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Centre for Freshwater Management

Spatial review of the Marlborough District Council raingauge network

WCFM Technical report 2023-001

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Section 1. Introduction

Marlborough District Council (MDC) has monitored rainfall since 1963. The network was last reviewed in 2017. The emphasis of the review reported here is the adequacy of the spatial coverage of the region, for the purpose of assessing long term trends and water resources, as well as for flood warning during significant weather events. The extent of the MDC's territorial region (10,458 km^2), not including inland water or oceanic areas, is shown in Figure 1.

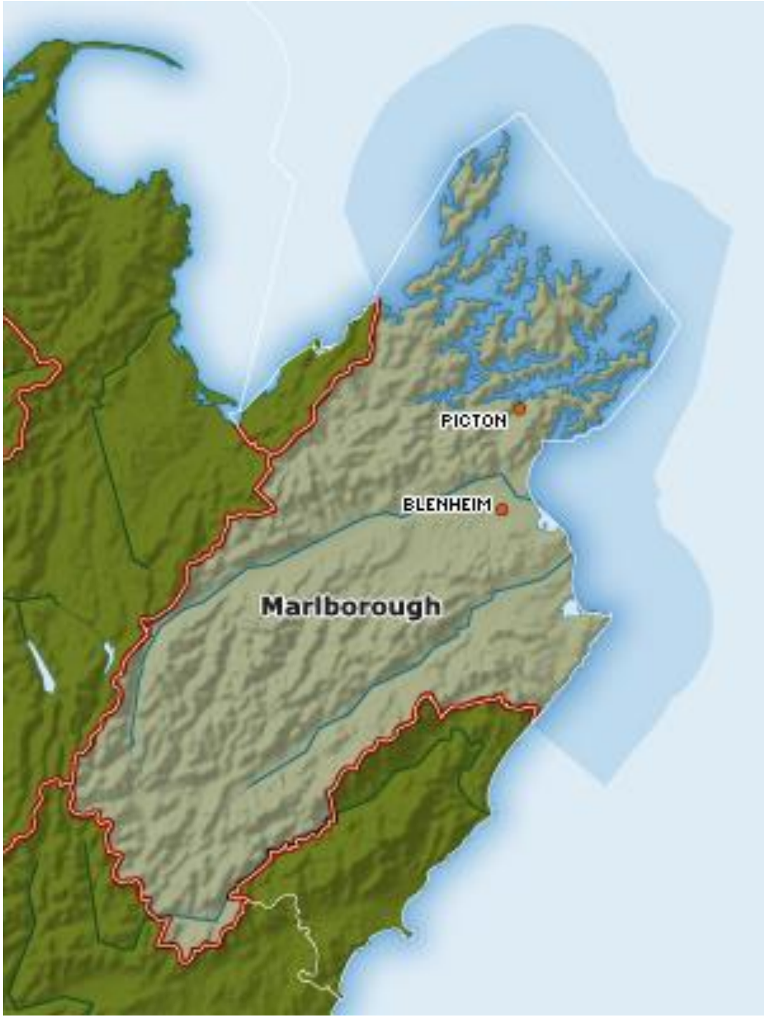

Figure 1: The extent of Marlborough District Council's territory.

The overall objective for a District Council network is to provide a basis for the sustainable management of the region's water resources and for monitoring the State of the Environment. The rainfall network is part of this hydrological network and key objectives are listed below (Pearson et al 2001, and Duncan et al 2007):

- To provide input to flood warning systems;

- To characterise rainfall at a range of spatial and temporal scales so that storm and drought events can be accurately monitored and reported;
- To measure long term trends in rainfall totals and intensities, including those caused by climate change;
- To provide rainfall data that can be reliably transferred to parts of the region where little or no rainfall data is available.

Key matters to be addressed by the review are:

- Optimum spatial coverage and number of raingauges in the network to understand long and short term variations throughout the region;
- The rainfall network is required to provide real time data for flood warning, rainfall at spatial and temporal scales to enable the reporting of drought and storm events, as well as climate change impacts upon rainfall;
- To identify which sites of the current network could be removed, and which sites should be added;
- To provide an integrated overview of findings and recommendations for a sustainable and cost-effective rainfall network that meets the management needs of the District Council.

Section 2. The rainfall network

MDC currently has access to data from 63 open raingauges. The network consists of 12 daily manual raingauges and 51 recording raingauges; this includes eight raingauges just outside the MDC boundary which are archived by the MDC. Of the 51 recording raingauges 50 are telemetered. Of the telemetered raingauges, 26 are operated by MDC while the remainder (7) are operated by Tasman District Council, with one additional shared site with MDC, the National Rural Fire Authority(NRFA) also referred to as Fire and Emergency New Zealand (FENZ) (15) and Environment Canterbury (1). For the raingauges with daily readings, the recording authority is NIWA (8) and MetService (4).

There are 146 additional automatic or manual raingauge sites in the MDC region. Many will be closed but some useful sites will remain open.

2.1 Rainfall Network Review Method

The rainfall-recording network is of primary importance for characterising rainfall information for the Marlborough region, including storm rainfalls and climate change, and for knowledge and understanding of the region’s ground and surface water systems and their interactions.

MDC requested that this review follow the template used by Duncan et al. (2007) when completing a raingauge network review for Hawkes Bay Regional Council. Duncan et al. (2007) followed a methodology compiled by Pearson et al. (2001). Both reports are referred to in the review that follows.

Initial criteria for establishing a network include division of the region into hydrologic subregions, function/ purpose, rainfall processes, location, frequency of measurement and duration of deployment (Table 1), following Pearson et al (2001)

The criteria in Table 1 were used to define a minimum MDC raingauge network, by ensuring that each criterion in Table 1 was covered by at least one raingauge. For example, a long term gauge is required in each of the nineteen hydrologic subregions listed. In the initial data analysis the two main purposes, Long-Term Baseline and Storm monitoring (hereafter LTB and STM) allow the reduction of data analysis for examination of regional variability of important rainfall statistics; and an assessment of the minimum gauge separation necessary for the adequate definition of these statistics, as per the methodology of Pearson et al (2001).

When following the Pearson et al. (2001) methodology, Duncan (ibid.) did not attempt this particular analysis due to time constraints. The Pearson et al. (2001) analysis of raingauge spacing is completed for all MDC gauges with over 20 years record length. The site spacing relationship was attempted via correlation analysis between inter-gauge distance on two key rain statistics - annual rainfall total and annual series of maximum one-hour rain intensity.

