Wainui Te Whara Stream:
Urban Channel improvement works

Supporting Documents

Volume 1 of 2

Resource Consent Application and AEE

Wainui Te Whara Stream:

Urban Channel Improvement Works

Stage Two – Channel works

Comprising Earthworks, erosion protection, channel reshaping, deepening and stream realignment

SUPPORTING DOCUMENTS:

S1	Cultural Impact Assessment – prepared by Ngāti Awa Environmental
S2A	Wainui Te Whara hydrological review – prepared by Pattle Delamore Partners
S2B	Easter flood analysis (memorandum to Hydrological review) – prepared by Pattle Delamore Partners
S3	Wainui Te Whara lower channel hydraulic capacity assessment – prepared by Opus International Consultants
S3A	Peer review of Hydraulic channel model – prepared by DHI Water and Environment Ltd
S3B	Wainui Te Whara channel scour analysis – prepared by Opus International Consultants
S4	Ecological report – prepared by River Lake Ltd
S4A	Supplementary Ecological report, prepared specifically for stage two works – prepared by River Lake Ltd
S5	NES/contaminated land assessment – prepared by Opus International Consultants
S6	Archaeological assessment report – prepared by Opus International Consultants
S6A	Approved Archaeological authority
S7	Geotechnical Design report – prepared by Opus International Consultants
S8	Construction Noise desktop assessment – prepared by Marshall Day Acoustics

S1 Cultural Impact Assessment – prepared by Ngāti Awa environmental

17 November 2015

Attention: Clive Tozer (Environmental Project Manager)

Whakatane District Council
c-o Opus International Consultants Ltd
P O Box 800
WHAKATANE 3158

WHAKATANE DISTRICT COUNCIL – LOWER WAINUI TE WHARA STORMWATER PROJECT

The following correspondence is in response to proposed improvements to the lower Wainui Te Whara Stream between Valley Road and Hinemoa Street in Whakatane. The proposal involves a range of works to improve the conveyance of stormwater during heavy rainfall events. The urban catchment surrounding the Wainui Te Whara Stream has suffered serious flooding issues in the past and this proposal is part of a range of responses both in the upper and lower catchment. Correspondence considered in this response has included the following;

- Wainui Te Whara Concept Plan, received via email 21 July 2015.

STATUTORY CONTEXT

The Wainui Te Whara Stream is located within Ngati Awa's rohe, the Ngati Awa Antiquities Protocol Area and the Ngati Awa First Right of Refusal Area. The Wainui Te Whara Stream is a tributary to the Whakatane River (Ohinemataroa), which is identified as a taonga of Ngati Awa and its various hapu. Ngati Awa's relationship with Ohinemataroa and its tributaries is covered by a Statutory Acknowledgement and Deed of Recognition. Therefore, Ngati Awa are tangata whenua, kaitiaki and hold mana whenua for this area.

PROPOSAL

The proposal to improve the conveyance of stormwater in the lower Wainui Te Whara Stream involves a range of works including widening and deepening of the channel, the construction of retaining walls and alterations to batter slopes. The proposal also includes the replacement or removal of several private bridges and the replacement of the existing Douglas Road and King Street bridges with high capacity box culverts. The overall intent of the proposal is to improve conveyance of water during high rainfall events. The proposal includes an opportunity to develop an environmental corridor and improved cycleway/walkway in the section between King Street and Hinemoa Street. This works description is based on limited information provided within the concept planning stage with specific works to be determined during detailed design.

NGATI AWA WAHI TAPU

Proposed works within the lower Wainui Te Whara Stream have been assessed using the Ngati Awa GIS Database and Wahi Tapu Sites of Ngati Awa October 1999 report. The relevant hapu of Ngati Awa in this area is Ngati Pukeko. The area's history has previously been discussed with Ngati Pukeko representative and Pukenga Mr Joe Mason. Mr Mason has advised that this area is significant to Ngati Pukeko both pre and post-colonial. Further to the south was the extensive fishing village or

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kainga Otangihaka. Overlooking this part of the Whakatane Township on the eastern ridge past Valley Road is the Ngati Pukeko pa site Umupurapura. Also to the south is the sacred rock Te Toka a Houmea where the famous Ngati Awa Tohunga Te Tahi resided.

Please recognise and provide for the Wahi Tapu sites of Ngati Awa Otamakaukau and Otahuhu.

- **Ngati Awa Wahi Tapu – Otamakaukau –** *This pa and land area is situated near the David Hogg memorial Hostel in Hinemoa Street. This land area extended from Awatapu Lagoon along Hinemoa Street out to the Eastbay Health Hospital site. In former times the Chief Pukeko used to bathe in a sacred spring which flowed at this site. It was a place of invocation, contemplation and preparation as a gathering place for the warriors of Ngati Pukeko before departing and returning from battles. On their return from war, Ngati Pukeko warriors would bathe and wash away the blood of their enemies. Hence the name of the area "Otamakaukau o Pukeko" The bathing place of Pukeko warriors. This is also the point where the Wainui Te Whara Stream discharges into the Awatapu lagoon.*

- **Ngati Awa Wahi Tapu – Otahuhu –** *This was a small settlement on the corner of King Street and Alexander Avenue at Kopeopeo where the Baptist church is situated. It was a flourishing village of Ngati Pukeko and next to the Wainui Te Whara Stream. It was close to many pa within the Kopeopeo area often being frequented by people throughout the district.*

The proposed works within the lower Wainui Te Whara Stream are located in an area that was traditionally occupied by Ngati Awa, in particular the Ngati Awa hapu Ngati Pukeko. This area was near the original course of Ohinemataroa (the Whakatane River) prior to drainage and flood protection works. Ohinemataroa is a taonga and pataka kai that Ngati Awa has a responsibility to protect as tangata whenua and kaitiaki. This area is still used today by Ngati Awa hapu located across the river from the Whakatane Township.

Given the range of works proposed and the traditional occupation and use of the general area TRoNA considers there is the potential for culturally significant items to be uncovered during works. In the event consent is granted TRoNA requests that the attached discovery protocol is adopted and applied to all ground disturbance works within the lower Wainui Te Whara Stream.

Recommendations

Te Runanga o Ngati Awa provides support for the proposed works within the lower Wainui Te Whara Stream as it will reduce flooding of the surrounding residential properties.

TRoNA requests that the attached discovery protocol "Ngati Awa Protocol for Dealing with Koiwi or Taonga Unearthed during Disturbance Works within the Lower Wainui Te Whara Stream" be adopted and applied to any disturbance works. Te Runanga o Ngati Awa Ngati Awa Claims Settlement Act 2005 includes Protocols for Engagement with the Ministry of Heritage and Culture and Heritage New Zealand. Any artefacts found on land within the Ngati Awa rohe will be subject to return to Ngati Awa who will seek ownership and custodianship of the artefact in perpetuity.

Te Runanga o Ngati Awa extends an offer to conduct karakia at the site prior to the commencement of excavation works. Please make contact with Te Runanga o Ngati Awa at least 2 weeks prior to commencing those works to arrange for karakia to be undertaken. This may involve a set fee to cover the costs of Ngati Awa representatives involved at the discretion of Te Runanga o Ngati Awa.

This correspondence was prepared by Ray Thompson, Environmental Manager, Te Runanga o Ngati Awa. If you have any queries, please contact the undersigned.
Naku noa, na

Ray Thompson
ENVIRONMENTAL MANAGER TE RUNANGA O NGATI AWA
FOR CHIEF EXECUTIVE

Copy to: Joe Mason (TRoNA Chairperson, TRoNA Board Representative Ngati Pukeko)
Te Runanga o Ngati Awa
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WHAKATANE 3158

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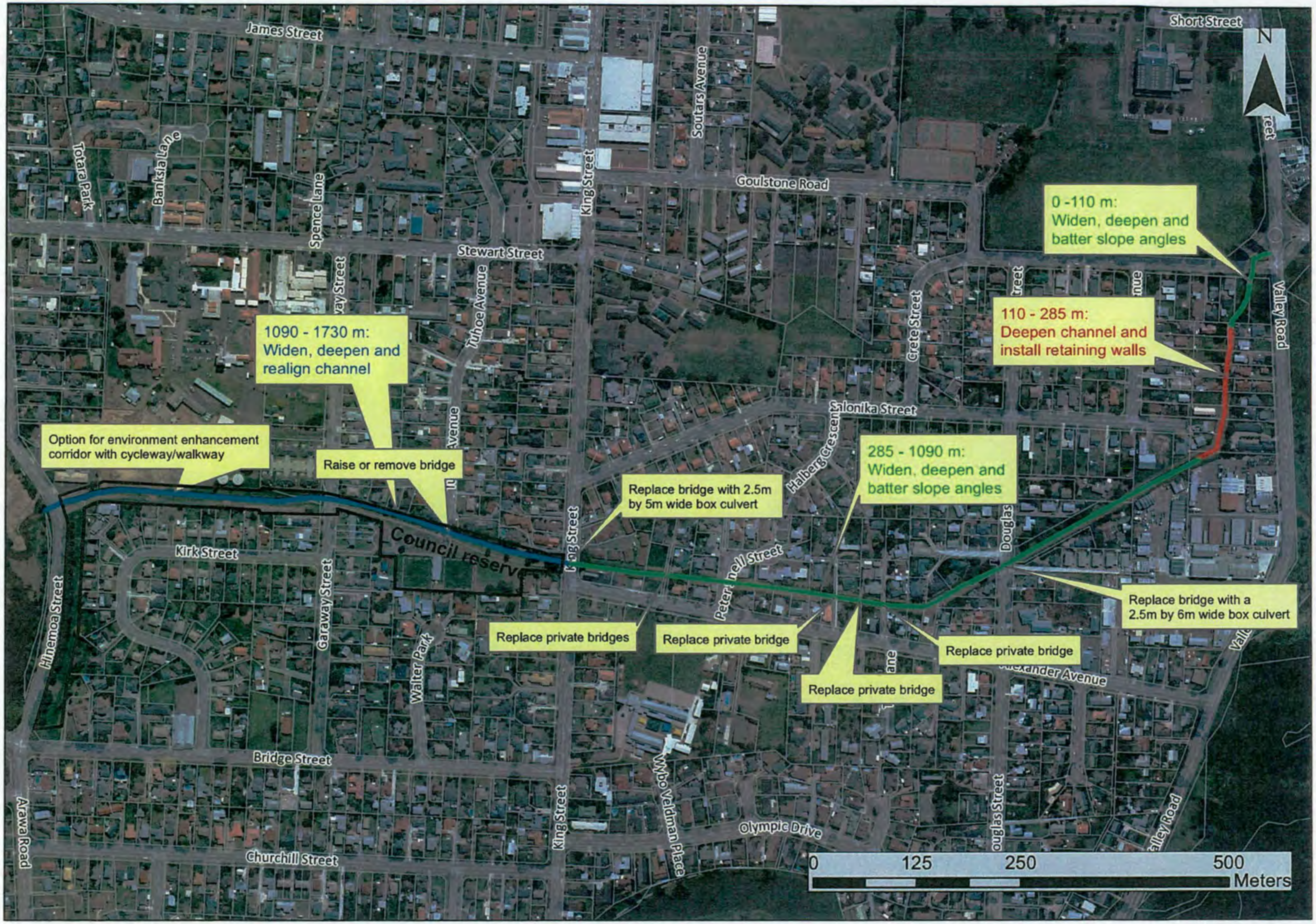
PO Box 2095
ROTORUA



James Street
Short Street
N
Totara Park
Banksia Lane
Spence Lane
Soutars Avenue
Goulstone Road
King Street
Stewart Street
0 -110 m:
Widen, deepen and batter slope angles
110 - 285 m:
Deepen channel and install retaining walls
Valley Road
1090 - 1730 m:
Widen, deepen and realign channel
Tuhoe Avenue
Crete Street
Salonika Street
Halberg Crescent
Option for environment enhancement corridor with cycleway/walkway
Raise or remove bridge
285 - 1090 m:
Widen, deepen and batter slope angles
Replace bridge with 2.5m by 5m wide box culvert
Council reserve
Kirk Street
Hinemoa Street
Garaway Street
Douglas
Replace bridge with a 2.5m by 6m wide box culvert
Replace private bridges
Replace private bridge
Replace private bridge
Replace private bridge
Walter Park
Bridge Street
Wybo Veldman Place
Olympic Drive
Arawa Road
Churchill Street
0
125
250
500
Meters

NGĀTI AWA PROTOCOL FOR DEALING WITH *KOIWI* OR *TAONGA*

UNEARTHED DURING DISTURBANCE WORKS WITHIN THE LOWER WAINUI TE WHARA STREAM

1. Background

1.1 Whakatane District Council is proposing a range of works to improve the conveyance of stormwater in the lower Wainui Te Whara Stream.

1.2 For the purposes of dealing with environmental and cultural matters in respect of the proposal, Te Runanga o Ngati Awa has been consulted.

1.3 As part of the consultation, the Whakatane District Council and Te Runanga o Ngati Awa have agreed that, in the event that *koiwi* or other *taonga* are unearthed during the course of proposed operations, the parties should adopt a protocol for dealing with this matter.

1.4 Accordingly, this protocol records those procedures that have been agreed between the Whakatane District Council and Te Runanga o Ngati Awa.

2. Definition

In this protocol the following terms have the meanings set out herein:

2.1 "***Koiwi***" means human remains such as skeletal material.

2.2 "***Taonga***" means cultural artefacts such as implements, weapons or decorations traditionally and historically utilised by tangata whenua and includes parts or the remains thereof. Archaeological features such as rua (caves) and pits are also taonga. People can gain a greater understanding of the way that pre-European Maori lived.

2.3 "***Site***" means the relevant location of the works.

Signed for the Whakatane District Council

____

Signed for Te Runanga o Ngati Awa

____

Dated this 23 day of NOVEMBER 2015

3. Unearthing of *Koiwi* or other *Taonga*

The following procedures will be adopted in the event that koiwi or taonga are unearthed or are reasonably suspected to have been unearthed during proposed works to improve the conveyance of stormwater in the lower Wainui Te Whara Stream.

(i) Immediately it becomes apparent or is suspected by workers at the sites that koiwi or taonga have been uncovered, all activity in the immediate area will cease.

(ii) The plant operator will shut down all machinery or activity in the area immediately, leave the area and advise the on-site supervisor of the occurrence.

(iii) The on-site Supervisor shall take steps immediately to secure the area in a way that ensures that koiwi or taonga remain untouched as far as possible in the circumstances and shall notify the site Manager.

(iv) The Site Manager will immediately notify Te Runanga o Ngāti Awa (07 307 0760) Louvain Street, PO Box 76, Whakatane, that it is suspected that koiwi or taonga have been uncovered at the site.

(v) Te Runanga o Ngati Awa where necessary, will contact the appropriate kaumatua to act on their behalf in this matter in order to guide and advise the Whakatane District Council (and/or their contractors) and any other parties as to the appropriate course of action and will immediately advise the site Manager of the identity of such persons and such other details as may be appropriate in the circumstances.

(vi) The site Manager will notify the New Zealand Police and Heritage New Zealand that it is suspected that koiwi and taonga have been uncovered at the site.

(vii) Ngati Awa Pukenga (cultural experts) and kaumatua (elderly person) are vested with discretion to request the attendance of a fully qualified and experienced archaeologist in the event that the Heritage New Zealand is unable to send an officer to the site.

(viii) The site Manager will ensure that all site staff are available to meet and guide kaumatua, Police, or Heritage New Zealand staff to the site, assisting with any requests that they may make.

(ix) If the kaumatua are satisfied that the koiwi or taonga are of significance to them, the kaumatua will decide how they are to be dealt with and will communicate such decision to the land owner, NZ Police and such other parties as are considered appropriate. Note that the Ngati Awa Research & Archives Centre at Louvain House, Louvain Street, Whakatane is a registered collector of artefacts. An alternative destination for artefacts is the Whakatane Museum.

(x) Activity in the relevant area will remain halted until kaumatua, the Police, and Heritage New Zealand (as the case may be) have given approval for operations in that area to recommence. IN the event that rua (caves) pits or other archaeological features are discovered, photographs of these are to be taken and labeled by the archaeologist and copies sent to the respective iwi authorities, and the Heritage

New Zealand, NZ Archaeological Association filekeeper and the Heritage Co-ordinator at the Bay of Plenty Regional Council.

(xi) The Whakatane District Council shall ensure that kaumatua are given the opportunity to undertake karakia (prayer) and such other religious or cultural ceremonies and activities at the site as may be considered appropriate in accordance with tikanga Maori (Maori custom and protocol). This may involve a set fee to cover the costs of Ngati Awa representatives involved at the discretion of Te Runanga o Ngati Awa.

S2A Wainui Te Whara hydrological review – prepared by Pattle Delamore Partners

Wainui te Whara Catchment – Review of Hydrology

Prepared for
Whakatane District Council

February 2014

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Rob Docherty

Limitations:

This report has been prepared on the basis of information provided by National Institute of Water & Atmospheric Research, Environment Bay of Plenty and Whakatane District Council. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

This report has been prepared by PDP on the specific instructions of Whakatane District Council for the limited purposes described in the report. PDP accepts no liability if the report is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

Executive Summary

The urban area of Whakatane downstream of Valley Road is prone to flooding from Wainui te Whara Stream and the most recent significant storms (24 May 2010 and 1 June 2010) caused significant damage to properties in this area. Downstream of Valley Road Wainui te Whara Stream has a confined channel and flows through a largely residential before discharging into the Whakatane River via Awatapu Lagoon. The current conveyance capacity of Wainui te Whara Stream between Valley Road and Hinemoa Street is approximately 18 m^3/s with no freeboard or 15.6 m^3/s with approximately 300 mm freeboard (Opus, 2008). One of the options to mitigate flooding is to build a detention dam in the upper catchment to reduce the peak flow through the confined channel downstream of Valley Road.

WDC has commissioned Pattle Delamore Partners Ltd (PDP) to review and update the hydrology for the Wainui te Whara catchment. The aim of this report is to produce design flood flow estimates for the Wainui te Whara Catchment with and without the proposed detention dam in place and to quantify the required storage volumes for the detention dam based on different design standards.

Several methods were used to estimate peak design flood flows for the Wainui te Whara Catchment. It is considered that the results from the calibrated rainfall-runoff provide realistic peak flow estimates for both the proposed dam site and Valley Road.

Design inflow hydrographs were routed through the proposed detention dam to estimate the required storage volumes at the dam site and the resulting attenuated peak flows at Valley Road. The results of the routing indicate that:

- A detention dam would provide a significant reduction in peak flows at Valley Road.
- The difference in peak flows at Valley Road (with the proposed dam in place) is relatively large for the modelled scenarios due to the contribution of the Wainui te Whara catchment area below the dam which is expected to generate a large amount of runoff during the design storm events.
- The low flow culvert size (0.75 m or 1.05 m) makes a large difference in terms of required storage volume however the relative difference in required dam height between a 0.75 m and 1.05 m culvert is much smaller.

Routing the design hydrographs through the detention dam indicates that a detention dam, at the location currently proposed, would only reduce the peak flood flows to the current conveyance capacity of the lower reaches(without freeboard) up to the 100 year return period using a 0.75 m low flow culvert (or orifice plate).

If WDC wishes to adopt a level of service greater than the 100 year return period it is recommended that the following items will be investigated further:

- A detention dam located further downstream in the Wainui te Whara Catchment;

- Combining downstream flood flow mitigation options with a detention dam in the upper Wainui te Whara Catchment;
- Progressive implementation of a combined option (detention dam and downstream mitigation options) to provide short term relief while working on additional mitigation measures to ultimately deliver the desired level of service to the flood-prone areas.

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Appendices

1.0 Introduction

The urban area of Whakatane located between Valley Road and Hinemoa Street has experienced significant flooding from Wainui te Whara Stream in the past. The Wainui te Whara headwaters are within a small steep catchment which emerges downstream of Valley Road in a confined channel and flows through a largely residential area before discharging into the Whakatane River via Awatapu Lagoon. The urban area downstream of Valley Road is prone to flooding and the most recent significant storms (24 May 2010 and 1 June 2010) caused significant damage to properties in this area. The current conveyance capacity of Wainui te Whara Stream between Valley Road and Hinemoa Street is approximately 18 m^3/s with no freeboard or 15.6 m^3/s with approximately 300mm freeboard (Opus, 2008).

For a number of years the Whakatane District Council (WDC) has been investigating options to mitigate this flooding. One option is to build a detention dam in the upper catchment to reduce the peak flow through the confined channel downstream of Valley Road. Several reports have analysed the hydrology of Wainui te Whara Stream and different design peak flow estimates and hydrograph shapes along with a variety of required storage volumes for a detention dam have been proposed over the years (i.e. Opus reports issued in September 2006, May 2010 and March 2011).

WDC has commissioned Pattle Delamore Partners Ltd (PDP) to review and update the hydrology for the Wainui te Whara catchment. The aim of this report is to produce design flood flow estimates for the Wainui te Whara Catchment with and without the proposed detention dam in place and to quantify the required storage volumes for the detention dam based on different design standards. In addition, estimates are provided for the probable maximum flood (PMF) at the dam site, the hydrological recorder site and Valley Road.

This report describes the analysis undertaken to derive the design flood flows and to determine the required storage volumes. The report includes:

- A description of Wainui te Whara catchment
- Rainfall analysis, which covers:
  - a comparison between the relevant raingauges;
  - an analyses on the severity of the 1 June 2010 event using the 'Whakatane at Kopeopeo' raingauge;
  - Design rainfall depths using HIRDS V3;
  - Probable Maximum Precipitation.
- Design flood flow estimates, which covers:
  - Rainfall-runoff modelling using the non-linear reservoir method;
  - Regional flood methodology;
  - Probable Maximum Flood (PMF).
- Development of design hydrographs based on historical events.
- Results of routing the design storms through the proposed detention dam.

2.0 Wainui te Whara Catchment Description and Available Flow Data

Wainui te Whara Stream originates in the hills south east of Whakatane Township. Both the main stream and side streams are relatively steep and elevations in the catchment range from approximately 250 mamsl (metres above mean sea level) in the upper reaches to around 20 mamsl at Valley Road Bridge.

The Wainui te Whara catchment has a catchment area of approximately 5.72 km^2 at Valley Road, 5.42 km^2 at the recorder site (Mokorua Gorge) and 2.93 km^2 at the proposed dam site (refer to Appendix A, Figure 1).

Bay of Plenty Regional Council (BOPRC) provided PDP with their available flow information for Wainui te Whara Stream at Mokorua Gorge. This site has audited flow data available from 23 November 2006 through to 13 December 2013.

The soils in the Wainui te Whara catchment are described by Rijkse (1993). This data was obtained from BOPRC in GIS format and is shown in Appendix A, Figure 2.

The upper catchment consists of Whakatane Hill Soil (WxH) and Whakatane Loamy Sand Wx) with underlying volcanic tephra. The catchment further downstream consists of Ngatiawa Steepland Soils (NS) and Tawhia Steepland Soils (TyS) which are described as tephra overlying sandstone and greywacke. These soils are shallow by nature with weathered greywacke clays and marine stone layers not far beneath the surface. West (2012) considers the WxH and Wx soils as most highly permeable with the NS and TyS soils being less permeable. A very small portion at the lower end catchment consists of Rewatu Soils (Re) which were considered by West (2012) as most highly impermeable.

3.0 Rainfall

3.1 Available Data

Several rainfall stations record rainfall in the area around Whakatane. Whakatane Aero AWS (Metservice site 76995) has been recording hourly rainfall since January 1995. BOPRC installed a rainfall gauge measuring sub-hourly rainfall in Whakatane Township in April 2008 (Whakatane at Kopeopeo, site 769908) and in June 2012 (following the May and June 2010 floods) a rainfall gauge was installed in the upper Wainui te Whara catchment (site 779007). The location of these rainfall stations relative to the Wainui te Whara catchment is shown in Appendix A, Figure 3 and information on these rainfall stations is listed in Table 1 below.

Table 1: Site name, site number, recording authority and available record length for relevant rainfall stations around Whakatane Township

Site name	Site number	Recording authority	Available record length
Whakatane Aero AWS	76995	Metservice	January 1995 – December 2013[1]
Whakatane at Kopeopeo	769908	EBOP	April 2008 – December 2013
Wainui te Whara at Munro's	779007	EBOP	May 2012 – December 2013

1) Daily rainfall totals are available up to December 2013, however hourly data is only (freely) available up to December 2012.

Other rainfall stations record rainfall in and around Whakatane. However, these rainfall stations are located further away or do not record sub-hourly or hourly rainfall totals. These rainfall stations were, therefore, not considered in this study.

Whakatane District Council also provided PDP with rainfall radar imagery of the June 2010 storm. Unfortunately the resolution of this imagery is insufficient to allow analysis of rainfall intensities and rainfall totals between the flat terrain around Whakatane Township and Wainui te Whara Catchment. Metservice was also contacted (John Crouch) to check whether more detailed radar imagery was available for the May and/or June 2010 events. Metservice indicated that detailed radar imagery is available from 2011 for the Whakatane area (a new radar station was installed in Rotorua in 2011). Any radar imagery prior to that would not provide sufficient detail as the radar stations are located too far away from Whakatane Township.

3.2 Rainfall Analyses

The rain storms that caused the two major floods in Wainui te Whara Stream on 24 May and 1 June 2010 have been analysed by McKerchar (NIWA, 2010) and OPUS (2011). The analysis from McKerchar indicates that the 1 June 2010 storm as recorded at the Whakatane Aero AWS raingauge exceeded the 100 year (HIRDS V3) estimates for durations of one to six hours. The rainfall totals for the Whakatane at Kopeopeo gauge were much lower and considering the large variability in rainfall over such a short distance WDC was interested in comparing the rainfall depths between the Whakatane at Kopeopeo and the recently installed raingauge in the upper Wainui te Whara catchment (Wainui te Whara at Munro's). Section 3.2.1 compares the rainfall data from these three raingauges.

The McKerchar (2010) report does not analyse the severity of the rainfall for the 1 June 2010 event for the Kopeopeo gauge. Therefore, an analysis was also undertaken comparing the 100 year HIRDS V3 rainfall depths with the 1 June 2010 rainfall depths at the Kopeopeo gauge. This is detailed in section 3.2.2.

3.2.1 Rainfall Comparison

In order to get an indication whether there is a significant and consistent difference between rainfall on the flats in and around Whakatane Township and rainfall in the Wainui te Whara catchment a comparison was made between the rainfall totals and mean annual rainfall for the available overlapping period of record using the three rainfall sites listed in Table 1. Table 2 below shows the results of this comparison.

