# GUIDELINES ON THE USE OF AGS2007 FOR LANDSLIDE RISK ASSESSMENT IN AUCKLAND FOLLOWING THE 2023 FLOODING AND CYCLONE

## INTRODUCTION

It is anticipated that the use of the **AGS2007 guidelines** will form a core part of the risk assessment process for recovery in Auckland. This guidance has been developed to support practitioners in implementing the AGS guidelines by providing location and event specific information and advice, along with lessons learned from earlier implementations.

This guideline will be revised regularly as more information becomes available, and as new lessons are learned.

Risk assessment is expected to be undertaken on a site-specific basis. Nothing in this document relieves the person undertaking the risk assessment of their obligations to properly assess the conditions at each location and to make an assessment relevant to the site. These general guidelines may support this process, but deviation from the guidelines is to be expected where conditions dictate.

## ESTIMATING THE TEMPORAL PROBABILITY

For most residential properties it is expected that occupation will be based on an average value of about 70% occupancy. This is based on typical occupation of 16 hours per day on weekdays, and 20 hours per day on weekends. Note that this is the time that any person is present, not the duration of occupancy of a specific individual.

Alternative estimates are acceptable. However, low current use alone is not appropriate as a guide for the likely use of a property over its entire lifecycle. Homes can be sold to other parties who will use them differently, or they could be rented out (for example, as an AirBnB) which would significantly chance the usage pattern. Such alternatives would need to be justified with evidence that either:

- The use is not likely to increase significantly over the long term
- The current use is unusually high and therefore, to be reasonably cautious, a higher value should be used

## DERIVING PROBABILITY OF A LANDSLIDE OCCURRING

In the 2007 update of the AGS guidelines, it was noted that some practitioners were incorrectly deriving indicative probability values for risk to life analysis. The 2000 version Appendix G Likelihood table was being used from left to right; that is a descriptor was selected from the description (or even by preference for the descriptor), and then the indicative probability assigned accordingly. This method is wrong. The Likelihood Table was reordered to indicate the correct sequence of logic from left to right and as discussed in section C5.4.2, an estimate of the probability should be made based on apparent performance, trigger probabilities etc, and then the descriptor assigned accordingly.

The tables provided in Appendix C of AGS2007c should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not vice versa.

## GENERAL CONSIDERATIONS FOR RAINFALL ARI

### Short-term vs Long-term risk

In many cases there will be a requirement to assess the short-term risk (for the purposes of RBA placarding and building occupation) and the long-term risk (for risk categorisation and consenting if remedial works are required).

### Short-term considerations

Short-term risk (nominally 1 year) will not need to consider the potential for climate change to increase the frequency of high-intensity rainfall. However, consideration should be given to the extremely wet 2023 summer which has led to unusually high groundwater levels. This could mean that landslides are more likely than normal in smaller rainfall events.

### Long-term considerations

Long-term risk (nominally 100 years) should consider the potential for climate change to increase the frequency of high intensity rainfall.

More information on this can be found:

- In a summary of Auckland climate projections prepared by NIWA (2018): **https://knowledgeauckland.org.nz/media/1171/tr2017-031-2-auckland-region-climate-change-projections-and-impacts-summary-revised-jan-2018.pdf**
- In a technical paper: **https://www.nzgs.org/libraries/climate-change-sustainable-development-and-geotechnical-engineering-a-new-zealand-framework-for-improvement/**

## ASSESSING THE ARI OF THE CYCLONE GABRIELLE EVENT - MURIWAI

Based on the best available data from rain radar, the rain experienced during Cyclone Gabrielle in Muriwai was >100-year event at a 12-hour duration.

This was a significant event for the region which came off the back of a significant “wet” period, including the event on the 27th of January 2023.

In Muriwai there are two sources of rainfall data available for analysis.

1. Physical TB3 tipping bucket rain gauge.
2. Auckland Councils Quantitative Precipitation Estimate (QPE) Rain Radar System.

### TB3 tipping bucket rain gauge.

Unfortunately, during Cyclone Gabrielle, the tipping bucket rain gauge at Muriwai failed and was inundated by flood waters. This event record presented below in figure 1 is compromised as a result but provides an indication of the rainfall intensities at Muriwai prior to the site failing.

Prior to the gauge failing (01:15 am on the 14th), the gauge had recorded 129mm of rain with a peak 6-hour total of 88mm of rain, which is >20-year event (TP108, Auckland design rainfall depths).

Due to the missing record and the site being inundated during the event, this record is not recommended to be used to describe the event.

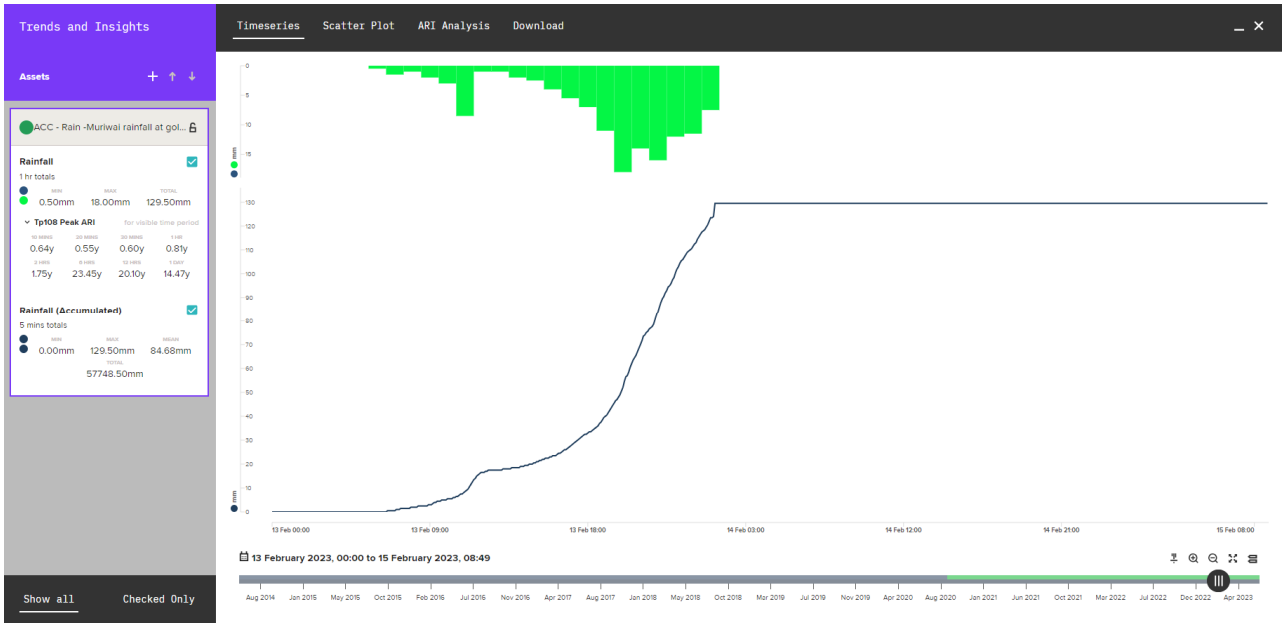



*Figure 1: Muriwai TB3 tipping bucket rain gauge hourly totals and cumulative total. (note, the event is missing data from 01:15am 14th February due to being inundated)*

### Quantitative Precipitation Estimate (QPE) Rain Radar System.

The QPE rain radar system is a real-time rainfall product which utilises the Metservice radar (reflectivity), which is transformed using a relationship to rainfall depths based on the tipping bucket gauge network. The result is spatially representative rainfall depths across the region, as shown in figure 2.

