Assessment of the 20th June 2021 Weather Event

Te Kaunihera o Te Tairāwhiti
GISBORNE
DISTRICT COUNCIL

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August 2021

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This report is to remain in draft until the local community has had the opportunity to assess and provide feedback

Executive Summary and Conclusions

1. On the morning of 19th of June, the MetService issued a heavy rain warning for Gisborne advising the region to expect 100 to 150mm of rainfall north of Tolaga with peak intensities of 20 to 30mm/hr of rain in the evening and again the following morning. An update that evening advised to expect a further 70 to 100mm of rain on top of what had already fallen with peak intensities of 20 to 30 mm/hr Sunday 20th June.

2. The weather event developed largely as forecast by MetService with heavy rain in the Waikura Valley area in the northwest and in a band extending northeast towards Tokomaru Bay and Tolaga. Rainfall accumulations were rather higher than forecast, however, with the highest occurring in the Waikura valley area (184mm/12 hr, 194.8mm/24 hr) with heavy rain from Te Puia/Waipiro Bay to Tokomaru Bay (150.4mm/12 hr, 154.4mm/24 hr at Te Puia). A private gauge at Tokomaru Bay recorded 160mm over 12 hours.

3. The weather event lasted up to 13 hours depending on location but 93% of the mean rainfall accumulation occurred across all rain gauges within a 12 Hour window and this assessment analysed rainfall at each site for 1 hour and 12-hour intervals as it was assessed that this best defined the storm.

4. Surface flooding occurred widely from south of Tolaga Bay to Te Araroa but slips were only significant on the main highway at Oweka near the Lottin Point turnoff.

5. Unexpectedly heavy rain occurred at Tokomaru Bay starting at or soon after 6am on the Sunday with a peak rainfall from 7am to 8:30am and this cause significant flash flooding affected both the Mangahauini and Waiotu/Kaiawha catchments, particularly along Arthur Street in the Waiotu catchment and Toa Street in the Mangahauini Catchment. Deep surface flooding also occurred in low lying areas between the two catchments in the Hatea-A-Rangi area. It is estimated that around 75mm fell within 1 ½ hours but it may have been higher.

6. Using HIRDS v.4 the overall storm had a 12 hour rainfall accumulation ARI (Annual Recurrence Interval) of 2.5 years but the 12 hour rainfall recorded at the private rain gauge at Tokomaru Bay had an ARI of 13.5 years. The short duration high intensity storm had an ARI of 30 to 35 years if the accumulation occurred over 1 ½ hours or 100 years if most of that heavy rain fell within an hour.

7. Flooding impacts were exacerbated by an associated storm surge which impeded drainage of flood waters.

8. Neither the Mangahauini or Waiotu/Kaiawha catchments have river flow or rain gauges and hence the event was only captured by the private gauge which could only provide overall event rainfall accumulation.

9. Rain radar data from the Mahia station provided a useful qualitative view of the storm as it progressed from off Bay of Plenty through to Tairawhiti but did not capture the heavy rain event that hit the Tokomaru Bay area as the radar was imaging precipitation around 2km and above rather than on the ground. Post-event rain gauge corrected radar showed a narrow band of rain (at 2km +) travelling down the coast east of Te Puia.

10. The flooding affecting Arthur Street resulted from heavy rain in the Kaiawha tributary of the Waiotu rather than the Waiotu itself, and was exacerbated by significant overland flow. A large willow planted in Waiotu Stream is not considered to have acted to significantly exacerbate flooding.

11. Flooding in the Mangahauini river overtopped the Tokomaru transfer station and a very limited amount of overtopping of the stopbank on the true right bank close to the bridge over the river occurred but is not considered to have exacerbated flooding in the Café 35 – Hatea-A-Rangi area which was primarily the result of overland flow and direct-to-ground ponding.

12. A blocked culvert on State Highway 35 at "Marotiri" Stream resulted in flow down the highway towards Tokomaru Bay. Some of this overland flow re-entered "Marotiri" Stream immediately downstream of the culvert but greater volumes would have left the water table at two locations between the culvert and the sub-station.

13. The flooding at Toa Street is largely the result of overland flow from the hillslopes above State Highway 35 which was channelled towards the street via the water tables either side of the highway. Additional inundation was the result of direct-to-ground rainfall accumulation. Some water from the blocked culvert reached Toa Street but it may not have dominated the inundation. The overgrown drain between the substation and Toa Street reduced its conveyance capacity which would have exacerbated overland flow.

14. The storm surge associated with the weather event caused coastal impacts from Te Araroa to Turihaua Point. At Te Araroa, the surge resulted in erosion at the top of the beach which exposed and remobilised previously deposited woody debris. This woody debris comprised indigenous and willow/poplar. Forestry harvest residues do not appear to have contributed to the wood on the beach.

15. At Waipiro Bay, the storm surge events of June and earlier in the year have resulted in erosion of the road that provides access to the houses beyond Taurapu Stream on McIlroy road. This road has largely been built on fill and protected by a range of informal means of armouring. This road will become increasingly at risk from future storm surges and king tides, and sea level rise will further exacerbate this risk.

16. Storm surge damage at Tokomaru Bay was most evident at the reserve at the mouth of the Mangahauini River which was fully inundated by water and suffered additional damage over and above that experienced during the May storm surge (and previous events). At the mouth of the Waiotu, the storm surge caused flood waters to back up and threw a lot of woody debris onto land beyond the beach.

17. At Tolaga Bay the principal impact of the storm surge was to remobilise woody material already incorporated into the dune system at the top of the beach.

18. The impacts of storm surge along the freedom camping areas from Pouawa to Turihaua was largely from saltwater inundation which resulted in salt burn to the grass, thrown up rocks and woody debris and erosion. At Turihaua Point the erosion was largely of soil and grass on top of the wave cut platform while to the north the dune system was significantly eroded and inundated by salt water.

19. A number of issues were identified in the course of this assessment.

   a. Extensive willow woody debris washed up on Tolaga Bay beach on the 20th of June and was traced back to a recent clearance of willows at Mahanga Stream above where it crosses State Highway Thirty Five. This clearance was substantial and as was observed on the day, the woody residues were stored in locations vulnerable to flood.

   b. The culvert of State Highway 35 immediately north of Tokomaru Bay was known to be blocked before the event and Waka Kotahi had planned to clear the blockage but this was not completed before the weather event. The scale of the event was such that the culvert would most likely have blocked in any event.

   c. The presence of a freshly cut log suggests movement of logs harvested within the catchment since the 2018 Queens Birthday storm. The source of this log was not identified.

Recommendations

Installing a rain gauge in the vicinity of Tokomaru Bay

The absence of a rain gauge or flow gauge at Tokomaru would not have altered the outcome. A key part of any post-weather event assessment is, however, to maximise the understanding of what happened and when so that lessons are learnt and applied during the next event. Additionally, the majority of other coastal townships have one or more rain gauges in relatively close proximity and the absence of one at Tokomaru Bay is a gap. A suitable location would be at Hatea-A-Rangi School provided a suitable secure site can be identified. It is noted that the fortuitous presence of a private rain gauge at Tokomaru Bay proven invaluable in this analysis.

Assessment of the overall district rain gauge and river flow gauge network

It was noted in the body of the report that Gisborne/Tairawhiti has an extensive rain gauge network relative to adjacent regions and there are few performance issues with the network (although there were some anomalous readings). On the other hand, the region has a very complex topography which results in a high degree of variability in rainfall. Some locations such as Poroporo has more than one gauge in close proximity which in this instance produced comparable results (12 hour maxima of 123.4 and 129.2 mm respectively). There is thus the case for assessing whether or not the network can be enhanced without a significant increase in workload for the Environmental Monitoring team.

Comprehensive Legacy Landfill risk assessment

Some work on a risk assessment of the legacy landfills has already been undertaken but a coherent work programme should be undertaken to assess and prioritise risk and develop risk mitigation plans and actions. The Tokomaru landfill is the most obviously vulnerable site but the Te Araroa, Tikitiki, and Tolaga sites as well as others require further assessment.

Better fact-finding engagement with affected communities

The locals on the ground are a largely untapped source of information that could be better utilised to inform the post event review; for example improving information about flood spread and accessing social media feeds, and raw photos and video.

Table of Contents

Figures

Tables

Introduction

On the morning of the 18th of June 2021, the MetService twitter feed published a map indicating that there was high confidence that heavy rain would occur from Saturday 19th June to Monday 21st June 2021 for the Bay of Plenty and the northern half of the Raukumara. A low confidence rating was put on the Tokomaru Bay to Hawkes Bay area for the period Sunday 20th to Tuesday 22nd (**Figure One**).

On the morning of 19th of June, the MetService issued a formal heavy rain warning for Gisborne;

Issued: 9:47am Saturday, 19th June 2021
Area: Gisborne north of Tolaga Bay
Valid: 1:00pm Saturday to 11:00am Sunday
Expect 100 to 150mm of rain. Peak intensities of 20 to 30mm/hr this evening, and again tomorrow morning with possible thunderstorms.

This was updated in the evening of the 19th June 2021;

Issued: 8:07pm Saturday, 19th June 2021
Area: Gisborne north of Tolaga Bay
Valid: 8:00pm Saturday to 1:00pm Sunday
Expect a further 70 to 100mm of rain to accumulate on top of what has already fallen. Peak intensities of 20 to 30mm/h Sunday morning with possible thunderstorms.

Accordingly a weather watch was initiated from mid-morning on the 18th of June, primarily using the MetService detailed 3 day rain forecast and rain radar. As the modelling from MetService can be different from other weather providers, the Weatherwatch, MetVUW and FNMOC systems were also reviewed and a high degree of forecast congruence was evident. This gave confidence that the MetService modelling was likely to be accurate within the context that it's a forecast and thus subject to the vagaries inherent in complex natural systems.

The detailed synoptic map forecast from midday on the 19th of June for 6AM Sunday 20th showed that an extensive area would be covered by heavy rain and in particular the forecast showed intensive rain cells for the Wharerata and the northern part of the district north-west of the Waiapu. The forecast also showed an even more dense north-south oriented cell located offshore of central Bay of Plenty. The Poverty Bay area and coastal regions north to Te Araroa were indicated to only experience light to moderate rain within the 6AM 20th June window (**Figure Two**). The rain radar data between midday and 10pm Saturday 19th was consistent with the forecast model.

The rain radar was again assessed at 6:45AM on the 20th June and the 120km range radar showed an intense east-west oriented rain cell immediately south of Tolaga Bay covering part of the Uawa and Pakarae/Whangara Catchments (**Figure Three**). The 7AM 120km range rain radar showed this rain cell breaking up and moving offshore. Obviously enough, the 300km range radar covers a wider area than the 120km radar and the 7:06AM image shows a dense band of rain was crossing the centre of the region particularly covering the area from Poverty Bay north to Tokomaru Bay (**Figure Four**).

At 7:30AM on the 20th June, the Tairawhiti Civil Defence stood up in response to flood warning reports and by 8:30AM facebook posts started appearing showing the flooding in Tokomaru and elsewhere.

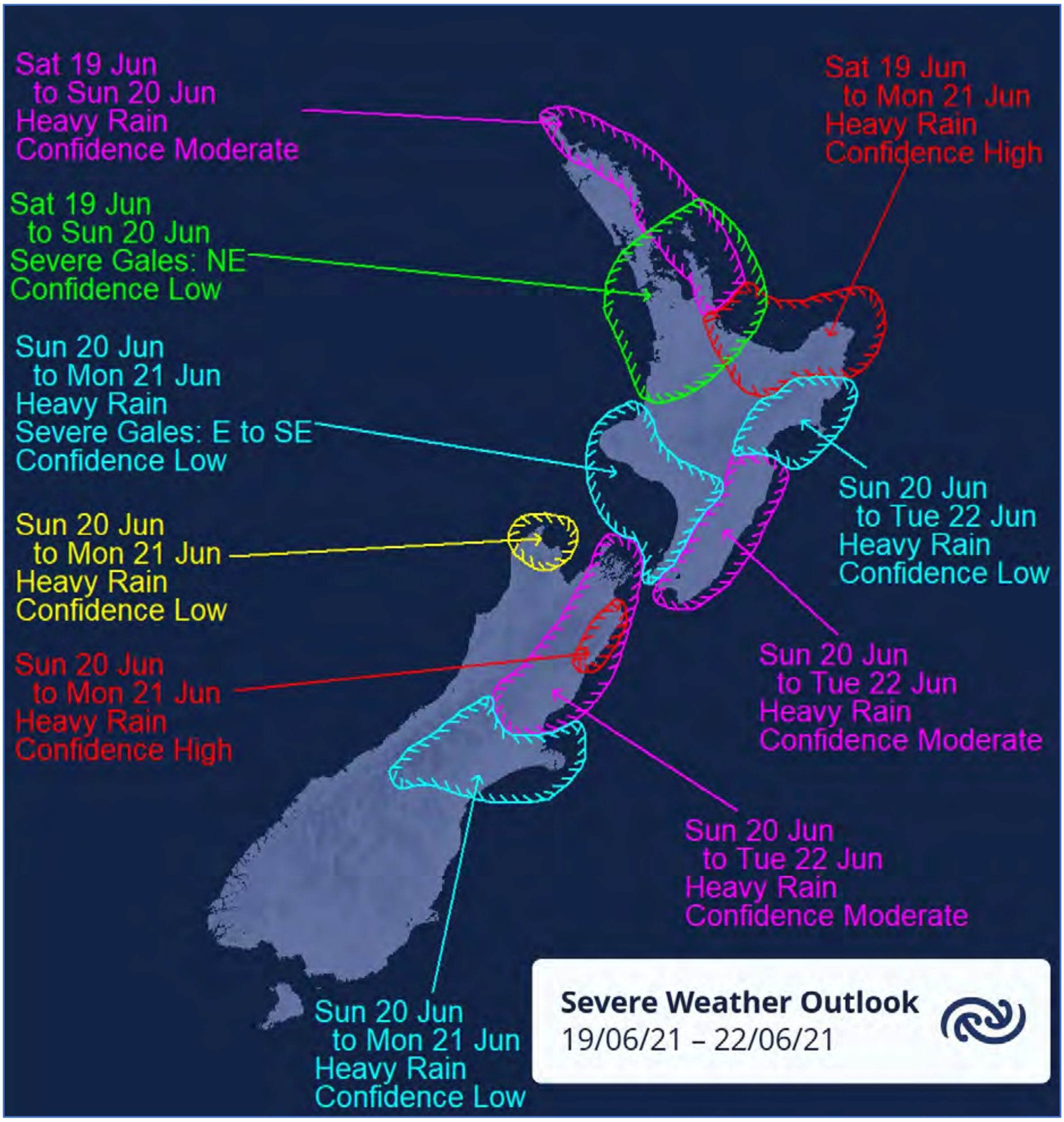

Figure One. *Severe weather outlook published by the MetService via Twitter on the morning of Friday 18th June 2021.*

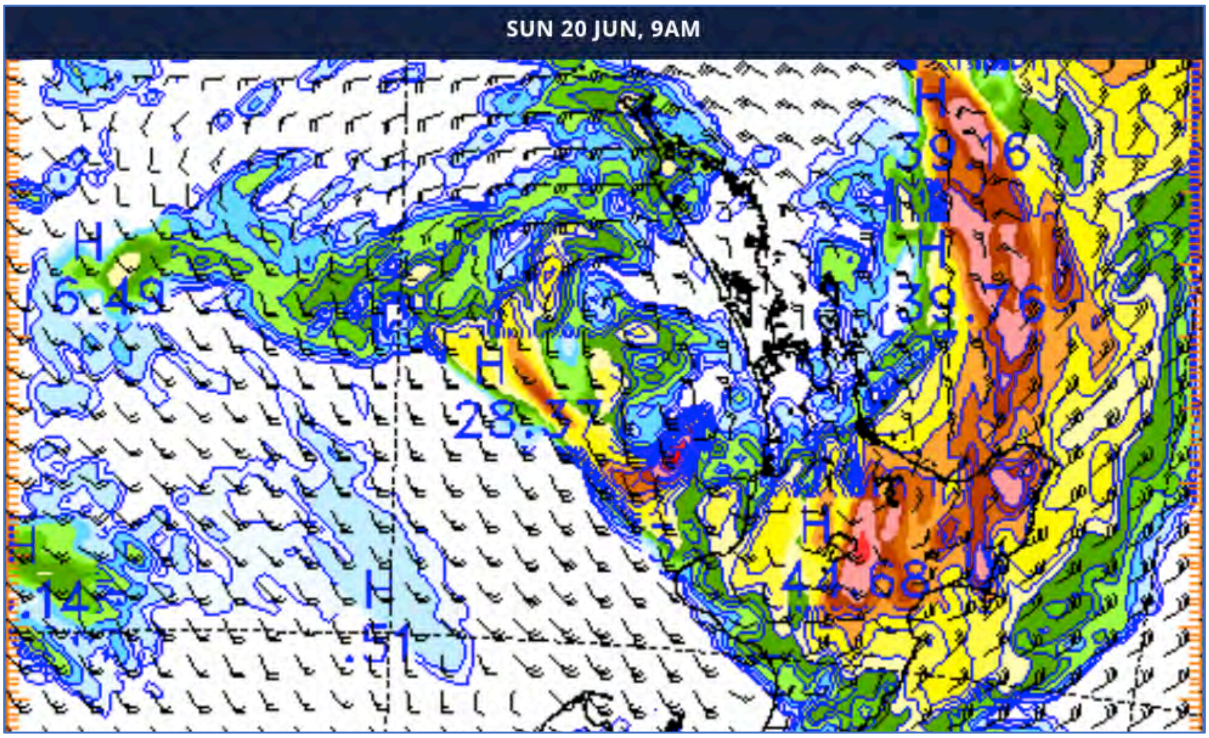

Figure Two. *MetService forecast map from Friday 18th June 2021 showing a synopsis of the rainfall expected for 9am Sunday 20th June 2021.*