Table 2: Rainfall totals and mean annual rainfall (mm) for overlapping record periods.

	Wainui te Whara at Munro's (site 779007)	Whakatane at Kopeopeo (site 769908)	Whakatane Aero AWS (site 76995)
Total rainfall for WtW at Munro's record period (30 May 2012 - 13 December 2013)	1,887	1,527	1,389
Total rainfall for Whakatane at Kopeopeo record period (17 April 2008 - 13 December 2013)		7,613	7,514
Mean annual rainfall for Kopeopeo period of record (1 January 2009 - 31 December 2012)[1]		1,448	1,442

Note 1: Mean annual rainfall was not calculated for Wainui te Whara at Munro's due to short record length

The maximum 1-hour, 2-hour and 24 hour measured rainfall totals were also calculated for the Wainui te Whara at Munro's and Whakatane at Kopeopeo rainfall gauges for the 5 largest monthly maximum flood events at the WtW at Mokorua Gorge recorder site. The results are listed in Table 3 below. Unfortunately the most recent (2013) sub - hourly data is no longer (freely) available from the Whakatane Aero AWS so this data has not been included in the analysis.

Table 3: 1 hourly, 2 hourly and 24 hour maximum measured rainfall for the 5 largest flow events at Wainui te Whara at Mokorua Gorge flow recorder between 30/5/2012 and 16/12/2013

Date		5-12 2013	30-7 2012	20-8-2013	22-8 2013	9-6-2013
WtW flow recorder Peak Flow (m^3/s)		3.6	2.1	1.6	1.6	1.5
1 hour maximum rainfall (mm)	Wainui te Whara at Munro's	15.8	15.6	10.8	16	21.2
	Whakatane at Kopeopeo	12.9	17.5	11	18.2	15.5
2 hour maximum rainfall (mm)	Wainui te Whara at Munro's	28.7	20.8	18.3	25.5	32.3
	Whakatane at Kopeopeo	23.1	23.5	17.8	30.3	21.5
3 hour maximum rainfall (mm)	Wainui te Whara at Munro's	42.0	22.7	18.3	37.0	37.1
	Whakatane at Kopeopeo	32.3	26.5	17.8	35.4	25.0
24 hour maximum rainfall (mm)	Wainui te Whara at Munro's	151.7	35	28	52	45.8
	Whakatane at Kopeopeo	102.2	38	28.9	48	34

As can be seen in Table 2 when considering the rainfall totals for the overlapping record periods the Wainui te Whara at Munro's rainfall totals are 24 % higher compared to the Kopeopeo gauge. When considering the overlapping record periods between the Kopeopeo and Whakatane Aero site the rainfall totals and mean annual rainfall are very similar.

Table 3 indicates that when comparing the maximum measured 1 hour, 2 hour, 3 hour and 24 hour rainfall totals for the Wainui te Whara at Munro's and Kopeopeo gauge the rainfall totals are higher for the largest event. The smaller events do not show a consistent pattern of either higher or lower rainfall. It has to be noted though that the analysis above is based on a limited amount of rainfall data and that the flow events considered are relatively small as no significant flood events have occurred since the installation of the Wainui te Whara rainfall station.

West(2012) comments that the rainfall in the coastal escarpments in the Bay of Plenty are thought to be subject to an extreme weather effect that occurs during periods of intense thunderstorm-type events leading to extreme rainfall intensities on time-scales of around 1-2 hours. Even though the orographic component is small in convective (thunderstorm-like) rainfalls, there is strong evidence of steep rainfall gradients immediately inland from the coast and thus rainfalls recorded at low altitude gauges are likely to underestimate mean catchment rainfalls. Blackwood(2005) noted that this effect contributed to the devastating flooding at Matata in May 2005. Design rainfalls based on HIRDS are not modified by orographic enhancement factors and therefore he suggested a multiplication factor of 1.3 for HIRDS design rainfall intensities in design analyses for catchments along the Matata escarpment. The HIRDS interpolation process between gauges takes no account of the significant orographic uplift at the high cliffs in the vicinity of Matata.

West(2012) comments that such a factor may also be appropriate for the hill catchments at Whakatane and recommends that this factor is considered when analysing rainfall events in the hills behind Whakatane.

PDP concur with the analysis from Blackwood (2005) and the comments from West (2012). Therefore, based on these comments and the initial rainfall analyses described above it was considered appropriate to increase the measured rainfall depths at Kopeopeo and the HIRDS V3 design rainfall depths for the Wainui te Whara catchment. For the purpose of rainfall-runoff modelling (refer to section 4.1)the Wainui te Whara catchment was divided into two sub-catchments, representing the catchments upstream and downstream of the proposed detention dam (Refer to Appendix A, Figure 1). Based on catchment elevation from the lower Wainui te Whara catchment and upper Wainui te Whara catchment it was decided to increase the measured Kopeopeo rainfall data and HIRDS V3 design rainfall depths by a factor of 1.15 for the lower Wainui te Whara catchment and 1.25 for the upper Wainui te Whara catchment.

3.2.2 1 June 2010 storm

The severity of the 1 June 2010 event for the Wainui te Whara catchment was assessed by comparing the totals for the various durations with the rainfall depths for the 100 year return period (based on HIRDS V3) for the Whakatane at Kopeopeo raingauge. Table 4 shows the results of this comparison. The depth-duration curve for the data in Table 4 is plotted on the graph in Appendix B.

Table 4: HIRDS V3 100 year rainfall depths versus maxima recorded during the 1 June 2010 storm at the Whakatane at Kopeopeo raingauge for storm durations between 0.5 and 24 hours

Duration (hours)	**Rainfall depth (mm)**	
	HIRDS V3: 100 year return period	**Kopeopeo raingauge: 1 June 2010 storm**
0.5	46	38
1	67	65
2	89	97
3	106	107
4	120	113
6	142	121
12	190	124
24	254	124

The maximum rainfall depth recorded during the 1 June 2010 storm is higher than the 100 year return period rainfall depth for the 2 hour duration and is similar to the 100 year return period rainfall depths for the 1 hour, 3 hour and 4 hour durations. For the other durations in shown Table 4 the rainfall maxima during the 1 June 2010 storm are less than the 100 year return period rainfall depths.

This indicates that the severity of the 1 June 2010 event as measured at the Whakatane at Kopeopeo gauge is lower than the severity at Whakatane airport which is consistent with the fact that the rainfall totals for this event were lower at the Kopeopeo gauge as well. The McKerchar (2010) report indicates that the 1 June 2010 storm as recorded at the Whakatane Aero AWS raingauge exceeded the 100 year (HIRDS V3) estimates for durations of one to six hours.

3.3 Design Rainfall Depths

Design rainfall depths are required to enable rainfall-runoff modelling. The BOPRC hydrological and hydraulic Guidelines (August 2012) recommends the use of the National Institute of Water and Atmospheric Research (NIWA) HIRDS version 3 to derive rainfall depths. To check the variability of the design rainfall depths throughout the catchment rainfall depths for three different locations in the Wainui te Whara catchment were obtained from HIRDS V3. A comparison of the data indicated that design rainfall depth were very similar at all three locations (lower catchment, centre of the catchment and upper catchment). As described in section 3.2.1 design rainfall depths based on HIRDS are not modified by orographic enhancement factors. The HIRDS V3 rainfall depths for the relevant design storms are presented in Table 5 below. The rainfall depths shown in this Table were multiplied by a factor of 1.15 for the lower catchment and 1.25 for the upper catchment to derive design rainfall depths. Refer to Appendix D for the resulting design rainfall depths for the upper and lower catchments.

This table also includes the rainfall depths adjusted for climate change. Rather than using the climate change predictions for the year 2040 or 2090 as described in the climate change guidelines from the Ministry for the Environment (MfE, 2008) it was considered more appropriate to consider the climate change predictions for the design-life of the proposed detention dam. Based on a design life of 100 years and assuming that the dam will be built in 2015 climate change predictions for the year 2115 were used. The expected temperature increase for 2115 was estimated by extrapolating Figure 2.1 of MfE's 2008 guidelines for the IPCC A1B mid scenario. The resulting estimated temperature increase for 2115 is 2.4 °C with an estimated increase in rainfall depth of 19% (based on an 8% increase in rainfall depth for every 1 °C of warming).

Note that IPCC's A1B's mid scenario shows a slowing in temperature increase towards the end of the 21st century and the shape of this projection has been used to define the shape of the projected MfE A1B growth curve used for the extrapolation.

The resulting rainfall depths(without the factor of 1.15 and 1.25 for the lower and upper catchment respectively) are shown in Table 5 below. The standard HIRDS V3 output does not provide rainfall depths for durations between 2 and 6 hours nor does it provide rainfall depths for the 300 year return period. Therefore, the HIRDS V3 eight coefficients were used to determine rainfall depths for durations between 2 and 6 hours and for rainfall depth extrapolation for the 300 year return period.

Table 5: HIRDS V3 Rainfall depth (mm)

Duration:	No climate change		Climate change (2115)	
	100 year	300 year	100 year	300 year
1 hour	66.9	86.0	79.7	102.5
2 hours	89.5	114.7	106.6	136.7
3 hours	106.1	135.7	126.4	161.8
4 hours	119.7	153.0	142.7	182.4
6 hours	141.9	181.1	169.2	200.1
12 hours	189.9	241.5	226.3	287.9

3.4 Probable Maximum Precipitation

In order to determine the probable maximum flood (PMF) for the Wainui-te-Whara catchment estimates for the probable maximum precipitation (PMP) are required. Determining the Probable Maximum Flood (PMF) requires the development of a rainfall-runoff model as described in section 4.1.

The PMP is theoretically the greatest depth of rainfall that is meteorologically possible over a given duration at a particular time of the year (World Meteorological Organization, 1986). Thompson and Tomlinson (1993) determined a method for estimating the PMP for small areas (less than 1,000 km^2) and short durations (up to 6 hours). This is the standard methodology used in New Zealand for determining the PMP.

Once the catchment average 1 hour PMP is determined rainfall depths for other durations can be determined based on 6:1 hour ratios.

For the WtW catchment a 6:1 hour ratio of 2 was chosen because this is close to the ratios observed during the largest 4 floods on record (refer to Table 6). The resulting PMP estimates are shown in Table 7.

Table 6: Six to one hour ratio's for the 4 largest flood flows on record for Wainui te Whara at Mokorua Gorge

Event	Measured peak flow at Mokorua Gorge (m^3/s)	1 hour max rainfall (mm)	6 hour max rainfall (mm)	6:1 hour ratio
1/06/2010	30.65	64.8	120.5	1.86
24/5/2010	18.37	47.1	90.8	1.93
18/06/2011	13.15	40.5	88	2.17
29/01/2011	12.91	32.4	84	2.59
Average				2.14

Table 7: Calculation of probable maximum precipitation for the Wainui te Whara catchment

Step	Description	Result					
1	Catchment details: • Area • Maximum altitude	 5.4 Km^2 250 m					
2	Reference 1 hour PMP	200 mm					
3	Adjustment for location	96.25%					
4	Adjustment for altitude	N/A					
5	Catchment average 1 hour PMP	193 mm					
	Duration (hours)	**1**	**2**	**3**	**4**	**5**	**6**
6	Percentage adjustment (%)	100	131	153	171	186	200
7	Resulting PMP rainfall depth (mm)	193	253	295	330	359	386

Note that the PMP estimates do not include the multiplication factor of 1.15 and 1.25 for the lower and upper catchment (as the PMP is already the theoretically greatest depth of rainfall that is meteorologically possible over a given duration).

4.0 Flood Flows

For the purpose of estimating flood flows for different return periods and for the PMF at the proposed dam site and at Valley Road a rainfall-runoff model was developed. Flood flows were also estimated using the regional flood methodology. This section describes the rainfall-runoff modelling, regional flood methodology and how the design hydrographs were developed.

4.1 Rainfall-Runoff Model

To determine peak flows for the Wainui te Whara catchment at the proposed dam site and at Valley Road a rainfall-runoff was developed using the non-linear reservoir method. The following sections describe the rainfall-runoff model including model description, model configuration, model calibration and design storm modelling.

4.1.1 Model Description

BOPRC have recently used the non-linear reservoir method for flood forecasting purposes and provided PDP with an example spreadsheet for Waihua Stream which was part of the Rangitaiki Non Linear Reservoir flood forecasting model (Peter West, personal communication).

In this method the loss function determines how much rainfall becomes rainfall excess through an initial and saturated runoff coefficient. The initial runoff coefficient (Ci) represents the initial runoff from unsaturated soil and the saturated runoff coefficient (Cs) represents the increased runoff rate from saturated soil. The saturated rainfall (Rsa) represents a switch point when the soil is saturated. These parameters can be calibrated to estimate the effective rainfall (rainfall excess).

The shape of the hydrograph is determined by an Exponential coefficient (P) and a proportional coefficient (K). These parameters can be calibrated to match the shape of the calculated hydrograph to the observed hydrograph.

More details on the non-linear reservoir method can be found in the InfoWorks user manual (Wallingford Software Ltd, 2001-2008) 'Non Linear Routing Methodology Boundary' and 'Japanese Runoff Methodology'.

4.1.2 Model Configuration

The Wainui te Whara catchment was divided into two sub-catchments, representing the catchments upstream and downstream of the proposed detention dam. These sub-catchments are shown in Appendix A, Figure 1.

The rainfall-runoff model was calibrated using rainfall data from the Whakatane at Kopeopeo raingauge and flow data from the Mokorua Gorge flow recorder. For the calibration process the largest four flood events on record were used (refer to Table 6). This was considered appropriate since WDC is interested in the design flood flows for the 100 year and 300 year return period. Selecting a larger number of flood events for the calibration process would result in using flood events with peaks less than 10 m^3/s which is significantly less than the design flow events. The four selected events are considered to represent the rainfall-runoff characteristics of the catchment during the most extreme events on record.

4.1.3 Model Calibration

The calibration process involved calibrating the loss parameters (Ci, Cs, Rsa) against recorded runoff volume and calibrating the exponential and proportional coefficients (P and K) against the observed peak flow and hydrograph shape.

Antecedent wetness conditions of the catchment were taken into account by assuming that a quarter of the total rainfall depth in the 14 days prior to the event was still present in the catchment as antecedent rainfall depth (Ra). In other words the switch point when the soil is saturated is reached sooner when antecedent wetness conditions are higher prior to the storm.

Based on the geology of the catchment as described in section 2.0 the initial and saturated runoff coefficients (Ci and Cs) were set slightly lower for the upper catchment then for the lower catchment. A portion of the upper catchment consists of Whakatane Hill Soil and Whakatane Loamy Sand which have higher infiltration rates than the other soils in the Wainui te Whara catchment and hence lower runoff rates can be expected.

The catchment parameters required to achieve a good fit between modelled and recorded flows can vary from one historical event to the next, reflecting the variable state of the catchment and storm event over time and space (e.g. antecedent moisture conditions, temporal and spatial variability in rainfall are different for each storm).

Appendix C shows the modelled and observed hydrographs for the four calibration events. Modelled hydrographs are shown using both the 'best fit' parameters for the individual event and the final adopted parameters. The final parameters (refer to Table 8) chosen were a weighted average of the calibrated parameters for the individual events. The contribution of the 'best fit parameters' for each event was weighted based on the magnitude of the peak flow of the event, with a higher peak flow event carrying a higher weighting.

Table 8: Final calibration parameters

Parameter		**Upper Catchment**	**Lower Catchment**
Initial Runoff Coefficient	Ci	0.24	0.29
Saturated Runoff Coefficient	Cs	0.59	0.64
Saturated Rainfall (mm)	Rsa	105	105
Proportional Coefficient	K	18.3	18.3
Exponential Coefficient	P	0.39	0.39

It is recognised that calibration is only undertaken against flows at Mokorua Gorge. The Ci and Cs runoff coefficients for the upper and lower catchment were chosen based on available soil information. Even though there is some uncertainty about the relative contribution of the upper and lower catchment to flows at Valley Road these runoff coefficient estimates are considered best estimates based on the available information.

4.1.4 Design Storm Modelling

The design rainfall events for the 100 year and 300 year return periods with and without climate change (refer to Table 5) and PMP (refer to Table 7) were run through the calibrated rainfall-runoff model for the Wainui te Whara catchment to derive design peak flows. The design rainfall depths in Table 5 were increased by a factor of 1.15 for the lower catchment and 1.25 for the upper catchment as detailed in section 3.2.1.

The 'typical' temporal distribution of storms in the Bay of Plenty has not been researched in the Bay of Plenty and therefore the 'typical' design storm temporal distribution (design hyetographs) is unknown. West (2012) used a Chicago storm profile in the Whakatane stream catchment study. As recognised in this report this approach produces conservative design outcomes because it represents the nominated storm probability at all duration indices up to 72 hours in a single simulation. Using a Chicago storm is therefore likely to overestimate both peak flood flows and runoff volume. However, using constant intensity design rainfall is likely to underestimate peak flows as design rainfall for short duration storms derived from frequency- duration data (such as Hirds V3) does not generally represent rainfall in complete storms. Rather, these rainfalls represent intense bursts within storms (Pilgrim and Cordery, 1975). To overcome this issue it was assumed that the catchment was saturated prior to the intense short duration burst. In other words it was assumed that the saturated runoff coefficients apply for the design storm when applying the constant intensity rainfalls to the calibrated rainfall-runoff model.

The resulting peak flows for the upper and lower catchment, the gauge (Wainui te Whara at Mokorua Gorge) and for Valley Road are summarised in Table 9. The flows at Valley Road are simply scaled up to catchment size using the lower catchment peak flows. The design peak flows for all the different duration storms are shown in Appendix D.

Table 9: Modelled peak flows for Wainui te Whara catchment

Scenario	**Return Period**	**Flow(m^3/s)**			
		Upper Catchment	**Lower Catchment**	**Gauge**	**Valley Road**
Current	100	14.9	13.1	27.2	28.7
	300	21.9	19.3	39.4	41.7
	PMP	52.4	51.9	98.2	104.4
Climate Change (2115)	100	19.6	17.3	35.2	37.3
	300	28.3	25.4	51.2	54.1
	PMP	68.2	72.7	125.6	133.3

4.1.5 Discussion of Design Flood Modelling Results

As shown in Appendix D, the critical duration for the Wainui te Whara at Mokorua Gorge was found to vary with the modelled scenario. However, the critical duration for the 100 year and 300 year return period floods with and without climate change are reasonably consistent at approximately 3 hours at the Wainui te Whara recorder site. The time of concentration at this location using the Bransby-Williams equation is 2.6 hours and West (2012) determined that the time to peak (Tp) for the Wainui te Whara catchment was around 100 minutes which equates to a time of concentration of approximately 2.5 hours.

The shorter critical duration for the PMP events (around 2 hours) is likely to be an effect of the 6:1 hour ratio's chosen for the PMP (refer to section 3.4) which is slightly lower than the 6:1 hour ratios for the 100 year and 300 year return periods (with and without climate change).

The design peak flow for the 100 year return period at the gauge is 27.2 m^3/s which is slightly lower than the 1 June 2010 event (30.7 m^3/s). This is considered reasonable since, when assuming that the rainfall return period at the Kopeopeo gauge is representative of the rainfall return period in the Wainui te Whara catchment, the rainfall return period was slightly higher than the 100 year return period for the 2 hour maximum rainfall totals (refer to section 3.2.2) and the relatively high antecedent wetness conditions (due to the 24 May 2010 storm). Note that the scaling factors (of 1.15 and 1.25 for the lower and upper catchment respectively) do not influence the return period of the rainfall as the factors were applied to both the measured rainfall at Kopeopeo and the HIRDS V3 rainfall depths.

4.2 Regional Flood Methodology

McKerchar and Pearson (1989) derived contour maps of New Zealand to allow the calculation of the Mean Annual Flood ($Q_{2.33}$) for ungauged catchments. They also derived contour maps which enables floods with return periods between 5 and 200 years to be determined. This approach is an accepted, independent method of checking flood frequency estimates of gauged catchments, although it is considered less accurate for catchments less than 10 Km^2 (McKerchar and Pearson, 1989). The method also allows for pooling the available site data with the flood estimation contour maps.

The $Q_{2.33}$ determined by the Q_{pool} method outlined in this publication gives $Q_{2.33}$ = 5.18 m^3/s. The $Q_{100}/Q_{2.33}$ ratio is approximately 2.7 for Wainui te Whara at Mokorua gorge which results in a Q_{100} flow of approximately 14 m^3/s. As recognised in the McKerchar and Pearson (1989) publication there are relatively large uncertainties associated with using this method for small catchments. The hydrological and hydraulic Guidelines from EBOP (August 2012) comment that:

"In the Bay of Plenty Regional Council's experience the method tends to underestimate flows particularly in smaller catchments. This may be due to the contour maps being derived mainly from large catchment sizes –sometimes larger than the subject catchment by one to two orders of magnitude'

Based on these considerations it was considered that the Q_{100} flow derived using this method was too low.

The original OPUS estimates for the Q_{100} and Q_{300} flows at the dam site for the Wainui te Whara catchment (2006 draft report) were based on frequency analysis using catchments similar in size to the Wainui te Whara catchment and which were either from the same geographical location and/or coastal. Flood flows at the dam site were estimated using the $A^{0.8}$ area reduction technique. They selected the Mangawhai at Omokoroa catchment as being the most representative of the Wainui te Whara catchment. These estimates were used in subsequent hydrology reports to estimate flood flows at the gauge (WtW at

Mokorua Gorge) and Valley Road using catchment scaling. The Mangawhai at Omokoroa catchment is a coastal, west facing catchment approximately 12 kilometres west of Tauranga with elevations from 20 m to 180 m and a catchment size of 2.95 km^2.

Using this technique the peak flows (as estimated by OPUS) are closer but still lower than the results from the rainfall-runoff modelling (Q_{100}: 24.4 m^3/s and Q_{300} : 30.7 m^3/s at Valley Road). However, the most recent OPUS report (March 2011) states that these estimates are likely to be too low in light of the May/June 2010 storms and comments:

"What was previously assessed as the Q_{300} (31 m^3/s) event now appears to be closer to a Q_{100} flood".

Based on our analysis we consider that the results from the PDP rainfall-runoff model are realistic. The peak flows determined from PDP's rainfall run-off model were adopted for routing flows through the dam site and estimating peak flows at Valley Road for the design scenarios with and without the detention dam in place.

5.0 Hydrograph Shape

Rather than using the results of the rainfall-runoff model to determine the hydrograph shape for detention dam inflows (which is based on a theoretical constant intensity rainfall storm) it was considered more realistic to use actual observed hydrograph shapes to determine design hydrographs. Therefore, the design peak flows were fitted to design hydrographs to determine the performance of the detention dam (refer to section 6.0). A normalised design hydrograph was obtained by assessing the Wainui te Whara record. The approach was based on work by Evans et al (2004), and Throssell B (2012).

The design events have a return period of 100 years or greater and therefore, the normalised hydrograph was constructed using only the four largest events in the Wainui te Whara (Appendix E, Figure 1) record as these were considered to be the most representative of an extreme event. The four events were normalised (divided by peak flow) and from the normalised events, the 50th and 75th hourly flow percentiles were obtained (design hydrographs). The contribution of each event to the design hydrograph was weighted based on the magnitude of the peak flow of the event, with a higher peak flow event carrying a higher weighting.

Appendix E, Figure 2 shows the 50th and 75th percentile normalised design hydrographs as well as the normalised June 2010 event. Both the 50th and 75th percentiles show a slightly more conservative (when assessing flood volume) profile in comparison to the June 2010 event. The 75th percentile normalised design hydrograph was adopted for design purposes to account for any uncertainties associated with the shape of the design hydrograph.

The normalised design hydrograph was multiplied by the design flow to obtain a hydrograph to route through the detention dam. The design inflow hydrographs for the proposed detention dam are shown in Appendix E, Figure 3.

6.0 Routing Flows through Detention Dam

A spreadsheet was developed to route the design inflow hydrographs through the detention dam to estimate the required storage volumes at the dam site and the resulting attenuated flows at Valley Road with the proposed detention dam in place. A level - volume relationship was derived using the latest (2010) Lidar data for the Wainui te Whara catchment (obtained from WDC, refer to Table 10). The associated elevation-storage curve is shown in Appendix F.

Table 10: Level-Volume table for proposed detention dam

Water level (m RL)	Storage volume (m^3)
68	0
69	84
70	1,197
71	3,814
72	9,128
73	17,381
74	29,245
75	45,582
76	66,675
77	92,802
78	123,054
79	157,307
80	195,584

As outlined in the 'scope of work' with WDC two different culverts were modelled with diameters of 0.75 m and 1.05 m. The 100 year and 300 year design flow hydrographs (with and without climate change) were routed through the detention dam. A summary of the results is shown in Table 11 and the full outputs are shown in Appendix G. For comparative purposes the OPUS estimates (March 2011 report) are also shown together with the estimated peak flows without the detention dam in place.

Table 11: Results from routing design hydrographs through detention dam									
	Peak discharge from dam (m^3/s)		Peak discharge at Valley Road (m^3/s)			Required storage volume (m^3)		Required dam height (m)	
Culvert size (m)	**0.75**	**1.05**	**0.75**	**1.05**	**No dam**	**0.75**	**1.05**	**0.75**	**1.05**
OPUS (June 2010 event)[1]	3.4		17.1			73,800		9.5[2]	
100YR No Climate Change	3.5	6.1	17.8	20.3	28.7	83,052	45,955	9.6	8.0
300YR No Climate Change	3.9	6.9	25.0	27.9	41.7	151,592	91,715	11.8	10.0
100YR 2115 Climate Change	3.7	6.7	22.8	25.5	37.3	128,175	75,747	11.2	9.4
300YR 2115 Climate Change	4.2	7.5	32.1	35.2	54.1	221,032	140,126	13.5	11.5

1) Based on the Opus March 2011 report
2) Based on a slightly different storage – elevation curve derived from site survey data rather than LIDAR data.

The peak discharge at Valley Road consists of flow from the catchment beneath the dam (lower catchment) and the discharge from the detention dam culvert. Given that the culvert restricts flow from the detention dam to a relatively uniform magnitude, the peak flow at Valley Road will coincide with the peak flow produced by the lower catchment. In terms of required dam height a freeboard of 1 m was assumed above spillway crest level.

When comparing the peak flows at Valley Road with and without a detention dam in place it can be seen that a detention dam would provide a significant reduction in peak flows at Valley Road.

