Review of Nelson City Council's Hydrometric Network

Prepared for Nelson City Council

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Executive summary

Nelson City Council (NCC) has sought a review of the hydrometric network that it operates in the Nelson Region. As highlighted in the latest State of the Environment (SoE) report (NCC 2018), the data from the hydrometric network are indispensable for environmental studies, water resource assessment, flood management, water quality monitoring, climate change studies, water management and planning, and ecological research. In this report, we review the current **rainfall, surface water flow and groundwater level monitoring network**.

The rainfall network operated by NCC consists of eight gauges complemented by three NIWA automatic climate stations, one Met Service automatic climate station and one Fire and Emergency New Zealand automatic rain gauge. The examination of the spatial distribution of the gauges revealed gaps in the network, particularly in the eastern part of the region as well as in high elevation areas. Finding accessible and secure rain gauge sites in the mountains might be a challenge, but there are some locations with ready access where satisfactory sites could be located.

The surface water recording network operated by NCC comprises 11 open sites. The review considered the length of record as long records allow extreme events to be put into context and statistics to be examined for responses to phenomena such as El Niño/Southern Oscillation, the Inter-Decadal Pacific Oscillation and climate change. The review also examined the transferability of hydrometric information acquired from monitoring sites to different locations within the Freshwater Management Units (FMU) being monitored. The flow site network is required for the ongoing SoE monitoring, flood warning, and other operational matters such as consent compliance and engineering design. Overall, the existing network is adequate for current NCC information needs. However, there are some clear gaps in the network and several aspects of note regarding the data collection. Recommendations have been made for installing five new surface water flow sites and relocation of one site.

In terms of continuous groundwater level records, there is only one site in the NCC region. This is primarily due to the absence of extensive aquifers within the region. However, because of the importance of continuous groundwater level monitoring in coastal areas for the sustainable management of freshwater resources, protection of ecosystems, and adaptation to changing environmental conditions, we suggest that the recommendations for designing a monitoring network (Zarour 2017) be taken into consideration. Implementing such a network would prove invaluable in assessing saltwater intrusion, the impacts of sea level rise and tides on groundwater level, land subsidence, climate change adaptation, and resource planning and regulation.

A review of the water quality network was not in the scope of this report. However, a summary of the current SoE monitoring and some recommendations for improvement have been given, for completeness, in Appendix C.

Long-term monitoring sites are necessary for analysing the effects of climate change and providing a comprehensive understanding of extreme events within their broader context. The value of continuous long-term records cannot be overemphasised and the temptation to remove such sites from the network for short-term budgetary gain should be firmly resisted.

1 Introduction and background

Nelson City Council (NCC) requested NIWA to review its rainfall, river flow and groundwater level network as part of an ongoing review of its hydrological monitoring network. The goal of the City Council's hydrological network is to provide a basis for sustainable management of the Nelson region's water resources. This will assist it in future planning and managing of the region's Freshwater Management Units (FMUs) for flood warning, water resource and water quality management, state of the environment reporting, land use change planning, drought monitoring and understanding climate change impacts.

NCC's longest data record dates back to 1944 (daily rainfall – now event based) whilst the newest continuous record is only one year long. Hydrology sites have been added to the network in an ad hoc manner as needs arise. When NCC became a unitary authority in the early 1990s, hydrometric monitoring was contracted to Tasman District Council (TDC) which has maintained sites, ensuring continuity of record. During the last five years NCC has been building an environmental monitoring team and contracting less work to TDC. There is a two-year process of phasing out the contracted work with TDC and running the hydrometric network - telemetry, site maintenance and data processing in-house.

The August 2022 Nelson Floods (see the Appendix A showing the hydrological records during the event) highlighted the importance of a fit for purpose network design but also for consideration of climate change. With changes in local climate already being experienced, and modelling indicating further changes are expected, network design needs to consider the potential impacts of climate change. To date this has not been explicitly accounted for.

The aim of this project was to review the existing monitoring network and make recommendations for improvement of monitoring of rainfall, water level/flow and groundwater level, and to ensure the monitoring network:

- is cost effective;
- is scientifically defensible;
- can monitor the potential impacts of climate variability and change, including sea level rise;
- is fit for State of the Environment (SoE) monitoring;
- is fit for The National Policy Statement for Freshwater Management (NPSFM) reporting including water accounting;
- meets the principles of the Te Mana o Te Wai (TMoTW) hierarchy of obligations;
- will help ensure that water is available for future economic growth;
- will allow assessment of surface-groundwater interaction including streamflow depletion resulting from groundwater abstraction;
- will yield results that can be used in engineering design;
- is appropriate for forecasting the entire hydrological spectrum including extremes (e.g., floods and droughts).

The key issues to be addressed as part of this study included assessment of:

- the optimum number of sites and locations required to measure long-term trends in the hydrology of the region, including those caused by climate change;
- the optimum number of rainfall sites and locations required to measure seasonal and long-term trends in rainfall totals and intensities throughout the region, including those caused by climate change;
- network requirements in areas of high surface water use that will enable the sustainable management of water resources and the future of groundwater demand;
- network requirements for measuring the effect of land use change;
- network requirements to support water quality and ecological monitoring;
- network requirements that will allow hydrological data to be reliably transferred to parts of the region where little or no hydrological data are collected;
- evaluation of the need to differentiate between monitoring networks for example:
- sites to provide a long-term baseline;
- sites for ongoing water management;
- short-term monitoring sites for projects or special purposes;
- providing an integrated/holistic overview of findings and recommendations for a sustainable and cost-effective hydrological monitoring network that is scientifically defensible and meets the needs of the City Council.

The goal of the NCC hydrological monitoring network is to provide a scientific basis for sustainable management of the region's water resources. More specifically the developed monitoring network should allow the council:

- To measure long-term trends in the hydrology of the region (including those caused by climate variability and change).
- To measure long term and seasonal trends in rainfall total and intensity (including those caused by climate change).
- To characterise rainfall at a range of spatial and temporal scales so that storm and drought events can be accurately monitored and reported.
- To collect data that will aid investigation of water resources, and which will allow effective policy decisions (e.g., NPSFM and TMoTW) to be made.
- To assess the effectiveness of water management policies that aim to ensure the sustainable management of water resources (including the impact of water and land use).
- To provide river-flow, groundwater level and rainfall data which can be used to improve hydrological estimation in ungauged catchments/areas.

- To provide hydrological data for a range of climate, hydrologic regimes, land uses, and catchment sizes found in the region, that can be used to support balanced water quality and ecological monitoring.

The network review presented in this report has considered the comprehensiveness of the current network and how, if any, shortfalls and gaps could be addressed.

2 Review of existing monitoring network

Hydrometric networks are essential for collecting data relating to water resources and hydrological processes. The design of such networks is critical for ensuring that the data collected are representative and sufficient for effective water management. Different methods to review hydrometric network design include:

- Statistical analysis: Statistical analysis can be used to evaluate the effectiveness of an existing hydrometric network design by assessing the spatial and temporal coverage of the network. This analysis can identify gaps in the network that need to be filled to improve the quality of the data collected.
- Remote sensing: Remote sensing technologies, such as satellite imagery and aerial photography, can be used to assess the coverage and density of an existing hydrometric network. This information can be used to identify areas that are under-represented and need additional monitoring stations.
- Hydrological modelling: Hydrological modelling can be used to simulate the behaviour of a catchment or river system, and evaluate the impact of different hydrometric network designs on the accuracy of the model output and quantify model uncertainty. This analysis can help identify areas where additional data are needed to improve the accuracy of the model.
- Expert opinion: Expert opinion from hydrologists, water managers, and other stakeholders can provide valuable insights into the effectiveness of an existing hydrometric network design. These experts can help identify areas where additional monitoring is needed and provide guidance on the most effective locations for monitoring stations.
- Cost-benefit analysis: Cost-benefit analysis can be used to evaluate the effectiveness of different hydrometric network designs based on their cost and the value of the data collected. This analysis can help identify the most cost-effective approach to monitoring water resources in a particular area.

A combination of these approaches was used to review NCC's hydrometric network and ensure that data collected are representative and sufficient for effective water management. NCC maintains a hydrometric network consisting of rainfall, river flow and groundwater. The stations in the network are classified as:

1. Rainfall – any station recording rainfall data on a daily or sub-daily basis.
2. River flow- any station providing flow rates on daily and sub-daily basis.
3. Groundwater – any station providing continuous records of groundwater level.

2.1 Freshwater management units (FMUs)

For the purpose of this review, the hydrometric stations operated by the NCC were arranged based on FMUs. An FMU is a water body or multiple water bodies, that is assigned as a management unit for defining freshwater objectives and limits. This can be a river catchment, part of catchment, or a group of catchments. The FMUs are based firstly on the catchments of the major rivers and interactions between surface and groundwater. Secondly catchments have been grouped together that flow to the same coastal environments. The Nelson Region has been divided into five FMUs: Maitai, Rodong, Stoke, Wakapuaka and Whangamoa (Figure 2-1 and Table 2-1).

The Maitai FMU is the largest in the Nelson Region with a catchment area of 130 km^2. The Maitai River originates in the Bryant Range. The upper catchment has two branches draining conservation and water supply protection land, and includes a large headwater water storage reservoir on the North Branch (Maitai Dam, 36 m high, 32 ha area), and an intake weir on the South Branch which together provide water for Nelson City. The mid catchment is an important recreational and production forest area, and the lower Maitai flows through Nelson City, before flowing into Tasman Bay.

The Whangamoa FMU is the second largest in the Nelson Region (112.2 km^2) and is located to the north-east of the Wakapuaka catchment. It is sourced from the Bryant and Whangamoa Ranges. The main tributaries are the Collins River, Graham Stream and Dencker Creek. The Whangamoa River flows into the Kokorua Estuary.

The Wakapuaka FMU includes the Wakapuaka River and its tributaries: the Lud and the Teal. The river flows into the Delaware Estuary. The Wakapuaka catchment includes a variety of land uses including plantation forest, protection forest, farming, and lifestyle blocks.

The Roding FMU includes the Roding River and its tributaries inside the Nelson Region (49.5 km^2), it then flows into the Tasman District Region. It is of great importance to water resources and contains one of the main Nelson region water supplies located in the upper part of its catchment.

The Stoke FMU is the smallest unit in the Nelson Region with a catchment area of 37.5 km^2. It includes four main streams: Jenkins Creek, Poorman Valley Stream, Orphanage Stream and Saxon Creek.

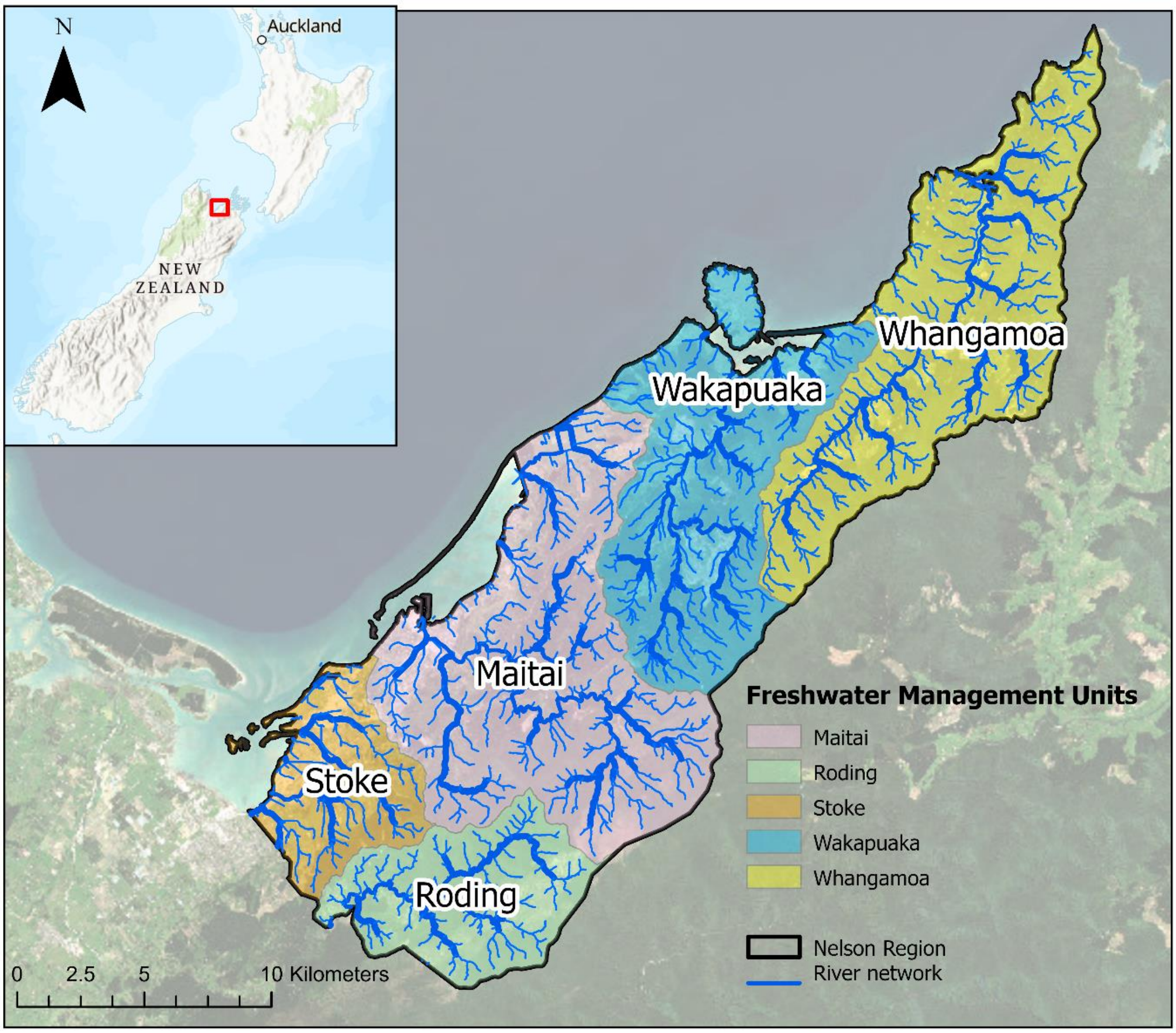


Figure 2-1: Freshwater management units in Nelson region.

Table 2-1: Freshwater management units in the Nelson Region.

FMUs	Maitai	Roding	Stoke	Wakapuaka	Whangamoa
Area (km^2)	130.3	49.5	37.5	93	112.2
Major rivers	Maitai North branch Maitai South branch Brook Sharland/Packer York	Roding	Poorman Orphanage Saxton Creek Jenkins	Wakapuaka Lud Teal	Whagamoa Collins Graham Dencker

2.2 Rainfall monitoring network

The automatic rainfall monitoring network operated by NCC consists of eight operating automatic rain gauges (Figure 2-2). Data from the gauges are predominantly retrieved hourly. There is also one automatic weather station (AWS) operated by Met Service, three stations operated by NIWA and one operated by Fire and Emergency New Zealand (FENZ). This review does not include the daily manual rain gauge network which complements the automatic gauge network. Manual gauges are typically operated by volunteers and many of the data are archived by NIWA.

