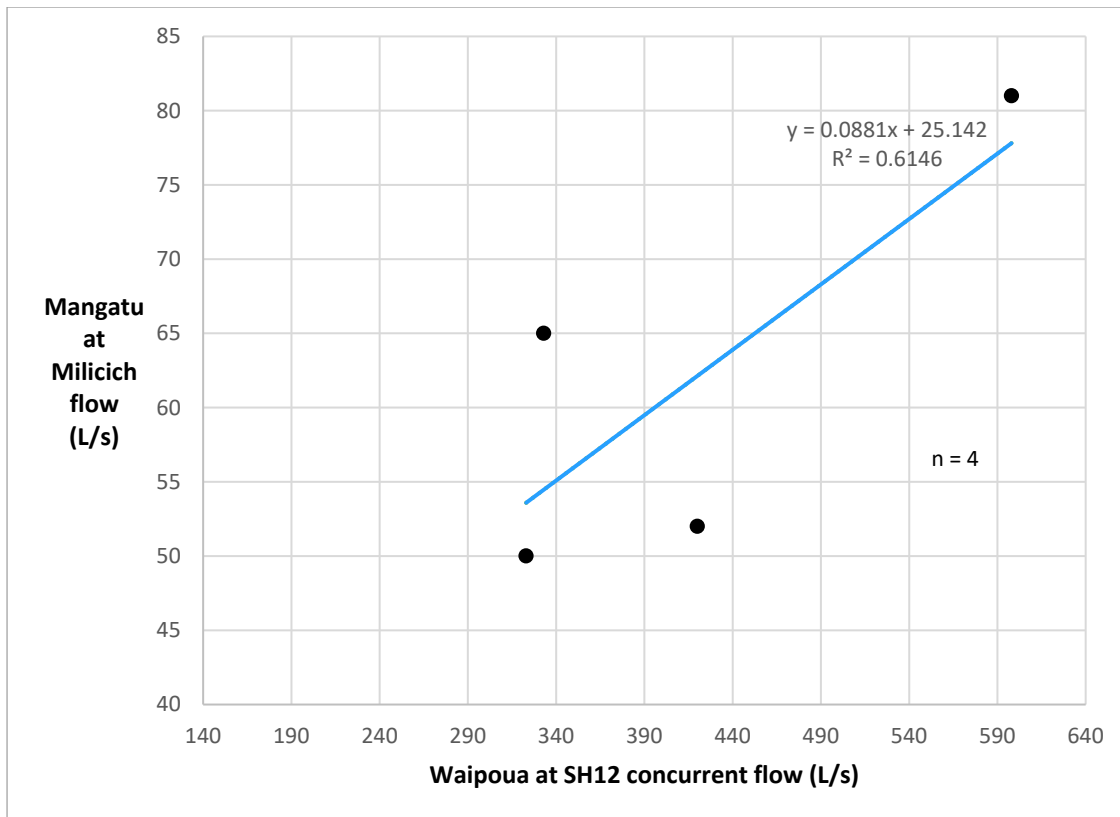


Figure 9: Waipoua at SH12 – Mangatu at Mudfords flow correlation

Evaluation of observed low flows against Waugh regional estimates across geological settings

The specific discharge rates derived from low-flow gaugings for three selected sites in the Kaihu catchment were assessed against the Waugh regional value. Table 14 presents a comparison of the specific discharge ranges with the Waugh regional estimate of 3.8 L/s/km² for the corresponding sites.

The results generally indicate that the three sites generally compare with the Waugh regional estimate. The values are consistent with the characteristics of basalt-influenced systems, which typically exhibit higher permeability, greater storage capacity, and enhanced groundwater contributions.

Although detailed aquifer mapping has not been undertaken for the Kaihu catchment, the Waipoua Basalts are likely to exhibit similar hydrogeological characteristics to other basalt aquifers in Northland. Streams draining basalt-influenced headwaters in the region are commonly sustained by groundwater contributions, including baseflow and spring discharge, particularly near the margins of basalt formations.

Table 14: Comparison of low-flow gauging-derived specific discharge with Waugh regional minimum-flow estimates across selected geological settings

Site	Area (km ²)	Geology	Number of gaugings (n)	Gauged flows (L/s)	Specific discharge (L/s/km ²)	Waugh regional value (L/s/km ²)
Mangatu at Milicich (Mudfords)	6.9	basalt (100%)	4	50 - 81	7.2 - 11.7	3.8
Waima at Burkes (Lambars)	40.8	basalt (99%)	3	171 - 480	4.2 - 11.8	3.8
Waima at Trounson Park Road	21.1	basalt (91%); sand (9%)	2	130 - 151	3.5 - 4	3.8

However, the limited number of low-flow gaugings available for each site (n = 2–4) constraints the interpretation of the results. Additional low-flow gaugings are required to improve the dataset and enable a more robust assessment of the specific discharge and the Waugh regional estimates.