As can be seen in Table 11 the low flow culvert size makes a large difference in terms of required storage volume, however, the relative difference in required dam height between a 0.75 m and 1.05 m culvert is much smaller. This is due to the available storage volume increasing rapidly with dam height (refer to Table 10 and Appendix G). The difference in peak discharge from the dam with a 0.75 m culvert compared to a dam with a 1.05 m culvert is approximately 2.5 - 3.0 m^3/s depending on the scenario modelled. This indicates that increasing the size of the culvert from 0.75 m to 1.05 m would result in a relatively small increase in peak flows at Valley Road for the modelled design storms.

The relative difference in required dam height is relatively small when comparing the different modelled scenarios. However, the relative difference in peak flows at Valley Road (with the dam in place) is relatively large for the modelled scenarios. This is due to the contribution of the WtW catchment area below the dam which is expected to generate a large amount of runoff during the design storm events.

As discussed in section 3.2.1 it was decided to increase the measured Kopeopeo rainfall data and HIRDS V3 design rainfall depths by a factor of 1.15 for the lower Wainui te Whara catchment and 1.25 for the upper Wainui te Whara catchment. It is noted that if a higher rainfall gradient was chosen for the Wainui te Whara catchment (for example a multiplication factor of 1.3 for the upper catchment and 1.1 for the lower catchment) the runoff from the upper catchment would be (relatively) higher and for the lower catchment (relatively) lower. The adopted rainfall multiplication factors of 1.25 and 1.15 for the upper and lower catchment respectively are therefore considered conservative in terms of design flows at Valley Road (as the runoff from the lower catchment is relatively higher compared to a scenario with a multiplication factor of 1.1 and 1.3 respectively). The adopted multiplication factors are, however, considered unconservative in terms of required dam volume. In other words using multiplication factors of (for example) 1.1 and 1.3 instead of 1.15 and 1.25 would result in more runoff being generated from the upper catchment relative to the lower catchment resulting in a (slightly) higher required detention volume.

Note that the PMP and PMP climate change scenarios have not been routed through the dam. It is recommended that this be done once WDC has adopted a design criterion for the detention dam such that spillway design criteria can be determined based on a chosen storage volume and dam height.

7.0 Discussion and Conclusion

The current conveyance capacity of Wainui te Whara Stream between Valley Road and Hinemoa Street is approximately 18 m^3/s with no freeboard or 15.6 m^3/s with approximately 300mm freeboard (Opus, 2008).

The results of routing the design hydrographs through the detention dam indicates that a detention dam, at the location currently proposed, would only reduce the peak flood flows to the current conveyance capacity of the lower reaches(without freeboard) for the 100 year return period scenario using a 750 mm culvert (or orifice plate).

A detention dam in the upper Wainui te Whara catchment provides limited options to provide a level of service over and above the 100 year return period. This is due to the runoff generated by the lower catchment which cannot be attenuated by the proposed dam. The benefits of reducing the outflow (by increasing the throttling effect) from the detention dam are small as a smaller culvert size (or orifice plate) would result in only a small decrease in flows measured at Valley Road. In addition, reducing the size of the low flow culvert, will result in a significant increase in required storage volume.

A detention dam which captures the runoff from a larger portion of the catchment would be preferable. However, it is PDP's understanding that options for moving the location of the proposed detention dam further downstream are limited due to access and the location of the reserve (personal communication WDC, Glenn Cooper). This should be investigated further.

Even though an upper catchment detention dam (as the only mitigation measure) is unlikely to provide a level of protection greater than the 100 year return period it will still provide a significant reduction in peak flood flows. It is estimated that the level of protection for the downstream reach will improve from a 40 year return period (current conveyance capacity as estimated by Opus, 2008) to around a 100 year return period. It is also likely that a detention dam designed for a 100 year return period will decrease the severity of flooding during more extreme events. The required storage volumes and resulting dam heights are based on the maximum water level in the dam without overflow into Wainui te Whara stream via the spillway. The maximum water level in the dam occurs after the peak inflow since the water level will keep rising as long as the inflow is higher than the outflow from the low flow culvert. Therefore, it can be expected that for events in excess of the design flow event the spillway starts to operate after the peak from the lower catchment has passed resulting in a reduction of the peak flow at Valley Road compared to a "no dam" scenario.

If WDC wishes to adopt a higher level of service for Wainui te Whara Stream additional mitigation measures are required. The options assessment undertaken by PDP in 2011 (PDP, 5 October 2011) outlined some options. This report does not include a combined option with a detention dam in the upper Wainui te Whara catchment. Some of the options described in the 2011 report could be combined with a detention dam in the upper Wainui te Whara catchment.

Progressive implementation of a combined option would provide short term benefits (i.e. If the upper detention dam were constructed first, storms in excess of the current 40 year conveyance capacity but less than the 100 year design flow would be contained within the downstream channel). This progressive approach would allow WDC to provide short term relief while working on additional mitigation measures to ultimately deliver the desired level of service to the flood-prone areas.

8.0 Recommendations

It is recommended that the following items be investigated further:

1) A detention dam located further downstream in the Wainui te Whara Catchment;
2) Combining downstream flood flow mitigation options with a detention dam in the upper Wainui te Whara Catchment;
3) Progressive implementation of a combined option to provide short term relief while working on additional mitigation measures to ultimately deliver the desired level of service to the flood-prone areas.

9.0 Acknowledgement

PDP wish to acknowledge Peter West and Mark James from BOPRC for discussions related to previous work carried out in the Wainui te Whara catchment and flood forecasting modelling in the Bay of Plenty and Peter West for providing example spreadsheets for the non-linear reservoir method and the SCS method.

10.0 References

Bay of Plenty Regional Council Guideline 2012/02 (August 2012). Hydrological and Hydraulic Guidelines. Report prepared by Environmental Hazards Group.

Blackwood, P. (2005). Matata Flooding 18 May 2005: Meteorology. Peter Blackwood 28 June 2005, File 5810 03 2005-06-28.

Evans, S. Y, Riches, D. Russel, M. and Wood, T. A. (2004). New Approach to Flood Estimation Using Flood Peak and Duration – A Case Study Informing Incident Management Plans for Exeter: Environment Agency, United Kingdom.

'Non Linear Routing Methodology Boundary' and 'Japanese Runoff Methodology'. InfoWorks RS user manual. Wallingford Software Ltd. 2001-2008.

Ministry for the Environment (July 2008). Preparing for Climate Change, A guide for local government in New Zealand, ME Publication Number 891.

Opus International Consultant Ltd (September 2006). Wainui Te Whara Detention Dam Design Hydrology, draft report. Report reference 289288.01_1we.

Opus International Consultant Ltd (May 2010). Wainui Te Whara Stream, Options For Mitigating Flood Risk, Update Report May 2010. Report 10/022.

Opus International Consultant Ltd (March 2011). Wainui Te Whara Stream Options For Mitigating Flood Risk. Review Following May and June 2010 Storm Events. Report WK 11/010.

McKerchar, A. (2010). Major storms at Whakatane: May-June, 2010. NIWA Client Report: CHC2010-100 August 2010. Report prepared for Environment Bay of Plenty.

Opus International Consultant Ltd (October 2008), Wainui te Whara Stream Lower Channel(urban) Flood Capacity Assessment. report 08/42.

Pattle Delamore Partner Ltd(2011), Options Assessment: Wainui te Whara Stream Flood Mitigation.

Pilgrim, D.H., Cordery, I.(1975). Rainfall Temporal Patterns For Design Floods. Journal of the Hydraulics Division. January 1975.

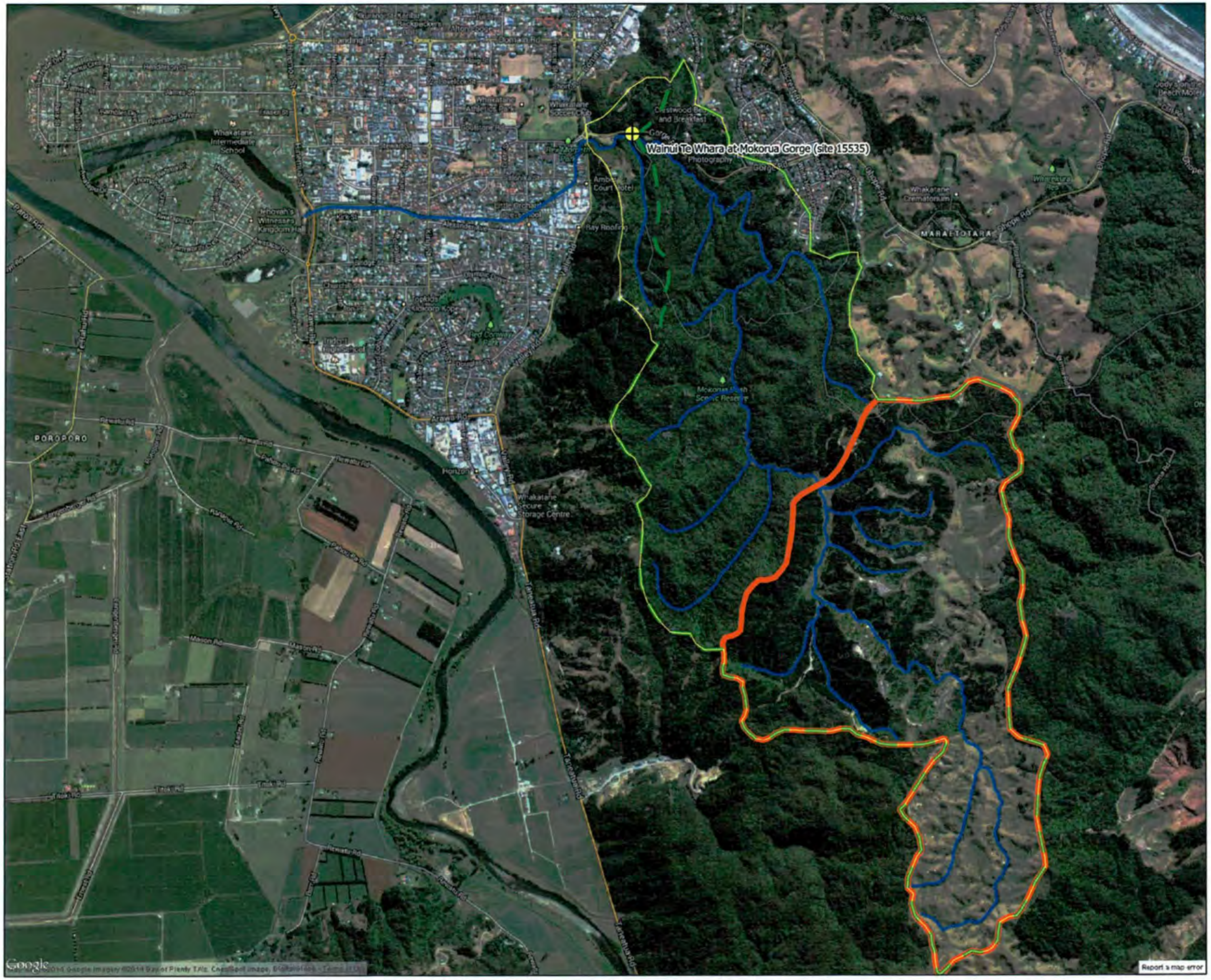
Rijkse, W.C. (1993). Soils of Whakatane County, North Island New Zealand, Landcare Research, ISSN 01130056.

Thompson C.S., Tomlinson, A.I. (1993). Probable Maximum Precipitation in New Zealand for Small Areas and Short Durations. Journal of Hydrology (NZ) 31 (2): 78-90.

Throssell, B. 2012: A comparison of three methods for generating design hydrographs: Presentation at the 2012 New Zealand Hydrological Society Conference.

West, P.(2012). Whakatane stream catchments study. Hydrological investigations into rain intensities, stream flows, and river levels for use in the design of urban stormwater systems. Bay of Plenty Regional Council Operations publication 2011/04.

World Meteorological Organization(1986). Manual for estimation of probable maximum precipitation. Operational Hydrology Report No.1, WMO No 332.



KEY :

N

Flow Gauge

Wainui te Whara Stream

Catchments

Mokorua Gorge Gauge

Proposed Dam

Valley Rd

NO.	REVISION		
A	ISSUE 1	R1	BT
NO.	REVISION	XXXX	XX

CLIENT :

Whakatane District Council

PROJECT :

Wainui te Whara Hydrology

TITLE :

Figure 1: Delineated cathment areas

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SCALE : 1:25,155 (A3)

0 0.25 0.5 0.75 1 km

PROJECT NO. :	FIGURE NO. :	REVISION :
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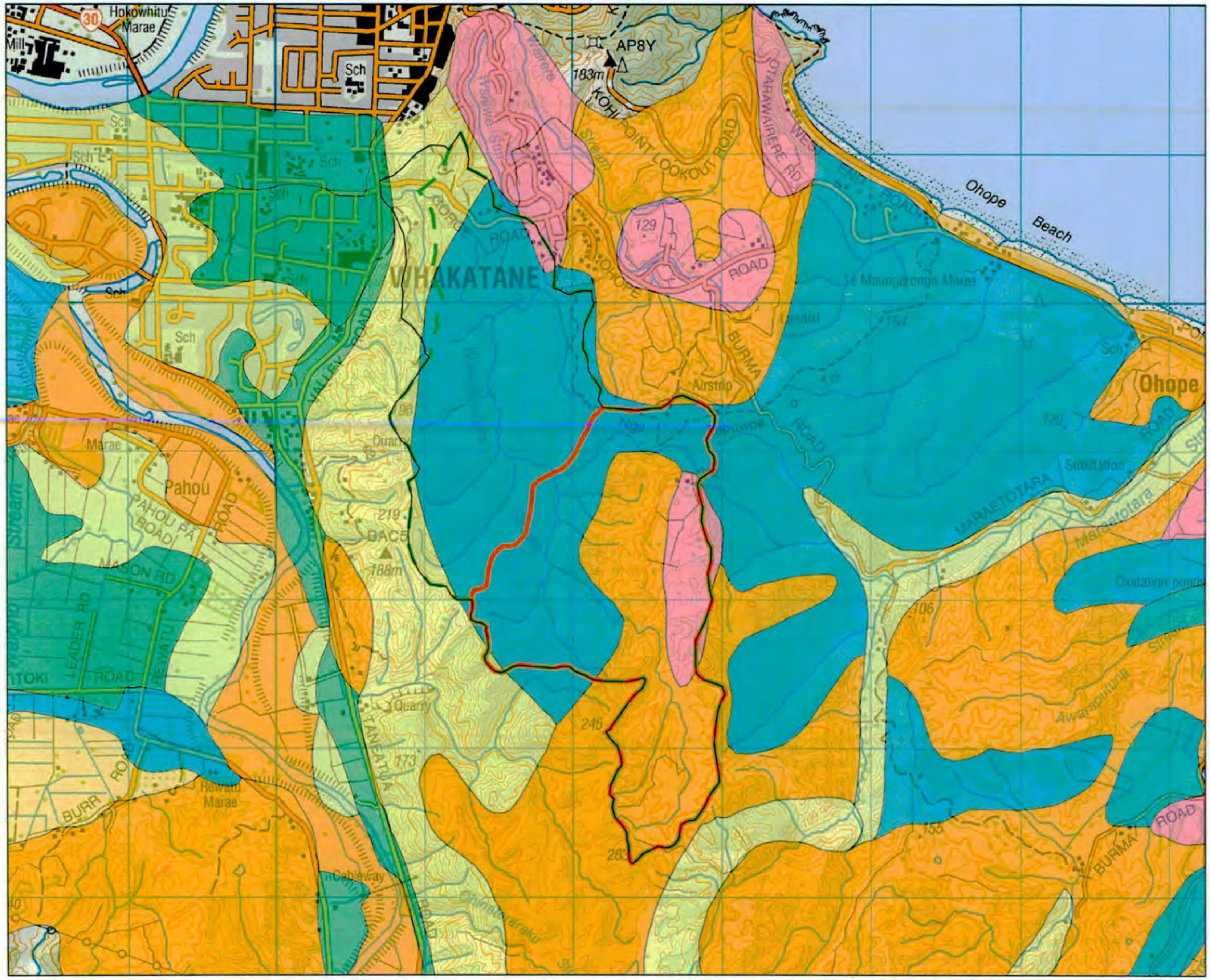

KEY :

N

Catchments

- Mokorua Gorge Gauge
- Proposed Dam
- Valley Rd

Soil Classification

- Ngatiawa steepland soils
- Rewatu soils
- Tawhia steepland soils
- Whakatane hill soils
- Whakatane soils

NO.	REVISION		
A	ISSUE 1	R1	BT
NO.	REVISION	XXXX	XX

CLIENT :

Whakatane District Council

PROJECT :

Wainui te Whara Hydrology

TITLE :

Figure 2: Soil classification for Wainui te Whara catchment

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SCALE : 1:25,000 (A3)

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PROJECT NO. :	FIGURE NO. :	REVISION :
T01502501	2	A

T01502501 Q001.QGS

KEY :

Wainui te Whara Stream

Rainfall Gauges

Catchments

Valley Rd

NO.	REVISION	XXXX	XX
A	ISSUE 1	R1	BT

CLIENT : Whakatane District Council

PROJECT : Wainui te Whara Hydrology

TITLE : Figure 3: Location of rain gauges

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SCALE : 1:50,000 (A3)

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PROJECT NO. :	FIGURE NO. :	REVISION :
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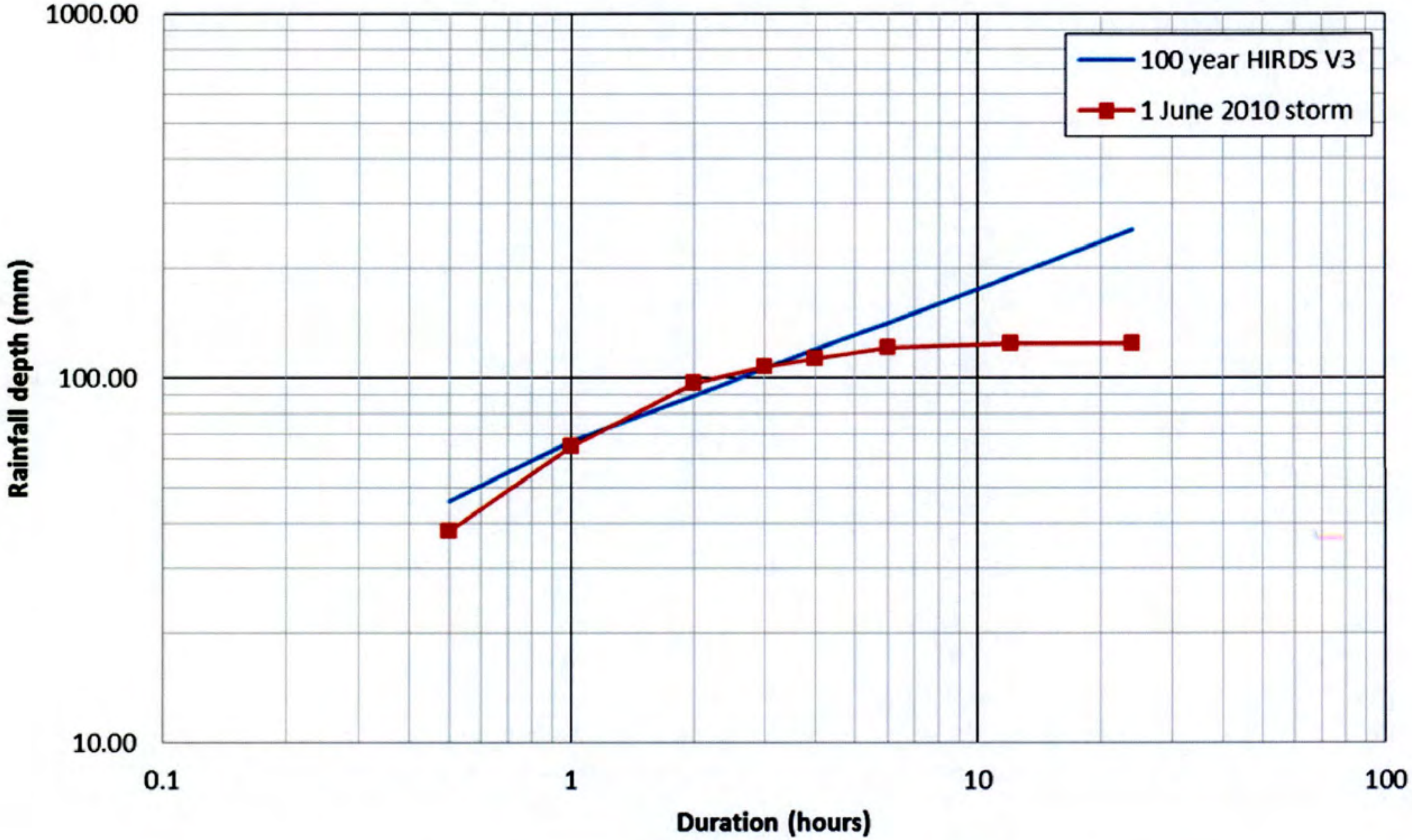
T01502501 Q001.QGS

Appendix B

Rainfall depth-duration curve



Appendix B: Depth- duration curve comparison between HIRDS V3 100 year return period and rainfall maxima for the 1 June 2010 storm

Appendix C

Calibration results

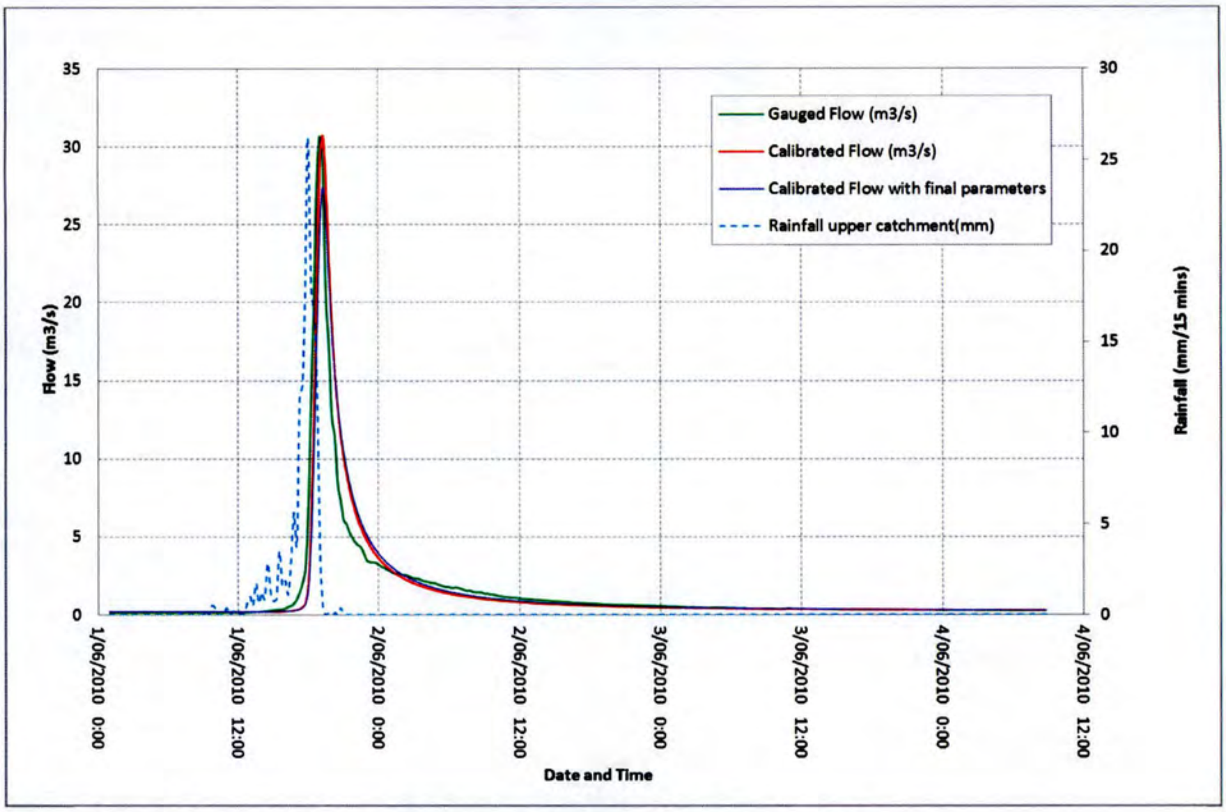


Figure 1: Calibration Wainui te Whara Stream at Mokorua Gorge – 1 June 2010 event

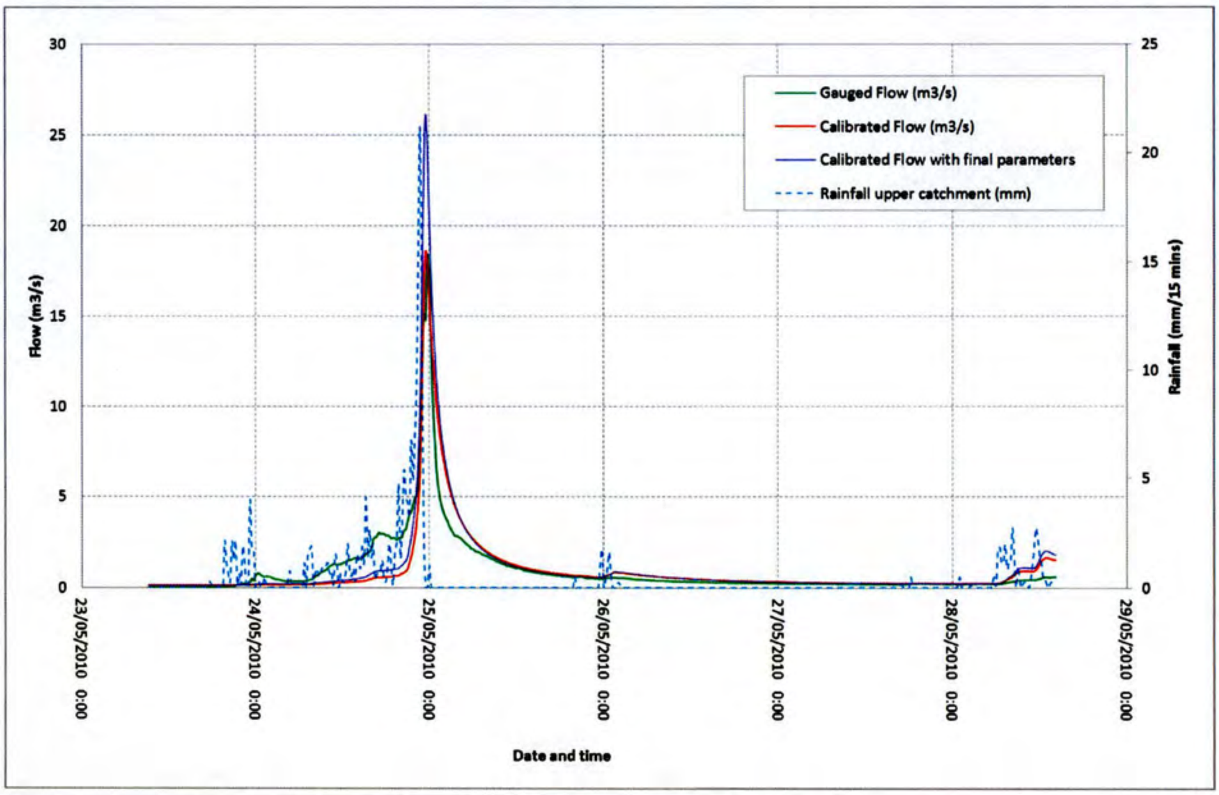


Figure 2: Calibration Wainui te Whara Stream at Mokorua Gorge – 24 May 2010 event