This product enables full, region wide analysis of extreme rainfall events in catchments where rain gauges are not located and when a gauge fails, as in the case with the Muriwai gauge.

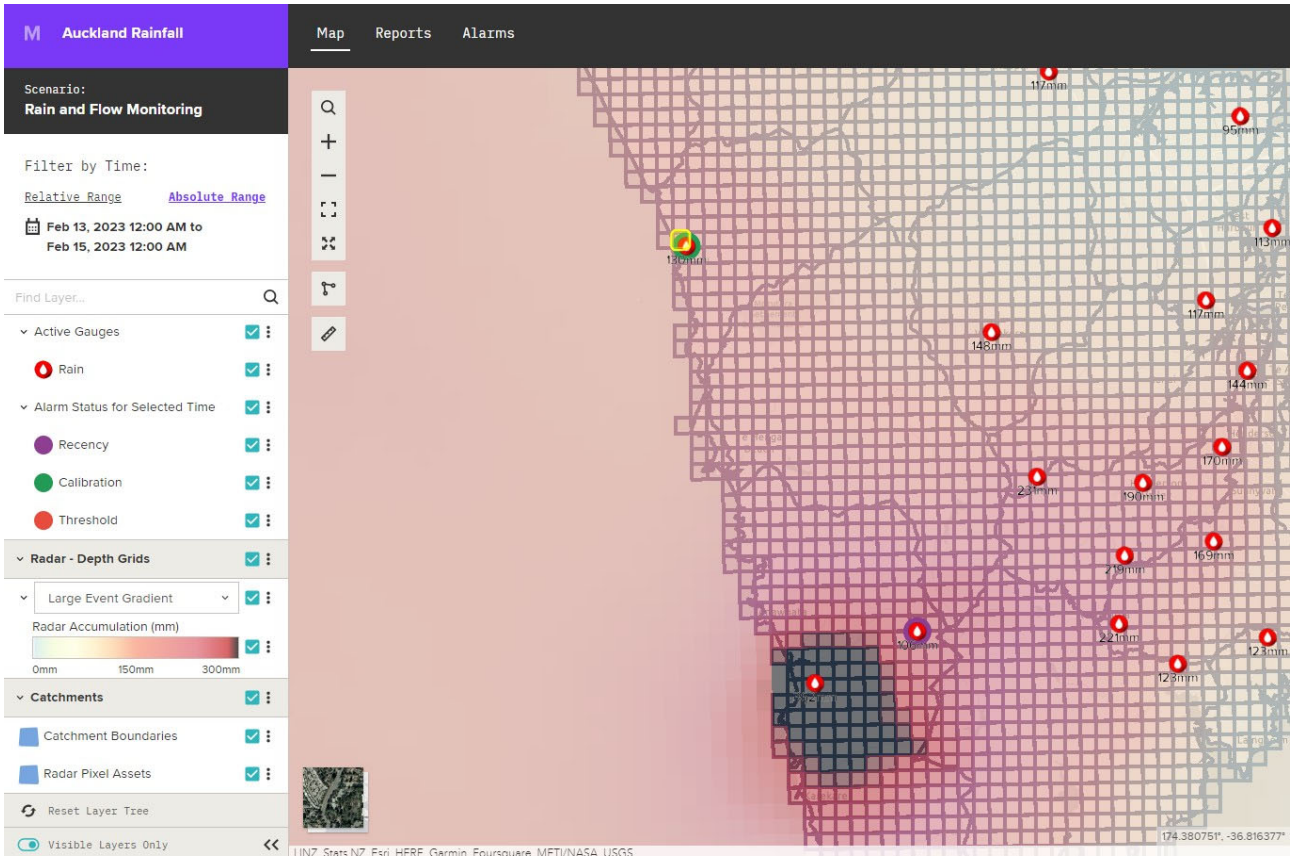



*Figure 2: QPE Rain radar depth accumulations 13 February 2023 to 15 February 2023. The yellow grid location is the rainfall at the raingauge location at Muriwai*

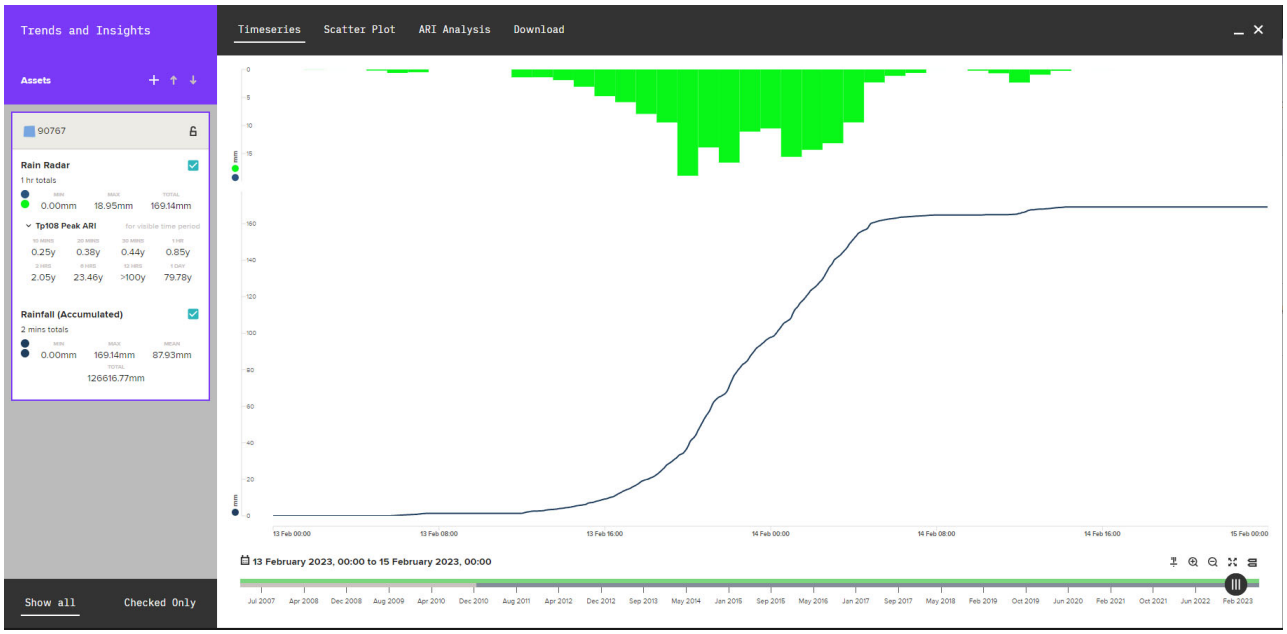
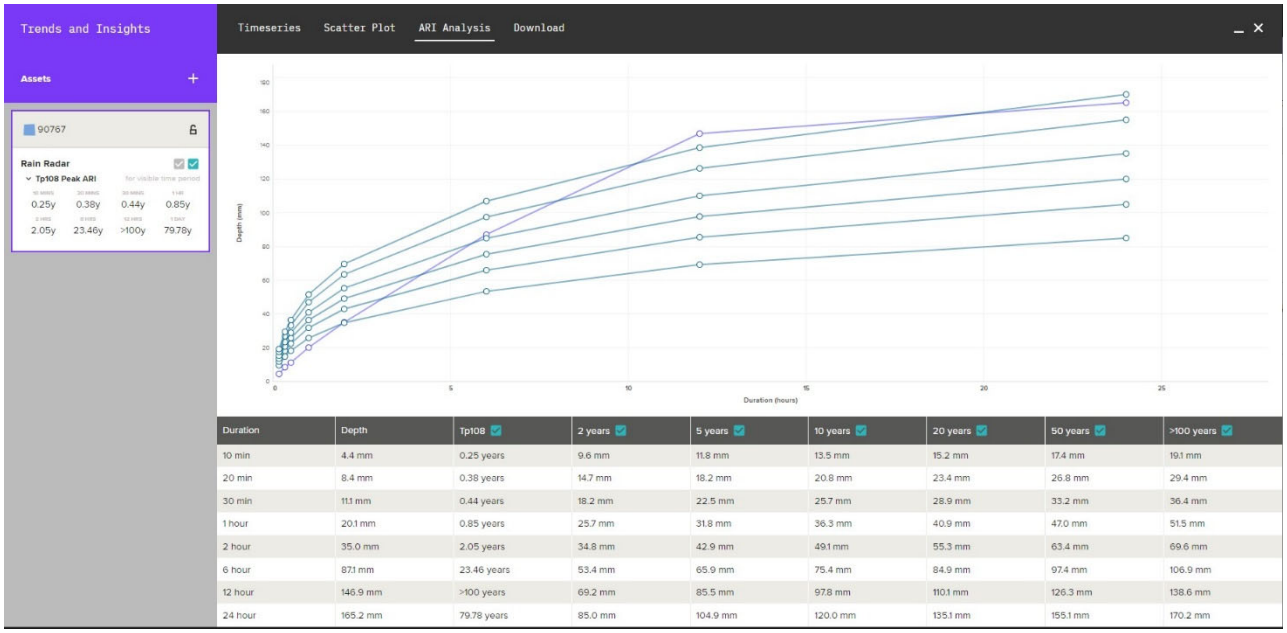