5. Assumptions and limitations

The following assumptions and limitations have been acknowledged in this study.

Assumptions

1. It is assumed that spot-gauged flows at the receiver sites and concurrent flows recorded at the donor flow recorder sites are representative of the same prevailing hydrological conditions at the time of measurement.
2. It is assumed that the selected donor flow recorder sites reasonably represent regional low-flow behaviour for the corresponding receiver catchments, based on geographic proximity and perceived similarities in hydrological and catchment characteristics.
3. It is assumed that low flow gaugings including historic gaugings were all undertaken under stable or slowly receding low-flow conditions, such that short-term rainfall-runoff responses did not significantly influence the observed relationships.
4. It is assumed that specific discharge derived from spot gaugings is a suitable metric for comparing low-flow behaviour across catchments of different sizes.

Limitations

1. A relatively small number of paired low-flow gauging measurements were available for pairings for most of the sites. This limits the statistical robustness and confidence of the derived regression relationships. Accordingly, the derived donor–receiver relationships should be interpreted as indicative and preliminary until supported by additional low-flow gauging and further hydrological assessment.
2. The relationship between some donor and receiver sites may vary under very low flows, moderate recession flows, or higher flow conditions. Accordingly, a single linear regression relationship may not fully represent hydrological behaviour across all flow conditions.
3. Only gauging sites that are not affected by water takes, or for which flows can be reasonably naturalised were included in the preliminary correlation analysis to ensure that the relationships assessed reflect natural hydrological conditions as closely as possible.
4. Actual water use records for most water take consents are available from approximately the 2015/2016 water year onwards. Gaugings undertaken prior to this period for sites with takes cannot be accurately naturalised due to the absence of these water take records. Consequently, these were excluded from correlation analysis, as their inclusion could introduce additional uncertainty of donor receiver relationships.
5. Some historic gaugings are relatively old (e.g. recorded between approximately 1981 and 1995). While these data provide useful context on low-flow conditions, they cannot be confidently used for correlation analysis as catchment conditions may have changed over time, including climate variability, water use, and land use. In addition, long temporal gaps between gaugings (e.g. 1985 to 2019 or 1995 to 2017 for some sites) further reduce their suitability for establishing reliable relationships.

6. Conclusions

The following conclusions can be drawn from the low flow gauging investigations for the Whangārei Harbour, Upper Wairua and Kaihu catchments:

1. Gauged stream flows across the Whangārei Harbour, Upper Wairua and Kaihu catchments were generally low and consistent with seasonal expectations under prolonged dry conditions. Low flow gaugings derived from flow recorder sites indicate widespread hydrological stress during the monitoring periods.
2. Most ungauged sites within the Whangārei Harbour, Upper Wairua and Kaihu catchments currently have an insufficient number of low-flow measurements to support correlation-based flow estimation with a high degree of confidence. Existing data are valuable for characterising hydrological coherence but are generally inadequate for robust low-flow correlation without additional gaugings.
3. Preliminary correlation analyses show that the strength of donor–receiver relationships varies across the catchments, ranging from weak to very strong correlations. This variability reflects differences in local catchment characteristics and hydrological response, indicating that hydrological coherence is site-specific rather than uniform across the region.
4. Preliminary correlation analyses for selected sites in the Whangārei Harbour, Upper Wairua and Kaihu catchments indicate that, while some paired sites exhibit moderate to strong relationships, the limited number of concurrent low-flow observations restricts the statistical reliability of these relationships. As such, the current correlations should be regarded as indicative of hydrological coherence rather than suitable for predictive application.
5. Strong correlations observed in some site pairings demonstrate that correlation-based methods have the potential to support refinement of low flows in ungauged catchments where suitable donor sites exist. However, weaker relationships at other sites highlight the limitations of this approach where catchments differ in scale, geology, or groundwater contribution.
6. Although preliminary analyses provide useful insight into hydrological relationships between sites, the current dataset is insufficient to support predictive application. Additional concurrent low-flow gaugings, collected across a broader range of low-flow conditions, are required to confirm and strengthen these relationships before they can be used to refine low-flow statistics with confidence.
7. Comparison of observed specific discharge with Waugh regional estimates indicates that the regional value provides a reasonable first-order approximation of low flow yield within the study areas. However, a robust analysis could not be undertaken given the limited number of gaugings per each ungauged site.
8. The influence of underlying geology on low-flow behaviour is evident across the catchments. Streams associated with high-yielding basalt and greywacke formations generally exhibited higher and more sustained baseflows, while streams draining melange and low-permeability sediments frequently recorded very low or zero flows, reflecting limited groundwater contributions.
9. Some gauging sites, particularly in the Upper Wairua catchment, are located downstream of consented water take points or in areas influenced by groundwater abstraction. At these sites, observed flows may be partially affected by abstraction, highlighting the importance of considering abstraction effects and applying flow naturalisation where appropriate.

