Waikato Regional Council Technical Report 2018/09

Grahams Creek flood protection scheme design report

www.waikatoregion.govt.nz
ISSN 2230-4355 (Print)
ISSN 2230-4363 (Online)

Waikato
REGIONAL COUNCIL
Te Kaunihera ā Rohe o Waikato

Prepared by:
Ghassan Basheer

For:
Waikato Regional Council
Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

23 April 2018

Document #: 12305172

Peer reviewed by:
Dean Allen Date October 2018

Approved for release by:
Greg Ryan Date November 2018

Disclaimer

Acknowledgement

The Grahams Creek Flood Protection Scheme was developed, designed, and implemented over a number of years. The scheme is the result of the joint effort and collaboration of the local Tairua Township community, local Iwi, Department of Conservation (DOC), Thames Coromandel District Council (TCDC) and Waikato Regional Council (WRC).

The writer wishes to acknowledge the significant effort and input of Julie Beaufill, Emily O'Donnell, Kerry Smith, Duncan Grant and other staff for their efforts in bringing this project to a successful conclusion.

Special thanks to Waikato Regional Council elected members as well as TCDC staff Matt Busch and Garry Towler and elected members Mayor Glenn Leach and Community Board Chair Bob Renton, for their continued support through the whole project, and ensuring the District Council's commitments were met.

We wish to acknowledge the Grahams Creek community working party community members; Joyce Birdsall, Tony Jacobs, Phil Smith, Ian Jowett, Jim Jackson and Graham Turner , who have diligently assisted the development of the scheme requirements and offered great support and insight during design and delivery phases. Special thanks also, to Graham Turner whose property holds the key scheme assets and offered his floodplain property to develop and construct the key scheme components.

We wish to acknowledge Bryn Quilter of Tonkin and Taylor Consultants and Hugh McMurray of Barnett and McMurray for their design input and technical support. Special thanks and acknowledgement goes to Juan Jose Martinez for his efforts in development and design of the self-closing floodgate which operates by differential hydraulic head.

Table of Contents

Table of Figures

List of Tables

Abstract

The purpose of this report is to document how key aspects of the Grahams Creek flood protection scheme in Tairua came into being and the level of flood protection it offers this community.

Specifically the report provides an outline of the community demand for the scheme, community participation in defining the scheme parameters and levels of service, the scheme components and future requirements. It also describes the existing residual flood risks having constructed the flood protection works, to ensure that the beneficiaries of the scheme and local communities are aware of the scheme limitations.

The technical details and data sets are covered in other technical and design reports, management reports, and project reports, which are referenced within this report.

The scheme is considered innovative and unique in a number of aspects, including rehabilitating the stream bed, self-regulating floodgate, translocation of saltmarsh and extensive riparian planting to reduce the likelihood of flooding.

Executive summary

The area
Tairua Township is located on the east coast of the Coromandel Peninsula along the northern bank of the Tairua River and Harbour.

The Grahams Creek catchment, which runs through the town and into the Tairua River is susceptible to short duration but high intensity rain events causing flash flooding and debris flow in the streams and surrounding land with little or no warning.

The Grahams Creek community is located at the base of the catchment on a coastal alluvial formation. The presence of residential dwellings on the low-lying land adjacent to Grahams Stream means that many properties are subject to flood hazard from the stream.

Since the introduction of the Peninsula Project in 2004, the Waikato Regional Council (WRC) and Thames Coromandel District Council (TCDC), have worked with the Grahams Creek community to develop a flood mitigation strategy to address the Grahams Stream flood hazards.

For the success of the development of the Grahams Creek Flood Protection Scheme it was essential that the community was involved. A working party was established in the community to liaise with the various authorities, define issues, discuss options, and work together to implement the project.

Flood issues along Grahams Creek
The primary reason for flooding of properties in this area was due to floodplain obstructions. These included the undersized Manaia Road Bridge, historic bunds and drain cleaning material, infilling of the floodplain, vegetation and the relative position and levels of properties within the floodplain in relation to flood levels and tidal conditions.

Flood scheme design
Hydraulic modelling was undertaken to assess the most appropriate flood scheme design for Grahams Stream. The final flood scheme design option was selected and approved by the community.

The approved flood scheme design provides flood reduction that varies between the left bank (Ocean Beach Road) and the right bank.

The approved design provides protection from a 1% AEP (100 year ARI) flood event along the right bank for the properties on Manaia, Hapenui, and Hornsea Roads.

Properties on Ocean Beach Road are provided flood reduction for up to 60 properties, with flood levels being reduced by up to 1.45m (with an average 0.48m) for a 1% AEP (100 year ARI) flood event. The reduced levels result in existing building floor levels along Ocean Beach road to be above a 2% AEP (50 year ARI) flood event, although inundation will still occur on the properties. For the 2% AEP (50 year ARI) flood event, water levels for some properties will be less than 500 mm from the floor level.

In a 1% AEP (100 year ARI) flood, water levels will exceed some existing floor levels along Ocean Beach Road, however flood inundation times will be significantly reduced dependent on location and elevation.

The scheme has been operational since constructed as designed over 2015 and 2016. The scheme has performed as designed with no issues during significant rainfall events in 2017.

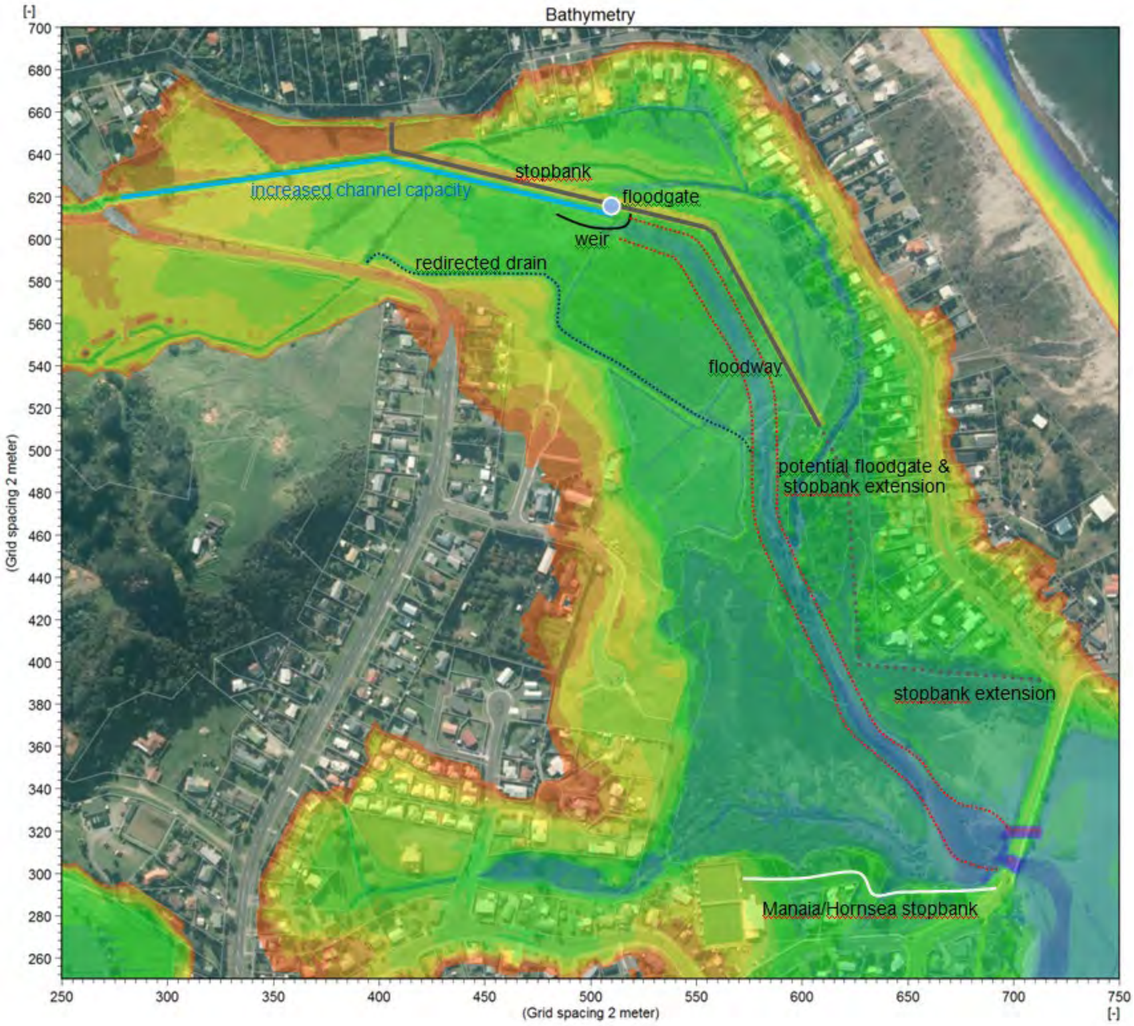

Figure 1 Outline of flood protection scheme in the Grahams Creek community.

Managing the residual risk to the area

Based on the flood hazard status of land in the community, TCDC has various planning controls in place via the Thames Coromandel District Plan, that restrict what land use activities can be undertaken.

The main channel of the Grahams Stream is monitored and periodically maintained by WRC to remove accumulated sediment and debris. This work maintains the capacity of the stream and reduces the risk to adjacent land that would otherwise be inundated more frequently.

If there are any significant changes in land use in the Grahams Creek catchment the scheme viability and design would need to be reviewed.

Catchment management and soil conservation works are recommended for the Grahams Creek catchment to complement the flood mitigation works undertaken.

1 Introduction

1.1 Catchment overview

1.1.1 Catchment description

Grahams Creek is located on the east coast of the Coromandel Peninsula, north of the Tairua town centre on State Highway 25 (refer to Figure 2).

Figure 2 Location of Tairua, on the Coromandel Peninsula

The Grahams Stream catchment covers an area of 9.45km^2 (Figure 3). The upper catchment is predominantly steep with a cover of bush and scrub rising to an elevation of approximately 380m. The lower floodplain and foothills proximal to Tairua and the State Highway (SH25) have been cleared for development or pasture.

Bush and scrub cover approximately 80% of the catchment, whilst the remainder is pasture or residential. As the catchment is short and steep it can produce very high flows under short periods of intense rainfall.

Figure 3 Grahams Stream catchment extent – 9.45km^2

1.1.2 Grahams Stream

The Grahams Stream flows out of the Coromandel Ranges and through the Grahams Creek community before discharging into Paku Bay and Tairua Harbour (refer to Figure 4).

Figure 4 Grahams Stream floodplain between Hornsea Road and SH25 at Tairua

The stream is incised and steep as it flows in the hill catchment, then widens and flattens as it enters the low developed part of Tairua. The gravelly bed is dynamic and bed load movement occurs naturally with significant volumes mobilised during flood events.

The stream is also tidal within its downstream boundary. The tidal effect extends approximately 1km upstream of the Manaia causeway bridge on Hornsea Road. The combination of tidal influence, stream flow and bed load movement has infilled the lower floodplain, reducing storage capacity upstream of the causeway.

The Manaia Causeway Bridge on Hornsea Road was found to be undersized with a waterway capacity equivalent to the annual flood flow.

The floodway associated with the stream channel was also heavily vegetated and infilled within the lower 600m. Further upstream, the stream channel runs within and adjacent to residential properties backyards. Some owners have constructed small bridge crossings over the stream channel.

The ground levels and general land topography are shown in Figure 5 below.