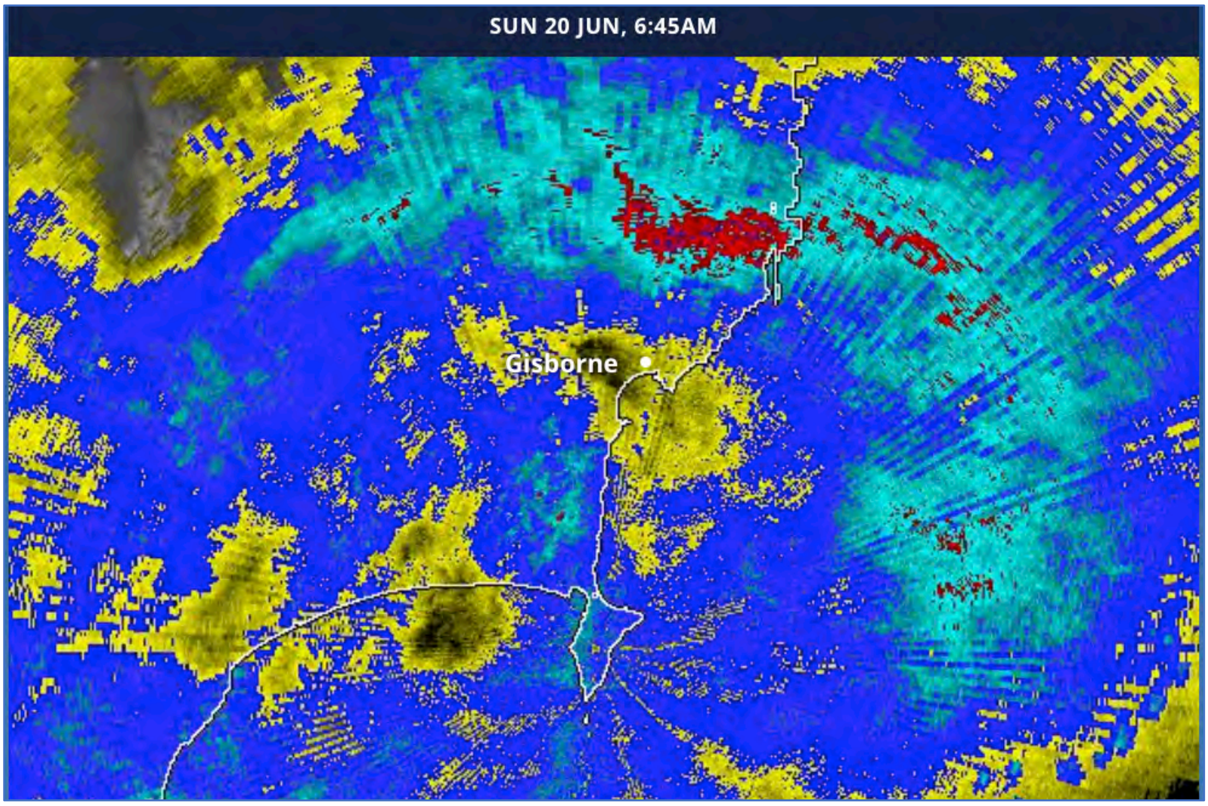

Figure Three*. MetService 120km range rain radar based on the Mahia radar station showing an intense rain cell immediately south of Tolaga Bay at 6:45AM on Sunday 20th June 2021.*

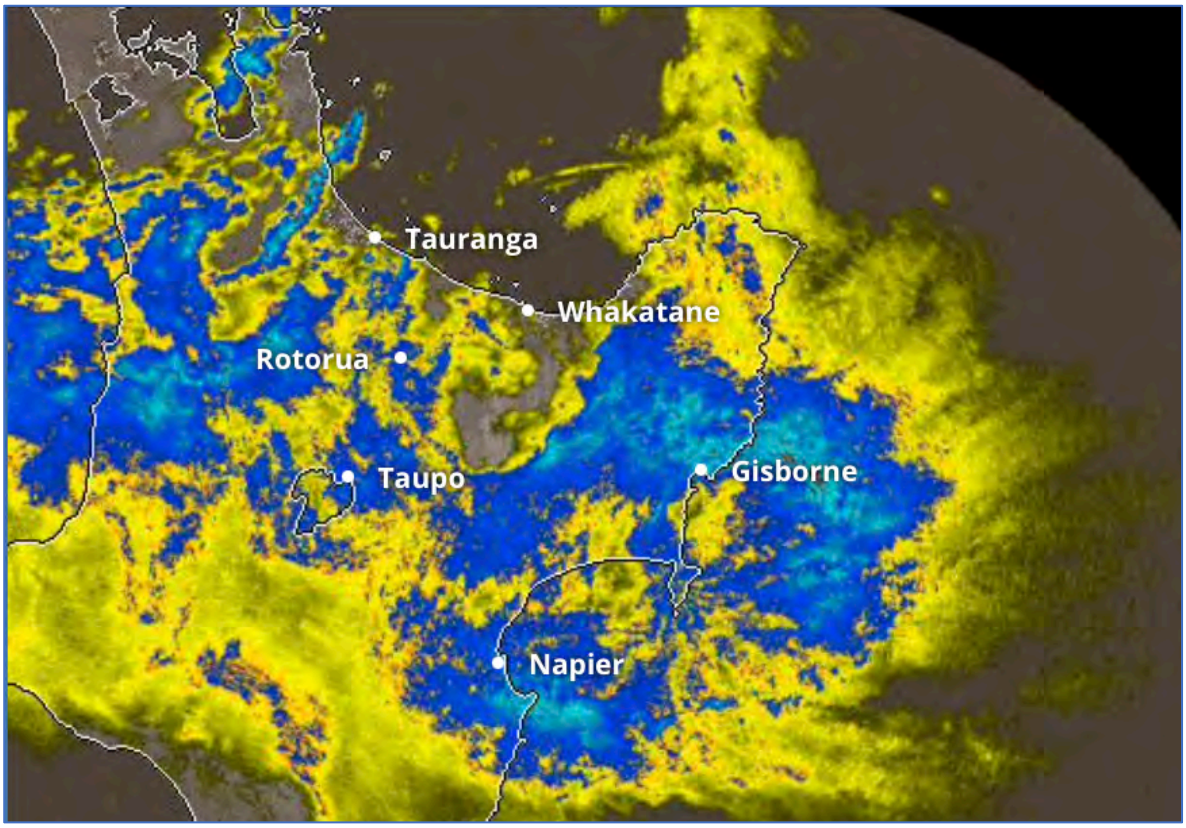

Figure Four. *MetService 300km range rain radar based on the Mahia Peninsula rain radar site showing a dense band of rain crossing the region from Poverty Bay north to Tokomaru Bay at 7:06am Sunday.*

The Weather Event

The impacts of the severe weather event have been broadly documented aided by the widespread social media postings, site visits, community reports, and news media reports (**Figure Five**). The event was experienced widely from the top of East Cape, particularly in the vicinity of the Waikura valley, Oweka area where a large slip blocked the road (**Figure Six**) while flooding occurred widely from Te Araroa (**Figure Seven**), at Ruatoria (**Figure Eight**) and to Tolaga Bay (**Figure Nine**). The flooding on the road to Anaura at the junction with State Highway 35 (**Figure Ten**) resulted in the mobilisation of piles of willow waste wood stowed in a vulnerable location on the stream bank (**Figure Eleven**).

At Hiruharama a pre-existing river scour affecting one house after storms in 2020 was significantly exacerbated. The garage had already been dismantled after the 2020 storm as its edge was overhanging the slip. After the 20th June 2021 event the water tank and house now at risk of being lost to the river[1] (**Figure Twelve**).

At Tolaga Bay[2], the storm surge scoured the top of the north and south beaches and remobilised pine logs. An additional contribution of fresh willow debris on the north beach suggested that the willow piles observed being mobilised at the Anaura Bay turn-off migrated to the beach (**Figure Thirteen**).

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[1] The Hiruharama risk assessment is being separately reported in more detail.

[2] The impacts on Tolaga Bay Beach is being separately reported in more detail

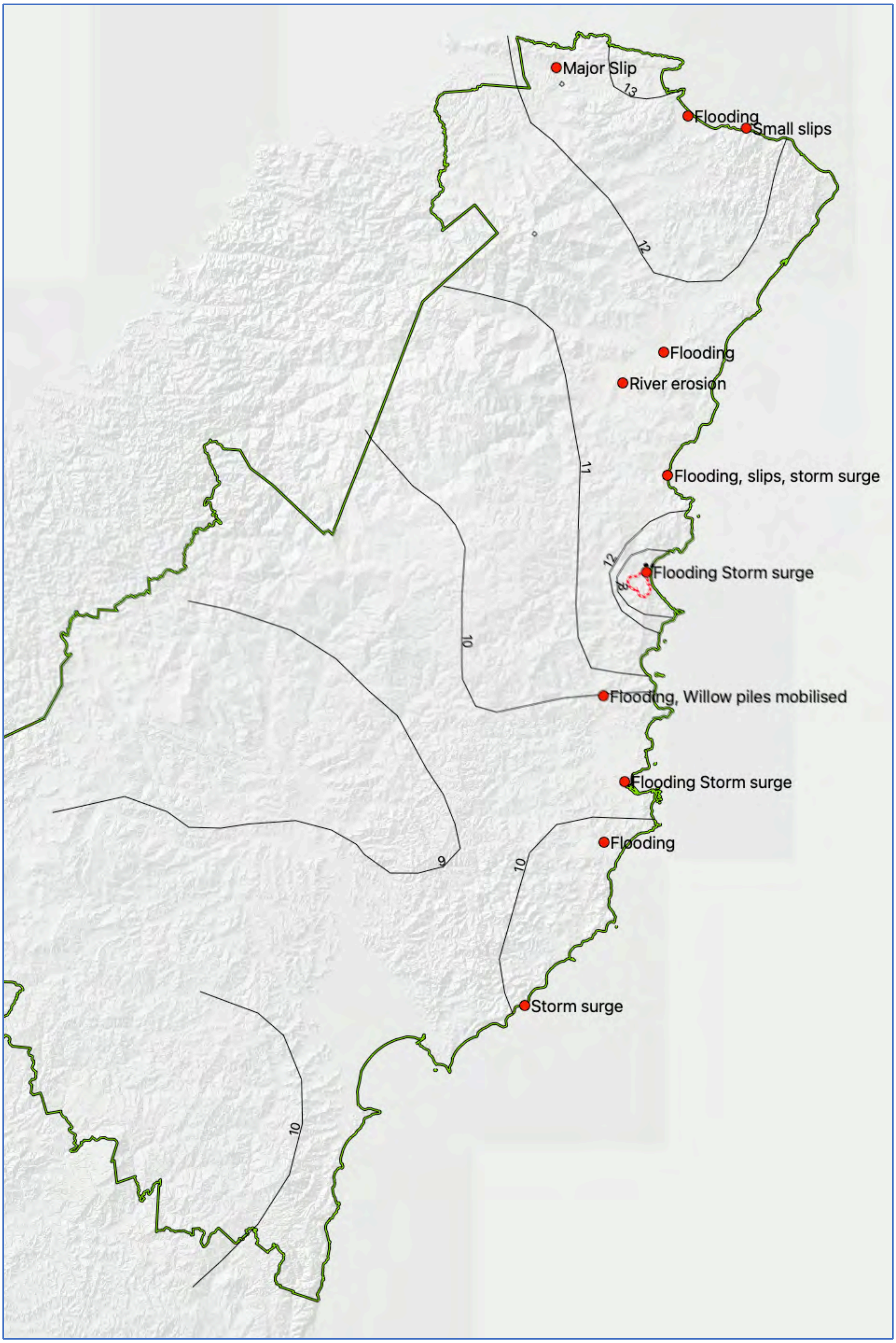

Figure Five. *Map of the Tairawhiti Region showing a contour of the main storm duration and location of main events.*

Figure Six. *Clearing the significant slip blocking State Highway 35 at Oweka close to the Lottin Point turn off (photograph Rex Rongo Stainton).*

Figure Seven. *Flooding on the road north of Te Araroa (Tairawhiti Civil Defence..*

Figure Eight. *Flooding at Ruatoria. Manu Caddie facebook feed.*

Figure Nine. *Flooding at Tolaga Bay (Uawa Live Facebook post).*

Figure Ten. *Flooding on the road to Anaura east of the junction with State Highway 35.*

Figure Eleven. *Willow piles being eroded upstream of State Highway 35 Bridge, Mahanga Stream. These were observed migrating to the Hikuwai River.*

Figure Twelve. *Drone footage of property at Hiruharama, south of Ruatoria where slipping from a side creek is threatening a house.*

Figure Thirteen. *New woody debris deposited on Tolaga Bay north beach after the 20th June 2021 storm.*

Figure Fourteen. *Flooding on State Highway 35 south of Tolaga Bay.*

Tokomaru Bay

The most significant impacts of the flooding occurred in the coastal township of Tokomaru Bay where residents reported heavy rain over night. Some residents in Kaiawha Road reported the rain getting especially heavy from around 6am while those in Toa Street and on the main road report heavy rain from early morning.

One resident in Toa Street reported flooding around their house about 7 AM or soon thereafter while at 3552 Waiapu Road sheets of water were reported running down the property from the hill behind at 7:15 AM and the road was flooding. At 8 AM photographs and video started appearing on Facebook showing the flood at full height (**Figures Fifteen, Sixteen and Seventeen**).

Figure Fifteen. *Photograph hosted on the Uawa Live Facebook page credited to Kuipo Saulala and described as taken at approximately 8am showing the approach to Tokomaru Bay.*

Figure Sixteen. *Photograph posted to Facebook at 8:45 AM. Image taken from number 3552 Waiapu Road by Hoana Forrester with the image taken around 8:15 AM based on the comments.*

Figure Seventeen. *Screenshot from a video posted at 8:46 AM by Tianna Rongonui showing what is estimated as close to the maximum extent of the flood.*

Based on the information available (facebook posts and interviews), it appears that while there was moderate rain over night, rainfall intensity increased significantly from around 6 AM and flooding in Tokomaru was evident by 7 AM to 7:15 AM and reached a peak between 8:30 to 8:50 AM. The floods receded rapidly and the road became passable sometime after 9:30 AM. The event thus meets the criteria for a flash flood and that has implications regarding flood capacity to model and risk assess the flood.

Tokomaru Bay Catchments

Tokomaru Bay lies within three catchments. The largest of these is the Mangahauini Stream in the north which has an area of 2,518 ha and has its headwaters just 1.6km south of Te Puia. In the south is the Kaiawha catchment which has an area of just over 535 ha (length 3.25km), and between these two catchments is the Waiotu Stream which has an area of 278.5 ha (length 3.56 km). The Kaiawha is a tributary of the Waiotu Stream joining the Waiotu just upstream of the first houses in the Tokomaru Bay settlement (**Figure Eighteen**). Flooding appeared to be generally consistent with catchment size with the Kaiawha dominating flood flow for the Waiotu/Kaiawha combined catchment. For the Mangahauini there are some indications that minor coastal sub-catchments such as the Makarangu (165.8 Ha, length 11.05km) and the small stream that rises to Marotiri (35.9 Ha, length 2.33km) disproportionately contributing to the flow.