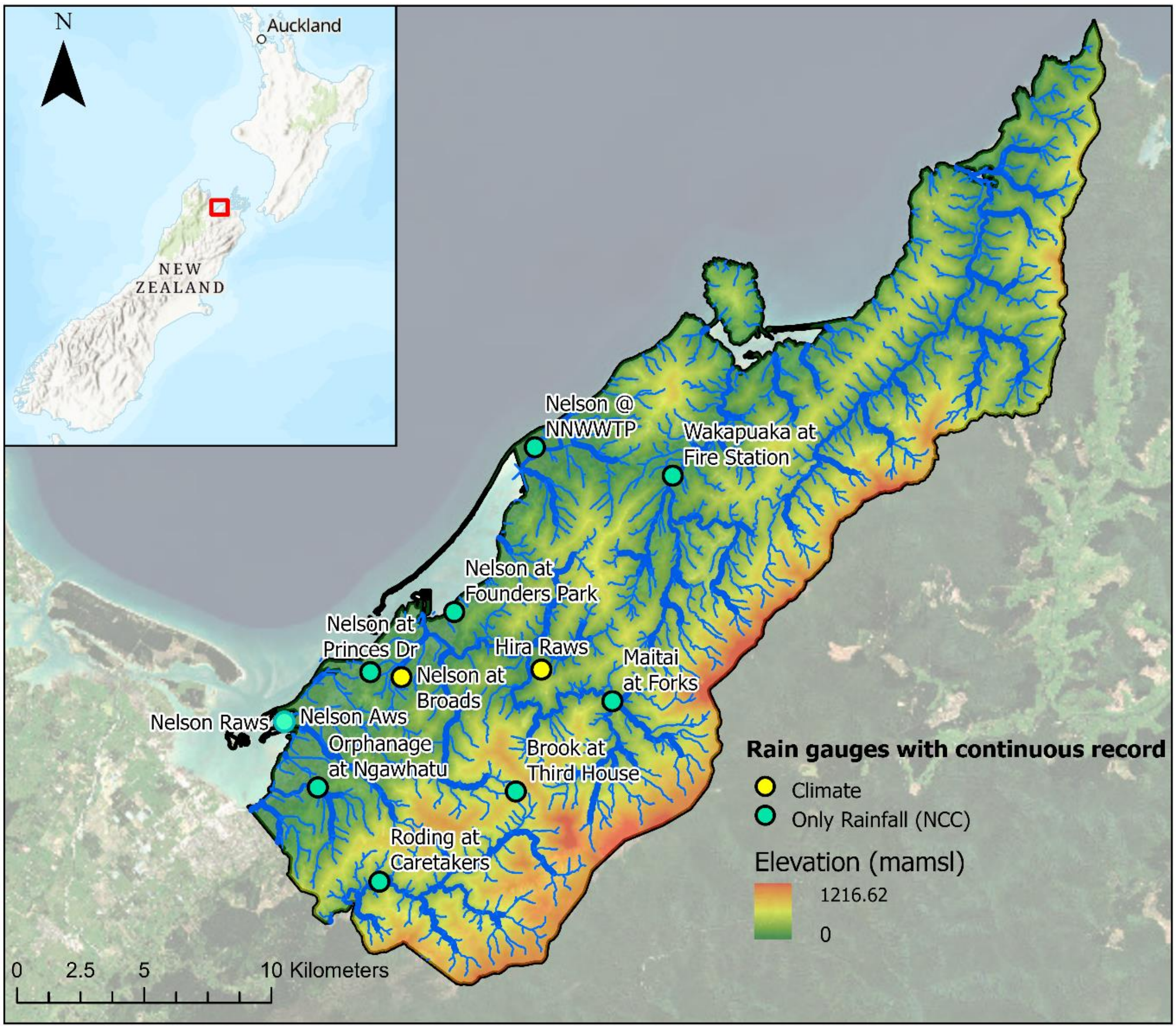


Figure 2-2: Automatic rainfall monitoring network in Nelson region.

2.2.1 Current best practice of rainfall network

Data from the rainfall monitoring network are essential for SoE reporting, characterising rainfall information, hydrological modelling, water resource management, flood forecasting, and climate analysis, and for knowledge and understanding of the region's ground and surface water systems and their interactions. The specific design of the network will depend on the objectives, budgetary constraints, and local conditions of the study area. WMO guidance on Network Design Principles (WMO 2021) include the following practices:

1. Spatial Distribution: Rain gauges should be strategically located to provide adequate spatial coverage across the study area. The distribution should consider factors such as topography, dominant weather patterns, and variations in rainfall intensity. It is important to capture the spatial variability of rainfall, especially in regions with diverse climatic conditions or significant variations in precipitation patterns.
2. Density: The density of rain gauges refers to the number of gauges per unit area. Higher density is preferred in areas with high rainfall variability or complex terrain, where local variations in rainfall can be significant. In contrast, areas with relatively uniform rainfall patterns may require a lower density of gauges. The goal is to strike a balance between capturing localised rainfall events and obtaining representative data for the whole region.
3. Network Homogeneity: The rain gauge network should be designed to ensure homogeneity in terms of gauge type, measurement protocols, and data quality standards. This allows for consistent and comparable measurements across the network. The use of standardised gauges and measurement techniques minimises errors and inconsistencies, facilitating accurate rainfall data collection and analysis.
4. Accessibility: Rain gauges should be placed in locations that are easily accessible for maintenance and data collection. This includes considering factors such as proximity to roads, availability of power supply, and ease of access during adverse weather conditions. Accessible locations facilitate regular maintenance, calibration, and data retrieval, ensuring the reliability of the network.
5. Calibration and Quality Control: Regular calibration of rain gauges is crucial to ensure accurate measurement of rainfall. The network should include protocols for calibration and quality control to verify the accuracy and reliability of measurements. This may involve periodic comparison with reference gauges or independent calibration facilities.
6. Long-Term Stability: The rain gauge network should be designed with long-term stability in mind. This includes selecting robust and durable gauges, ensuring proper installation and protection from environmental factors, and establishing protocols for regular maintenance, including debris removal and gauge cleaning.
7. Data Sharing and Integration: Consideration should be given to data sharing and integration within the network and with other meteorological or hydrological monitoring networks. This promotes collaboration, allows for data validation through intercomparison, and supports a comprehensive understanding of regional rainfall patterns.

Pearson et al. (2001) defined the main criteria for establishing a minimum network in New Zealand based on purpose/function, region/location, frequency of measurements and duration of deployment. Table 2-2 summarises the main criteria for a rain gauge monitoring network (after Pearson et al. 2001):

Table 2-2: The main criteria for rain gauge monitoring networks defined by Pearson et al. (2001).

Criteria	Long-Term Baseline (LTB)	Storm (STM)
Purpose of the network	Climate change Design rainfall depth duration frequency information Design flood estimation for urban development areas Input to hydrological modelling	Storm characterisation Flood forecasting and warning
Rain processes	Orographic effects of Bryant Ranges Rainfall gradients across the region Storm directions and tracks across the region	
Location	Standard meteorological locations away from Buildings trees etc. At locations useful for aquifer and catchment modelling	Upstream in (and of) catchments for flood forecasting/warning purposes.
Frequency	Automatic (daily suffices for climate change monitoring)	Automatic Telemetry for flood warning (and access to real-time radar images)
Duration	Indefinite	Indefinite

The criteria in Figure 2-2 were used to define a minimum rain gauge network by ensuring that each factor mentioned in the table was covered by at least one rain gauge, e.g., a long-term rain gauge is required in each region. Data analysis consisted of an examination of regional variability of important rain statistics and an assessment of the minimum gauge separation necessary for adequate definition of these statistics (Pearson et al. 2001). The results showed that for annual totals, high correlations were common between gauges up to 50 km apart and in some cases as much as 80 km. Correlation of rain gauge totals for a range of durations versus distance between gauges elsewhere in New Zealand suggests that satisfactory correlations for short (<24 hours) and long durations occur when inter-gauge spacing is less than 10 km and 20 km, respectively (Figure 2-3). However, for investigating storm tracks and rain intensities which are of great importance during flooding, inter-gauge spacing of 5 km should be the maximum allowed. For derivation of design statistics, especially depth-duration-frequency tables, graphs and maps, an inter-gauge spacing of approximately 10 km is recommended.

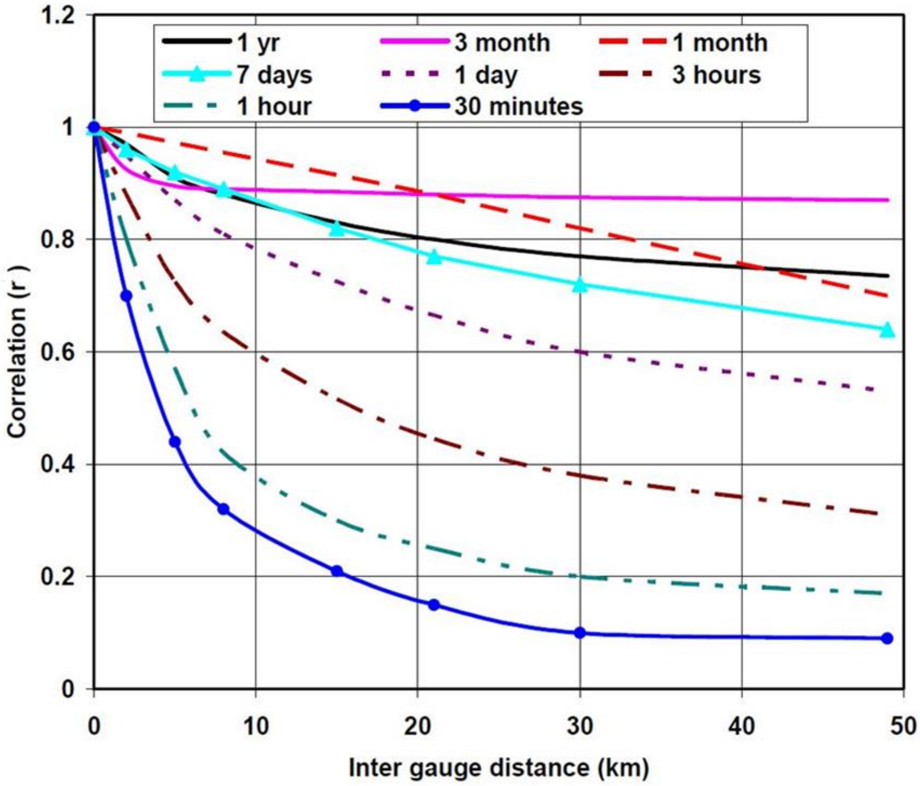


Figure 2-3: Relationship between inter-gauge distance and correlation for eight different accumulation intervals.

A 5 km radius was plotted for each gauge to identify spatial overlaps and gaps, as shown in Figure 2-4. Generally, there is a good coverage of gauges in the Nelson Region; however, a few gaps were identified in the eastern part of the region (e.g., in the Whangamoa catchment) as well as upper terrains of the catchments (e.g., Bryant Range in the Maitai catchment, Figure 2-5). The installation of new recording rain gauges should be based on placing the gauge at the best place to fill the gap, keeping in mind access and security. Some of the new gauges may be close to daily gauges and it would be worthwhile compromising the location of these new gauges to place them with the daily gauge.

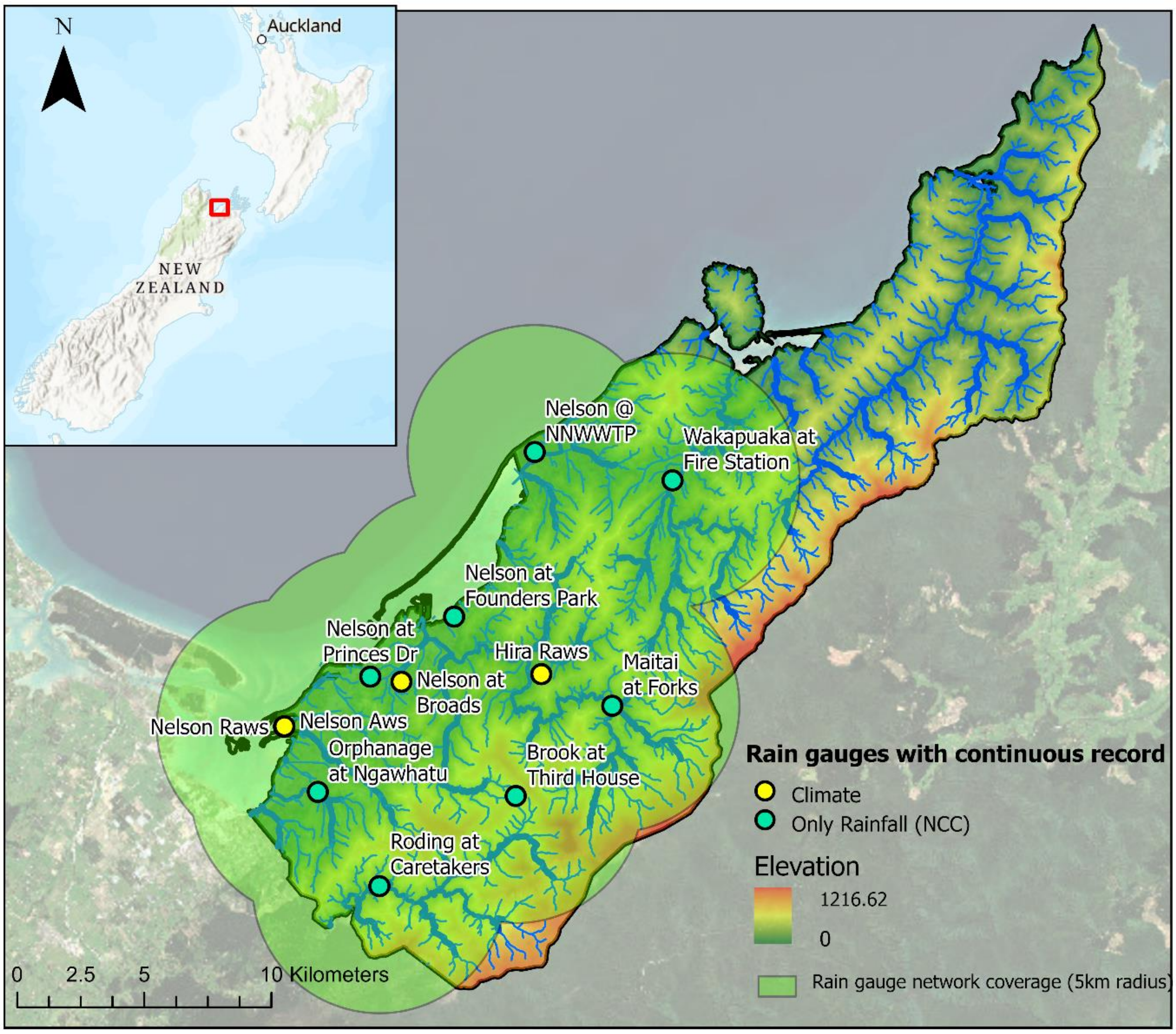


Figure 2-4: Rainfall network with 5 km radius coverage.

Similarly, the coverage of rain gauges in the upper parts of Stoke, Roding, Whangamoa and Wakapuaka FMUs is insufficient. Installing rain gauges in Jenkins Hill, Monster Mines and Mt Duppa (Table 2-3) will provide valuable data for understanding the spatial and temporal patterns of precipitation, including the amount, intensity, and duration of rainfall events. Also, the addition of the rain gauge in the upper catchment allows for real-time monitoring of precipitation, providing important information for flood forecasting and warning systems. By tracking rainfall patterns, forecasters can assess the likelihood and timing of peak flows, the authorities would be able to issue timely warnings to downstream communities. To fill the gap in the eastern part of the region in Whangamoa FMU, three more rain gauges are recommended to add the current network. There were two rain gauges (Whangamoa and Collins Valley (Table 2-3) in the past that can be re-opened. Also, a new rain gauge can be installed beside the current flow gauge (Figure 2-6) where a suitable location that is level and has adequate exposure and accessibility can be found.

For different reasons such as accessibility or security, rain gauges might have been placed between buildings. This could lead to significant under recording. A concern was raised during visiting the site by NCC staff regarding the accuracy of the rain gauge located in the Roding catchment, namely Roding at Caretakers. Because of the important of this station with more than 20 years of data, we recommend the relocation of the site be considered. The site can be replaced by a new gauge installed close by the flow gauge (Figure 2-7).

All the locations selected for the new network seem to be accessible from roads identified on 1:50,000 scale topography maps and some are near farmhouses, which will offer greater security.

Figure 2-8 shows the revised automatic network and location of the new gauges suggested and their coverage with a radius of 5 km.

Analysis of rain gauge records to determine climate trends requires long-term continuous records of data collected and archived to the highest standards.

Table 2-3: Recommended rain gauges in Nelson Region.