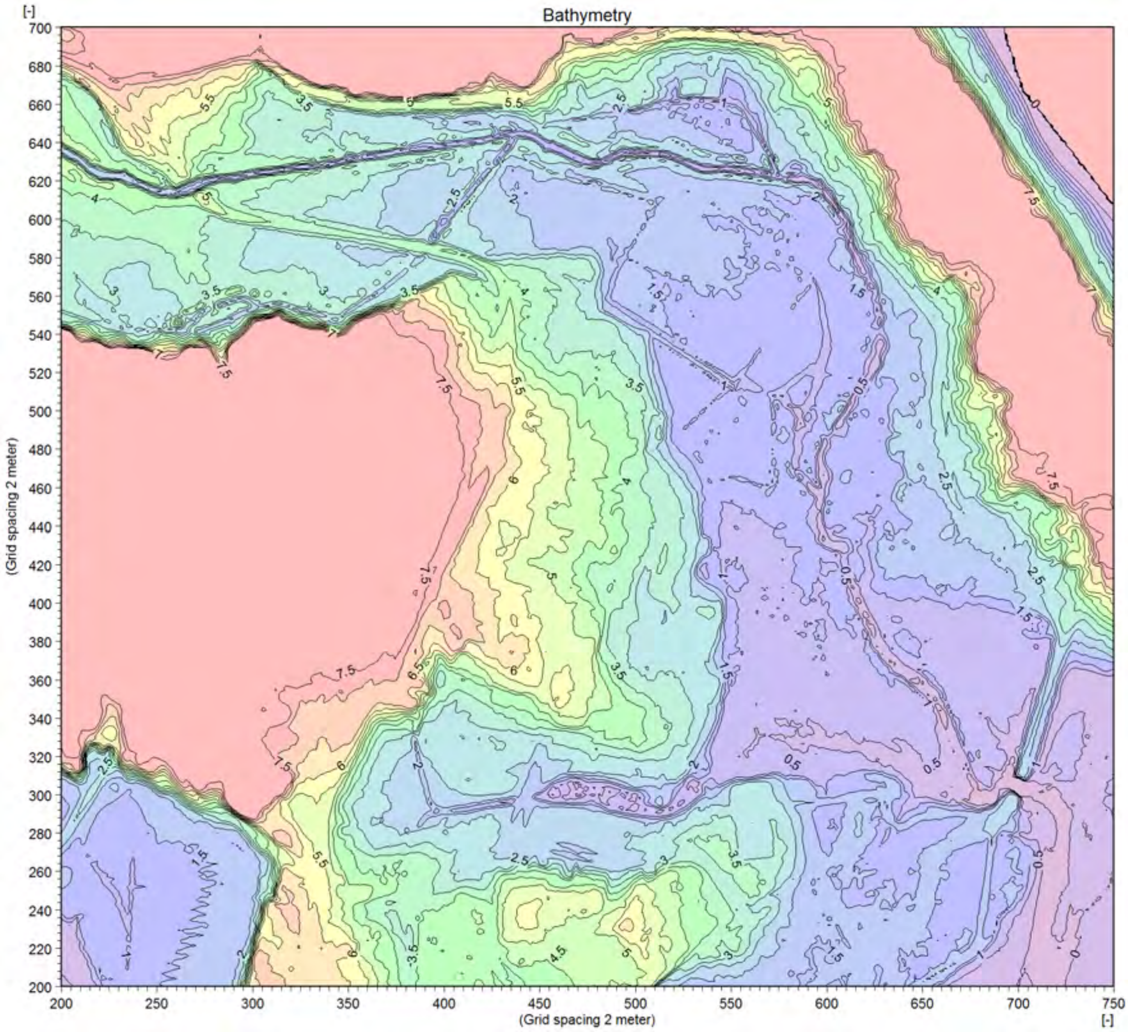

Figure 5 Existing topography of Grahams Creek area (relative to Moturiki Vertical datum)

1.1.3 Flooding issues

Properties adjacent to the lower Grahams Stream between the Manaia Road Causeway and SH25 are subject to flooding. This includes properties on the left bank on Ocean Beach Road, and on the right bank on Manaia, Hapenui, and Hornsea Roads. The flooding of properties is primarily due to both floodplain obstructions and the relative position and levels of these properties within the floodplain in relation to flood flows and tidal conditions.

The primary floodplain obstruction is the Manaia Road Causeway which significantly reduces the downstream conveyance of floodwaters from entering Tairua Harbour. Further upstream SH25 crosses the floodplain restricting the downstream conveyance of floodwater. However the SH25 embankment allows upstream floodplain storage of approximately 23,000m^3 prior to overtopping without impacting on residential properties. The floodplain in pasture between Manaia Road causeway and SH25 also has a number of channels and bunds relating to historic drainage works which have an effect on the passage of floodwater. Further downstream the floodplain is heavily vegetated within a reserve area.

Whilst most of the adjacent properties on Ocean Beach Road are potentially affected by flooding, the main channel flows through the rear of many properties which are subject to a greater flood risk associated with higher floodwater velocities and depths.

Properties on Manaia, Hapenui, and Hornsea Roads are potentially affected by overland flows overtopping an existing low stopbank on the right bank, aligned between the causeway and the bowling club some 200m west. These properties can be more easily protected from fluvial floods by raising the crest levels on the existing stopbank and/or increasing the discharge capacity at the causeway. However, this area is also particularly low relative to sea levels and is subject to potential flooding from extreme sea levels, and in the future possible sea level rise. The area is currently protected by a foreshore stopbank and flapped stormwater outlets, and therefore local runoff or overland flows may pond when sea levels exceed ponded water levels.

The area potentially affected by a 1%AEP (100 year ARI) flood inundation is shown in Figure 6 below. While the area along Manaia Road is protected by a foreshore stopbank, it is subject to flooding from the Grahams Stream right bank. The stopbank does not have adequate height to prevent overtopping.

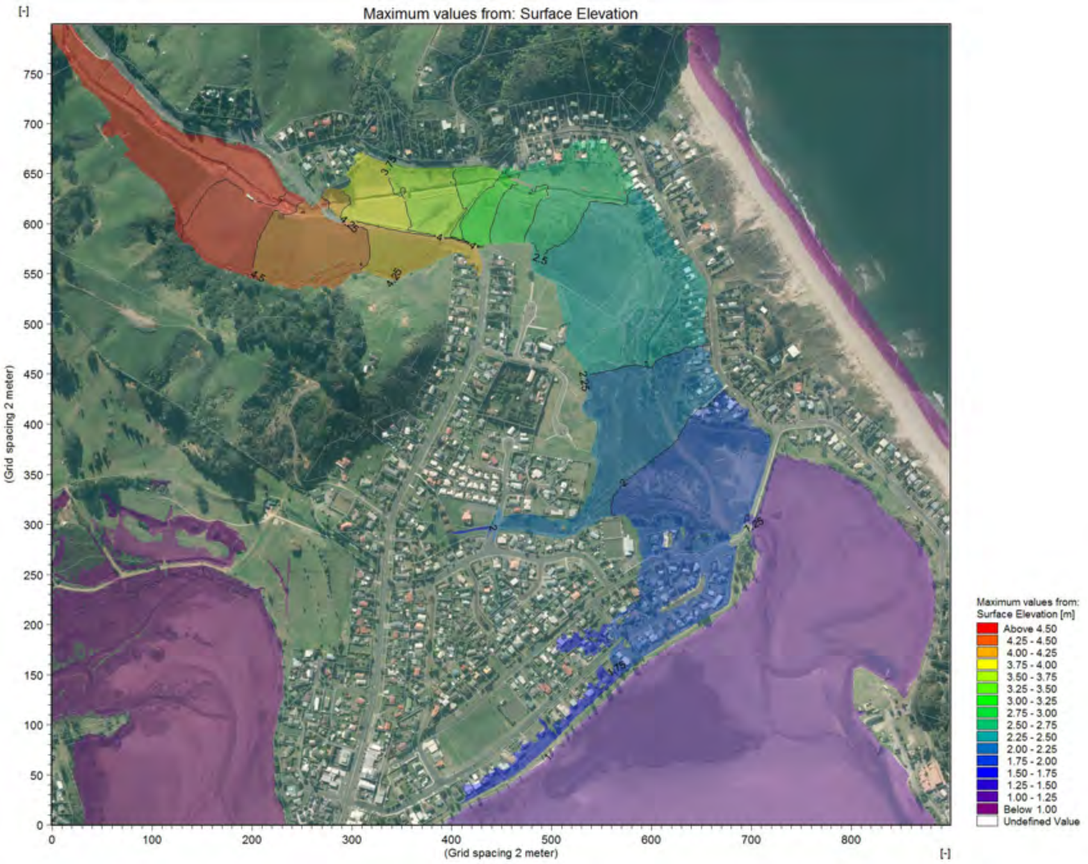

Figure 6 Predicted inundation for the pre scheme 100y flood levels (relative to Moturiki vertical Datum)

The significance of the flood hazard to the Grahams Stream community has been demonstrated several times over the last 30 years. Damage to properties was focused on those properties adjacent to the stream and floodway.

2 Hydrology

The following section describes the methods used to determine the peak flood flows and the flood hydrograph.

2.1 Peak flood flows

Discharges for the various model scenarios are based on the recent hydrological review (Barnett & MacMurray, 2014). This was undertaken for average recurrence intervals (ARI) of 2, 5, 10, 20, 50 and 100 years (Table 1).

The peak flows determined in the review were determined by scaling the statistical analysis of gauged flows from a 'donor' catchment with similar catchment characteristics. In this case the donor catchment was the Tairua River at Broken Hills which provided a flow record of 38 years, with scaling of peak flows in proportion to the catchment area to the power of 0.8 (McKerchar and Pearson, 1989).

Climate change discharge assumed an average increase in temperature of 3ºC, and 8% increase in rainfall for each one degree increase in temperature.

Table 1 Estimated peak flood flows for Grahams Stream.
(Source: Barnett & MacMurray, 2014)

%AEP (Average recurrence interval)	Discharge (m^3/s)
50%AEP (2 year)	46.5
20%AEP (5 year)	70
10%AEP (10 year)	86
5%AEP (20 year)	102
2%AEP (50 year)	122
1%AEP (100 year)	137
1%AEP CC*(100 year CC*)	170*

*Climate change discharge based on simplified approach assuming a 24% increase in rainfall depth gives a similar increase in peak discharge

2.2 Flood volume and hydrograph shape

For the purposes of establishing a realistic hydraulic model for Grahams Stream, a direct-rainfall-runoff MIKE21 model was developed. This included the entire catchment using an 8m grid based on WRC's GEOGRAPHX DTM database. Application of steady high intensity rainfall for different durations showed that the time to peak downstream of SH25 Bridge was between one and two hours.

Sensitivity testing was then undertaken with various loss rates and roughness values. HIRDS (version 3) rainfall depths for various durations were then applied including nesting tests. Again the catchment response in terms of time to peak and peak discharge was assessed, and this confirmed similar to those above at one to two hours.

Following several trials of rainfall depth/duration and times to peak, it was found that the hydrograph generated from the catchment wide application of a 1h HIRDS rainfall depth, with a time to peak of 1.5h produced the most realistic hydrograph shape and this was scaled for the various model inflows.

Figure 7 shows the inflow hydrographs for the various events applied to the hydraulic model.