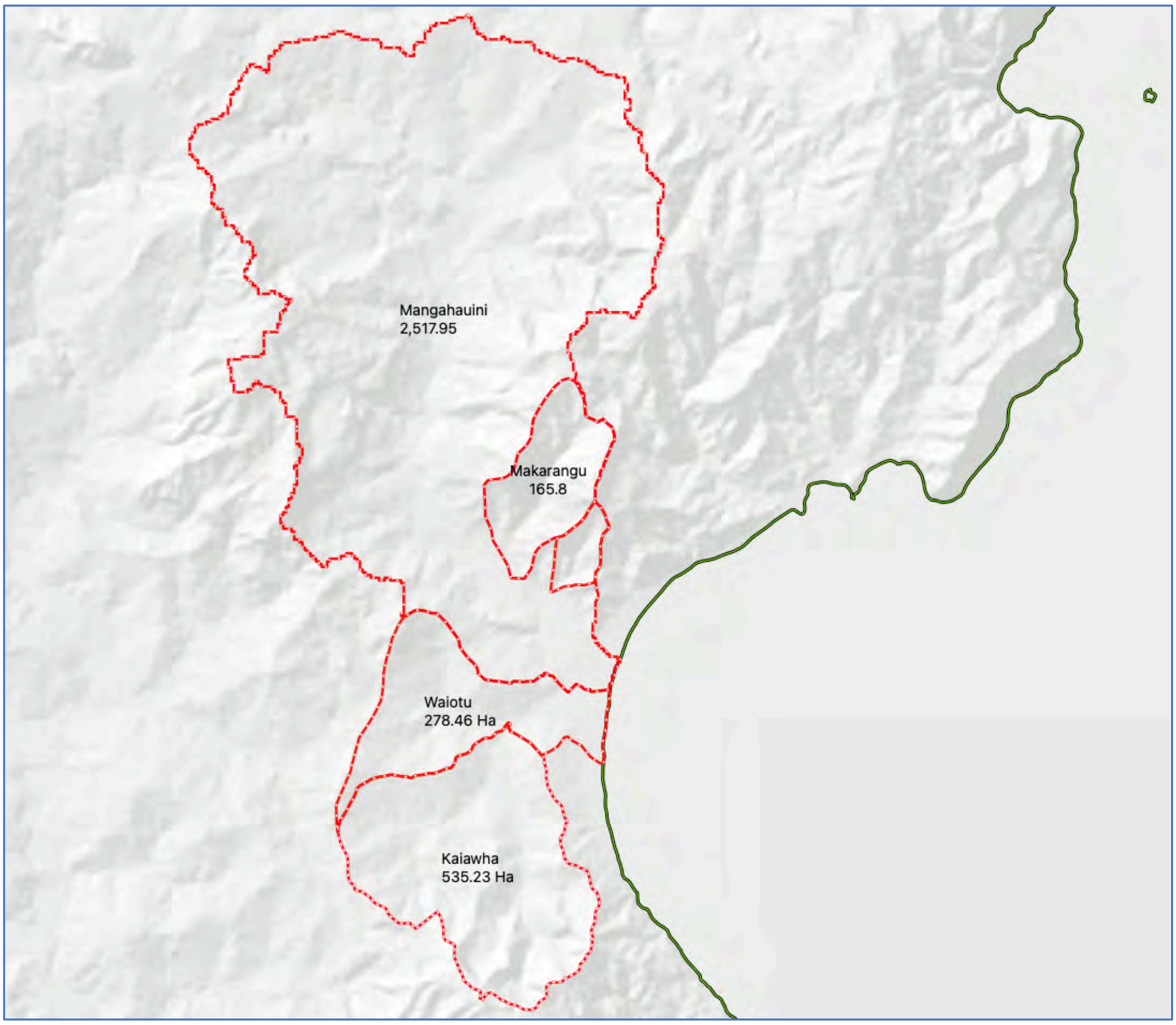

Figure Eighteen. *River catchments that drain into the sea at Tokomaru Bay.*

Weather Data Analysis

Data Sources

There are three main sources of data used in this analysis.

• The MetService Mahia Peninsula Rain Radar
• Barry Sanders Rain Gauge at 17 Beach Road Tokomaru Bay.
• Gisborne District Council rain gauge network.

Rain Radar

The rain radar is presented in two forms;

- The (close to) realtime web-based rain radar which is presented as either 120km range (cf **Figure Three**) or 300km range radar imagery (cf **Figure Four**).
- Post event rain gauge corrected imagery supplied directly by MetService.

Rain radar provides a valuable insight into the progress of a storm but the imagery (and associated digital data) needs to be treated with caution. The MetService operates a set of ten single-polarisation, C-band scanning rain radar with the closest site to Gisborne/Tairawhiti located at Mahia Peninsula. While the radar has the ability to measure radar reflectivity up to 250km there are limitations to its value at those limits. The MetService has noted that the Mahia radar "doesn't cover yor regiin at all well. The Bay of Plenty radar is even worse" Gerrit Keyser, MetService pers comm.

These limitations including increasing beam spreading with distance, and attenuation, where the power of the radar energy is reduced as a result if passing through dense medium such as heavy rain, snow or hail. A particularly key issue is the climbing effect associated with curvature of the earth which means that at 100km from source, the radar is measuring reflectivity at between 1.5 and 3km above the ground (**Figure Nineteen**). This means that at 100km and beyond, what the radar is not necessarily seeing what is occurring on the ground below.

For this reason, the maximum optimal range of the radars for quantitative precipitation estimation (QPE) is limited to 100km (Sutherland-Stacey *et.al* 2017). Even here, it is generally noted that "*it is practically impossible to get error-free QPEs due to the inherent limitations of weather radar as a precipitation measurement tool*" Wijayaranthe *et. al.* (2020).

Tokomaru Bay is 120km from the Mahia and at this distance the rain radar is imaging rain events at 2km+ elevation above the Bay (**Figure Twenty**). This does not mean that the rain radar lacks value, but rather than the imagery is not directly showing the true state of the weather on the ground.

The real-time rain radar (cf. **Figures Three** and **Four**) suggest that on the 20th June heavy rain was falling in the vicinity of Tolaga township at 6:45 AM and that by 7:05 AM at Tokomaru Bay the weather was easing. This is consistent with the timing based on the Facebook posts which suggest that by 8 AM rainfall was easing. The value of the rain radar in this instance, is that in an ungauged catchment it helps tell when the heaviest rainfall occurs in close to real-time, but because its beyond 100km from the radar station it cannot give an accurate estimation of the amount of rain (rainfall depth) that has fallen.

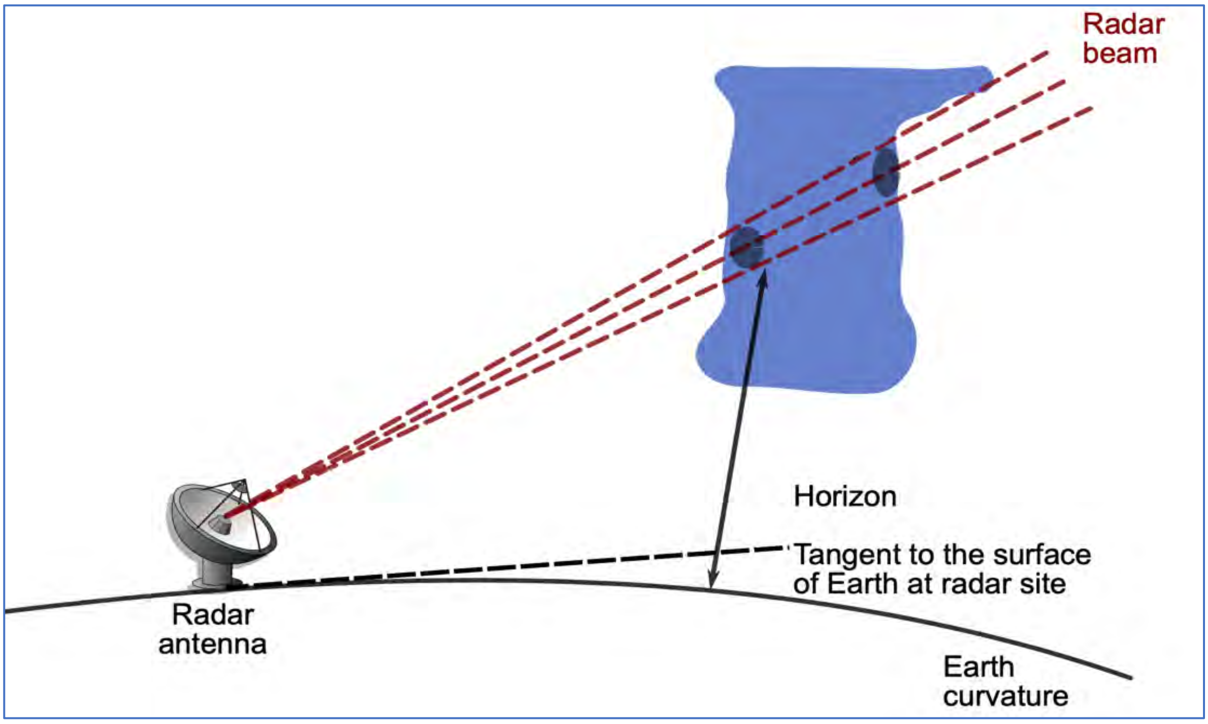

Figure Nineteen. *Diagrammatic representation of a C-band rain radar showing the impacts of increased distance on the height at which the radar reflections record.*

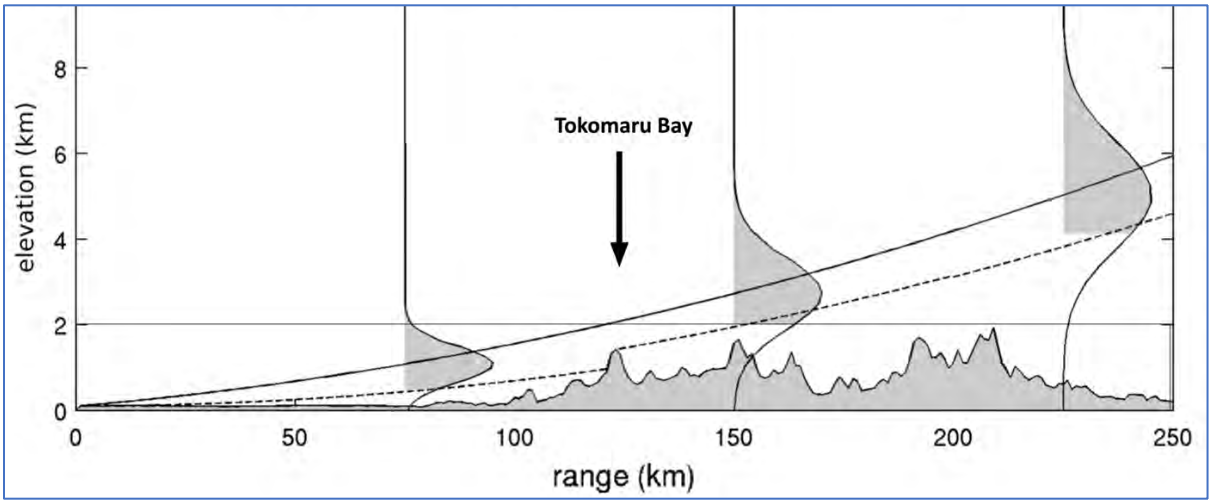

Figure Twenty. *Diagram showing the relationship between range and elevation for rain radar for Tokomaru Bay with the bay at 120km from the rain radar and the recording height at 2km and above (from Sutherland-Stacey et al 2017).*

Gauge corrected radar is, as the name suggests, when rain radar data is merged with rain gauge data in order to mitigate against some of the inherent errors of rain radar. Even here, however, the merging techniques do not necessarily result in a low-error estimation of precipitation quantities. The analysis needs to account for a sparse and uneven gauge network, complex topography, and a complex and variable distribution of precipitation (Amorati *et. al* 2012).

Three days after the storm, the MetService provided a series of gauge corrected rain radar images from 1800 hours to 2100 hours 19th June 2021. These times are in UTC or coordinated universal time and thus each of the 25 images need to be corrected to standard New Zealand time which is 12 hours ahead of UTC. Thus 1800 hrs is 6PM UTC 19th June or 6AM 20th June and 2100 hours is 9PM UTC or 9AM 20th June. It is not clear why the information was supplied in UTC rather than in New Zealand time.

The gauge corrected rain radar for the period 6 AM to 7 AM is shown below (**Figure Twenty One**). Bearing in mind that the rain radar is not showing precipitation at the surface, it shows a band of heavy rain approaching Tokomaru Bay at around 6 AM with the band passing through by 6:30 AM. By the 6:30 AM image rain cells marked by dense red patches are evident to the south of Tokomaru Bay and these can be seen building as they move south and by 6:52 AM these dense cells are south of Tolaga Bay while a linear NNW band of denser cloud approaches Tokomaru Bay from the north arriving at Tokomaru Bay by 7 AM.

It is notable that these denser cells are not visible at Tokomaru Bay in the images from 6 AM to 6:22 AM and only become apparent to the south from 6:30 AM. It is considered probable that the 6 to 6:22 AM images recording the rain mass at a height of 1.5 to 3km was masking heavier rain at altitudes below 1.5km. As the rain band moved south the radar is imaging the weather at progressively lower altitudes and the dense cells thus become more apparent. Because there are no official rain gauges in the vicinity of Tokomaru Bay, this inference cannot be verified. It is, however, consistent with the on-the-ground observations by some residents.

The gauge corrected rain radar for the period from 7 AM to 9 AM is shown in **Figure Twenty Two** below. This shows the narrow NNW oriented linear rain band sliding down the coast passing over Tokomaru Bay from 7 AM to 8:30 AM. By 8:45 AM this linear rain band clears Tokomaru Bay and moves out to sea.

While the gauge corrected rain radar data cannot be used for quantitative precipitation estimation (QPE), it can be used for a qualitative assessment of the duration of the event and it also is a useful tool for interpreting the movement of rain cells which will not necessarily associate with rain gauge sites. This is particularly significant in this storm as while the closest rain gauge at Te Puia captured the main part of the storm that passed over Tokomaru Bay between 6 and 7 AM the narrow NNW oriented band of rain that followed seems to have passed to the east of Te Puia and thus would not have been fully reflected in the records from that site. A direct comparison between the uncorrected and gauge corrected radar image for just after 7Am is shown in **Figure Twenty Three** below.

Barry Sanders Rain Gauge at 17 Beach Road Tokomaru Bay

Gisborne District Council does not have a rain gauge in the Mangahauini, Kaiawha or Waiotu catchments which discharge into the sea at the north end and south end of Tokomaru Bay. Fortuitously, Council engineer Barry Sanders has a gauge at his holiday home at 17 Beach Road, Tokomaru Bay. This gauge does not meet the functionality of the council rain gauge network and is not subject to the same rigorous calibration tests as the council gauges. Barry was, however, able to provide an appropriate level of documentation that indicates that the gauge can be used to provide an indication of the rainfall over the duration of the event. He observed, "*Rain was measured for period from after lunchtime day before the rain and at 10am next morning after rain had stopped. I measured 160mm at 17 Beach Road Tokomaru bay. I don't think it started raining until after 5 pm the day before - so 160mm fell between 5pm and 10am (more likely 9am*)".

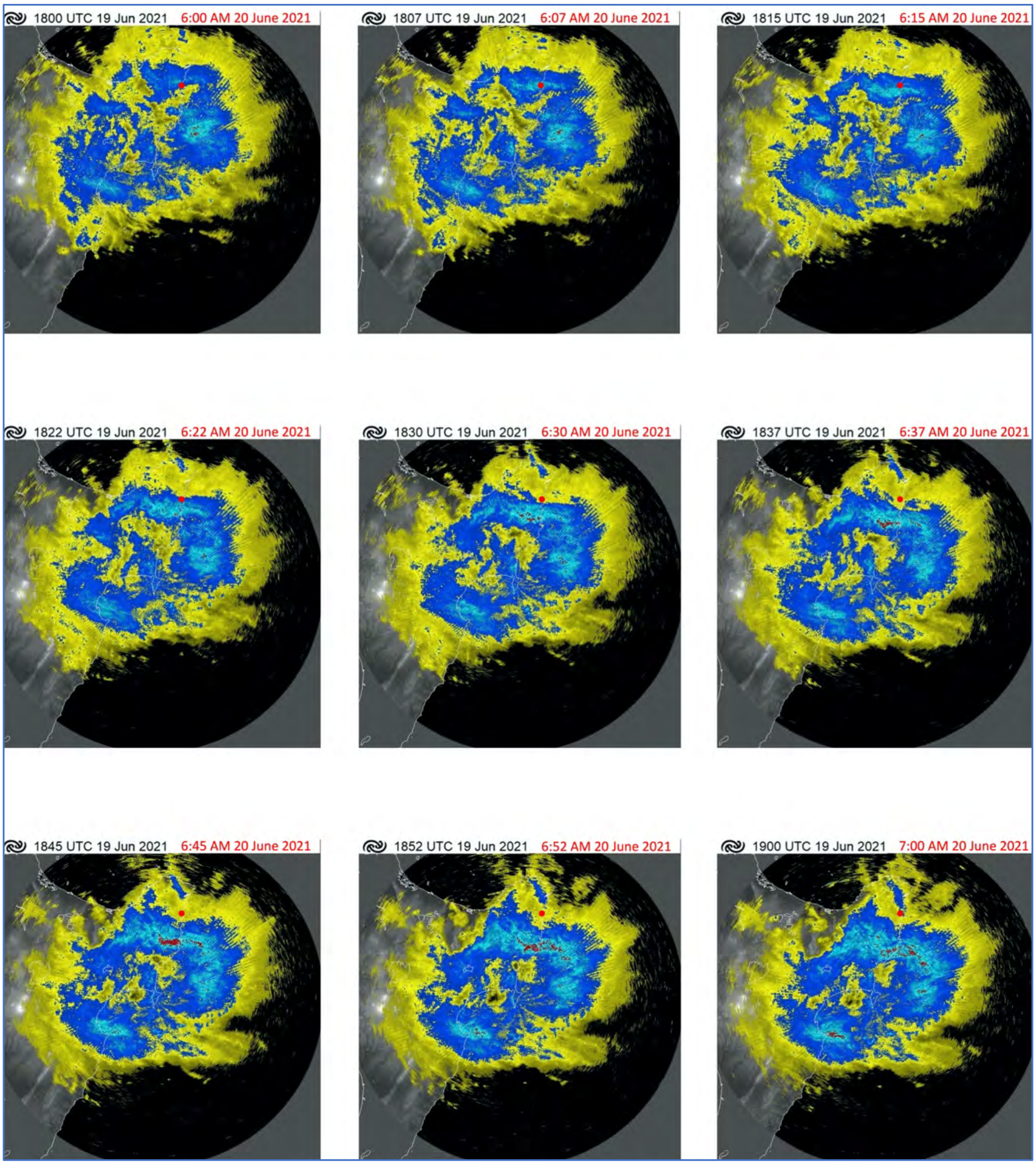

Figure Twenty One. *Gauge corrected rain radar imagery from MetService for 6 AM to 7 AM showing the gradual movement of the rainstorm as it moved from the north to the south east. The red dot marks the location of Tokomaru Bay.*

