MANAGING THE INTERFACE WITH NATURAL STSTEMS

Kyle Christensen - Water & Environment Leader, Cardno

Tim Strang - Senior Advisor Stormwater, Wellington Water Limited

Des Scrimgeour – Senior Engineer Operations, Wellington Water Limited

Sam Lister – Manager Contracts and Customer Service, Wellington Water Limited

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ABSTRACT

Where the piped stormwater network joins with the open channel network can often be a point at which numerous issues arise, particularly during flood events. At the upstream end of the system there can be large natural catchments which bring down large volumes of water and debris (gravel and vegetation) which result in blockage of intakes. At the downstream end of the piped stormwater network there will be a discharge point into either a natural stream or river or the coast. The dynamic nature of these boundaries, particularly with regard to aggrading bed levels can significantly affect the performance of the network.

In the large flood events in the Wellington Region in April/May 2015 there were significant issues at both the upstream and downstream ends of the piped stormwater network with intakes and outfalls being blocked or buried with gravel. At the upstream end of the system the common issue was gravel and vegetation that was bought down during the event blocked culvert intakes. At the downstream end of the network a number of stormwater outlets were blocked due to longer term build of river bed levels.

The combined effect of the upstream and downstream blockages was significant overflows, surcharging and inundation of a large number of residential and commercial properties including most of the Porirua CBD.

This event highlighted the need for more active management of sediment and river bed levels in both the upstream and downstream channels to ensure the performance of the urban network is not compromised when it is most needed to function effectively.

In response to this event Wellington Water has initiated investigations to install sediment traps at all of the key locations where large upstream catchments meet with the stormwater network. A more active monitoring approach for critical reaches of the downstream river systems is also being developed in collaboration with Greater Wellington Regional Council to ensure that outlets remain functional.

KEYWORDS

Sediment, debris, aggradation, degradation, blockage, overflow

PRESENTER PROFILE

Kyle Christensen is the Water & Environment Leader for Cardno in New Zealand. Kyle leads a team of engineers, scientists, planners, spatial analysts, and landscape architects to deliver innovative river, stream and stormwater projects across the country. Kyle is a technical specialist in hydrology, hydraulics and sediment transport and has a philosophy of working with the processes occurring in natural systems to create effective long term solutions.

1 INTRODUCTION

A northwesterly weather system brought significant high intensity rainfall across the Porirua District on the morning of the 14th of May 2015. This was after similar very large events (30 to 80 year return period) hit the Wellington City and Lower Hutt Districts on the 28th of April and the 12th of May.

The peak rainfall on the 14th of May occurred between 11:00 am and 11:30 am when 33.6 mm of rain fell in 30 minutes which is estimated to be in excess of a 100 year event. This high intensity rainfall fell on the catchments on the eastern slopes of Colonial Knob including Takapuwahia Stream, Te Araroa Trail Stream and Mitchell Stream as well as across the central business district (CBD) and the lower end of Keneperu Stream in Porirua East.

The extreme nature of this event meant that vast quantities of water as well as gravel, silt, trees and vegetation came down these waterways which resulted in blockages of culvert inlets and secondary flood overflows down roads and through properties. These secondary overflows, particularly from the Raiha Street/Prosser Street system, eventually ended up in the CBD causing significant disruption and damage to commercial properties.

In addition to the secondary overflows into the CBD this central area was also affected by direct rainfall which is also estimated to be in the order of a 100 year event. The CBD stormwater system was not functioning as efficiently as it could have done due to a number of stormwater outlets in Porirua Stream being buried by gravel. It is estimated that gravel build up in lower reaches of Porirua Stream is in the order of 0.5 m to 1.0 m but it is not clear how much of this build up occurred during this event.

In some areas the natural channels broke their banks and streams changed course causing inundation through residential properties. This was the case for Takapuwahia Stream at the downstream end of Rangituhi Park where four residential properties were affected.

Another significant problem was the Raiha Street culvert on Mitchell Stream. This culvert became blocked with debris during the event and water flowed through the road embankment fill resulting in material being internally eroded (piping) and the road slumping.

Overall this was a very significant event which affected a wide area and a large number of people. Extensive clean up and emergency works were completed at a number of sites and there are a number of possible longer term improvements that could be investigated following the issues highlighted during this event.