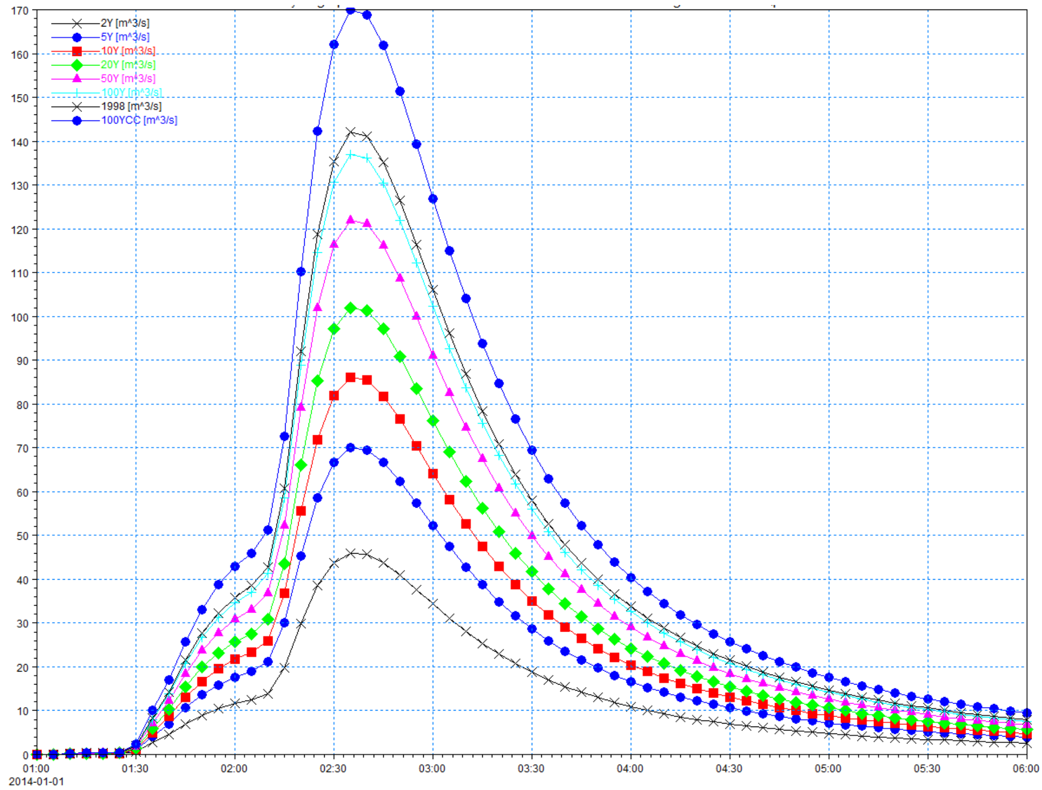

Figure 7 **Inflow hydrographs for Grahams Stream for various events**

3 Hydraulic model parameters

The following chapter describes the hydraulic modelling undertaken for Grahams Stream to investigate a flood alleviation proposal to reduce flood levels within the low-lying floodplain between the Manaia Road causeway and SH25.

It briefly describes the hydraulic model parameters established to understand current flood behaviour, and that for the design case. Modelling of different flood scenarios was used to confirm the flood alleviation scheme design parameters.

3.1 Model bathymetry

The model bathymetry (2m grid) is based on LIDAR which provides high resolution (1m) topographic datasets useful in developing 2-dimensional model surfaces. The LIDAR and model datasets are in the horizontal datum New Zealand Transverse Mercator (NZTM). The vertical datum was established following review of the 2004 and 2012 LIDAR data sets, and ground level surveys undertaken in 2014 to confirm accuracy of the LIDAR data. The model vertical datum is Moturiki Vertical Datum 1953.

The bathymetry derived from 2012 LIDAR has been used to represent the existing case (Figure 8) with modifications made as required to represent the proposed flood alleviation option. The 2m grid developed provided high resolution representation of the floodplain, storage and overland flow-paths and was an improvement on the previous models used at conceptual design stage.

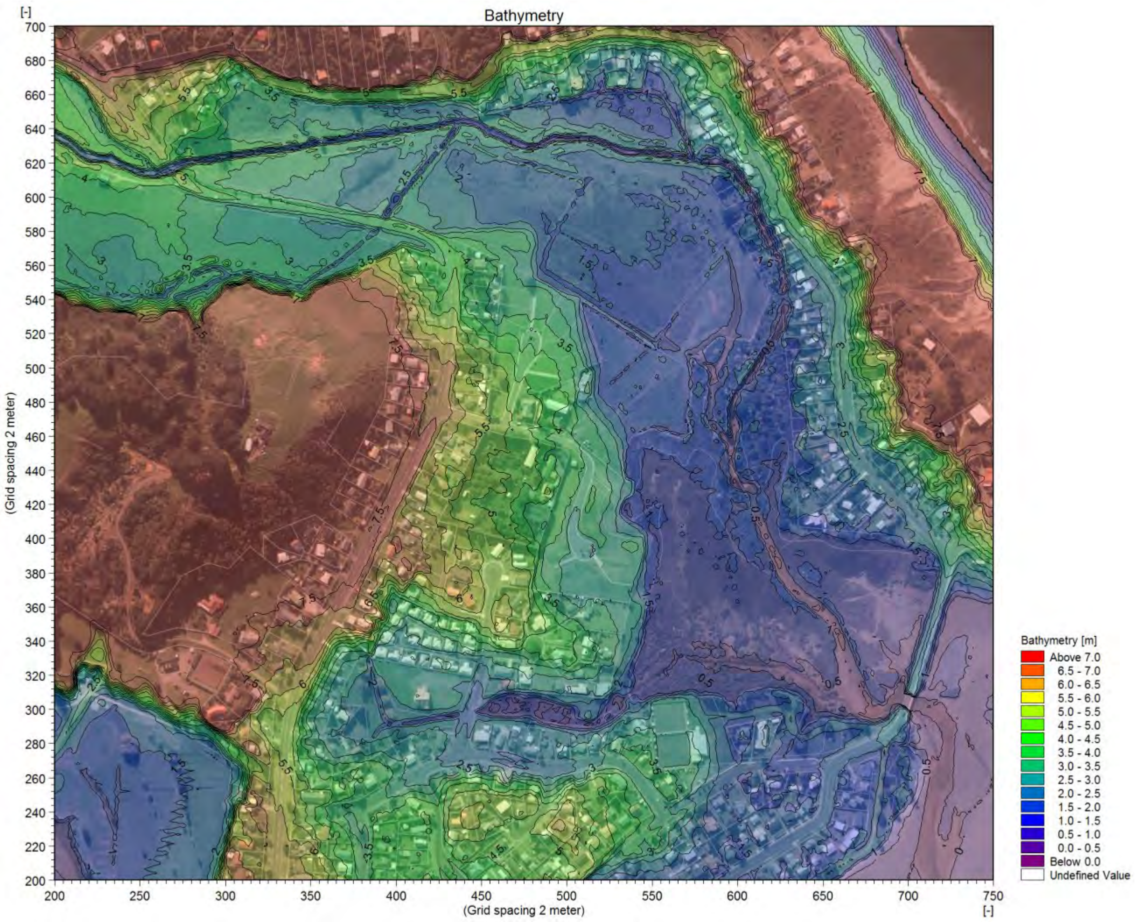

Figure 8 **Existing 2012 LIDAR bathymetry used in modelling the existing case with aerial/land parcel background (relative to Moturiki vertical datum)**

3.2 Sea levels

In order to ensure that the correct tide levels were used with the correct bathymetry datum, a review of reference datum used for all previous reports and surveys was undertaken, and differences documented. A design high tide level for the model was established and confirmed as an appropriate downstream boundary.

Tide levels assumed in the model are detailed in Table 2.

Table 2 Tide levels used in hydraulic modelling.

Tide	Moturiki Vertical Datum 1953 (MVD-53) (m)
Design high tide + 0.8m SLR	1.80
Design high tide	1.00

Tidal inundation assuming no flood protection under the design high tide condition and the climate change scenario (design high tide + 0.8m sea level rise) is shown in Figure 10, highlighting the low ground levels along Ocean Beach Road properties and those in the Manaia, Hapenui, and Hornsea Road area.

Figure 9 Tidal inundation during design high tide

Figure 10 Tidal inundation during design + 0.8m sea level rise

3.3 Roughness

A roughness file was used to reflect the various surfaces in the model domain, whether in-channel, within the floodway or the heavier vegetation of the reserve. The roughness was also adjusted dependent on the simulation to represent the conditions being modelled (e.g. floodway, additional bridge opening, etc.).

Manning's M roughness values used are in-channel and floodway (40), floodplain (20), and reserve (10). Roughness maps used in the existing case and the proposed case are shown in Figure 11.

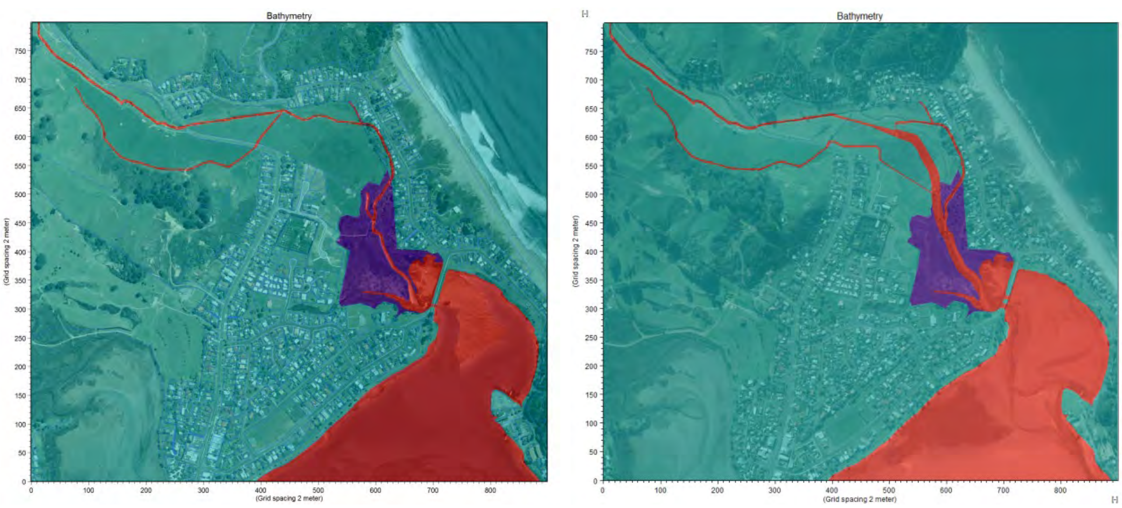

Figure 11 Roughness maps used in existing and proposed case

3.4 Boundary conditions

Dependent on the event being modelled, the flows described in Section 2 were applied at the upstream extent of Grahams Stream in the model, approximately 650m upstream of the SH25 Bridge.

The downstream boundary was modelled conservatively as a static tide either RL 1.00m for the present day design high tide, or RL 1.8m for the climate change design high tide plus 0.8m sea level rise. Testing of tide levels for the modelled scenarios indicated a minimal effect on peak flood levels upstream of the causeway as found in past flood studies.

3.5 Model calibration

In order to provide some verification for the MIKE21 2D model the severe flood event of December 1998 was modelled and compared to surveyed flood levels. This event triggered the initial investigations of flooding within Grahams Creek community by TCDC. Reports by Montgomery Watson Consultants (2000 & 2001) provided detailed description of the flood event, properties affected and flood levels.

The 1998 event was assessed to have a discharge of $142m^3/s$, which is slightly above the 100 year event coinciding with a high tide level of approximately 1.0m. This event represents the actual flood case in the area, for which flood alleviation measures were to be designed.

Model calibration results confirmed that the MIKE21 2D model replicated the 1998 flood event actual measured flood levels across the floodplain with minor differences.

4 Community consultation

A key step in designing a flood protection scheme is to establish the level of protection that the community is seeking, how that aligns with how much the community is prepared to pay, and what they will tolerate in terms of the residual risks of floods exceeding that protection level.

To do so, WRC established a working party along with TCDC, made up of local community representatives, WRC and TCDC elected representatives and staff to consider different flood alleviation options and select a preferred option that meets the expectations of the community. It is noted that numerous options were developed, consulted on and considered before the preferred option was confirmed following annual plan consultation.

4.1 Scope of flood scheme works

The community working party representatives held several workshops and meetings to discuss and agree the parameters and final design of the flood protection scheme. The key parameters that were used as a reference point throughout the design process were established at the first workshop. These parameters stated that the scheme should include the following:

a. The Manaia Causeway Bridge be extended to pass the design event flow without overtopping the causeway.
b. The bridge extension should be a 2-lane structure similar to the existing bridge with cycleway and pedestrian footpath.
c. The stream channel and associated floodway must be enlarged, re-contoured and obstructions to flow removed.
d. The residential properties along the right bank of Grahams Stream be protected against flooding of a current 1%AEP (100 year) event with 500 mm freeboard.
e. The residential area along the left bank of Grahams Stream be protected to a minimum of a current 2%AEP (50 year) event with varying freeboard. This specifically related to existing habitable floors as many of the residential sections flood in relatively small flood events and/or tidal events.
f. The stream path through the backyards of Ocean Beach Road properties be retained for normal stream flows.
g. The environmental values of the lower floodway wetland be retained and enhanced.
h. The scheme design should allow for potential future extension and upgrade of the scheme to meet future requirements.