Hydrologic region	**Subregion**	
Blenheim	East Coast Hills Wairau flood plain Wairau Valley flats	
Blairich	Taylor – Omaka Waihopai Wairau South Bank	
Kaikoura Range	Upper Awatere Mid Awatere Flaxbourne – Medway	
Spenser	Wairau Dip Flat Branch Acheron - Mid Clarence	
Marlborough	Richmond Range West Richmond Range East Pelorus – Wakamarina Sounds West (Rai) Sounds North Sounds Central Sounds East	
Criteria	**Long-Term Baseline (LTB)**	**Storm (STM)**
Function/Purpose	Climate change Long term trend Monitoring water resources Design rainfall depth-duration-frequency information Input to hydrological modelling	Storm and drought characterisation Flood forecasting and warning
Rain Processes	Orographic effects of the Bryant, Richmond, Arnaud, Raglan, Spenser and Inland Kaikoura Ranges. Rainfall gradients across the Marlborough region Storm directions and tracks across the Marlborough region	
Location	Standard meteorological locations away from buildings, trees etc Adequate spatial regional coverage Locations useful for aquifer and catchment modelling	Standard meteorological locations away from buildings, trees etc Adequate spatial regional coverage Upstream in (and of) catchments for flood forecasting / warning purposes
Frequency	Automatic (daily suffices for drought and flood reporting and climate change monitoring)	Automatic Telemetry for flood warning
Duration	Indefinite	Indefinite

Table 1: Hydrologic regions and raingauge monitoring criteria.

2.2 Rainfall Network Review Results

2.2.1 Data analysis results

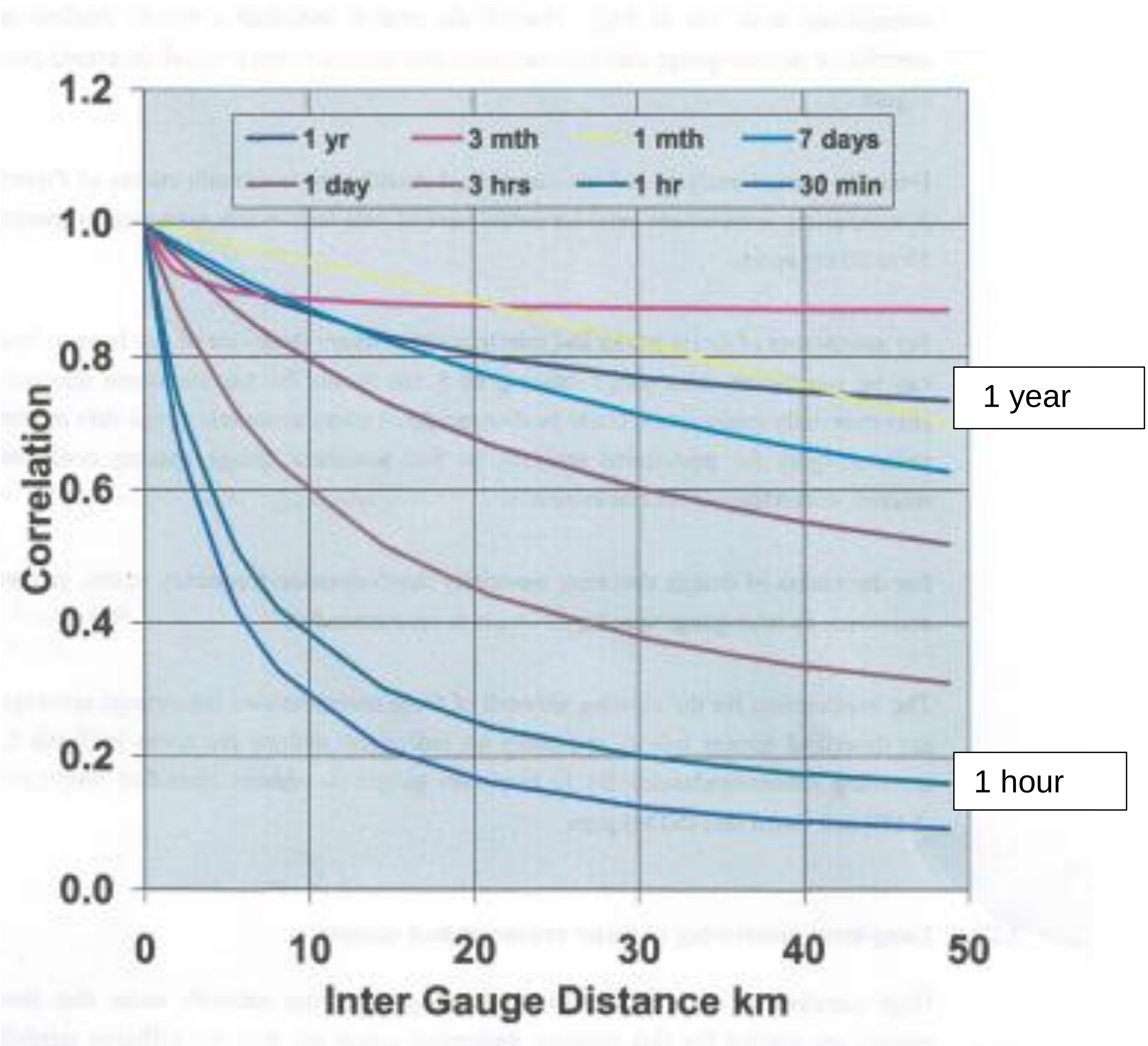

Figure 2: Pearson et al (2001); Auckland City relationship between inter-gauge distance and correlation for eight different rainfall accumulation intervals.