Name	Type	FMU	Description
Dun Mountain	Automatic rain gauge	Maitai	Reopen G13333
Collins at Drop Structure	Automatic rain gauge	Whangamoa	Beside the current flow gauge
Whangamoa	Automatic rain gauge	Whangamoa	Reopen G131151
Collins Valley	Automatic rain gauge	Whangamoa	Reopen G13153
Mt Duppa	Automatic rain gauge	Whangamoa	Upper Whangamoa catchment
Bush hill	Automatic rain gauge	Whangamoa	The most eastern site in Nelson Region
Monster Mines	Automatic rain gauge	Roding	Upper Rodding catchment
Roding at Skit Site	Automatic rain gauge	Roding	Replacement of the caretaker's rainfall gauge
Jenkins Hill	Automatic rain gauge	Stoke	Upper Stoke on the range
Saddle Hill	Automatic rain gauge	Wakapuaka	Upper Wakapuaka catchment

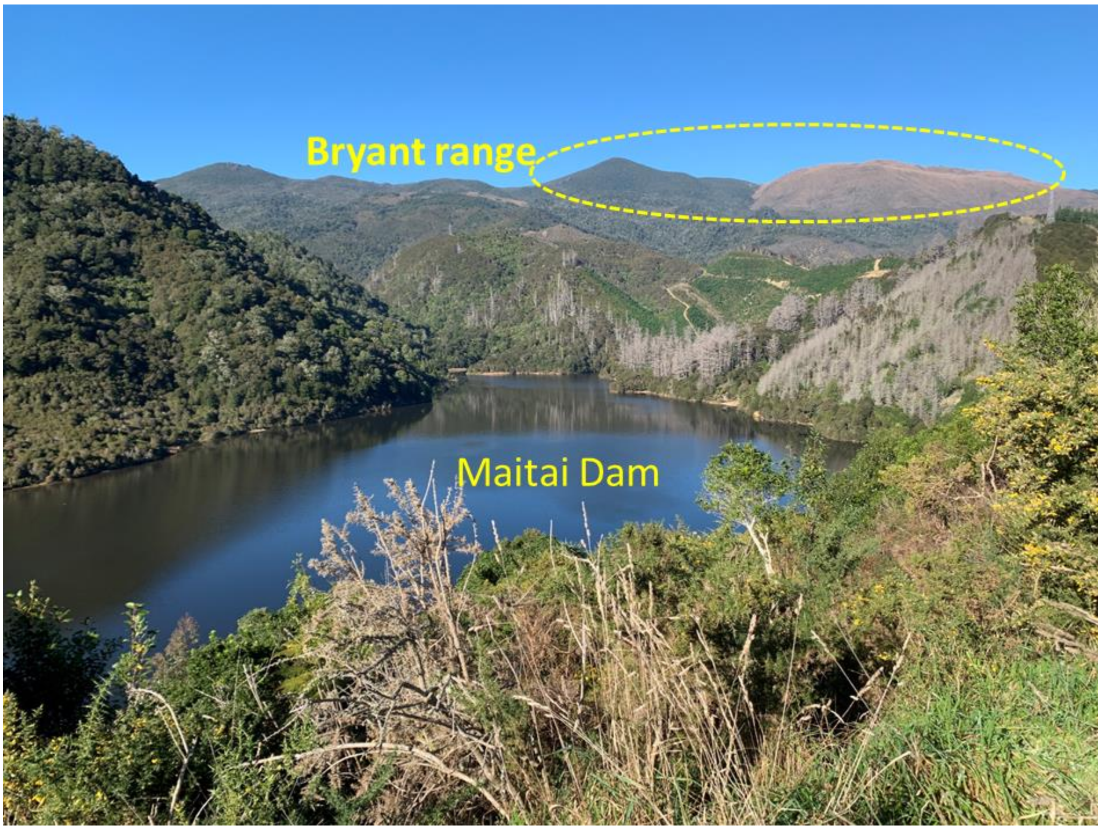


Figure 2-5: Bryant Range in the upper parts of the Maitai River catchment.

Figure 2-6: Potential location for installing a rain gauge beside the Collins River at Drop Structure flow site.

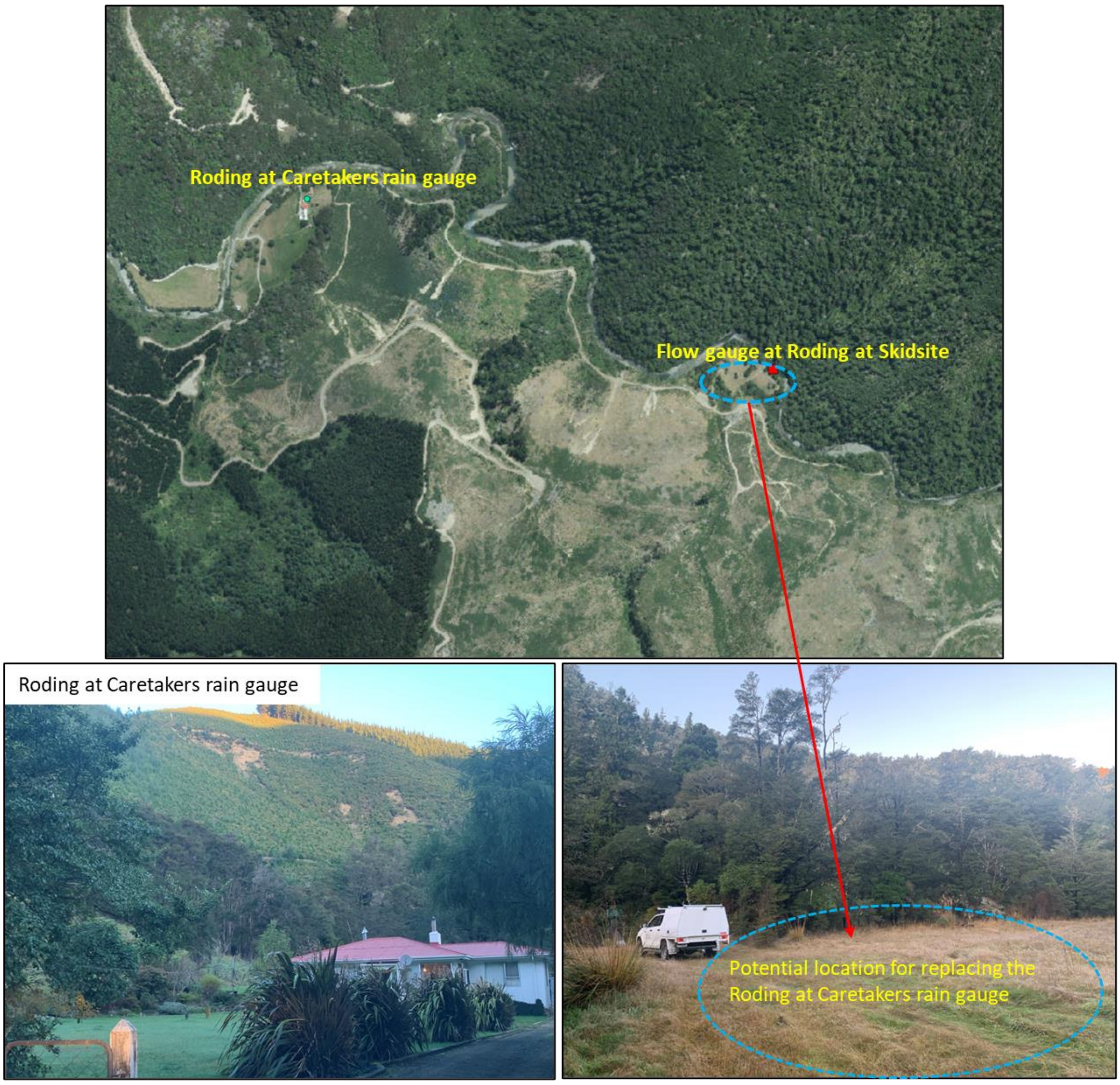


Figure 2-7: Potential location for replacing the rain gauge at Roding at Caretakers.

2.2.2 Summary of recommendations

1. That recording rain gauges be installed promptly in the eastern parts of the region to fill a significant gap in the network.

2. That the installation of a further four rain gauges be considered in the upper parts of Stoke (upper parts of the Marsden valley), Maitai (on Bryant Range), Roding and Wakapuaka catchments.

3. Relocating the rain gauge at Roding at Caretaker (moving to the space close to the river gauge Roding at Skid Site).

4. That sufficient resources be available to allow rainfall data to be collected and archived to the highest standards to ensure their utility for detecting climate change and other purposes.

5. That the value of maintaining long-term rain gauge sites and records be recognised should network rationalisation be required.

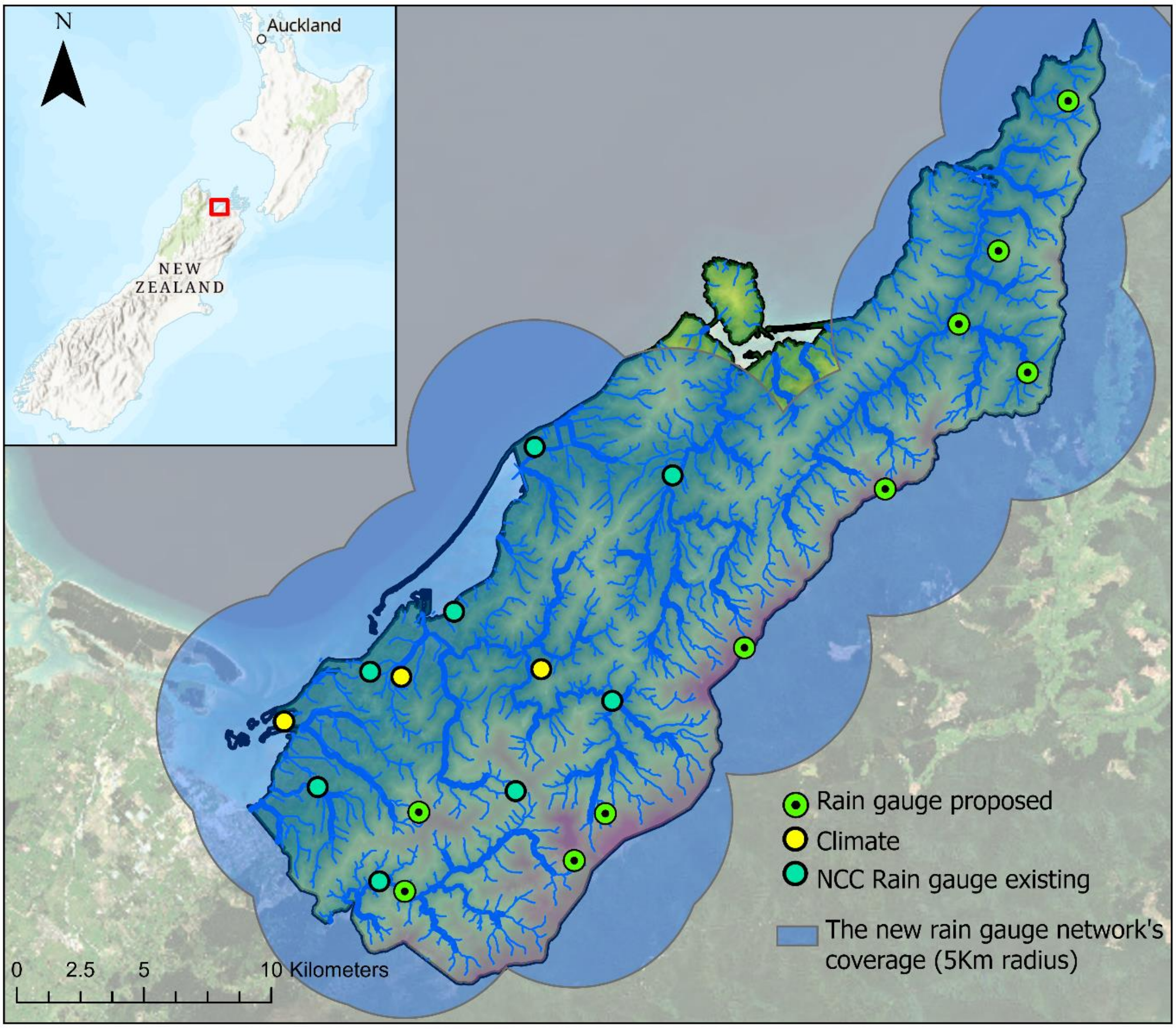


Figure 2-8: The recommended rain gauge network coverage with a 5 km radius of each gauge.

2.3 River flow monitoring network

NCC's surface water recording network consists of 11 sites. Data for the analysis were supplied by NCC. The data used were time series of stream flows, generated in each case by application of stage-discharge rating curves to recorded stream water level data (levels typically recorded every 15 minutes).Table 2-4 and Figure 2-9 show the details and the locations of the flow network in the Nelson region. Maitai FMU has the largest number of flow sites in the region (6 sites, Figure 2-10). There are two sites in Roding FMU (Figure 2-11), while other FMUs (Whangamoa, Wakapuaka and Stoke) has only one site each (Figure 2-12 - Figure 2-14). A summary of statistical analysis of river flow data are listed in Table 2-5.

Table 2-4: NCC's flow monitoring network.

Site ID	Name	Easting	Northing	Catchment area (km²)	Start date	Length of record (years)
57810	Brook at Seymour Ave	1624373	5429839	16.0	2/07/2013	10
57809	Maitai at Avon Tce	1624477	5430894	90.0	12/11/2004	18
57808	Maitai at Forks	1630685	5428900	35.7	7/03/1997	26
57806	Maitai at Girlies Hole	1624819	5430420	71.9	25/01/1986	37
57812	Maitai North at u-s Lake	1631824	5427942	8.0	22/10/2015	7
57807	Maitai South Above Old Intake	1630884	5427749	17.8	12/05/1995	28
581000	Wakapuaka at Hira	1633149	5437213	41.9	8/08/1978	44
583020	Collins at Drop Structure	1644611	5443463	17.6	29/09/1960	62
575021	Roding at Skidsite	1622852	5421168	38.0	22/02/1995	28
570521	Roding at Caretaker	1621826	5421543	41.5	13/02/2001	22
576000	Orphanage at Ngawhatu	1619405	5425254	7.75	3/05/2004	19

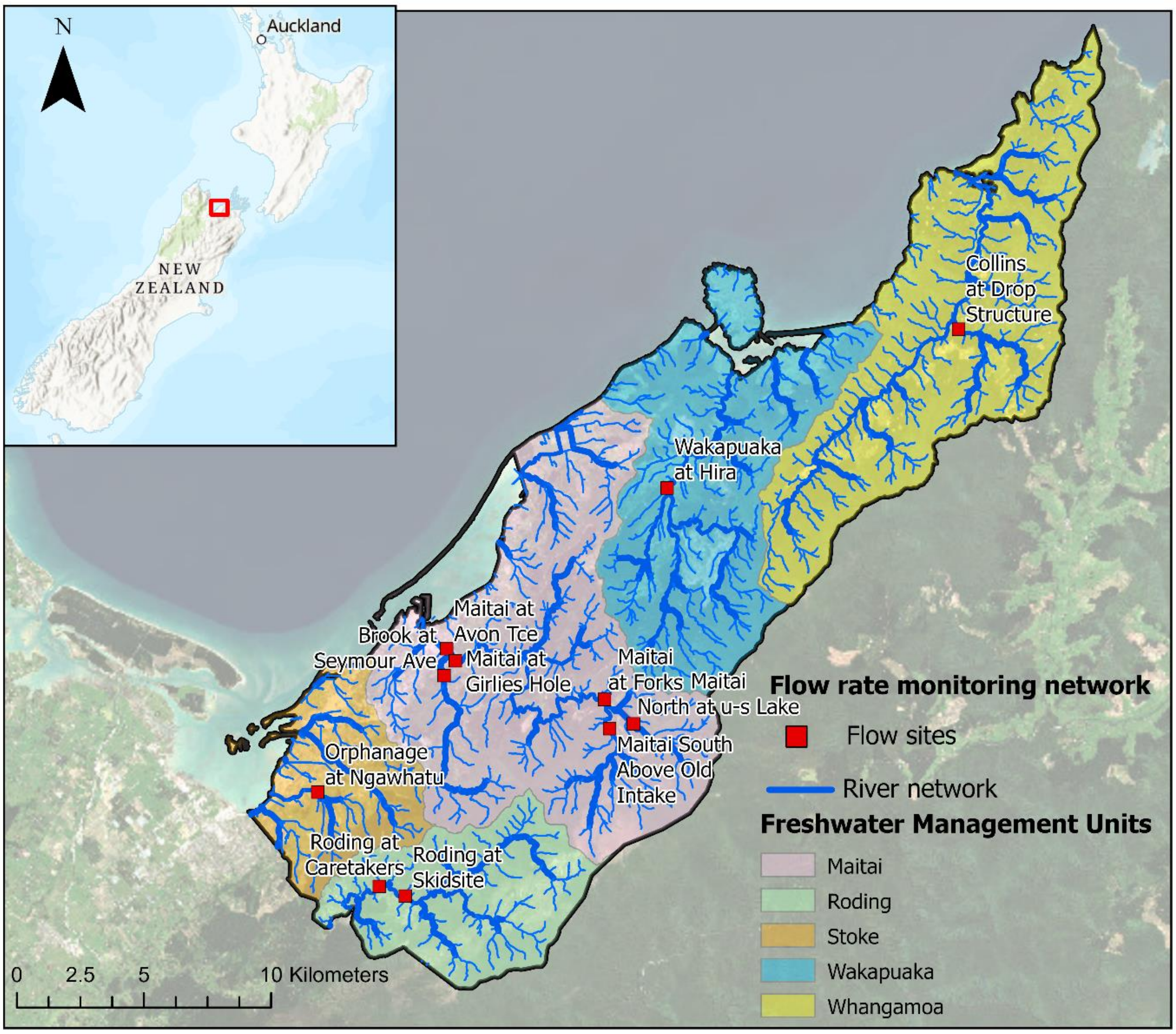


Figure 2-9: Flow monitoring sites operated by NCC.