It was noted that key points raised through the annual plan consultation process were that while the desire of the community to have a flood scheme was high, the willingness to absorb the major share of the costs burden was not.

Throughout the scoping, collaborative design process and build, WRC technical staff provided technical advice as to what is achievable and how best these requirements could be accommodated within the scheme design. The design was developed and a physical 3D terrain model was produced by a member of the working party to assist the community visualising the scheme.

4.2 Sign off to proceed

A preferred option was put forward as part of the 2014 annual plan process. This was then used by the working party as a baseline for discussion. The resulting final design and build achieved a greater level of protection, as well as environmental and social gains.

With TCDC being prepared to completely fund the upgrade of the Manaia Road Causeway the regional council decided during the annual plan deliberation process that it would proceed, ending several decades of discussions about the viability of a flood protection scheme for the area.

WRC staff believe that the community consultation/engagement process followed was a key success factor in this project and allowed the works to be delivered. Failure to work this way would have likely resulted in the project been abandoned. This shift assisted in 10 resource consents being granted non-notified due to the high level of consultation and engagement including the support and sign off of all iwi in the area and all environmental groups as well as DOC.

A detailed stakeholder register for the Grahams Creek flood protection is documented in (WRC doc. #3143136). A communication plan for the project was also developed (WRC doc. #3143561).

The landowner of the floodway area agreed to allow all required scheme works on his land to be undertaken subject to a number of conditions (WRC doc. #3298641).

5 Agreed service levels

The Coromandel Zone Management Plan (River and Catchment Services et al, 2011) outlines the agreed levels of service for the Coromandel Zone. The agreed levels of service provided for the Coromandel Zone were initially developed when the Peninsula Project was established in 2004. The current service levels were confirmed through an extensive consultation process initially undertaken in 2003/04, and subsequently updated by the LTP processes in 2006 and 2009.

In the Coromandel Zone Management Plan, the Thames Coast including Coromandel Town, and Grahams Creek were identified as a high priority area for flood protection schemes and other river and catchment management works. Additional works could focus on hillside erosion and stabilising erosion prone pastoral lands.

Routine stream management was identified for high priority catchments to reduce the risks of localised flooding through removal of vegetation congestion and blockages and to provide long term environmental benefits through improved water quality; keeping stock out of waterways and fencing and planting of stream margins to reduce bank erosion. Details of the annual operation and maintenance programme undertaken on Grahams Stream is discussed in Section 7.

The general location of the flood protection assets is shown in Figure 13. Refer to Appendix A for design details for the flood protection works at Grahams Stream. As-built survey data is provided in Appendix B and C.
The flood protection scheme on Grahams Stream in Tairua was identified as needing to be maintained and managed to ensure the service level for flood protection assets was maintained.

The service level provided by the scheme at Grahams Creek is varying for the true right and left banks. The agreed Level of Service did not include provision for projected Climate Change.

5.1 Right bank service level

Current climate 1%AEP event (100 year ARI) plus 500mm freeboard for all properties along the right bank of the stream.

5.2 Left bank service level

Current climate up to 2%AEP event (50 year ARI) with varying freeboard to minimum floor levels of existing dwellings (as at 2012). Note that the left bank stopbank is constructed to a 1%AEP (100 year ARI) standard however given the embankment is open-ended, the protection standard achieved on the residential side of the stopbank is current climate 2%AEP (50 year) with varying freeboard. The freeboard specifically relates to existing habitable floor levels as many of the residential sections flood in relatively small flood events and/or tidal events (refer Section 6.5).

6 Technical design

6.1 Proposed flood alleviation components

Modelling of the various flood alleviation components was undertaken to test the effect of these features on reducing flood levels. The components include increased causeway bridge capacity, stopbanks, floodway formation via floodplain re-contouring and increased channel conveyance. These are described in more detail in the following sections and are shown schematically in a potential configuration in Figure 13.

6.2 Bridge capacity

The existing Manaia Road Bridge structure has a span of 16m with a flow capacity of approximately 40m^3/s, and larger flows back up and raise flood levels upstream. The design waterway capacity of the bridge required an extension of the bridge, by adding another 16m span, adjacent to the existing bridge. This was a key requirement for the flood protection scheme. TCDC, as the asset owner, approved the design and construction of the bridge extension required.

Figure 12 Existing (pre-scheme) Manaia Road Bridge and Causeway.

6.3 Channel and floodway capacity

The channel capacity is very small, especially the reach that runs along the backyards of the residential properties. On average, flows of 12m^3/s do cause some form of flooding. Some sections were identified as having a flow capacity as low as 6m^3/s, which means that the stream was overflowing the banks more than 10 times annually.

The floodway associated with the stream channel included several drains and bunds that held the water back within the upper part of the floodplain. This affected the flooding characteristics, causing water levels to rise and spread back upstream, then flow as a wide sheet across the whole floodplain downstream. This increased the flood duration as flood storage occurred at the early stages of the flood. This phenomenon was confirmed by both actual observations and hydraulic modelling.

The design focused on increasing the channel and floodway capacity to convey the flood flows at lower levels than those experienced. The design principles included an estimation of the total flow volume generated by the design event, and increased the floodway capacity to accommodate and convey this volume at lower levels within a shorter period of time. The scheme works included the following elements (use Figure 13 for reference):

A. Stream channel enlargement

The stream channel between SH25 Bridge and No. 51 Ocean Beach Road was approximately 300m long and included low land adjacent to the road on the left bank. The scheme included enlargement of the channel and infilling the low land to divert flows toward the floodway along the right bank.

B. Stream diversion channel

Downstream of the enlarged section above, the stream was diverted into a new channel extending approximately 300m to a point where this diversion returned to meet the original channel. Before its confluence with the original channel, the diversion channel was throttled by an appropriately sized culvert (refer to Section 6.4), to ensure normal low flows continued to feed the stream.

The old channel was completely backfilled after relocating the fish and removing some of the bed material and gravels to line the new diversion channel bed.

C. Spillway and floodway

Immediately upstream of the culvert and floodgate and at the end of the diversion channel, a spillway was constructed to allow overflow over the stream diversion bank. The spillway section had a flatter downstream slope and was strengthened to protect the surface from erosion during overflow.

D. Drain enlargement

Along the right bank of the floodway, a new drain to accommodate flows from the upstream floodplain (above SH25) was constructed. Pre-scheme, this drain was running across the floodplain to feed into the main stream. The drain banks were acting as bunds across the floodway. The new drain has a larger capacity and meets the main stream at the downstream wetland. In effect, isolating the drainage flow reduced the overall flow within the stream under flood conditions. It also improved the water quality within its upper section.

E. Floodway development

The floodway included three separate but connected areas including:

<u>Upstream floodway section</u>: this section included the farmland and stream upstream of the SH25 Bridge. This area was not developed as part of the scheme design. However, it formed part of the total flood storage.

Downstream floodway section: this section extended between SH25 Bridge and the estuarine wetland downstream and included the area of farmland and stream between the properties along both sides of the stream. The design included re-contouring of this section to act as an efficient flood conveyance area. The design provided for the flows within the stream to overtop the stream right banks and convey the volume of water at low level further downstream into the estuary. A 400m long, 32m wide floodway channel was formed downstream of the diversion channel spillway to convey flood flows.

Estuary floodway section: this section extended between the farmland and the Manaia Road Bridge/Causeway. It incorporated saltmarsh plants and wetland species, with overgrown congested stream channel and silted areas. The design included opening up a conveyance channel and removal of vegetation and silt build up to improve its conveyance efficiency.

6.4 Culvert and floodgate

A concrete culvert (1350mm diameter) was placed on the diversion channel, and was constructed to allow normal flows of up to 6m^3/s to feed the stream. Higher flows started to back up the diversion channel. The culvert was large enough to allow bed material movement as well to ensure the stream natural processes continued.

A floodgate specifically designed for the scheme was installed on the inlet of the culvert. This floodgate was designed to operate in response to water levels upstream under hydraulic pressure. When water levels exceeded a specific designed level, a buoy attached to the flap rose, and a lever mechanism pushed the gate to close. At this point, the upstream level rose and breached its bank over a designed spillway. This approach met the working party aspirations of maintaining the stream at the back of the Ocean Beach Road properties, while diverting flood flows away into a designated floodway.

6.5 Stopbanks

Stopbanks have been designed to retain the floods within the channel and adjacent floodway. These included the following:

A. Left bank (northern) stopbank:
The stopbank extended from Ocean Beach Road embankment at a point upstream of property No. 51 Ocean Beach Road and ran along the stream diversion channel, crossed over the flood-gated culvert and continued along the downstream floodway section. The stopbank terminated at the upstream end of the Estuary floodway section.

This stopbank was designed to meet community wishes to retain the existing stream channel through the backyards of residential properties for amenity values. Therefore, the stream channel and adjacent properties are exposed to tidal flooding and backwater effect under flood conditions from the downstream end of the stopbank. However, due to the difference in hydraulic profile along both sides of the stopbank, the floodway side will experience higher flood levels than the residential side.

The stopbank is designed to a protection standard of current climate 1%AEP (100 year) flood event with 500 mm freeboard in the main stream and floodway. The protection standard achieved on the residential side of the stopbank is current climate 2%AEP (50 year) flood event with varying freeboard height. This specifically relates to existing habitable floors as many of the residential sections flood in relatively small flood events and/or tidal events.

In line with the agreed design principles, the stopbank design is versatile in that it can be extended downstream after adding another flood-gated culvert and construction of a floodwall that ties into high ground. It also can be raised and strengthened to accommodate future sea level rise and climate change.

The alignment of the stopbank and floodgates for the partial and full protection cases are shown in Figure 13.

B. Right bank (southern) stopbank:
This stopbank is also referred to as Manaia Road stopbank. A low level stopbank historically existed as a contiguous defence along the estuary foreshore between the southern end of the Manaia causeway and higher ground at the bowling club on Hornsea Road (Figure 13). The stopbank is approximately 250m long and provides protection from floodwaters upstream of the causeway to properties on Manaia/Hapenui/Hornsea Roads.

The scheme included upgrading this existing stopbank by raising and widening to a standard protection of the current climate 1%AEP (100 year) flood event with 500mm freeboard.

On the downstream side of the causeway an existing stopbank forms a contiguous line of defence along the foreshore to the south to provide protection from high sea levels in Tairua Harbour. This stopbank is not part of the scheme and remains a district council asset.