2 EVENT RAINFALL SUMMARY

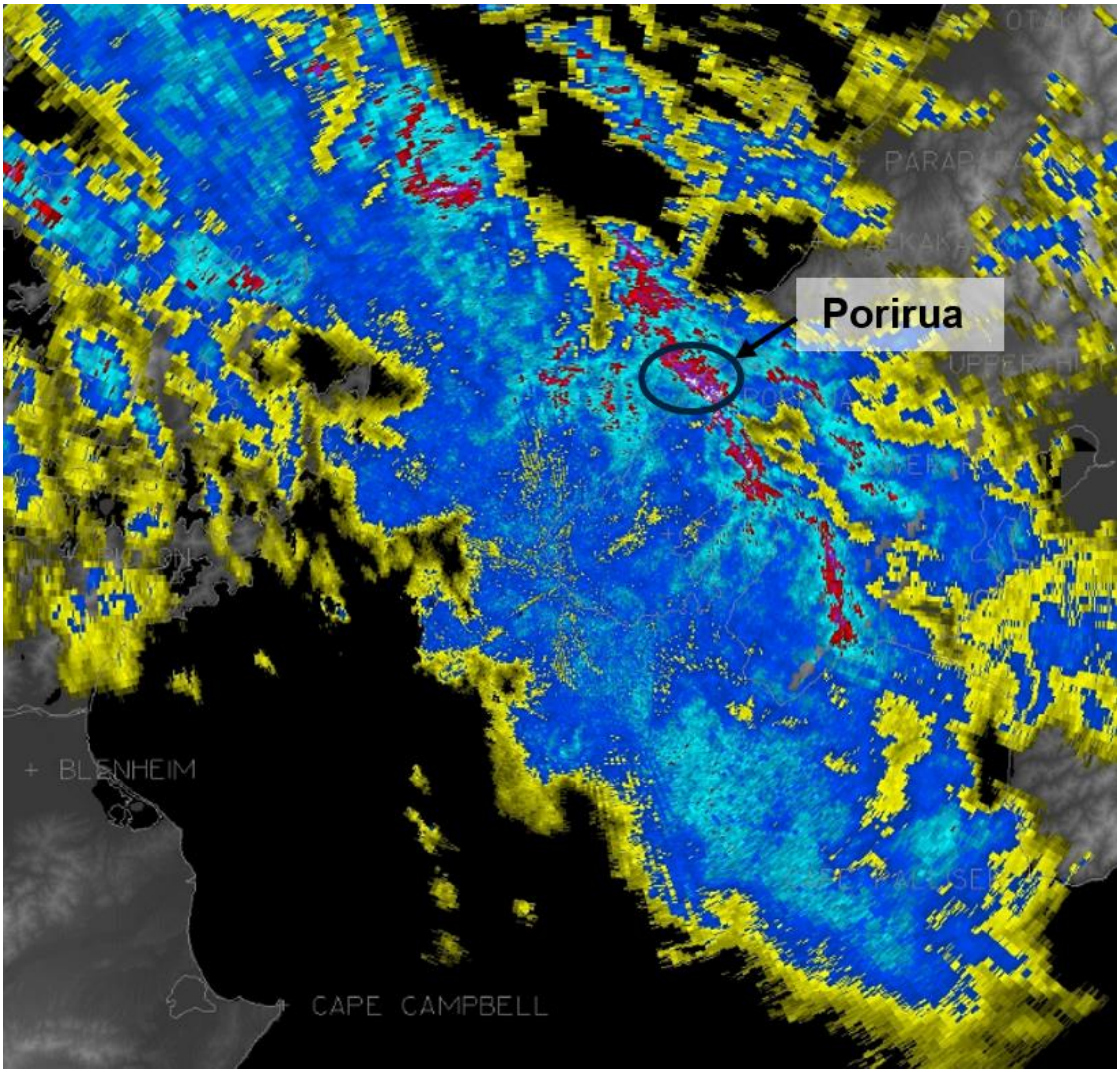
2.1 RAINFALL EVENT

On the morning of the 14th of May a strong north-westerly weather system tracked over the lower North Island delivering intense thunderstorms to the Kapiti Coast, Porirua, Tawa and Hutt Valley. The event was characterised by very high intensity rainfall over a short duration which resulted in rapid run-off from the small, steep stormwater catchments on the eastern slopes of Colonial Knob, across the Porirua CBD and into the lower sections of Keneperu Stream in Porirua East. The following section provides a summary of the rainfall information that was measured during the event around Porirua as well as an initial assessment of the return period (probability) of this event.