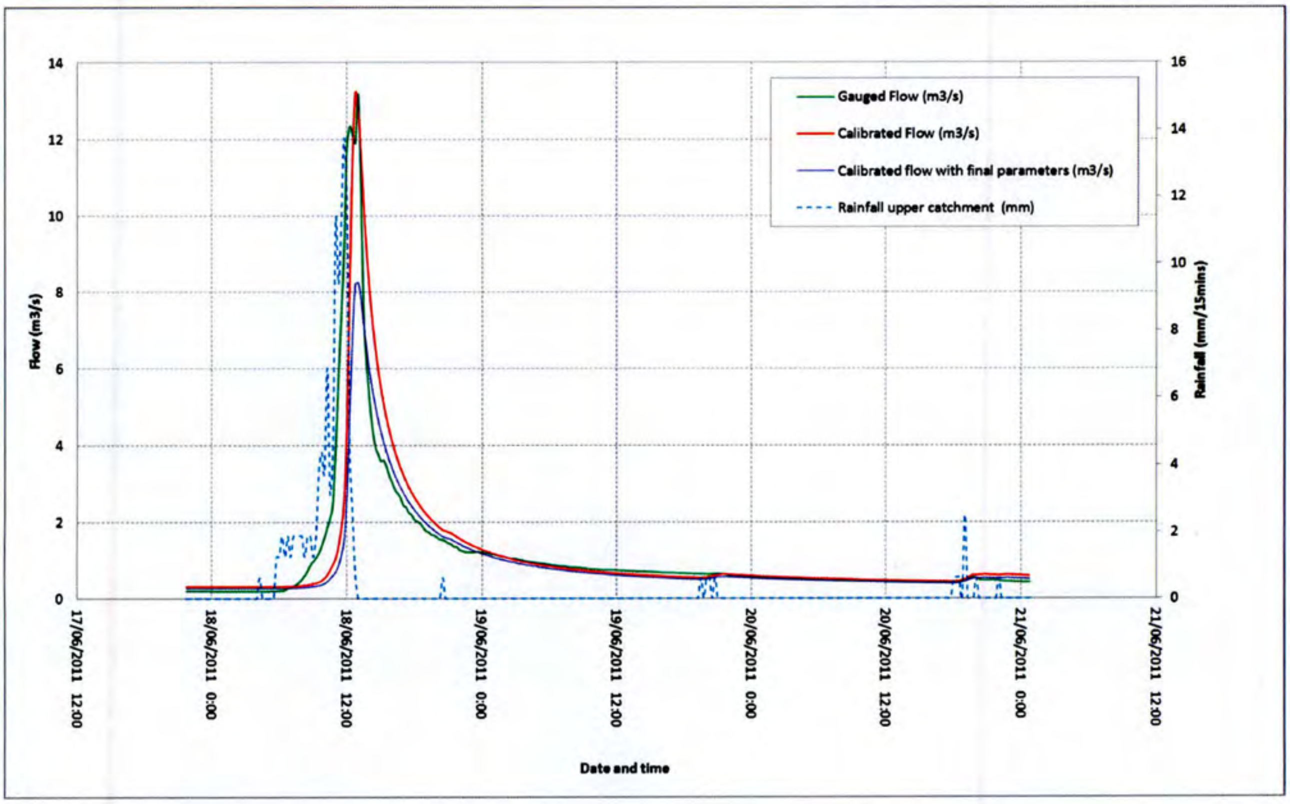


Figure 3: Calibration Wainui te Whara Stream at Mokorua Gorge – 18 June 2011 event

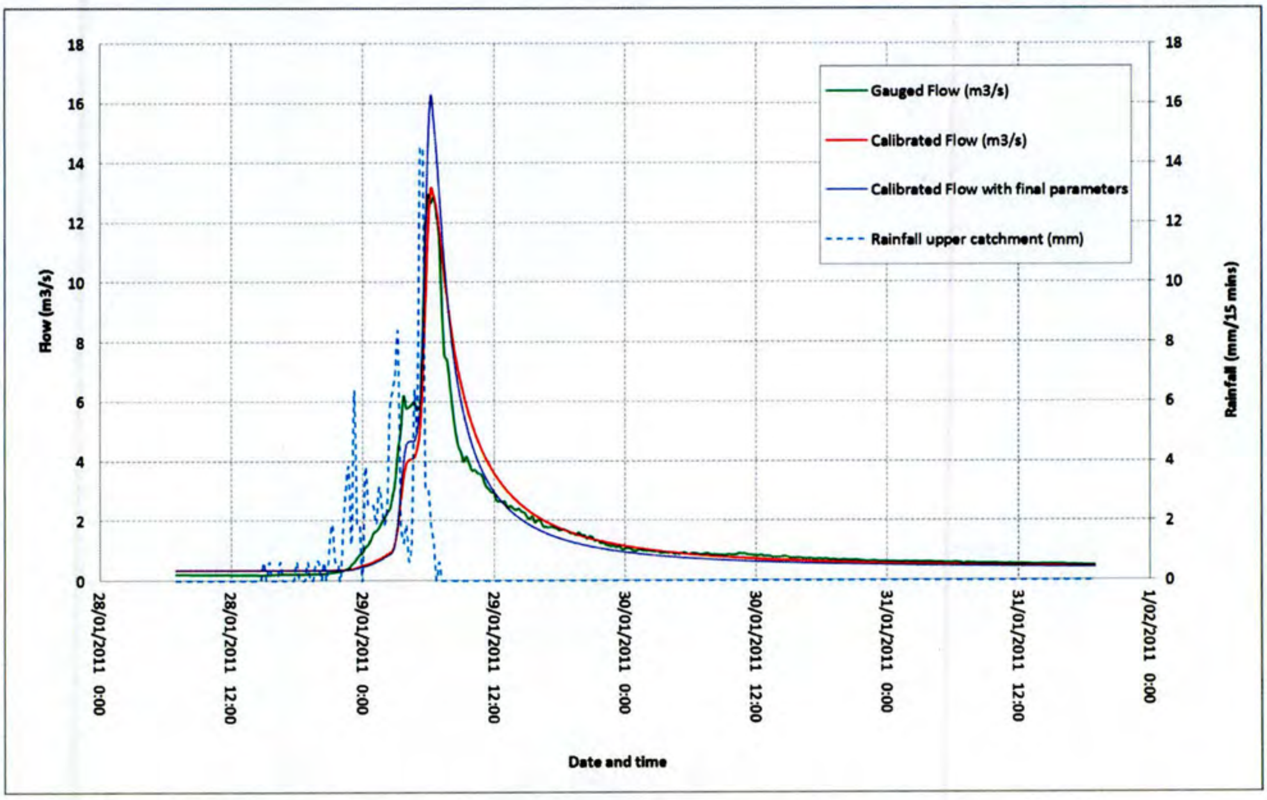


Figure 4: Calibration Wainui te Whara Stream at Mokorua Gorge – 29 January 2011 event

Appendix D

Design rainfall and flows

Scenario	Return Period	Duration (hours)	Rainfall Depth (mm) Upper Catchment	Rainfall Depth (mm) Lower Catchment	Flow (m^3/s) Upper Catchment	Flow (m^3/s) Lower Catchment	Flow (m^3/s) Gauge	Flow (m^3/s) Valley Road
Current	100	1	83.6	76.9	8.7	7.2	14.9	15.8
		2	111.8	102.9	13.4	11.5	23.1	24.5
		3	132.6	122.0	14.7	13.1	26.4	28.0
		4	149.6	137.6	14.9	13.0	27.2	28.7
		6	177.4	163.2	13.5	11.6	24.9	26.3
		12	237.4	218.4	9.6	8.1	17.7	18.7
	300	1	107.5	98.9	15.3	12.3	25.3	26.8
		2	143.4	131.9	21.0	18.6	36.7	38.9
		3	169.7	156.1	21.9	19.3	39.4	41.7
		4	191.2	175.9	20.9	18.0	38.2	40.4
		6	226.3	208.2	17.8	15.2	32.8	34.6
		12	301.9	277.8	12.2	10.3	22.5	23.8
	PMP	1	193.0	193.0	50.2	51.9	84.2	90.5
		2	252.8	252.8	52.4	51.7	98.2	104.4
		3	295.2	295.2	45.6	42.8	87.2	92.4
		4	330.0	330.0	39.2	36.4	75.4	79.8
		6	385.9	385.9	30.9	28.6	59.5	62.9
Climate Change scenario (2115)	100	1	99.6	91.6	13.0	10.5	21.6	22.9
		2	133.3	122.6	18.5	16.2	32.2	34.2
		3	158.0	145.4	19.6	17.3	35.2	37.3
		4	178.3	164.1	19.1	16.5	34.8	36.8
		6	211.5	194.5	16.5	14.1	30.4	32.1
		12	282.9	260.3	11.4	9.7	21.1	22.3
	300	1	128.1	117.9	22.3	18.0	35.8	38.0
		2	170.9	157.2	27.9	25.4	49.4	52.4
		3	202.3	186.1	28.3	24.6	51.2	54.1
		4	228.0	209.7	26.0	22.3	47.7	50.4
		6	250.1	230.1	19.8	16.9	36.6	38.6
		12	359.9	331.1	14.5	12.3	26.8	28.3
	PMP	1	230.0	230.0	68.2	72.7	114.7	123.5
		2	301.3	301.3	66.7	64.2	125.6	133.3
		3	351.9	351.9	55.4	51.6	106.3	112.5
		4	393.3	393.3	47.1	43.6	90.5	95.7
		6	460.0	460.0	36.9	34.0	70.9	75.0

Appendix D: Design Rainfall Depths and Flows for Wainui te Whara Catchment

Appendix E

Design hydrographs

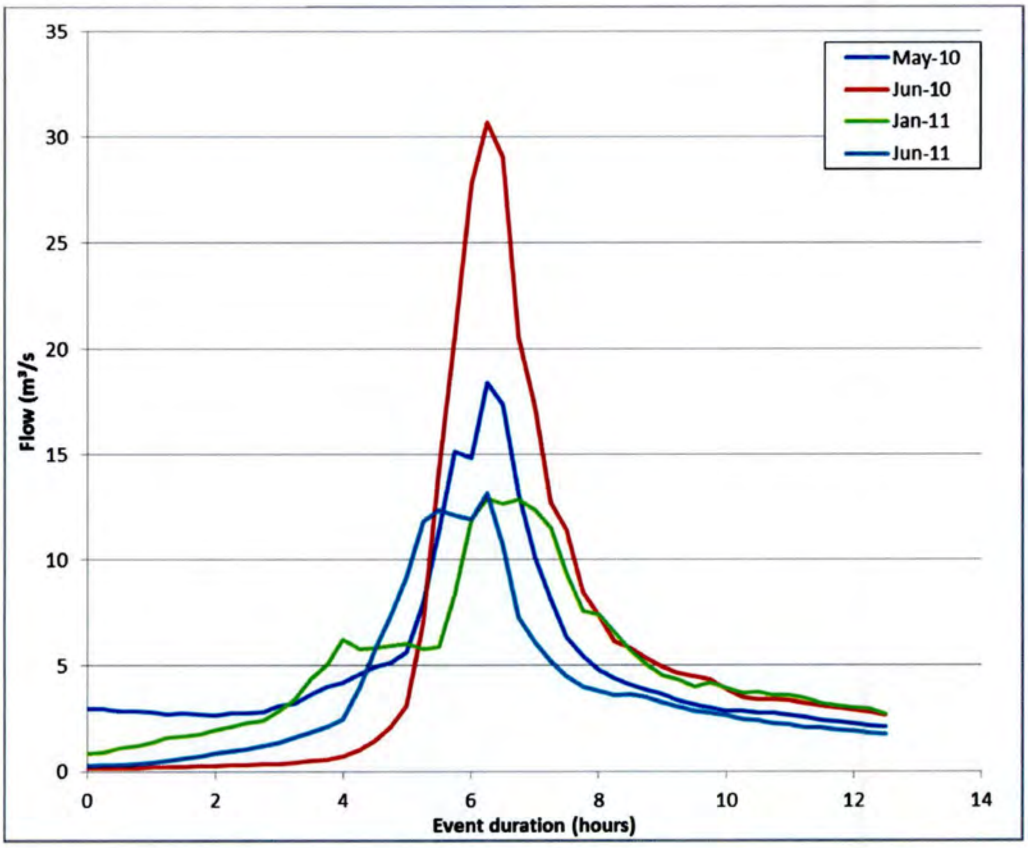


Figure 1: The four historical events used for construction of the normalised design hydrographs

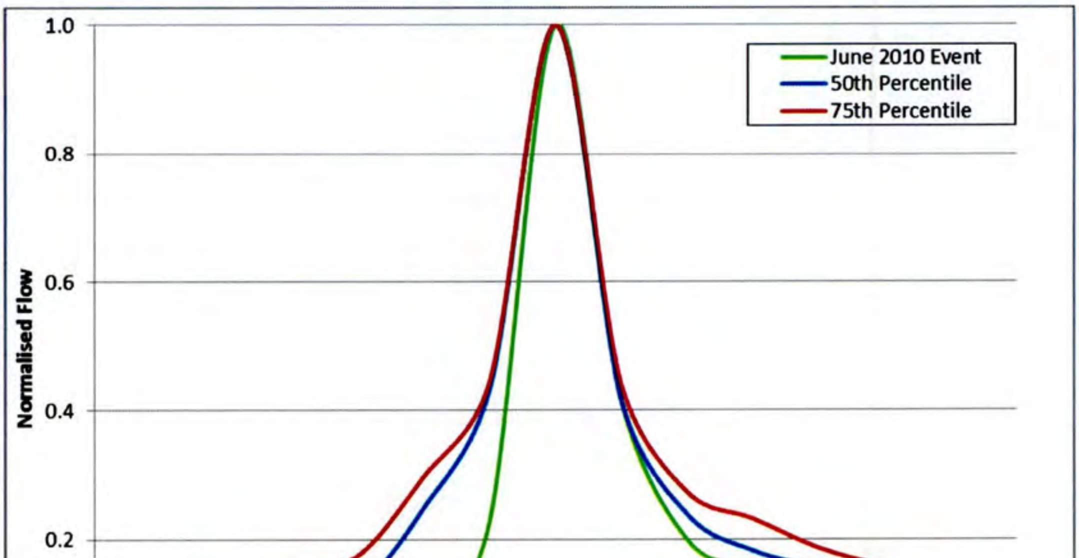


Figure 2: Normalised design hydrographs and the normalised June 2010 event

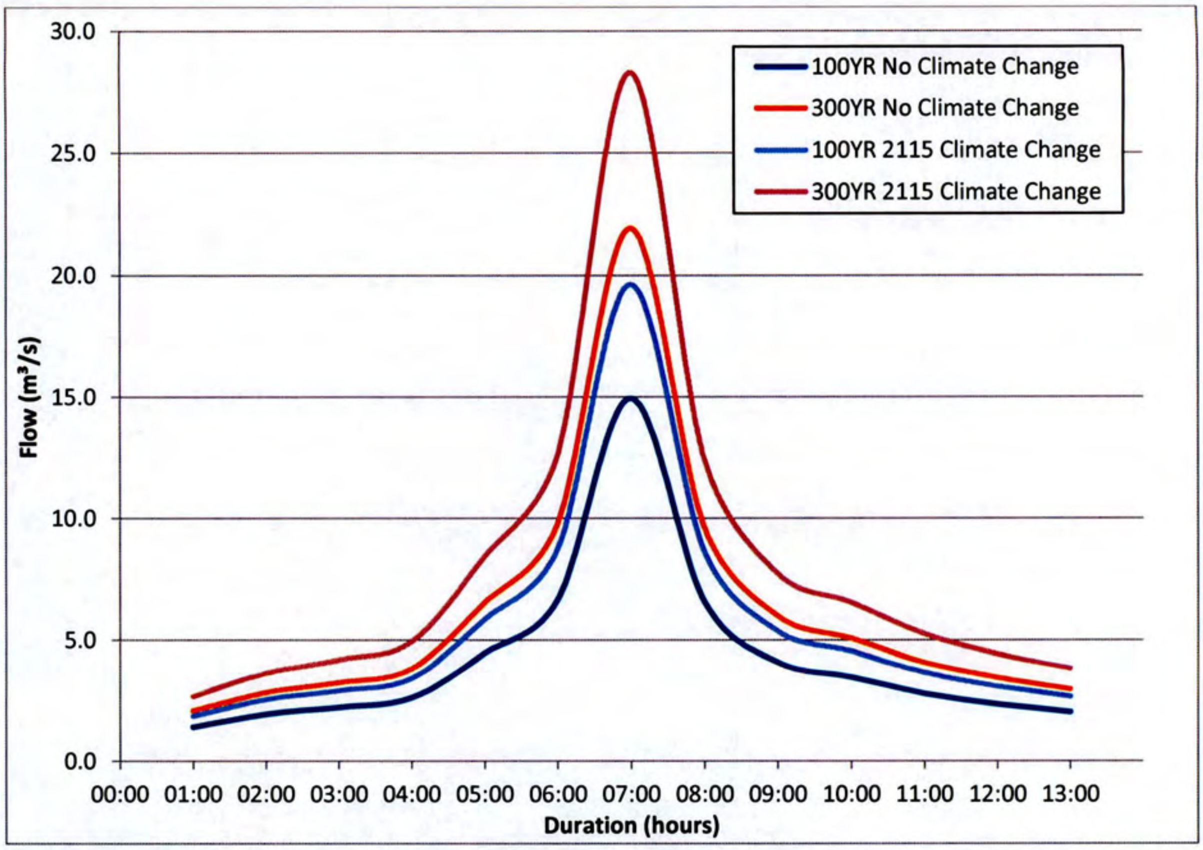
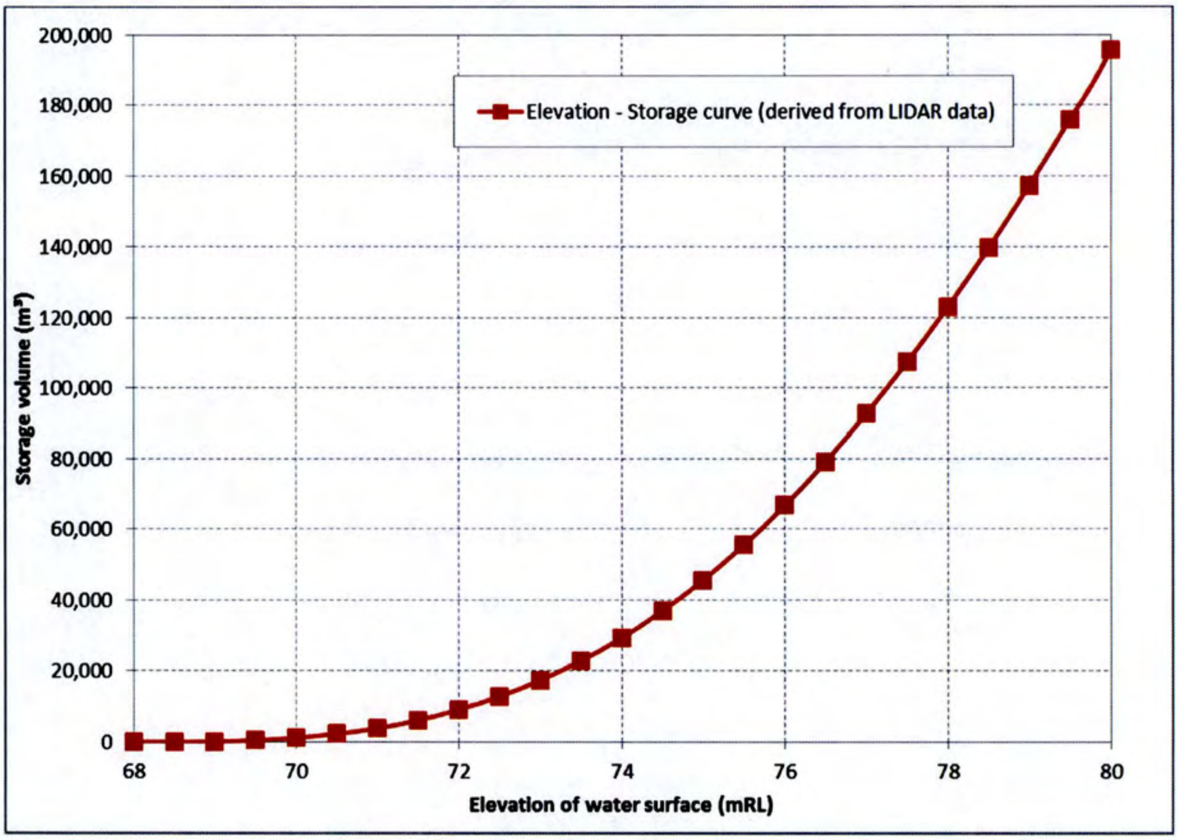


Figure 3: Design inflow hydrographs for proposed detention dam

Appendix F

Elevation-Storage curve



Appendix F: Elevation - storage curve for proposed detention dam

Appendix G

Routing results

	Peak discharge from dam (m^3/s)		Peak discharge at gauge (m^3/s)		Peak discharge at Valley Road (m^3/s)		Required storage volume (m^3)		Peak elevation of water surface (m)		Required dam height (m)		Time for dam to empty (hr)	
Culvert size (m)	**0.75**	**1.05**	**0.75**	**1.05**	**0.75**	**1.05**	**0.75**	**1.05**	**0.75**	**1.05**	**0.75**	**1.05**	**0.75**	**1.05**
OPUS June 2010 event	3.4		-		17.1		73,800		8.5		9.5		13.6	
100YR No Climate Change	3.5	6.1	16.2	18.7	17.8	20.3	83,052	45,955	8.6	7.0	9.6	8.0	11.7	5.3
300YR No Climate Change	3.9	6.9	22.7	25.6	25.0	27.9	151,592	91,715	10.8	9.0	11.8	10.0	16.0	8.0
100YR 2115 Climate Change	3.7	6.7	20.7	23.4	22.8	25.5	128,175	75,747	10.2	8.4	11.2	9.4	14.7	7.1
300YR 2115 Climate Change	4.2	7.5	29.1	32.2	32.1	35.2	221,032	140,126	12.5	10.5	13.5	11.5	19.5	10.0

Appendix G: Results from routing design hydrographs through detention dam

S2B Easter flood analysis (memorandum to hydrological review)

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Memorandum

TO:	Whakatane District Council
ATTENTION:	Glenn Cooper
FROM:	Bas Veendrick and Kyle Christensen
DATE:	06/05/2014
RE:	Hydrological and hydraulic analyses for the Easter 2014 flood event

---

1. Introduction

Pattle Delamore Partners Ltd (PDP) was engaged by Whakatane District Council (WDC) to analyse the severe storm that occurred in Whakatane on 18 April 2014. The rainfall during this event resulted in Wainui te Whara (WtW) Stream flows that exceeded the capacity of the channel in the downstream reaches resulting in flooding of the surrounding urban areas.

This memorandum describes the hydrological analyses undertaken using the available rainfall data from the Whakatane at Kopeopeo and WtW at Munro's raingauges and the flow data from the WtW at Mokorua Gorge flow recorder. The severity of the 18 April 2014 rainfall event for the WtW catchment was assessed by comparing the recorded rainfall depths with HIRDS V3. The recorded flow for WtW at Mokorua Gorge was used to validate the hydrological modelling undertaken by PDP (February 2014) including routing the flow hydrograph for the upper Wainui te Whara catchment through the proposed detention dam.

For background information regarding the proposed flood detention dam in the WtW Catchment and rainfall and hydrological analyses using the available rainfall and flow data up to December 2013 we refer to the PDP February 2014 report. This memorandum should be read in conjunction with this report.

2. Analyses: Rainfall and Flow

Bay of Plenty Regional Council (BOPRC) provided the most recent archived (QA checked) rainfall and flow data for the following sites:

- Rainfall gauge: Whakatane at Kopeopeo (site 769908);
- Rainfall gauge: WtW at Munro's (site 779007);
- Flow recorder: WtW at Mokorua Gorge (site 15535).

The Whakatane at Kopeopeo site records rainfall in Whakatane Township and the WtW at Munro's gauge records rainfall in the upper WtW catchment, both on a sub-hourly basis.

Figure 1 below shows the hourly recorded rainfall totals for WtW at Munro's together with the recorded flows for WtW at Mokorua Gorge. The 18 April 2014 event resulted in a peak flow of approximately 29 m^3/s at the recorder site. This compares with a peak flow of around 31 m^3/s for the June 2010 event and a flow of around 27 m^3/s for the 100 year return period as estimated by PDP in the February 2014 report. As can be seen the rainfall on 17 April 2014 resulted a peak flood flow of around 3.5 m^3/s which is close to the mean annual flood for the catchment.