7. Recommendations

The following recommendations may be considered by NRC:

1. It is recommended that the number of low-flow gaugings per site be increased to a minimum of ten, in line with hydrological best practice, to improve the statistical robustness of analyses and support more reliable development of correlation relationships and refinement of low-flow statistics.
2. Additional targeted low-flow gaugings should be undertaken concurrently with flow recorder sites across a wider range of low flow conditions, particularly during drought and very low-flow conditions. This will better define donor–receiver relationships across critical low flow conditions and improve their reliability for predictive use.
3. Sites that exhibit moderate to strong preliminary correlations should be prioritised for ongoing monitoring to further develop and validate donor–receiver relationships and assess their consistency across multiple low-flow events.
4. Correlation-based methods should continue to be applied alongside geology-based approaches (e.g. Waugh regional estimates) to improve confidence in low-flow estimation and refinement. This combined approach enables both regional context and site-specific variability to be considered, supporting more robust and defensible low-flow estimates.
5. Flow recorder sites with long-term continuous data should continue to be used as reference points for calibrating low-flow estimates and improving the accuracy of regional modelling approaches, including refinement of 7d-MALF estimates.
6. Given the limitations associated with correlation-based methods, particularly where data are sparse or relationships are weak or site-specific, rainfall–runoff modelling should be considered as a complementary approach. Models can be calibrated using flow recorder site data and supported by low-flow gaugings to improve reliability under low-flow conditions.

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Appendices

Appendix 1: Low flow gauging results for the Whangārei Harbour Catchment

Site name	Catchment area (km ²)	Easting	Northing	NZREACH ID	2023/2024 gauging		2024/2025 gauging		Number of historic low flow gaugings	Period of historic low flow gaugings (water years)	Range of historic low flow gaugings (L/s)
					Date	Flow (L/s)	Date	Flow (L/s)			
Te Waiti at Rewarewa Road Bridge	4.9	1719232	6042748	1019086	25/03/2024	5.366	19/03/2025	5.618	14	1980/1981 – 2019/2020	2.38 – 102.00
Te Waiti at Toetoe Road	3.8	1718882	6041996	1019233	–	–	18/03/2025	6.894	0	–	–
Whangarei Harbour Trib at Grahamtown Road, Waikaraka	1.2	1724512	6042922	1019140	25/03/2024	2.303	19/03/2025	1.627	4	2018/2019 – 2019/2020	0.17 – 2.02
Tamaterau at Waitotara Lane	2.1	1726468	6040770	1019424	25/03/2024	1.235	19/03/2025	2.863	0	–	–
Whangārei Harbour / Waikaraka Trib at Attwood Street culvert	0.8	1726700	6040439	1019534	25/03/2024	1.134	19/03/2025	1.751	0	–	–
Limeburners Creek Trib at Kioreora Road	1.1	1720026	6043624	1018964	26/03/2024	0.50	19/03/2025	0.25	5	2016/2017 – 2019/2020	0 – 0.50
Limeburners Creek at SH1 Bridge	1.2	1718296	6042982	1019093	–	–	19/03/2025	0.783	0	–	–
Parua Bay Trib at Pepi Rd Culvert	1.5	1739895	6039993	1019665	25/03/2024	4.427	18/03/2025	3.308	2	2018/2019	1.85 – 1.88