*Figure 3: QPE Rain radar depths in Muriwai 13 February 2023 to 15 February 2023*

Figure 4 below shows the Depth-duration-Frequency curve for the QPE grid location at Muriwai. The X-axis shows duration, y axis shows depth in a given event, and the curves show the expected rainfall depths for a range of ARIs from 2 to 100-year return period (TP108, Auckland design rainfall depths).

What happened during the event is plotted in purple. This analysis and the figures in table 1 shows that the peak rainfall total during the event of 146.9mm occurred over 12-hour period. This total is >100-year event at a 12-hour duration.




| Duration | Depth | Tp108 | 2 years | 5 years | 10 years | 20 years | 50 years | >100 years |
|---|---|---|---|---|---|---|---|---|
| 10 min | 4.4 mm | 0.25 years | 9.6 mm | 11.8 mm | 13.5 mm | 15.2 mm | 17.4 mm | 19.1 mm |
| 20 min | 8.4 mm | 0.38 years | 14.7 mm | 18.2 mm | 20.8 mm | 23.4 mm | 26.8 mm | 29.4 mm |
| 30 min | 11.1 mm | 0.44 years | 18.2 mm | 22.5 mm | 25.7 mm | 28.9 mm | 33.2 mm | 36.4 mm |
| 1 hour | 20.1 mm | 0.85 years | 25.7 mm | 31.8 mm | 36.3 mm | 40.9 mm | 47.0 mm | 51.5 mm |
| 2 hour | 35.0 mm | 2.05 years | 34.8 mm | 42.9 mm | 49.1 mm | 55.3 mm | 63.4 mm | 69.6 mm |
| 6 hour | 87.1 mm | 23.46 years | 53.4 mm | 65.9 mm | 75.4 mm | 84.9 mm | 97.4 mm | 106.9 mm |
| 12 hour | 146.9 mm | >100 years | 69.2 mm | 85.5 mm | 97.8 mm | 110.1 mm | 126.3 mm | 138.6 mm |
| 24 hour | 165.2 mm | 79.78 years | 85.0 mm | 104.9 mm | 120.0 mm | 135.1 mm | 155.1 mm | 170.2 mm |

*Figure 4 Depth-duration-Frequency curve for the QPE grid location at Muriwai (90767).*

*Table 1 Depth-duration-table for the QPE grid location at Muriwai (90767).*

| Duration | Depth | Tp108 |
|---|---|---|
| 10 min | 4.4 mm | 0.25 years |
| 20 min | 8.4 mm | 0.38 years |
| 30 min | 11.1 mm | 0.44 years |
| 1 hour | 20.1 mm | 0.85 years |
| 2 hour | 35.0 mm | 2.05 years |
| 6 hour | 87.1 mm | 23.46 years |
| 12 hour | 146.9 mm | >100 years |
| 24 hour | 165.2 mm | 79.78 years |

*Table 2 – Depth-duration table from NIWA (HIRDSv4) including 250-year return period, with the 12-hour duration highlighted*

Results

Site Details | Historical Data | RCP2.6 Scenario | RCP4.5 Scenario | RCP6.0 Scenario | RCP8.5 Scenario

**Rainfall depths (mm) :: Historical Data**

| ARI | AEP | 10m | 20m | 30m | 1h | 2h | 6h | 12h | 24h | 48h |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.58 | 0.633 | 10.7 | 13.9 | 16.2 | 21.2 | 27.6 | 41.6 | 52.9 | 66.0 | 80.3 |
| 2 | 0.500 | 11.7 | 15.1 | 17.6 | 23.0 | 30.1 | 45.3 | 57.7 | 72.0 | 87.7 |
| 5 | 0.200 | 14.9 | 19.3 | 22.5 | 29.4 | 38.5 | 58.1 | 74.1 | 92.6 | 113 |
| 10 | 0.100 | 17.2 | 22.3 | 26.0 | 34.1 | 44.6 | 67.4 | 86.0 | 108 | 131 |
| 20 | 0.050 | 19.5 | 25.3 | 29.6 | 38.8 | 50.8 | 76.9 | 98.2 | 123 | 150 |
| 30 | 0.033 | 20.9 | 27.1 | 31.7 | 41.6 | 54.5 | 82.6 | 105 | 132 | 161 |
| 40 | 0.025 | 21.9 | 28.4 | 33.2 | 43.6 | 57.1 | 86.6 | 111 | 139 | 169 |
| 50 | 0.020 | 22.6 | 29.4 | 34.4 | 45.1 | 59.2 | 89.7 | 115 | 144 | 176 |
| 60 | 0.017 | 23.2 | 30.2 | 35.3 | 46.4 | 60.8 | 92.3 | 118 | 148 | 181 |
| 80 | 0.013 | 24.2 | 31.5 | 36.8 | 48.3 | 63.5 | 96.3 | 123 | 154 | 189 |
| 100 | 0.010 | 25.0 | 32.5 | 38.0 | 49.9 | 65.5 | 99.4 | 127 | 160 | 195 |
| 250 | 0.004 | 28.0 | 36.4 | 42.6 | 56.1 | 73.7 | 112 | 143 | 180 | 221 |

Depth standard error (mm) :: Historical Data

## Conclusions

The above information suggests that for the 12-hour duration rainfall the ARI is >100 years, and may be in the order of 250 years. However, the calculation above the 100-year assessment becomes increasingly unreliable, primarily because of the relatively short rainfall record available in New Zealand.