Figure 2-10: Flow sites in Maitai FMU.

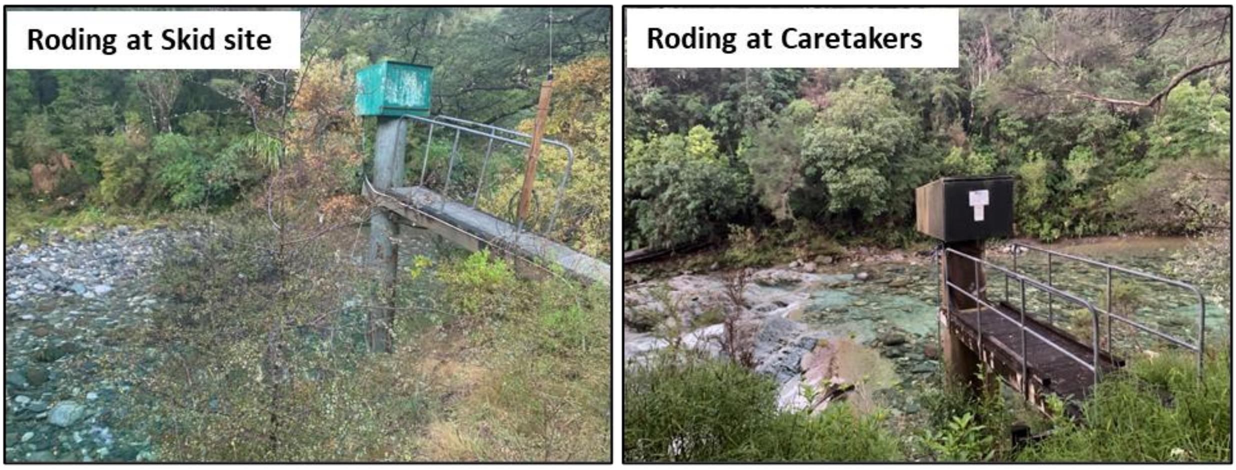


Figure 2-11: Flow sites in Roding FMU.

Figure 2-12: Flow site at Wakapuaka at Hira; the only flow site in Wakapuaka FMU.

Figure 2-13: Flow monitoring site at Collins at Drop Structure; the only flow site in Whangamoa FMU.

Figure 2-14: Flow monitoring site at Orphanage at Ngawhatu; the only flow monitoring site in Stoke FMU.

Table 2-5: Statistics of flow data in the Nelson region. (flow in L/s except Maximum in m^3/s).

Catchments	Site No	Area (km^2)	Maximum (m^3/s)	Date	Mean	Std.Dev	Coeff of Variation	Median	Lower Quartile	Upper Quartile	Upper 95%
Orphanage at Ngawhatu	5760810	7.75	57.1	21-Apr-13	87	343	3.9	27	14	70	323
Roding at Skid Site	5752210	38	237	23-Feb-95	1,695	4,905	2.9	616	365	1198	5,838
Roding at Caretakers	5752410	41.5	158	18-Feb-16	1,720	5,293	3.1	561	268	1211	5,861
Maitai at Avon Terrace	5780910	85	322	17-Aug-22	2,590	7508	2.9	989	593	2063	8,727
Maitai at Forks	5780810	35.7	211	17-Aug-22	1,475	4,284	2.9	572	343	1181	4,809
Maitai North at u-s Lake	5781210	8.0	31.6	17-Aug-22	1,036	634	0.6	1027	852	1217	1,454
Maitai South at Old Intake	5780710	17.8	65.5	17-Aug-22	860	1,835	2.1	404	262	725	2,902
Brook at Seymour Ave	5781010	16	40.2	20-Aug-22	363	918	2.5	167	99	318	1,232
Wakapuaka at Hira	5810110	41.9	204	23-Feb-95	1,376	3,221	2.3	747	476	1282	3,964
Collins at Drop Structure	5830110	17.6	123	5-Feb-22	555	1,615	2.9	228	129	455	1,796
Maitai at Girlies Hole	57806	71.9	195	25-Jan-86	2,548	3,346	1.3	1838	553	1989	7,234

2.3.1 Length of the flow records

The length of data is crucial in climate change and hydrological studies to identify long-term trends. Having long-term data records enables scientists and decision makers to detect and analyse these trends accurately. By comparing current data with historical records, we can detect shifts in river flows, changes in precipitation patterns, alterations in groundwater levels, and modifications in other hydrological parameters. These trends provide valuable information for water resource management and planning. Long-term observations in hydrological studies are essential for understanding natural variability, detecting trends and changes, quantifying extreme events, supporting water resources management, validating models, assessing climate change impacts, and informing policy and planning decisions. They provide a foundation of knowledge for sustainable water management and adaptation to changing hydrological conditions.

The length of flow records in NCC region vary from 62 years (at Collins at Drop Structure) to seven years (at Maitai North at u-s Lake). Seven flow sites have records of more than 20 years (Table 2-6, Figure 2-15).

Table 2-6: The length of flow observations in Nelson's FMUs.

FMUs	Maitai	Roding	Stoke	Wakapuaka	Whangamoa
Total number of rated flow sites	6	2	1	1	1
Maximum length of flow record	37 years at Matai at Girlies Hole	28 years at Roding at Skid Site	19 years at Orphanage at Ngawhatu	44 years at Wakapuaka	62 years at Collins at Drop Structure
Number sites with 20 years of more flow records	3	2	-	1	1

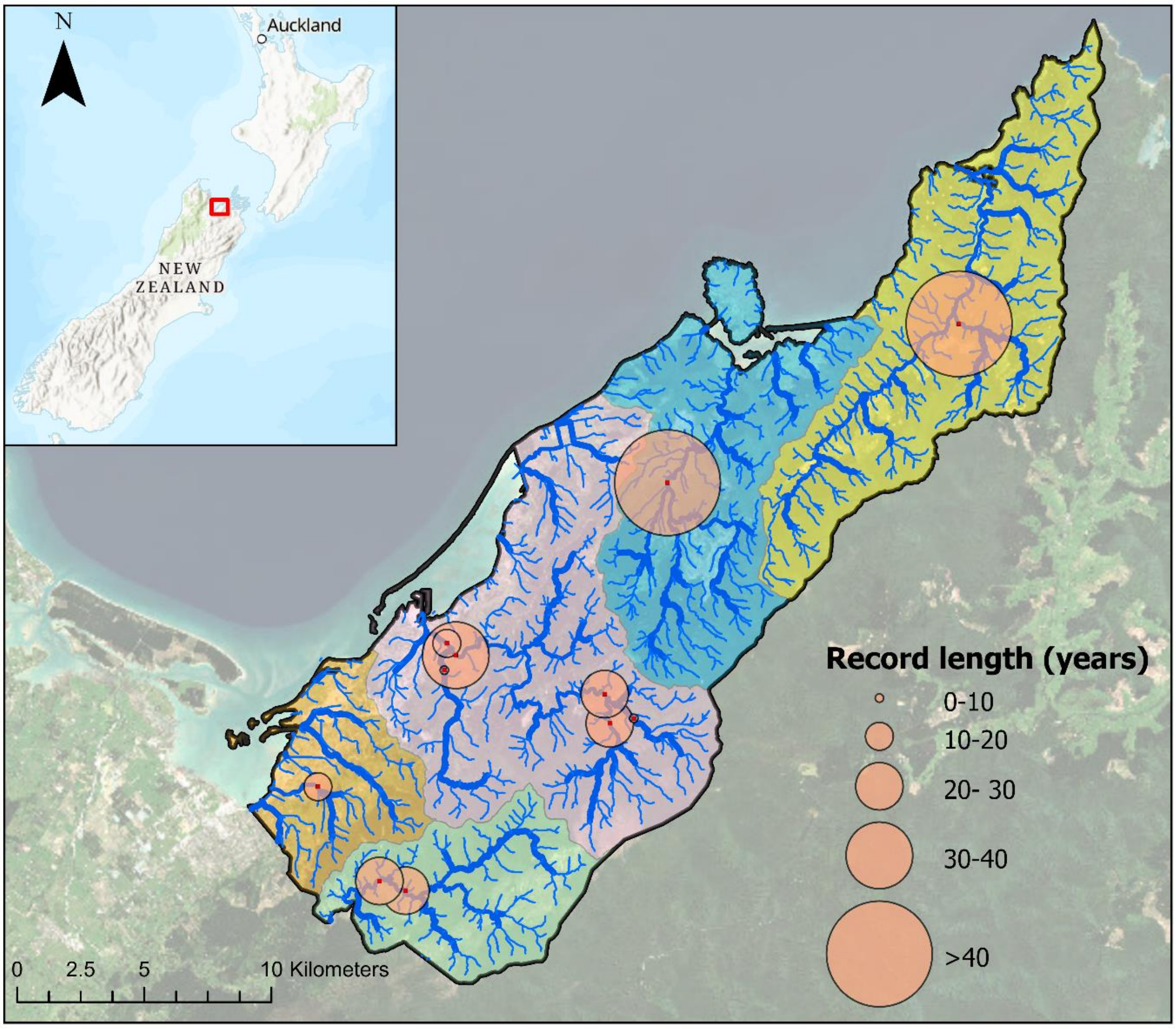


Figure 2-15: Length of flow records in Nelson. The longest record belongs to Collins at Drop Structure (62 years).

2.3.2 Current river flow monitoring network design and recommendations

Maitai

Generally, there is a good network of monitoring sites to record the flow in the Maitai FMU in the upper catchment and the lower catchment. However, gaps have been found in some parts of the region, especially in the mid catchment. The main tributary in the mid catchment is the Sharland Creek with no monitoring station. Considering the importance of the mid catchment for recreational and production forest activities, we recommend installing a new site on Sharland Creek. This site will be useful for monitoring the impact of land use on flow regimes in the region. Also, the records from the site will be used to study the ongoing impacts of climate change and for recording extreme events over long time periods, so having such comprehensive records would enable accurate contextualisation of future extreme events when they occur.

Wakapuaka

There is only one flow monitoring station in the Wakapuaka FMU. The upper tributaries of Wakapuaka River are poorly gauged. Monitoring the flow at the two main tributaries, the Lud and the Teal are recommended to be added to the existing network. The Teal River has a site for monthly monitoring of water level. This location is a candidate for a permanent site. Also, due to recent floods in the Nelson region, the riverbed and riverbanks at the location of the current monitoring site have been impacted (Figure 2-12). This has resulted in temporary relocation of the sensors by several metres by NCC. If the original gauge cannot be relocated, a temporary flow gauge is an option to continue monitoring the flow until a permanent solution is established. These temporary gauges can provide valuable data during a transition period. The possibility of relocating the gauge at Wakapuaka at Hira permanently should be considered in future. It is worth noting that the decision to relocate flow gauges depends on the specific circumstances of the river and the severity of the washout event. Local hydrological experts and authorities responsible for monitoring and managing the river system should be involved in the decision-making process to ensure appropriate actions are taken to maintain accurate and reliable flow measurements.

Whangamoa

The Whangamoa River is one of the largest rivers in the Nelson region, however, there is only one monitoring flow station at one of its main tributaries the Collins River. It is recommended that a hydrometric station be installed on the Whangamoa River before entering the Estuary. Unless we have a measure of water available, it will be difficult to quantify the influence of land use change on water use in the whole Whangamoa catchment. Therefore, such hydrometric sites can be complemented by measuring sediment loads in rivers, allowing us to analyse the impacts of land use practices on sedimentation patterns. The new station will be useful to study trends in flows due to climate change too.

Roding

Given the significance of Roding in water supply in the Nelson region, there are two hydrometric stations in the upper parts of Roding catchment which provide sufficient data for hydrological studies.

Stoke

Of the four main streams in the Stoke FMU, only one is monitored. We recommend installing a new hydrometric station on Poorman Valley Stream (Figure 2-17) to compliment the hydrological record in this FMU.

Table 2-7 show the recommended flow sites in the region. The recommendations can be broadly classified into three categories:

1. Retain - We recommend all the current active sites in the network be retained. The majority of these sites have valuable long-term data. There are seven sites with more than 20 years of records. The significance of continuous long-term records in providing context for climatic events cannot be overstated, and it is essential to firmly resist any inclination to remove such sites from the network. These sites provide data that could be used for assessing climate change trends and the impact of land use change especially in those regions affected by forestry.

2. Open - The addition of five new flow sites into NCC's existing network would ensure adequate coverage of river flow in the Nelson region (Figure 2-18).

3. Relocation - The possibility of relocating the gauge at Wakapuaka at Hira due to riverbank washouts should be considered.

Table 2-7: Recommended flow sites in the Nelson region.

Name	River	FMU	Description
Sharland Creek	Sharland Creek	Maitai	Active and moving riverbed
Whangamoa	Whangamoa	Whangamoa	Whangamoa
Poorman Stream	Poorman Stream	Stoke	Marsden Valley Rd
Wakapuaka at Hira	Wakapuaka at Hira	Wakapuaka	Re-location due to moving riverbed and riverbanks
Teal river	Teal River	Wakapuaka	Before or after the confluence
Lud River	Lud River	Wakapuaka	Suitable location based on river morphology

Figure 2-16: Recommended location for flow gauging at the Poorman Valley Stream by the gravel extraction site.

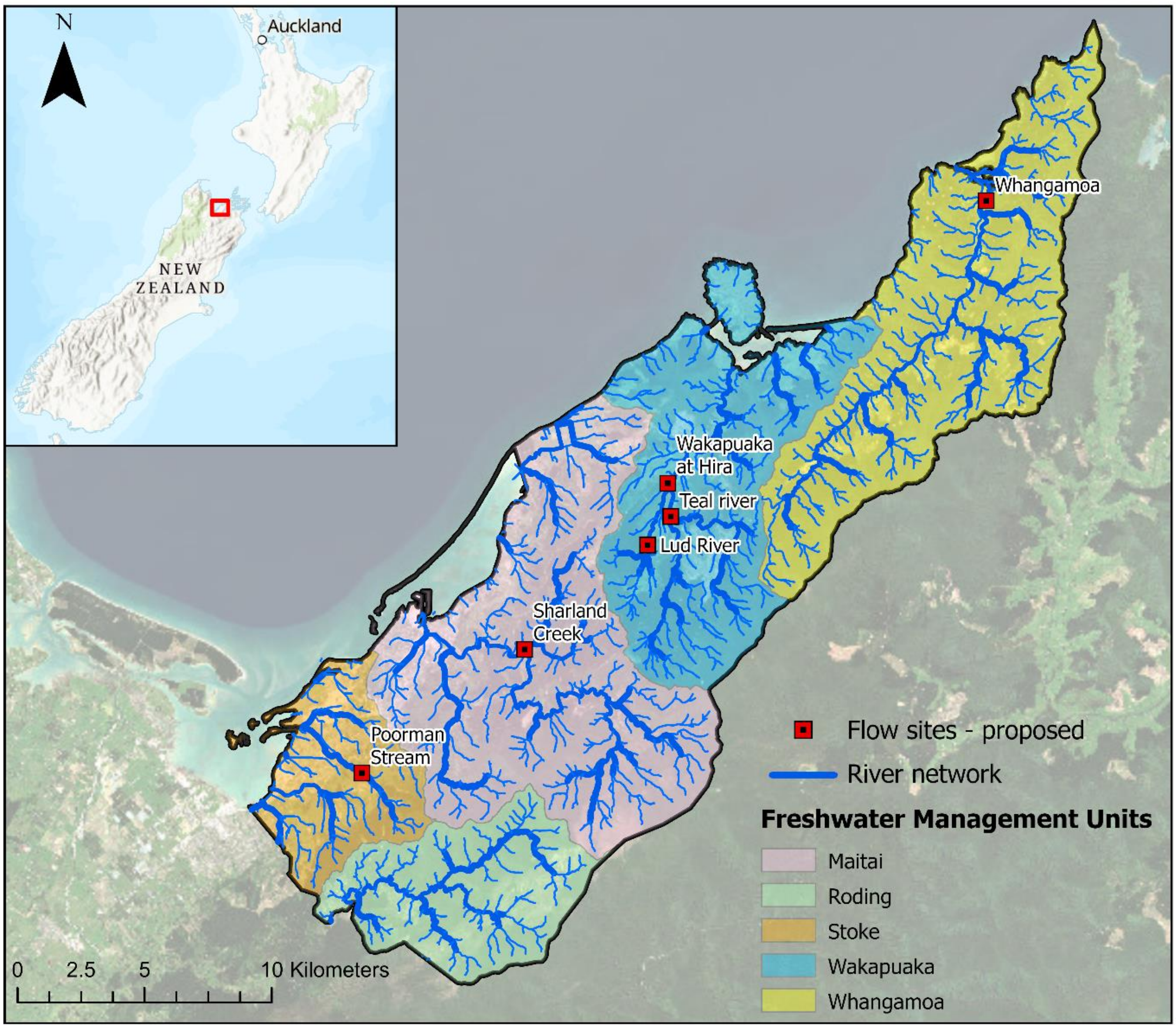


Figure 2-17: Proposed river flow monitoring sites in the Nelson region.