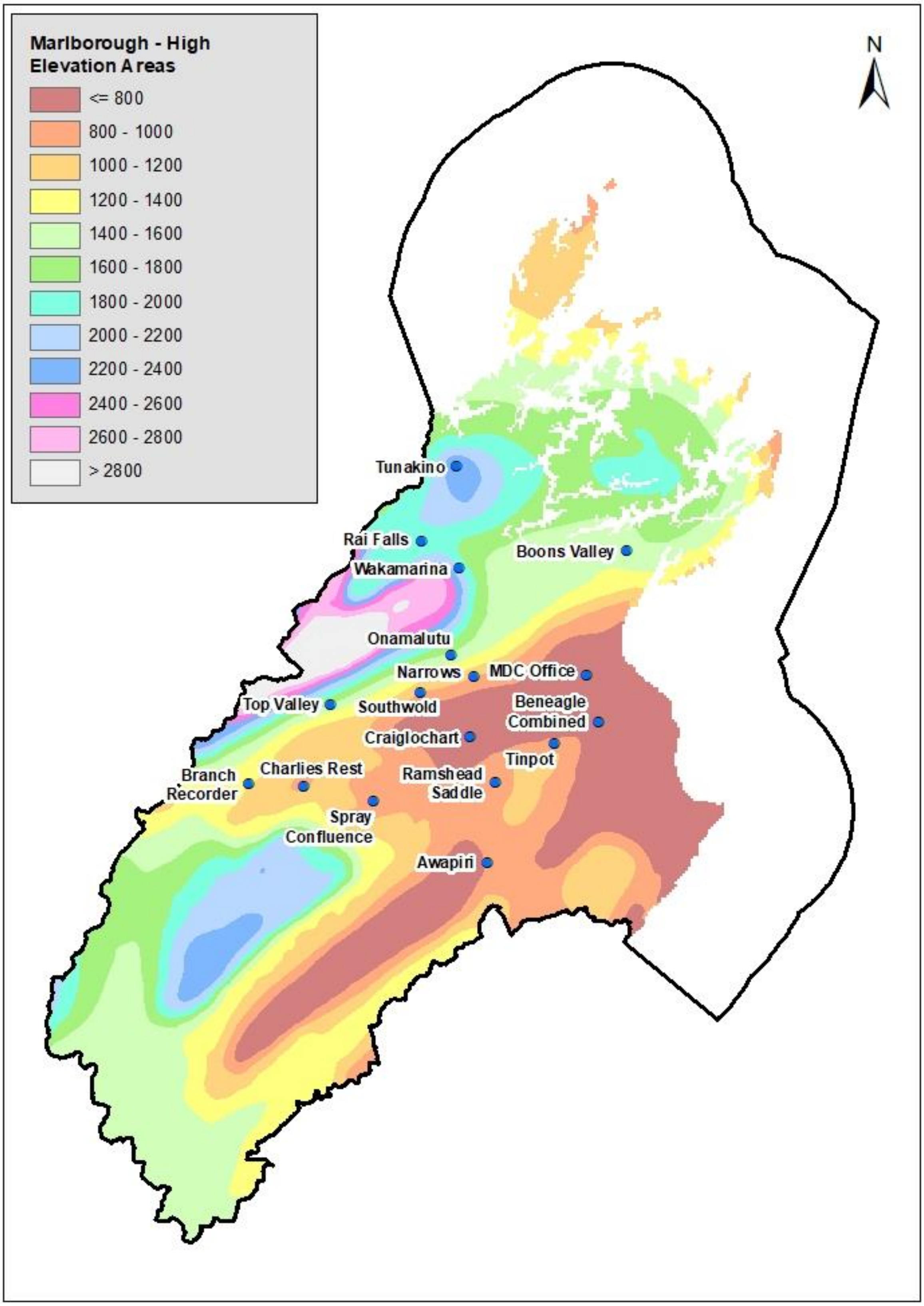

Figure 3: Location of MDC raingauges with over 20 years record and annual rainfall isohyets detailing high elevation areas.

The Pearson et al (2001) analysis for Auckland City (previously Auckland Regional Council), shows that the closer two raingauges are, the closer their rain records are likely to be. Figure 2 shows how well these records match over distance and for different rainfall total durations. Interestingly, high correlations were reported to be common for annual totals between gauges 60 km apart and in some cases up to 80 km. The annual maximum series of one hour intensities were, however, not as high as would be expected. However, overall, Figure 2 shows remarkable correlations, displaying that the spatial correlation increased with the integration time. As a result Pearson et al (2001) used the spacing between raingauges as a method to review the Auckland City rainfall network.

The same correlation analysis for annual and one hour durations was completed for the MDC raingauges with over 20 years record (Figure 3) and the results are displayed in Figure 4 and 5 respectively.

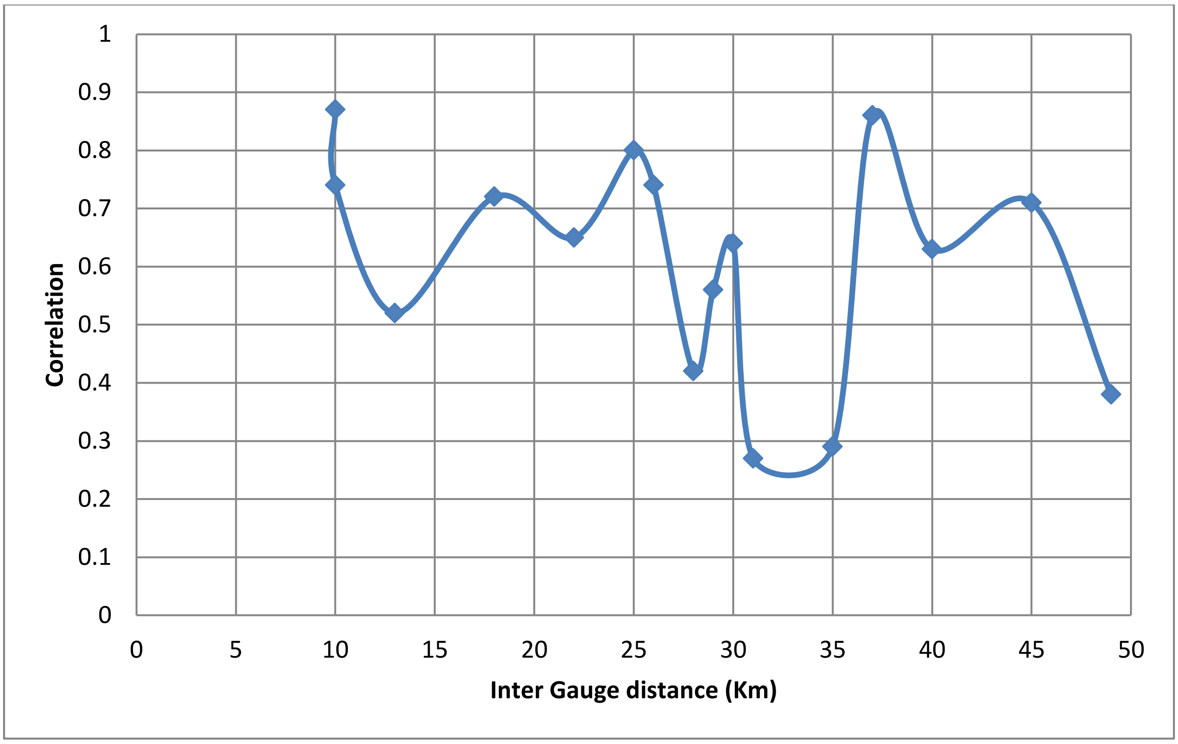

Figure 4: Relationship between inter-gauge distance (from Southwold) and correlation with annual rainfall totals

This analysis of the inter gauge correlations with distance reveals a far more complex pattern than evident in the Auckland Region and precludes the use of a simple method to review MDC's raingauge network. While disappointing, it is not surprising, as in Marlborough a north west rainfall event may only affect the northern half the region, and a south easterly frontal rain event may only affect the southern half. While these patterns are smoothed over long periods (giving rise to moderate annual correlations between gauges up to 40-50 km apart), strong event scale differences in synoptic conditions result in the very low gauge correlations revealed for the 1 hour totals shown in Figure 5. Furthermore MDC annual rainfall ranges from very wet (2800 mm) to very dry (500 mm), whereas Auckland experiences rainfall with less variation (900 – 1700), over a significantly reduced land area (50%).

This was a suitable approach for Auckland as displayed in Figure 2, but unfortunately not so for MDC as observed in the lack of any relationships in Figures 4 and 5.

It is considered that determining the spatial coverage based upon distance between sites, may over estimate the number of new raingauges required, especially in the remote areas of the region such as Upper Wairau, Upper Awatere, Acheron Mid Clarence, and the Marlborough Sounds which includes large areas of ocean.