For the other durations modelled, the rainfall was below the 100-year event.

## 2023 Rainfall and antecedent conditions

The rain experienced in the Auckland region since the 1st of January 2023 has been historically significant.

During the period from the 1st of January to the 15th of February, 491mm of rainfall has fallen at Muriwai. Compared to the average rainfall for Muriwai for January of 70mm, indicates just how much rain has fallen at this location.

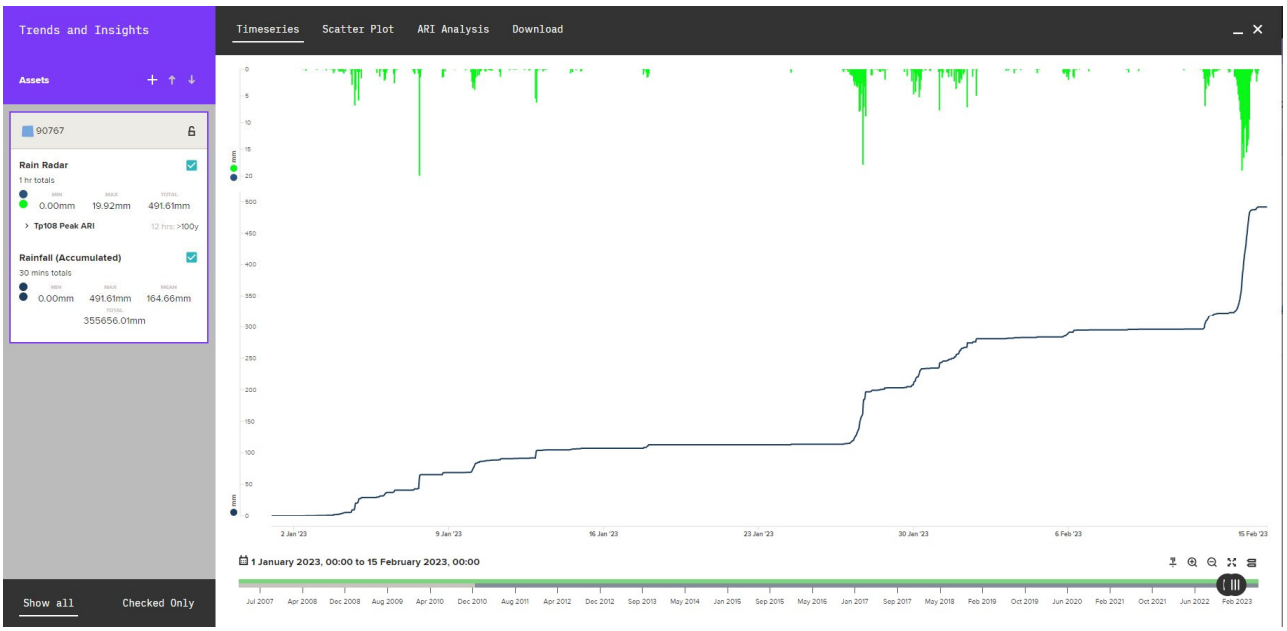


*Figure 5 QPE Rain radar depths in Muriwai 1 January 2023 to 15 February 2023*

### Caveats

This interpretation is using data sampled from the rain gauges that doesn't include the statistics from the recent events that Auckland has experienced – the theory is that including these events in the record will shift and change the return periods and depth for all of Auckland.

Auckland Council have commissioned NIWA to undertake the analysis to re-run HIRDS 4 for Auckland to include the recent 3 years of extreme rainfall data – the results of this are expected by November 2023.

### Recommendations

There are several different methods to extrapolate return periods which will all give very different and uncertain results.

It is recommended that for reporting purposes that an envelope of "risk" is determined as the ARI figures will change over time. In general for Muriwai it is considered reasonable to consider the event to be in the range of 100-250 year ARI.

For long-term risk assessment a 20% increase in rainfall intensity over the period has been projected by NIWA. A simplistic assessment (without climate modelling input) suggests this would change a 250-year ARI event to a 50-year ARI event. Risk assessment should consider both the current and future risk by re-calculating the risk taking into account this increased frequency.

For short-term risk assessments consideration should be given to the anticident ground saturation that is likely to persist at least through the winter of 2023.

## ASSESSING THE ARI OF THE CYCLONE GABRIELLE EVENT – PIHA & KAREKARE

Based on the best available data from rain radar, the rain experienced during Cyclone Gabrielle in Piha was >100-year event at a 6-hour duration.

This was a significant event for the region which came off the back of a significant "wet" period, including the event on the 27th of January 2023.

In Piha there are two sources of rainfall data available for analysis.

1. Physical TB3 tipping bucket rain gauge.
2. Auckland Councils Quantitative Precipitation Estimate (QPE) Rain Radar System.

### TB3 tipping bucket rain gauge.

During Cyclone Gabrielle, the tipping bucket rain gauge at Piha recorded 349.5mm of rain. This event record is presented below in figure 6