2.4 Groundwater level monitoring network

The NZ Hydrological Unit Map dataset developed by GNS (White et al. 2019) shows the extent of aquifers in the Nelson region (Figure 2-18). The groundwater resource in Nelson is distributed in distinct locations and three types of geological units including (1) Holocene alluvium, (2) other Quaternary sediments, and (3) the Plio-Pleistocene Port Hills and Moutere gravels (Zarour et al. 2017). Under the Resource Management Act 1991, Regional Councils are responsible for monitoring and reporting on the SoE. In 2017, Zarour et al. documented management requirements for Nelson groundwater resources. Provisional locations of 15 groundwater level monitoring sites were recommended (see Zarour et al. 2017). Since the report, NCC has added one continuous groundwater level monitoring site (Figure 2-18). There is also periodic recording of groundwater level at 13 locations (see Appendix B). We recommend NCC considers the possibility of designing a systematic groundwater level monitoring network based on the above-mentioned report.

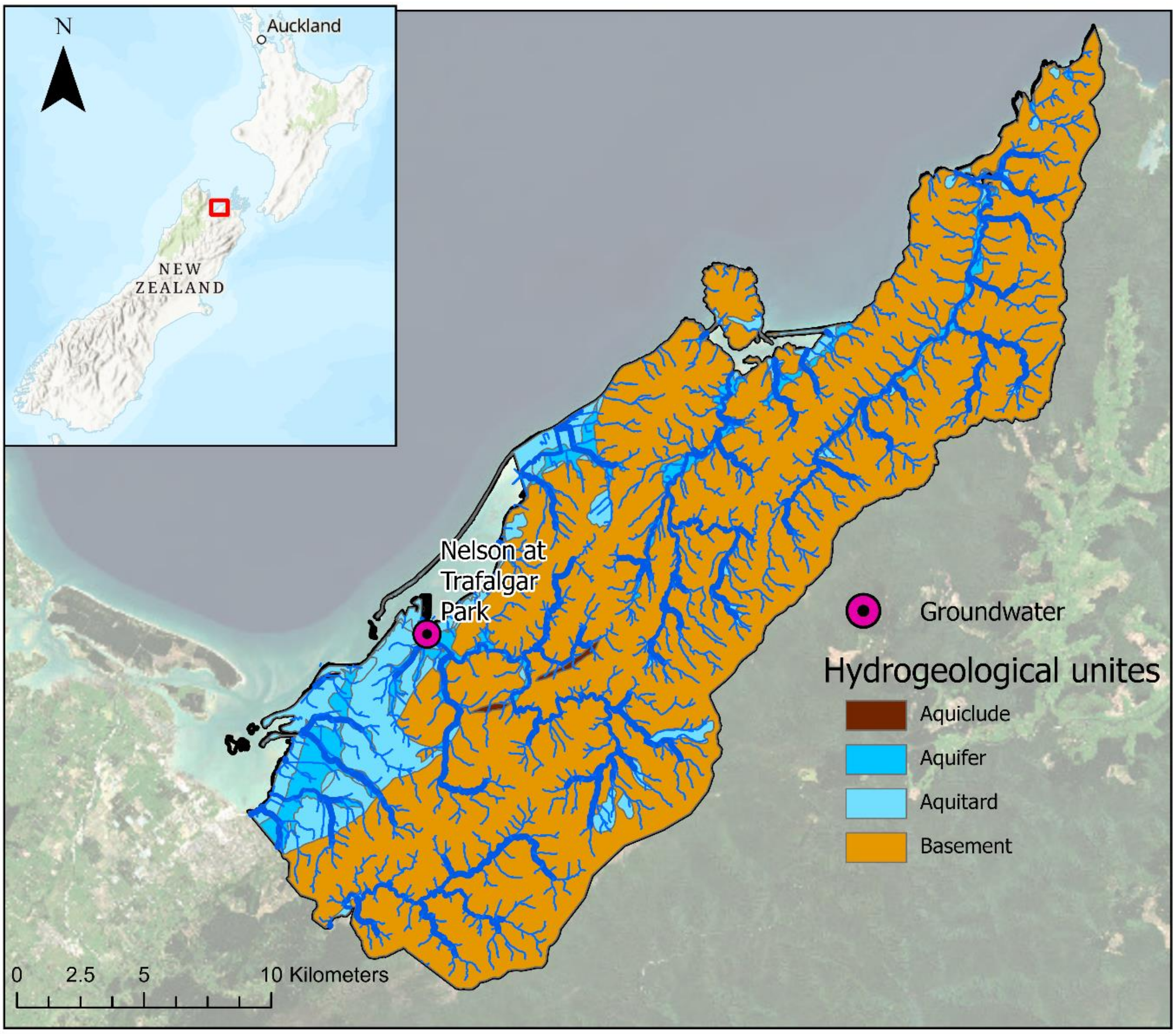


Figure 2-18: Hydrogeological units and continuous groundwater monitoring site in Nelson region.

Designing a groundwater level network involves several considerations to ensure its efficiency and effectiveness. It is important to note that groundwater level monitoring network design is a complex process and often requires the expertise of hydrogeologists, engineers, and other professionals experienced in groundwater management and infrastructure design. Continuous records of groundwater levels are crucial for aquifer management, water resource planning, understanding groundwater-surface water interactions, assessing water availability and sustainability, supporting early warning systems, conducting environmental impact assessments, and calibrating groundwater models. Groundwater monitoring provides valuable information for sustainable water management and informed decision-making regarding groundwater resources. Table 2-8 summarises the benefits of continuous records of groundwater levels in managing and sustaining groundwater resources, understanding the impact of human activities on aquifer systems, and addressing challenges related to climate change and water availability (Alley and Leake 2004; Zektser and Everett 2004; Taylor 2013).

Table 2-8: The benefits from continuous records of groundwater levels.

Aquifer Management	Continuous records of groundwater levels provide valuable information for managing aquifers sustainably. They help in assessing the status and trends of groundwater resources, understanding aquifer dynamics, and developing effective strategies for groundwater allocation and protection.
Water Resource Planning	Continuous groundwater records assist in long-term water resource planning by providing insights into the availability and reliability of groundwater supplies. This information can guide decisions regarding infrastructure development, water allocation, and drought management.
Groundwater-Surface Water Interactions	Many surface water systems are interconnected with groundwater, with exchanges occurring through seepage, recharge, and discharge processes. Continuous groundwater monitoring helps in understanding the dynamics of these interactions. It provides insights into groundwater contributions to streamflow, impacts on aquatic ecosystems, and the vulnerability of water resources during dry spells or flooding events.
Environmental Impact Assessment	Monitoring groundwater levels over an extended period provides valuable information for environmental impact assessments. It helps evaluate the potential impacts of water abstraction, land use changes, and infrastructure projects on groundwater-dependent ecosystems, wetlands, and sensitive habitats. Continuous records support effective decision-making by identifying potential risks and guiding mitigation measures.
Groundwater Model Calibration and Validation	Groundwater models are used to simulate aquifer behaviour, predict future conditions, and assess management scenarios. Continuous groundwater records serve as essential data for calibrating and validating these models. Comparing observed groundwater levels with model outputs helps refine model parameters, improve accuracy, and enhance confidence in model predictions.

Saltwater Intrusion Management	Coastal aquifers are particularly vulnerable to saltwater intrusion, which occurs when saline water from the ocean infiltrates freshwater aquifers. Groundwater monitoring helps assess the extent, magnitude, and movement of saltwater intrusion, enabling effective management and mitigation strategies. By tracking changes in groundwater salinity over time, authorities can take appropriate measures to prevent excessive intrusion and protect freshwater resources.

Designing a groundwater status monitoring network requires building a system to continuously monitor and evaluate groundwater resources. The main goal of the network may include assessing groundwater levels, quality parameters, trends, and potential impacts from human activities and investigating the impacts of climate change and sea level rise. Spatial coverage of the network should consider the area of the groundwater basin, the distribution of wells, and the location of potential impacts such as tidal impacts, surface water, and current and potential future abstractions. It is important to identify appropriate well locations to represent hydrogeological units and land uses within the groundwater basins. Factors such as well depth, proximity to potential pollution sources, and accessibility for monitoring purposes.

3 Summary and recommendations

Long-term rainfall and flow monitoring sites are required for analysis for the effects of climate change, and to assist adaptation to and mitigation of extreme events. Continuous long-term records are crucial for water resource management and identifying impacts of extreme climate extremes such as droughts and floods.

- The rainfall network will benefit from the installation of a further nine rain gauges across the region. These new sites will fill the gap in rainfall data at high elevations as well as the eastern parts of the region where there is a lack of rainfall monitoring.
- The recommended surface water flow monitoring network contains five new sites. These sites will fill the gaps in the region and provide critical information for environmental monitoring, water resource management, flood forecasting, drought monitoring, hydrological research, and infrastructure design.
- Relocating the Wakapuaka at Hira flow site after the riverbed and riverbank washouts during August 2022 floods is a possibility. However, when a flow gauge is relocated, it is important to compare the data collected before and after the relocation to identify any discrepancies or calibration issues. This validation process will ensure the continuity and reliability of the flow data and helps maintain the accuracy of historical records.
- We suggest recommendations for designing a groundwater level monitoring network (Zarour 2017) be taken into consideration.

4 Glossary of abbreviations and terms

AWS	Automatic weather station
FENZ	Fire and Emergency New Zealand
FMU	Freshwater Management Unit
Met Service	Meteorological Service of New Zealand Limited
MAMSL	Metres Above Mean Sea Level
NCC	Nelson City Council
NEMS	National Environmental Monitoring Standard
NIWA	National Institute of Water and Atmospheric Research Limited
NPSFM	National Policy Statement for Freshwater Management
TMoTW	Te Mana o te Wai
SoE	State of the Environment
WMO	World Meteorological Organisation

5 Acknowledgements

Thanks to Stefan Beaumont and Emma Reeves from NCC for supplying the site lists, data and information. They also kindly provided insights during the site visits and in preparing this report. Thanks to Kathy Walter of NIWA for converting the data to TIDEDA format.

6 References

Alley, W.M., Leake, S.A. (2004) The journey from safe yield to sustainability. Ground Water, 42(1), 12-16.

Dudley, D. B. (2019) A water quality monitoing programme for estuaries in the Nelson Region. NIWA Client Report: 2019055CH.

Gibbs, M., Woodward, B. (2017) CSSI-based sedient source tracking study for the Maitai River, Nelson.

McArthur, K. (2016) Nelson freshwater quality: An analysis of state and issues. Catalyst Group Report No. 2016/068. 118 pp.

Ministry for the Environment (2022) Guidance for implementing NPS-FM sediment requiremnts. Prepared for the Ministry for the Environment by Arman Haddadchi, Murray Hicks, Juliet Milne, Annette Semadeni-Davies, Yvonne Matthews, Andrew Swales, Christo Rautenbach, National Institute of Water and Atmospheric Research (NIWA).NEMS-Suspended Sediment (2020) National Environmental Monitoring Standard - Measurement of Fluvial Suspended Sediment Load and its Composition v1.0.0.

NCC (2018) State of environment report: A guide to our environment programmes and initiatives for the Nelson region. Nelson City Council.

NCC (2022) Freshwater quality monitoring annual report 2021. Nelson City Council.

Pearson, C.P., Henderson, R.D., Pattle, A. (2001). Review of Auckland Regional Council's hydrological monitoring networks. NIWA Client Report: CHC00/78. 47 p.

Taylor, R.G., et al. (2013) Ground water and climate change. Nature Climate Change, 3(4), 322-329.

White, P.A., Moreau, M., Mourot, F., Rawlinson, Z.J. (2019) (Revised 2022). New Zealand groundwater atlas: hydrogeological-unit map of New Zealand. Lower Hutt (NZ): GNS Science Consultancy Report 2019/144.

WMO (World Meteorological Organisation) (2021) Guide to WMO integrated global observing system, (WMO-No. 1165), Geneva.

Zarour, H., Kaelin, N., Zarour, D. (2017) Nelson City groundwater resources – management requirements for the Whakamahere Whakatū Nelson Plan. Nelson City Council and Groundwater Services New Zealand (gH2Onz).

Zektser, I.S., Everett, L.G. (2004) Groundwater resources of the world and their use. Cambridge University Press.

Appendix A Flows from the Nelson region sites during the August 2022 flood

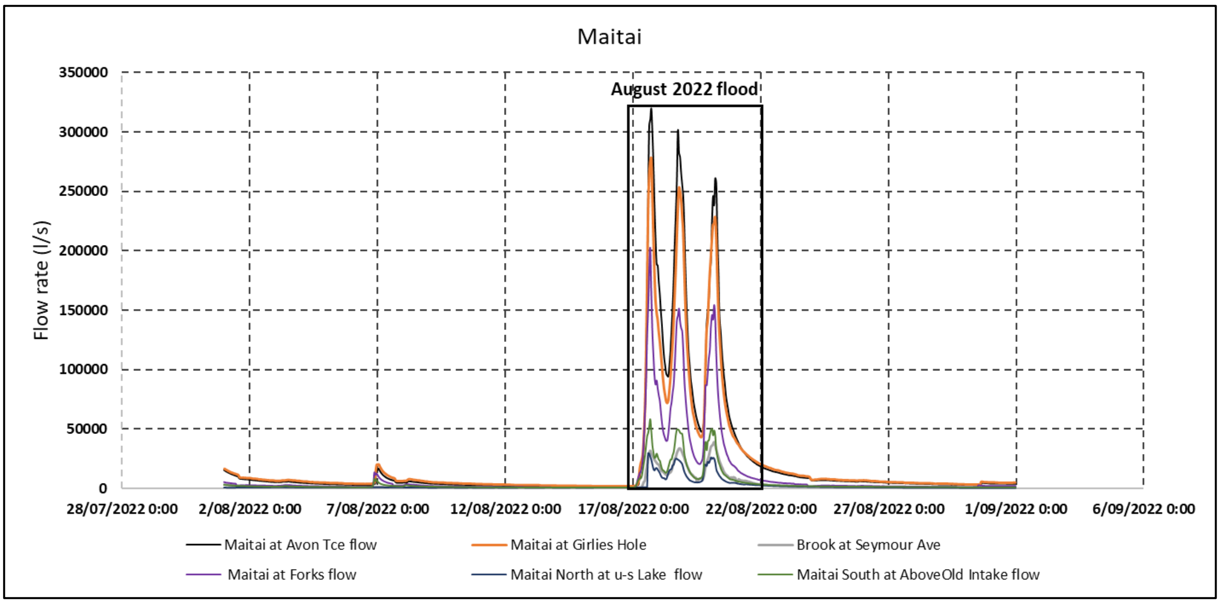


Figure A-1: Flows at Maitai catchment during August 2022 floods.