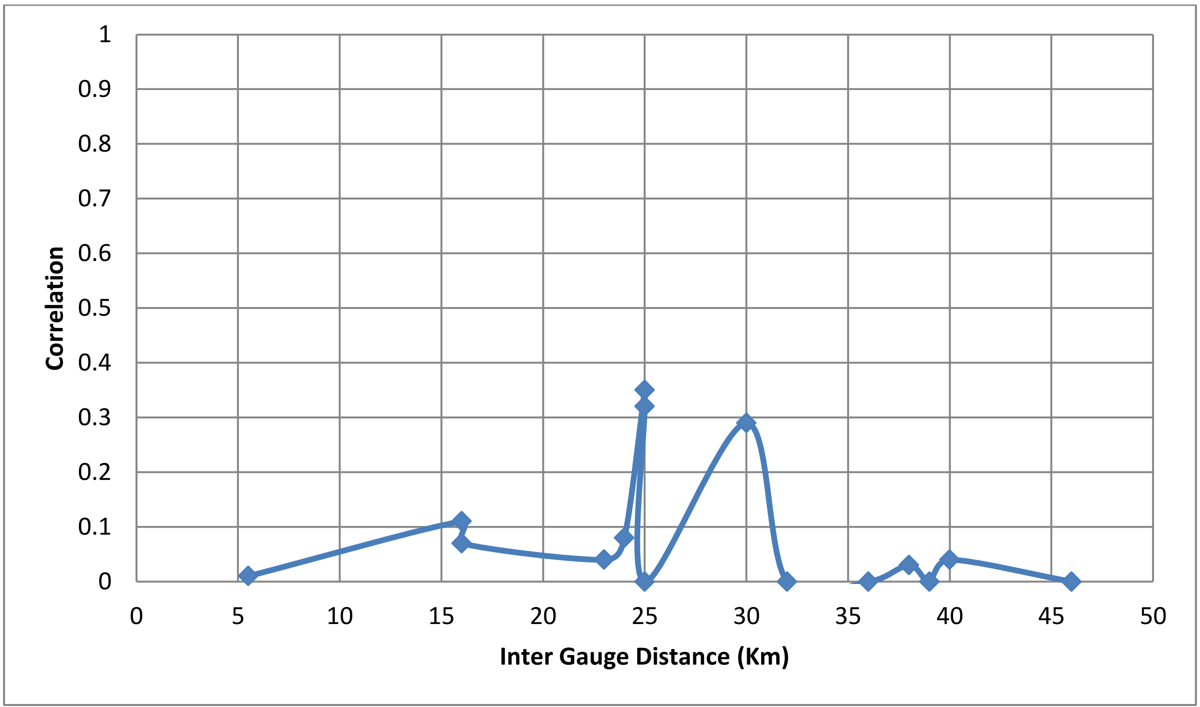

Figure 5: Relationship between inter-gauge distance (from Onamalutu) and correlation with annual maximum series of one-hour intensities.

2.2.2 Selected network review methodology - hydrologic regions

Toebes and Palmer (1969) developed the hydrologic regions of New Zealand for the purpose of identifying hydrologically similar regions to aid the collection of hydrology data in New Zealand. This resulted in the establishment of a network of representative basins at this time. Toebes and Palmer's classification is based upon: annual rainfall; geology (mainly permeability); and topography (mainly slope). These New Zealand regions have been used in recent years by NIWA scientists when completing flood frequency studies. The five regions in the MDC region were Blenheim, Blairich, Kaikoura Range, Spenser and Marlborough as shown in Figure 6.

Brin Williman (former MDC River Engineer) developed a mean annual flood predictor (coefficient to multiply the ungauged area to the power 0.8) for ungauged catchments from an analysis of measured flow records throughout Marlborough, Williman (2015). Williman defined a local set of hydrological similar catchments within Marlborough using storm rainfall and catchment slope, along with a set of additional variables defining catchment altitude and shape, storm duration and annual rainfall, and soil permeability and vegetation cover. These hydrologic subregions are shown in Figure 6. In this analysis, Wlliman divided the Wairau floodplain into two; Wairau FloodPlain Permeable and Wairau FloodPlain Drainage. For this study these two were combined. The Acheron-Mid Clarence region was added for completion, because for MDC engineers this it is not an operational flood issue.

The hydrologic subregions represent differing runoff relationships with rainfall throughout the region. They are therefore key for defining raingauge locations for storm flood forecasting and warning, as well as other end uses from long term monitoring.

This set of hydrologic subregions (Figure 6) adapted from Williman were then used to review the spatial coverage of MDC raingauge network.

