

Marlborough Flood Event August 2022





Marlborough Flood Event Report, 16-20 August 2022

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Executive Summary

August saw a slow-moving weather system bring huge quantities of rain from the tropics to northern Marlborough and the top of the south at large over a five-day period from the 16 to 20 August.

Rainfall over winter had been high, with most rainfall monitoring sites in the region recording about twice the average monthly rainfall in July. This meant the Marlborough region was particularly susceptible to the effects of a significant rain event. Soils throughout Marlborough were at field capacity, with soils in Northern Marlborough and the Sounds in a moisture surplus.

There was good warning prior to the rainfall event, with MetService issuing a severe weather outlook on Friday August 12th, four days before the event began. A Heavy Rain Watch was issued on Sunday 14 August for the Marlborough Sounds and Richmond Range, including the Rai Valley. This was upgraded to an Orange Heavy Rain Warning on Monday 15 August.

The event was split into three distinct bands of rain. From 16 August to early on 19 August (Tuesday to Friday morning), two bands of rain were concentrated over northern Marlborough, with high rainfall in Rai Valley, the Marlborough Sounds, and the Richmond and Bryant Ranges. The third band of rain moved further south and led to a wider distribution of heavy rainfall, encompassing the Wairau catchment in addition to northern Marlborough.

Over the five-day event, the Tunakino raingauge was found to have the greatest rainfall significance of any rainfall monitoring site in the top of the south, with 5.2 times more rainfall falling over five days than in an average month.

The three bands of rain led to a unique three-peaked flood event in the Pelorus/Te Hoiere and Rai Rivers. The Pelorus River/Te Hoiere upstream of State Highway 6 bridge had peak flow of 1,700 m³/s, the fourth largest flood since 1977.

The long duration of high intensity rainfall is what made this event unique:

The first time 1000 mm of rain was exceeded in one storm event (1,126 mm recorded at Tunakino rain gauge).

The largest flood in the Rai River on record, with a 60-year return period.

The third largest flood in the Wairau River recorded at the Tuamarina monitoring station.

Widespread landslips leading to road closures, surface flooding and damage to property.

A new rainfall runoff flood model set up by the rivers department was able to estimate peak flow in the Wairau River to within 12%. This model is a significant improvement to the previous flood model used in the July 2021 event, and it's use in other catchments is being investigated.

Table of Contents

Executive Summary	i
1. Weather.....	1
1.1. Winter Rainfall.....	1
1.2. Soil Moisture	1
1.3. River Flows.....	2
1.4. Snow Accumulation	3
1.5. Weather Situation	4
1.6. MetService Alerts.....	5
2. Rainfall.....	6
2.1. Regional Rainfall Distribution & Significance	6
3. Te Hoiere Catchment	10
3.1. Rainfall.....	10
3.2. River Flows.....	11
4. Wairau Catchment	13
4.1. Rainfall.....	13
4.2. River Flows.....	14
4.3. Comparison to July 2021 Flood	15
4.4. Modelled River Flow	17

Table of Figures

Figure 1: Combined 2022 rainfall from all monitoring sites in Marlborough, compared to monthly average rainfall.	1
Figure 2 Soil moisture deficit map of New Zealand, retrieved from NIWA 08/08/2022. The lefthand image shows the historical average deficit for this date, the central image shows the soil deficit on this date in 2021, and the right-hand image shows the soil moisture deficit as of 08/08/2022.....	2
Figure 3 Snow accumulation of approximately 1 metre at Mount Morris (1,550 m elevation), 4 August 2022. Photo courtesy of John Sutherland.....	3
Figure 4 MetService 12pm surface pressure maps, Monday 15 August to Saturday 20 August.....	4
Figure 5 MetService severe weather outlook maps. The map on the left was issued on Friday 12 August, while the map on the right was issued on Sunday 14 August.	5
Figure 6 MetService gauge-corrected rainfall radar imagery, 16 August 2022 at 12:00 to 20 August at 23:00	7
Figure 7 MetService gauge-corrected rainfall radar imagery, showing the rainfall distribution over Marlborough for the three bands of rain 16-20 August.	8
Figure 8 Tasman and Marlborough rainfall significance for 16-20 August 2022. This map was produced by the Tasman District Council Hydrology team.....	9
Figure 9 Northern Marlborough rainfall monitoring sites.....	10
Figure 10 River Flow sites in the Te Hoiere catchment.	11
Figure 11 Rai River at Rai Falls flow and hourly rainfall totals, from 16-21 August 2022.	12
Figure 12 Rai River at Rai Falls flow and hourly rainfall totals, from 16-21 August 2022.	13
Figure 13 Wairau catchment river monitoring sites.....	14
Figure 14 Wairau River at Tuamarina flow, from 16-21 August.....	15
Figure 15 Wairau River at Tuamarina flow, from 16-19 July 2021.	16

Table of Tables

Table 1: <i>July 2022 River flow statistics for major rivers in Marlborough</i>	3
Table 2 Rainfall totals for Northern Marlborough from the 16-20 August, and the Average Recurrence Interval (ARI) of the 5-day event.....	10
Table 3 Flood peaks for river flow sites in the Te Hoiere catchment, along with average return intervals for the largest flood peaks.	12
Table 4 Rainfall totals for the Wairau Catchment from the 16-20 August, and the Average Recurrence Interval (ARI) of the 5-day rainfall event.	14
Table 5 Flood peaks and timing for river flow sites in the Wairau catchment, along with average return intervals (ARI).	15
Table 6 Flood statistics for the Wairau Catchment, July 2021, and August 2022.	16

1. Weather

Prior to the August 2022 storm event, there were several contributing factors that left Marlborough particularly vulnerable to any broad scale, intense rainfall event.

1.1. Winter Rainfall

June and July 2022, total rainfall recorded in Marlborough was much higher than average throughout. Blenheim itself recorded the wettest month on record in July 2022, with most rainfall monitoring sites throughout the region recording close to twice their average monthly rainfall in July.

Looking at the combined rainfall from all rainfall monitoring sites in Marlborough (Figure 1), June rainfall was 184% of the long-term average, while in July 277% of average monthly rainfall was recorded.