Site name	Catchment area (km²)	Easting	Northing	NZREACH ID	2023/2024 gauging		2024/2025 gauging		Number of historic low flow gaugings	Period of historic low flow gaugings (water years)	Range of historic low flow gaugings (L/s)
					Date	Flow (L/s)	Date	Flow (L/s)			
Waikaraka at Straight End (Old Orange Tree Site)	8.6	1724785	6042360	1019128	25/03/2024	27.9	19/03/2025	23.6	4	2018/2019 – 2019/2020	14.18 – 40.32
Waimahanga at Riverside Drive	4.1	1723292	6043999	1018863	25/03/2024	11.8	19/03/2025	10.5	5	2017/2017 – 2019/2020	6.20 – 23.36
Awaroa Trib at Jacksons (One Way Bridge)	3.0	1723801	6045284	1018613	25/03/2024	8.696	18/03/2025	4.877	5	2016/2017 – 2019/2020	1.30 – 8.73
Awaroa Trib at Stables (New site to replace Blackberry Drain)	4.2	1723287	6045469	1018497	25/03/2024	0.00	21/03/2025	5	3	2018/2019 – 2019/2020	2.30 – 8.51
Waioneone Creek at Abbey Caves Rd	1.3	1722187	6046195	1018370	25/03/2024	7.58	18/03/2025	4.4	5	2016/2017 – 2019/2020	1.00 – 11.00
Ocean Beach Trib at Bottom Car Park	1.3	1742040	6033043	1020931	25/03/2024	0.30	18/03/2025	0	4	2018/2019 – 2019/2020	0 – 0.01
Ocean Beach Trib at 274 Ocean Beach Road	0.7	1741229	6032532	1020904	25/03/2024	0.218	18/03/2025	0	3	2018/2019 – 2019/2020	0 – 0.11
Ocean Beach Trib at 276 Ocean Beach Road	1.0	1741178	6032502	1022112	25/03/2024	0.50	18/03/2025	0	4	2018/2019 – 2019/2020	0
Ocean Beach Trib at 427 Ocean Beach Road	0.6	1740010	6032428	1022179	25/03/2024	1.134	18/03/2025	0.394	4	2018/2019 – 2019/2020	0.20 – 0.57

Site name	Catchment area (km ²)	Easting	Northing	NZREACH ID	2023/2024 gauging		2024/2025 gauging		Number of historic low flow gaugings	Period of historic low flow gaugings (water years)	Range of historic low flow gaugings (L/s)
					Date	Flow (L/s)	Date	Flow (L/s)			
Urquharts Bay Trib at Whangarei Heads Rd	0.8	1738715	6032640	1020964	25/03/2024	0.10	18/03/2025	0	4	2018/2019 – 2019/2020	0 – 0.39
McLeods Bay Trib at Batting South	0.9	1736109	6035333	1020476	25/03/2024	0.74	19/03/2025	0	4	2018/2019 – 2019/2020	0.34 – 0.71
McLeods Bay Trib at Batting North **	0.02	1735999	6035672		–	–	19/03/2025	0	14	1986/1987 – 2019/2020	0 – 17.00
McLeods Bay Trib at Dudin Weir	0.6	1735707	6036332	1020295	25/03/2024	3.497	18/03/2025	2.949	16	2016/2017 – 2019/2020	2.16 – 3.59
McLeods Bay Trib at Kemps House	0.6	1735706	6036632	1020171	25/03/2024	2.949	19/03/2025	1.8	5	2016/2017 – 2019/2020	0.67 – 2.09
McLeods Bay Trib at Frosts	0.2	1735652	6036962	1020132	25/03/2024	0.25	19/03/2025	0.477	5	2016/2017 – 2019/2020	0 – 0.51
McLeods Bay Trib at Donaldson **	0.03	1735696	6037287		–	–	19/03/2025	0	4	1990/1991 – 2018/2019	0 – 0.45
McLeods Bay at Playground	0.4	1735881	6035812	1020399	28/03/2024	1.901	19/03/2025	0.5	0	–	–
Takahiwai at Dam Outfall	1.0	1728061	6031843	1021072	26/03/2024	1.00	19/03/2025	0	4	2018/2019 – 2019/2020	0 – 1.00
Takahiwai at Carr Quarry Rd	2.7	1729347	6031012	1021177	26/03/2024	8.696	19/03/2025	3.308	4	2018/2019 – 2019/2020	0.50 – 3.79
Mangapai Trib at 50 Knagg Rd	1.6	1719340	6031991	1021109	26/03/2024	1.00	19/03/2025	1.134	2	2018/2019	0.10 – 1.00