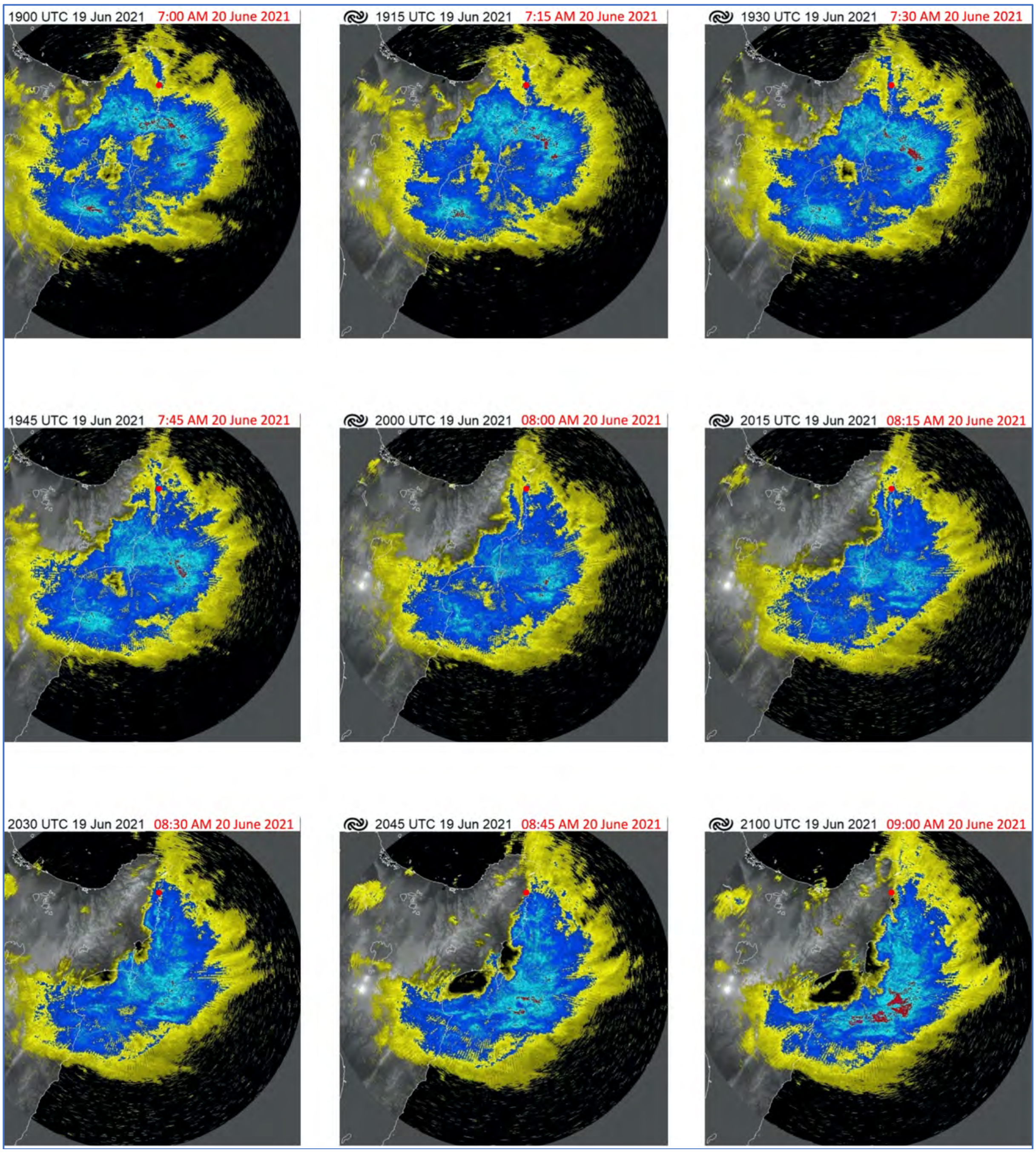

Figure Twenty Two. *Gauge corrected rain radar imagery from MetService for 7 AM to 9 AM showing the narrow NNW oriented linear rain event. The red dot marks the location of Tokomaru Bay.*

The Council gauges record at 5 minute intervals while the Sanders gauge only gives us the total rainfall for the event. The council gauges and the rain radar both indicate that this storm lasted for about 12 hours and locally a bit more. What it does say is that Tokomaru Bay received 160mm over the storm duration. This is less than the 180mm+ received at Waikura Valley but is more than the 12 hour accumulation at Te Puia (150.4mm) even though Te Puia is less than 8.5km northwest of Tokomaru Bay.

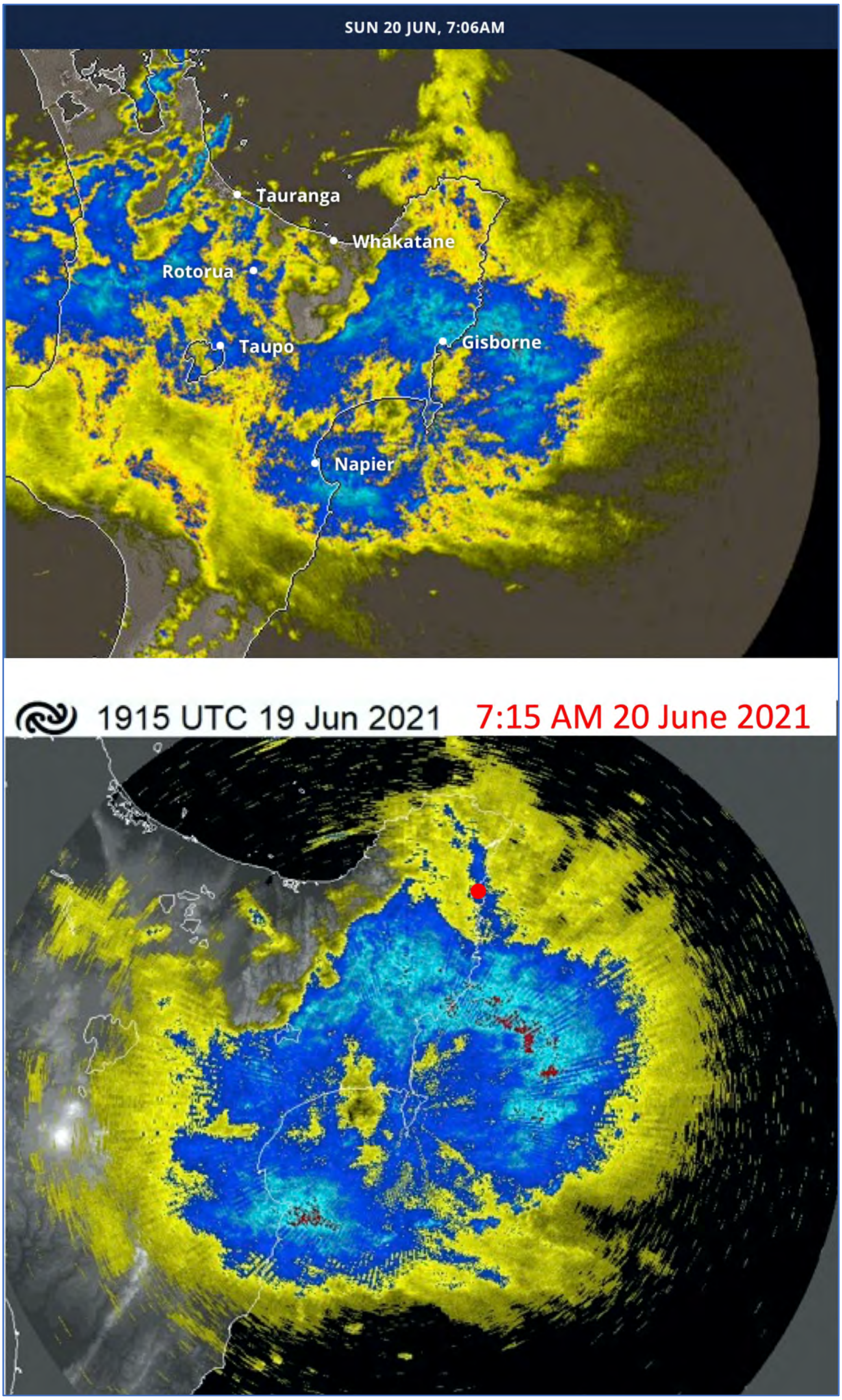

Figure Twenty Three. *Comparison between the 7:06 uncorrected rain radar with the 7:15AM gauge corrected rain radar showing the more distinct tail in the gauge corrected radar..*

Assessment of the Gisborne District Council Rain Gauge Network

Gisborne District is fortunate that it has an extensive rain gauge network relative to some other regions. The 20th June 2021 storm (as with other events such as the Queens' Birthday storms of 2018) demonstrates that no rain gauge network can capture all of the detail of every storm. The rain gauge network is, by definition, based on discreet locations and can thus only reflect what is happening at that point at that date and time. A localised rain cell may fortuitously miss a rain gauge and thus the network may under-report, or not accurately record individual storm events. This seems to have been the case with the storm of 11-12th June 2018 and with respect to Tokomaru Bay the same appears true on the 20th June 2021.

This is not a critique of the Council rain gauge network which is, as noted above, more comprehensive than those in some other districts. The topography of Tairawhiti is unique with a spine of higher ranges in the Raukumara and a largely hilly hinterland between the ranges and the sea marked by very limited river valleys with a pronounced NW orientation for those river valleys between Tolaga Bay and Te Puia. This means that rainfall will be strongly controlled by localised orographic influences and there will thus always be a strong degree of unpredictability.

The rain gauge network and the 12 hour accumulations for the 20th June 2021 storm are shown in **Figure Twenty Four** below. This shows that there is a good gauge coverage for the Raukumara ranges from Tokomaru Bay north and also a good coverage of the Waipaoa catchment. There are, however, gaps in the south west, in the southern raukumara, and between the Raukumaras and the coastal sites, as well as between coastal sites in the northern half of the region. It needs to be noted that adding rain gauges to the system will add additional load on the Environmental Monitoring Team and thus have potential resource capacity implications.

It also needs to be stressed that any assessment of rainfall and storm events generally requires that a qualitative lens is placed over the data. For example, a 12 hour period has been used in this assessment but as exemplified by **Figure Five** above, the heaviest rainfall period ranged from 9 hours to 12 hour plus. A 12 hour period was determined after assessing the rainfall at each site on a 1 hour, 12 hour and 24 hour interval.

A statistical analysis indicated that 93% of the mean rainfall fell across all rain gauges in the region within that 12 hour window (See **Table One** for the rainfall data used). The 12 hour maximum accumulation shown in **Table One** has been used to generate a contour map that encapsulates the storm event **(Figure Twenty Five**).

There were some outliers such as Wheatstone road (86%), Tatapouri Hill (84%), Raukumara Station at 73% and East Cape Lighthouse at 85%. The biggest outlier at Raukumara Station is understood to be related to the exposed nature of the site where wind-loading can distort the data. Following the initial assessment, Mangaheia at Willowbank site also looks anomalous with a 12 hour rainfall accumulation of 55mm.

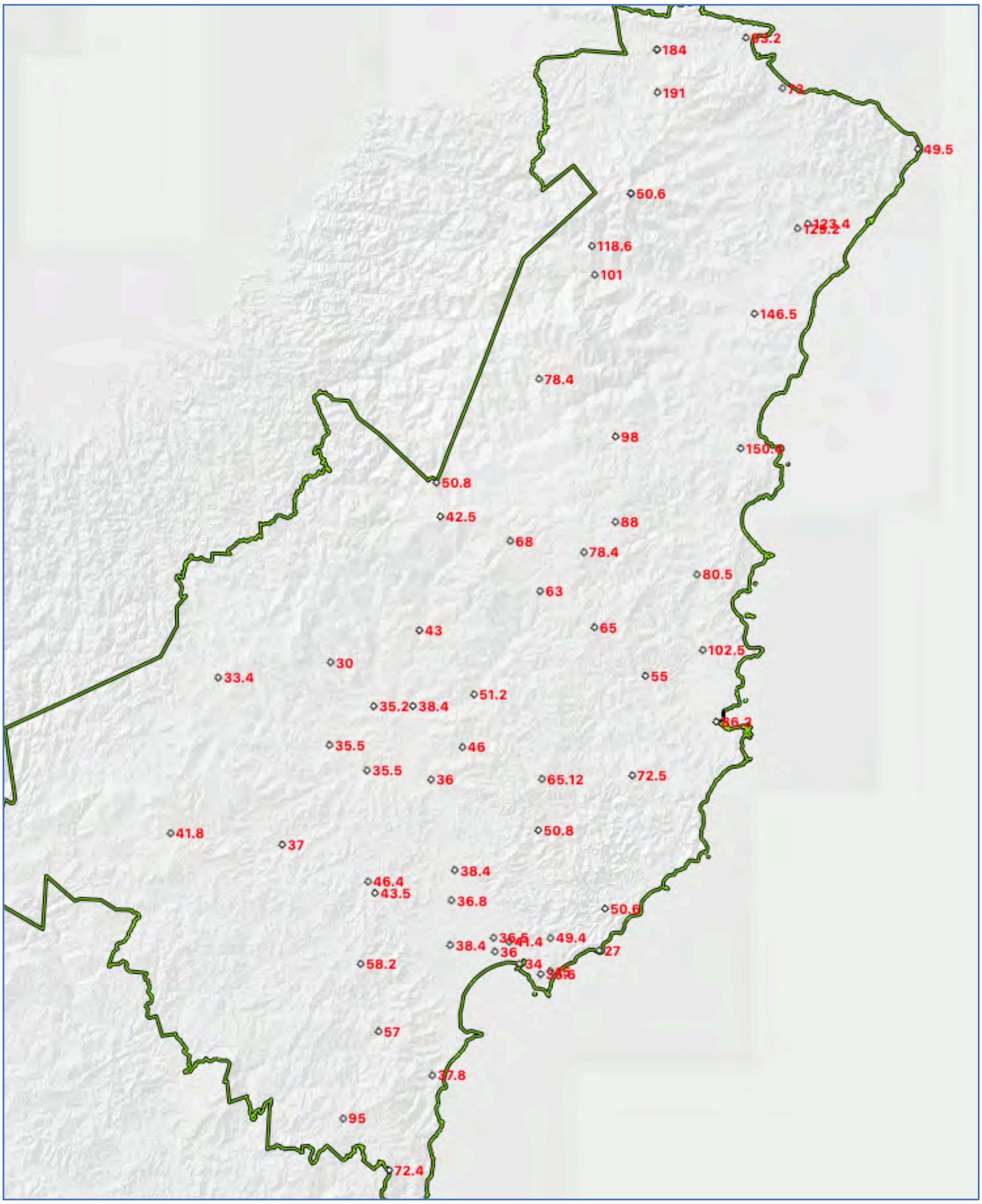

Figure Twenty Four. *Location of Gisborne District Council rain gauge sites showing the maximum rainfall accumulations over the 12 hour storm event at each gauge site.*

Further, this assessment is based on data exported from the Hilltop software system for hourly intervals from midnight 18th June through to midnight 22nd of June. Thus the "hours" used are the normal hours in New Zealand time. This gives a maximum hourly peak for Te Puia at 60.1mm, whereas Hilltop gives the hourly peak at 70mm because it picks the maximum 60 minute interval accumulation rather than at which hour that maximum accumulation occurs. Neither is right or wrong, they are just recording accumulations in subtly different ways.