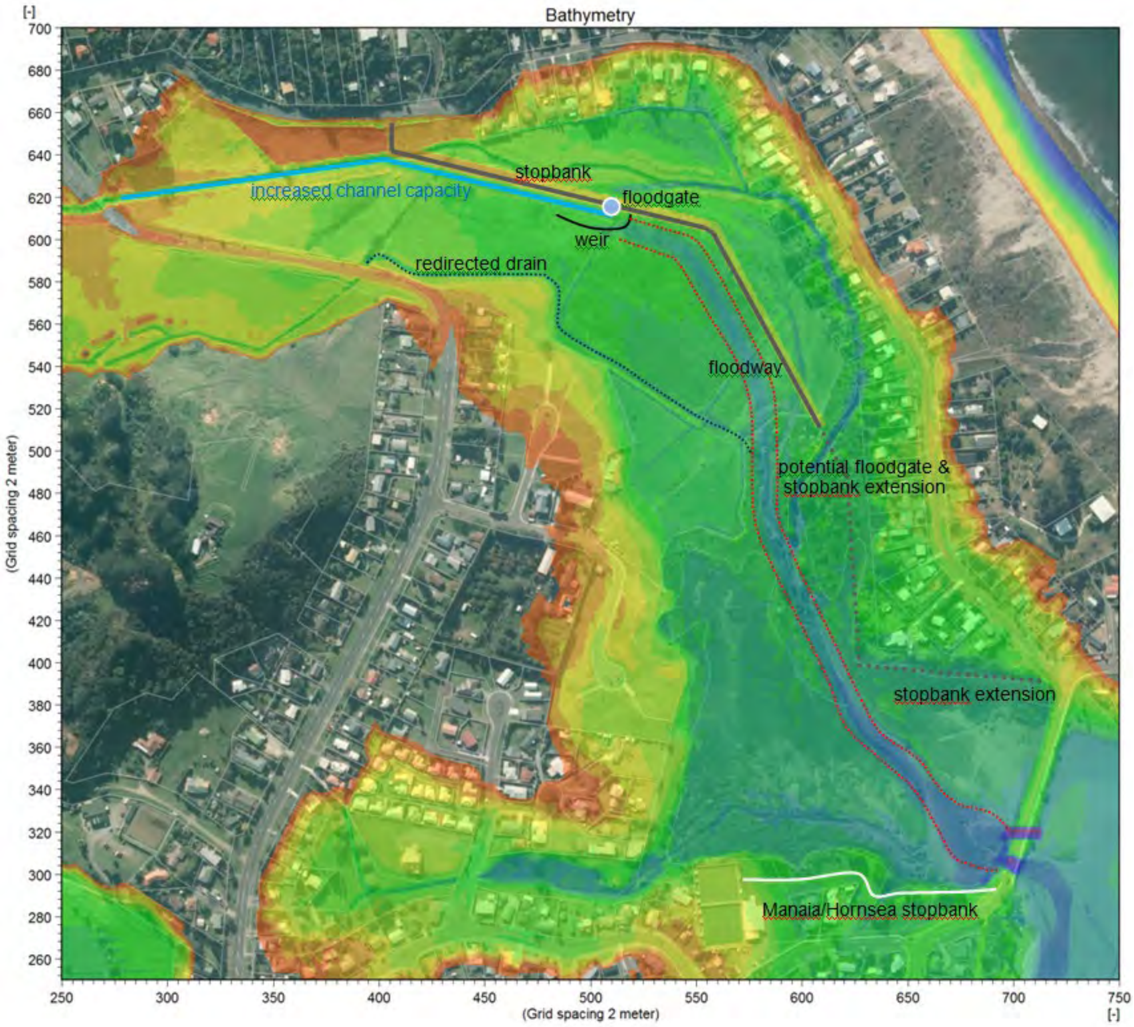

Figure 13 **Schematic showing bathymetry and location of flood alleviation components including stopbanks, increased channel capacity, floodway, floodgate, and redirected drain.**

6.6 Scheme Construction

The scheme was implemented as designed with no significant changes during construction. Appendix B and C shows the "As Built" drawings which are in general accordance with the design.

6.7 Future works

At this stage no further capital works are proposed at Grahams Creek. If at some point in the future the community decides it requires additional protection, and is able to fund the works, then WRC would look to extend the works to accommodate the community needs if practicable. This can be achieved by extending the left stopbank as indicated by the dotted line in Figure 13 above, a floodgate and further raising stopbanks levels. Appendix A, Figure A17 to A24 show predicted flood levels for the potential future scheme extension to provide full protection.

7 Operation and maintenance

The main channel of the Grahams Stream, floodway and right bank drain are monitored and periodically maintained by WRC to remove accumulated sediment and debris (refer to Figure 14 below for the indicative extent of works). This work maintains channel capacity and reduces the risk to adjacent land that would otherwise be inundated more frequently from stream flooding.

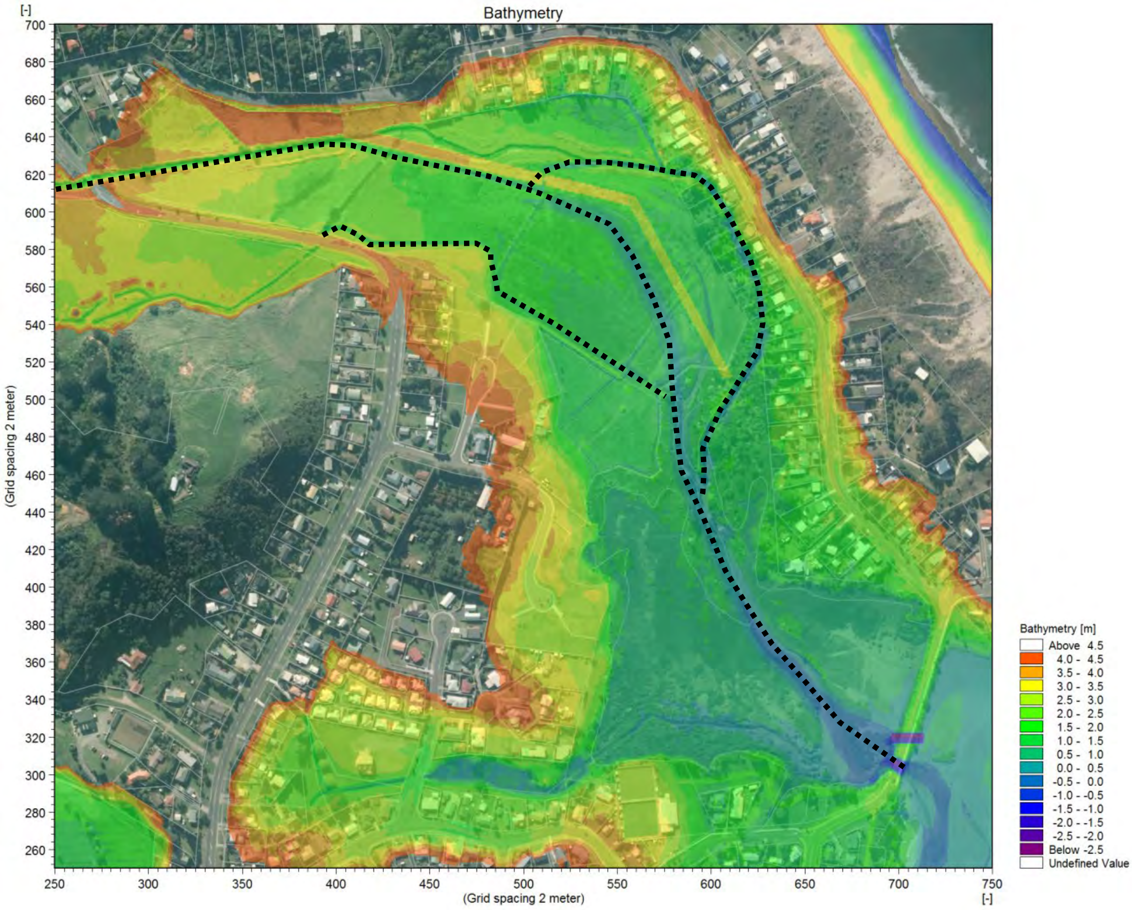

Figure 14 **Extent of channel maintenance in Grahams Stream, floodway and right bank drain (black dotted line).**

The annual maintenance programme includes the removal of accumulating gravel and sediment in Grahams Stream, based on current cross sectional areas. These works are carried out after annual inspection and monitoring of changes in the stream. The specific activities associated with this annual works programme include:

- Removal of accumulated gravel, sand and debris from various reaches including Grahams Stream, floodway and right bank drain totalling 2,300m (refer to Figure 14 for proposed extent – black dotted line).
- Removal of accumulated gravel, sand and debris from under the SH25 Bridge and Manaia Road Causeway Bridge across the Grahams Stream.
- Disposal of excavated gravel, sand and silt on the local foreshore below the high tide level.

Constructed flood protection works at Grahams Creek (a combination of stopbanks, diversion culvert, spillways and overflow floodway are inspected annually for:

- Visible damage to the sections of stopbank and spillways.
- Visible damage to the batter slope and crest of the sections of earth stopbank.
- Any associated stream channel erosion and scour and potential undermining of flood protection assets.

Any necessary repair work is undertaken as required.

Crest levels of the stopbanks are to be surveyed every ten years. Stopbanks are topped up where necessary.

Floodgate operational inspections, debris and blockage removal is necessary to ensure reliability of operation.

Flood response operations including inspections during floods, maintaining records and undertaking remedial works following significant floods is also included within the maintenance programme.

This maintenance programme is consistent with other flood protection works managed by WRC in the Waikato Region (e.g. Lower Waikato Waipa Control Scheme).

8 Flood hazard assessment

8.1 River flood hazard classification

A river flood hazard classification describes the significance of river flooding with regard to the likely impact on people and property. The classification that forms part of this assessment has been developed using the following considerations:

- Floodwaters have the potential to cause a person to become unstable and unable to manoeuvre. International research suggests that there is a danger of being knocked over when the product of the flood depth and flood speed exceeds 0.5, with a significantly greater risk to life when the same product exceeds 1.0.
- Floodwaters have the potential to impede a person's ability to rescue themselves or others. When the flood depth exceeds 1.0 m (i.e. waist depth), a person's ability to navigate through flood waters (both on foot and using a vehicle) is restricted, therefore impeding the rescue of themselves and others.
- Floodwaters have the potential to damage buildings, both superficially and structurally. International research suggests that structural damage is likely when the flood speed exceeds 2m/s. It is also likely that structurally weak points such as doors and windows will be damaged when the flood speed exceeds 1m/s.

These considerations have been translated into a river flood hazard classification by first defining four distinct levels of river flood hazard based on the likely impact on people and property. These levels are outlined in Table 3.

Table 3 Description of river flood hazard categories.

Category	Impact on people	Damage to property
Low	The combined depth and speed of floodwaters are unlikely to impede the manoeuvrability or stability of the average person.	Damage to property is likely to be non-structural and mainly due to inundation and deposition of sediment.
Medium	The combined depth and speed of floodwaters are likely to start to impede the manoeuvrability or stability of the average person.	Damage to property is unlikely to be structural provided that weak points such as windows and doors are retained above flood level.
High	The combined depth and speed of floodwaters are likely to significantly impede the manoeuvrability or stability of the average person.	Damage to property is likely to be widespread and structural, including instances where buildings have been raised above the 'flood level'.
Defended	This flood hazard category identifies land that is within an identified river flood hazard area but has been subsequently protected by a flood protection scheme up to the agreed Level of Service (design flood event) that is managed and maintained by the Waikato Regional Council.	

The three levels of river flood hazard (low, medium and high) have then been quantified through the creation of a matrix that assigns a river flood hazard level based on the predicted depth and speed of flooding (refer to Figure 15).

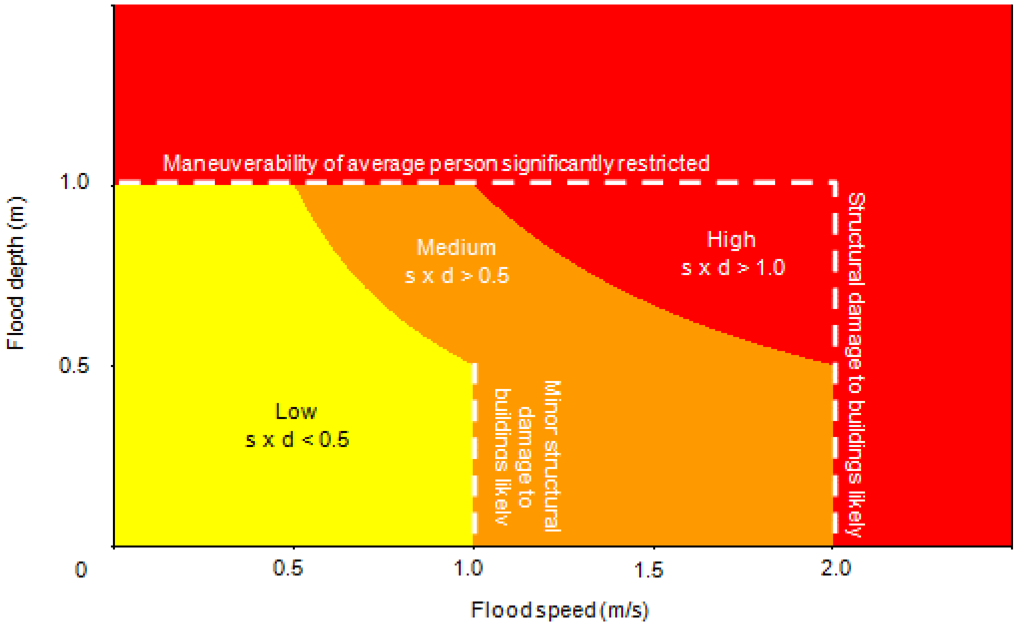

Figure 15 River flood hazard classification matrix.