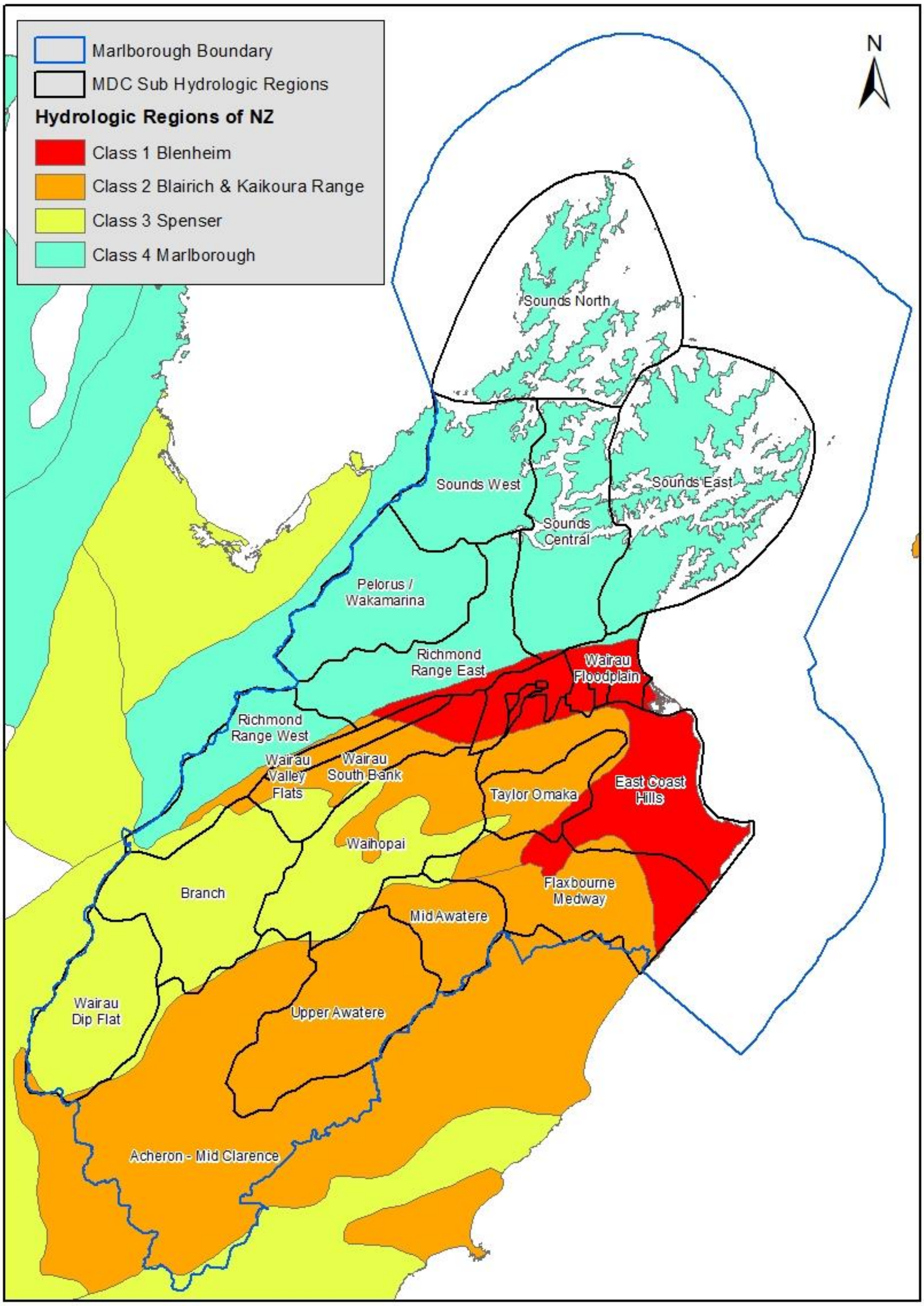

Figure 6: Hydrologic Regions of New Zealand and Williman Hydrologic Subregions

2.2.2.1 Long-term monitoring of water resources and climate

An important requirement for the review using different hydrologic regions is to ensure that areas of water resource and water demand are comprehensively covered. Also, the length of record is important for undertaking an assessment of climate trends. This is particularly important in a New Zealand context, as the climate experiences long-term fluctuations that respond to a range of decadal phenomena associated with the global circulation. In particular, the Interdecadal Pacific Oscillation (IPO) has periods longer than 30 years. There are 14 currently operating raingauges in the MDC network with records longer than 40 years, which is considered useful when observing climate trends within the global circulation oscillations.

The number of raingauges with records longer than 40 years will double if the recommendations of this report are implemented, along with a greater spatial coverage as a result of this review as detailed in Appendix 1 and described below:

- The only hydrologic region without 40 years of record is Wairau at Dip Flat (no current raingauges at all). This could be advanced by including all 38 years of Malings data, while outside this catchment there appears to be no other options.
- The Acheron-Mid Clarence longest currently recording site is the Upper Clarence (8 years). However, there is a reported 50 years at Tarndale, but only 10 years can be found on the Clidb database. Further searching for the remaining record is recommended. If found, then this site should be re-opened.
- For the Waihopai hydrologic region, it is recommended to re-establish the Spray Point gauge to enable a record length over 40 years. This could be resolved by supplying a manual gauge to the farmer.
- The Upper Awatere region has two records that exceed 60 years, one by combining the old Molesworth site data to the current one and, secondly, adding the Middlehurst active site to the network.
- An improved spatial coverage in the Flaxbourne – Medway region can be achieved by re-opening the historically long record site Aotea.
- For Richmond Range East region the current site Onamalutu at Bartletts Creek actually started in 1983, find the 1983 to 1988 daily data and add to the archive. Also obtain the currently operating site Fabians Valley G13556 (1948-current data) and add this site to the network.
- For Pelorus - Wakamarina there is an opportunity to include the Canvastown current site records since 1950 (72 years) to the MDC network.
- For Sounds-West, there is an opportunity to extend the current Rai Falls record (23 years) to 52 years by combining the historic Rai Falls (1970- 1991) manual data. Also, the spatial coverage would be improved with the inclusion of the currently operating site Okiwi Bay manual dailies since 1996. Obtain Rai Valley RAWS G13263 from 1996 – current and add this site to the real time network.

- For Sounds North, this hydrologic region only has one current site, Stephens Island with 17 years of data. This could be extended to 128 years by combining with the records starting in 1894. It is recommended that the current daily manual Maud Island rainfall site (started in 1992) be added to the MDC network.
- For Sounds Central, obtain the manual data for Koromiko G13391 (1944-1985), and add to the current site extending the record to 46 years.
- For Sounds East, this region's longest rainfall record, Brothers Island AWS, can be extended from 39 years to 141 years by obtaining the Brothers Island lighthouse data. Also, the old Keneperu Head site data can be combined with Keneperu Head NRFA to achieve 37 years of data.

It is possible most of the long-term historic site data discussed above are already on the MDC archive as closed sites.

An important requirement of rainfall data for long-term monitoring is continuity of record. The automatic raingauges may have missing records for a number of reasons. Validation with check gauges is important to identify when issues arise. These may result in periods of missing record or substandard record. However, this can be alleviated by having manually read gauges in the vicinity, thus allowing the collection of continuous record required for climate assessment.

Many of the long term monitoring sites identified here are automatic and telemetered and are also used for storm tracking and storm total analysis described in the next section.

2.2.2.2 Storm track and storm total analysis

Analysis and reporting of severe storms is key function of MDC. Flooding can occur in all hydrologic regions and real time data can appear to be sparse when attempting to report on flooding, especially when required to determine the return periods of rainfall totals that occurred. At these times daily rainfall totals can be disaggregated for storm extent studies.

Figure 7 displays the current open MDC raingauge network positioned over the hydrologic subregion available for storm analysis. Sites indicated by blue dots provide real time rainfall measurements. New sites and additional available sites are detailed in Appendix 1.

- A gap is evident in the Wairau at Dip Flat subregion where there is no recording raingauge and re-establishment of a recording raingauge at the NIWA flow station is recommended.
- With the sparse gaps apparent at Wairau at Dip Flat and neighbouring Acheron – Mid Clarence, it is recommended that an historic site at Tarndale be re-opened, as a telemetered automatic site.
- When storm tracking, excellent use of existing telemetered raingauges from neighbouring authorities occurs (Tasman District Council, Environment Canterbury