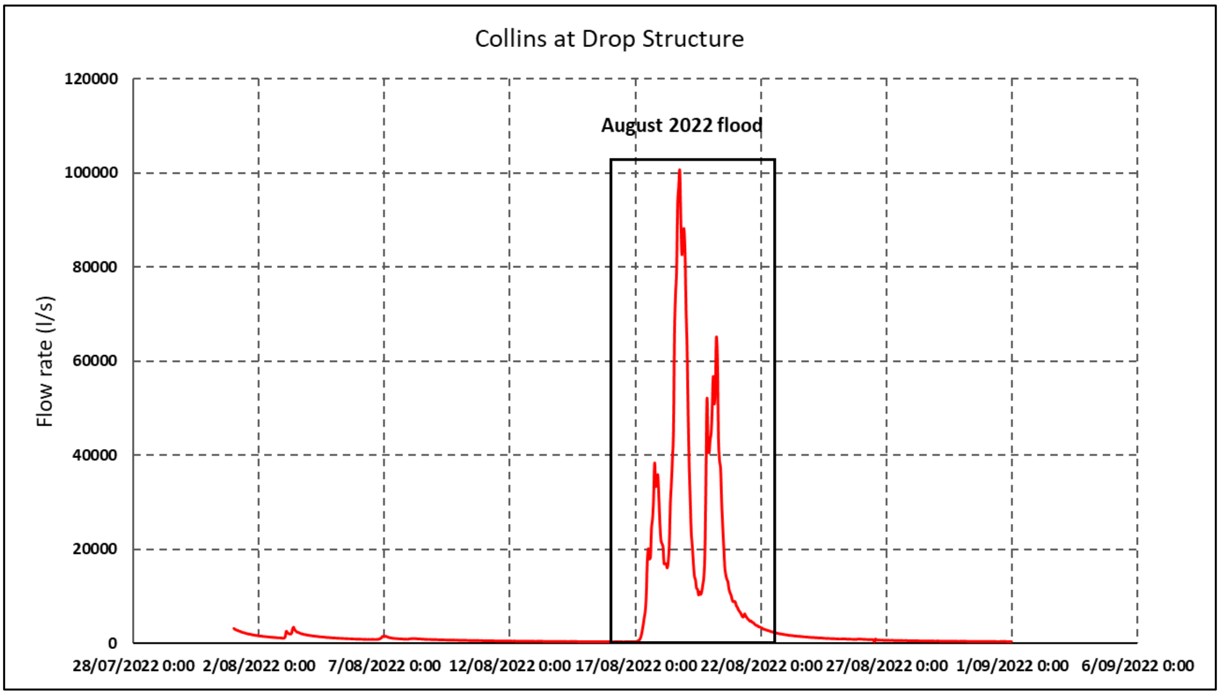


Figure A-2: Flows at Collins River during August 2022 floods.

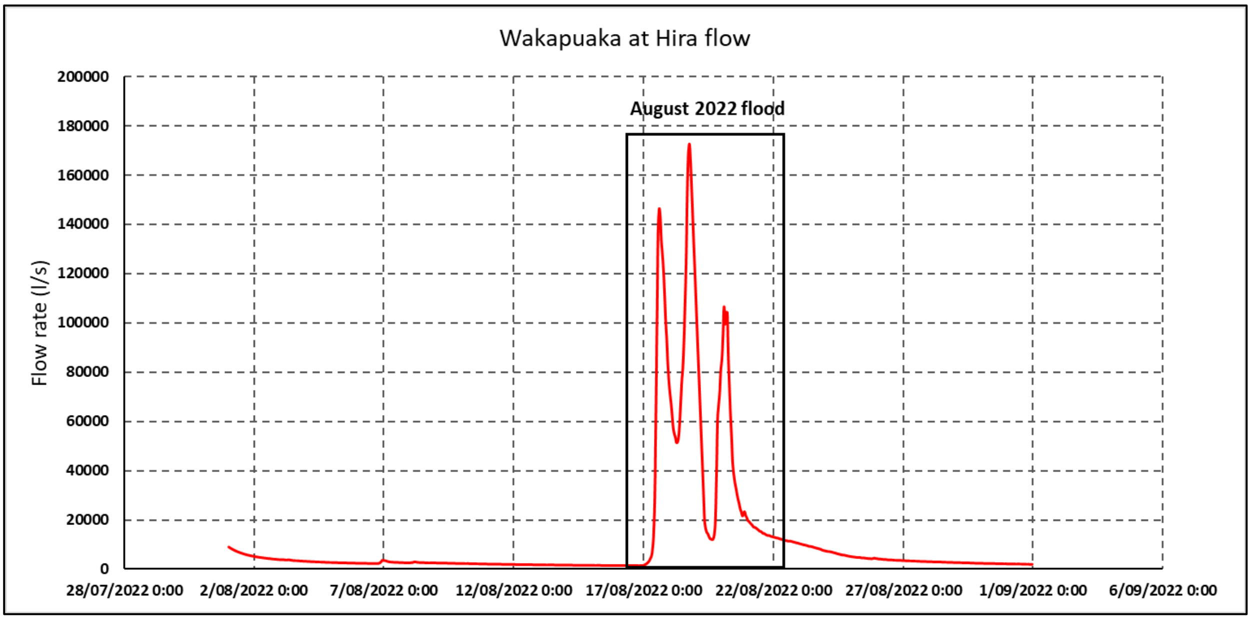


Figure A-3: Flows at Wakapuaka River during August 2022 floods.

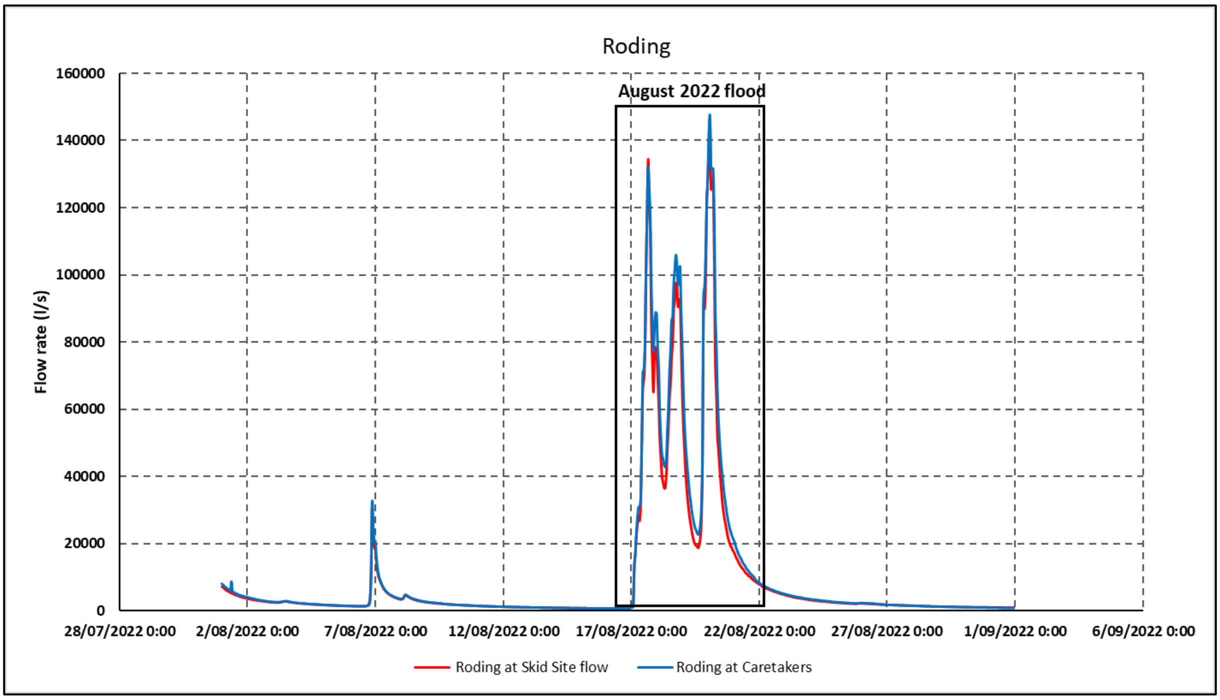


Figure A-4: Flow Roding River during August 2022 floods.

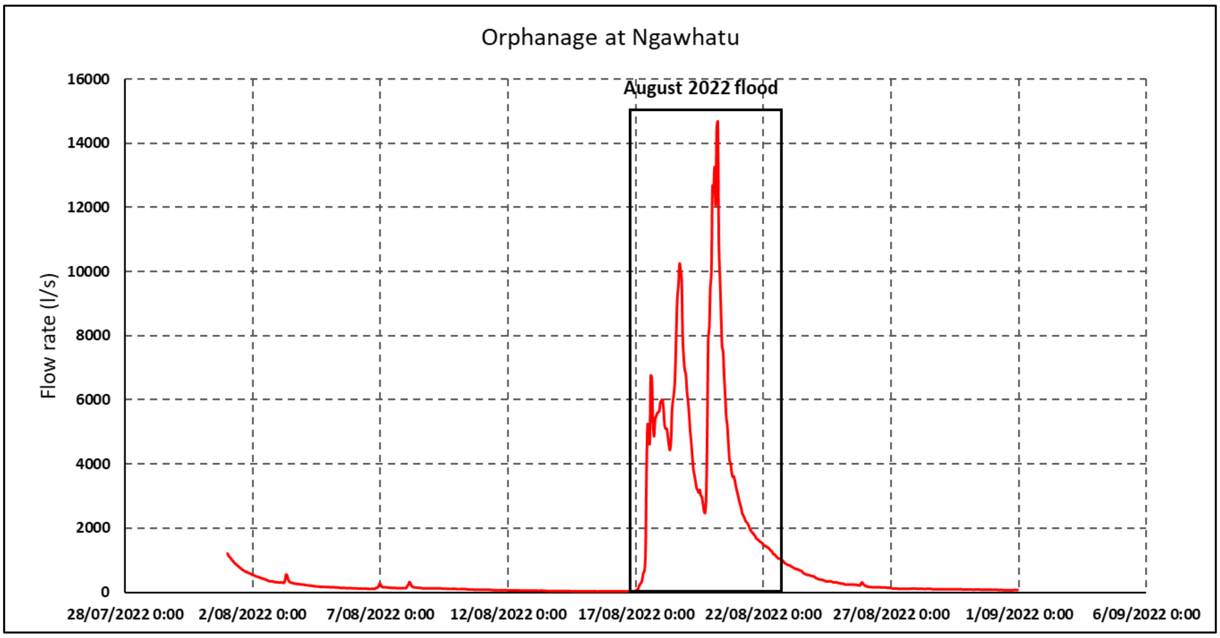
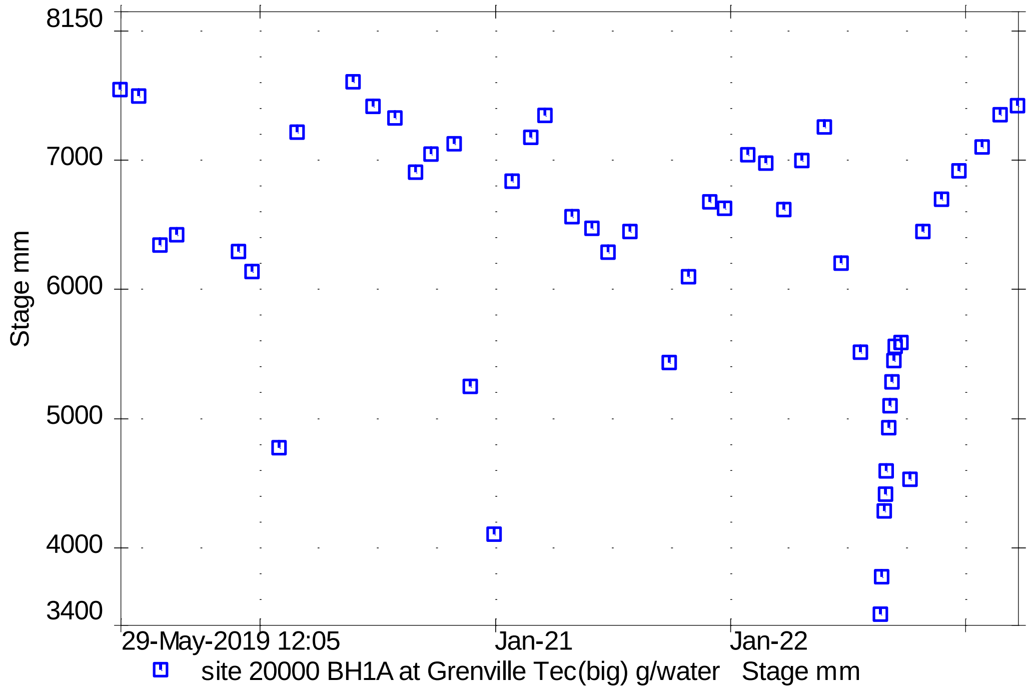
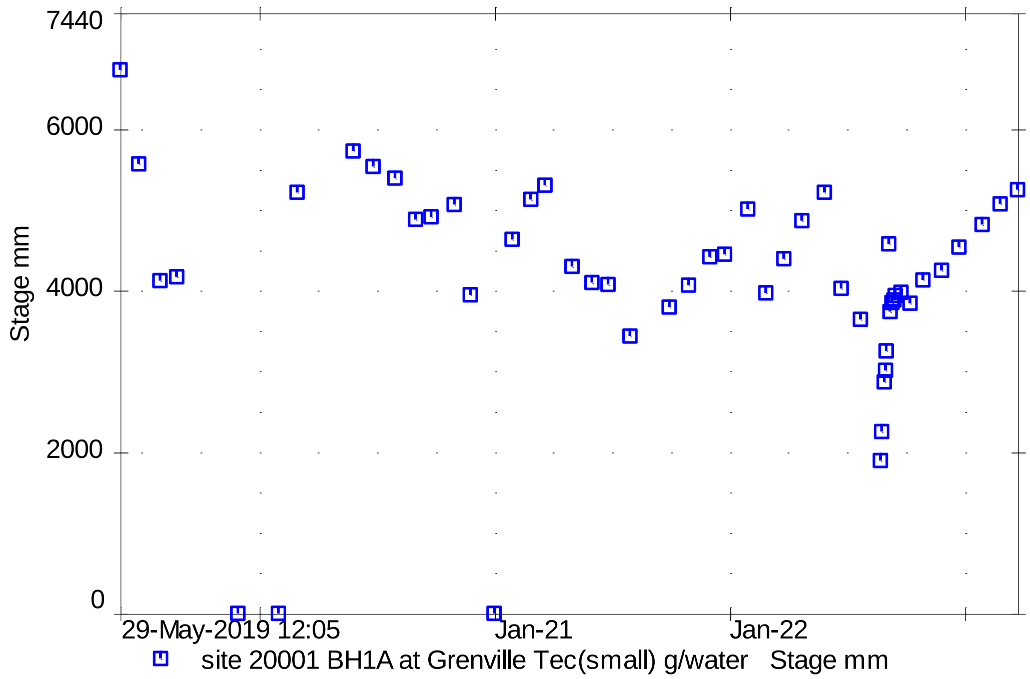
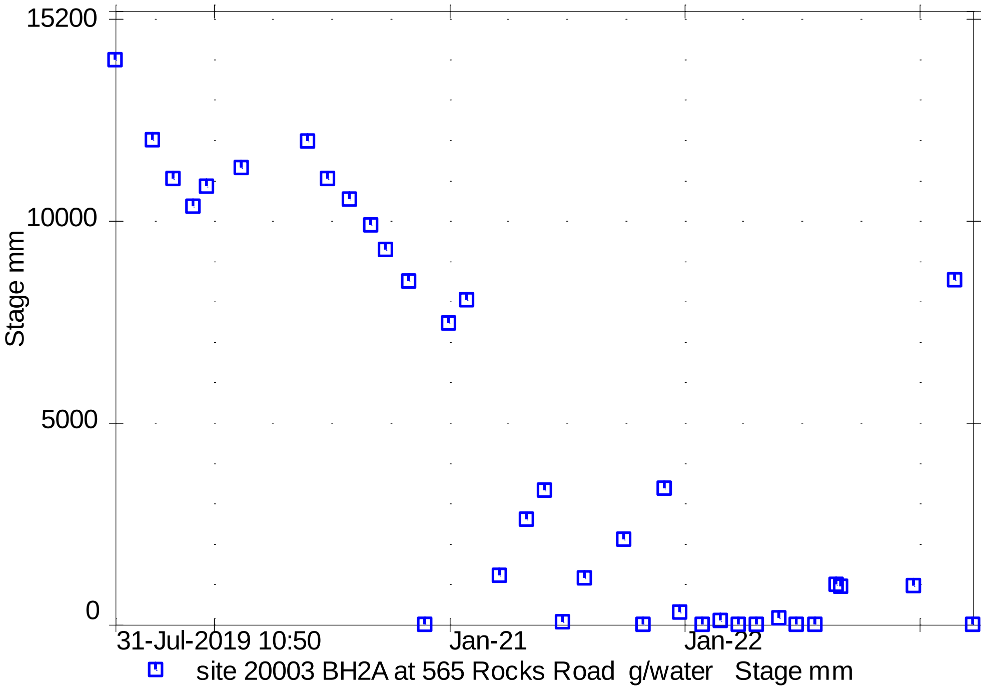


Figure A-5: Flows at Orphanage Stream during August 2022 floods.