2.2 RAINFALL DATA SOURCES & QUALITY

The MetService operates a rain radar that picks up the relative intensity of rainfall across the Wellington region. An image at close to the peak of the rainfall intensity is shown in Figure 1. This provides an indication of the extent of the highest rainfall intensities. The figure shows the highest intensities across the Colonial Knob catchments, the CBD as well as into Porirua East.

Figure 1 - Rain Radar Image at Close to Peak Rainfall Intensity ~10:30 am 14 April 2015 (Source: MetService)



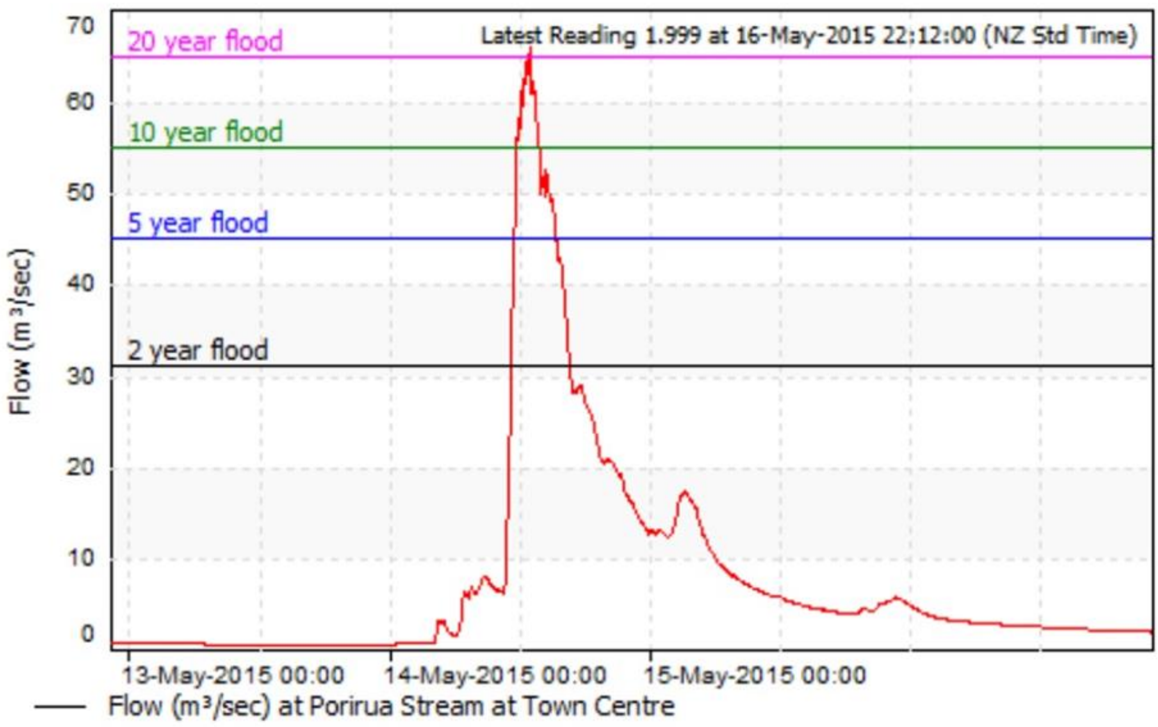
Greater Wellington Regional Council (GWRC) maintains a network of four rain gauges within the Porirua and Tawa areas that provide reliable data to examine for this event. A number of other rain gauges are operated within this area but appeared to malfunction during this event. One additional gauge on Tuna Crescent in Titahi Bay, which is operated and maintained by Mott MacDonald on behalf of PCC, has been considered in this analysis and there is no reason to doubt the accuracy of this particular gauge. Together these five rain gauges provide a good level of data across the network to assess rainfall depths and return periods. This data goes through a careful audit and checking process before being officially published but due to the short timeframes necessary for reporting on this event the raw "unchecked" data has been used. No gross anomalies were found in the data through initial checking by Cardno and it is considered that this data is fit for the purpose of reporting the overall characteristics and extent of this rainfall event. The peak recorded rainfall depths for the 10 minute, 30 minute and one hour durations are provided in Table 1.