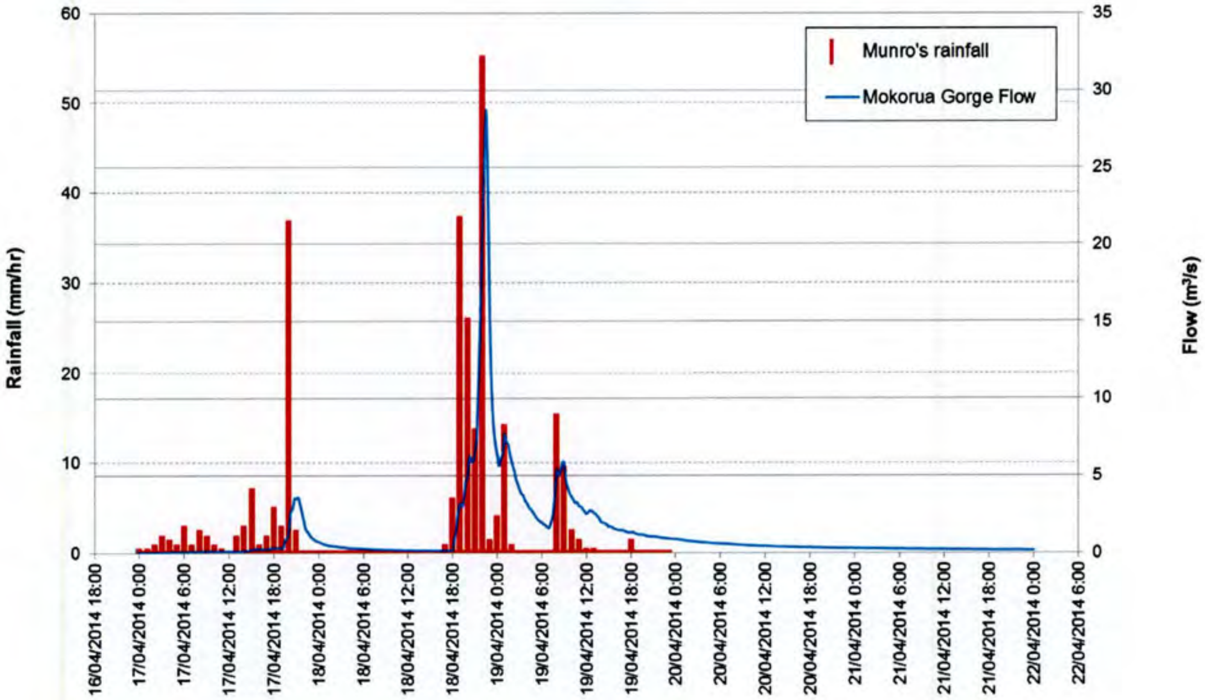

Figure 1: WtW at Munro's hourly rainfall totals and WtW at Mokorua Gorge flow

Figure 2 and Figure 3 below show a comparison of the hourly rainfall totals and cumulative rainfall distribution for the Kopeopeo and Munro's rainfall sites. As can be seen the rainfall patterns between the two sites are very similar. The Kopeopeo gauge recorded a total rainfall of 235 mm and the Munro's gauge a total of 272 mm over three days (17 – 19 April). The rainfall that caused the main flooding (rain between 18 April 4 pm and 19 April 4 am, refer to Figure 2) included a total rainfall of 131 mm at Kopeopeo and 161 mm at Munro's.

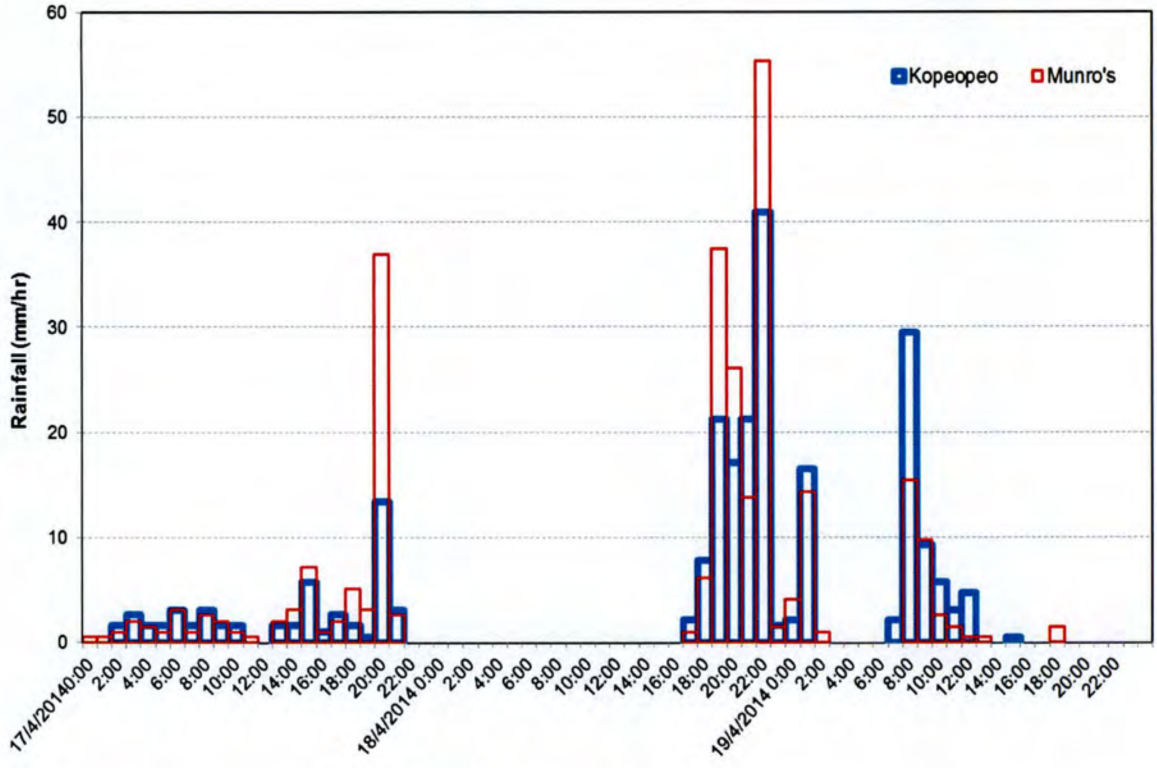

Figure 2: Whakatane at Kopeopeo and WtW at Munro's hourly rainfall totals

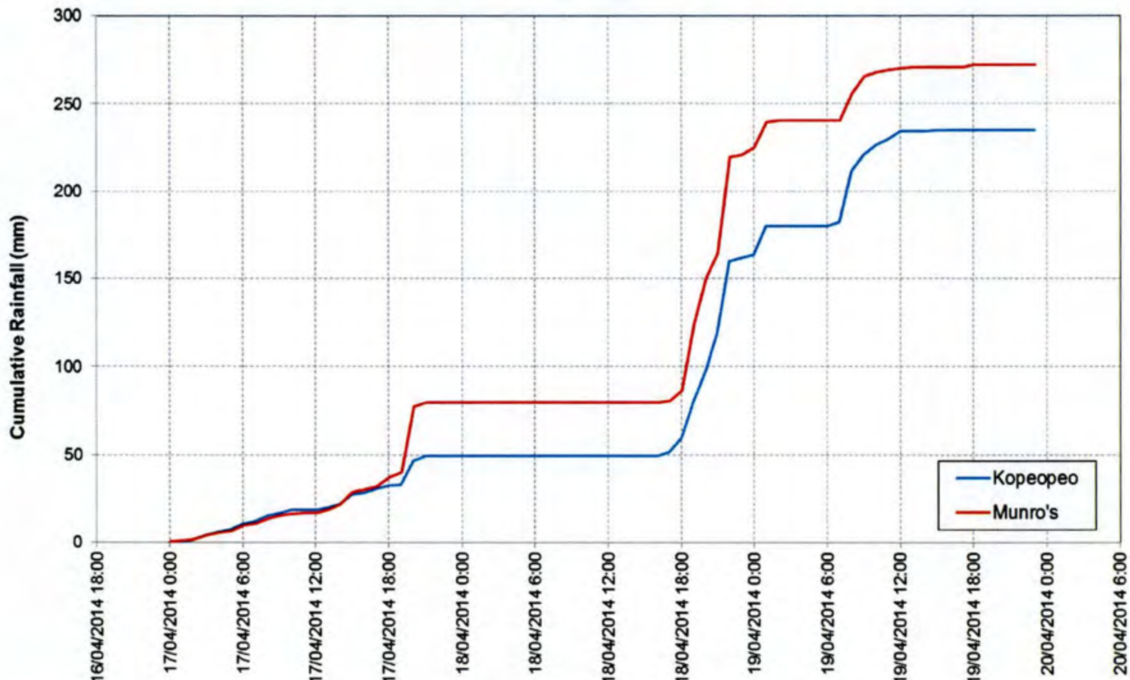

Figure 3: Whakatane at Kopeopeo and WtW at Munro's cumulative rainfall for 17 April to 20 April 2014

The severity of the 18 April 2014 event (rainfall event between 18 April 4 pm and 19 April 4 am) was assessed by comparing the maximum totals for various durations with the rainfall depths for the 50 and 100 year return period (based on HIRDS V3) for the Whakatane at Kopeopeo raingauge. Table 1 and Figure 4 show the results of this comparison.

Table 1: HIRDS V3 100 year and 50 year rainfall depths versus maxima recorded during the 18 April 2014 event at the Kopeopeo and Munro's raingauge for storm durations between 0.5 and 12 hours

Duration (hours)	Rainfall depth (mm)			
	100 year HIRDS V3	50 year HIRDS V3	18 April 2014 storm Kopeopeo	18 April 2014 storm Munro's
0.5	46	39	30	41
1	67	57	55	65
2	89	76	66	78
3	106	91	80	106
4	120	102	105	136
6	142	122	112	142
12	190	163	130	161

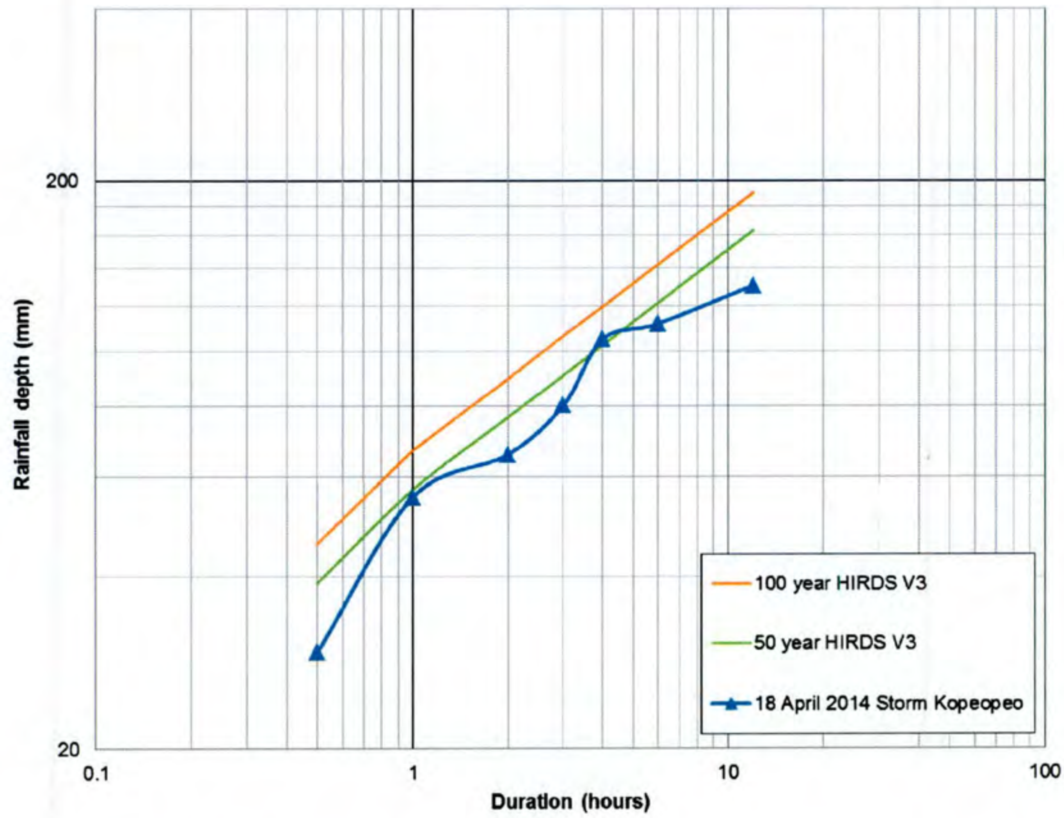

Figure 4: HIRDS V3, 18 April 2014 depth-duration curve

The maximum rainfall depth recorded during the 18 April 2014 event is around the 50 year return period for the 1 hour and 4 hour duration. For the other durations shown in Table 1 the rainfall maxima during the 18 April 2014 event are less than the 50 year return period rainfall depths.

For the purpose of completeness the maximum totals for various durations at the WtW at Munro's gauge are also shown in Table 1. As detailed in the PDP (February 2014) report these totals should not be compared with the HIRDS V3 data due to HIRDS not taking into account the steep rainfall gradients in the coastal escarpments in the Bay of Plenty (refer to p.5 of PDP February 2014 report). In other words HIRDS underestimates rainfall depths in these areas and determining the return period of a rainfall event based on a comparison between HIRDS V3 and Munro's would overestimate the return period of the event. A comparison between the two gauges indicates that the rainfall at Munro's is approximately 20 – 30 % greater than the Kopeopeo gauge which is consistent with the assumptions in PDP (2014) report where the design rainfall depths from HIRDS V3 and the recorded rainfall depths for the Kopeopeo gauge were multiplied by a factor of 1.25 to derive rainfall estimates for the upper WtW catchment.

Based on the considerations above it appears that the 18 April 2014 rainfall event (in the area around the Kopeopeo gauge) has a return period of around 50 years for durations of one and four hours and is less than the 50 year return period for other durations. Based on the previous PDP analyses (February 2014) the resulting peak flood flow of approximately 29 m^3/s in Wainui te Whara Stream at Mokorua Gorge appears to be around the 100 year return period. This is likely to be a result of the relatively saturated antecedent conditions of the catchment due to the high rainfall on 17 April (a total of around 80 mm at the Munro's gauge). It is also worth noting that a rainfall event of a particular return period does not necessarily result in a peak flood flow with the same return period.

3. Flow routing

The 18 April 2014 hydrograph was routed through the proposed dam to assess the maximum water level elevation and storage volume resulting from this event. The recorded hydrograph for the 18 April 2014 event was scaled down to the proposed dam site based on the ratio of the peak flow between the upper (proposed dam site) catchment and the recorder site as previously determined for the 100 year event (PDP February 2014 report, p.12, Table 9, i.e. 14.9/27.2 = 0.55). This hydrograph was routed through the proposed detention dam assuming both a 750 mm and 1050 mm low flow culvert. The resulting peak water level elevation and storage volumes are shown in Table 2 below. For comparative purposes the results of the design storm with a 100 year return period are also presented. The previously reported (PDP, 2014) dam height assumes a freeboard of 1 m above the spillway crest level, therefore the required dam height for the 100 year return period, no climate change design event is 9.6 m which is the maximum water level during the design event (8.6 m) plus 1 m.

Table 2: Comparison of maximum water level and storage volume for the 18 April 2014 event and the 100 year design storm

Culvert size (mm)	750		1050	
	Maximum water level (m)	Storage Volume (m^3)	Maximum water level (m)	Storage Volume (m^3)
100YR No Climate Change	8.6	83,052	7.0	45,955
18 April 2014 event	8.0	67,403	6.73	40,820

4. Conclusion and recommendation

The 18 April 2014 event provides a very useful validation of the design hydrology for the proposed dam in Wainui te Whara Stream undertaken by PDP in February 2014. Routing this event through the proposed dam indicates a maximum water level depth of approximately 8.0 m and a maximum storage volume of 67,403 m^3 which is less than the maximum water level and storage volume for the design 100 year return period (no climate change) event. Even though this event is fully contained within the proposed dam it is recommended that the hydrological model is recalibrated including the 18 April 2014 event. Recalibrating the hydrological model may change both the peak flow and shape of the design hydrograph which may result in changes to required dam heights and design flows at Valley Road.

References

Pattle Delamore Partners Ltd (2014). Wainui te Whara Catchment – Review of Hydrology. Report prepared for Whakatane District Council.

S3 Wainui Te Whara lower channel hydraulic channel capacity assessment - prepared by Opus International Consultants

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TO	Peter Askey
COPY	
FROM	Daniel McMullan and Grant Webby
DATE	16 January 2015
FILE	2-34105.75
SUBJECT	Wainui Te Whara Stream Lower Channel Investigations

1 Introduction

Wainui Te Whara Stream (Figure 1) is a small highly-modified stream in an urban environment that discharges into the Awatapu Lagoon in Whakatane. Insufficient channel capacity has historically caused significant flooding for local residents near the stream. This report details the results of an investigation into the current channel capacity and the effects of various channel modifications.

Figure 1 Typical reach of Wainui Te Whara Stream

The current investigation follows on from previous Opus investigations of the stream channel in 2008 (Labaznova, 2008) and 2010 (Belleville, 2010)). As the stream channel is crossed by a large number of bridges (both road bridges and footbridges), the current investigation used a HEC-RAS[1] model of the stream in contrast to the two previous studies which used a MIKE11[2] model. The HEC-RAS software is considered to better describe the flow behaviour through bridge structures including the effects of surcharging on bridge decks.

2 Methodology

2.1 Hydraulic Model

A HEC-RES model of the Wainui Te Whara stream was developed to assess the existing channel capacity and to assess the effects of various channel modifications on discharge capacity. The model extent included Valley Road bridge down to Hinemoa Street bridge.

The channel cross-sections and bridge levels were surveyed in August 2014. A summary of the bridge levels that were included in the hydraulic model can be seen in Table 1. All levels are measured in the Mean Sea Level (Moturiki) Datum.

Table 1 Summary of bridge levels included in hydraulic model

Bridge	Chainage (m)	Soffit Level (RL m)	Deck Level (m)
Valley Road	0	10.00	10.15
Footbridge	193	8.10	8.40
Douglas Street	556.88	6.07	6.63
Footbridge	720	5.99	6.32
Footbridge	770	5.88	6.41
Peter Snell Street	920	5.50	5.96
Footbridge	970	5.65	6.04
King Street	1100	4.86	5.25
Tuhoe Avenue	1255	4.60	5.25
Garaway Street	1400	4.64	5.19
Hinemoa Street	1729.62	3.56	4.10

Photos of Douglas Street Bridge, Peter Snell Street Bridge, King Street Bridge, Tuhoe Avenue Bridge and Hinemoa Street Bridge can be seen in Figures 2a – 2e.

Figure 2a Douglas Street Bridge looking downstream

[1] HEC-RAS is an open-source one-dimensional computational hydraulic model developed by the US Army Corps of Engineers.
[2] MIKE11 is a one-dimensional computational hydraulic model developed by the Danish Hydraulic Institute (DHI)

Figure 2b **Peter Snell Street Bridge**

Figure 2c **King Street Bridge**

Figure 2d **Tuhoe Avenue Bridge**

Figure 2e **Hinemoa Street Bridge**

2.2 Model Calibration

To calibrate the hydraulic model, Manning's n values were adjusted in the hydraulic model to ensure the modelled flood levels approximately matched the actual flood levels from a moderate flood event that occurred on the 9th of September 2014. The flood levels were determined by surveying the debris marks left by the flood waters. The debris levels are detailed in Table 2. It must be noted that the accuracy of measuring the peak flood levels from the debris is estimated to have been in the order of ±50 mm. This limited the ability to accurately calibrate the model and therefore careful judgement was required to be exercised.

Table 2 **Summary of debris levels from September 2014 flood**

Chainage (m)	Debris Level	Chainage (m)	Debris Level
32.5	7.30	922.5	3.76
114.5	6.53	976.1	3.74
169.5	6.30	991	3.64
237.5	5.88	1061	3.47
278	5.90	1093	3.40
340	5.63	1114	3.31
423.5	5.39	1169	3.18
483	5.18	1251	3.13
555	4.87	1260	3.06
574	4.69	1266	3.14
628.3	4.57	1333.5	2.82
671	4.50	1396	2.74
718.3	4.33	1413.5	2.51
726.1	4.46	1448	2.65
745	4.28	1523	2.46
773	4.19	1585	2.31
784.3	4.27	1662	2.04
858.3	4.01	1689.5	1.85
909	3.90	1724	1.26

The September 2014 flood event had an approximate peak flow of 4.7 m^3/s based on the current gauging station stage/discharge rating curve. The stream has been gauged a reasonable number of times with flows up to this magnitude. This estimate is therefore considered to be reasonably reliable (the gauging station is located in a rocky gorge and the rating curve is fairly stably).

It is not known how much the Douglas Street pumps discharged to the stream during the 9th September 2014 flood event[3]. It was conservative to ignore this small additional contribution to the stream channel for the model calibration. In any case, the peak discharge to the stream from urban runoff may well have preceded the flood peak in the stream due to the much shorter time of concentration of the contributory urban sub-catchments.

It is expected that for flows much larger than the September 2014 flood peak, that there will be significant movement of gravel on the channel bed which will increase the hydraulic roughness of the channel invert (the channel sides are mostly grass-lined). To allow for this effect within the model, the base Manning's n values obtained from calibration were increased by 0.005 except under the Douglas Street Bridge where the n value was already high. The Manning's n values are summarised in Table 3.

Table 3 Summary of Manning's n values used in model calibration

Location description	Chainage (m)	Manning's n values from initial calibration	Manning's n adjusted for effects of bed load movement (base calibration for high flows)	Manning's n values used in sensitivity test
Downstream of Valley Rd	0 - 343	0.020	0.025	0.030
	343 - 545	0.027	0.032	0.037
Douglas St	545 - 581	0.050	0.050*	0.050*
Douglas St to Tuhoe Ave	581 - 1262	0.020	0.025	0.030
	1262 - 1635	0.025	0.030	0.035
Upstream of Hinemoa St	1635 - 1729	0.030	0.035	0.040

* This Manning's n value was not increased by 0.005 as it was already a high value

Despite the adjustment of the calibrated Manning's n channel roughness values along the stream to account for the effects of gravel bed movement under extreme flood conditions, there still remains some uncertainty over the actual Manning's n values under such conditions. For this reason, a sensitivity test was carried out for one flow case (case C in Section 2.3) in which the Manning's n values were increased by a further 0.005 everywhere except past the Douglas Street Bridge.

Previous studies conducted by Opus in 2008 and 2010 assumed a Manning's n value of 0.035 along the entire channel based on very limited calibration information. The Wainui Te Whara has a very uniform channel cross-section along most reaches which explains the lower

[3] These pumps each have a peak discharge capacity of about 0.45 m^3/s.

Manning's n values obtained from the model calibration against the 9th September 2014 flood.

2.3 Channel Modifications

The channel was modified along much of its length below the Valley Road Bridge by excavating where possible the left and right bank of the stream to create terraces within the channel. These terraces are on average 0.5 m above the stream bed and range from 1.5 m to 3 m in width. A typical modified channel cross-section can be seen in Figure 3.

The changes made to the cross-sections are based upon sketches provided by Glenn Cooper in his emails dated 2nd December 2014 and 6th January 2015.

The modifications covered by the 6th January 2015 email include widening two cross-sections at 244 m and 256 m. These changes were previously thought unnecessary due to the available freeboard in the existing channel, however analysis based on the original channel modifications have shown that these changes are needed to contain the floodwaters within the channel.

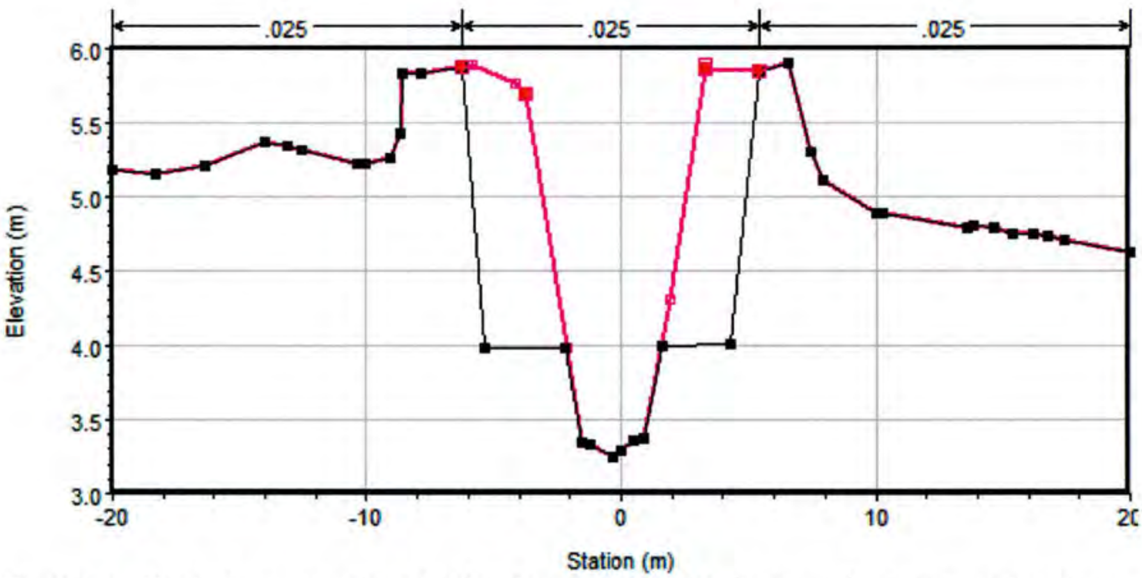

Figure 3 Typical cross-section that has been modified to increase the cross-sectional area of the stream

2.4 Model Runs

Eight key scenarios were analysed to assess the bankfull channel capacity, the impact of a varying water level at Awatapu Lagoon, the impact of removing Douglas Street bridge, the sensitivity to Manning's n channel roughness, and the required bank level to contain 35 m^3/s. These are summarised in Table 4.

The tailwater level assumption relates to a constant water level at the most downstream cross-section in the hydraulic model. This cross-section is at the point where the Wainui Te Whara Stream discharges into the Awatapu Lagoon. At a tailwater level of RL 2.7m, pumping of floodwaters from the lagoon to the Whakatane River commences to supplement the natural drainage outflow from the lagoon under gravity. A tailwater level of RL 3.75m corresponds to the peak flood level in the lagoon from a concurrent flood in the Whakatane River.

The Base Case and Cases A through to E were also re-analysed to assess the increase in the channel's hydraulic performance as a result of the channel modifications described in section 2.3.