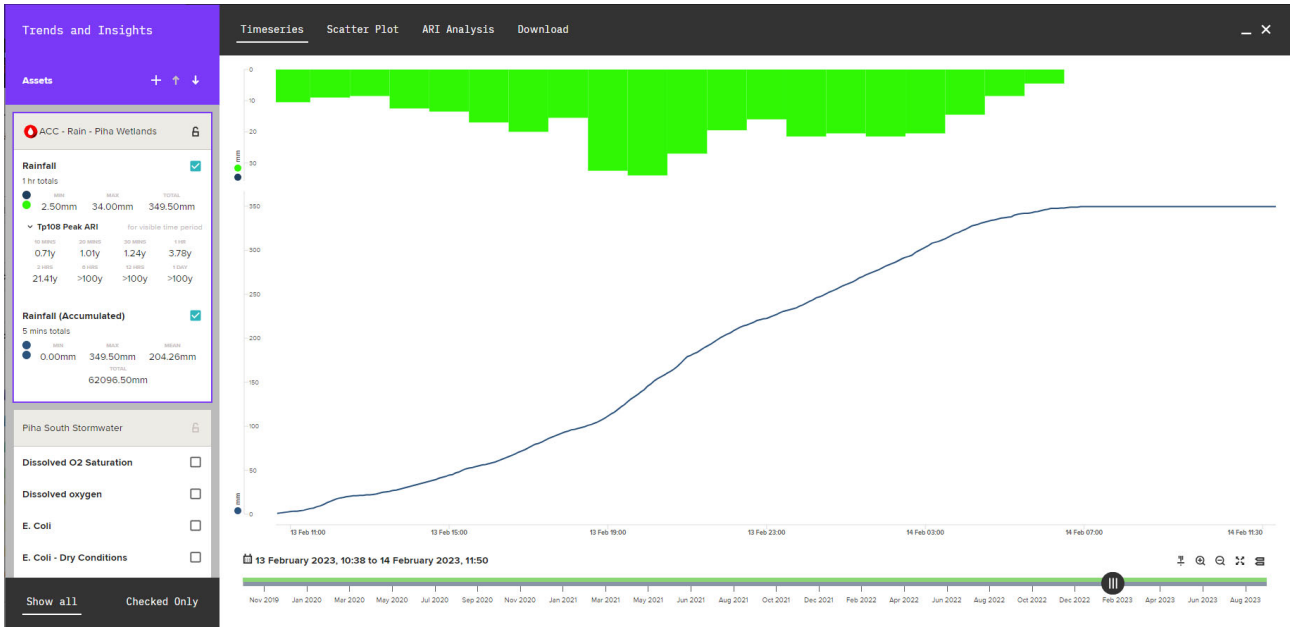



*Figure 6: Piha TB3 tipping bucket rain gauge hourly totals and cumulative total*

## Quantitative Precipitation Estimate (QPE) Rain Radar System.

The QPE rain radar system is a real-time rainfall product which utilises the Metservice radar (reflectivity), which is transformed using a relationship to rainfall depths based on the tipping bucket gauge network. The result is spatially representative rainfall depths across the region, as shown in figure 7. This product enables full, region wide analysis of extreme rainfall events.

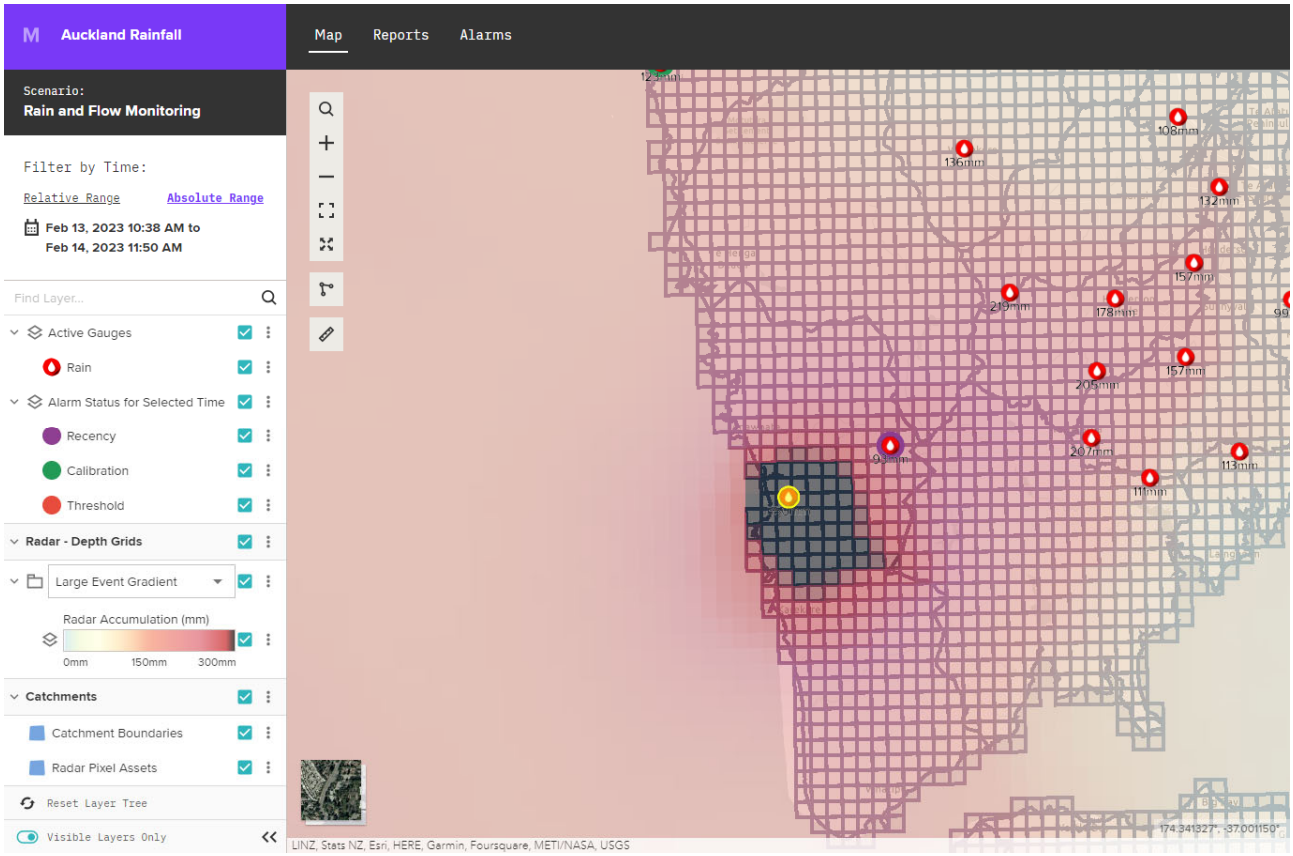



*Figure 7: QPE Rain radar depth accumulations 13 February 2023 to 15 February 2023. The yellow grid location is the rainfall at the raingauge location at Piha*