These durations have been presented as they are the ones that are most relevant in terms of the "time of concentration" of the stormwater catchments that were most affected. The "time of concentration" is an indication of the travel time of stormwater from the upstream to the downstream end of the catchment. This in effect limits the area of the catchment that is able to contribute to the peak flow i.e. an extreme 10 min duration rainfall will effect localised sub-catchments within a larger catchment but these sub-catchment flows will not coincide to produce a larger event at the downstream end of the catchment. This is partly evidenced by the flows measured in the Porirua Stream which have been estimated as peaking at only a 20 year return period as shown in Figure 2. The lower return period of the measured flows in Porirua Stream is also likely due to the reducing rainfall intensities in the upper reaches of the Porirua Stream catchment. Longer duration (60 minutes +) extreme events result in larger parts of the catchment contributing to peak flows and have the potential for network capacity to be exceeded.

Table 1 Recorded Rainfall Depths (Source: GWRC & Mott MacDonald)*

Rain Gauge Site	**10 minute rainfall depth (mm)**	**30 minute rainfall depth (mm)**	**1 hour rainfall depth (mm)**
Taupo Stream @ Whenua Tapu	10.9	19.6	26.1
Battle Hill	11.5	19.5	30
Titahi Bay @ Pikarere*	20.8	33.6	36.4
Tawa @ Pool	8	22	39
Seton Nossiter Park	6.8	12.2	17.2

Figure 2 - Porirua Stream Flows 14 May 2015 (Source: Greater Wellington Regional Council)



2.3 RAINFALL DISCUSSION

The peak rainfall intensity occurred between 11:00 am and 11:30 am on 14 May with 33.6 mm of rain recorded in Titahi Bay (Pikarere) in just 30 minutes. The areas affected by the highest intensity rainfall have been estimated to cover the eastern slopes of Colonial Knob, the CBD and the lower end of Porirua East. The next highest recordings were in Tawa where 22 mm fell in 30 minutes and 39 mm within an hour. The key feature of this rainfall is that it occurred over a very short period. A contour map providing an approximate spatial distribution of the 30 minute rainfall is provided in Appendix A. This contour map is based on the measured figures at each site then fitted by hand taking account of the rainfall radar imagery provided by the MetService.

Figure 3 - 14 May 2015 - 5 min interval rainfall depths Titahi Bay/Pikarere (Data Source: Mott MacDonald)