Appendix B Time series of groundwater level monitoring in Nelson



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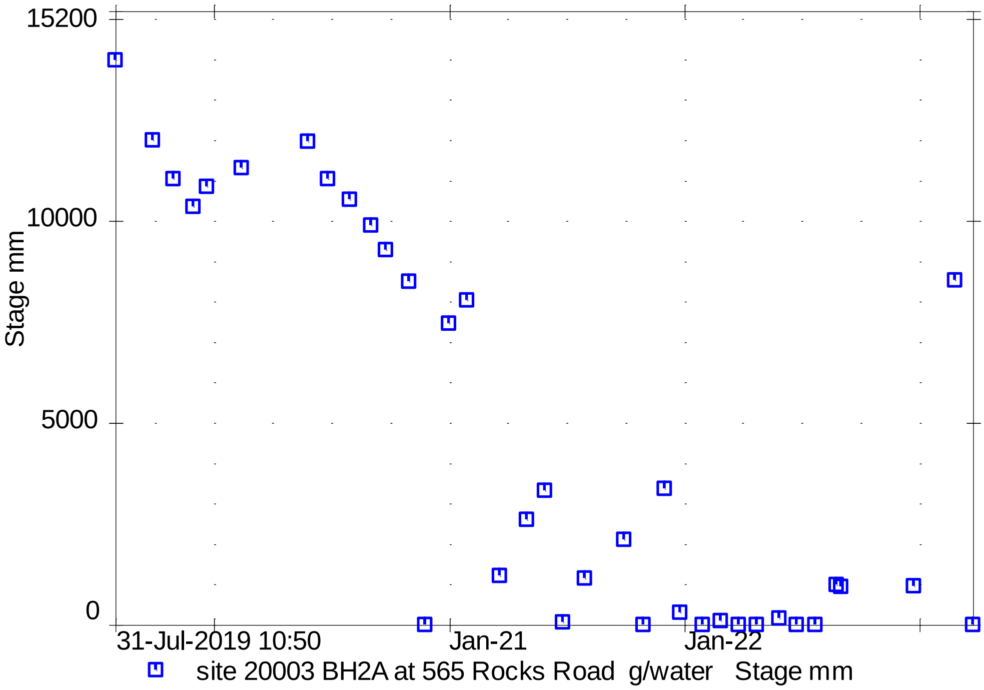
10000
5000
0
Stage mm
31-Jul-2019 10:50
Jan-21
Jan-22
site 20003 BH2A at 565 Rocks Road g/water Stage mm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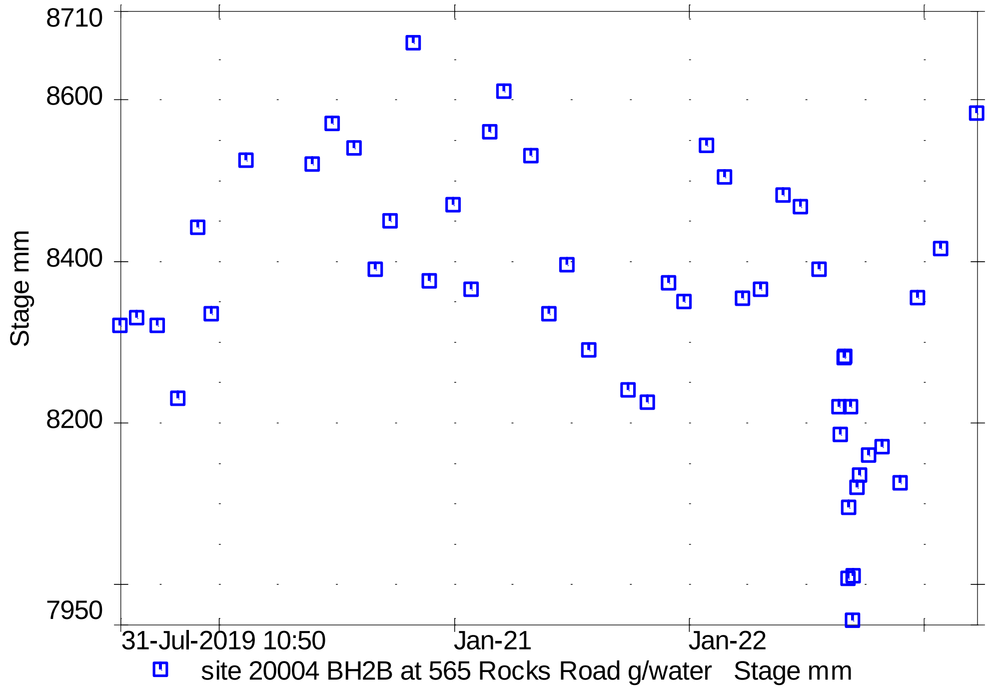
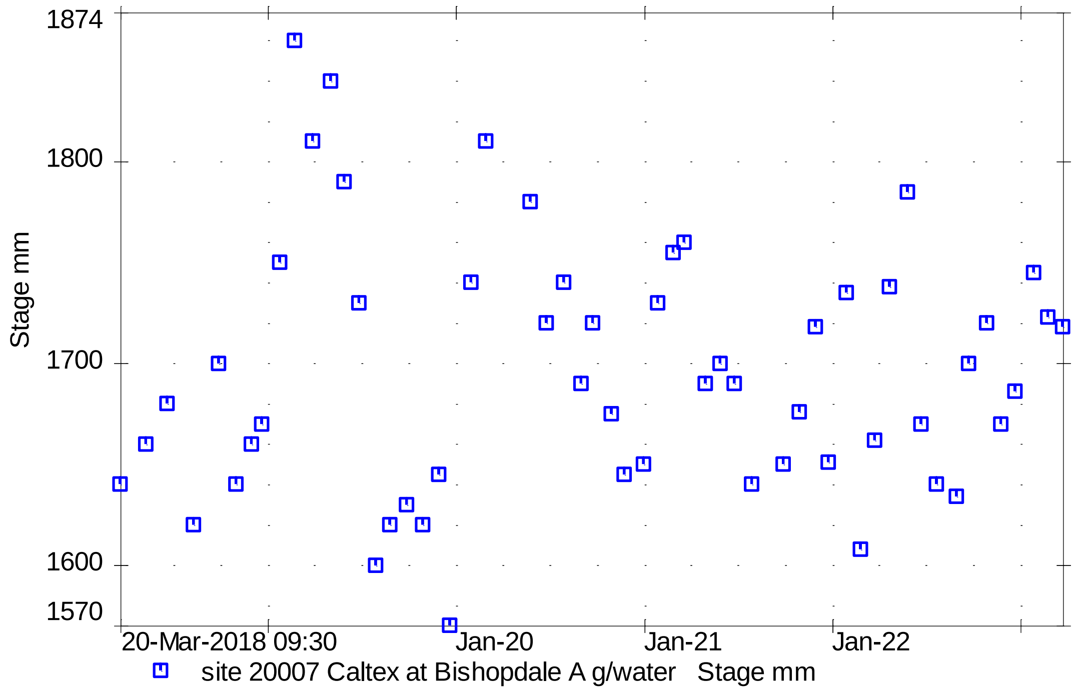
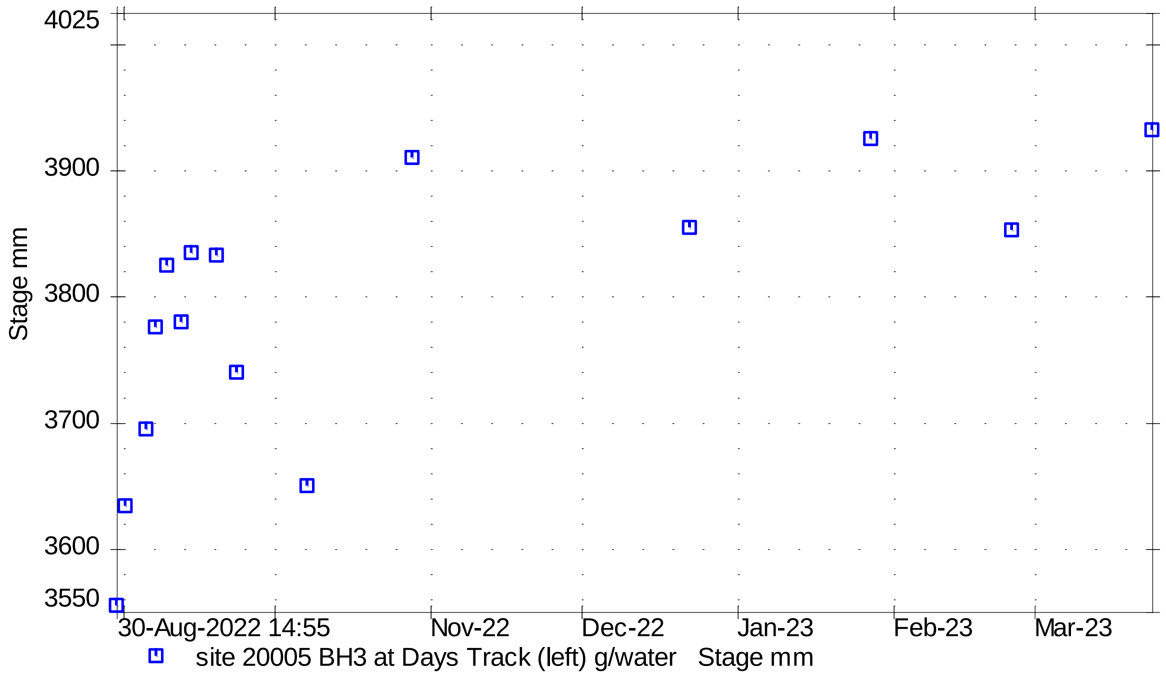
10000
5000
0
Stage mm
31-Jul-2019 10:50
Jan-21
Jan-22
site 20003 BH2A at 565 Rocks Road g/water Stage mm


8710
8600
8400
8200
7950
Stage mm
31-Jul-2019 10:50
Jan-21
Jan-22
site 20004 BH2B at 565 Rocks Road g/water Stage mm


1874
1800
1700
1600
1570
Stage mm
20-Mar-2018 09:30
Jan-20
Jan-21
Jan-22
site 20007 Caltex at Bishopdale A g/water Stage mm