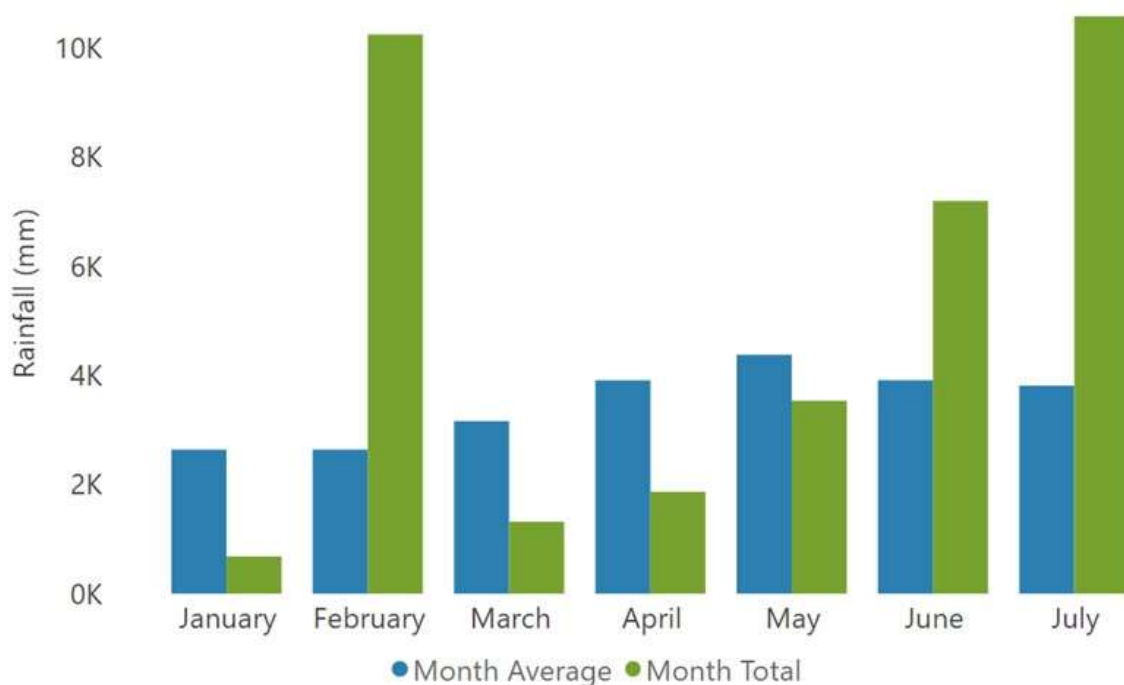


Figure 1: Combined 2022 rainfall from all monitoring sites in Marlborough, compared to monthly average rainfall.

Rainfall sites in the Te Hoiere Catchment experienced very high rainfall totals in June and July prior to the August flooding. The Wakamarina and Rai rain gauges recorded about twice as much rainfall in June and July than average, while the Tunakino rain gauge recorded 150% of average June rainfall, and 200% of average July rainfall.

1.2. Soil Moisture

Following on from the high rainfall totals in June and July, the soil moisture deficit map below (Figure 2) shows that soils throughout the region were at field capacity in the first week of August, with soils in Northern Marlborough (including the Te Hoiere and Tōtaranui Sounds) in a water surplus.

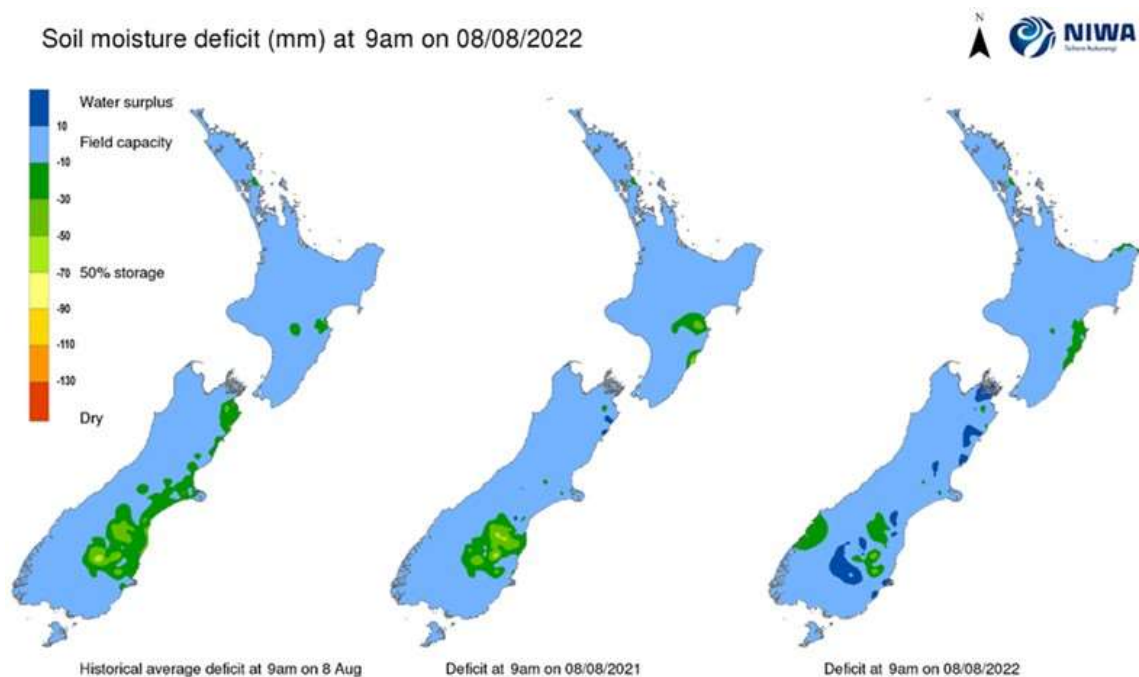


Figure 2 Soil moisture deficit map of New Zealand, retrieved from NIWA 08/08/2022. The lefthand image shows the historical average deficit for this date, the central image shows the soil deficit on this date in 2021, and the right-hand image shows the soil moisture deficit as of 08/08/2022

1.3. River Flows

The high flows in rivers around Marlborough were also a factor leading up to the flooding in mid-August. At the end of July, rivers in the region had much higher-than-average flow for the time of year, reflecting the high rainfall totals seen that month.

In Table 1 below it can be seen that rivers in Northern Marlborough (the Pelorus, Rai, and Kaituna rivers) had flows of around 180% of their monthly averages for July.

Wairau River at Barnett's Bank (State Highway One) had an average flow of 285 m³/s in July, more than double the long-term average July flow of 125 m³/s.

The Branch and Waihopai rivers, both large south bank tributaries to the Wairau, had 176% and 251% of average July flow respectively.

Table 1: July 2022 River flow statistics for major rivers in Marlborough.

River	Site	July mean flow 2022 (m ³ /s)	July mean flow all records (m ³ /s)	% of monthly average	Records begin	Catchment area (km ²)
Pelorus	Bryants	46.75	26.48	177	1977	375
Rai	Rai Falls	27.06	15.41	176	1979	211
Kaituna	Higgins Bridge	12.29	6.69	184	2006	133
Branch	Intake Weir	40.65	23.12	176	1958	550
Wairau	Barnetts Bank	285.24	125.53	227	1960	3,430
Wairau	Dip Flat	49.76	23.03	216	1951	505
Onhinemahuta	Domain	3.92	1.46	268	1998	33
Waihopai	Craiglochart	48.05	19.17	251	1960	764
Awatere	Awapiri	34.96	18.78	186	1977	987
Omaka	Gorge	4.95	2.36	210	1994	90
Taylor	Borough Weir	4.08	1.55	263	1961	64
Flaxbourne	Corrie Downs	6.49	1.39	467	2003	70

1.4. Snow Accumulation

Another factor in the lead up to the flood event was the accumulation of snow in mountainous areas around the region. By the beginning of August there was considerable snowpack in the upper Wairau Catchment, as can be seen in the photo below (Figure 3). This image was taken on 4 August at the rain gauge site on Mount Morris (1,550 m elevation) with over one metre of snow accumulated.