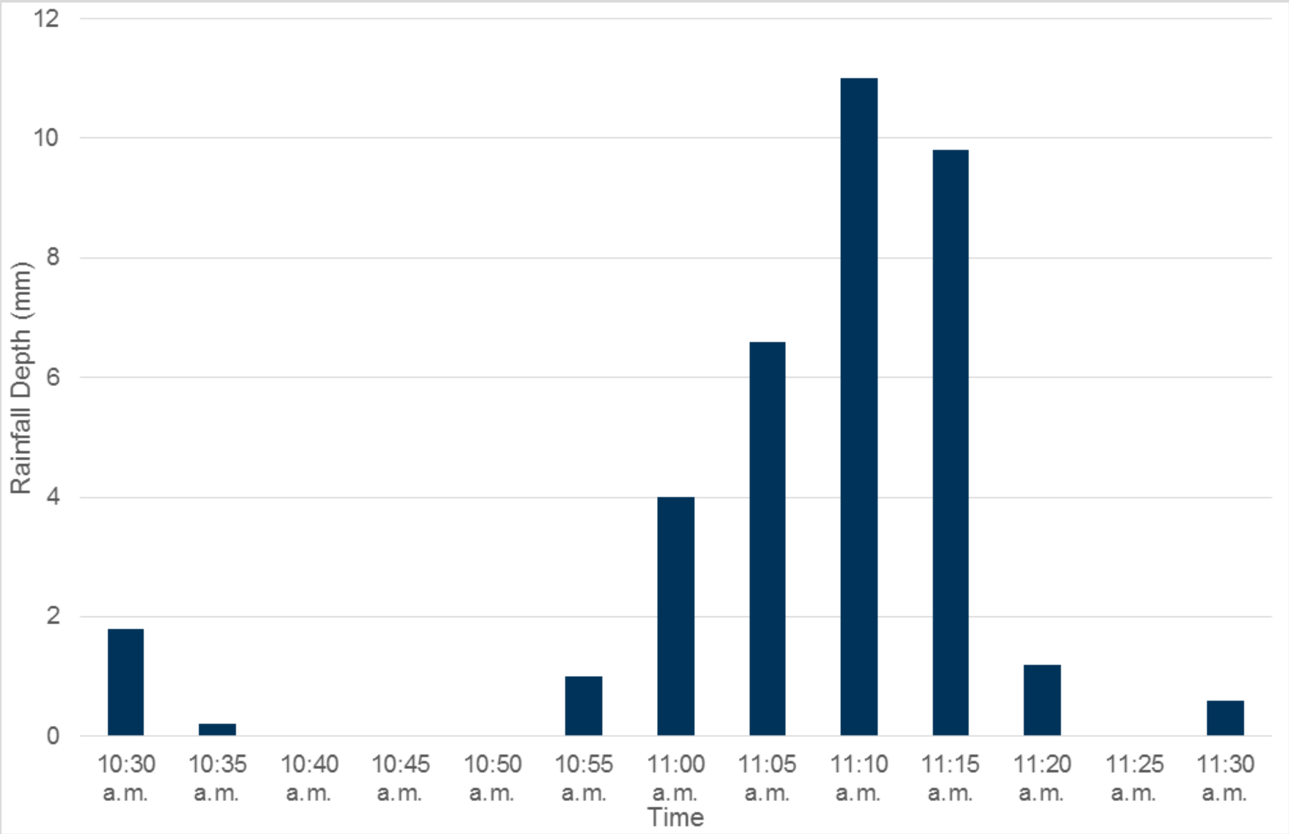
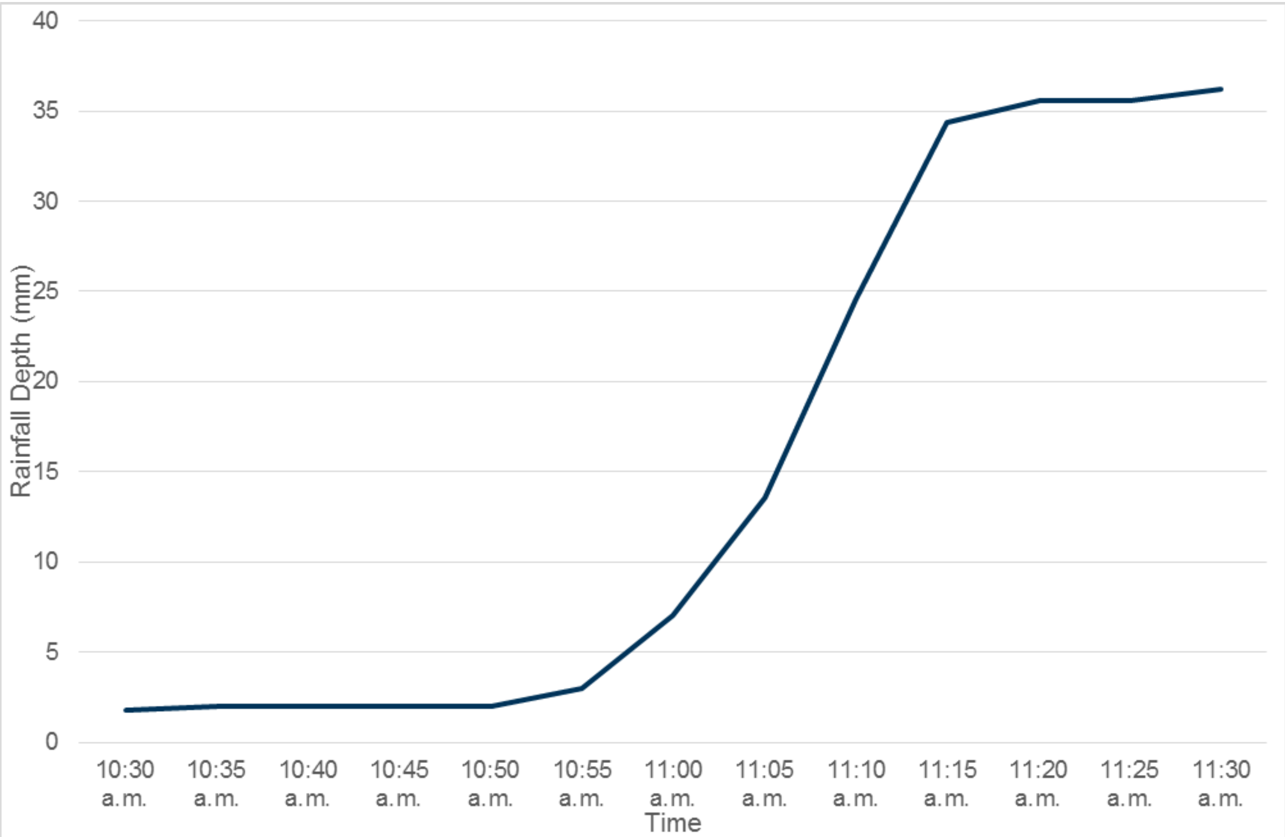