Table 4 Summary of scenarios

Case	Flow (m^3/s)	Tailwater Level at Awatapu Lagoon (RL m)	Bridges	Inflow from Douglas St Pumps (m^3/s)	Manning's n Values
base	20	2.7	Included	0.0	Base
A	25	2.7	Included	0.0	Base
B	25	3.75	Included	0.0	Base
C	25	2.7	Included	0.0	Sensitivity test
D	25	2.7	Douglas St Bridge removed	0.0	Base
E	25	2.7	Included	0.9	Base
F	35	2.7	All bridges removed	0.0	Base
G	35	3.75	All bridges removed	0.0	Base

3 Results – Existing Channel

3.1 Bankfull channel capacity – existing situation (Base Case)

Wainui Te Whara Stream is at full channel capacity for a flow of approximately 20 m^3/s (Figure 4). At about 125 m downstream of Valley Road Bridge, it is expected that the water will just begin to break out of the channel on the left bank. Due to the steepness of the channel at this location, the water level is relatively insensitive to the assumed Manning's n value.

Figure 4 also shows that the first bridge to limit the flow capacity of the stream channel is the Douglas Street Bridge. Under a flow of 20 m^3/s, the water level is also just beginning to reach the underside of the King Street Bridge. This flow marks the onset of surcharging at these bridges.

3.2 Impact of a flood event with a flow of 25 m³/s (Case A)

Figure 5 shows that at a flow of 25 m^3/s, flood levels have:

- become fully surcharged to about deck level on the Douglas Street Bridge;
- just started to overtop the deck of the King Street Bridge; and
- just started to surcharge on the soffit of the Tuhoe Avenue Bridge.

These effects will cause floodwaters to start breaking out of the stream channel:

- along the left bank at about chainage 120 m downstream of the Valley Road Bridge;
- along the right bank upstream of the Douglas Street Bridge;
- along the left bank at about chainage 800 m between the Douglas Street and Peter Snell Street Bridges;
- along both banks between chainages 1000 m and 1100 m upstream of the King Street Bridge; and
- along the right bank at about chainage 1440 m below the Garaway Street Bridge.

3.3 Tailwater level sensitivity at a flow of 25 m³/s (Case B)

Figure 5 also shows the backwater effect of a higher tailwater level in the Awatapu Lagoon for a stream flow of 25 m^3/s.

For a tailwater level of RL 3.75 m, floodwaters back up at the lower end of the stream channel over a distance of about 500 m compared to case B. In addition to the effects noted above for case B, flood levels are also surcharged on the upstream side of the Hinemoa Street Bridge.

3.4 Manning's n sensitivity at a flow of 25 m³/s (Case C)

Figure 6 shows that by increasing the base Manning's n channel roughness valuesby a further 0.005, flood levels will increase by up to 300 mm at the following locations:

- Douglas Street Bridge
- Peter Snell Street Bridge
- King Street Bridge
- Tuhoe Avenue Bridge

This will cause floodwaters to overtop the Douglas and King Street Bridges.

3.5 Effect of Douglas Street Bridge removed (case D)

Figure 7 shows that, by removing Douglas Street Bridge (Figure 2a), water levels upstream of the bridge are reduced by up to 200 mm over a distance of at least 200 m. This reduction in level is sufficient to prevent floodwaters from breaking out of the stream channel along the left bank upstream of the site of the Douglas Street Bridge.

3.6 Effect of additional inflow from Douglas St pumps (Case E)

Figure 8 shows that an additional inflow of 0.9 m^3/s from the Douglas Street pumps to a flow of 25 m^3/s from the upstream catchment has quite a dramatic effect on the flood level profile along the stream. The profile becomes stepped with surcharging at the Douglas St Bridge, the footbridges at chainages 720 m and 770 m, the Peter Snell Street Bridge, the King Street Bridge and the Tuhoe Avenue Bridge. Other channel constrictions at about chainages 690 m, 1060 m and 1630 m, and upstream of the Garaway Street Bridge also induce step changes in the flood level profile. In summary, Case E shows that if the flow increases past 25 m^3/s, then the water will begin to back up behind most of the bridges in the channel and cause the flood level profile to drastically increase.

3.7 Impact of a flood event with a flow of 35 m^3/s (cases F and G)

Figure 9 shows the expected water levels in the existing channel for a flow of 35 m^3/s. Regardless of the tailwater level of either RL 2.7 m or RL 3.75 m, the water still spills out at multiple locations on both the left and right sides of the channel.

The average height that the channel banks would need to be raised to contain the floodwaters is approximately 300 mm. The maximum height is approximately 650 mm.

It must be noted that these results are based on a scenario where all the bridges downstream of Valley Rd have been removed. The inclusion of any of these bridges would cause the water levels to increase behind the bridges.

4 Results – Modified Channel

4.1 Bank-full channel capacity – modified channel (Base Case)

The existing Wainui Te Whara Stream is at bank-full capacity for a flow of approximately 20 m^3/s. After the channel has been modified, the water levels in the channel are up to 0.8 m lower (Figure 10). The average reduction in water level is approximately 0.35 m.

The water levels also no longer reach the soffit level of Douglas Street Bridge or King St Bridge.

4.2 Impact of a flood event with a flow of 25 m^3/s (Case A)

Figure 11 shows clearly shows the effects of widening the stream channel for a flow of 25 m^3/s. At this flow rate the waters levels reach the soffit level of King Street Bridge and are approximately 100 mm beneath the soffit level of Douglas Street Bridge. The average reduction in water level is approximately 0.40 m.

Figure 11 also shows the significant improvement in the hydraulic performance around a chainage of 60-250 m as a result of widening the channel cross-sections at 244 m and 256 m in addition to the original modifications. The water levels at these locations have dropped by approximately 0.40 m.

4.3 Tailwater level sensitivity at a flow of 25 m^3/s (Case B)

Figure 12 shows that if the tailwater level at Awatapu Lagoon is increased to RL 3.75 m from RL 2.7 m, then the water is likely to spill out of the channel approximately 50 m downstream of Garaway Street Bridge.

4.4 Manning's n sensitivity at a flow of 25 m^3/s (Case C)

Figure 13 shows that by increasing the base Manning's n channel roughness values by 0.005, flood levels will increase by up to 0.3 m. This is the same result for the existing channel.

There is some uncertainty in the Manning's n channel roughness values for a modified stream channel. It is possible that the channel roughness could be lower than the calibration values for the existing base case due to the reshaping and smoothing of the channel. The change in water levels in the sensitivity test shown in Figure 13 provides some indication of how the water levels could drop if the Manning's n values of the channel were to decrease. However we would not expect the drop in water levels would be as much as 0.3 m as the reduction in base Manning's n channel roughness values is likely to be lower than 0.005.

4.5 Effect of removing Douglas Street Bridge (Case D)

As the water levels no longer reach the soffit level of Douglas Street Bridge for a flow of 25 m^3/s, there is no improvement in channel performance by removing Douglas Street Bridge.

4.6 Effect of additional inflow from Douglas Street pumps (Case E)

Figure 14 shows that an additional inflow of 0.9 m^3/s from Douglas Street pumps to a flow of 25 m^3/s from the upstream catchment has minimal impact on the water levels in the channel. The average increase in water level is 0.04 m and does not cause the water to spill out of the channel or reach the soffit levels of any bridges.

5 Conclusions

5.1 Existing Channel

The bankfull capacity of the existing stream channel is estimated to be about 20 m^3/s with floodwaters just starting to break out of the channel along the left bank about 125 m downstream of the Valley Road Bridge.

The absolute limit on channel capacity is estimated to be between 20 and 25 m^3/s. Any further increase in flow or increase in channel roughness causes the peak flood level profile to surcharge on most of the bridges and cause large increases in flood levels as concluded below.

At a stream flow of 25 m^3/s, flood flows become fully surcharged against the Douglas Street Bridge, start to overtop the King Street Bridge and just start to surcharge on the soffit of the Tuhoe Avenue Bridge. Flood breakout also occurs at a number of locations along both banks of the stream channel.

There is some uncertainty regarding the accuracy of the base Manning's n channel roughness values. A sensitivity test shows that increased Manning's n channel roughness values cause floodwaters to spill out of channel in more places and the Douglas and King Street Bridges to be overtopped.

An additional of 0.9 m^3/s to the stream channel with an upstream catchment inflow of 25 m^3/s has a dramatic effect on the flood level profile along the stream channel with surcharging against bridges and stream channel constrictions producing distinct steps in the flood level profile.

The backwater effect of a higher tailwater level in the Awatapu Lagoon extends about 500 m upstream from the outlet of the stream channel into the lagoon.

Removal of the Douglas Street Bridge reduces flood levels by up to 200 mm over a distance of at least 200 m upstream of the bridge site.

For the channel to contain a flow of 35 m^3/s with all the bridges removed, the stopbank levels would need to be increased by up to 0.65 m.

5.2 Modified Channel

The analysis into increasing the cross-sectional area of Wainui Te Whara Stream has shown that water levels are reduced by up to 0.8 m for flows of both 20 m^3/s and 25 m^3/s. The average reduction in water level is approximately 0.35 m and 0.40 m for each flow respectively.

The additional channel modifications around chainages ~200-250 m have lowered the water levels between chainages 60 m and 250 m by approximately 0.40 m.

The water no longer reaches the soffit level of Douglas Street Bridge. As a result, there is no need to remove Douglas Street Bridge to achieve greater hydraulic performance in the channel.

Additional inflow of 0.9 m^3/s from the Douglas Street pumps has minimal impact on the stream water levels.

The back water effect of a higher tailwater level in the Awatapu Lagoon extends about 600 m upstream from the outlet of the stream channel into the lagoon.

This investigation does not consider the geotechnical stability of the cut slopes resulting from the formation of terraces along the stream channel. We recommend that this aspect is investigated further, particularly the effects of rapid draw down during the falling phase of a flood.

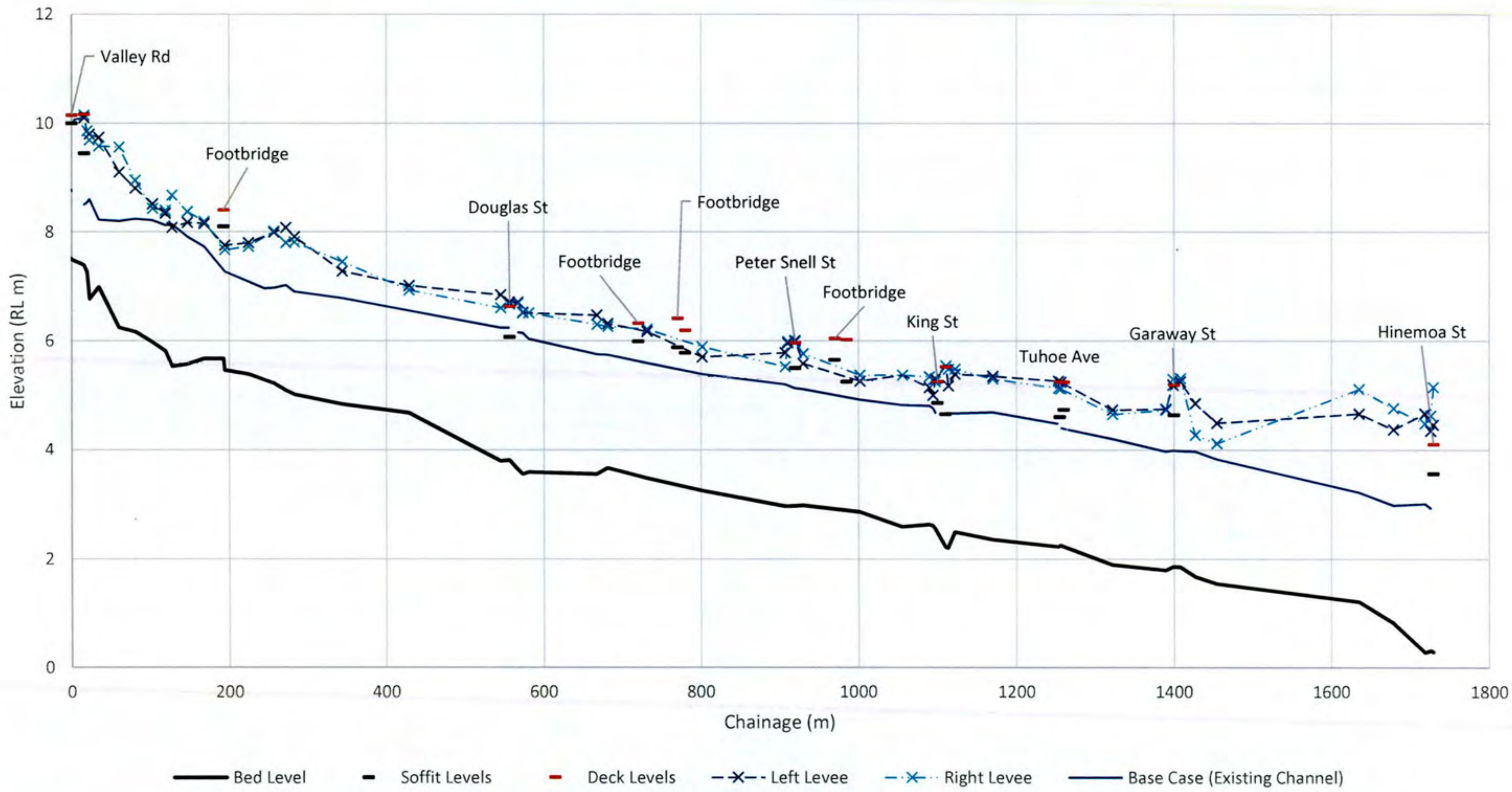

Figure 4 **Profile of the existing Wainui Te Whara Stream at full channel capacity during a flow of 20 m³/s (Base Case)**

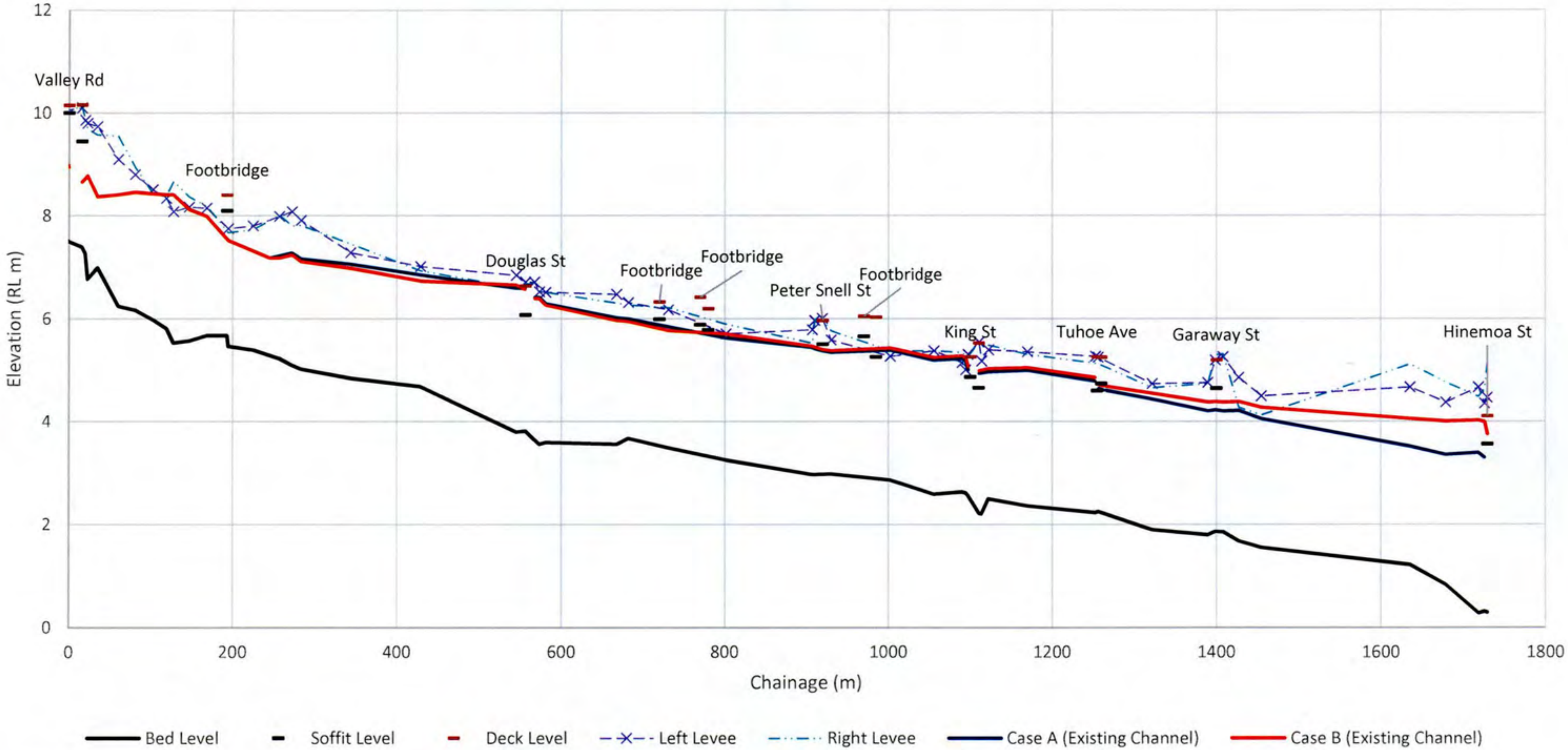

Figure 5 **Profile of the existing Wainui Te Whara Stream showing the effect of a varying downstream water level at Awatapu Lagoon for a flow of 25 m³/s (Cases A and B)**

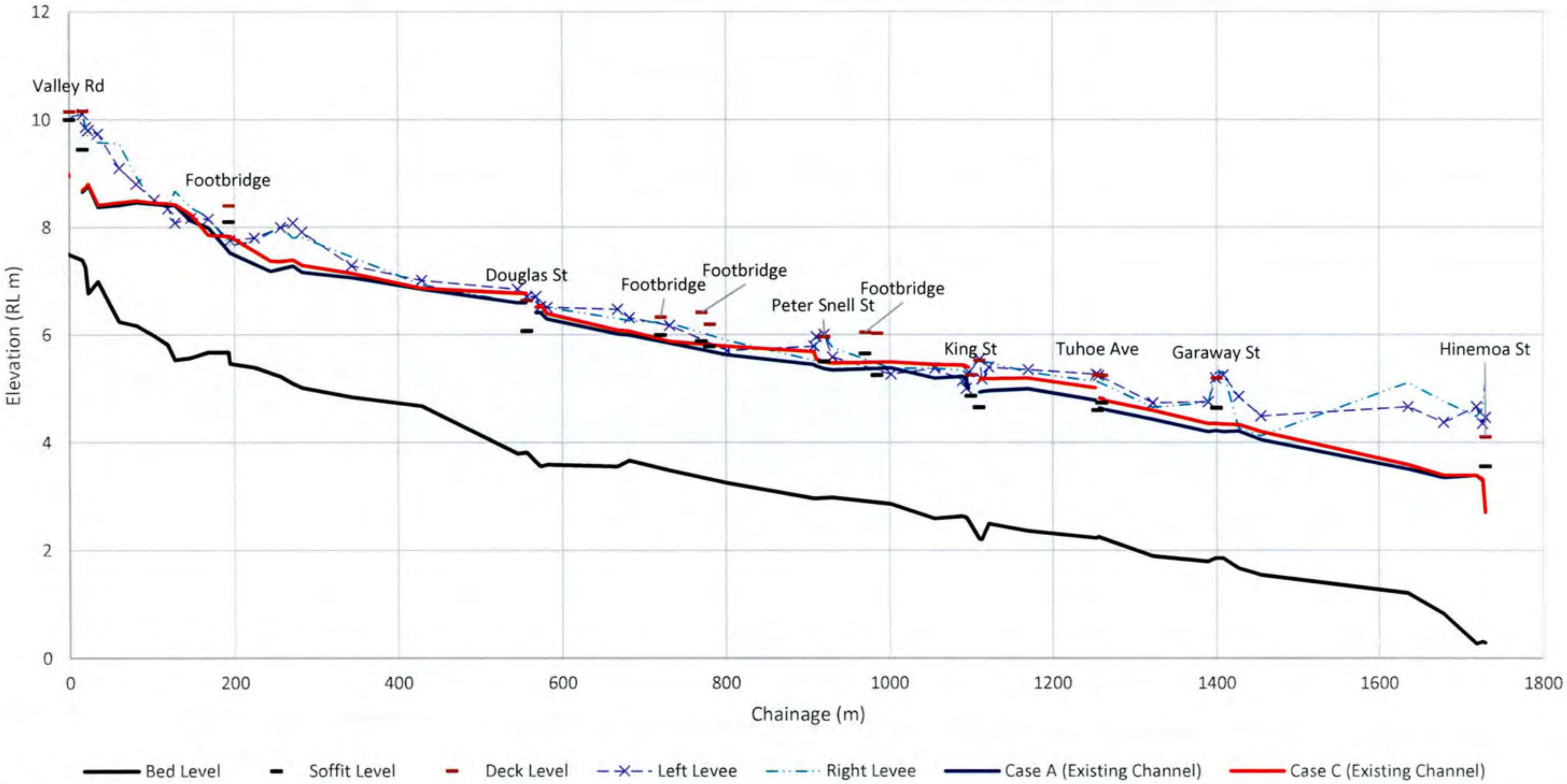

Figure 6 **Profile of the existing Wainui Te Whara Stream showing the effect of increasing the base Manning's n channel roughness values by 0.005 for a flow of 25 m^3/s (Cases A and C)**

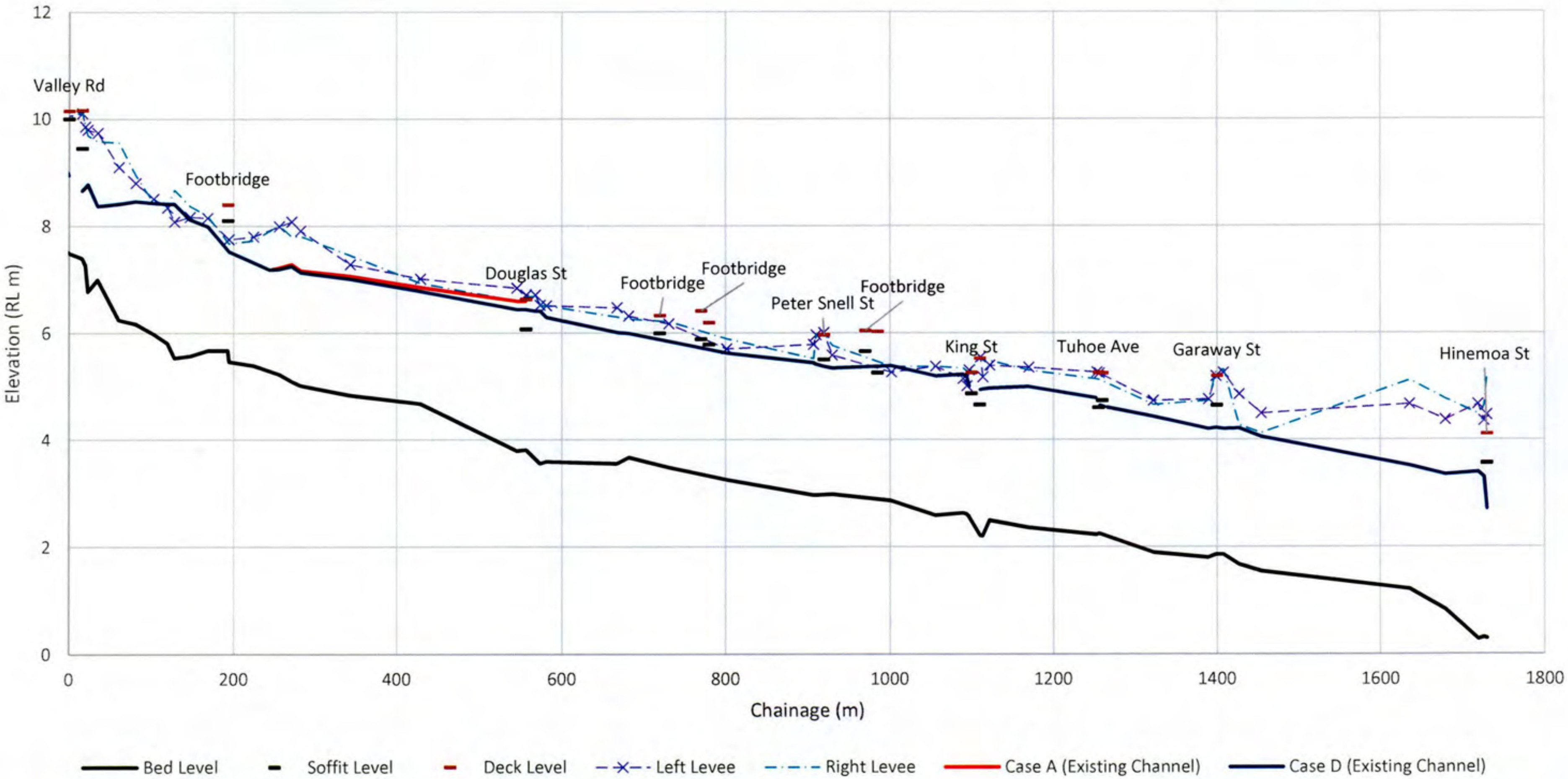

Figure 7 **Profile of the existing Wainui Te Whara Stream showing the effect of removing Douglas Street bridge for a flow of 25 m³/s (Cases A and D)**