Table One*. The peak rainfall accumulation period in hours, plus 24 hour, 12 hour and 1 hour maximum accumulations.*

Site	Peak Period	24 hours	12 hours	1 Hour Max
Arowhana Repeater	9	53.6	50.8	7.6
Caesar Rd No.1 Bore GPG058	8	40.4	38.4	8.6
Cameron Rd No.1 Bore GPB099	7	38.5	36.5	12
East Cape at Lighthouse	8	58	49.5	9
Fernside Station Telemetry Station	10	93	88	16
Gisborne Airport Met Stn	7	38.8	36	11
Hika No.1 Bore Ferry Road GPE032	8	39.2	36.8	8.8
Hikuwai River at No 4 Bridge	11	84	80.5	15.5
Hikuwai River at Willowflat	9	109	102.5	37
Karakatuwhero River at SH35 Br	12	86	73	18
Komihana Station	8	31	30	6.5
Mangaheia at Willowbank	9	57.5	55	10
Mangapoike at Reservoir	10	99.5	95	16
Mangatu River at Omapere Station	6	37.2	35.2	6.8
Maraetaha River at No.3 Br	8	42.4	37.8	8
Mata River at Pouturu Br	10	106.5	98	14.5
Matawai Telemetry Station	8	34.6	33.4	6.8
Ngatapa school	8	49.2	46.4	10.4
Oweka River @ SH35	12	194.8	184	41.6
Pakihiroa Telemetry Station	10	109	101	18.5
Panikau Rd - Reed Rd	10	75.5	72.5	17.5
Parone Rd RG	9	37.8	35.6	9.8
Poroporo Fire	12	146.2	129.2	27.2
Poroporo River at SH35 Bridge	12	141	123.4	24.4
Pouawa Fire	10	56.4	50.6	10.4
Puketawa Station	10	88.6	78.4	15.8
Puketoro Telemetry Station	10	84.4	78.4	13.4
Raparapaririki (RIP)	11	130.6	118.6	18.2
Raukumara Stn	11	69.4	50.6	7.4
Ruatoria Telemetry Stn at Barry Ave	11	160	146.5	55.5
Stout St RG	9	44.2	41.4	12.4
Tatapouri Hill	9	32	27	6.5
Tauwhare Station	9	69.8	68	16.4
Te Arai River at Pykes Weir	10	60.5	57	12.5
Te Puia	11	154.4	150.4	60.1
Te Rata Telemetry Station	9	43.5	42.5	8
Tuahu Station	10	66.5	65	11
Tutamoe Station Telemetry Station	9	64.5	63	12
Uawa River at SH35 Bridge	9	95	86.2	34.6
Waerenga-O-Kuri	10	61.8	58.2	14.2
Waihora River at No.3 Br	8	48	46	9.8
Waikanae Creek at Customhouse Str Br	8	35.8	34	9.4
Waikohu River at No.3 Br	9	37.5	35.5	7.5
Waikakariki Stream at Kirkpatrick Br	8	46	43.5	10
Waikohu River at Mahaki Station	8	37.5	35.5	7.5
Waikura Valley	12	207	191	49.5
Waimata River at Goodwins Rd Bridge	9	52	49.4	11.6
Waimata River at Monowai Bridge	9	52.8	50.8	10.8
Waingaromia River at Terrace Station	8	52.4	51.2	12.4
Waipaoa River at Kanakanaia	9	37.5	36	7.5
Waipaoa River at Matawhero Bridge	9	41.8	38.4	10.4
Waipaoa River at Te Hau Station Rd Br	8	40.4	38.4	10
Waipaoa River at Waipaoa Station	8	43.5	43	7.5
Wakaroa Trig	8	67.4	65.2	14.4
Wharekahika River at Hicks Bay Rd Br	13	102.6	93.2	29
Wharekopae River at Rangimoe	8	40	37	10.5
Wharekopae School	7	43.8	41.8	8.4
Wharerata at Radio Track Rd	7	80.8	72.4	12
Wheatstone Rd	7	17.5	15	7.5

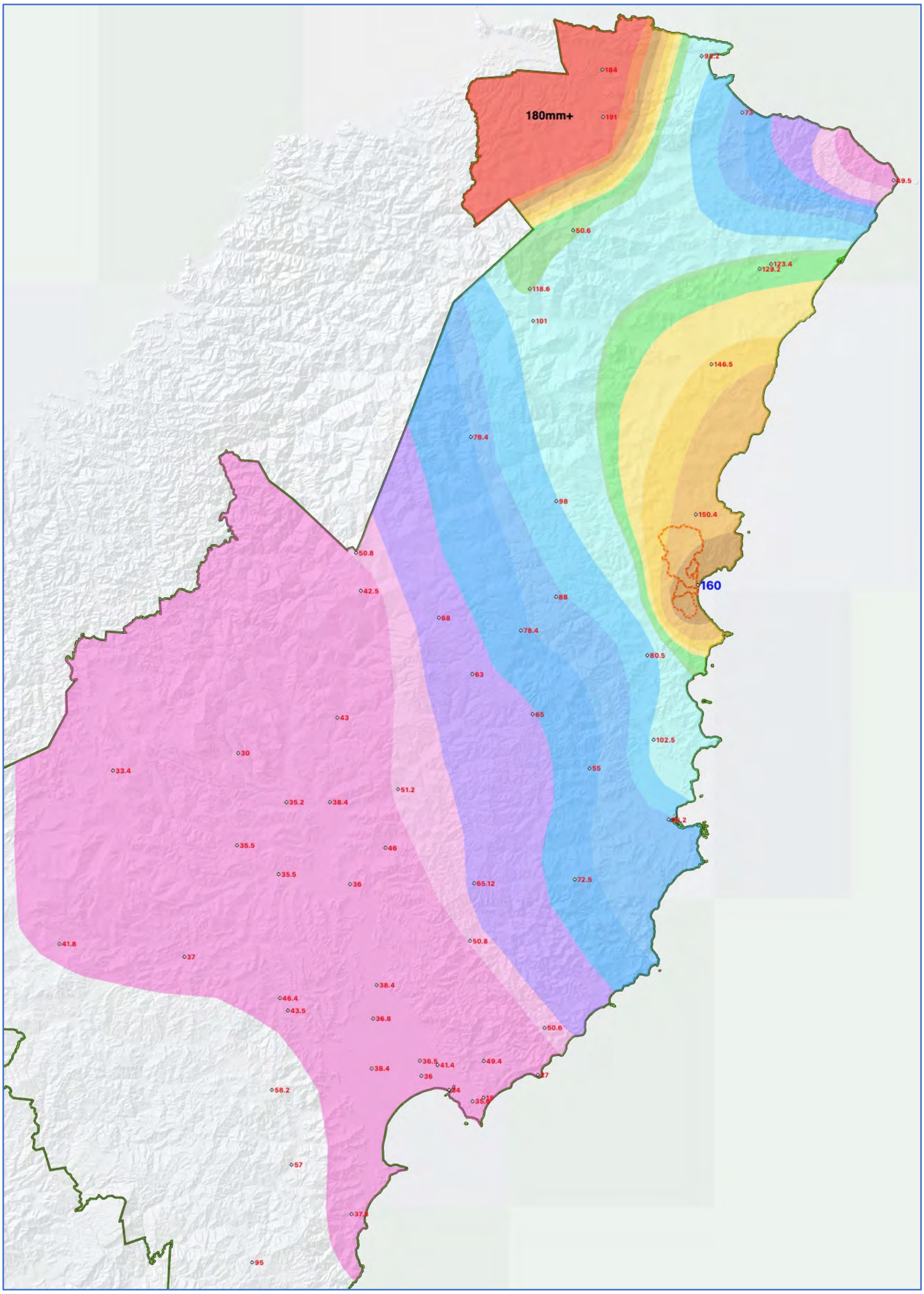

Figure Twenty Five. *Contour plot of the 20th June 2021 storm using the 12 hour accumulations including the Sanders Tokomaru Bay data but discounting the Raukumara and Mangaheia at Willowbank gauges. This shows two key rainfall hotspots at the Waikura Valley and centred on Waipiro Bay to Tokomaru Bay.*

Because the rain gauge data for Tokomaru Bay only provides for a total event accumulation, the two closest gauges at Te Puia and Hikuwai at No.4 Bridge have been looked at in more detail. This highlights the strongly localised nature of the event with Te Puia showing a short very pronounced short duration rainfall accumulation peak that is largely absent at Hikuwai and No.4 bridge but apart from that pronounced peak the two rainfall accumulations are very similar (**Figure Twenty Six**). It also shows that the rain event started in this area at around 10 PM on the 19th and was steady until 5 AM on the 20th when the rain started to ease. At 6AM the rainfall started to climb again at both sites peaking at 60mm at just after 8 AM at Te Puia and at 15mm at 8:30 AM at Hikuwai. Rainfall had largely stopped at 9:30 AM at both sites. The data indicates that the heaviest rain fell primarily between 7 and 9:30 AM (1 ½ hours) and then cleared rapidly.

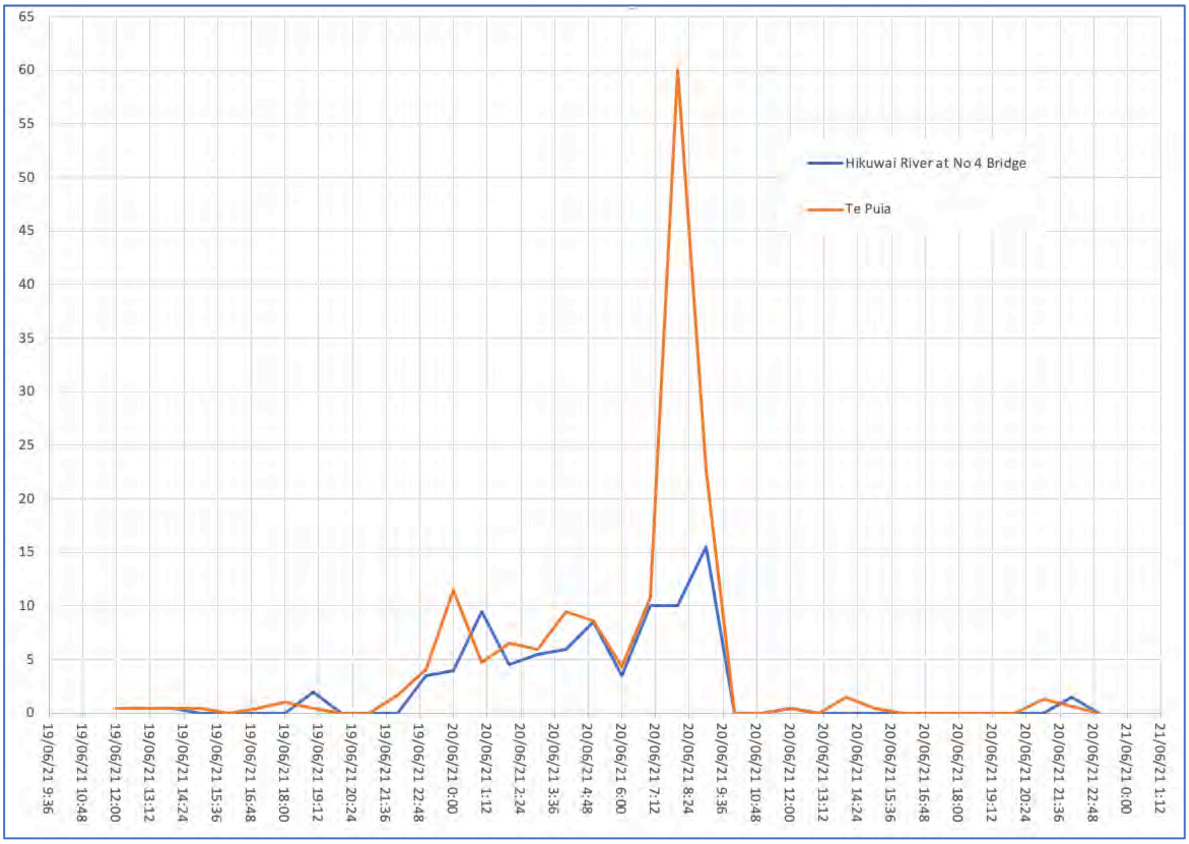

Figure Twenty Six. *Rainfall accumulations for Te Puia (red) and Hikuwai at No. 4 Bridge for the 20th June 2021 event. This shows that the rainfall was very similar for both sites except for the short duration peak at Te Puia.*

HIRDS v.4

The NIWA HIRDS (**H**igh **I**ntensity **R**ainfall **D**esign **S**ystem) v.4 was used to determine the Average Recurrence Level (ARI) for the event. There are no gauge sites at Tokomaru Bay although there were two sites there previously (Tokomaru Bay 1 which recorded daily values from 1916 to 1968 and Tokomaru Bay 2 which recorded daily rainfall from 1967 to 1975). HIRDS does, however, allow the generation of an ARI based on a virtual rain gauge site. Assessment of such a virtual gauge site at the Tokomaru Bay War Memorial indicates that the 160mm recorded at Barry Sanders house would have an 12 hour rainfall accumulation ARI of 13.5 years, while the event overall had a 12 hour rainfall accumulation of ARI of 2.5 years[3]. It is estimated that the peak rainfall over 1 ½ hours would have had an ARI of 30 to 35 years assuming that around 70 to 75 mm fell within that 1 ½ hour window or a 100 year ARI if it fell within an hour.

Conclusions from rainfall analysis

While the gauge at Tokomaru Bay cannot tell us exactly when the most intense rainfall was in the township, the alignment of the accounts from the locals, along with the adjacent rain gauge data and the rain radar all essentially tell different elements of the same story. That is, a relatively typical rainfall event with a 2.5 ARI as determined by comparison with Hikuwai and had an overprint of a short high intensity rainfall accumulation over a one and a half hour period equivalent to an ARI of 35 years or up to 100 years over a 1 hour period.

The rain radar cannot be used to corroborate this assessment, but in this particular storm the radar was useful. It shows that the event overall was marked by a frontal system which moved across Tairawhiti with moderate to heavy rainfall from late evening on the 19th to around 6 AM on the 20th. A pronounced linear tail to this event looks innocuous on the rain radar but acted like a narrow conveyor belt bringing sustained heavy rain to a confined coastal area between Waipiro Bay and Te Puia south to Tokomaru Bay. The impact of this conveyor was not felt further south as the system moved offshore.

Flooding

Tokomaru Bay experienced severe flooding on the morning of 20th June but since there are no flood gauges in the 3 catchments that discharge into Tokomaru Bay, the observations of local residents are the only means of assessing flood duration. The flooding was exacerbated by having both main catchments, the Mangahauini in the north and the Waiotu/Kaiawha in the south receiving significant rainfall over a short duration.

The flooding was particularly dramatic as the images and video of State Highway 35 at the southern approach to Tokomaru Bay attest (see **Figures Fifteen, Sixteen and Seventeen** above). The reports from the local residents point to flooding being evident from 7 to 7:15 AM and reaching a peak by 8:30 to 8:50 AM before rapidly receding. The combination of a very short (1.5 hour) very heavy rainfall event very closely coinciding with a flood duration points to flash flood conditions.

Impact of tides and storm surge on flood spread

Council staff were on site soon after 10 AM by which time the flood had receded and local contractors had started working on clearing mud off the road. During the site

[3] The normal event can only be estimated of course and is based on subtracting the peak rainfall at Te Puia from that at Hikuwai No. 4 Bridge to derive a 12 hour rainfall of 100 mm.

inspection, it was observed that there was a significant number of logs thrown onto the foreshore at the mouths of both the Waiotu and Mangahauini Rivers (**Figures Twenty Seven and Twenty Eight**). A high tide or storm surge can affect the impact of a flood in a coastal environment such as Tokomaru Bay by creating a barrier preventing flood flows from efficiently discharging to sea. The presence of the logs and erosion at the mouth of the Mangahauini indicates that there was a coastal influence but not whether or not it was due to the tide or the result of storm surge.

Figure Twenty Seven. *Woody debris thrown up onto the freedom camping area south of the mouth of Waiotu Stream.*

Figure Twenty Eight. *Woody debris thrown up onto the reserve immediately north of the Mangahauini Stream. Also evident is the extent of erosion of the banks at the reserve.*

The tidal data for the period was obtained from the NIWA Tide Forecaster website (**Figure Twenty Nine**) and this showed that low tide was at 7:24 AM on the 20th June 2021. Thus the flood coincided with low tide and would not have exacerbated the effect of the flood.

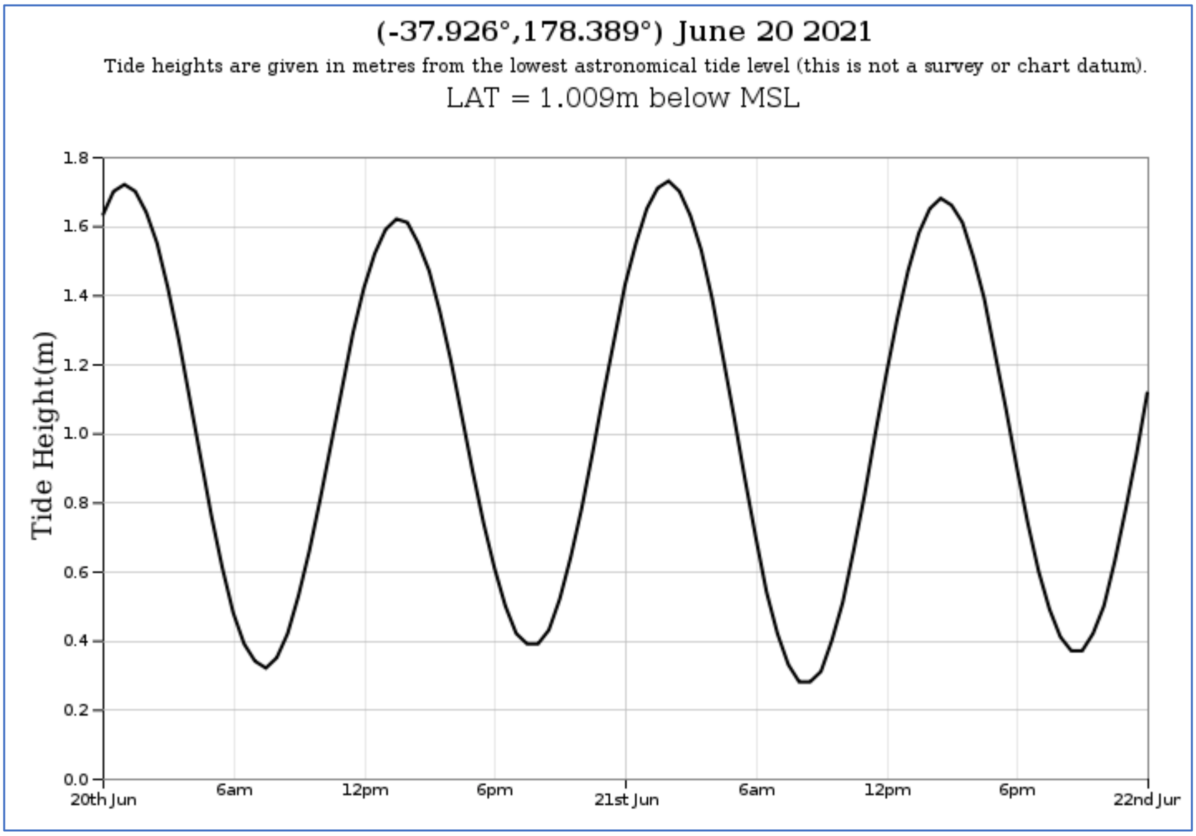

Figure Twenty Nine. *Tide chart for the 20th June 2021 from the NIWA Tide Forecaster website showing that low tide coincided with the flood period.*

The swell map from Weatherwatch for the 20th of June showed a 4M+ swell offshore but the Swellmap website showed a more significant swell or storm surge event with 4 to 5m swells close to shore along with NE winds (**Figure Thirty**). These maps only provide a generalised perspective of swell or storm surge and it is anticipated that a storm surge was generated by the tail end of the weather event as it moved down the coast.