Figure 4 - 14 May 2015 - Cumulative rainfall Titahi Bay/Pikarere (Data Source: Mott MacDonald)



2.4 RAINFALL RETURN PERIODS

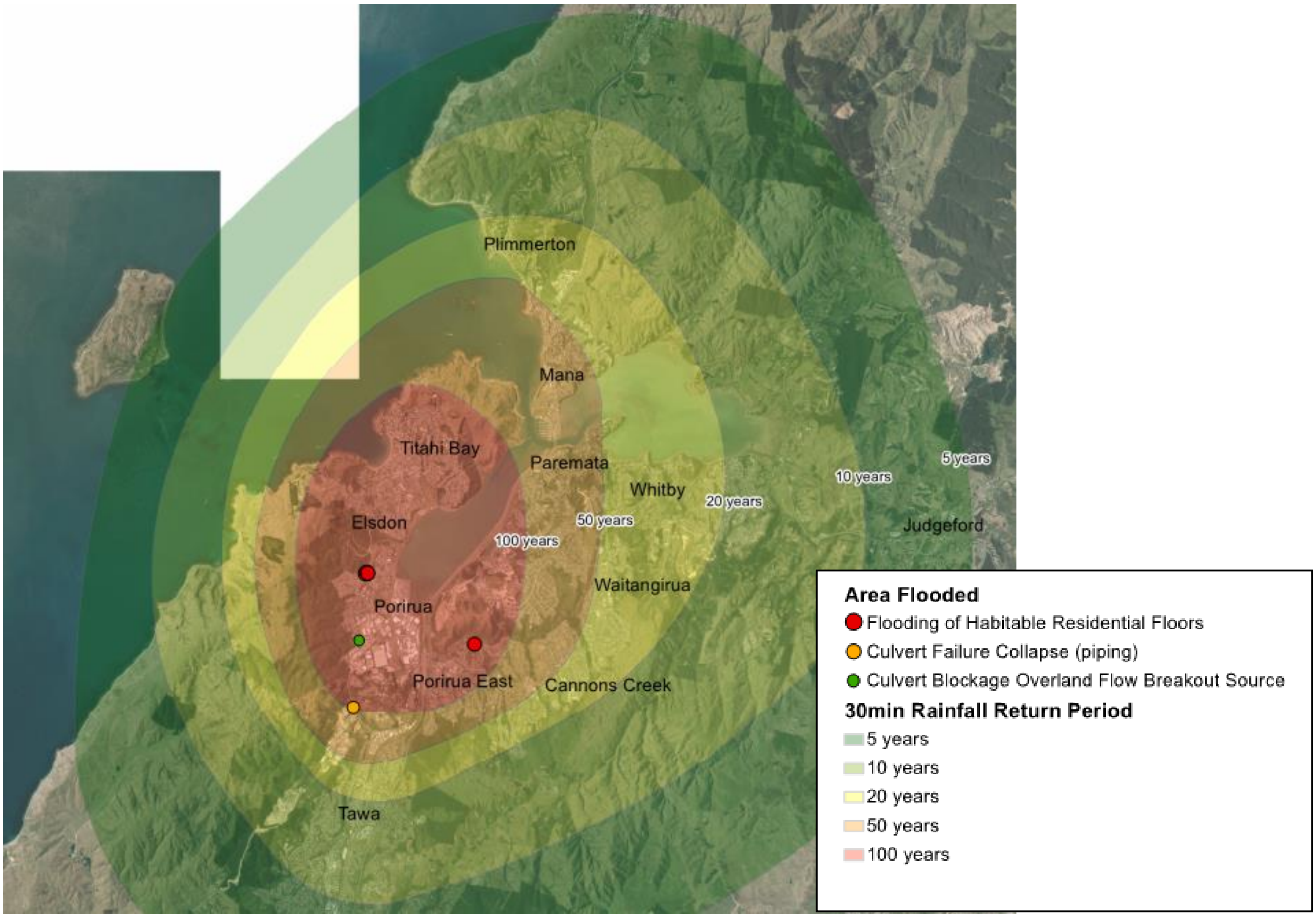
The return periods assigned to the recorded rainfall depths at each site have been approximated based on the NIWA Rainfall interpolation tool (HIRDS V3). The use of these approximate return periods is considered sufficient for the purposes of this report but at-site analysis could be considered to confirm appropriate rainfall depths for design purposes.