The fourth level of flood hazard (Defended) is intended to represent areas that benefit from a flood protection scheme and is protected from the specific design flood event.

For the Grahams Creek scheme the Defended area is the difference between the pre works and post works. Along the left bank (Ocean Beach Road), the flood scheme provides a reduced flood hazard and is therefore not fully defended. As a result, the Defended category for Grahams Creek only denotes areas where the design flood hazard has been removed post scheme.

8.2 River flood hazard map

The river flooding information described in the sections above has been used to produce a river flood hazard map for Grahams Creek Community due to Grahams Stream. Figure 16 shows the flood hazard map for Grahams Creek with the land and floodplain subject to flooding in a current climate 1%AEP (100 year) flood event reflecting the severity of the flood hazard.

Following completion of the works, the flood hazard for the current climate 1%AEP (100 year) event is reduced for all properties except the stream and floodway. Figure 17 shows the extent and severity of flooding hazard.

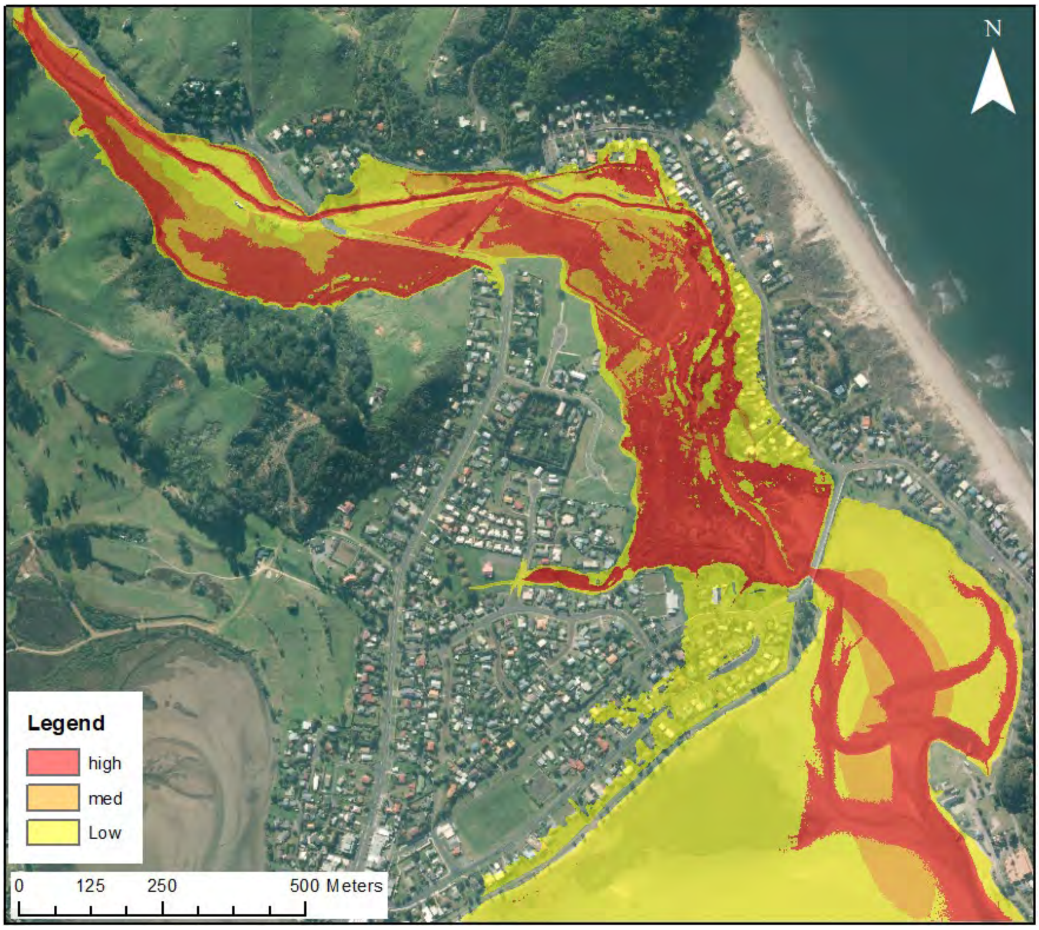

Figure 16 **Pre-Scheme current climate 1%AEP (100 year ARI) river flood hazard classification map for Grahams Creek.**

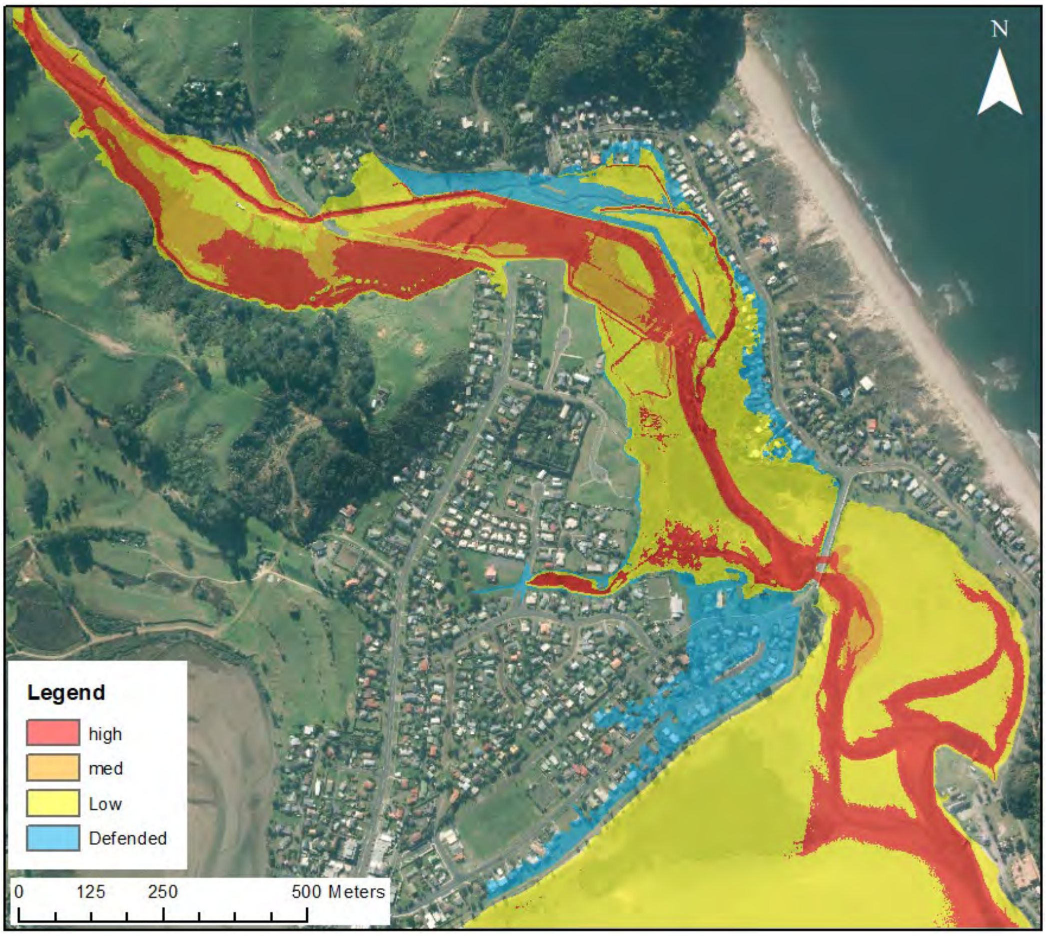

Figure 17 **Post-Scheme (current climate 1%AEP (100 year ARI) river flood hazard classification map for Grahams Creek.**

8.2.1 Climate Change

Following recent guidance from MfE (Ministry for the Environment) on managing climate change impacts, a range of sea level rise scenarios have been modelled.

The figures below show the projected flood extents with a 1% AEP river flood event and projected climate change with sea level increase of 0.5, 0.8, 1.0 and 1.2 m. The modelled extents are based on the agreed flood scheme. Much of the increased flood extents are due primarily to coastal inundation.

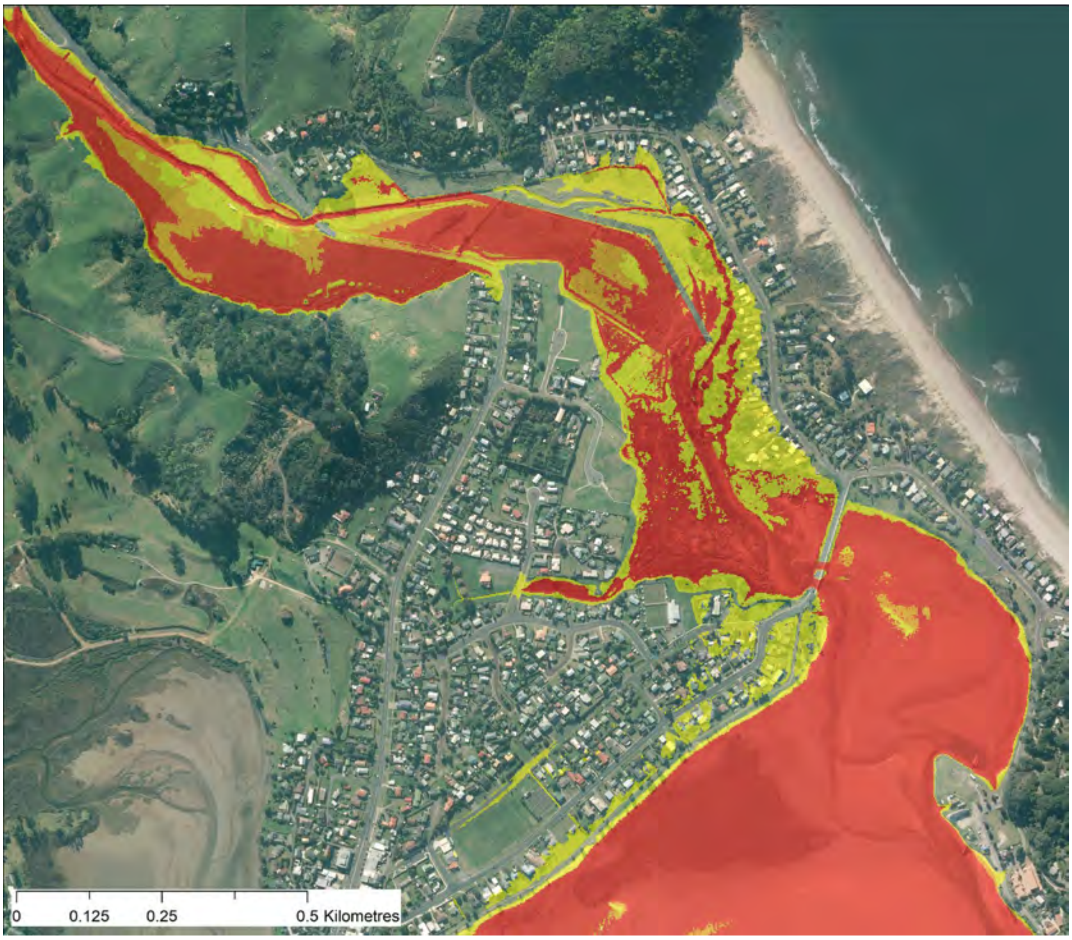

Figure 18 **Post-Scheme 1%AEP (100 year ARI) river flood hazard classification map for Grahams Creek with a projected 0.5 m sea level rise**