Figure 3 Snow accumulation of approximately 1 metre at Mount Morris (1,550 m elevation), 4 August 2022. Photo courtesy of John Sutherland.

1.5. Weather Situation

On Tuesday 16 August, an anticyclone lay to the north-east of New Zealand, scooping up damp air from the tropics, while a low-pressure system lay over the Tasman Sea. This created a 'squash zone', a line of tight isobars between the low- and high-pressure systems, feeding large amounts of rain to the top of the South Island in what is known as an 'atmospheric river'. The high-pressure system to the north-east of the country was slow moving, blocking the low from moving through and leading to multiple days of heavy rainfall in Marlborough. The progression of this weather system can be seen below in daily surface pressure maps (Figure 4).

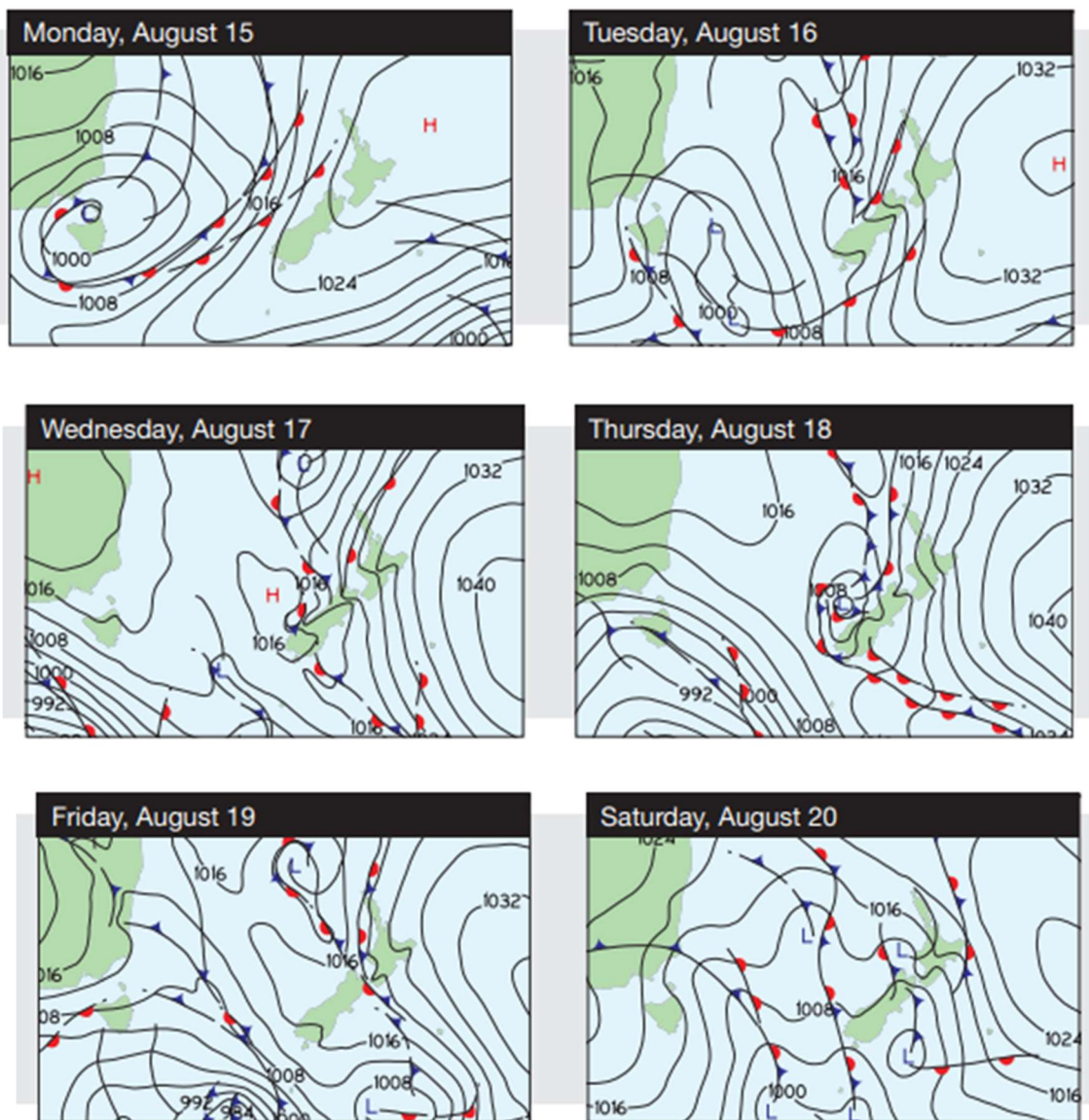


Figure 4 MetService 12pm surface pressure maps, Monday 15 August to Saturday 20 August.

Freezing levels were forecast to rise above 2,600m on the 16 August as the weather system moved in from the tropics and was forecast to continue rising in the following days. This meant that snowpack in high elevation areas was likely to melt and contribute to river flood peaks.

1.6. MetService Alerts

MetService first warned of heavy rainfall in Northern Marlborough on Friday 12 August, with a Severe Weather Outlook of moderate confidence for heavy rain on Tuesday 16 and Wednesday 17 August (see Figure 5). By Sunday the 14 August, the confidence was high for heavy rainfall from Tuesday - Thursday, with low confidence of heavy rainfall on Friday.

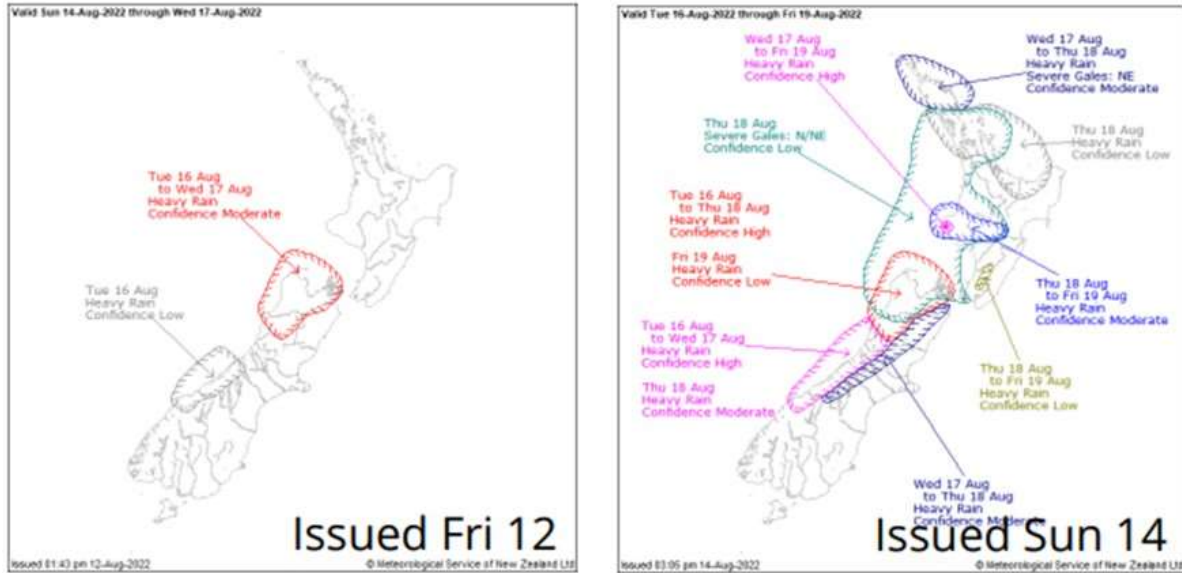


Figure 5 MetService severe weather outlook maps. The map on the left was issued on Friday 12 August, while the map on the right was issued on Sunday 14 August.