It must also be noted that the return periods provided in Table 2 are based on assessment of rainfall over the past hundred years without any allowance for future climate change. If the recommended 16 – 20% (Ministry for Environment & Greater Wellington Regional Council Policy) increase in rainfall over the next 100 years is applied these return periods will generally be cut in half i.e. the current 50 year return period rainfall depth is equivalent to a 25 year return period when considering the 2115 climate.

Table 2 - Approximate Rainfall Return Periods Across Affected Area

Rain Gauge Site	10 minute rainfall return period (years)	30 minute rainfall return period (years)	1 hour rainfall return period (years)
Taupo Stream @ Whenua Tapu	8	10	8
Battle Hill	10	8	11
Titahi Bay / Pikarere	>100	>100	>100
Tawa @ Pool	4	24	68
Seton Nossiter Park	2	2	2

Figure 5 – May 2015 Rainfall Return Periods



3 EVENT IMPACT SUMMARY

3.1 Overview

This section describes why the flooding occurred and the key areas that were impacted across the Porirua District. The assessment is based on observations during the event and response/recovery activities undertaken by PCC staff and contractors. It is noted that due to the widespread nature of the flood event, particularly within the commercial area of the CBD, specific addresses have not been provided for all areas.

3.2 Flooding Mechanisms

The very high rainfall intensity of this event meant that the small, steep stormwater catchments on the eastern slopes of Colonial Knob were severely affected. The critical duration of rainfall for these smaller catchments will be in the 10 minute to 30 minute range with larger catchments such as the Porirua Stream being affected to a lesser degree due to the event not being long enough for the full catchment to contribute to peak flows in the downstream reaches.

The severity of the event across a short duration resulted in not only significant water flowing in these catchments but substantial debris including sediment and vegetation. At the interface of where the natural stream channels meet the piped stormwater network significant issues arose due the vast volume of water as well as the blockage of inlets due to the debris load. As these inlets became overwhelmed secondary flow paths began to operate which flowed down roads as well as through houses before ending up in the CBD.

3.3 Takapuwahia Stream – Rangituhi Crescent & Takapuwahia Drive

The Takapuwahia Stream catchment is within the zone of the highest rainfall intensity and was significantly affected by this event. The volume of flow and debris overwhelmed the inlet structure at the upstream end of Porirua Scenic Reserve (see Figure 6) and flood waters then tracked overland before flowing through gardens and garages on Rangituhi Crescent (see Figure 7).

Figure 6 - Inlet structure upstream end of Rangituhi stormwater network

Figure 7 - Rangituhi Crescent adjacent to Rangituhi Park near peak of event

3.3.1 POSSIBLE IMPROVEMENTS FOR INVESTIGATION – RANGITUHI/TAKAPUWAHIA

Emergency works were undertaken to redirect the channel back into its existing course at the downstream end of Rangituhi Park as well as clearance of the debris blocking the inlets at the upstream end of Porirua Scenic Reserve. During a post event site inspection an option for improving the upstream end of the overflow path in the Porirua Scenic reserve with an increased bund protecting the adjacent properties was discussed. This would need to be combined with regrading of the road adjacent to Rangituhi Park to allow secondary flow into the park via an engineered spillway rather than through neighbouring properties. There could also be an opportunity to use the park as a temporary detention dam for extreme events to reduce downstream flows.

Investigation and a resource consent application is currently being sought for a sediment trap upstream of the culvert inlet to ensure that the piped system can be utilised rather than effectively being "empty" due to a blocked inlet and total upstream flow being conveyed by secondary flow paths.