4025
3900
3800
3700
3600
3550
Stage mm
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Dec-22
Jan-23
Feb-23
Mar-23
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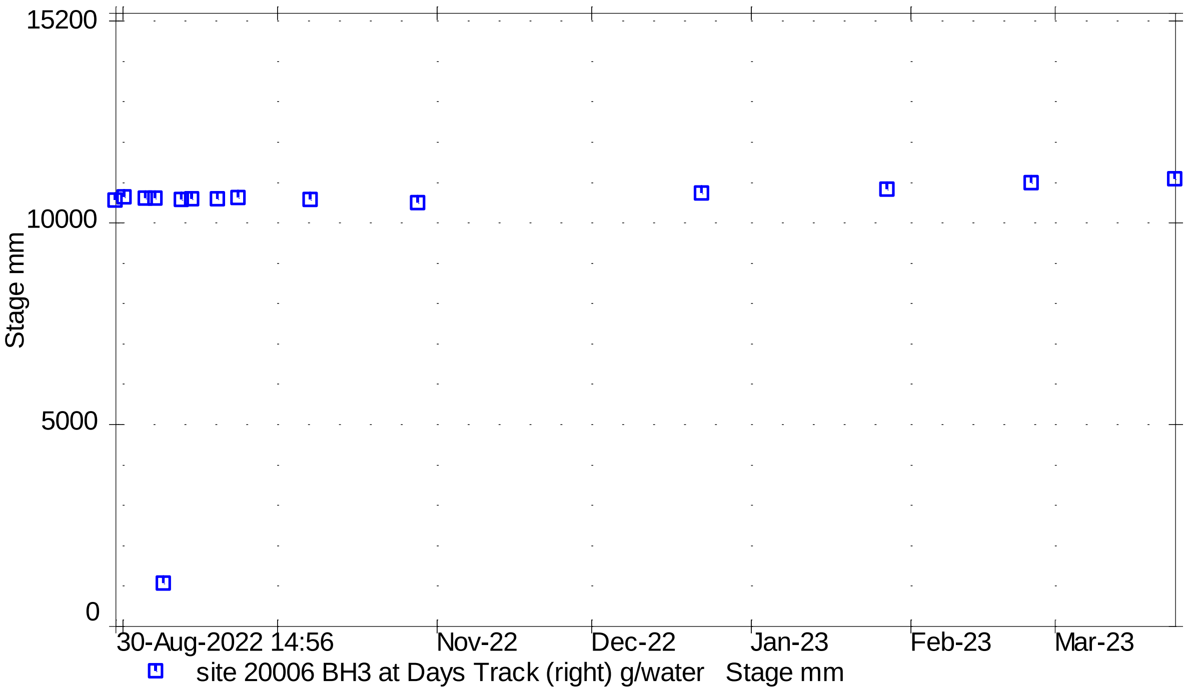
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10000
5000
0
Stage mm
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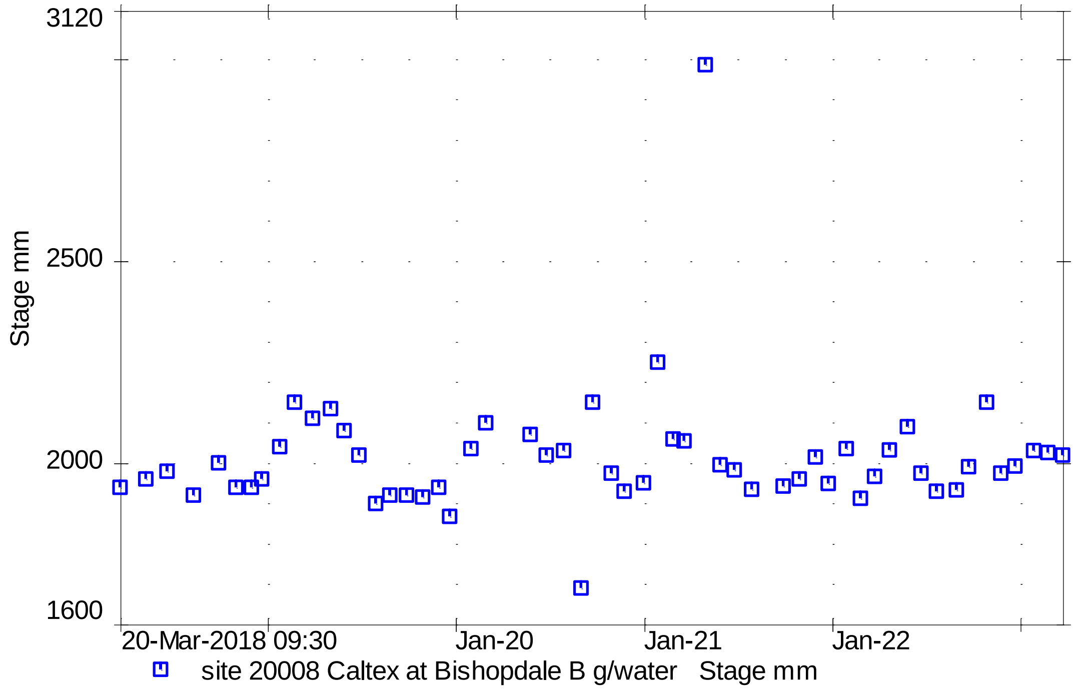
Nov-22
Dec-22
Jan-23
Feb-23
Mar-23
site 20006 BH3 at Days Track (right) g/water Stage mm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2500
2000
1600
Stage mm
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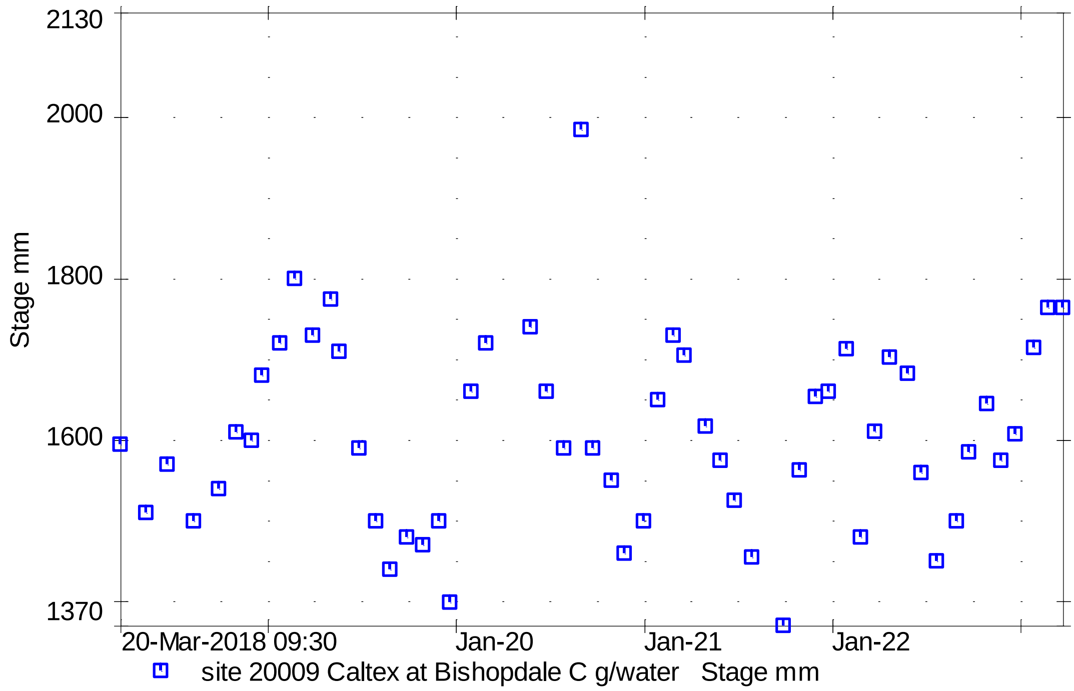
Jan-20
Jan-21
Jan-22
site 20008 Caltex at Bishopdale B g/water Stage mm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2000
1800
1600
1370
Stage mm
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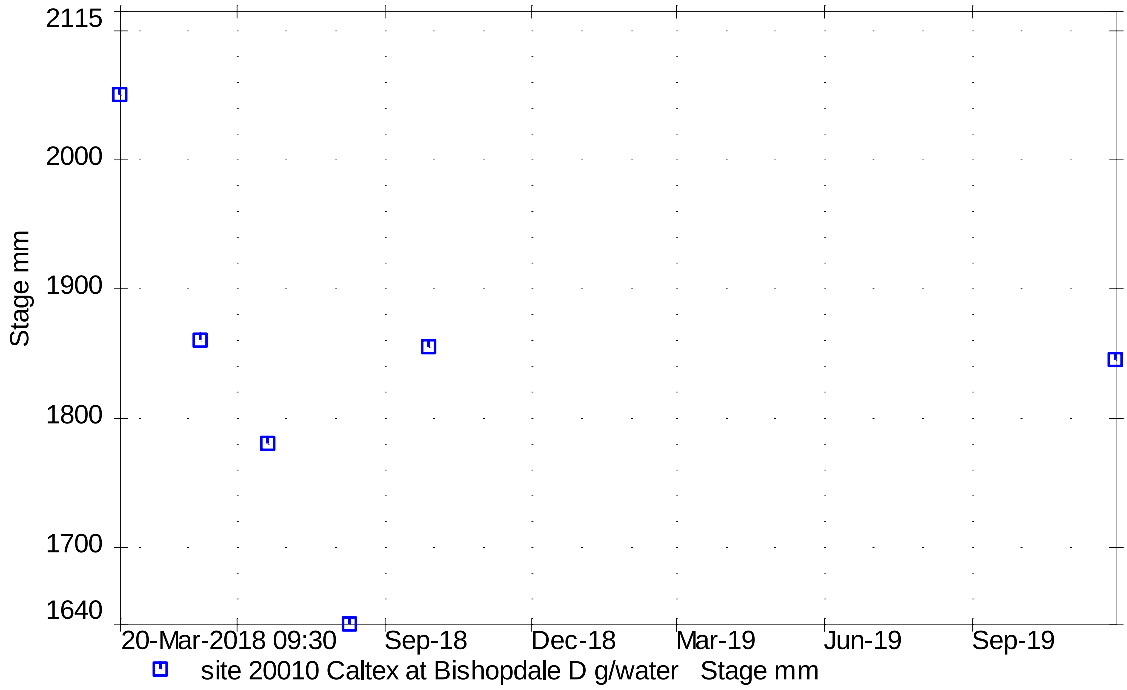
Jan-20
Jan-21
Jan-22
site 20009 Caltex at Bishopdale C g/water Stage mm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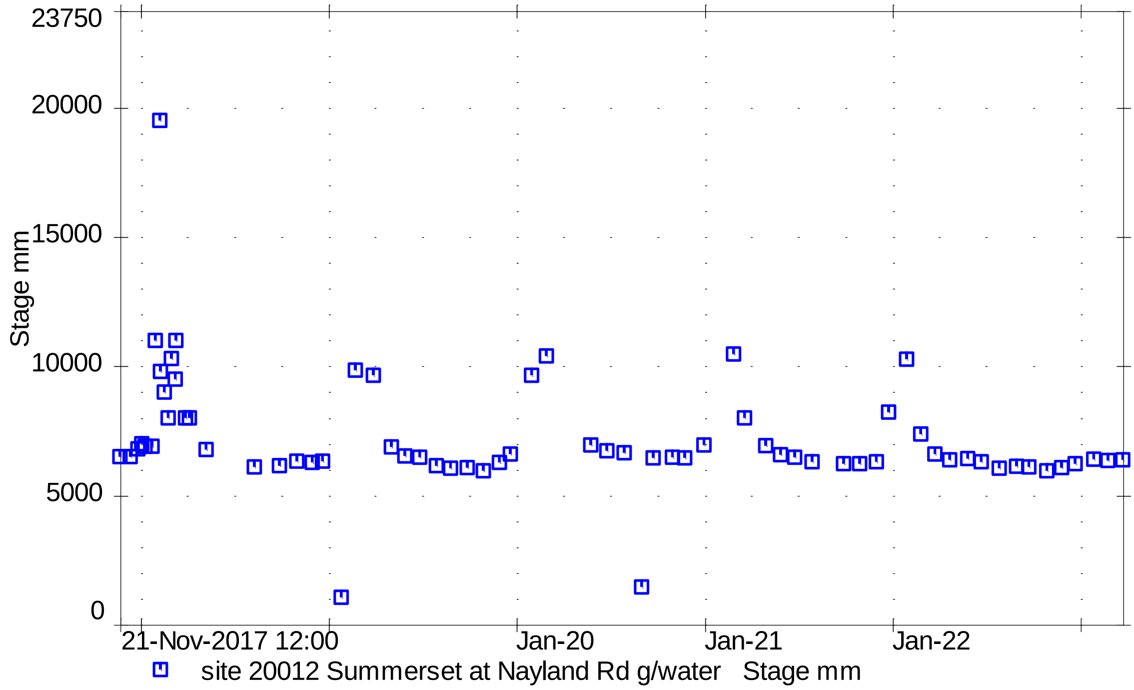
2000
1900
1800
1700
1640
Stage mm
20-Mar-2018 09:30
Sep-18
Dec-18
Mar-19
Jun-19
Sep-19
site 20010 Caltex at Bishopdale D g/water Stage mm


23750
20000
15000
10000
5000
0
Stage mm
21-Nov-2017 12:00
Jan-20
Jan-21
Jan-22
site 20012 Summerset at Nayland Rd g/water Stage mm

Appendix C Water Quality Network

The most recent SoE report for the Nelson region was published in 2018 (NCC 2018) which provided a consolidation of knowledge concerning the environment (land, sea, freshwater and air) in the region. The report highlighted the importance of systematic monitoring of water quality in the region. There is a monthly monitoring programme to assess river and stream water quality by measuring a range of physicochemical and microbiological variables in four FMUs including Maitai, Stoke, Wakapuaka and Whangamoa. The measurements include nutrients (nitrogen and phosphorous), microbiology (*E. coli*), sediment (water quality, suspended and deposited sediment) and other variables such as dissolved oxygen, pH, and conductivity Table C-1. The locations and the details of the monitoring programme within NCC's FMUs are given in Figure C-1 and Table C-2.

Table C-1: Water quality monitoring in the Nelson region. Source: from NCC website.

Variable	Lab	Method	Detection limit/units
Total Nitrogen	Hill	Alkaline persulphate digestion, automated Cd reduction/sulphanilamide colorimetry. APHA 4500-N C & 4500-NO_3^- I (modified) 23rd ed. 2017.	0.010 g/m^3
	Watercare	Persulphate Digestion and Flow Analysis. APHA (online edition) 4500-P J, 4500-NO3 F (modified)	0.010 mg/L
Total Oxidised Nitrogen	Hill	Nitrate-N + Nitrite-N. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.0010 g/m^3
	Watercare	Calculation Nitrate-N + Nitrite-N. APHA (online edition) 4110 B and EPA 300.0	0.002 mg/L
Ammoniacal Nitrogen	Hill	Phenol/hypochlorite colorimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH3 H 23rd ed. 2017.	0.005 g/m^3
	Cawthron	APHA 21st Edn 4500 NH3 H	g/m^3
	Watercare	Colorimetry/Discrete Analyser MEWAM, HMSO 1981, ISBN 0117516139	0.005 mg/L
Nitrite-N	Hill	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.0010 g/m^3
	Watercare	Anions by Ion Chromatography (0.45 µm Filtered). APHA (online edition) 4110 B and EPA 300.0	0.002 mg/L
Nitrate-N	Hill	Calculation: (Nitrate-N + Nitrite-N) - NO_2N.	0.0010 g/m^3
	Cawthron	APHA 21st Edn 4500 NO_3 I	g/m^3

Variable	Lab	Method	Detection limit/units
	Watercare	Anions by Ion Chromatography (0.45 µm Filtered). APHA (online edition) 4110 B (Modified)	0.002 mg/L
Dissolved Inorganic Nitrogen	Combination	Calculation: Total Oxidised Nitrogen + Ammoniacal Nitrogen	0.01 mg/L
Total Phosphorus	Hill	Total phosphorus digestion, automated ascorbic acid colorimetry. Flow Injection Analyser. APHA 4500-P H 23rd ed. 2017.	0.002 g/m^3
	Watercare	Persulphate Digestion and Colorimetry/Discrete Analyser. APHA (online edition) 4500-P B, J (modified)	0.004 mg/L
Dissolved Reactive Phosphorus	Hill	Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G 23rd ed. 2017.	0.0010 g/m^3
	Cawthron	APHA 21st Edn 4500 P A, G	g/m^3
	Watercare	Colorimetry/Discrete Analysis. APHA (online edition) 4500-P B, F (modified)	0.002 mg/L
Escherichia coli	Hill	Sample filtration through 0.45µm membrane filter, Count on mFC agar, Incubated at 44.5°C for 22 hours, APHA 9222 I 23rd ed. 2017.	1 cfu / 100mL
	Cawthron	APHA 21st Edn 9222D/9222G	cfu/100mL
	Watercare	Membrane Filtration (0.45 µm) APHA (online edition) 4500-P B (preliminary filtration), USEPA Method 1603 (2002)	2 cfu/100mL
Water Clarity	Field technicians	Black disk (20 mm disk or clarity tube if clarity <0.5 m, 60 mm disc for clarity between 0.5 m and 1.5 m, 200 mm disc for clarity >1.5 m)	0.01 m
Deposited fine sediment	Field technicians	Cover of the streambed in a run habitat determined by the instream visual method, SAM2 as defined in Clapcott et al. (2011)	0.05%
Total Suspended Solids	Hill	Filtration of a 2 L sample using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	0.5 g/m^3
	Cawthron	APHA 21st Edn 2540 D+E	g/m^3
	Watercare	Gravimetry APHA (online edition) 2540 D	0.2 mg/L

Variable	Lab	Method	Detection limit/units
pH	Hill	pH meter. APHA 4500-H^+ B 23rd ed. 2017. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH units
Electrical conductivity	Field technicians	Field meter	0.1 µS/cm

Figure C-1: SoE monitoring sites in Nelson region. (NCC website).

As noted in the Executive Summary, a review of the water quality network was not in the scope of this report. That noted, for completeness we have highlighted some recent reports on this topic for the Nelson region and have provided some additional thoughts. These are only preliminary thoughts on this topic and the following text should not be considered a review of the water quality network for the region.

The Nelson freshwater quality network was reviewed in 2016 (McArthur 2016). Also, a comprehensive investigation of the water quality monitoring programme in four main estuaries in the region (Waimea Inlet, Nelson Haven, Delaware Estuary and Kokorua Estuary) has been carried out (Dudley 2019). The existing freshwater SoE water quality monitoring network in the Nelson region has provided a good foundation for water quality monitoring network. Freshwater SoE sites near the terminal reach of major rivers are suitable for estimating contaminant loads entering all four major estuaries. Calculation of contaminant loads to Waimea Inlet requires data from three further terminal reach river sites from the Tasman District Council surface water quality monitoring network (Dudley 2019). Please see Dudley (2019) for further recommendation about the water quality monitoring for the four main estuaries.

Table C-2: List of SoE monitoring sites in each FMU in the Nelson region.

FMU	Sites
Maitai	Brook at Burn Pl Brook at Manuka St Brook at Motor Camp Hillwood at Glen Rd Maitai South Branch at Intake Maitai at Groom Rd Maitai at at Avon Tce Sharland at Maitai Confluence Todds at SH6 York at Waimea Rd
Wakapuaka	Lud at 4.7km Lud at SH6 Wakapuaka at Duckpond Rd Wakapuaka at Hira Wakapuaka at Maori Pa Rd Teal at 1.9km
Whangamoa	Collins at SH6 Dencker at Kokorua Rd Whangamoa at Hippolite Rd Whangamoa at Kokorua Bridge
Stoke	Jenkins at Pascoe St Orphanage at Saxton Rd East Poorman at Barnocoat Walkway Poorman at Seaview Rd Saxton Creek Below Confluence Saxton upstream of Champion Rd
Roding	Roding at Skid Site Roding at Caretakers

The major streams in Stoke including Orphanage, Poorman and Jenkins are monitored as part of SoE (Figure C-1). As highlighted in McArthur (2016), a monitoring site at Saxon Creek was required due to its proximity to the Waimea inlet. Monitoring started at two sites on Saxton Creek; Saxton Creek Below Confluence and Saxton upstream of Champion Road.

Maitai (10 sites), Wakapuaka (6 sites) and Whangamoa (6 sites) generally have a good network of monitoring sites with sites located in both the upper part and lower part of the river network. However, the lack of sites monitoring the rivers entering the estuaries in these regions has been documented by Dudley (2019).

Because of the importance of the Roding River for the water supply in the region, two SoE sites at Roding at Skidsite and Roding at Caretakers have been added to the network since 2021.

A previous study in the Maitai catchment (Gibbs and Woodward 2017) highlighted the importance of a continuous sediment gauging site in the region. Using a forensic compound specific stable isotope (CSSI) technique, Gibbs and Woodward (2017) showed that harvesting forests and bank erosion produce a substantial amount of sediment in the Maitai catchment. Even though the current SoE monitoring network is collecting several sediment related variables (e.g., clarity, suspended and deposited sediment), there is a need for a continuous sediment monitoring network in the region. This network will help understand sediment transport processes, assessing erosion risks, managing water quality, predicting floods, maintaining river stability, identifying sediment sources, studying climate change impacts, and supporting research and modelling efforts. It provides valuable data for effective sediment management and informed decision-making in river catchments. It is important to consult relevant guidelines, standards, and local environmental agencies or experts during the development of a sediment monitoring network. Ministry for the Environment (MfE) has provided guidance for sediment monitoring (MfE 2022).