Site name	Catchment area (km²)	Easting	Northing	NZREACH ID	2023/2024 gauging		2024/2025 gauging		Number of historic low flow gaugings	Period of historic low flow gaugings (water years)	Range of historic low flow gaugings (L/s)
					Date	Flow (L/s)	Date	Flow (L/s)			
Mangapai Trib at End of Knagg Rd	0.3	1719168	6031813	1021068	–	–	19/03/2025	0	0	–	–
Mangapai Trib at McCullough Rd	2.4	1717897	6032656	1020892	26/03/2024	0.00	19/03/2025	0	4	2018/2019 – 2019/2020	0 – 0.95
Taihu at Pines Golf Club	4.2	1728601	6039613	1019770	27/03/2024	8.206	18/03/2025	8.863	5	2018/2019 – 2019/2020	0.90 – 12.00
Kohinui Stream at Crisp Road	3.5	1731458	6040778	1019401	27/03/2024	7.706	18/03/2025	11	5	2016/2017 – 2019/2020	8.00 – 15.42
Rukuwai Stream at Taraunui Road Bridge	8.3	1733518	6042422	1019159	27/03/2024	35.00	18/03/2025	29	5	2016/2017 – 2019/2020	19.96 – 58.00
Taiharuru Trib at Taiharuru Rd	2.3	1737886	6041912	1019248	28/03/2024	1.751	18/03/2025	0	0	–	–
Ōtaika at Kay *	35.1	1715526	6039894	1019622	25/03/2024	143	19/03/2025	93.3			
Waiarohia at Lovers Lane *	17.5	1719093	6045829	1018445	22/03/2024	44	20/03/2025	45			
Raumanga at Bernard Street *	15.9	1718759	6044938	1018618			20/03/2025	59			
Hatea at Whareora Road *	38.5	1720292	6048353	1017989			20/03/2025	94			
Otangarei at Whareora Road	2.7	1720212	6048324	1018013	–	–	20/03/2025	8.5	0	–	–
Kirikiri at Cheviot Street footbridge	3.5	1718119	6044919	1018610	–	–	19/03/2025	7.4	3	2009/2010	4.94 – 11.52

Site name	Catchment area (km ²)	Easting	Northing	NZREACH ID	2023/2024 gauging		2024/2025 gauging		Number of historic low flow gaugings	Period of historic low flow gaugings (water years)	Range of historic low flow gaugings (L/s)
					Date	Flow (L/s)	Date	Flow (L/s)			
Taurikura Bay Trib at Tennis Courts	0.5	1737752	6034387	1020658	–	–	18/03/2025	0.1	0	–	–
Taurikura Bay Trib at Culvert under Ody Road (Natural Jetty) **	0.03	1737999	6034158		–	–	18/03/2025	0.5	0	–	–

* indicates telemetered flow recorder sites that were excluded from historic flow gauging analysis

** indicates unmapped streams without NZREACH ID

– indicates that no low flow gauging data is available for the site for the specified period

Appendix 2 : Low flow gauging results for the Upper Wairua Catchment

Site name	Catchment area (km ²)	Easting	Northing	NZREACH ID	Flow Measurement Method	2023/2024 gauging		Number of historic low flow gaugings	Period of historic low flow gaugings (water years)	Range of historic low flow gaugings (L/s)
						Date	Flow (L/s)			
Mangere at Woods Road	15.6	1709346	6047276	1018129	Flow Tracker	3/04/2024	58	7	2009/2010 – 2013/2014	43 – 97
Mangere at Kara Road Bridge	16.0	1709388	6047363	1018129	Flow Tracker	3/04/2024	60	10	2005/2006 – 2015/2016	61 - 102
Mangere at Kokopu Road	49.3	1706885	6048856	1017835	Visual Estimate	3/04/2024	70	7	1982/1983 – 2012/2013	80 – 200
Mangere at Knight Road *	74.9	1703608	6048968	1017791	Flow Tracker	3/04/2024	88			
Okoihu at Wharekohe Road	3.5	1700160	6043408	1018950	Visual Estimate	3/04/2024	0	0	–	–
Okoihu at Whatitiri Road	6.0	1699186	6044680	1018724	Visual Estimate	3/04/2024	0	0	–	–
Kauritutahi at Mangakahia Rd (SH15)	8.6	1706206	6042659	1019083	Flow Tracker	3/04/2024	5	24	1979/1980 – 1991/1992	7 – 137
Waipuakakahua at Tapuhi Road	51.9	1709033	6069054	1013162	Flow Tracker	3/04/2024	4	1	2008/2009	7
Waiotu at SH1 Bridge *	120.7	1711408	6067208	1013585	Flow Tracker	3/04/2024	161			
Waiariki at SH1	25.4	1712238	6066663	1013771	Flow Tracker	3/04/2024	39	15	1941/1942 – 2009/2010	39 – 136
Waiariki at Mine Road	18.0	1714129	6070167	1012942	Flow Tracker	3/04/2024	30	6	1982/1983 – 2009/2010	25 – 134