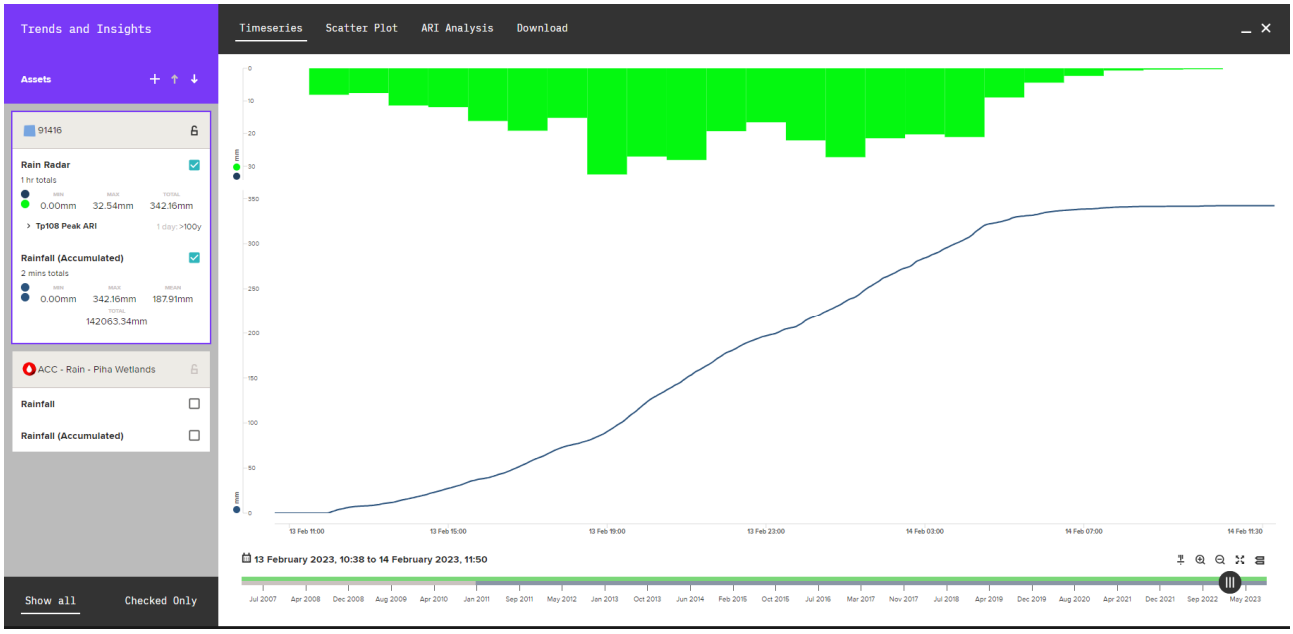
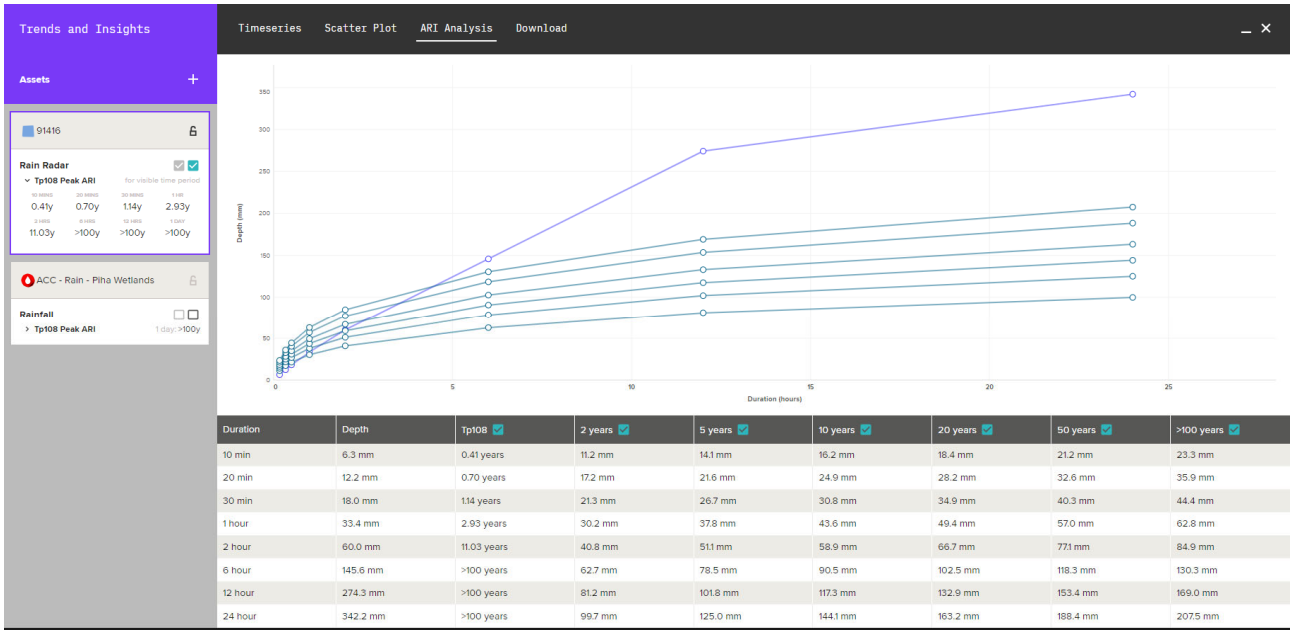



*Figure 8: QPE Rain radar depths in Muriwai 13 February 2023 to 15 February 2023*

Figure 9 below shows the Depth-duration-Frequency curve for the QPE grid location at Muriwai. The X-axis shows duration, y axis shows depth in a given event, and the curves show the expected rainfall depths for a range of ARIs from 2 to 100-year return period (TP108, Auckland design rainfall depths).

What happened during the event is plotted in purple. This analysis and the figures in table 3 shows that the rainfall total exceeded the 100-year event from a 6 to 24 hour duration.




| Duration | Depth | Tp108 | 2 years | 5 years | 10 years | 20 years | 50 years | >100 years |
|---|---|---|---|---|---|---|---|---|
| 10 min | 6.3 mm | 0.41 years | 11.2 mm | 14.1 mm | 16.2 mm | 18.4 mm | 21.2 mm | 23.3 mm |
| 20 min | 12.2 mm | 0.70 years | 17.2 mm | 21.6 mm | 24.9 mm | 28.2 mm | 32.6 mm | 35.9 mm |
| 30 min | 18.0 mm | 1.14 years | 21.3 mm | 26.7 mm | 30.8 mm | 34.9 mm | 40.3 mm | 44.4 mm |
| 1 hour | 33.4 mm | 2.93 years | 30.2 mm | 37.8 mm | 43.6 mm | 49.4 mm | 57.0 mm | 62.8 mm |
| 2 hour | 60.0 mm | 11.03 years | 40.8 mm | 51.1 mm | 58.9 mm | 66.7 mm | 77.1 mm | 84.9 mm |
| 6 hour | 145.6 mm | >100 years | 62.7 mm | 78.5 mm | 90.5 mm | 102.5 mm | 118.3 mm | 130.3 mm |
| 12 hour | 274.3 mm | >100 years | 81.2 mm | 101.8 mm | 117.3 mm | 132.9 mm | 153.4 mm | 169.0 mm |
| 24 hour | 342.2 mm | >100 years | 99.7 mm | 125.0 mm | 144.1 mm | 163.2 mm | 188.4 mm | 207.5 mm |

*Figure 9: Depth-duration-Frequency curve for the QPE grid location at Piha (91416).*

*Table 3 Depth-duration-table for the QPE grid location at Piha (91416).*

| Duration | Depth | Tp108 ☑ |
|---|---|---|
| 10 min | 6.3 mm | 0.41 years |
| 20 min | 12.2 mm | 0.70 years |
| 30 min | 18.0 mm | 1.14 years |
| 1 hour | 33.4 mm | 2.93 years |
| 2 hour | 60.0 mm | 11.03 years |
| 6 hour | 145.6 mm | >100 years |
| 12 hour | 274.3 mm | >100 years |
| 24 hour | 342.2 mm | >100 years |

*Table 4 – Depth-duration table from NIWA (HIRDSv4) including 250-year return period.*

Results

Site Details | Historical Data | RCP2.6 Scenario | RCP4.5 Scenario | RCP6.0 Scenario | RCP8.5 Scenario