MetService first issued a Heavy Rain Watch on the morning of Sunday the 14 of August:

HEAVY RAIN WATCH

Period: 51 hours from 6.00 am Tuesday, 16 August – 9.00 am Thursday, 18 August.

Area: The Marlborough Sounds and Richmond Range, including the Rai Valley.

Forecast: Periods of heavy rain. Rainfall amounts may exceed warning criteria.

This was then upgraded on morning of Monday 15 August to an Orange Heavy Rain Warning, with minor alterations to the expected rainfall totals in the Monday evening update:

HEAVY RAIN WARNING - ORANGE

Period: 56 hours from 1.00 pm Tuesday, 16 August – 9.00 pm Thursday, 18 August.

Area: The Marlborough Sounds, Bryant and Richmond Ranges, including the Rai Valley.

Forecast: Periods of heavy rain. Expect 350 to 500 mm of rain to accumulate about the ranges, and 150 to 250 mm about the Sounds. Peak rates of 10-15 mm/hr about the ranges.

The timing of the beginning of the warning was changed on Tuesday morning, with rain forecast to begin later Tuesday night.

As the event progressed, a Red Heavy Rain Warning was issued for the Nelson Region on Wednesday 17 of August, while Marlborough remained at an Orange Heavy Rain Warning. At this point in time the Tunakino raingauge in Marlborough had recorded 318 mm of rain in less than 24 hours, with the forecast expecting a further 31 hours of heavy rainfall.

On Thursday morning, an additional Orange Heavy Rain Warning was issued for the same area for 24 hours from midday Friday to midday Saturday. The forecast was for an additional 140-190 mm about the ranges, and 70-110 mm elsewhere.

There are a few points to note about the issuing of warnings issued throughout this event. Firstly, MetService have only been issuing red weather warnings since May 2019, and in that time, there have been eight red warnings issued (seven rain and one wind). Met Service have acknowledged that the Marlborough rainfall in August was a 'missed' red warning event and that is how it should have been classified.

The second point to note is that the long duration of this rain event was highly unusual. Rain watches are usually issued for rain beginning the day after tomorrow, while rain warnings are usually issued for rain beginning tomorrow. The last band of rain on Friday 19 and Saturday 20 would usually have been issued as a Heavy Rain Watch on the Wednesday, if it was a stand-alone event. However, this was overshadowed by the rain from the 16-18, which meant the first severe weather statement issued for Friday was an Orange Heavy Rain Watch on the Thursday morning. This meant there was less notice of the magnitude of this last rain band than is ideal.

This weather event provided an opportunity for relationship building between MetService, Emergency Management, and Council staff. The few issues that arose because of the drawn-out nature of this event have led to meaningful discussion of the severe weather alert system and improvements to this system.

2. Rainfall

2.1. Regional Rainfall Distribution & Significance

The total duration of the rainfall event was five days, from Tuesday the 16 to Saturday the 20 of August. The Met Service rain radar data has been corrected to the MDC raingauge data and is displayed below in **Error! Reference source not found.** It shows the largest amounts of rainfall were seen on the Bryant and Richmond Ranges, in the Rai Valley area, and in higher elevation areas on the south bank of the Wairau River.

The rainfall can also be split up into three distinct bands of rain (see Figure 7), the first of which fell from midday on 16 August to midnight on the 17 August. The heaviest rain during this time was concentrated on Northern Marlborough, including the Rai, Ronga, Tunakino, and Opouri Valleys, as well as Tennyson Inlet and Okiwi Bay.

The second band of rain fell throughout the 18 of August and into the early morning on the 19 August. Again, this rainfall was concentrated on Northern Marlborough, showing how the high to the north-east of the country was blocking the low-pressure system from making any significant progress across the region. Looking at the central map in Figure 7 below, the Kenepuru/Mount Stokes area also received some of the heaviest rainfall during this rain band.

In Northern Marlborough, the first band of rain had the largest rainfall totals, and highest hourly rainfall intensities, with the subsequent bands of rain recording slightly less rainfall with reduced hourly intensities. An example of this can be seen in Figure 11, where the rainfall at the Rai Falls site is

plotted as hourly totals. Maximum rainfall intensity at this site was 24 mm/hr in the first band of rain, 18.5 mm/hr in the second band, and 16.5 mm/hr in the third band of rain.

During the first two bands of rain the predominant wind direction was north-east, which meant the Wairau catchment received less rain than originally forecasted. However, the final band of rain from 6.00 am on the 19 of August through to midnight on the 20 August came with a slight change in wind direction, moving to a true north/slight north-west flow. This resulted in a wider distribution of heavy rainfall, including the south bank of the Wairau with 8 - 10 hours of high-intensity rainfall in the upper Branch and Waihopai catchments. This led to a much larger flood peak in the Wairau than was seen from the first two bands of rain, as both the north and south bank tributaries were contributing significantly to the Wairau River flow.