Site name	Catchment area (km ²)	Easting	Northing	NZREACH ID	Flow Measurement Method	2023/2024 gauging		Number of historic low flow gaugings	Period of historic low flow gaugings (water years)	Range of historic low flow gaugings (L/s)
						Date	Flow (L/s)			
Whakapara at Cableway *	162.6	1715253	6066134	1013904	Stream Pro	3/04/2024	518			
Tapahina at Mangakahia Rd (SH15)	4.1	1702082	6044517	1018529	Visual Estimate	3/04/2024	0	0	–	–
Waipao at Kokopu Road	41.7	1709097	6043664	1018553	Visual Estimate	4/04/2024	250	1	1991/1992	75
Waipao at Draffin Road *	31.1	1701995	6045845	1018472	Flow Tracker	4/04/2024	220			
Poroti Springs at Fig Tree	2.6	1702897	6044548	1018685	Flow Tracker	4/04/2024	158	8	2016/2017 – 2018/2019	38 – 186
Waipao at McBeth Road	23.1	1704296	6044951	1018672	Flow Tracker	4/04/2024	33	14	1979/1980 – 2006/2007	30 – 220
Kauritutahi at McBeth Road	13.8	1704376	6044877	1018694	Calculation	4/04/2024	11	0	–	–
Waiotu at Tapuhi Road	46.5	1709230	6070354	1012820	Flow Tracker	4/04/2024	129	7	1982/1983 – 2009/2010	110 – 381
Waiariki at Rockells Ford	11.4	1715323	6072069	1012456	Flow Tracker	4/04/2024	18	22	1993/1994 – 2004/2005	18 – 312
Waiariki at Rockells Dam outflow downstream	2.9	1715088	6073352	1012125	Weir	4/04/2024	10	0	–	–
Whakapara at Russell Road Bridge	111.9	1716266	6065981	1013867	Flow Tracker	4/04/2024	362	0	–	–
Mangawhero Stream at George St Bridge	5.8	1716590	6059821	1015450	Flow Tracker	4/04/2024	27	0	–	–

Site name	Catchment area (km ²)	Easting	Northing	NZREACH ID	Flow Measurement Method	2023/2024 gauging		Number of historic low flow gaugings	Period of historic low flow gaugings (water years)	Range of historic low flow gaugings (L/s)
						Date	Flow (L/s)			
Mangahahuru at SH1	28.7	1717109	6056845	1016060	Flow Tracker	4/04/2024	97	3	2009/2010 – 2012/2013	103 – 359
Mangahahuru at County Weir *	21.1	1718795	6055188	1016433	Flow Tracker	5/04/2024	132			
Kaimamaku at Hodgson Road	37.5	1717397	6069490	1013042	Flow Tracker	5/04/2024	130	1	2009/2010	151
Kaiikanui at Pigs Heads Road	15.6	1721322	6069419	1013058	Flow Tracker	5/04/2024	67	8	1982/1983 – 2009/2010	67 – 179
Mataroa at Bushby Road	19.6	1722069	6068983	1013127	Flow Tracker	5/04/2024	56	1	2009/2010	82
Kaimamaku at Peach Orchard Road Bridge	27.3	1718027	6073272	1012168	Flow Tracker	5/04/2024	81.4	0	–	–
Taotaoroa at Peach Orchard Road	19.1	1717899	6074854	1011939	Flow Tracker	5/04/2024	58.3	0	–	–
Taotaoroa at Peach Orchard 1 way bridge	1.8	1717778	6074828	1011703	Visual Estimate	5/04/2024	5	0	–	–
Haumakariri at Russell Road (opposite Matheson Rd)	1.6	1718288	6073450	1011850	Visual Estimate	5/04/2024	10	0	–	–
Kaimamaku Trib at Matheson Road	4.5	1721322	6069419	1012142	Flow Tracker	5/04/2024	15.1	0	–	–
Wairua at Wairua Bridge *	707.3	1698897	6045537	1018572	ADCP	5/04/2024	1,696			
Wairua at Purua *	544.1	1704173	6053947	1016617	ADCP	5/04/2024	1,323			

Site name	Catchment area (km ²)	Easting	Northing	NZREACH ID	Flow Measurement Method	2023/2024 gauging		Number of historic low flow gaugings	Period of historic low flow gaugings (water years)	Range of historic low flow gaugings (L/s)
						Date	Flow (L/s)			
Mangapiu at Kokopu Block Road	2.9	1707794	6045719	1018483	Visual Estimate	5/04/2024	0	0	–	–

* indicates telemetered flow recorder sites that were excluded from historic flow gauging analysis

– indicates that no low flow gauging data is available for the site for the specified period