and the National Rural fire Authority). It is recommended that the ECan site at

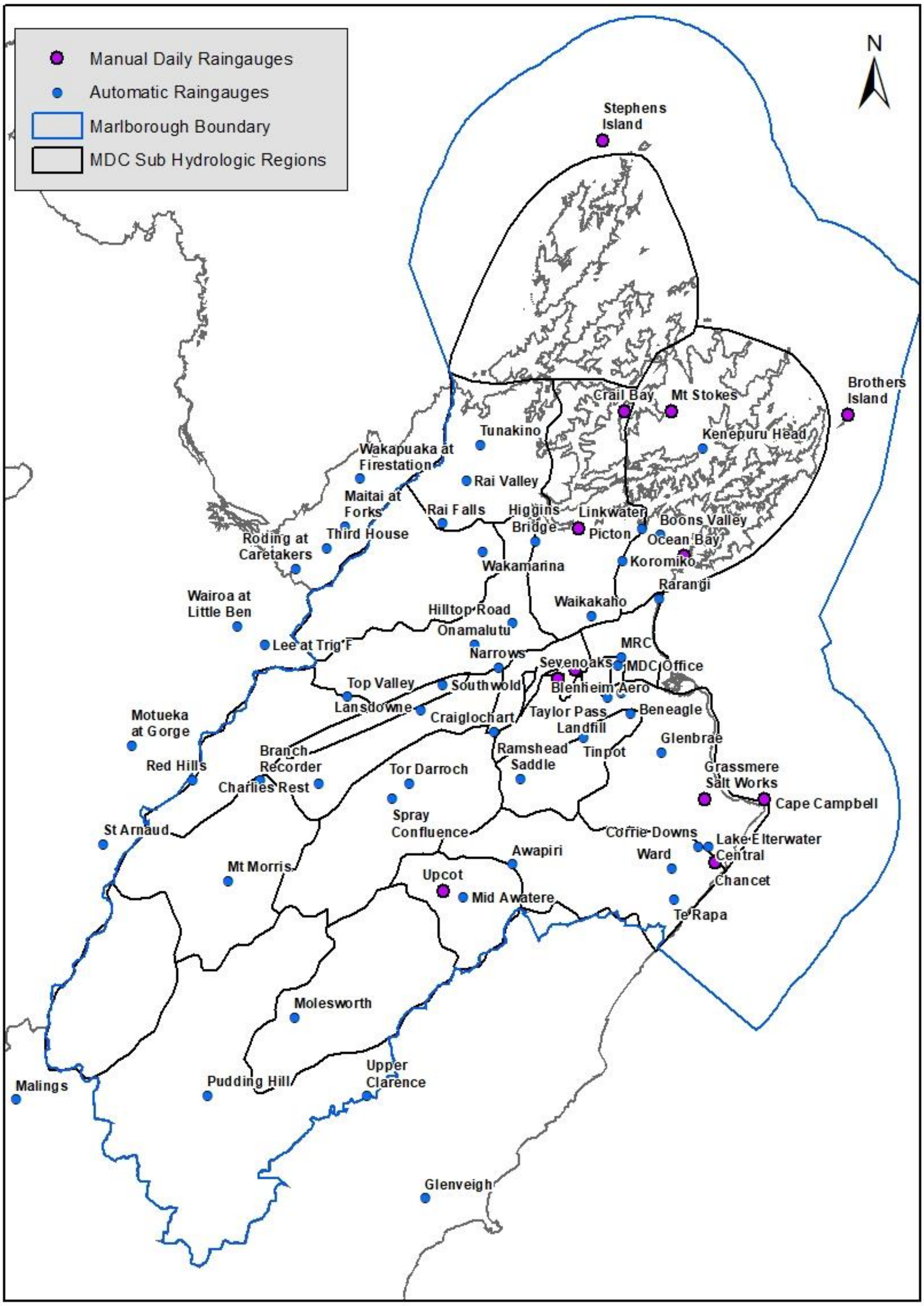

Figure 7: MDC current raingauge network and hydrologic subregions

Shingle Fans be added to the network to receive data for tracking southerly, south-east, and easterly events on the east coast.

- A gap is apparent in the Upper Pelorus catchment as it is exposed to north-west storms over the Bryant Range. Additionally, if the Wakamarina at Twin Falls were to fail then the only north-west storm information would be dependent upon TDC raingauges. To this end a second site is required. Either re-open Oakleys site or install a new site in the Upper Pelorus catchment to be serviced by helicopter.
- Gaps are apparent in the Sounds West subregion. It is recommended that re-opening of the ex-NIWA raingauge site at Penzance which recorded from 1992 to 2012 be considered. Also, the Rai Valley RAWS site, operating since 1996, is worth considering for live feed of this data.
- There is no automatic raingauge in the Sounds North region. To that end it is recommended a telemetered site be installed at Waitata Bay, and daily manual records be obtained for 1916-1967 for this location (which is also useful for long term monitoring analysis).
- With the absence of any upwind warning information from the east for Sounds East hydrologic subregion, it is recommended that the Makara Hill at Quartz Hill Wind Farm Greater Wellington Regional Council telemetered site be added to the network.

2.2.2.3 Design statistics for storm issues

Rainfall design statistics for rainfall-runoff calculations are made from data from closed as well as current raingauges. With a continuous need to place recent events into a historical context, automatic and manual raingauges are required to be continuous and be measured in perpetuity. Gaps in automatic gauges have already been discussed in Section 2.2.2.1 . A site of possible redundancy is the Wairau at Narrows which is in close proximity to the Wairau Valley at Southwold site.

2.2.3 Recommended raingauge network

The criteria in Table 1 were applied to the hydrologic subregions to review the spatial raingauge network. The recommended network (Appendix 1) includes the current network, historical sites and new sites for filling spatial gaps, and other agency telemetered locations useful for upwind storm tracking and warning. Additions and any redundancy are summarised in Table 2.

Hydrologic subregion	Purpose	Type	Recommendation	Requirement
Waihopai	LTM	M	Re-establish Spray Point G13741 (obtain previous 1941-1989 data)	Re-establish site
Wairau South Branch	LTM STM	A	Narrows is a redundant site, in close proximity to Southwold	Close site
Upper Awatere	LTM	M	Obtain and combine Molesworth G23021 with NRFA site as in very close poximity.	Obtain data
	LTM	M	Obtain currently operating site Middlehurst G13941 (1949- current) data, and add to network.	Add existing site
Mid Awatere	Flood warning	A	Obtain Shingle Fans data from Ecan and add site to the network	Obtain real time data
Flaxbourne - Medway	LTM	M	Re-open G13782 Aotea (manual or telemetered), obtain data	Re-establish site
	Flood warning	A	Obtain Shingle Fans data from Ecan and add site to the network	Obtain real time data
Wairau Dip Flat	LTM	A	Obtain Malings earlier data (1984-2017)	Obtain data
	STM	A	Re-establish Dip Flat rain gauge at NIWA site. Obtain (1988-1994) data	Re-establish site
Acheron - Mid Clarence	LTM STM	A/M	Re-open G22191 Tarndale, obtain data (1944-1954) from Clidb search for 1954-1993	Re-establish site
Richmond Range East	LTM	A	Onamalutu at Bartletts Ck Saddle started 1983, find 1983-1988 daily data.	Obtain data
	LTM	M	Obtain Fabians Valley G13556 data (1948-2011), re-establish site	Re-establish site
Pelorus Wakamarina	LTM	M	Obtain Canvastown 1950-2005 data G13363 and re-establish site (may need to combine with G13262 data)	Re-establish site
	STM	A	Pelorus catchment has no rain gauge if Wakamarina fails. Renew site at 131516 Oakleys (1987-1996) or install new site in upper Pelorus (Helicopter)	New site
Sounds West	LTM	M	Obtain Rai Falls site data 132539 (1970 - 1999) and add to current site	Obtain data
	LTM	M	Obtain Okiwi Bay G13162 from 1996-2014 data, re-establish site.	Re-establish site
	STM	A	Penzance closed by NIWA 2012 (1992-2012); obtain data, re-establish new site at this location	Re-establish site
Sounds North	LTM	M	Obtain Stephens Island G04601 data from 1894, add to current site	Obtain data
	LTM	M	Obtain Maud Island G13083 (1997- current); add to network	Add existing site
	STM	A	New telemetered site at Waitata Bay G03991; (1916-1967 manual), or Saddle Hill N00396 (1989-2012 auto), or Bulwer (1993-2012 Auto)	Re-establish site
Sounds Central	LTM	M	Obtain data for Koromiko G13391 (1944-1985); add to current site	Obtain data
Sounds East	LTM		Obtain Brothers Island Lighthouse data G14141 started 1881; add to current site	Obtain data
	LTM	M	Obtain Keneperu Head O00829 data, from 1985; add to current site	Obtain data
	Flood warning	A	Add Makara Hill at Quartz Hill Wind Farm GWRC to the network	Obtain real time data

Table 2: Recommended additional raingauge network and site redundancy.