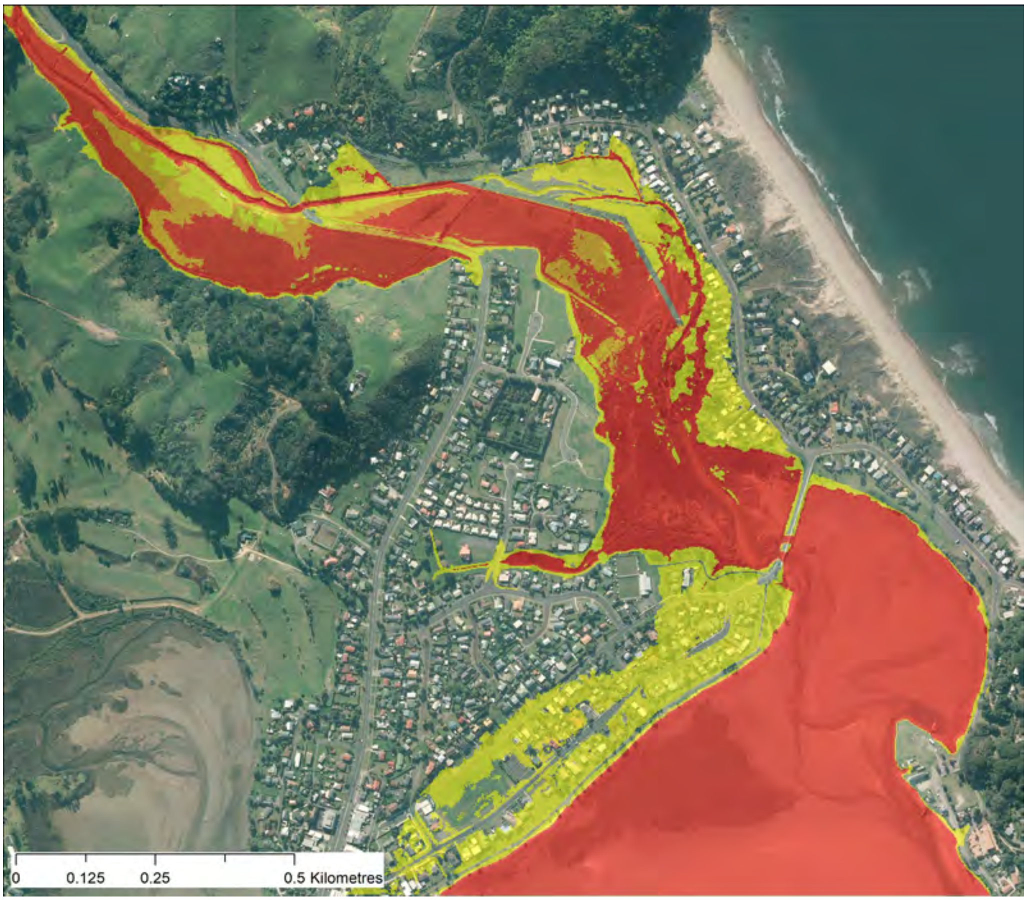

Figure 19 Post-Scheme 1%AEP (100 year ARI) river flood hazard classification map for Grahams Creek with a projected 0.8 m sea level rise

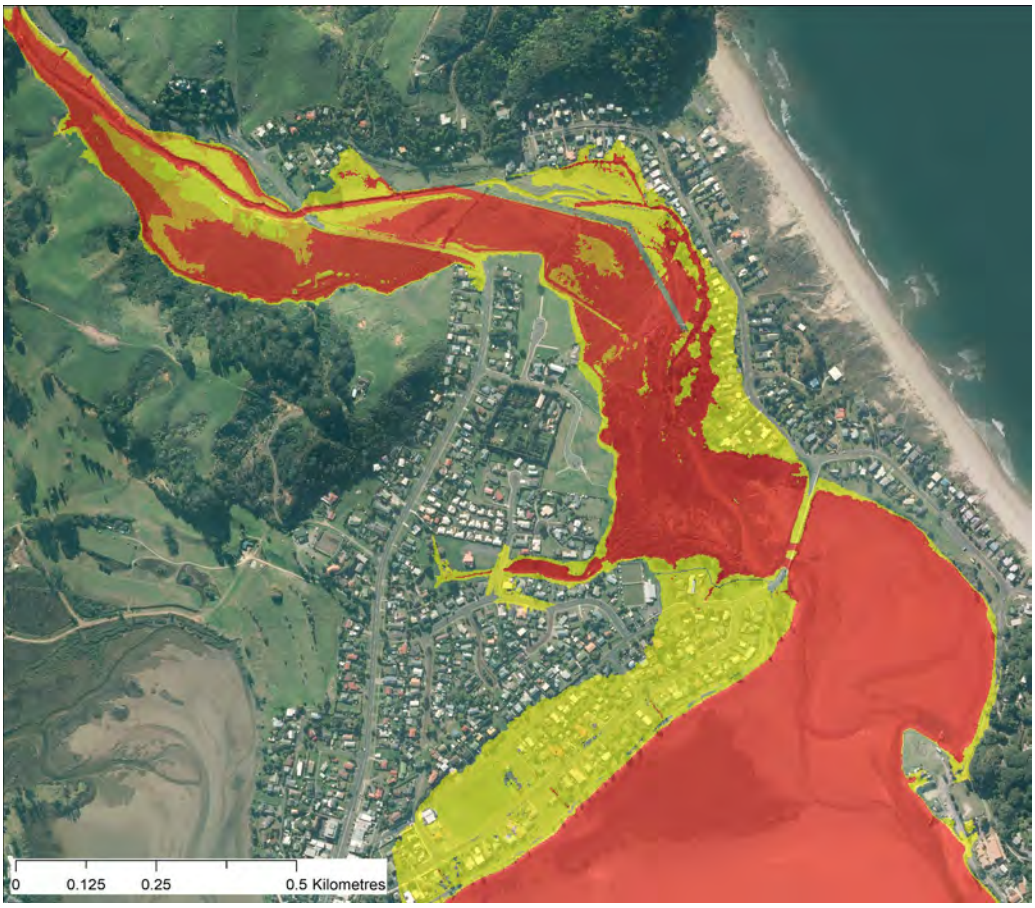

Figure 20 Post-Scheme 1%AEP (100 year ARI) river flood hazard classification map for Grahams Creek with a projected 1.0 m sea level rise

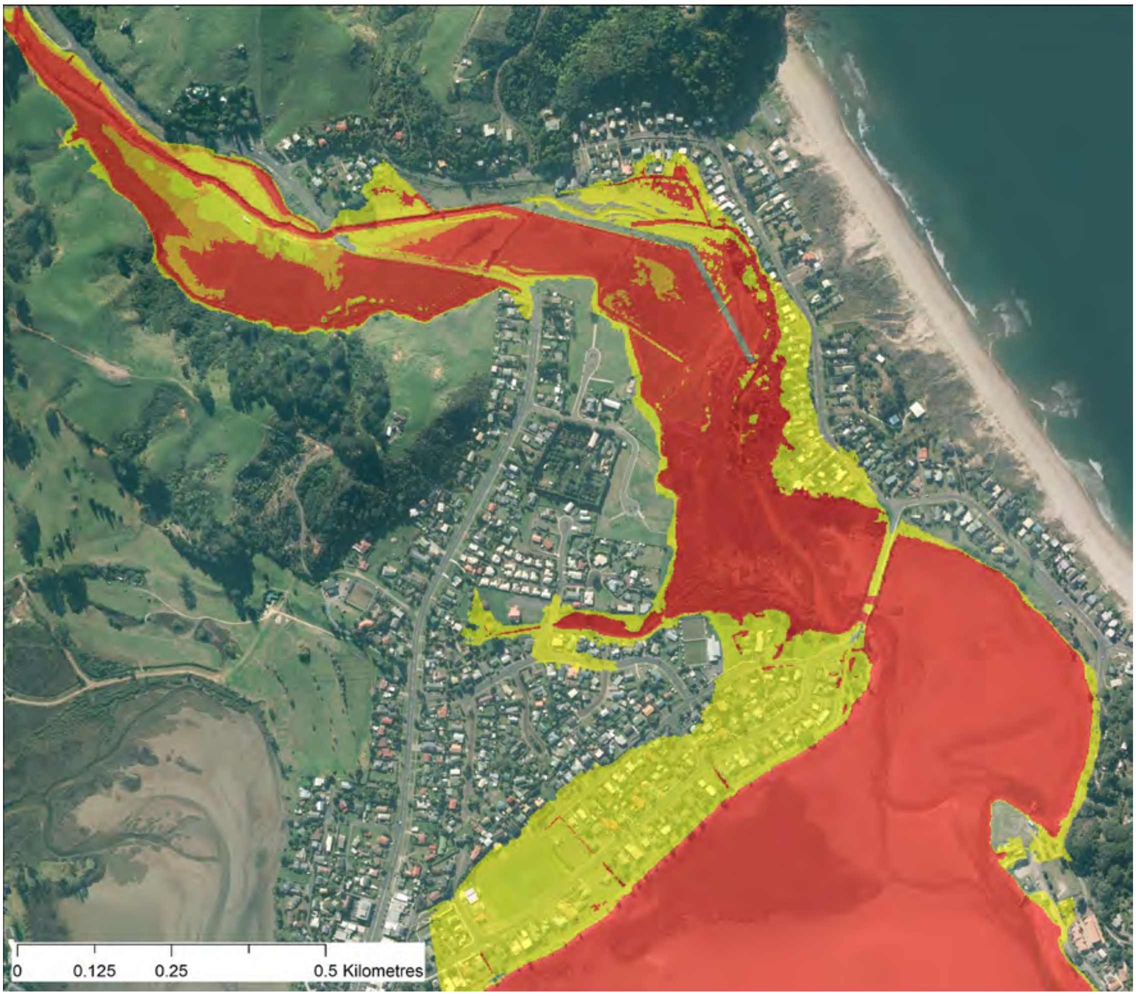

Figure 21 **Post-Scheme 1%AEP (100 year ARI) river flood hazard classification map for Grahams Creek with a projected 1.2 m sea level rise**

9 Residual flood risk

'Residual flood risk' is a term used to describe a river flood risk that exists due to the potential for 'greater than design' flood events to occur, failure of the scheme or impact from non-river flood events. The concept of residual flood risk provides a more complete assessment of risk when compared with traditional approaches that rarely look beyond 'design conditions'.

The residual flood risks that affect the Grahams Creek community are described as follows:

- The river flood model used to design the flood protection scheme is based on a 'design flood event' of a 1% AEP flood event of Grahams Stream for the right bank and 2% AEP flood event of Grahams Stream for the left bank. There is however the potential for larger flood events to occur, resulting in wider, higher and faster flood waters.
- The river flood model used to design the flood protection scheme is based on surveyed channel cross sections for Grahams Stream and detailed ground level information, but excludes obstructions in the streams and associated floodplains such as informal bridges, buildings and walls. These obstructions may result in wider, higher and faster flood waters.
- The river flood model used to design the flood protection scheme does not incorporate the impacts of sediment and debris. There may be instances where sediment and debris causes localised changes to the flood extent, depth and speed. This includes debris flow events that will produce significantly different flooding characteristics.