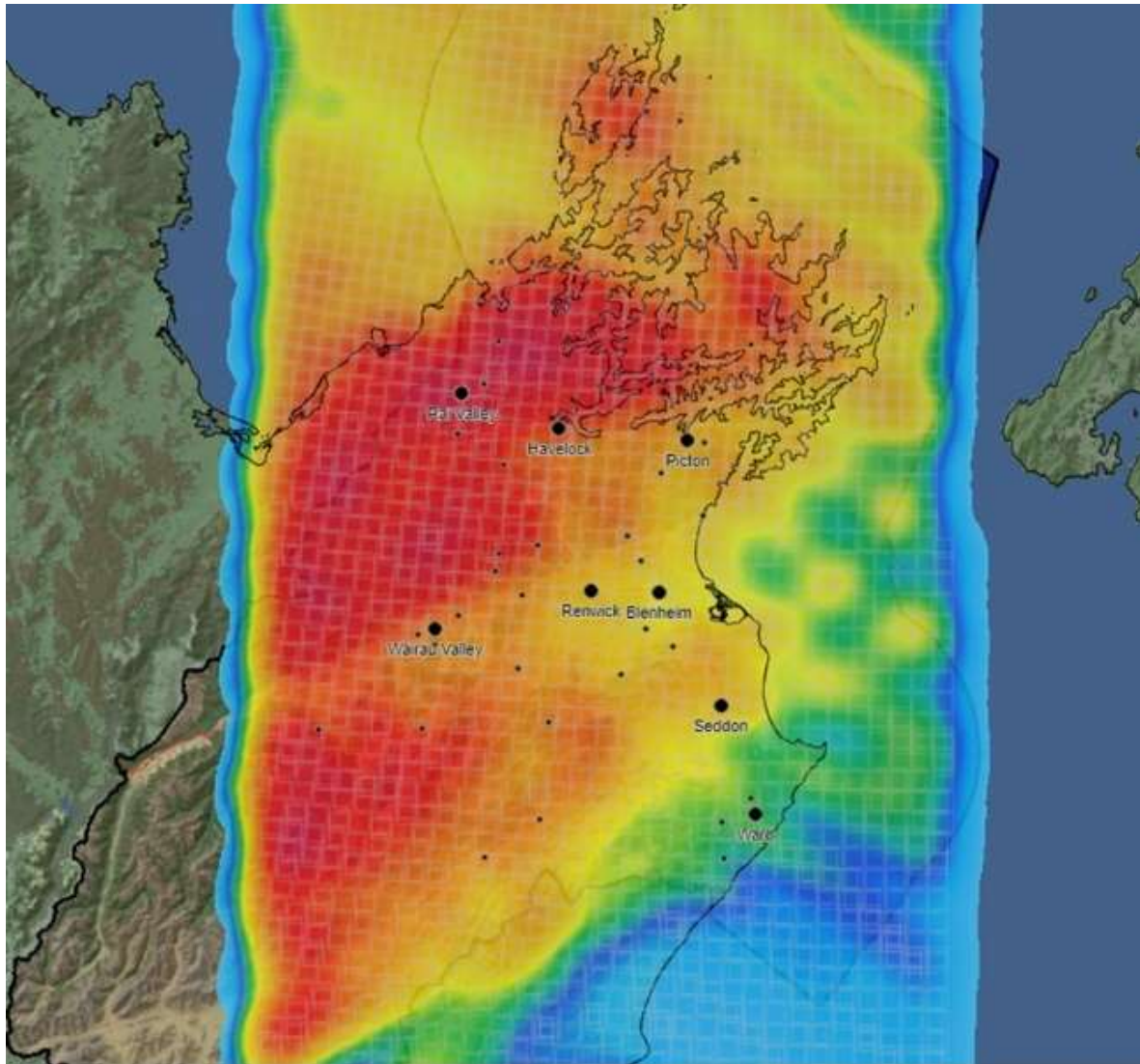


Figure 6 MetService gauge-corrected rainfall radar imagery, 16 August 2022 at 12:00 to 20 August at 23:00

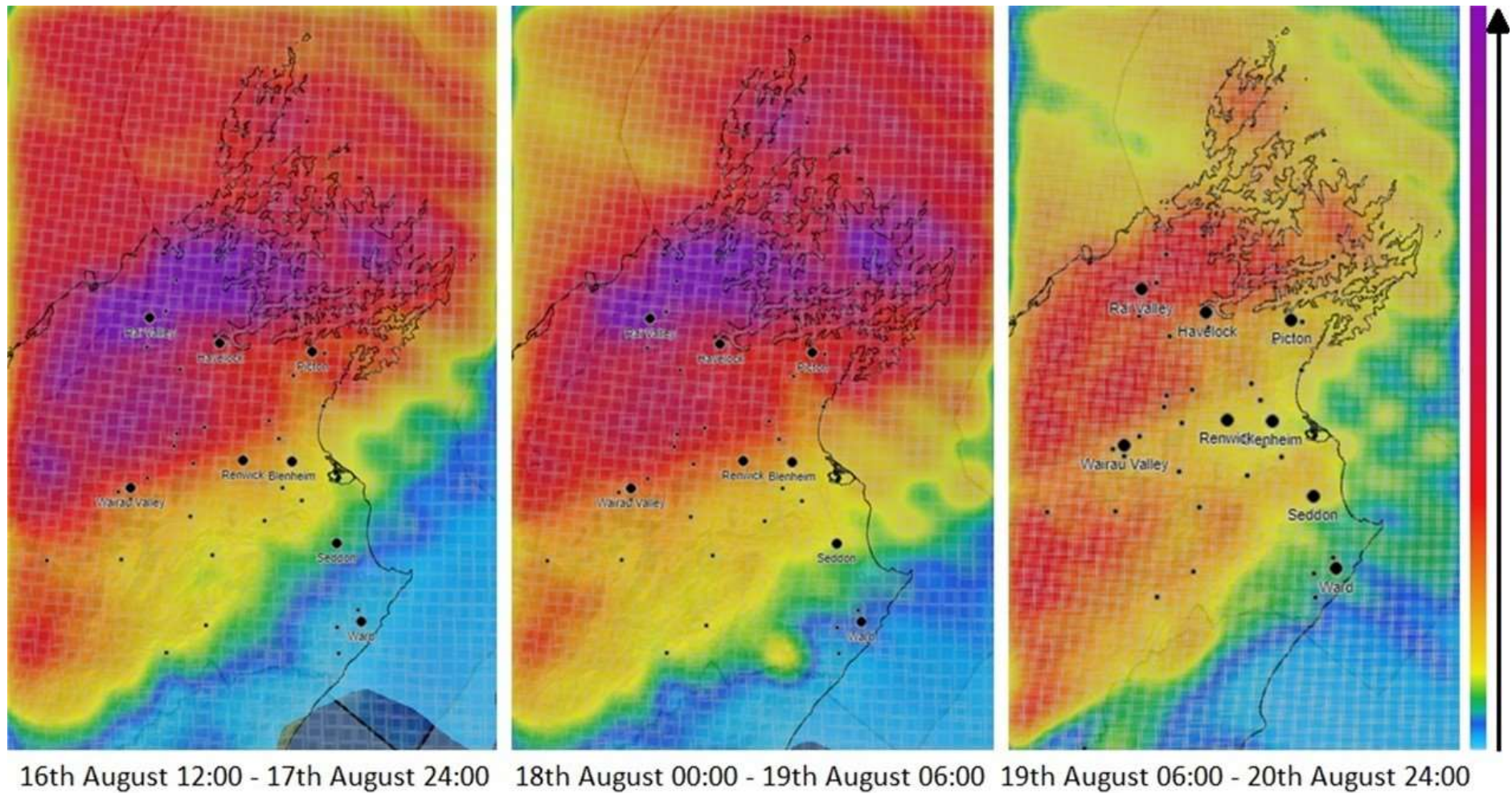


Figure 7 MetService gauge-corrected rainfall radar imagery, showing the rainfall distribution over Marlborough for the three bands of rain 16-20 August.

The map below (Figure 8) was produced by Tasman District Council to show the significance of the August rainfall event at each rainfall monitoring site in the Top of the South. The five-day rainfall total at each site was divided by average August rainfall, to give a ratio of significance.