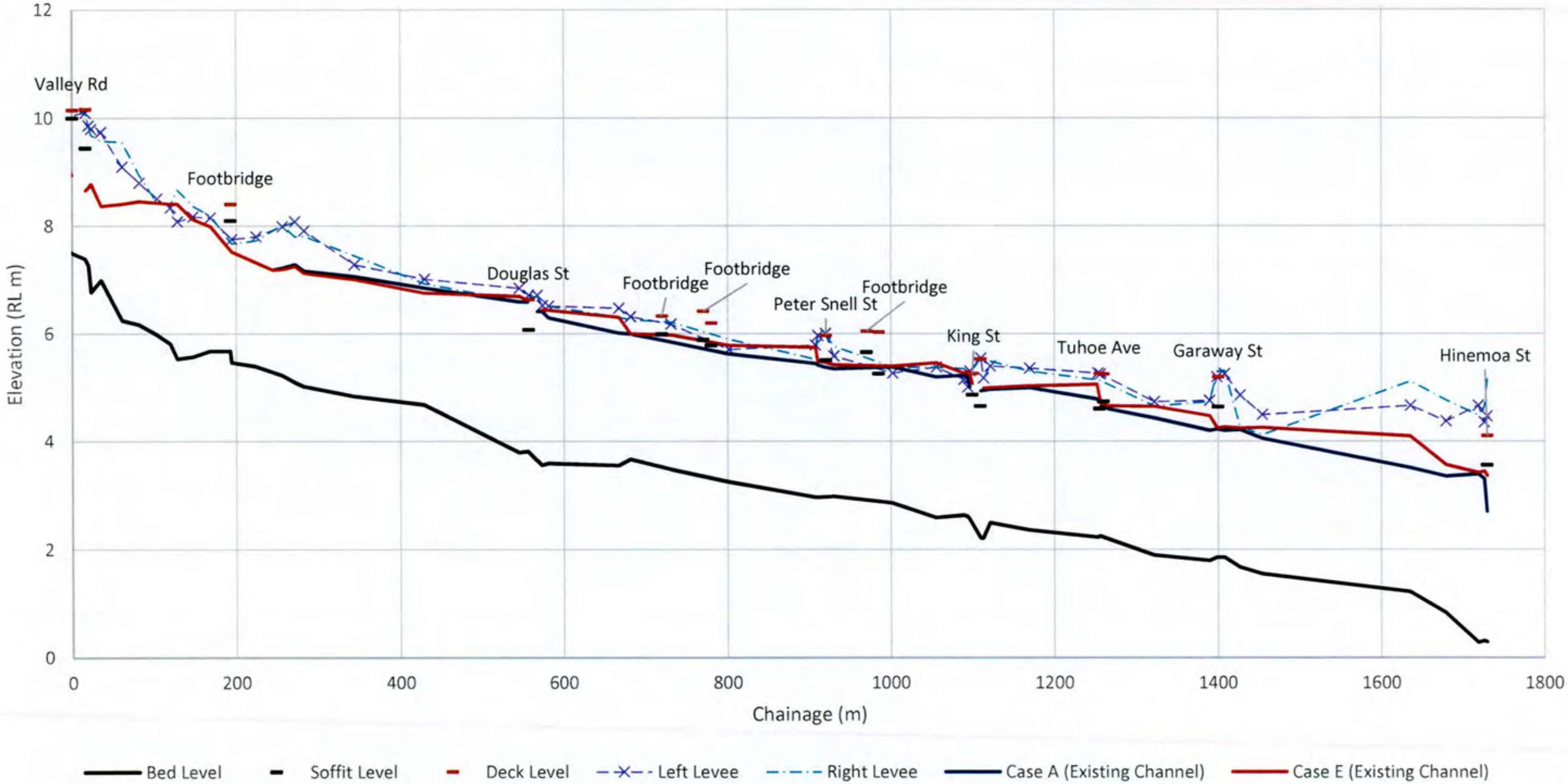

Figure 8 **Profile of the existing Wainui Te Whara Stream showing the effect of including 0.9 m^3/s of inflow at Douglas Street Bridge in addition to the 25 m^3/s from the upstream catchment (Cases A and E)**

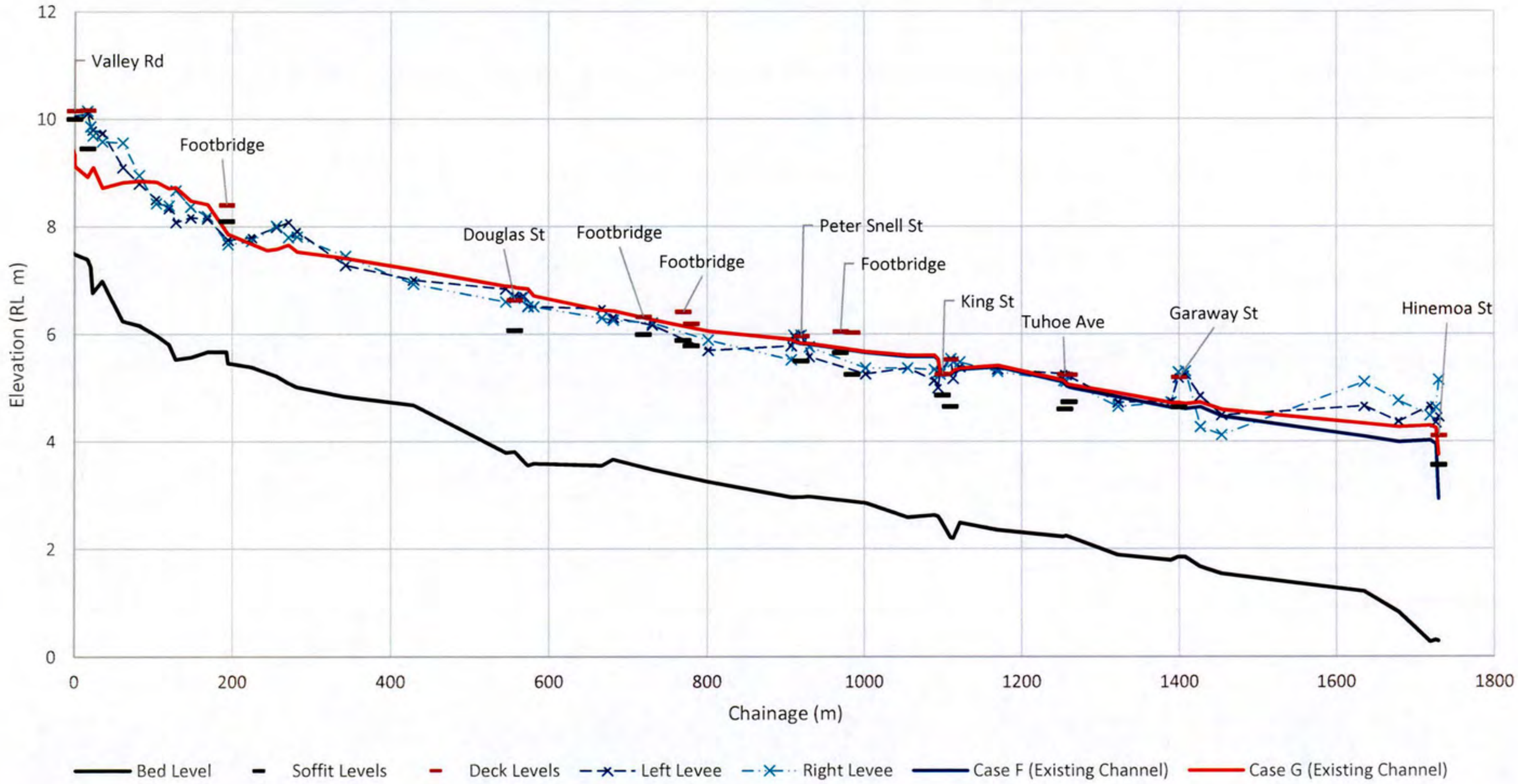

Figure 9 **Profile of the existing Wainui Te Whara Stream with all the bridges removed showing the effect of a varying downstream water level at Awatapu Lagoon for a flow of 35 m³/s (Cases F and G)**

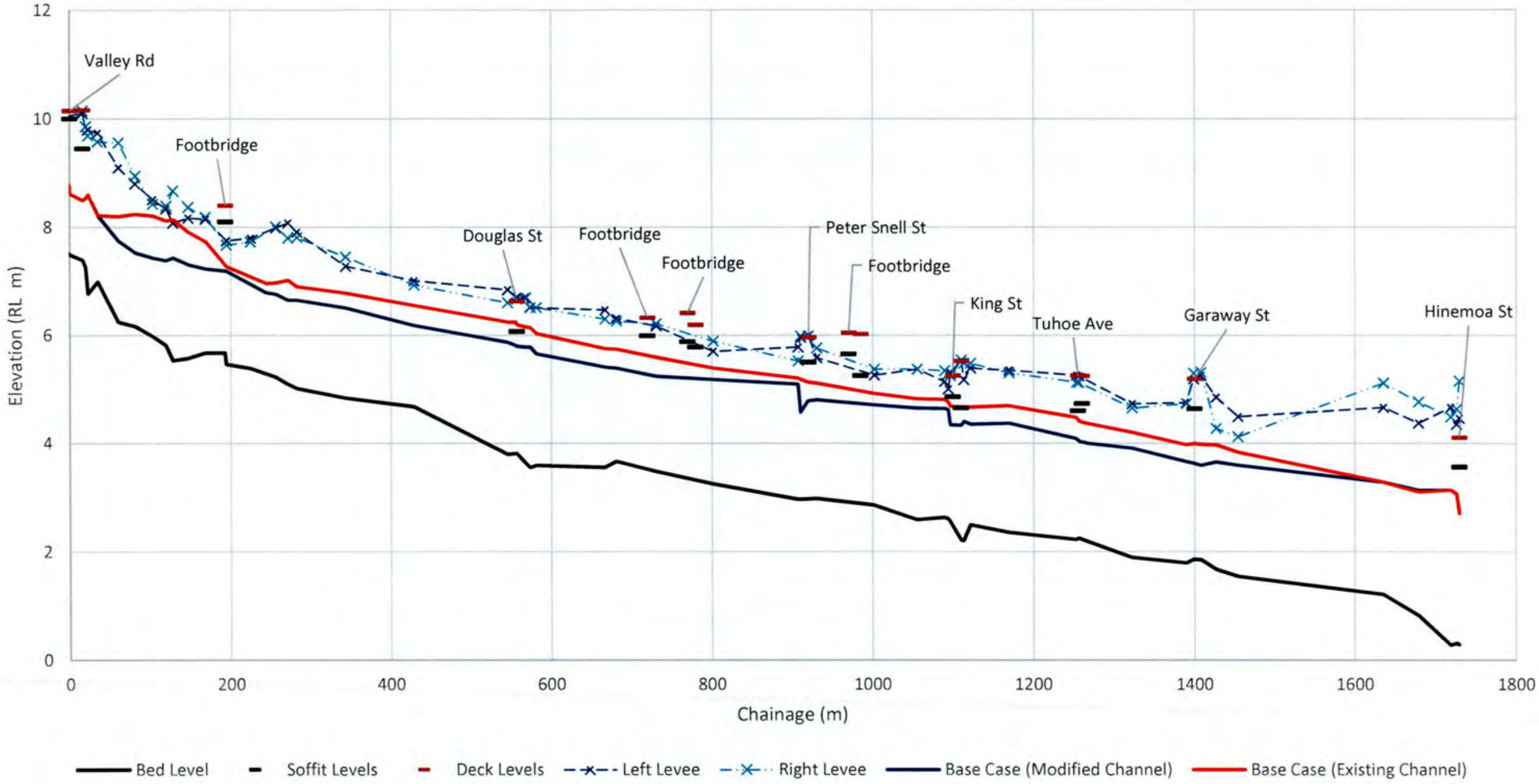

Figure 10 **Profile of the modified Wainui Te Whara Stream at full channel capacity during a flow of 20 m³/s (Base Case)**

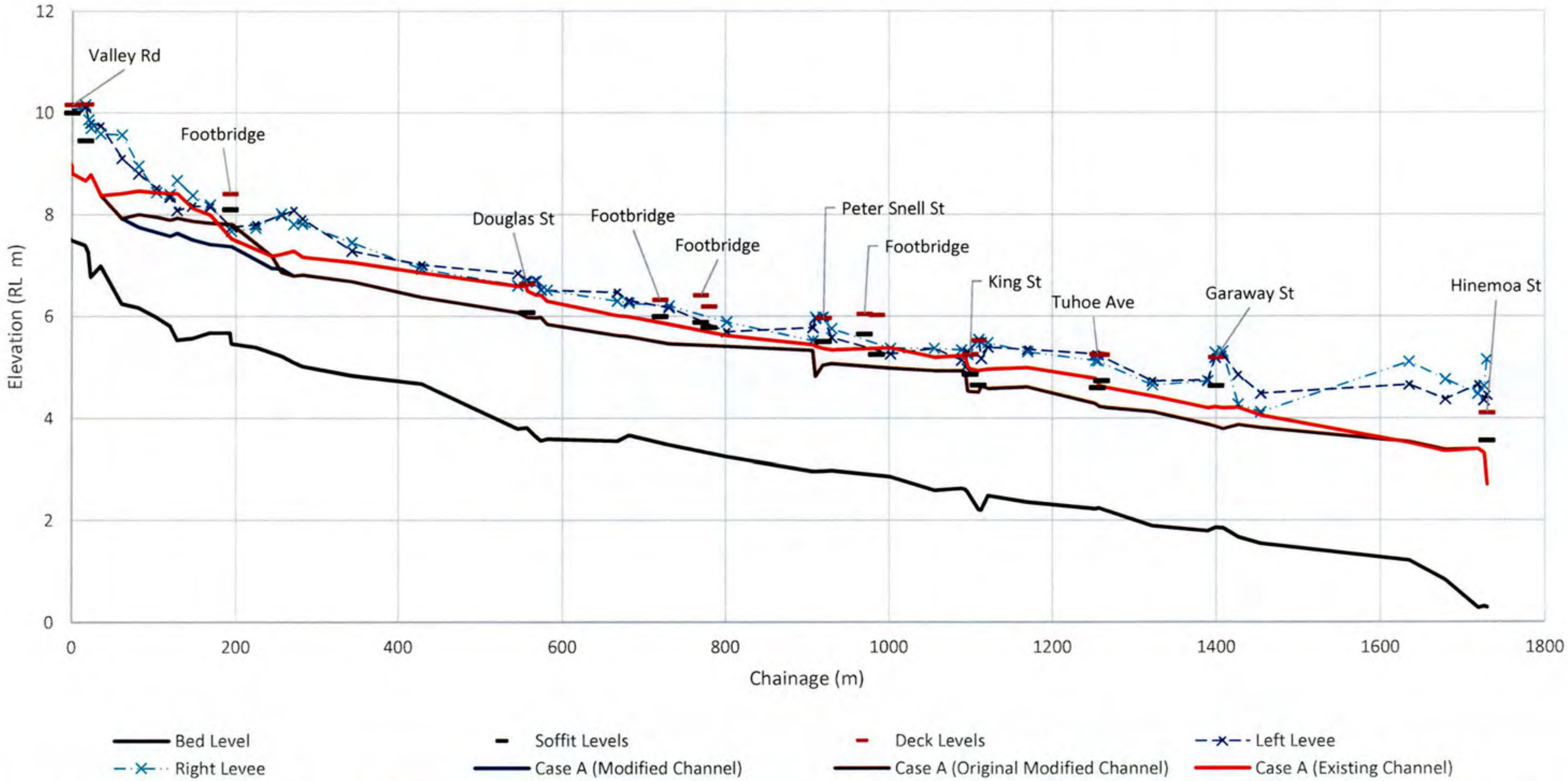

Figure 11 **Profile of the modified Wainui Te Whara Stream showing the effect of modifying the stream for a flow of 25 m³/s (Case A)**

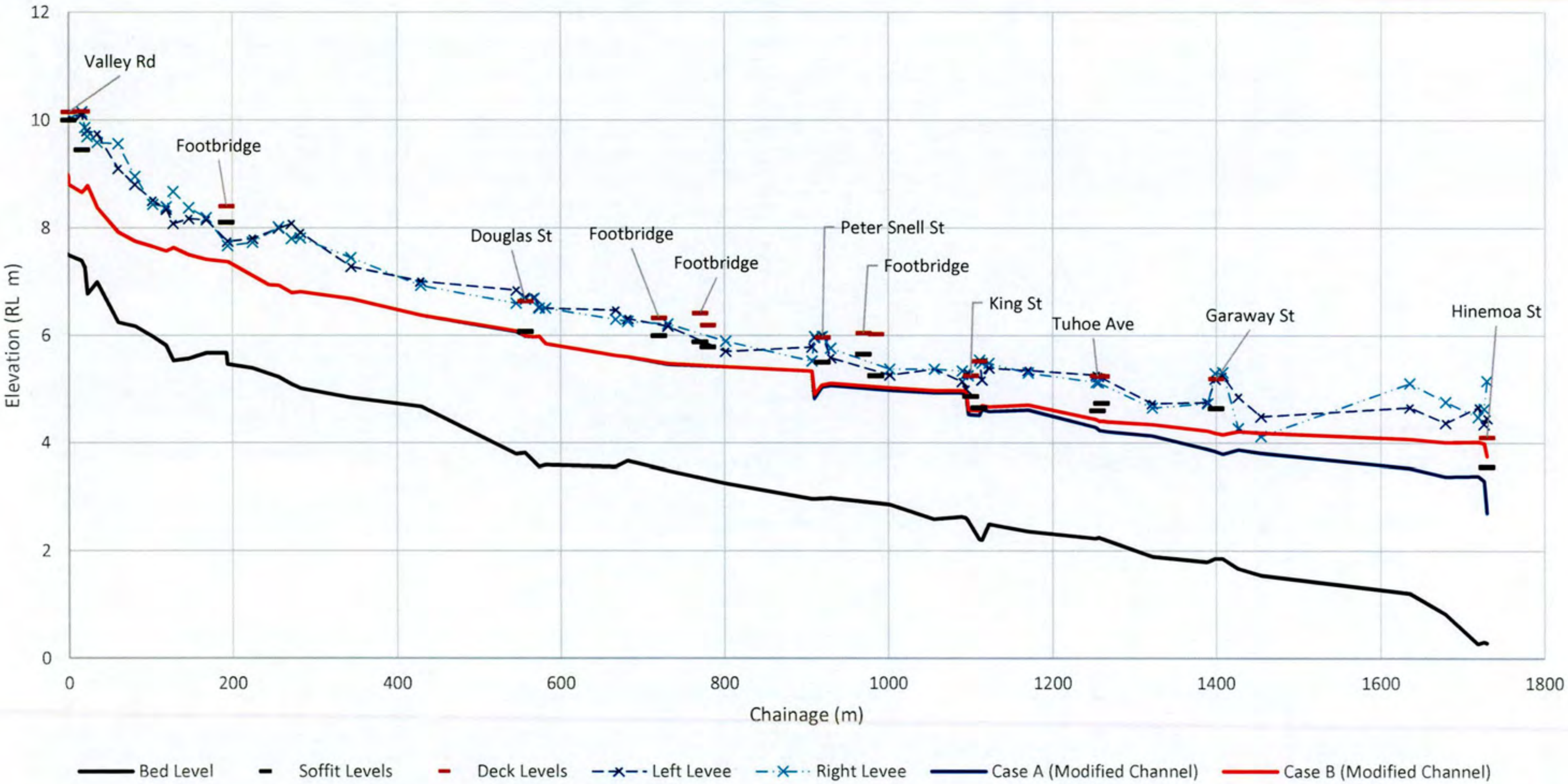

Figure 12 **Profile of the modified Wainui Te Whara Stream showing the effect of a varying downstream water level at Awatapu Lagoon for a flow of 25 m³/s (Cases A and B)**

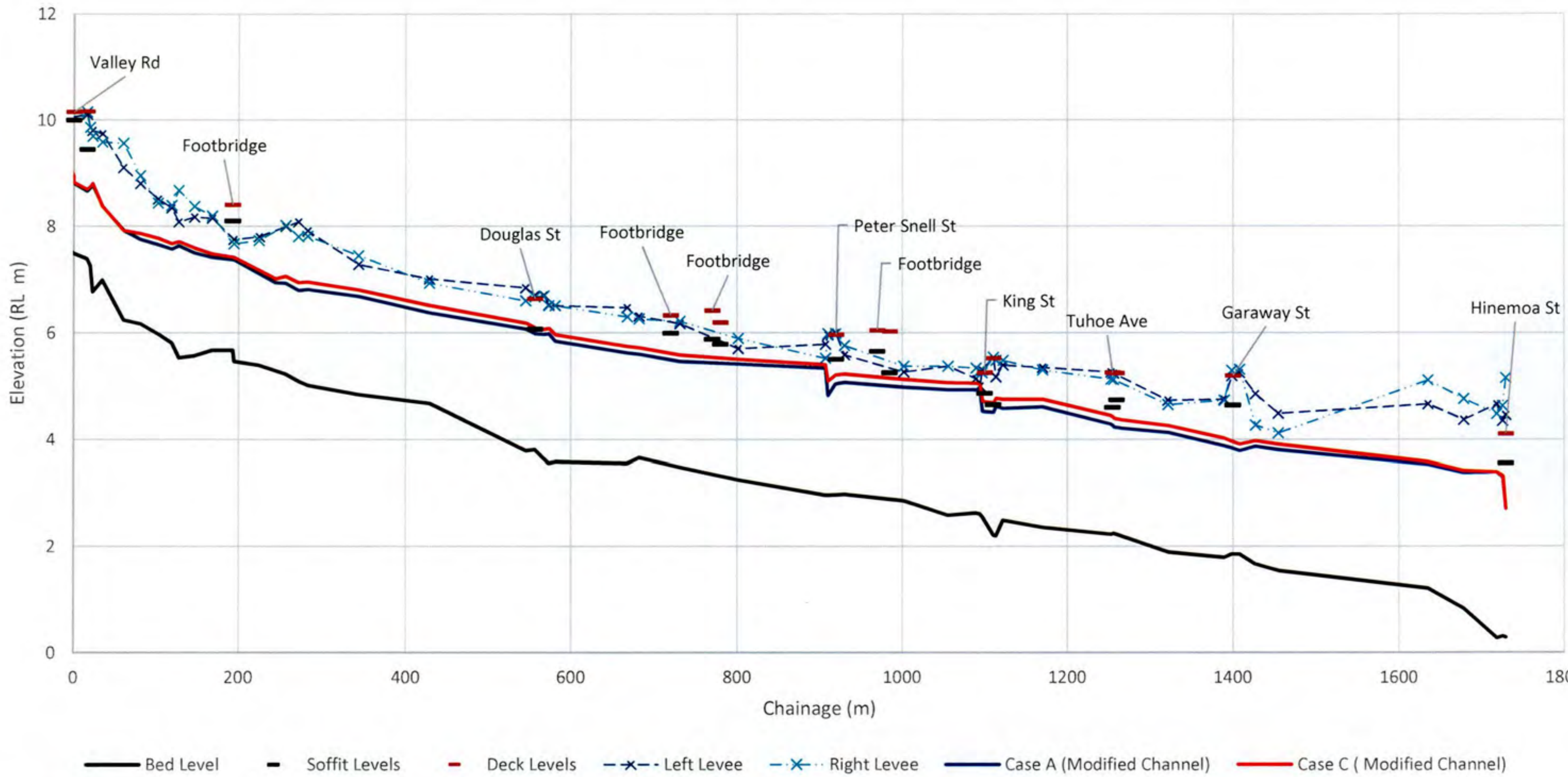

Figure 13 **Profile of the modified Wainui Te Whara Stream showing the effect of increasing the base Manning's n channel roughness values by 0.005 for a flow of 25 m³/s (Cases A and C)**

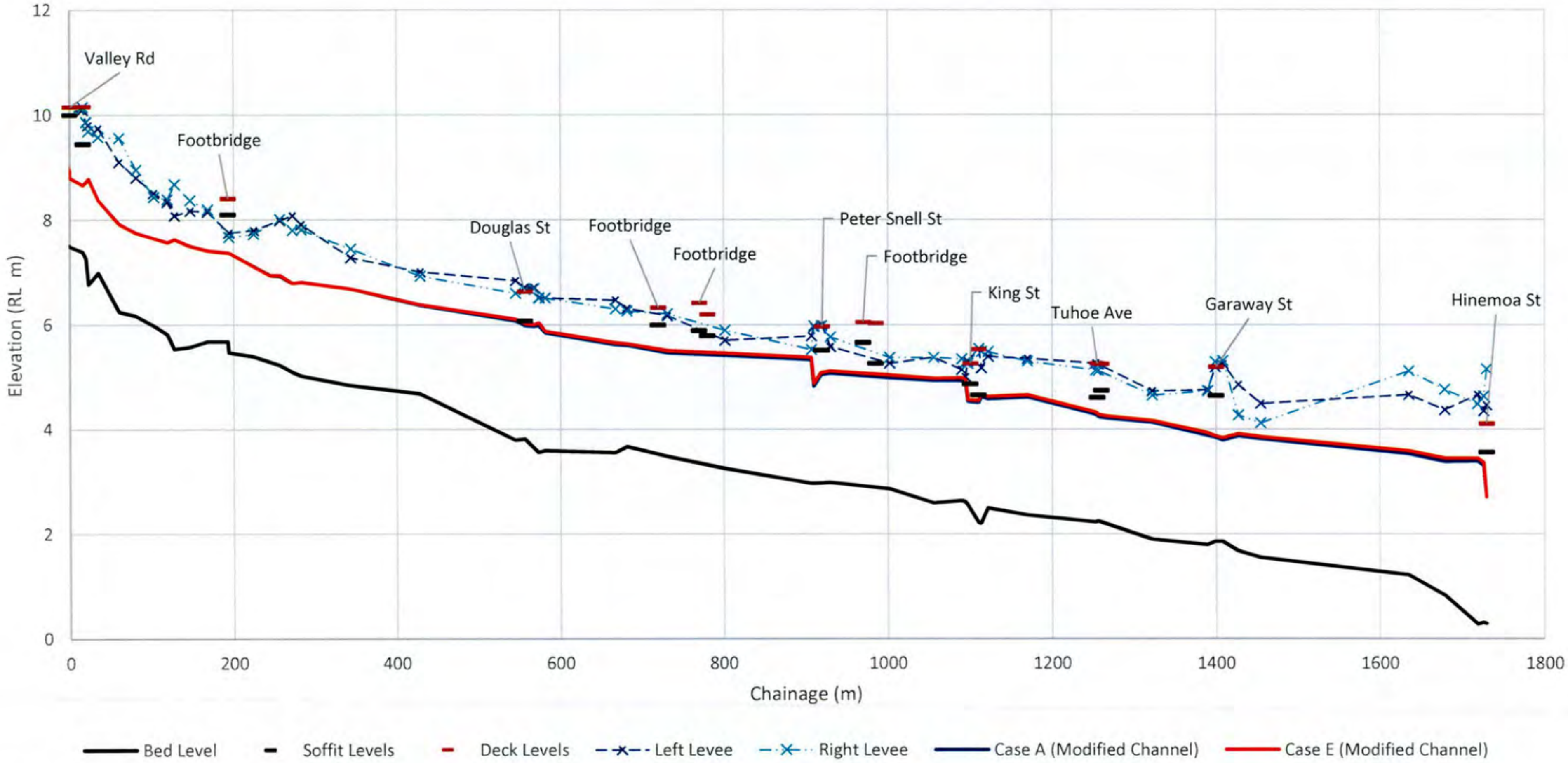

Figure 14 **Profile of the modified Wainui Te Whara Stream showing the effect of including 0.9 m³/s of inflow at Douglas Street Bridge in addition to the 25 m³/s from the upstream catchment (Cases A and E)**

6 References

Belleville, R., Redeker, M., Morrow, F., McConchie, J. (2008) "*Model Summary for Wainui Te Whara Stream*". Internal Memo prepared by Opus International Consultants Ltd. Reference 288091.56, February 2010.