**Rainfall depths (mm) :: Historical Data**

| ARI | AEP | 10m | 20m | 30m | 1h | 2h | 6h | 12h | 24h | 48h |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.58 | 0.633 | 11.8 | 15.5 | 18.1 | 23.3 | 29.7 | 42.7 | 52.9 | 64.8 | 78.5 |
| 2 | 0.500 | 12.9 | 16.9 | 19.7 | 25.4 | 32.4 | 46.6 | 57.7 | 70.8 | 85.7 |
| 5 | 0.200 | 16.4 | 21.5 | 25.1 | 32.4 | 41.4 | 59.7 | 74.1 | 91.0 | 110 |
| 10 | 0.100 | 18.9 | 24.9 | 29.1 | 37.6 | 48.1 | 69.4 | 86.2 | 106 | 129 |
| 20 | 0.050 | 21.5 | 28.3 | 33.1 | 42.8 | 54.8 | 79.2 | 98.5 | 121 | 147 |
| 30 | 0.033 | 23.0 | 30.3 | 35.5 | 45.9 | 58.8 | 85.0 | 106 | 130 | 158 |
| 40 | 0.025 | 24.1 | 31.8 | 37.2 | 48.1 | 61.7 | 89.2 | 111 | 137 | 166 |
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| 60 | 0.017 | 25.6 | 33.8 | 39.6 | 51.3 | 65.7 | 95.2 | 119 | 146 | 178 |
| 80 | 0.013 | 26.7 | 35.3 | 41.3 | 53.5 | 68.6 | 99.4 | 124 | 153 | 186 |
| 100 | 0.010 | 27.6 | 36.4 | 42.6 | 55.3 | 70.9 | 103 | 128 | 158 | 192 |
| 250 | 0.004 | 31.0 | 41.0 | 48.0 | 62.3 | 79.9 | 116 | 145 | 179 | 218 |

## Conclusions

The above data suggests that for the 6 to 24-hour duration the ARI is >100 years and may be in the order of 250 years. However, the calculation above the 100-year assessment becomes increasingly unreliable, primarily as a result of the relatively short statistical rainfall records available in New Zealand.

For the other durations modelled, the rainfall was below the 100-year event.

## 2023 Rainfall and antecedent conditions

The rain experienced in the Auckland region since the 1st of January 2023 has been historically significant.

During the period from the 1st of January to the 15th of February, 704 mm of rainfall has fallen at Piha. Compared to the average rainfall for Piha for January of 70mm, indicates just how much rain has fallen at this location.

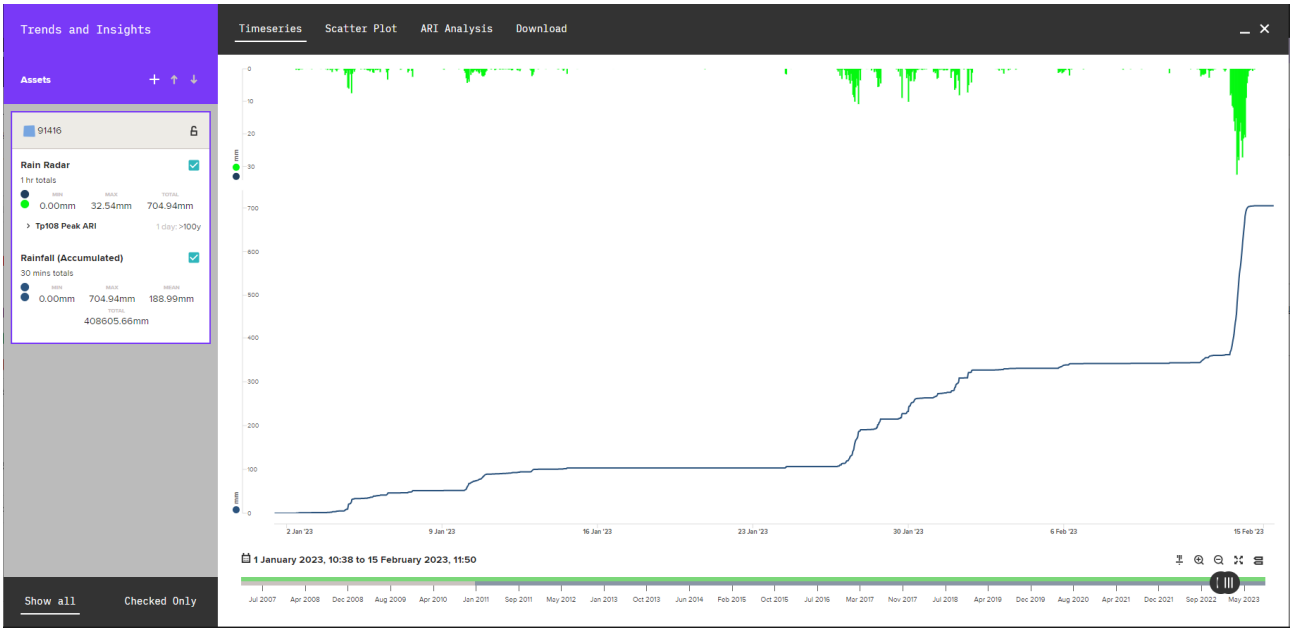


*Figure 10: QPE Rain radar depths in Piha 1 January 2023 to 15 February 2023*

## Caveats

This interpretation is using data sampled from the rain gauges that doesn't include the statistics from the recent events that Auckland has experienced – the theory is that including these events in the record will shift and change the return periods and depth for all of Auckland.

Auckland Council have commissioned NIWA to undertake the analysis to re-run HIRDS 4 for Auckland to include the recent 3 years of extreme rainfall data – the results of this are expected by November 2023.

## Recommendations

There are several different methods to extrapolate return periods which will all give very different and uncertain results.

It is recommended that for reporting purposes that an envelope of "risk" is determined as the ARI figures will change over time and as these events are incorporated into the statistical record. In general, for Piha it is considered reasonable to consider the event to be in the range of 100-250 year ARI.

For long-term risk assessment a 20% increase in rainfall intensity over the period has been projected by NIWA. A simplistic assessment (without climate modelling input) suggests this would change a 250-year ARI event to a 50-year ARI event. Risk assessment should consider both the current and future risk by re-calculating the risk considering this increased frequency.

For short-term risk assessments consideration should be given to the antecedent ground saturation that is likely to persist at least through the winter of 2023.

## ASSESSING THE ARI OF THE AUCKLAND ANNIVERSARY FLOODS – CENTRAL AUCKLAND

Auckland experienced its largest ever rain event on the 27th January 2023. The majority of urban Auckland received rainfall in excess of the 100 year event. Thousands of houses and commercial buildings were inundated with floodwater.

Extreme rainfall was widespread across the region, with a wide front tracking in a southerly direction from the Northeast, impacting the Hibiscus Coast, North Shore, West, and Central Auckland before passing to the South of the Auckland Region.

While the rain was widespread across the region, including reported flooding in the Northern and Southern Rural areas, it was our urban city catchments which bore the brunt of the event and have experienced significant flooding issues.

Regionally there are two sources of rainfall data available for analysis.

1. Physical TB3 tipping bucket rain gauge.
2. Auckland Councils Quantitative Precipitation Estimate (QPE) Rain Radar System.