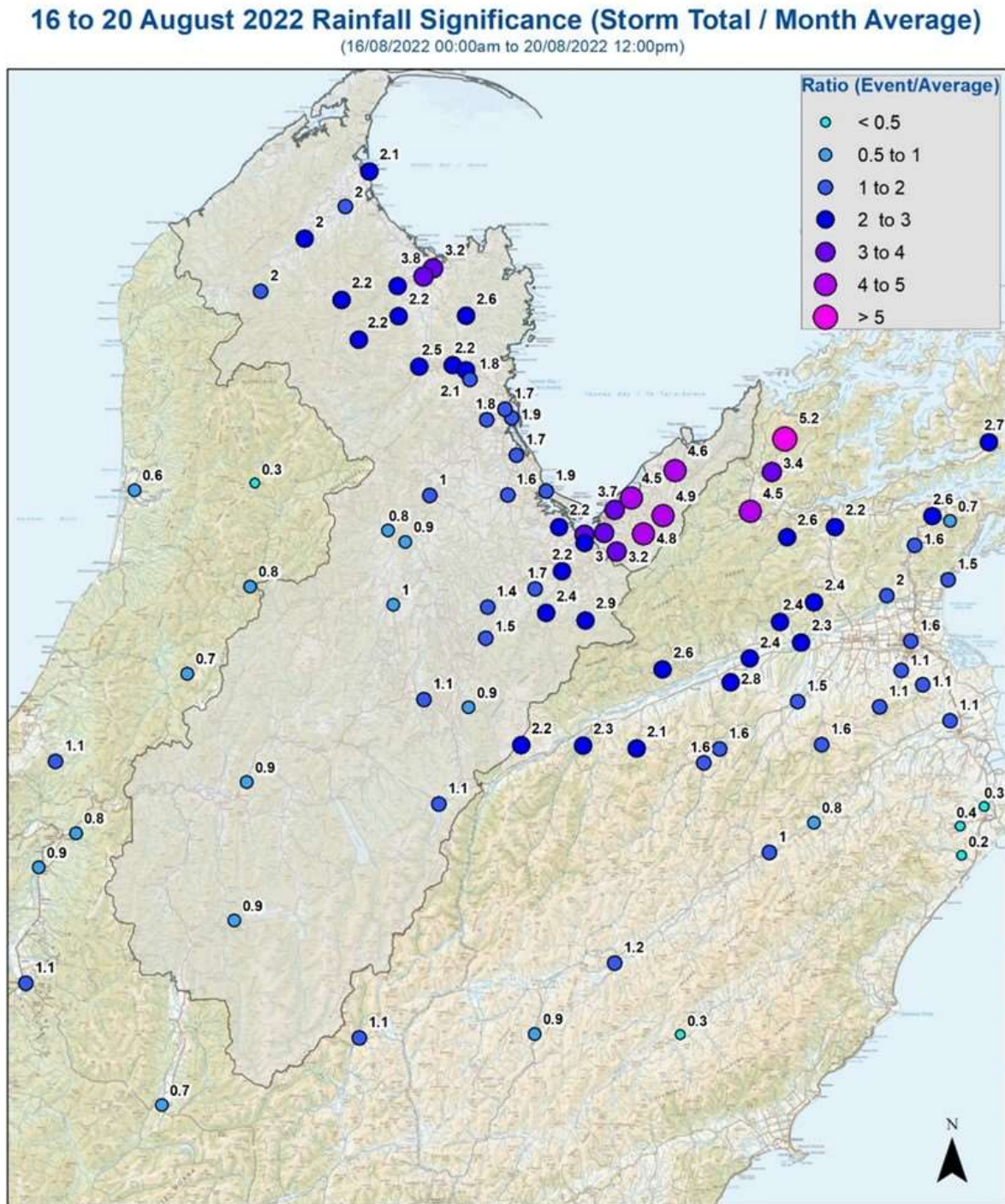


Figure 8 Tasman and Marlborough rainfall significance for 16-20 August 2022. This map was produced by the Tasman District Council Hydrology team.

The site with the greatest rainfall significance was the Marlborough District Council raingauge in Tunakino Valley. During the five day storm event 1,126 mm of rain fell, which is 5.2 times more rainfall than an average month (215 mm). Figure 8 also shows the Rai Valley raingauge had 4.5 times more rainfall in the five days than in an average month, with many of the raingauges in Nelson City having a similar rainfall significance value.

Additionally, many of the rainfall sites in the Wairau Catchment, as well as in the Kaituna, Wakamarina, Kenepuru, and Picton all recorded more than twice average monthly rainfall over the five-day event.

3. Te Hoiere Catchment

3.1. Rainfall

The rainfall in the Te Hoiere catchment and the Marlborough Sounds was captured by four Marlborough District Council sites (Tunakino, Rai, Wakamarina and Kaituna), and one Fire and Emergency NZ site (Kenepuru Head).



Figure 9 Northern Marlborough rainfall monitoring sites.

The rainfall totals at these sites are shown in Table 2 below.

Table 2 Rainfall totals for Northern Marlborough from the 16-20 August, and the Average Recurrence Interval (ARI) of the 5-day event.

Rainfall Site	Rainfall (mm) beginning 16 th August 2022			ARI of 5-day event (years)
	2-day total	3-day total	5-day total	
Tunakino	402	832	1,126	80+
Rai at Rai Falls	306	572	789	42+
Wakamarina	155	306	454	55+
Kaituna	96	198	290	28
Kenepuru Head FENZ	118	288	390	25+

The Tunakino station received an unprecedented 1,126 mm of rain over the five-day event. To put this into context, average annual rainfall at the site is 2,516 mm, meaning that the volume of rain that fell in five days is equivalent to almost six months of average rainfall. The long duration of high intensity rainfall is what made this event so unique; there were 20 hours during this event where rainfall intensity at Tunakino was over 20 mm/hr, and the average rainfall intensity over the five days was 13.4 mm/hr.

The likelihood of a certain rainfall event occurring can be described with an average recurrence interval (ARI), which is the average period between rainfall events of that magnitude. It is difficult to give an accurate ARI for many of these rain gauge sites because the length of record at the sites is insufficient to describe the likelihood of the August event occurring. In those cases, the ARI is indicated with a +, to show the true ARI may be found to be significantly higher if the length of record was suitably long. Despite this, ARI does give an indication of significance when comparing between sites.

The ARI of the five-day event at Tunakino is more than 80 years. Another way to show the rainfall's significance is by the records broken at the Tunakino site during this event:

- The highest rainfall to occur over a 12-hour period
- The highest rainfall to occur over a 24-hour period
- The highest rainfall to occur over a 36-hour period
- The highest rainfall to occur over a 48-hour period
- The highest rainfall to occur over a 60-hour period
- The highest rainfall to occur over a 72-hour period

The Rai Valley station recorded 789 mm of rain in the 5-day event, which is the same amount expected in an average five-month period. The ARI is more than 42 years. The Wakamarina, Kaituna, and Kenepuru stations all received about the same amount of rain over the five days as would usually be expected in three months.

3.2. River Flows

River flows in the Te Hoiere catchment were captured by two Marlborough District Council sites (Rai River at Rai Falls, Kaituna River at Reader's Road), and one NIWA site (Pelorus River at Bryants). The flow of the Pelorus River is not currently measured downstream of the Rai or Wakamarina River confluences, so total flow into the Te Hoiere Sound is unknown.



Figure 10 River Flow sites in the Te Hoiere catchment.