3.4 Mitchell Stream – Raiha Street Culvert

Mitchell Stream was also significantly affected during the event with a large volume of water and debris (see Figure 8) flowing down the stream and causing the Raiha Street culvert to block. This blockage resulted in water building up on the upstream side of the structure and then flowing through the road embankment fill. The water flowing through the road embankment fill washed out the finer material resulting in slumping of the road (see Figure 9) and erosion around the culvert trench at the downstream end (see Figure 10. This failure mechanism is known as "piping" and is more commonly encountered in embankment dam situations. It is fortunate that this piping failure didn't result in full failure and collapse of the road embankment as this would have likely resulted in a sudden wave of sediment and water down Mitchell Stream.

Figure 8 - Debris upstream Raiha Street Culvert – Mitchell Stream (post event)

Figure 9 - Slumping of Raiha Street above culvert

Figure 10 - Piping failure of embankment fill (downstream side)

3.4.1 POSSIBLE IMPROVEMENTS – MITCHELL STREAM/RAIHA STREET CULVERT

The road was immediately closed due to the risk of collapse through the voids in the embankment above the culvert. Services were also isolated on both sides of the culvert to mitigate the risk of gas/sewer/water leaks. Following initial investigations the damaged fill was excavated and then re-compacted with the road reinstated. There is also a design and resource consent application underway for a large sediment/debris trap upstream of the culvert to mitigate the risk of future blockage.

3.5 CENTRAL BUISNESS DISTRICT (CBD)

Vast areas of the CBD were affected by this event with water entering a large number of commercial properties (see Figure 11). This water was partly sourced from the overflows occurring from the Raiha/Prosser system in addition to the rainfall landing directly on the CBD itself. The outfalls from the CBD stormwater network are likely to have been affected by gravel build up in Porirua Stream and were either partially or completed blocked during the event. The extent of this gravel build up appears to be from the Porirua Stream flow gauging station down to the confluence with Keneperu Stream. Visual inspection suggests that 0.5 m to 1.0 m of gravel has built up through this reach (See Figure 12). It is not clear how much of this build up occurred during the event.

Figure 11 - Porirua CBD 14 May 2015 (Source: Greater Wellington Regional Council)

Figure 12 - Gravel build up to the top of the ~ 1 m high river bank walls in Porirua Stream

3.5.1 POSSIBLE IMPROVEMENTS – CBD

The proposed Titahi Bay Road stormwater interceptor project would capture a significant portion of the overland flows before they reached the CBD and would have an outlet that would be less affected by channel aggradation. Notwithstanding this the functioning of the CBD stormwater network relies on the outfalls into Porirua Stream operating effectively. As highlighted above these were buried by gravel at some stage during the event. Emergency works were undertaken to clear the gravel build up within the immediate vicinity of the outlets. Subsequently Greater Wellington Regional Council have confirmed bed levels through this reach have risen since the previous survey and have removed 4,000 m^3 of gravel from this reach.

4 CONCLUSIONS

1. The interface of the pipe network with natural systems is a key area of risk that needs to be monitored, managed and maintained to ensure the pipe network and overland flow systems work effectively when needed.

2. Overland flow paths are a vital part of the stormwater network and ensuring they work effectively and can ultimately return stormwater back into the river/stream network is essential. This becomes more difficult when the downstream receiving stream/river is protected by stopbanks. In some cases consideration is needed of specific outlets and or pumped systems to allow secondary flows back into the downstream systems.

3. Having "empty" stormwater pipes due to inlets being blocked with sediment increases the reliance on overland flow paths and steps need to be taken to ensure the primary system can function during large events. Having well designed and maintained sediment traps upstream of key inlets where sediment blockage is an

essential part of minimising blockage risk. Also trapping and removing this material before it gets into the piped system is a far more cost effective than trying to remove it once it is within the network.

4. Monitoring and managing the downstream receiving environment is equally important in terms of the overall performance of the stormwater network. Build-up of sediment (aggradation) in the stream/river will affect the hydraulic performance of the stormwater network and in the worst case can completely bury the outlet. This can be the case in river and coastal environments. Ensuring that bed levels are maintained or outlets are modified to provide the required performance during storm events is essential.

ACKNOWLEDGEMENTS

We would like to acknowledge the patience and positive attitude of all the residents and businesses affected by the 2015 flooding as we work towards increasing the resilience of the stormwater network.