- This river flood model used to design the flood protection scheme is only relevant to flooding caused by the Grahams Stream. However, there is also the potential for flooding to occur in other waterways due to the overwhelming (or lack) of local land drainage infrastructure.
- The Scheme has not been designed to mitigate coastal storm tide events or projected sea level rise.
- The river flood model is based on the existing condition of the Grahams Stream catchment at the time of the design process. Any significant change to this condition will affect the river flood hazard that affects the Grahams Creek community. For example, land use changes, deforestation and the intensification of development. Where significant changes do occur, this river flood model and associated flood protection scheme should be reviewed.
- Following the completion of the protection works and bridge extension, there remains some residual risks arising from extreme (greater than design) and debris flood events. The criteria for managing the residual risk include the following:

  - The structural integrity of the Manaia Causeway Bridge should not be compromised by the protection works. Hence, the Causeway is designed to be overtopped and operate as a spillway.
  - The protection structures should not fail catastrophically when overtopped in greater than design events.
  - The risks should be recognised in existing and future development and specific planning controls be implemented to avoid and/or mitigate these in the long term.

10 Planning controls

Based on the flood hazard status of land in the community, TCDC has various planning controls in place via the Thames Coromandel District Plan, that restrict what land use activities can be undertaken. The planning controls include measures such as:

- No development or re-development allowed in the floodway, and in residual high risk areas. Note that infilling and development of the property along Ocean Beach Road owned by Graham Turner (Lot 1 DP 459335) was included in the scheme hydraulic modelling and design. This was allowed as a compromise for the landowner to surrender the floodway for the implementation of the scheme.
- Minimum floor level restrictions and construction requirements (e.g. flood proofing) for areas not protected by the works.
- For other protected areas within the present flood hazard areas, limited floor level restrictions would have to apply.

Refer to the Thames Coromandel District Plan and Thames Coromandel District Council staff for details.

11 Targeted Rating Classification

A targeted rating classification was undertaken by Andrew Honeyfield to determine rating differential for both direct and indirect benefit areas. An initial report was undertaken in December 2012 (WRC doc#2548802). A subsequent review was undertaken in February 2015 (WRC doc#3509651) that took into account modifications of the scheme design. A summary of the benefit areas are described in the following section.

11.1 Direct and Indirect Benefit areas

Direct and indirect benefit areas were classified as per Table 4 below and shown in Figures 22, 23 and 24.

Benefit Area	Code	Description
Stopbank direct-benefit	SB1	Flood mitigation benefits resulting from the north, west and east stopbanks.
	SB2	Flood mitigation benefits resulting from the south stopbank.
Channel direct-benefit	CH1	Greater degree of benefit accruing to properties in the mid and upper floodway resulting from channel enlargement and spillway construction.
	CH2	Lesser benefits accruing to the Mania, Haenui and Hornsea Road properties through reduced stopbanking costs.
Indirect benefit	IND	Indirect benefits are those resulting indirectly from the scheme.

Table 4 Description of direct and indirect benefit area classification for Grahams Creek

Figure 22 Stopbank direct-benefit areas for Grahams Creek

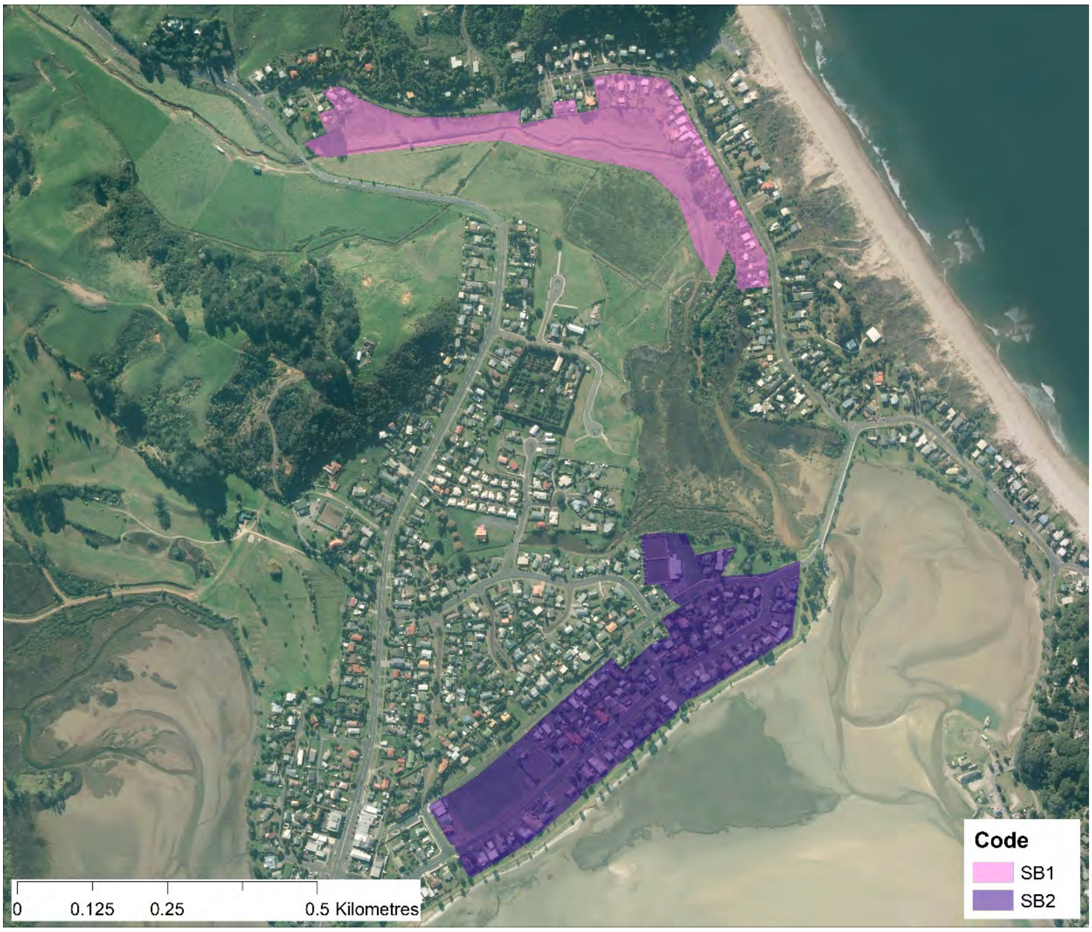

Figure 23 Channel direct-benefit areas for Grahams Creek

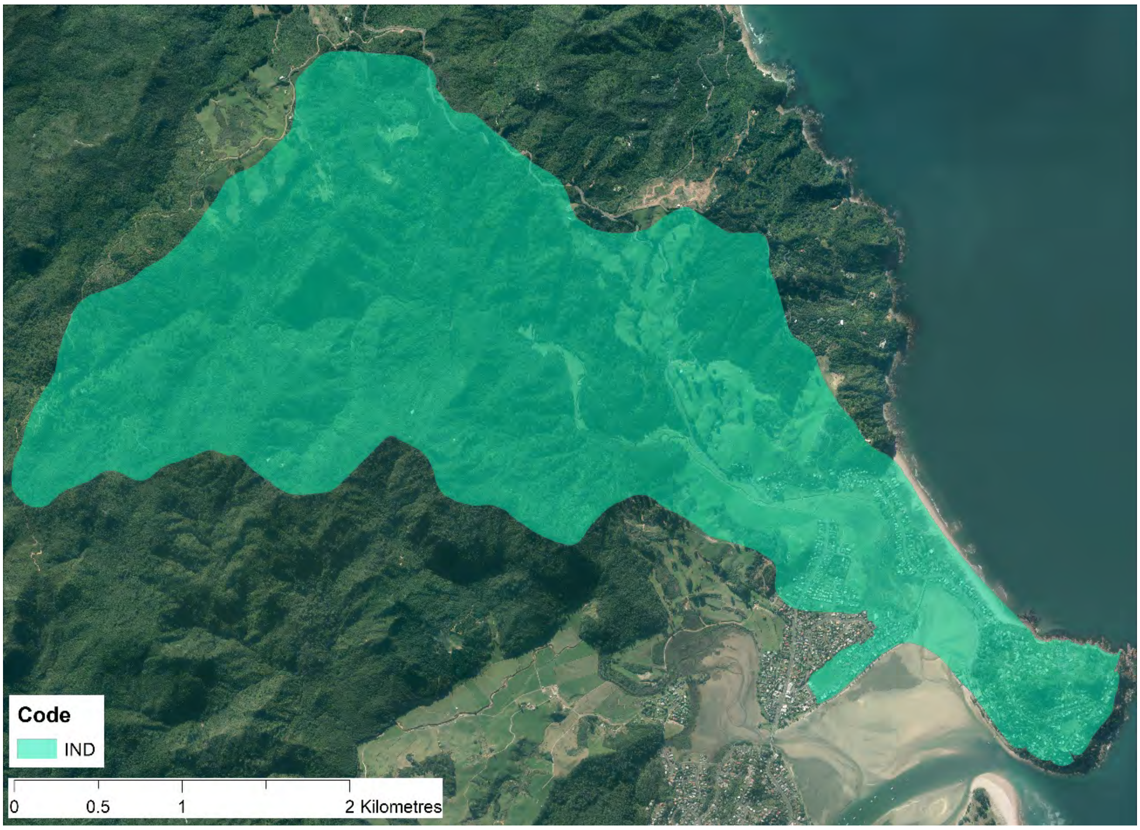

Figure 24 Indirect-benefit area for Grahams Creek

12 Scheme review

The Coromandel Zone Management Plan outlines agreed levels of service for the flood protection schemes on the Coromandel, including commentary on scheme reviews. It is stated that river and flood protection schemes will provide the standard of flood protection agreed with the community, and that this will be achieved by:

1. Maintaining stopbanks to the design heights, achieving performance grade 3 or better.
2. Responding to flood events by alerting communities prior to events, continuously monitoring river systems, undertaking emergency remedial works and reviewing system performance and maintenance requirements following flood events.
3. Undertaking ongoing visual inspections of flood protection structures, reporting formally on an annual basis and following up on maintenance and repair requirements following flood events.
4. Reporting annually to the subcommittee and catchment services committee on flood protection performance measures.
5. Undertaking flood protection works within consent conditions.
6. Making the likelihood and consequences of greater-than-design flood events clear to communities and providing advice for communities on managing these risks (residual flood risks).
7. Conducting all flood protection work in accordance with council health and safety policies.

The following procedures will measure whether performance targets are achieved:

1. Annual performance and condition inspections.
2. Yearly performance measures reports to subcommittee and catchment services committee.
3. Assessing ongoing changes to catchments, and undertaking design flood level reviews once every 5–10 years as required.
4. Annual health and safety audits.

The river flood model and hence the design of the flood mitigation scheme is based on the existing condition of the Grahams Stream catchment. Any significant change to this condition, for example land use intensification or deforestation, will affect the assumptions of the river flood model and hence compromise the basis of the scheme design. Where significant changes do occur, the river flood model and associated flood mitigation scheme should be reviewed.

References/Bibliography

Barnett & MacMurray Limited 2014. Grahams Stream flooding investigation peer review, September 2014. Prepared for Thames Coromandel District Council. Waikato Regional Council doc. #3202396.

Grant D 2014. Grahams Creek – Tairua: Hydraulic modelling of flood alleviation proposal, October 2014. Waikato Regional Council Internal Series 2014/27. Hamilton, Waikato Regional Council.

McKerchar AJ, Pearson CP 1989. Flood frequency in New Zealand. Hydrology Centre publication no. 20. Christchurch, Department of Scientific and Industrial Research, Hydrology Centre.

Montgomery Watson New Zealand Limited 2000. Grahams Creek flooding investigation. Prepared for Thames Coromandel District Council. Waikato Regional Council doc. #1105041.

Montgomery Watson New Zealand Limited 2001. Grahams Creek flooding investigation: Flooding of buildings and mitigation options. Prepared for Thames Coromandel District Council. Waikato Regional Council doc. #1105046.

Waikato Regional Council, Brendan Morris Consulting Limited 2012. Coromandel zone management plan. Waikato Regional Council Policy Series 2011/16. Hamilton, Waikato Regional Council.