2.2.4 Discussion with MDC staff

From discussions with MDC staff (Charlotte Tomlinson, Geoff Dick, Andy White, Emma Chibnall, and Mark Caldwell) during a meeting on 10 February, and later comments from Mike Ede, Val Wadsworth and Duc Nguyen. Two themes were clear as to why rainfall is recorded in the Marlborough region. Firstly, the variability of rain across the region on a storm basis in the form of storm tracking, providing flood warning and rainfall totals. Secondly all manually read and automatic gauges in the region were regarded as baseline stations for assessment of long-term trends in climate and water resources.

The recommendations in Table 2 were the focus of the discussion. MDC hydrologists preferred that sites which were previously manual daily rain gauges, and had been closed, should ideally be re-established as an automatic telemetered site. This provides instantaneous rainfall intensity information and better data security than relying on external parties to read and send in data periodically.

Along the same lines, Val Wadsworth (MDC consultant hydrologist) indicated his concern that long-term manual daily total sites still operating (often with long term records), may be lost in the future with changes in land ownership. Val's recommendation in these cases was to liaise with landowners and encourage a telemetered rain gauge to be installed alongside their manual gauge and collect an overlapping record for at least two years, before transitioning to a fully automatic rain gauge + storage gauge maintained by MDC.

This is a responsible approach, as in the past it was the MetService and NIWA that received the manually recorded data and had an overview of the national rain gauge network. This is no longer managed robustly, especially when issues arise such as a farm ownership changes. Today it is the local authorities who oversee New Zealand's rainfall gauge network collectively, and forms part of the reason for this review. Long term manually read rain gauges of concern to MDC are:

- Crail Bay
- Linkwater
- Ocean Bay
- Chancet
- Grassmere Saltworks
- Sevenoaks
- Upcot
- Middlehurst

The Rivers Department staff agreed that a new site in the Pelorus Catchment would be useful for flood warning and flood protection design in the future, as farmers occupy the highly productive floodplain land and are very interested in flood warning for the movement of stock to higher ground.

The Rivers Department staff had also observed a gap in rainfall knowledge in the Upper Wairau and supported a site around Dip Flat. They supported the removal of the Narrows rain gauge due to its close proximity to Southwold, but the Narrows water level site provides key information during floods and is to be retained.

A later comment from Duc Nguyen (Rivers Engineer) regarding the Wairau Flood Plain identified the closure of the O'Dwyers FENZ site left a gap ideally requiring two new sites; Renwick Fire Station or Blenheim Aero (G13585 1990 – current, telemetered site within this enclosure may suffice) and Marshlands (G14401 1917-1988) Spring Creek (Grovetown G13493 1894-1907 and Grovetown 2 1953 – 1989), or O'Dwyers Road, as operated by FENZ until August 2022 Information provided in brackets are historic records available in Clidb to provide to assistance with site selection.

Duc Nguyen also supported a telemetered site at Tarndale as a useful location, especially for the Upper Wairau flood warning. A new site in the Richmond Range West region located in the upper Boulder Stream Catchment was a high priority for flood warning. He also agreed with the need for a new site located in Fabians Valley in the Richmond Range East region. Duc did not see the need for the Canvastown site being re-opened, however along with Charlotte believes the historic data should be on the MDC archive.

For the Waihopai River, a need for an upper catchment rain gauge was signalled. During the review it had been considered that Mt Morris could provide useful information due its high altitude location in the neighbouring Branch catchment. In the East Coast Hill region, Duc also recommended a site mid-way between the currently operating sites Awapiri and Glenbrae. To that end, the Aotea site displayed in Table 2 is located approximately mid-way between these two sites. For the Upper Awatere and Marlborough Sounds no further flood warning sites are required in his view.

Mike Ede pointed out that about ¼ of rainfall sites in the region are operated by FENZ, and although operated for fire risk are also useful to MDC as their locations complement and fill gaps in the council rain gauge network. This introduces challenges however, as rainfall sites should ideally be run in perpetuity, whereas FENZ regularly close, open, and move their rainfall monitoring sites to fit their specific operational requirements. This impacts the quality of data, especially if these sites were to be used for long-term climate analysis in the future. Mike's suggestion is to connect with local FENZ staff to become aware of any changes to their network, and request maintenance records so that data quality can be assessed by MDC staff. A further suggestion is perhaps to install storage gauges at some key FENZ sites to improve the data quality for long-term climate monitoring.

An important point raised by Charlotte Tomlinson is that there are several rainfall sites in the Marlborough Sounds operated by the marine industry. However, because these data are collected and funded privately, there is likely a cost to obtain this information. These sites could be of interest if they are located near those closed by NIWA which had recorded over 20 years of useful record. These sites are identified in Table 2.

Acknowledgement

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Appendix 1.

Network review

Hydrologic subregion	Existing raingauge	Length of record (years)	Type	Comment
East Coast Hills				
LTM	Cape Campbell	35	M	
LTM	Chancet	110	M	Record length to identify climate cycles
LTM	Salt Works	78	M	Record length to identify climate cycles
STM	Lake Elterwater Central	1	A	QA using Ward
STM	Glenbrae NRFA	9	A	
STM	Taylor Pass Landfill	16	A	Flood warning for Blenheim, QA using Wither Hills
STM	Wither Hills	0.5	A	Flood warning for Blenheim, QA using Taylor Pass
Upwind warning	Ward, Glenbrae NRFA		A	Sufficient current sites
Wairau flood plain				
LTM	Bleheim Aero	31	M	
LTM	Sevenoaks	120	M	Record length to identify climate cycles
STM	MDC Office	30	A	QA using MRC
STM	MRC	32	A	
STM	Rarangi	12	A	QA using MRC
Upwind/upsteam warning	multiple upwind/upstream sites		A	Sufficient current sites
Wairau Valley Flats				
LTM	Southwold	105	M	Record length to identify climate cycles
STM	Southwold (since 2018)	4	A	QA using Lansdowe
Upwind/upsteam warning	multiple up wind/upstream sites		A	Sufficient current sites
Taylor – Omaka				
LTM	Tinpot	59	A	Record length to identify climate cycles. QA using Beneagle
LTM	Beneagle (combined)	46	A	Record length to identify climate cycles. QA using Tinpot
STM	Beneagle	7	A	QA using Wither Hills
STM	Ramshead Saddle	32	A	QA using Tinpot
Upwind/upsteam warning	Ramshead Saddle for Omaka River		A	Sufficient current sites
	Tinpot for Taylor River		A	Sufficient current sites
Waihopai				
LTM	Spray Point	48	M	Re-establish Spray Point G13741 (obtain previous 1941-1989)
STM	Craiglochart	24	A	QA using Ramshead saddle
STM	Tor Darroch NRFA	8	A	
STM	Spray Confluence	24	A	QA using Tor Darroch
Upwind warning	Mt Morris, Charlies Rest	A	A	Mt Morris good recent addition as upper half of catchment has no raingauge