Appendix 3: Low flow gauging results for the Kaihu Catchment

Site name	Catchment area (km ²)	Easting	Northing	NZREACH ID	Flow Measurement Method	2024/2025 gauging		Number of historic low flow gaugings	Period of historic low flow gaugings (water years)	Range of historic low flow gaugings (L/s)
						Date	Flow (L/s)			
Waima at Burkes (Lambars)	40.8	1656059	6046566	1018104	Flow Tracker	24/03/2025	171	2	2010/2011 – 2012/2013	250 – 480
Mangatu at Milicich (Mudfords)	6.9	1659705	6047007	1018250	Flow Tracker	24/03/2025	50	4	2010/2011 – 2016/2017	50 – 290
Waima at Trounson Park Rd (Top 10)	77.7	1660955	6043749	1018914	Flow Tracker	24/03/2025	239.7	1	2010/2011	651
Waiparataniwha at Ford 1 (Up Stream of KDC Take)	3.7	1665055	6041911	1019144	Flow tracker	24/03/2025	13	0	–	–
Waiparataniwha at Ford 1 (Down Steam of KDC Take)	3.7	1665049	6041753	1019144	Visual	24/03/2025	<1	0	–	–
Waiparataniwha at Ford 2 (Down Stream of KDC Take)	0.9	1665128	6041684	1019171	Visual	24/03/2025	< 1	0	–	–
Waiparataniwha at Ford 2 (Up Stream of KDC Take)	0.9	1665206	6041841	1019171	Flow tracker	24/03/2025	6	0	–	–
Waiparataniwha at Ford 3 (Down Stream of KDC Take)	4.4	1665395	6041665	1019278	Flow tracker	24/03/2025	8	0	–	–
Waiparataniwha at Ford 3 (Up Stream of KDC Take)	4.4	1665486	6041782	1019278	Flow tracker	24/03/2025	9	0	–	–
Kaihu at Rotu (Downstream of KDC Take) *	251.6	1669942	6030960	1021064	ADCP	24/03/2025	647			
Kaihu at Rotu (Upstream of KDC Take) *	251.6	1669896	6031005	1021064	ADCP	25/03/2025	716			
Kaihu at Rotu (Downstream of Take) *	251.6	1669942	6030960	1021064	ADCP	26/03/2025	598			
Kaihu Gorge *	114.0	1661809	6042221	1019201	ADCP	26/03/2025	464			

* indicates telemetered flow recorder site that was excluded from historic flow gauging analysis

– indicates that no low flow gauging data is available for the site for the specified period

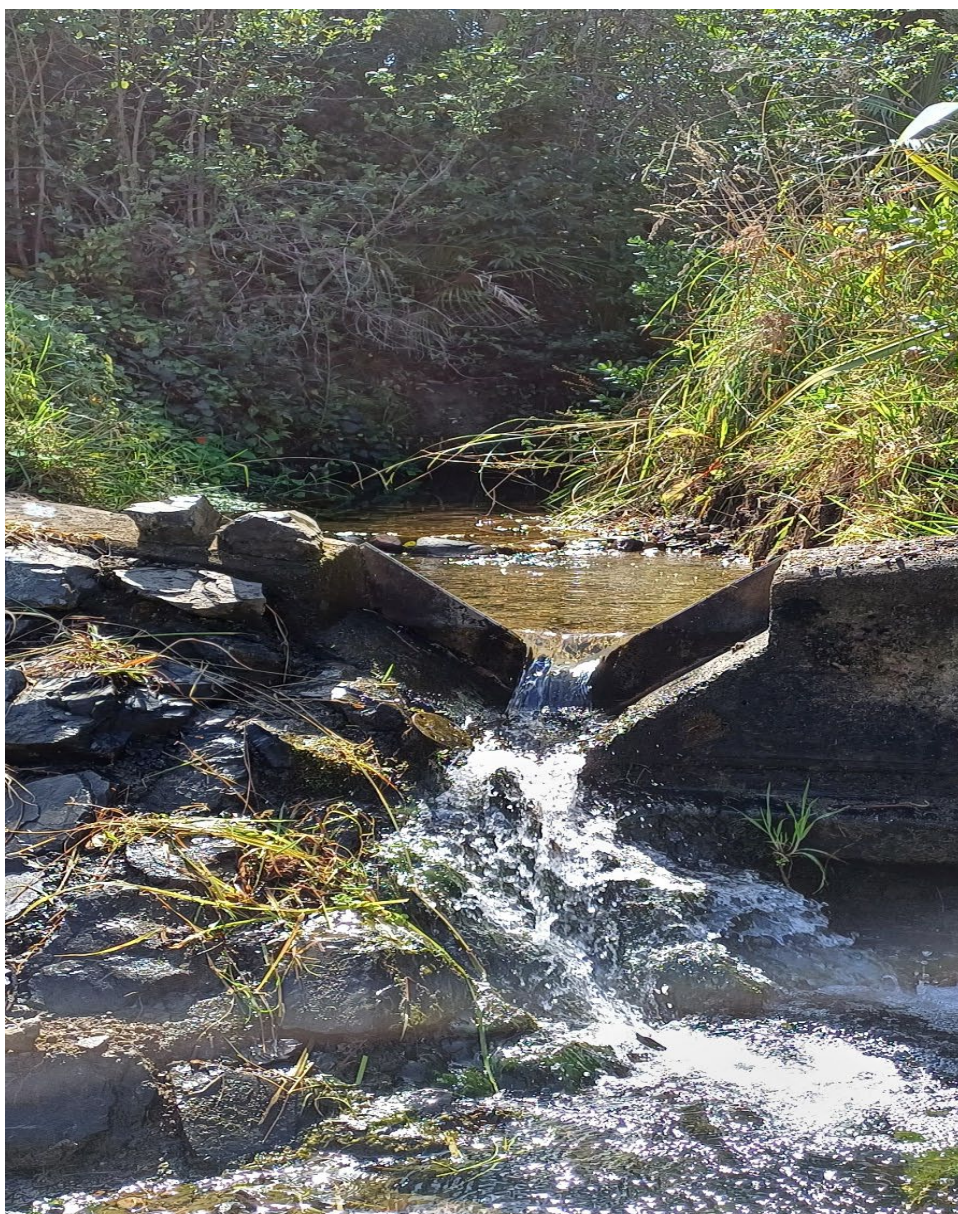
Appendix 4: Selected site photos from low flow gaugings