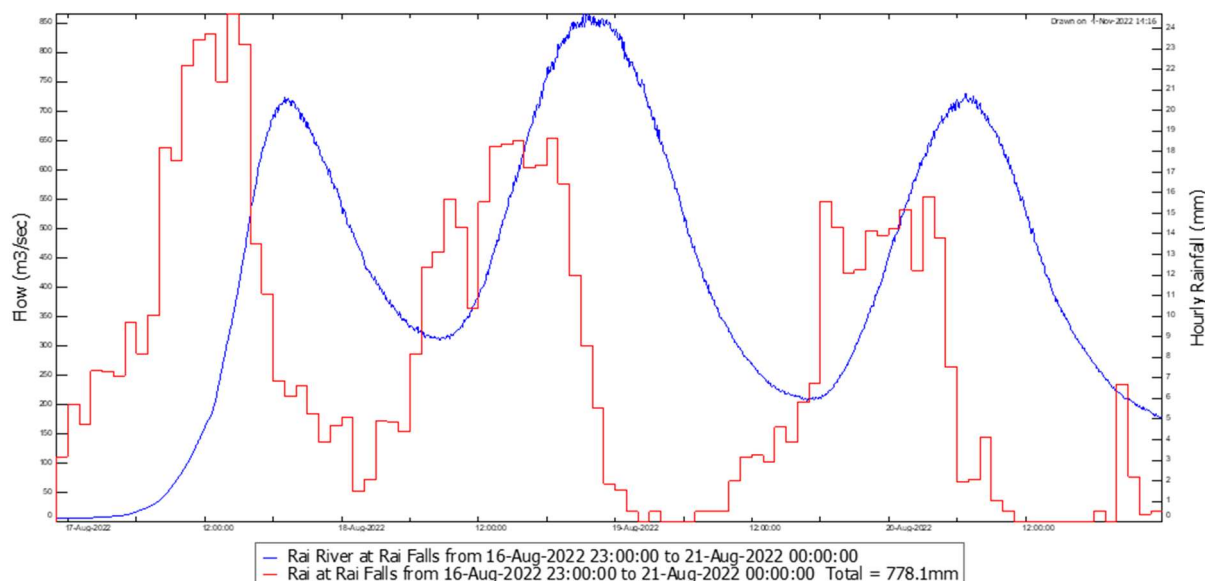
The Pelorus River at Bryants experienced three flood peaks of similar magnitude leading on from each of the three bands of rain. The final flood peak on the 20 of August was the largest at an estimated 1,700 m³/s (see Table 3). The ARI of this flood peak is 17 years. This is the fourth largest flood recorded since this site was established in 1977. The largest flood at the site was in December 2010, with peak flow of just over 1,900 m³/s.

The Rai River also experienced three flood peaks, which are shown below along with hourly rainfall totals at the same location (Figure 11). The middle flood peak on the 18 of August was the largest, with a flow of 865 m³/s. This is the largest flood on record in the Rai since the site was established in 1979, with an ARI of 60 years. The second largest flood in the Rai occurred in July 1998, with peak flow of 830 m³/s.

Table 3 Flood peaks for river flow sites in the Te Hoiere catchment, along with average return intervals for the largest flood peaks.

River Site	First Peak (m ³ /s)	Second Peak (m ³ /s)	Third Peak (m ³ /s)	ARI of largest peak (years)
Pelorus River at Bryants	1670	1600	1700	17
Rai River at Rai Falls	720	865	725	60
Kaituna River at Higgins Bridge	142	150	148	4.5

Figure 11 Rai River at Rai Falls flow and hourly rainfall totals, from 16-21 August 2022.



4. Wairau Catchment

4.1. Rainfall

Rainfall monitoring sites in the Wairau catchment have good spatial coverage, as can be seen in Figure 12, meaning we have a good understanding of rainfall distribution in the catchment.

From the 16 of August high rainfall was recorded on the Richmond Ranges (north bank of the Wairau), with the Top Valley and Onamalutu Saddle rain gauges recording 159 and 146 mm of rain respectively within the first 48 hours of the event (see Table 4). Rainfall on the south bank of the Wairau Catchment was moderate over the first three days of the event, with the most rainfall recorded at the Branch monitoring site, 140 mm over the first three days.

It was overnight on Friday the 19 of August that the weather system moved slightly south, resulting in high rainfall on both the north and south banks of the Wairau. Total rainfall at the north bank sites over the five days was upwards of 350 mm, with return periods of 60 years. In the Branch Catchment 236 mm was recorded over the five days, with a return period of 50 years.

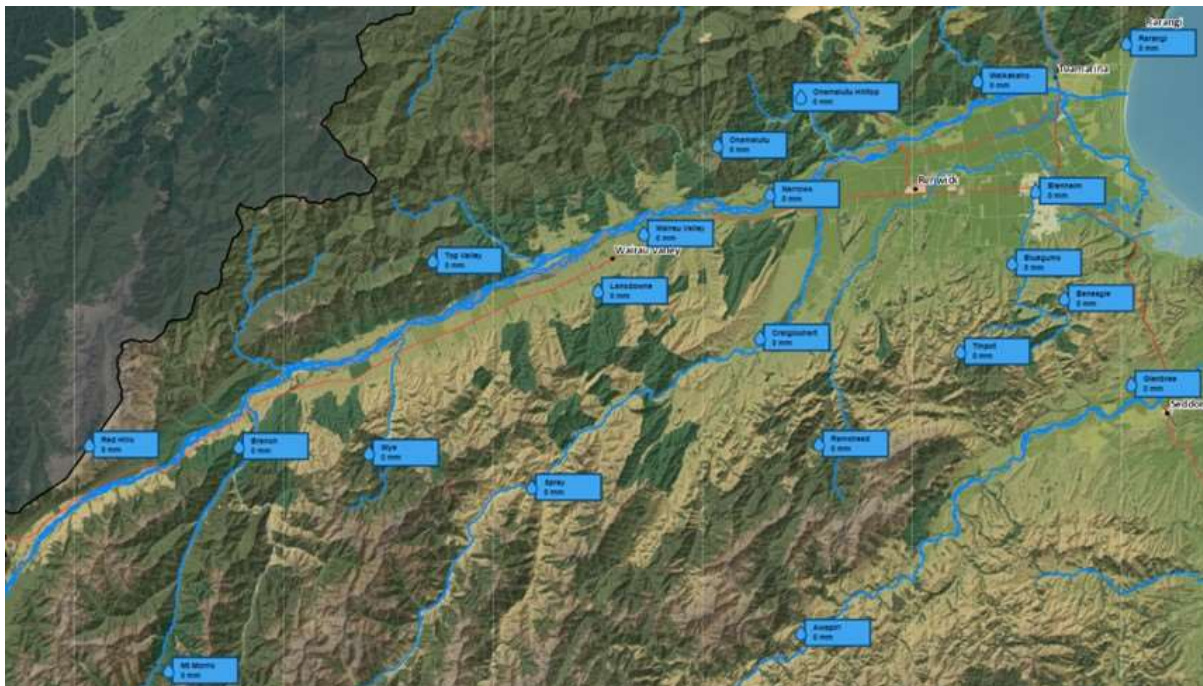


Figure 12 Rai River at Rai Falls flow and hourly rainfall totals, from 16-21 August 2022.