Drone mapping

Two drone flights were scheduled shortly after the event to see whether or not they could assist understanding of the flood spread from the event. These were flown on the 23rd June with the first covering the mouth of the Kaiawha Stream and the lower Waiotu (**Figure Thirty One**) with the second covering the Mangahauini Stream from upstream of the Tokomaru Transfer Station (**Figure Thirty Two**). The drone footage provides high resolution imagery and contours of the areas affected by the flooding and also compliments the on the ground inspections carried out on the 20th June and in the week following the flooding.

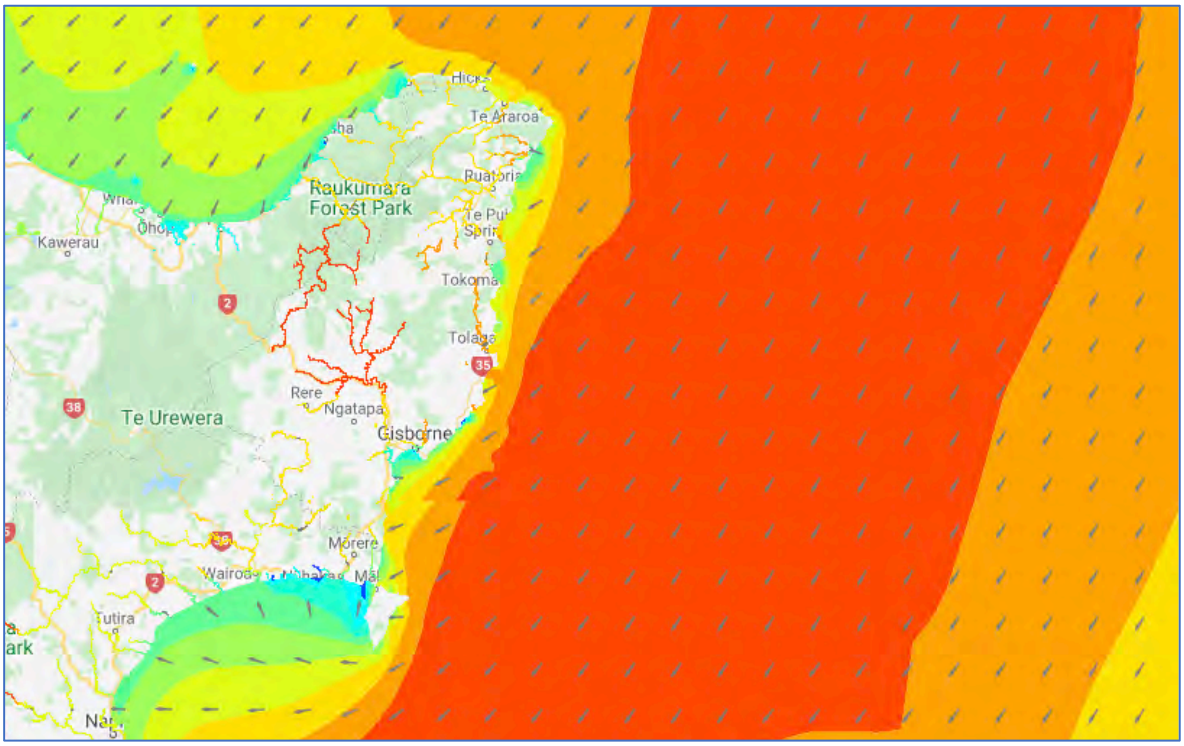

Figure Thirty. *Swell map for the Tairawhiti region for the 20th June 2021 showing 4m swells close to shore with 5m waves further offshore.*

Figure Thirty One. *Drone orthomap for the Kaiawha and Waiotu Streams flown on the 23rd June 2021.*

Figure Thirty Two. *Drone orthomap for Mangahauini Stream flown on the 23rd June 2021. The 160 annotation at] the right of the image indicates the location of the Sanders rain gauge site.*

Kaiawha Tributary Waiotu Catchment

Dramatic flooding occurred on State Highway 35 on the southern approaches to Tokomaru Bay and this is was an area of focus during the investigation into the flood event. No sign of flooding were observed until the bridge over Kaiawha Stream where mud could be seen on the true left bank of the stream immediately downstream of the bridge. There was some mud in the water tables on the road immediately east of the bridge but no sign of significant flooding until 100m passed the bridge[4]. A scan upstream of the Kaiawha Stream in the Waiotu did not show signs of significant flooding but some scour was evident looking up the Kaiawha.

On the 22nd June, the reach of Waiotu stream above the confluence with the Kaiawha were accessed from a variety of points. This did not reveal any signs of significant flooding. There was bank scour at a number of locations which caused some river bank trees to collapse into the river. Silt deposition was observed at one location very close to the normal riverbed level suggesting that relatively minor flooding occurred in the catchment (**Figure Thirty Three**).

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[4] *As local contractors were already working to clean mud off the road, no assessment on this area was undertaken on the 20th June.*

Figure Thirty Three. *View of Waiotu Stream upstream of the confluence with Kaiawha Stream showing signs of scour (top left) and silt deposition (middle right). The silt is very close to normal river level and there is no indication on inundation on the true right bank (bottom right).*

The Kaiawha River immediately upstream of the bridge on State Highway 35, however, showed more significant signs of flooding with the river a lot muddier, woody debris wedged against trees and a debris fence broken free from the true right bank (**Figure Thirty Four**). Mud and woody debris was observed wedged against the fence at the top of the bank indicating high flood levels (**Figure Thirty Five**).

Figure Thirty Four. *Kaiawha Stream upstream of the SH 35 Bridge showing the damaged debris fence and woody debris caught against the trees.*

Figure Thirty Five*. Fence at top of bank of Kaiawha Stream upstream of the SH 35 Bridge showing woody debris caught up in fence and mud deposited on the river side of the fence.*

Approximately 650m up Kaiawha Road a ford provides access to the road end farmhouse but was blocked by up to 60cm of silt deposition. The silt deposition height was approximately 1m above river level and there was a considerable amount of debris scattered on the river bank downstream of the ford. The force of the flood appears to have been strong enough to move large boulders. (**Figure Thirty Six**).

Figure Thirty Six. *Photograph of the ford 650m upstream of the bridge on State Highway 35 showing the depth of silt deposition (bottom left), the height of the flood spread based on the debris layer and the mobilised boulders on the ford path.*

Further upstream the extent of the flooding was even more obvious with debris at approximately 2m above river level (**Figure Thirty Seven**) and the flood spread reaching all the way across the valley floor (**Figure Thirty Eight**) while in slightly raised parts of the valley the edge of the flood was marked by a debris line of small woody debris (**Figure Thirty Nine**). Further upstream there was evident of overground flow (**Figure Forty**).

Figure Thirty Seven. *Photograph upstream of the ford on Kaiawha Road showing the extent of flooding upstream of the ford on the Kaiawha Road.*

Figure Thirty Eight. *Photograph upstream of the ford on Kaiawha Road showing debris caught up in the trees and mud deposited across the valley floor.*

Figure Thirty Nine. *Photograph upstream of the ford on Kaiawha Road showing the edge of the flood spread against higher ground.*

Figure Forty. *Photograph upstream of the ford on Kaiawha Road showing mud deposition resulting from over-ground flow.*

Based on the on-the-ground observations, it is evident that the flood that affected the southern half of Tokomaru Bay was largely the result of flooding out of the Kaiawha Stream rather than Waiotu Stream. This is confirmed by analysis of the drone flight from the 23rd of June and supplied video of the event. A detailed view of the drone footage is shown in **Figure Forty One** below. A few key points are evident in assessing this image. The first of these is that the flood in the Kaiawha Stream broke out of the true left river bank immediately downstream of the bridge on State Highway 35. In addition, the extensive silt deposition downstream of this discharge location. This contrasts with the lack of silt upstream in the Waiotu.

Figure Forty One. *View of the Kaiawha Stream below the bridge on State Highway 35 showing the flood overtopping on the true left bank discharging into Waiotu Stream and the silt deposition downstream from there.*

Video footage provided by Tianna Rongonui (cf. **Figure Seventeen** p.12) gave an good indication of maximum flood spread and enabled the drone mapping to be calibrated. It also help show that the willow in the middle of Waiotu Stream had a negligible effect on flood spread (**Figure Forty Two**). This is also evident from the mapped flood for this area (**Figure Forty Three**) which showed that it had a width of almost eighty metres while the river bed occupied by the willow was only eight metres wide.

Figure Forty Two. *Video still provided by Tianna Rongonui showing the flood spread and with the large willow in the river in the background. As can be seen the flood spread was considerable wider than the normal river banks at point and had occupied the entire flood plain.*

Figure Forty Three. *Mapped flood spread in the Waiotu below Kaiawha Stream showing that the willow occupying the river channel occupied only a small part of the flood spread.*

Figure Forty Four below which is also a still from Tianna Rongonui's video shows the extent of the flood spread on the true right and the contribution of overland flow from adjacent properties.

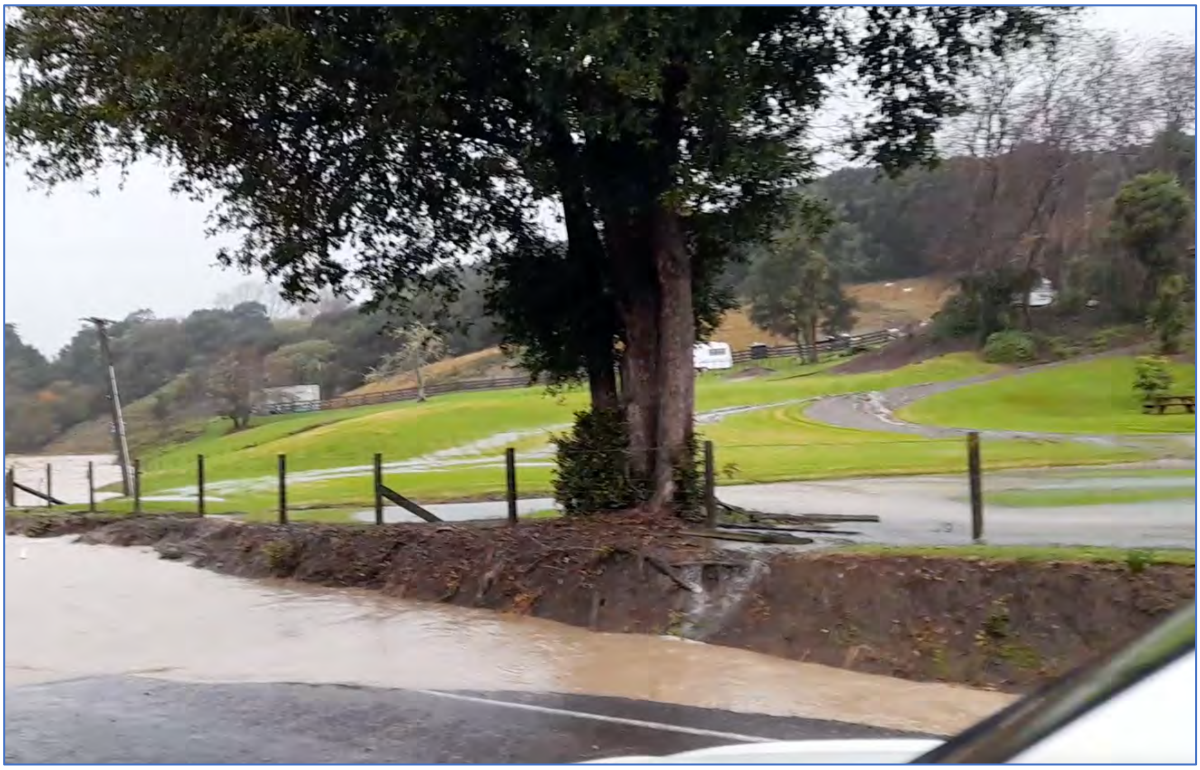

Figure Forty Four. *Still from the video provided by Tianna Rongonui showing the flood spread on the state highway approach to Tokomaru Bay with the flood spread contribution from adjacent properties.*

The video footage from 3552 Waiapu Road State Highway 35 (**Figure Forty Five**) is also helpful as it graphically demonstrates the significant degree of overland flow during the storm. This calibration is useful because post-event on the ground mapping and the drone footage cannot readily differentiate between flood spread and overland flow.

The role that overland flow had in this storm is evident in **Figure Forty Four** and **Forty Five** and it is considered that this overland flow was a significant exacerbating factor particularly in the vicinity of the School **(Figure Forty Six**), at Café 35 (**Figure Forty Seven**) and the Playgrounds (**Figure Forty Eight**). The force of the flood waters within the Kaiawha/Waiotu catchments is graphically illustrated in **Figure Forty Nine** which shows the scoured out true left abutment of the footbridge at the mouth of Waiotu Stream.

Figure Forty Five. *Video screenshot from No. 3552 Waiapu Road State Highway 35 showing the flood extent over the paddock and the considerable volume of overland flow on the hillside opposite.*

Figure Forty Six. *Flooding and silt deposition at Hatea-A-Rangi School, Tokomaru Bay.*

Figure Forty Seven. *Flooding at café 35, Tokomaru Bay. It is assessment that the flooding here was the result of overland flow rather than flooding from the Mangahauini River (Source Facebook post).*

Figure Forty Eight. *Flood water ponded at the north end of the Hatea-a-rangi Memorial Park.*

Figure Forty Nine. *The washed out abutment of the footbridge at the mouth of Waiotu Stream.*

Mangahauini River

On the 20th June, the Tokomaru Bay Transfer Station on the Mangahauini River, off Toa Street was visited. There was considerable mud along Toa Street with clear signs that flood waters had reached the floor plate of a number of houses. At the transfer station itself, it was clear that the flood waters had overtopped the area pulling apart the fence at the upstream side of the river and scouring the riverbank on which the transfer station is built. (**Figure Fifty**).

Figure Fifty. Flood impacts at the Tokomaru Transfer Station.

The flood in the Mangahauini was more complex than for the Kaiawha/Waiotu with overland flow playing a more significant role. It is therefore helpful to establish the relative roles of river flood flow and overland flow. The location of the highway above the houses meant that overland flow would also have exacerbated flooding at Toa Street but culvert issues were also relevant here and thus have been considered first[5].

Culvert on State Highway 35

The status of the culvert on State Highway 35 immediately north of Tokomaru Bay has been identified as a possible exacerbator of the 20th June 2021 floods. The culvert drains a relatively small stream immediately south of the prominent peak of Marotiri and has a catchment of 35.9 Ha (359,022 m^2).

Reliable information on its pre-flood condition was difficult to come by although there were anecdotal reports from local residents suggesting it was blocked. This was confirmed by Waka Kotahi sometime after the event who advised that they were aware of the blockage but were also concerned that the culvert would immediately block again due to the volume of sediment in the tributary it drained. Accordingly they had initiated planning for a medium to long term solution but had arranged for contractors to clear the culvert but that was not done before the storm hit.

The key issues were;

- how serious was the blockage (ie did the culvert allow some flow),
- how much flood flow was there, and
- what impact this blockage would have had on flow paths during the flood.

The drone footage and a site inspection were used to assess whether or not the culvert was fully blocked. This indicated that there was negligible flow through the culvert but some water also reached the stream downstream of the culvert via the road surface and the water table immediately east of the culvert on the downstream side of the road (**Figure Fifty One**).

The volume of water discharged by the creek was estimated using the Rational method which uses the catchment area, rainfall depth and a simplified runoff co-efficient. The runoff co-efficient was estimated using the areal reduction factor tables used in the Christchurch City Council Waterways, wetlands and drainage guide as a proxy for infiltration, natural retention, evaporation etc. Based on this a gross 27,000 m^3 of rainfall fell within the 1 ½ hour duration heavy rainfall event or 57,600 m^3 of rainfall during the 12 hour period. This would equate to a corrected available volume to discharge from the catchment of 23,220 m3 over 1.5 hours or 48,960 m3 over 12 hours. This equates to a peak discharge from "Marotiri" stream of 5,400 litres/second or 5.4 cumecs.

The culvert comprises two 1m diameter circular pipes which have a clear discharge rate of 1.07 cumecs each (ie 2.14 cumecs combined). No culvert will ever be

[5] *A key culvert on State Highway 35 north of Toa Street had been reported as blocked prior to the storm by local residents but it was initially not clear whether or not it was fully or partially blocked at the time. Waka Kotahi have subsequently confirmed that the culvert was fully blocked. This issue is discussed more fully below.*

completely clear, however, due to debris on the culvert floor and a discharge rate of 1.8 to 2 cumecs is more realistic. The typical culvert has a 20 year ARI design storm threshold and thus this threshold would have been exceeded by the 20th June event which had a 1 ½ hour ARI of 35 years (or a 100 year ARI if the peak duration was only 1 hour).