McLeods Bay Trib at Batting South (Whangārei Harbour catchment)



Te Waiiti at Rewarewa Road Bridge (Whangārei Harbour catchment)



McLeods Bay Trib at Dudin Weir (Whangārei Harbour catchment)



Mangere at Knight Road (Upper Wairua catchment)



Taotaoroa at Peach Orchard Road (Upper Wairua catchment)



Kaimamaku Trib at Matheson Road (Upper Wairua catchment)



Awaroa Tributary at Jacksons (One way bridge) [Whangārei Harbour catchment]



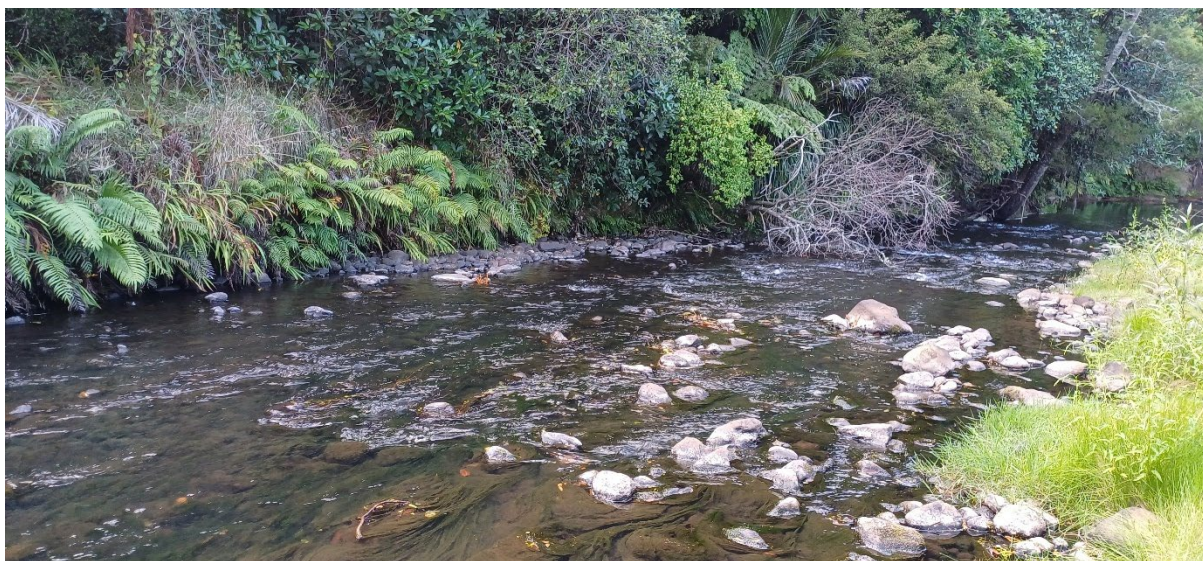
Takahiwai Dam (Whangārei Harbour catchment)



Takahiwai Dam at Outfall (Whangārei Harbour catchment)



Ōtaika at Kay (downstream of the flow station) [Whangārei Harbour catchment]



Waima at Burkes (Kaihu catchment)



Confluence of the Waima (right) and Mangatu (left) rivers downstream of the Waima at Trounson Park Road (Top 10) gauging site to form the Kaihu River (Kaihu catchment)

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