### TB3 tipping bucket rain gauge.

Rainfall totals during the period from 00:00am Friday 27/01/2023 to 07:00am Saturday 28/01/2023 were in excess of 230mm at many locations across the region's urban extents, with the maximum recorded total during this period being 318mm. Most of the rain fell in a 4 hour period. The Onehunga @ Harbourside rain gauge measured 146 mm of rainfall in a 2-hour period, the average total rainfall for January is 73.8mm.

*Table 5: Summary rainfall statistics by stormwater operational area 12am 27 Jan to 7am 28 Jan*

| | **Total (00:00 27 Jan 07:00 28 Jan) mm** | | **1 Hour Total mm** | |
|---|---|---|---|---|
| | Max | Average | Max | Average |
| **North** | 284 | 193 | 75 | 46 |
| **Central/West** | 286 | 217 | 91 | 50 |
| **South** | 263 | 163 | 75 | 32 |

*Summary figures are calculated from all rain gauges in each of the 3 sub-regional areas. i.e., the max is the rain gauge in each area with the highest total for the event. The average is the average rain across all the rain gauges in that sub region. For example, in North there are 25 rain gauges which were averaged to get 193mm*

### Quantitative Precipitation Estimate (QPE) Rain Radar System.

The QPE rain radar system is a real-time rainfall product which utilises the Metservice radar (reflectivity), which is transformed using a relationship to rainfall depths based on the tipping bucket gauge network. The result is spatially representative rainfall depths across the region, as shown in figure 11.

This product enables full, region wide analysis of extreme rainfall events.

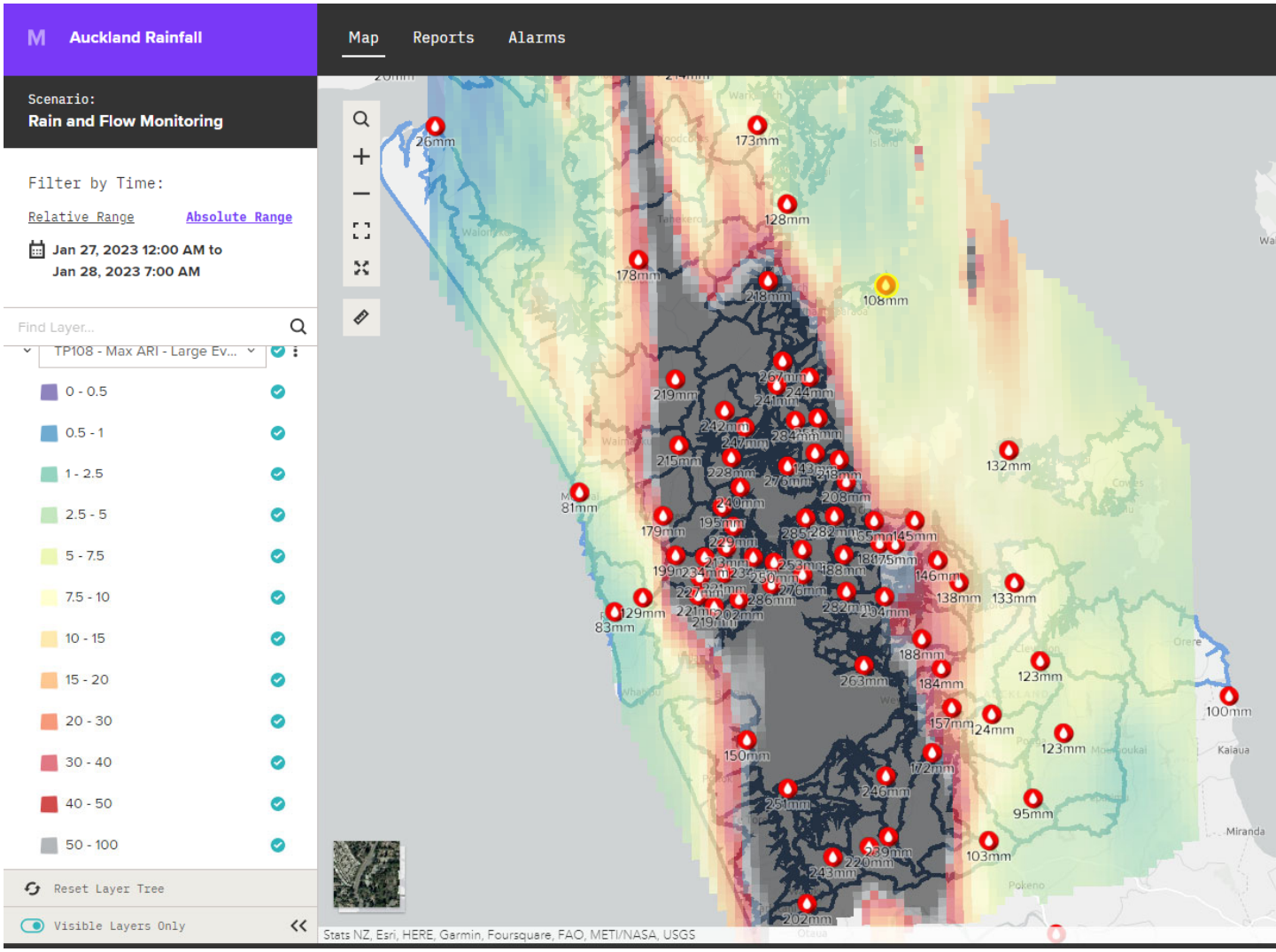


*Figure 11 Recorded Rainfall Radar Max Average Recurrence Interval (ARI). The black area is where rainfall was greater than a 100yr ARI (for any of the 10,20,30 min and 1,2,6,12,24-hour durations) In the black area the event was greater than 100yr for the vast majority of durations.*

## Conclusions

The above data suggests that for the majority of the region the ARI for this event is >100 years and may be in the order of 250 years. However, the calculation above the 100-year assessment becomes increasingly unreliable, primarily because of the relatively short statistical rainfall records available in New Zealand.

Further analysis of this event by NIWA (https://niwa.co.nz/news/auckland-suffers-wettest-month-in-history) highlights the extreme nature of this event, indicating that this event could be described a "at least a 1-in-200-year event".

## Caveats

This interpretation is using data and models sampled from rain gauges that doesn't include the statistics from the recent events that Auckland has experienced, the theory is that including these events in the record will shift and change the return periods and depth for all of Auckland.

Auckland Council have commissioned NIWA to undertake the analysis to re-run HIRDS 4 for Auckland to include the recent 3 years of extreme rainfall data – the results of this are expected by November 2023.

## Recommendations

There are several different methods to extrapolate return periods which will all give very different and uncertain results.

It is recommended that for reporting purposes that an envelope of "risk" is determined as the ARI figures will change over time and as these events are incorporated into the statistical record. In general, for the Auckland Anniversary floods it is considered reasonable to consider the event to be in the range of 100-250 year ARI.

For long-term risk assessment a 20% increase in rainfall intensity over the period has been projected by NIWA. A simplistic assessment (without climate modelling input) suggests this would change a 250-year ARI event to a 50-year ARI event. Risk assessment should consider both the current and future risk by re-calculating the risk considering this increased frequency.

For short-term risk assessments consideration should be given to the antecedent ground saturation that is likely to persist at least through the winter of 2023.