Ultimately the analysis indicates that if the culvert had not been blocked, the culverts discharge capacity would still have been exceeded by around 3.4 to 3.6 cumecs. Thus water from “Marotiri” stream would still have flowed down highway towards Toa Street but the blockage increased the volume of flow. Not all of the peak discharge of 5.4 cumecs would have reached Toa street by this pathway, however, as some did bypass the culvert and re-enter the stream immediately downstream of the culvert (c.f **Figure Fifty One**) while the assessment of overland flow suggests that a significant portion of this water flow discharged onto ground at two points west of Toa Street (*see overland discussion below*) .

Figure Fifty One*. drone footage of the blocked culvert on State Highway 35 showing the overland flow path to the creek downstream of the culvert.*

The upstream side of the culvert blockage prior to clearing out is shown in **Figure Fifty Two** below. The extensive area of debris fill is evident as is the overtopping of the fence on the edge of the water-table. The upstream side after removal of debris is shown in Figures Fifty Three and **Fifty Four**. This shows the buried culvert but also the considerable amount of debris remaining which poses an ongoing risk of culvert blockage in the typical storms to be expected in any winter.

Figure Fifty Two. *View of culvert on State Highway 35 north of Tokomaru Bay prior to clearing. Note the extensive infill of debris and the indications of overtopping on the fenceline.*

Figure Fifty Three. *View of culvert on State Highway 35 north of Tokomaru Bay after clearing showing the considerable volume of debris remaining above the inlet.*

Figure Fifty Four. *View of culvert on State Highway 35 north of Tokomaru Bay after clearing. This shows that only a small pit has been dug at the inlet to allow for drainage. It is understood that further clearance is planned and that an assessment is underway to increase culvert capacity.*

Mangahauini Flood flow

Because of the issues with the culvert and the position of State Highway 35 above the dwellings on Toa Street, it is important to differentiate between flood flow in the Mangahauini and the considerable degree of overland flow that occurred during the storm. The overland flow did merge with the river of course, so differentiating between the two is difficult. The assessment based on the drone mapping indicates that except for pinch points such as the transfer station and some old meander loops, the Mangahauini remained within the river channel and stop banks on the true river bank[6].

Accordingly, the river flood spread has been mapped separately from the overland flow to allow for the flood inundation to be assessed as accurately as possible. The river flood spread from a point immediately upstream of the "Marotiri" side stream to the bridge on State Highway 35 at the mouth of the Mangahauini has been mapped and is shown in **Figure Fifty Five** below. The river below the State Highway bridge has been excluded from the flood spread inundation as this area was predominately

[6] There were two points where minor overtopping of the stop bank occurred. Further assessment is required of these two points.

affected by storm surge during the event. As **Figure Fifty Five** indicates the Mangahauini River was largely confined to its bed during the flood. There was flood spread into a low lying area on the true left immediately downstream of where the "Marotiri" tributary joined the Mangahauini, on the true left above the transfer station and across the transfer station itself. Some further inundation on the true left bank occurred east of Toa Street but otherwise no break out occurred.

On the true right bank the river is controlled by a stop bank and this stop bank became close to overtopping along its length but at only two locations did actual overtopping occur. These are shown in **Figures Fifty Six** and **Fifty Seven** and described below.

Figure Fifty Five. *View of the river generated flood spread for the Mangahauini River from upstream of the "Marotiri" tributary to the bridge over the Mangahauini at the river mouth. The two sites where overtopping occurred are shown as red dots. The mouth itself below the bridge has been excluded from the flood spread as it is assessed that this area was dominated by storm surge during the storm. The location of the rain gauge is shown bottom right.*

A more detailed view of the overtopping points is shown in **Figure Fifty Six** below and each over topping point at close detail in **Figures Fifty Seven** and **Fifty Eight** below. Both of these over topping points are relatively close to the State Highway bridge with the upper breach around 170m above the bridge and the other 56m upstream.

The upstream overtopping site shows both silt deposition on the discharge side of the overtopping as well as possible erosion of the outside slope of the stopbank (**Figure Fifty Seven**). There does not, however, seem to be any silt deposition or vegetation flattening beyond eight metres from the overtopping point. Thus this breach is not considered to have made a significant contribution to the overland flow flooding that affected Café 35 and beyond.

Figure Fifty Six. *View of the lower true right bank of the Mangahauini showing the two overtopping points. The old road is shown at far right.*

The lower overtopping site shows no sign of stopbank erosion but silt deposition is more widespread with indications of flood spread extending out at least 18 metres beyond the stopbank (**Figure Fifty Eight**). It is thus possible that flood waters from this overtopping contributed to the flood spread in the vicinity of Café 35 and beyond. It is equally possible that these flood waters were confined to the area immediately adjacent to the stopbank and flowed back to the river via the old road surface immediately downstream of the overtopping. The inundation of area around Café 35 and towards Hatea-A-Rangi School was therefore just as likely the result of the rainfall accumulation on ground beyond the area flooded by the river.

Figure Fifty Seven. *View of the upper overtopping point showing the silt deposition and the indications of stopbank erosion.*

Mangahauini Overland flow and the impact of ponding

Overland flow off State Highway 35 was the primary cause the flooding at Toa Street rather than flooding from Mangahauini River. The *indicative*[7] flood spread resulting from the overland flow is shown in **Figure Fifty Nine** below. While the blocked culvert in the "Marotiri" tributary could have had an impact on the inundation at Toa Street it would not have been the only source of flooding. Indeed it has already been noted that some of the discharge from "Marotiri" tributary above the blocked culvert would have re-entered the creek immediately downstream. Still more of the flood from the "Marotiri" tributary appears to have discharged from the water table at two points

[7] It is difficult to differentiate between overland flow and in situ ponding in the drone footage and in addition flow through tall grasses or bush is difficult to ascertain.

before reaching Toa Street (c.f **Figure Fifty Nine**). The overgrown drain between the substation and Toa Street reduced its carrying capacity exacerbating flooding.

Figure Forty Five above showed that significant overland flow occurred in the Waiotu catchment and while no equivalent photographs have been located for the Mangahauini a similar amount of overland flow would have occurred.

It is calculated that the area above State Highway 35 but east of the "Marotiri" tributary is around 148,000 M^2. This area would have received around 11,100 M^3 of rainfall during the short but intense storm on the 20^{th} June and around 23,680 M^3 over the entire 12 hours of the overall storm. This would have been discharged directly on to the road surface and water tables, and this overland flow would have been directed down towards Toa Street.

Figure Fifty Eight. *View of the lower overtopping point showing the silt deposition extending out onto the low lying ground beyond. The imagery does not, however, suggest flood spread beyond 18m of the overtopping point.*

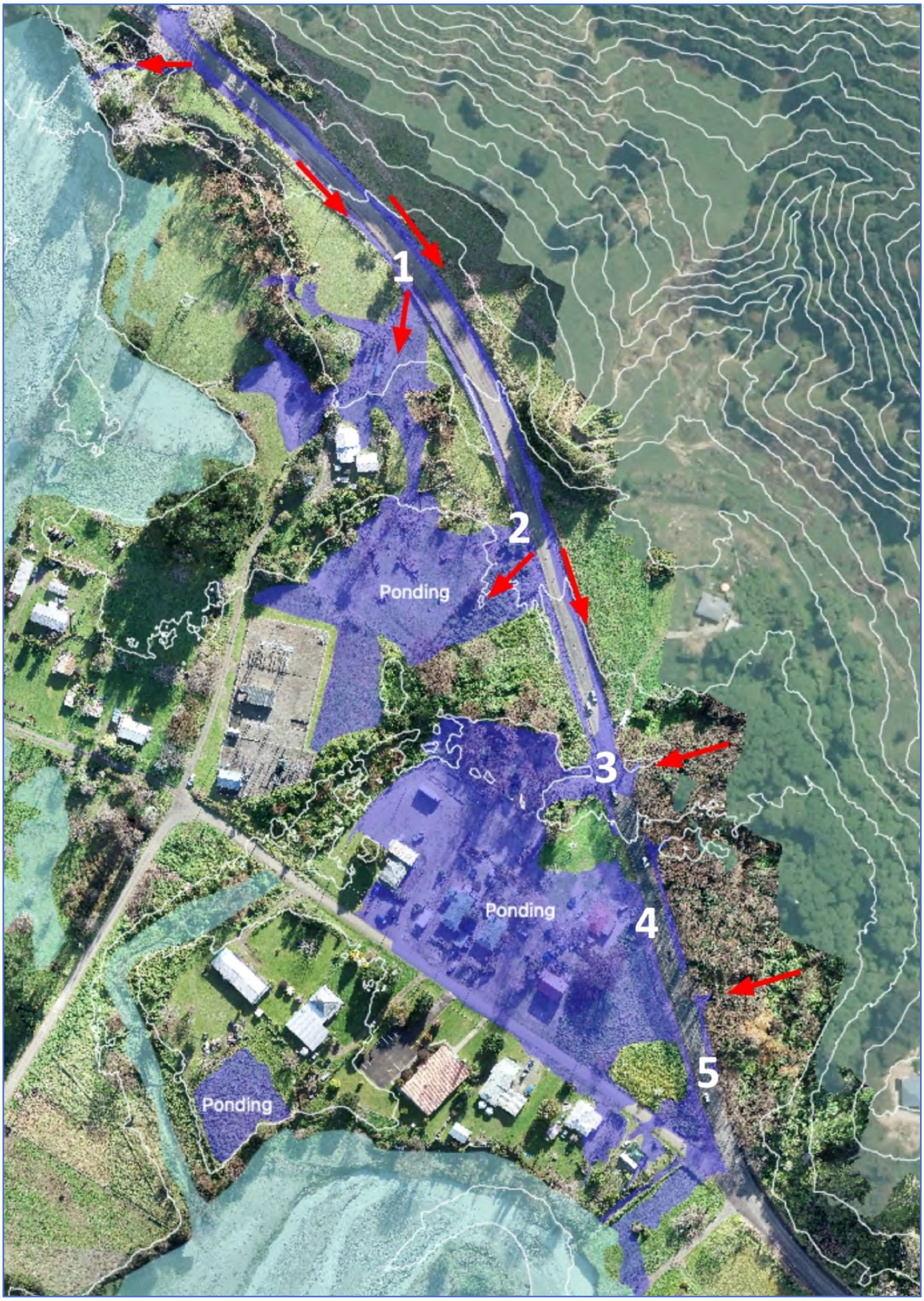

Figure Fifty Nine. *Overland flow from SH 35 discharging above the house upstream of the substation (Point 1), the substation (Point 2), and ponding in the vicinity of Toa Street (Points 3-5). The overgrown culvert between points 2 and 3 constrained flood conveyance and exacerbated overland flow.*

Ponding and direct-to-ground rainfall accumulation would also have had a significant impact at Toa Street. Around 1,712 M^3 of rainfall depth occurred over the 12 hours of the overall storm and with 802 M^3 of this falling on the worst affected north side of Toa Street during the period of the high intensity rainfall early on Sunday 20th June 2021[8].

This figure is likely to be an under-estimate, however, as more work would be required to accurately determine the area covered by direct-to-ground rainfall accumulation. Obviously, the depth of ponding was not uniform due the irregular ground surface in the vicinity of Toa Street and this would have resulted in variable impacts along the street. The capacity of Toa Street to act as a channel directing water away from the houses on the south side of the street also requires further assessment.

In summary, the flooding in the area around Toa Street was the result of a complex interaction between overland flow from the slopes east of the "Marotiri" tributary, discharge from "Marotiri" tributary as a result of the blocked culvert[9] and direct to ground rainfall accumulation.

Hatea-A-Rangi ponding

The Hatea-A-Rangi area between the Waiotu/Kaiawha and Mangahauini catchments is low lying and inundation here was influenced by overland flow, direct to ground rainfall accumulation and probably some degree of river flooding. Additionally the coastal area immediately east of Hatea-A-Rangi was subject to storm surge which allowed the inundation to back up and delayed the drainage of the flooded areas.

The approximate inundation for the Hatea-A-Rangi area is shown in **Figure Sixty** below. The inundation from overland flow has been estimated in two segments; The steeper slopes above Tuatini Marae, and the low lying areas between those steep slopes and the Mangahauini stopbanks west of State Highway 35. These have a combined area of 144,526 M^2 and would have accumulated 23,125 M^3 over the entire 12 main storm period and 10,840 M^3 over the short duration intense storm.

The indicative area of ponding shown in **Figure Sixty** is around 39,000 M^2 which would equate to a direct accumulation of 6,236 M^3 over the 12 hour period and 2,923 M^3 over the short duration intense storm. The combination of this direct accumulation and the overland flow would have accounted for much of the ponding in the Hatea-A-Rangi area. It is considered, however, that some flood water from the Waiotu/Kaiawha would have also contributed to flooding in this area. It is not possible to determine the balance between overland flow, river flood and direct accumulation.

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[8] *This estimate excludes the infiltration that may have occurred prior to the high intensity rainfall.*

[9] *It is noted that a significant portion of the flow from the blocked culvert may have exited the road surface before Toa Street having a more significant affect at locations 1 and 2 in **Figure Fifty Nine** than at Toa Street itself.*

Figure Sixty. *Hatea-A-Rangi indicative main ponding area, Tokomaru Bay. The area east of the white line was subject to storm surge.*

Storm Surge

Storm Surge had a significant impact during the 20th June 2021 storm from Te Araroa in the north to Turihaua Point in the south. Surge impacts were especially significant at Waipiro Bay and Tokomaru.

Te Araroa

Te Araroa was visited on the 16th July 2021 following an RFS (Request for Service) reporting logs on the beach attributed to the 20th June storm (Cave July 2021). Woody debris assessments were undertaken at 3 sites and found that the woody debris was largely weathered material and was dominated by a mix of indigenous timber plus willow and poplar. There was one fresh pine tree with its' root ball intact that had washed down in the recent storms.

The beach showed obvious signs of scouring (**Figure Sixty One**). It is inferred that some of this scour had occurred during the 20th June storm but the area had been subject to several significant storm surge events since Mid May. Hence not all of the woody material would necessarily have been remobilised during the June storm surge and some may have occurred during the previous storm surges.

Figure Sixty One. *Obvious erosional scour of the top of the beach that has exposed pre-existing driftwood. This is a mainly willow with some indigenous. The cuts look fresh and is probably due to being cut for firewood.*

Waipiro Bay

Waipiro Bay suffered from flooding with dropouts on Waikawa road and a washout on McIlroy Road at Taurapu Stream but the most significant damage due to storm surge was to the road beyond Taurapu Stream . Not all of the storm surge damage will have occurred on the 20th June but significant damage still occurred during that event. The extent of coastal erosion at this site is shown dramatically in **Figure Sixty Two** below with the line of pine logs pushed into the beach as a retaining wall showing the extent of recent erosion. Scour has resulted in channels cut into the road surface at the approaches to the last houses at Ohineakai (**Figure Sixty Three**). Beyond the houses at the end of the road in Waipiro Bay there's a track leading up to an isolated house. Erosion associated with a broken culvert (**Figure Sixty Four**) and tension cracks higher on the road (**Figure Sixty Five**) means that there is a high risk that this property will become inaccessible. It needs to be noted that the existing, now damaged road, has been constructed on fill within the coastal zone and will always have been at risk from coastal erosion. Future sea level risk will likely exacerbate this risk.

Figure Sixty Two. *The extent of recent coastal erosion at the northern end of McIlroy Road marked by the pine logs that had been pushed into the sand as retaining posts.*

Figure Sixty Three. *The extent of scouring and channelling of the road.*

Figure Sixty Four. *The road heading up to the last property at the end of McIlroy Road showing the scour and undercutting associated with the broken culvert, the car bodies and other debris used as armouring on the fill making up the access track and the "totem poles" used to buttress the slope. Note the over steepened face and overhangs.*

Figure Sixty Five. *Tension cracks on the bend in the road leading up to the last house.*

Tokomaru Bay

Storm surge damage was widespread along the length of Tokomaru Bay. At the north end of the bay, big seas caused further damage to the Tokomaru Bay wharf (**Figure Sixty Six**) and there was damage to the road near the Te Puka tavern. Extensive scour of the beach along with woody debris was evident at the mouth of Waiotu (**Figure Sixty Seven**) and more woody debris was thrown on the freedom camping site adjacent to Waiotu Road just to the south of the river mouth (**Figure Sixty Eight**).

The most obvious damage occurred at the reserve at the mouth of the Mangahauini River which had previously been damaged by storm surge and assessed as being highly vulnerable (Cave 2019a, 2019b). This area also experienced significant erosion as a result of storm surge in May 2021 but the 20th of June storm surge was more significant with the surge extending 25m in from the bank edge pre-event. Coincidentally, the area was drone mapped on the 18th of June 2021 to assess the damage from the May storm surge event making it easier to assess the degree of erosion resulting from the 20th June (**Figure Sixty Nine**)[10].

Figure Sixty Six. *Additional damage to the Tokomaru Bay wharf as a result of heavy seas*

Figure Sixty Seven. *Scour erosion of the top of the beach at the mouth of Waiotu Stream, with logs thrown up by the storm surge. Note the significant rubbish washed out by the flood.*

[10] The erosion at the Tokomaru Reserve and Playground is detailed in a separate report.