The second flood peak on August 20th at 1.00 pm was the third largest since records began in 1960, with a peak flow of 4,200 m³/s. The average recurrence interval (ARI) of this flood is 25 years.

The Branch and Waihopai flood peaks had ARIs of 13 and 11 years respectively (see Table 5), with flows of 910 m³/s and 685 m³/s. The north bank tributaries had much lower average recurrence intervals and did not contribute as much to the total flow seen in the Wairau at Tuamarina.

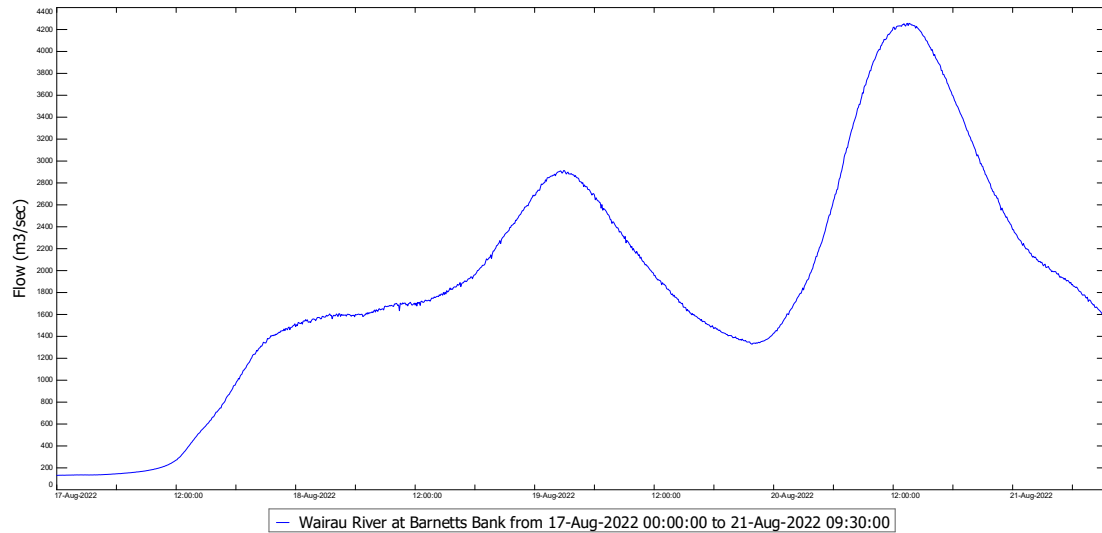


Figure 14 Wairau River at Tuamarina flow, from 16-21 August.

Table 5 Flood peaks and timing for river flow sites in the Wairau catchment, along with average return intervals (ARI).

Site	Peak Flood Flow (m ³ /s)	Flood Peak Timing	ARI (years)
Wairau at Tuamarina	4200	20 th Aug, 1 pm	25
Wairau at Dip Flat	550	20 th Aug, 6:30 am	12.5
Branch at Weir	910	20 th Aug, 6 am	13
Waihopai at Craiglochart	685	20 th Aug, 9 am	11
Goulter River at Horseshoe Bend	397	20 th Aug, 5 am	3
Ohinemahuta River at Domain	70	20 th Aug, 5 am	3
Are Are Creek	38	20 th Aug, 7 am	2.5

4.3. Comparison to July 2021 Flood

The August 2022 flood arrived on the heels of the July 2021 event, and they are naturally comparable. A similarity between the two events is that they both occurred after high rainfall months, so in both cases soil moisture was high preceding the event.

However, there are some key differences in the two events:

- The July 2021 flood in the Wairau at Tuamarina was about 1,000 m³/s larger than the August flood (see Table 6).
- The August flood was the result of an extended period of heavy rain spread over five days, while the July 2021 flood was from heavy rainfall mostly within 24 hours.

- The north bank tributaries (Goulter, Ohinemahuta and Are Are Creek) are estimated to have contributed 60% of total flow in July 2021, despite comprising only 30% of the total Wairau catchment area. In comparison, the August event had less input from these catchments.
- Prior to the August flood, there was more snowpack at high elevation in the Wairau catchment.
- The hydrograph from the July 2021 event was single-peaked and steep, rising from base flow to peak flow in about 36 hours (see Figure 15 below). In comparison, the hydrograph for the August flood had multiple peaks and the time from base flow to maximum flow was 96 hours (4 days).

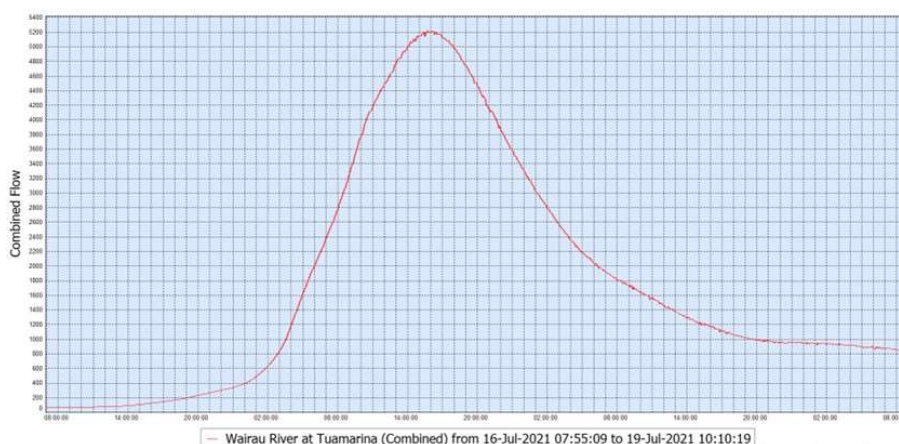


Figure 15 Wairau River at Tuamarina flow, from 16-19 July 2021.

Table 6 Flood statistics for the Wairau Catchment, July 2021, and August 2022.

Site	Flood peak 2021 (m ³ /s)	ARI (years)	Specific discharge (m ³ /s/km ²)	Flood Peak 2022 (m ³ /s)	ARI (years)	Specific discharge (m ³ /s/km ²)	Catchment area (km ²)
Wairau at SH1	5,280	87	1.54	4,200	25	1.22	3,430
Dip Flat	550	10	1.09	550	12.5	1.09	505
Branch	675	5	1.23	910	13	1.65	550
Waihopai	750	14	0.98	685	11	0.89	764
Goulter	518	-	3.24	397	3	2.48	160
Ohinemahuta	125	-	3.91	70	3	2.19	32
Are Are Creek	120	-	4.14	38	2.5	1.31	29

4.4. Modelled River Flow

The rainfall runoff model for the Wairau River estimated a flood peak of 4,700 m³/s on Saturday 20 August at 5.00 pm. This is a new model operated by the rivers department and has significant improvements over the flood prediction model operated by MDC at the time of the July 2021 flood. Use of this model in other catchments is being investigated.

This model proved to be fairly accurate – peak flow was estimated to within 12%. The observed flood peak was four hours earlier and about 500 m³/s less than the modelled peak.