Hydrologic subregion		Existing RG	Length of record (years)	Type	Comment
Wairau South Branch					
	LTM	Charlies Rest	52	A	Record length to identify climate cycles. QA using Branch Recorder.
	STM	Narrows	26	A	QA with Southwold. Redundant site, close proximity to Southwold
	STM	Lansdowne NRFA	9	A	
	Upwind warning	Top valley, Charlies Rest, Branch		A	Sufficient current sites
Upper Awatere					
	LTM	Molesworth G23021	67	M/A	Obtain and combine Molesworth G23021 with NRFA site as in very close 21roximity.
	LTM	Middlehurst G13941	73	M	Obtain this currently operating site data and add to network
	STM	Molesworth NRFA	11	A	
	Upwind warning	Pudding Hill, Upper Clarence		A	Sufficient current sites
Mid Awatere					
	LTM	Upcot	91	M	Record length to identify climate cycles
	STM	Mid Awatere Valley NRFA	5	A	
	Upwind warning	Te Papa, Upper Clarence NRFA, Molesworth NRFA, Glenveigh NRFA, Shingle Fans Ecan		A	Obtain Shingle Fans data from Ecan
Flaxbourne – Medway					
	LTM	Awapiri	41	A	Record length to identify climate cycles. QA using Aotea or Mid Awatere
	LTM	Aotea	53	M	Re-open G13782 Aotea, obtain data
	STM	Te Rapa	14	A	QA using Ward
	STM	Ward NRFA	8	A	
	STM	Corrie Downs	16	A	QA using Lake Elterwater
	Upwind warning	Te Rapa, Mid Awatere Valley, Lake Elterwater, Shingle Fans Ecan		A	Obtain Shingle Fans data from Ecan
Wairau Dip Flat					
	LTM	Malings	38	A	Obtain earlier data (1984-2017)
	STM	Dip Flat	6	A	Re-establish Dip Flat NIWA site. Obtain (1988-1994) data
	Upwind warning	Malings Ecan, St Arnaud NRFA		A	Sufficient current sites
Branch					
	LTM	Branch recorder	48	A	Record length to identify climate cycles
	STM	Mt Morris	1	A	QA using Branch recorder
	STM	Branch recorder	48	A	QA using Mt Morris
	Upwind warning	St Arnaud NRFA, Red Hills		A	Sufficient current sites

Hydrologic subregion		Existing RG	Length of record (years)	Type	Comment
Acheron – Mid Clarence					
	LTM	Tarndale	50	M	Re-open G22191 Tarndale, obtain data (1944-1954)
	STM	Pudding Hill NRFA	4	A	
	STM	Upper Clarence NRFA	8	A	
	Upwind warning	Upper Clarence NRFA, Glenveigh, Malings, Mt Morris		A	Sufficient current sites
Richmond Range West					
	LTM	Top Valley	37	A	QA using Lee Trig F
	LTM	Red Hills	17	A	QA using Motueka Gorge
	Upwind warning	Motueka Gorge, Lee Trig F, Wairoa at Little Ben			Sufficient current sites
Richmond Range East					
	LTM	Onamalutu at Bartletts Ck saddle	39	A/M	Started 1983 find 1983-1988 daily data. QA using Hilltop Rd
	LTM	Fabians Valley	63	M	Obtain Fabians Valley G13556 (1948-2011) Re-open
	STM	Hilltop Rd NRFA	13	A	
	Upwind warning	Wakamarina, Top Valley		A	Sufficient current sites
Pelorus Wakamarina					
	LTM	Canvastown	55	M	Obtain Canvastown 1950-2005 G13363 (may need to combine with G13262) Re-open
	STM	Wakamarina	31	A	No back up raingauge if down?
	STM	New site			renew site at 131516 Oakleys (1987-1996) or new site in upper Pelorus (Helicopter)
	Upwind warning	Rai Falls, Third House, Matai Forks, Roding at Care Takers		A	Sufficient current sites
Sounds West					
	LTM	Rai Falls	52	A/M	Obtain Rai Falls 132539 add (1970 – 1999)
	LTM	Okiwi Bay	18	M	Obtain Okiwi Bay G13162 from 1996-2014, Re-open
	LTM	Tunakino	43	A	QA using Rai Valley
	STM	Rai Valley NRFA	9	A	Obtain early data from Rai Valley RAWS
	STM	Penzance	20	A	Closed by NIWA 2012 (1992-2012), obtain data, new site at this location
	Upwind warning	Wakapuaka at Fire station		A	Sufficient current sites

Hydrologic subregion		Existing RG	Length of record (years)	Type	Comment
Sounds North					
	LTM	Stephens Island AWS	128	M	Obtain Stephens Island G04601 from 1894, then total 128 years
	LTM	Maud Island	25	M	Obtain Maud Island G13083 (1997- current) add to network
	STM	Waitata Bay or Saddle Hill or Bulwer	51	A	New telemetered site at Waitata Bay G03991, (1916-1967 manual) or Saddle Hill N00396 (1989-2012 Auto) or Bulwer N00401 (1993-2012 Auto)
	Upwind warning	Nil			
Sounds Central					
	LTM	Crail Bay	40	M	Record length to identify climate cycles
	LTM	Linkwater	84	M	Record length to identify climate cycles
	STM	Koromiko NRFA	46	A/M	Obtain data for Koromiko G13391 (1944-1985), total then 46 y.
	STM	Waikakaho	12	A	QA using Koromiko
	STM	Higgins Bge	16	A	QA using Wakamarina
	STM	Picton	4	A	QA using koromiko
	Upwind warning	Tunakina, Rai Valley, Wakamarina			Sufficient current sites
Sounds East					
	LTM	Brothers Island AWS	141	M	Obtain Light house data G14141 started 1881
	LTM	Mt Stokes	14	M	
	LTM	Ocean Bay	97	M	
	STM	Keneperu Head NRFA	37	A	Obtain Keneperu Head O00829 data, from 1985 total then 37 years
	STM	Boons Valley	28	A	QA using Picton
	Upwind warning	NW Higgins Bge, SW Waikakaho, East Makara Hill at Quartz Hill Wind Farm GWRC			Add Makara Hill at Quartz Hill Wind Farm GWRC to the network

LTM	Long term monitoring of water resources and climate
STM	Storm track and storm total
QA	Quality Assurance