Figure Sixty Eight. *A significant amount of woody debris was thrown up on the reserve south of the Waiotu Stream river mouth.*

Figure Sixty Nine. *Comparison between the Tokomaru Reserve and playground drone orthomapping dated 18th June and 24th of June 2021. Note the removed tree, the overhanging concrete pad bottom left and the erosion at the turn around bay.*

Tolaga Bay

Erosion at the Uawa river mouth as a result of storm surge has been occurring for the last year and is currently being assessed in detail. There did not appear to be a significant increase in erosion at the river mouth as a result of the 20th June event but increased erosion of the sand dunes north of the river mouth was observed. The principal impact of the storm surge at Tolaga was the remobilisation of logs and the spread of woody debris along the northern beach[11].

Pouawa to Turihaua Point

Monitoring for erosion of the freedom camping zone[12] between Pouawa and Turihaua was initiated in September 2020 and an initial report prepared in November 2020 (Cave 2020). A drone flight was undertaken in August 2021 and the limits for the May and June storm surge mapped on the ground is shown below on the drone orthomap in **Figure Seventy**. Evidence of storm surge was indicated by salt burnt grass, flattened vegetation and rocks and woody debris thrown up onto the top of the beach terrace (**Figure Seventy One**). Some erosion of top soil and grass on top of the wave cut platform was observed for both the May and June storm surges.

Figure Seventy. *Drone map of Turihaua Point showing the top of the bank from the 2018 aerial imagery (red), the June 2016 bank (green), the areas affected by overland flow and inundation in June 2021 (yellow area) and the storm surge limits for May and June 2021 (yellow line).*

The freedom camping area north of Turihaua Point also experienced erosion and over topping during both the May and June 2021 storm surge events. A considerable amount of erosion of the dunes is evident (**Figure Seventy Two**), as well as overtopping (**Figure Seventy Three)** and debris deposition (**Figure Seventy Four**).

[11] *Erosion and woody waste issues at Tolaga Bay are documented in a separate report in preparation.*

[12] *Note that this area has been re-classified as Freedom Camping areas under the Freedom Camping Bylaw 2021*

Figure Seventy One. *Photograph taken 30th June 2021 showing the debris thrown up during the 20th June storm surge.*

Figure Seventy Two. *Photograph showing dune erosion on the beach north of Turihaua Point.*

Figure Seventy Three. *Photograph showing overtopping and deposition of sand north of Turihaua Point. During the 2020-21 summer, campers occupied this site.*

Figure Seventy Four. *Photograph showing the debris line for the storm surge in June 2021. Grass beyond the debris line shows signs of salt burn indicating salt water inundation. Note that the large rocks were put there at 1 metre intervals to measure the extent of the surge.*

Issues

Three key areas for further work were identified during this assessment as discussed further below.

Mobilised willows

The 20th June storm resulted in a significant volume of woody debris being deposited on both ends of Tolaga Bay beach soon after an extensive clean-up of the beach had occurred. Some of the material on the beach during the storm was cannibalised from wood stocks buried in the beach dune system or elsewhere but new material sourced from the catchment was also identified (*c.f* prior section). A marked difference between much of this new material compared with prior influxes in 2017 and subsequent years is the high proportion of willow in the woody debris.

A rapid assessment of possible wood migration was undertaken on the day of the storm[13]. The Mangaheia, Tapuae, and Mangatokerau rivers on Paroa Road were also running dirty with sediment but no significant woody material was observed. The Hikuwai Bridge at Waiau Road and the Hikuwai on Arero Road were also clear as were the "three bridges" over the Hikuwai at Matairau Road.

At the State Highway 35 bridge over Mahanga Stream at Kopuatarakihi Road, however, significant volumes of willow wood was observed being eroded from piles of cut willow that was being stored on the banks of Mahanga Stream (*c.f* **Figure Eleven** page 8). A ten minute observation period was used to assess the quantity of material mobilising and several videos and photographs taken. It was not possible to do individual log counts as the material being mobilised were clumps which because the willow had not been de-limbed, incorporated multiple trees. From Mahanga Stream the woody debris was observed catching up on trees downstream but then being released and discharging into the Hikuwai River. Later on the 20th June 2021, willow woody debris was observed in the Hikuwai river at the Paroa Road bridge and then at the State Highway 35 bridge across the Uawa at Tolaga bay. Based on the assessment on the day, Mahanga stream location is the only likely source of the new willow on the Uawa beaches.

Satellite imagery was used to assess when the clearance of the willow was undertaken. A image dated 1st November 2020 shows the area with an extensive cover of willow while an image dated 18th of April 2021 shows a digger on site actively clearing the vegetation (**Figure Seventy Five**).

No search of Council records or the TRMP has been undertaken to assess whether or not the vegetation clearance was a permitted activity or one which would require a permit (and for which a permit was obtained). Irrespective, the earthworks associated with the vegetation clearance and the placement of the willow piles on the banks of the stream within the flood plan has resulted in the discharge of sediment and wood

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[13] This followed the same methodology used from 2017; namely, migrating log counts and assessment of perched woody at each of the bridges within the catchment.

waste into Mahanga Stream. From there is has entered the Hikuwai and then made its way downstream.

Figure Seventy Five*. Screenshots of satellite imagery dated 1st November 2020 (left) and 18th April 2021 for the Mahanga Stream (right) where it crosses State Highway 35 showing the active clearance of willow during April 2021.*

Fresh cut pine log on north Tolaga Bay Beach

On the day of the event a fresh cut pine log was found on the beach. The log had blue identifier paint on one end, obvious waratah marks and clean cut ends (**Figure Seventy Six**). Such fresh identifiable logs are not typically found on the beaches but several were identified on the beach in 2017 following Cyclone Cook.

Logs are more typically what are known as long-resident logs. That is, logs that have spent some time in the catchment and as a result of transport have abraded ends. A log this fresh indicates that had been graded and stored on a landing or skid site in preparation for transport to the port or a log yard. It could have come from any operator currently or very recently harvesting within the Uawa catchment. As it has not been treated it cannot have been lost off a ship. I am unaware of any self-reported skid failures within the catchment.

Figure Seventy Six. *A fresh pine log on north Tolaga Bay Beach 20th June 2021.*

Culvert blockage on State Highway 35

The role of the culvert on State Highway 35 immediately north of Tokomaru Bay on the flood has been discussed in detail above. Immediately following the 20th June event, the issue of the state of the culvert was raised as the local community had indicated that the culvert had been blocked prior to the storm. At that time it was determined that;

- Evidence of the prior blockage was anecdotal,
- The scale of the event and the level of influx of sediment was such that the culvert would likely have blocked up in any case and thus the prior state could not be retrospectively assessed,
- Waka Kotahi should have been undertaking regular assessments of culvert condition to meet level of service requirements.

Thus, it was assessed that the culvert may not have materially exacerbated the flood spread. None-the-less, following the assessment of the drone footage and an on the site evaluation, further information was sought from Waka Kotahi who sometime later who advised "*Yes the culvert was blocked prior to the event. It was in our forward works programme to clear but unfortunately the weather event struck before it could be cleared*." Additionally, Waka Kotahi had some concerns on how to fix the culvert long term and how to stop the culvert blocking up again straight away and instructed their contractor to clear the drain but the storm occurred before this clearance was actioned.

Waka Kotahi appears to have known that the culvert was fully blocked for some time and would have been aware that there was a risk of heavy rainfalls particularly from June to October. It is surprising that little urgency appears to have been put into clearing the culvert irrespective of their concerns about ongoing blockages which I note remains a concern as there is a considerable volume of sediment immediately above the culvert.

As also noted above, however, it cannot be established how much of the flood waters from the blocked culvert reached Toa Street which would have received a considerable amount of flood water from overland flow derived from the hillslopes east of the culvert. Some direct-to-ground inundation would have also occurred at Toa Street. It is possible that water diverted from the blocked culvert did inundate a house site west of Toa Street and the sub station located at the end of Toa Street. An overgrown drain between the sub-station and Toa Street would have limited its capacity to convey flood waters.

Silt dumping at Tokomaru Transfer Station

As a result of the flood, a significant volume of silt was deposited in Tokomaru Township. This was removed and dumped on natural ground on the town side of the transfer station pad. The volume and level of contamination of this material was a raised as a potential compliance issue. An assessment was undertaken (Cave 2021) which established that the material was less than 500 M^3 and thus could be considered a permitted activity subject to whether or not the material could be classed as a hazardous substance. The assessment established that the silt contained low amounts of *E.coli* but did not contain any of the indicator metals or chemicals that would define a hazardous substance under the TRMP or NES. External advice from the leading New Zealand expert confirmed the assessment that the silt did not constitute a hazardous substance and could be considered as cleanfill. The dumped silt which was placed on natural ground beyond the transfer station was therefore under the threshold for requiring a consent under the TRMP.

Summary and Conclusions

1. On the morning of 19th of June, the MetService issued a heavy rain warning for Gisborne advising the region to expect 100 to 150mm of rainfall north of Tolaga

with peak intensities of 20 to 30mm/hr of rain in the evening and again the following morning. An update that evening advised to expect a further 70 to 100mm of rain on top of what had already fallen with peak intensities of 20 to 30 mm/hr Sunday 20th June.

2. The weather event developed largely as forecast by MetService with heavy rain in the Waikura Valley area in the northwest and in a band extending northeast towards Tokomaru Bay and Tolaga. Rainfall accumulations were rather higher than forecast, however, with the highest occurring in the Waikura valley area (184mm/12 hr, 194.8mm/24 hr) with heavy rain from Te Puia/Waipiro Bay to Tokomaru Bay (150.4mm/12 hr, 154.4mm/24 hr at Te Puia). A private gauge at Tokomaru Bay recorded 160mm over 12 hours.

3. The weather event lasted up to 13 hours depending on location but 93% of the mean rainfall accumulation occurred across all rain gauges within a 12 Hour window and this assessment analysed rainfall at each site for 1 hour and 12-hour intervals as it was assessed that this best defined the storm.

4. Surface flooding occurred widely from south of Tolaga Bay to Te Araroa but slips were only significant on the main highway at Oweka near the Lottin Point turnoff.

5. Unexpectedly heavy rain occurred at Tokomaru Bay starting at or soon after 6am on the Sunday with a peak rainfall from 7am to 8:30am and this cause significant flash flooding affected both the Mangahauini and Waiotu/Kaiawha catchments, particularly along Arthur Street in the Waiotu catchment and Toa Street in the Mangahauini Catchment. Deep surface flooding also occurred in low lying areas between the two catchments in the Hatea-A-Rangi area. It is estimated that around 75mm fell within 1 ½ hours but it may have been higher.

6. Using HIRDS v.4 the overall storm had a 12 hour rainfall accumulation ARI (Annual Recurrence Interval) of 2.5 years but the 12 hour rainfall recorded at the private rain gauge at Tokomaru Bay had an ARI of 13.5 years. The short duration high intensity storm had an ARI of 30 to 35 years if the accumulation occurred over 1 ½ hours of 100 years if most of that heavy rain fell within an hour.

7. Flooding impacts were exacerbated by an associated storm surge which impeded drainage of flood waters.

8. Neither the Mangahauini or Waiotu/Kaiawha catchments have river flow or rain gauges and hence the event was only captured by the private gauge which could only provide overall event rainfall accumulation.

9. Rain radar data from the Mahia station provided a useful qualitative view of the storm as it progressed from off Bay of Plenty through to Tairawhiti but did not capture the heavy rain event that hit the Tokomaru Bay area as the radar was imaging precipitation around 2km and above rather than on the ground. Post-event rain gauge corrected radar showed a narrow band of rain (at 2km +) travelling down the coast east of Te Puia.

10. The flooding affecting Arthur Street resulted from heavy rain in the Kaiawha tributary of the Waiotu rather than the Waiotu itself, and was exacerbated by significant overland flow. A large willow planted in Waiotu Stream is not considered to have acted to significantly exacerbate flooding.

11. Flooding in the Mangahauini river overtopped the Tokomaru transfer station and a very limited amount of overtopping of the stopbank on the true right bank close to the bridge over the river occurred but is not considered to have exacerbated flooding in the Café 35, Hatea-A-Rangi area which was primarily the result of overland flow and direct-to-ground ponding.

12. A blocked culvert on State Highway 35 at "Marotiri" Stream resulted in flow down the highway towards Tokomaru Bay. Some of this overland flow re-entered "Marotiri" Stream immediately downstream of the culvert but greater volumes would have left the water table at two locations between the culvert and the sub-station.

13. The flooding at Toa Street is largely the result of overland flow from the hillslopes above State Highway 35 which was channelled towards the street via the water tables either side of the highway. Additional inundation was the result of direct-to-ground rainfall accumulation. Some water from the blocked culvert reached Toa Street but it may not have dominated the inundation. The overgrown drain between the substation and Toa Street reduced its conveyance capacity which would have exacerbated overland flow.

14. The storm surge associated with the weather event caused coastal impacts from Te Araroa to Turihaua Point. At Te Araroa, the surge resulted in erosion at the top of the beach which exposed and remobilised previously deposited woody debris. This woody debris comprised indigenous and willow/poplar. Forestry harvest residues do not appear to have contributed to the wood on the beach.

15. At Waipiro Bay, the storm surge events of June and earlier in the year have resulted in erosion of the road that provides access to the houses beyond Taurapu Stream on McIlroy road. This road has largely been built on fill and protected by a range of informal means of armouring. This road will become increasingly at risk from future storm surges and king tides, and sea level rise will further exacerbate this risk.

16. Storm surge damage at Tokomaru Bay was most evident at the reserve at the mouth of the Mangahauini River which was fully inundated by water and suffered additional damage over and above that experienced during the May storm surge (and previous events). At the mouth of the Waiotu, the storm surge caused flood waters to back up and threw a lot of woody debris onto land beyond the beach.

17. At Tolaga Bay the principal impact of the storm surge was to remobilise woody material already incorporated into the dune system at the top of the beach.

18. The impacts of storm surge along the freedom camping areas from Pouawa to Turihaua was largely from saltwater inundation which resulted in salt burn to the grass, thrown up rocks and woody debris and erosion. At Turihaua Point the erosion was largely of soil and grass on top of the wave cut platform while to the north the dune system was significantly eroded and inundated by salt water.

19. A number of issues were identified in the course of this assessment.

    a. Extensive willow woody debris washed up on Tolaga Bay beach on the 20th of June and was traced back to a recent clearance of willows at Mahanga Stream above where it crosses State Highway Thirty Five. This clearance was substantial and as was observed on the day the woody residues were stored in locations vulnerable to flood.

    b. The culvert of State Highway 35 immediately north of Tokomaru Bay was known to be blocked before the event and Waka Kotahi had planned to clear the blockage but this was not completed before the weather event. The scale of the event was such that the culvert would most likely have blocked in any event.

    c. The presence of a freshly cut log suggests movement of logs harvested within the catchment since the 2018 Queens Birthday storm. The source of this log was not identified.

Recommendations

Installing a rain gauge at Tokomaru Bay

The absence of a rain gauge or flow gauge at Tokomaru would not have altered the outcome. A key part of any post-weather event assessment is, however, to maximise the understanding of what happened and when so that lessons are learnt and applied during the next event. Additionally, the majority of other coastal townships have one or more rain gauges in relatively close proximity and the absence of one at Tokomaru Bay is a gap. A suitable location would be at Hatea-A-Rangi School provided a suitable secure site can be identified. It is noted that the fortuitous presence of a private rain gauge at Tokomaru Bay proven invaluable in this analysis.

Assessment of the overall district rain gauge and river flow gauge network

It was noted in the body of the report that Gisborne/Tairawhiti has an extensive rain gauge network relative to adjacent regions and there are few performance issues with the network (although there were some anomalous readings). On the other hand, the region has a very complex topography which results in a high degree of variability in rainfall. Some locations such as Poroporo has more than one gauge in close proximity which in this instance produced comparable results (12 hour maxima of 123.4 and 129.2 mm respectively). There is thus the case for assessing whether or not the network can be enhanced without a significant increase in workload for the Environmental Monitoring team.

Comprehensive Legacy Landfill risk assessment

Some work on a risk assessment of the legacy landfills has already been undertaken but a coherent work programme should be undertaken to assess and prioritise risk and develop risk mitigation plans and actions. The Tokomaru landfill is the most obviously vulnerable site but the Te Araroa, Tikitiki, and Tolaga sites as well as others require further assessment.

Better fact finding engagement with affected communities

The locals on the ground are a largely untapped source of information that could be better utilised to inform the post event review; for example improving information about flood spread and accessing social media feeds and raw photos and video.

Acknowledgements

The residents of Tokomaru Bay who provided information used in this assessment meant that the timing of the short duration intense storm could be better defined and particularly Tianna Rongonui is acknowledged for providing good quality video of the flooding on the southern approach to Tokomaru Bay. Also Kuipo Saulala who's Facebook post was helpful and the Uawa Live Facebook page.

Barry Sanders who owns a bach and art gallery at Tokomaru Bay, and who is also Building Engineer at Council who has a rain gauge and provided accurate information as to the overall quantum of the rainfall accumulation at Tokomaru Bay.

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The un-named digger operator on Kaiawha Road who made sure I didn't get up to my knees in mud while accessing Kaiawha Stream.

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