Labaznova, G. (2010) "*Wainui Te Whara – Flood Modelling Assessment*". Internal Memo prepared by Opus International Consultants Ltd. Reference 288031.59. June 2008.

S3A Peer review of hydraulic model – undertaken by Phil Wallace at DHI

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Ref:	Init:	Date:
44800819	plw	17 September 2015

Dear Daniel

Wainui Te Whara Stream – Review of HEC-RAS Model

1. Introduction

Opus has refined and used a HEC-RAS model of the Wainui Te Whara Stream in Whakatane to assess channel improvement options to reduce the flood hazard posed by the stream to the urban area. Opus requested that DHI undertake an independent peer review of the modelling, as outlined in the brief dated 10 July 2015 (memorandum from Peter Askey to Phil Wallace).

The review is based on the following information sources:

- A memorandum from Daniel McMullan and Grant Webby to Peter Askey dated 16 January 2015. This describes the modelling process, model assumptions and key results.
- "Wainui Te Whara – Concept Design Report" prepared by Opus, dated 6 May 2015. This includes a brief discussion on the modelling, including updates to the above.
- Discussions between Daniel McMullan and Philip Wallace on 16 July 2015
- Model files and spreadsheets provided by email on 16 July 2015.

Initial comments from the review were emailed to Opus on 6 August 2015. Subsequent emails (14, 19 & 20 August) between us clarified some of the points. This letter finalises my comments.

2. Review comments

My comments address the specific questions that we were asked to consider.

- (i) Modelling methodology used

  HEC-RAS modelling is an appropriate method to design and test open channel improvements such as for the Wainui Te Whara. It appears that a very detailed cross-section set was available. Inclusion of the various bridges over the stream is appropriate, as these might be expected to be significant influences on channel conveyance.

  Opus carried out a calibration of the model to give confidence in the model, followed by an interpretation of the calibration parameters and results. That interpretation indicated good practice.

- (ii) Sensitivity of results to modelling parameters

  As the calibration flows (4.7m3/s, estimated) were much less than the design flow (32m3/s), it is especially important to test the sensitivity of model results to various parameters.

  I note that the Mannings n values have been increased by 0.005 over the calibrated values, to allow for effects such as bed gravel movement at higher flows.

  Some sensitivity tests were carried out and briefly reported in the case of 25 m3/s flows, for example sensitivity to further 0.005 increase in n, sensitivity to downstream water level in Awatapu Lagoon, and sensitivity to Douglas St pump inflows.

  However, these were not tested for the 32m3/s case – I would expect that to be done and results presented, and conclusions/recommendations made. Your response (14 August email) indicated that while it would have been ideal to do this at the concept design stage, it could be conducted in the detail design stage. That seems reasonable.

  A further sensitivity test I suggest is on possible debris accumulation on the bridges. You mentioned that the debris trap at the bottom of the gorge should deal to that, but there is also the possibility of urban debris causing problems (albeit the length of channel between the gorge and the various bridges, i.e. the potential "catchment" for debris, is short). If any debris does catch on the soffit, then the upstream freeboard could be compromised. (See also my comment under (iv) below.) A good reference is the last Australian& Rainfall and Runoff Guidelines dealing with this issue. http://www.arr.org.au/wp-content/uploads/Blockage_guidelines_February-2015.pdf

- (iii) Steady Flow Assumption

  The assumption of steady flow, rather than unsteady flow, is reasonable. I agree that this would be slightly conservative and as such it is considered appropriate.

- (iv) head loss calculations through the bridges

  The location of the four sections (two upstream, two downstream) at bridge sites should be reviewed in some cases (e.g. Valley Rd). Cross-sections bounding the bridge are too close – see reference in the HEC-RAS user manual. *"This section is normally located near the toe of the upstream road embankment. This cross section should* ***Not*** *be placed immediately upstream of the bridge deck or culvert opening …"*

  I haven't considered if this would make much difference to results.

  The use of only the energy method option for the bridge/culvert hydraulics is acceptable (as there are no piers, so for instance the Yarnell method is irrelevant). (WSPRO could also have been used, but this probably complicates the input.)

  Note that the soffit levels Valley Rd are not as in Table 1 in the January 2015 report (the model seems correct, but the report levels are incorrect)

  I note that the Douglas St bridge soffit is surcharged in the concept design at the design flow. While you are correct that there is still 300mm freeboard to the upstream stopbank crest level (your response of 19 August), you may want to consider the possibility of debris catching on the soffit.

- (v) Any other general matters

  The stream is steep in places, especially upstream of Valley Rd. Results for calibration indicate critical flow – yet the model for calibration has only allowed for subcritical flow. I note that the concept model allows mixed super + subcritical flow conditions. You have indicated that you will undertake a rerun of the calibration model with this issue addressed. We agree however that this will be unlikely to change results significantly. (My quick test of calibration model shows that other than upstream of and immediately d/s of Valley Rd, water levels wouldn't be much different in most places.)

One would normally set the model downstream location in the Awatapu Lagoon receiving waters; this was done for the design simulations but not for calibration. You have confirmed that this was because there were no calibration data were available in the lagoon, and have indicated that you can run a sensitivity test of the calibration model with an updated downstream boundary to check what affect this has on the calibration.

The calibration model chainages do not use different left/centre/right lengths but the design model does. I also note that the lengths are to the nearest mm – I guess that there was some automated process for generating them. I understand that these were a carry-over from the return of the model from Harrison & Grierson. Neither is an issue that I'm concerned about.

I note that no cross slope has been allowed on the bridge deck/soffits, i.e. a simplification of these has been used. I agree however that this is not expected to any significant effect on the model results

A final comment relates to reporting. I accept that the modelling and the design report had not yet been finalised at the time of my review. This however made it a little difficult to review the modelling. The reporting should include tabulated results for the various scenarios and sensitivity tests modelled. Although the client had not specifically requested such reporting, perhaps it could have been offered as part of the design package for the client. I understand however that you are considering whether a final modelling report should be prepared.

I trust that these comments are helpful to you.

Kind regards
DHI

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S3B Wainui Te Whara channel scour analysis

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To	Gareth Francis
Copy	
From	Amir Montakhab, Daniel McMullan, Grant Webby
Date	-
File	2-34250.06/ 13HUB
Subject	Wainui Te Whara - Hydraulic Analysis of Detailed Design, Scour Analysis and Scour Protection Design

1 Introduction

Wainui Te Whara Stream is a small highly-modified stream in an urban environment that discharges into the Awatapu Lagoon in Whakatane. Insufficient channel capacity has historically caused significant flooding for local residents near the stream. We have previously undertaken a hydraulic analysis of the stream using a HEC-RAS model[1] to determine the existing flood risk (McMullan & Webby, 2015), and to assist in the conceptual design of channel improvement options (Francis et al., 2015).

An independent peer review of the HEC-RAS model used in the conceptual design phase was undertaken by DHI (Wallace, 2015). Section 2.1 summarises the conclusions of the peer review, and details the key items from the peer review.

We had three objectives for this study:

- To improve the HEC-RAS model based on the results of DHI's peer review
- To analyse the detailed design of the channel modifications and determine whether the detailed design will perform as required in a flood event
- To undertake scour analysis and scour protection design

This memorandum details the results of a hydraulic analysis of the detailed design, an analysis of the channel scour risk, and the design of scour protection throughout the channel.

[1] HEC-RAS is an open-source one-dimensional computational hydraulic model developed by the US Army Corps of Engineers.

2 Peer Review of HEC-RAS Model

2.1 Peer Review Conclusions

DHI has concluded our HEC-RAS model of the Wainui Te Whara Stream is fit for purpose (Wallace, 2015). However, DHI has asked us to consider the following scenarios in our analysis to see whether these scenarios affect our modelling results:

- **Scenario 1:** Apply Sensitivity Test, to further 0.005 increase in Manning (n), for maximum flow (32 m^3/s).
- **Scenario 2:** Add debris on bridges structures in the concept model.
- **Scenario 3:** Add culvert structure at the end of stream (Hinemoa Street) in the existing model and re-run calibration model (4.7 m^3/s) based on a mixed flow regime.

In the case of scenario 2, debris compares either flood transported woody debris or bedload transported sediment deposited during course of flood.

In case of scenario 3, a mixed flow regime comperes both sub-critical flow and localised occurrences of super-critical flow.

2.2 Re-run DHI scenarios

We have run the three scenarios as the DHI reviewer requested. The results of these scenarios have been compared to our original results.

[2]Channel Roughness

2.2.1 Scenarios

Table 1 shows the results of the changes in model for each scenario.

Table 1 Summary of the changes in model for each scenario

Scenario	Bed Level	Geometry: Add structure	Geometry: Channel Roughness (Manning, n)	Geometry: Debris	Boundary conditions: Discharge (m^3/s)	Boundary conditions: Water Level (RL m) D/S	Boundary conditions: Water Level (RL m) U/S	Flow regime
1	Existing and Concept design	Add culvert at the end of stream in the existing model	Add further 0.005 to base calibration	No	32	2.75	20.81	Mixed flow
2	Concept design		-	Yes	32	2.75	20.81	
3	Existing		-	No	4.7	1.26	19.88	

2.2.2 Scenario 2 - Debris

The peer reviewer has suggested using Australian & Rainfall and Runoff (2015) to estimate the blockage level in hydraulic structures in our model. As per the guideline, we have considered both floating debris (e.g. tree branches), and non-floating bed load debris.

Design Blockage Level

Inlet Blockage-Floating Debris
A medium size of floating debris has been assumed for the Wainui Te Whara Stream. Medium size floating debris, typically between 150 mm and 3 m long, mainly consists of tree branches of various sizes. This material is usually introduced into the flow path by channel erosion undermining riparian vegetation or through wind gusts during storms or by floodwaters flushing out vegetative material deposited on the ground.

For medium floating debris, the most likely inlet blockage level is 10% of water depth at a single span bridge hydraulic structures. Figure 1 shows of how a floating debris blockage is added to a bridge in the hydraulic model by lowering the soffit level.

Only three bridges (located in Douglas St, Peter Snell St, and King St) could potentially be affected by floating debris because of the proximity of the water level to the bridge soffit in each case (please see Figure A-1 in the appendix). We have blocked 10% of water depth below actual soffit level on these three bridges in the HEC-RAS model.

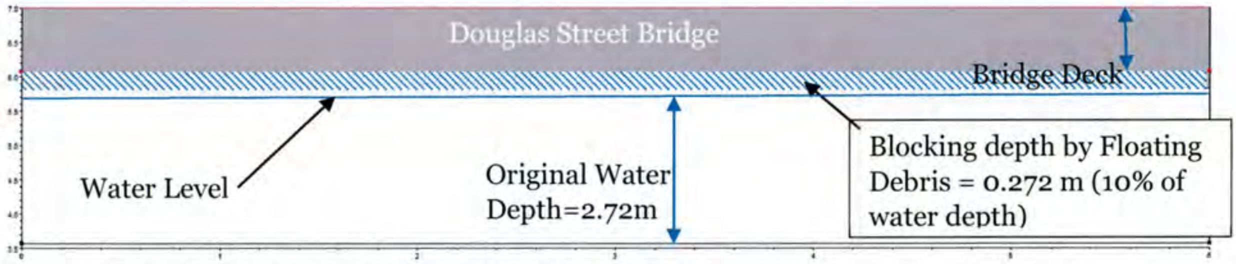


Figure 1 Debris blocking (floating) level in Hec-Ras model.

We have not included debris at any footbridges as floodwaters are assumed to flow over the top of these structures.

Barrel Blockage-Non Floating Debris (bed load)
According Australian & Rainfall and Runoff (2015), the most likely depositional blockage level in Wainui Te Whara Stream is between 15% and 25% of water depth.

We have increased the minimum bed level of the concept design to account for deposition of bedload transported sediment material as shown in Table 2. This reflects depositional run-out of sediment deposits from the upper catchment.

Table 2 increase minimum bed level of concept design for non-floating debris

Chainage (m)		
From	**To**	**Increase minimum bed level amount**
0	100	25% of water depth (for each cross-section)
100	200	10% of water depth (for each cross-section)

2.2.3 Results

Scenario 1
Figure A-2 and A-3 compare the original results and Scenario 1 (a further 0.005 increase in Manning's n). The results of this sensitivity test shows a positive correlation between Manning's n and water level. This result would be expected and confirm the suitability of model. Also, this will cause floodwaters to overtop the Douglas and King Street Bridges.

Scenario 2
This scenario shows the effect of debris rafting at bridges. The results shows the peak water level has been increased over the 550m upstream of the Douglas Street Bridge (see Figure A-4). The increase in flood level at the Valley Road Bridge is predicted to be 235 mm.

Scenario 3
As would be expected, the results of this scenario did not show any change in water level (see Figure A-5 in appendix) due to the addition of the Hinemoa Street culvert.

3 Detailed Design Review

The purpose of this section is to summarise the results of our analysis and to determine whether the detailed design for the modified channel will perform as required.

The scope of these channel modification is to achieve 300mm freeboard along the entire length of the Wainui Te Whara Stream during a flood event with a peak flow of 32 m^3/s.

3.1 Concept Design (Previous Study)

In 16 January 2015, we have completed a hydraulic investigation and concept design for the Wainui Te Whara Stream Lower Channel (McMullan & Webby, 2015).

Insufficient channel capacity has historically caused significant flooding for local residents near the stream. We have run several scenarios based on various channel capacity modifications to optimise the channel capacity for peak flood flows.

3.2 Detailed Design

We received cross-sectional data of the channel for our analysis into the hydraulic performance of the detailed design of the modified Wainui Te Whara Stream channel from the geotechnical designers. This detailed design allowed for the stability of the channel banks and the constraints of adjacent properties.

Figure A-6 compares minimum bed the existing channel, concept design and detailed design. Although the bed level in level profiles for the design is close to the concept design, there are some differences in the channel capacity.

We have optimised the channel bed profile and channel width to achieve a gradual varying bed slope and a subcritical flow regime throughout the channel.

3.3 Used Mixed Flow Algorithm

Figures A1, A3 and A4 show a dip in the predicted water surface profile just upstream of the footbridge at about chainage 200m. This reflects the occurrence of a localised hydraulic jump where the flood flow accelerated locally to a super-critical flow regime and then transactions back to a sub-critical regime. The mixed flow algorithm within HEC-RAS was selected to simulate water surface profile in these figures.
The flow in Scenario 3 is probably too low for the occurrence of super-critical flow.

3.4 Model Build

3.4.1 Overview

We have used our 1D HEC-RAS model for the existing situation and we have modified the model to represent the detailed design.

3.4.1.1 Geometry

Cross-Section

- Replace all cross-sections from 20 m downstream of Valley Road to chainage 1739.61 m which is located at the Hinemoa Street culvert based on the detailed design.

Hydraulic Structure

- Table A-1 in Appendix A shows basic data for six hydraulic structures that we have added to our detailed design model.

3.4.1.2 Flow

Table 3 shows the flow input data that has been used in our HEC-RAS model of the detailed design.

Table 3 Flow input data in detailed design model

Peak Flow, Q (m^3/s)	Water Level (RL m)		Flow Regime
	D/S	U/S	
32	20.81	2.75	Mixed

3.4.2 Sensitivity Test

3.4.2.1 Adjusting channel roughness

Due to the uncertainly in the final hydraulic roughness for the modified channel, upper and lower bound values of hydraulic roughness where applied to the hydraulic model as a sensitivity test.

The Manning's n values for the sensitivity test are summarised in Table 4

Table 4 Summary of Manning's n values used in model calibration

Location description	Chainage (m)	Manning's n Values		
		Same as Concept Design	lower bound	Upper bound
Valley Rd Bridge	0-16.311	0.025	0.020	0.020
Downstream of Valley Rd (Up to end of sheet pile wall)	16.3 - 235	0.025	0.025	0.025
Downstream of Valley Rd (after sheet pile wall)	235.1-340	0.025	0.030	0.035
	340-555.9	0.032	0.030	0.035
Douglas St	556-580	0.050	0.050	0.050
Douglas St to Garaway St	580.1-1290	0.025	0.025	0.030
	1290.1-1410	0.03	0.025	0.035
	1410.1-1610	0.03	0.025	0.035
Upstream of Hinemoa St	1610 – 1739.61	0.035	0.025	0.035

3.4.2.2 Apply debris

We have run two scenarios with debris, firstly, only with sediment debris and, secondly, with both floating and sediment debris.

The debris assumptions were as outlined in Section 1.2.2.

3.4.3 Scenarios

Five cases were analysed to assess the backwater profile along the channel for the 32 m3/s design flow including, sensitivity to Manning's n channel roughness, and debris effects. These are summarised in Table 5.

Table 5 Summary of Scenarios

Case	Manning's n values	Debris	Comment
A	Same as concept design	-	Base
B	Lower bound	-	Sensitivity Test
C	Upper bound	-	Sensitivity Test
D	Upper bound	Non-floating	Sensitivity Test
F	Upper bound	Both floating and non-floating	Sensitivity Test

The discharge (32 m^3/s), tailwater level at Awatapu Lagoon (2.75 RL m), and the cross-section data in detailed design were kept constant between all these flow cases. We have included all hydraulic structures detailed in Table A-1 in Appendix in all above scenarios.

3.5 Results

3.5.1 Comparison of Concept Design and Detailed Design (Case A)

Figure A-7 compares backwater profiles for the existing situation, concept design and detailed design. The results show that the peak water level profile in the detailed design does not exceed the profile predicted for the concept design except just upstream of the Peter Snell Street bridge.

The detailed design of the modified channel does not achieve 300 mm freeboard from Douglas Street to King Street bridges (refer Figure A-8).

3.5.2 Manning's n sensitivity test (Case B and C)

Figure A-9 shows the effect of lower / upper Manning's n channel roughness values. The results show that the floodwaters do not overtop the bridges/ culverts in all scenarios. The maximum variation in the backwater profiles is predicted to be ±300 mm.

3.5.3 Impact of flood event with debris (Case D and F)

Figure A-10 shows the impact of flood event with "sediment deposition along the bed" and "both sediment deposition and debris rafting". The results show that peak water level increases in both cases. However, floodwaters only overtop the Douglas Street Bridge in the case of both debris types (case F).

The model was run for only upper bound Manning's n values which gives a worst-case scenario.

4 Scour Analysis and Protection Design

The purpose of this section to identify the scour locations in Wainui Te Whara Stream and then analyse each of them to find scour depth at each location.

4.1 Bed Material

Figure 2 shows a soil profile (with soil types) for a channel cross-section in the most constrained sheet piled wall reach (chainage between 100 to 235m). We have assumed the banks along the whole stream channel have similar soil profile.

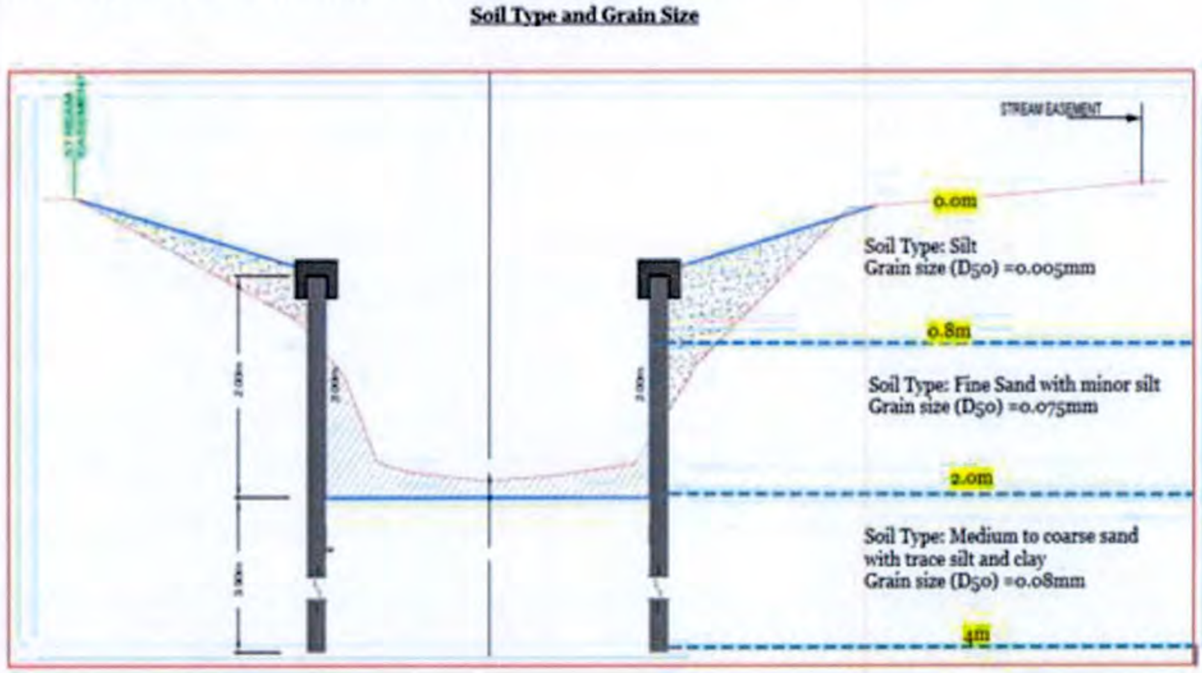


Figure 2 Soil profile along stream channel (chainage between 100 to 235m)

Photos of the stream channel indicate that the existing bed consists generally of a medium to coarse gravel material. It is assumed that this is a thin layer only overlying the underlying medium to coarse sand.
When excavating the modified channel, it is important the overlying gravel bed material layer is removed and then reinstated after channel excavation.

4.2 Hydraulic modelling

We have used Case A (in Section 2.3.3) to obtain all required hydraulic results that were required for the scour analysis and scour protection design (e.g. peak water level, velocity).

4.3 Scour depth and protection design

The method of scour assessment followed the approach outlined in Mellville and Coleman (2000) and Coleman and Melville (2001).

We have identified three areas where scour and bank erosion in Wainui Te Whara Stream needs to be considered as follows:

- Around the entrance and exit of bridge and culvert structures
- Around channel Bends
- Through channel Contractions

4.3.1 Bridge and culvert structures

Bridge and culvert structures require scour and erosion protection for two reasons:

- They cause a channel contraction which increases flow velocities through them resulting in scour of the bed. For this reason the bed needs to be protected with larger rock riprap material.
- Accelerating flow at a structure entrance and eddying flow at the exit cause bank erosion of the flanks of these structures requiring rock riprap protection behind wing walls.

Table 6a shows the predicted velocities and water levels in the vicinity of the proposed modified channel cross-section around hydraulic structures for a flow of 32 m^3/s.

Table 6a Predicted water level and flow velocity in the vicinity of the proposed modified channel

Name of location	Chainage (m)*	Velocity (m/s)	Peak Water Level (RL m)
Valley Rd Bridge	0	2.42	9.26
	16.311	3.64	8.53
Douglas Street Bridge	556	1.57	6.17
	568	2.12	5.97
Peter Snell St Bridge	900	2.02	5.07
	930	2.25	4.95
King St Bridge	1097	2.28	4.6
	1110	2.46	4.42
Garaway St Bridge	1390	2.4	3.78
	1410	2.3	3.72
Hinemoa St Culvert	1726	1.4	3.34
	1739.61	2.54	2.75

*Distance from Valley Road Bridge

Table 6b summarises the results of our scour analysis with the total scour level.

Table 6b: Scour analysis results

Name of location	Chainage (m)	Estimated Scour Depth (m)	Min Bed Level (m RL)	Foundation Level (m RL)
Valley Rd Bridge	0	1.5	7.5	6
	16.311	1.5	7.4	5.9
Douglas Street Bridge	556	0.6	3.5	2.9
	568	0.6	3.45	2.85
Peter Snell St Bridge	900	0.4	2.73	2.33
	930	0.4	6.69	6.29
King St Bridge	1097	0.4	2.25	1.85
	1110	0.4	2.25	1.85
Garaway St Bridge	1390	0.6	1.29	0.69
	1410	0.6	1.24	0.64
inemoa St Culvert	1726	0.4	0.25	-0.15
	1739.61	0.4	0.3	-0.1

The estimated scour depth is the depth below upstream channel levels that the invert level through each structure is predicted to be eroded by is recommended that the channel invert level is protected to prevent erosion.

Table 6c summaries the recommended armour bed material requirement.

We have designed a rock riprap protection for bridges/ culverts inverts (refer to Table 6c for details)

Table 6c Rock riprap protection for bridge and culvert structure inverts

Name of location	Chainage (m)	Rip-Rap Size	D_{50}	Layer Thickness
Valley Rd Bridge	0	100-300 mm	200 mm	400 mm
	16.311			
Douglas Street Bridge	556			
	568			
Peter Snell St Bridge	900			
	930			
King St Bridge	1097			
	1110			
Garaway St Bridge	1390			
	1410			
Hinemoa St Culvert	1726			
	1739.61			

Please refer to drawing in Appendix B for typical details for riprap protection of the structure inverts.

Table 6d summaries rock riprap protection requirements for the flanks of the bridge and culvert structure entrances and exits (behind the wing wall).

Table 6d Rock riprap protection for bridge and culvert structure entrances and exits (behind the wing wall)

Name of location	Rip-Rap Size	D_{50}	Layer Thickness
Valley Rd Bridge	100-300 mm	400 mm	400 mm
Douglas Street Bridge			
Peter Snell St Bridge			
King St Bridge			
Garaway St Bridge			
Hinemoa St Culvert			

4.3.2 Bend Scour

Table 7a shows the predicted velocities and water levels in the vicinity of the proposed modified channel bend cross-section for a flow of 32 m^3/s.

Table 7a: Predicted water level and flow velocity in the vicinity of the proposed modified channel bend

Location	Chainage (m)	Velocity at outside of bend (m/s)	Peak Water Level (RL m)
Point 1	20	1.9	8.64
	40	3.1	8.41
Point 2	270	2.7	7.01
	280	2.6	7.00
Point 3	667	2.7	5.66
	690	2.6	5.63
Point 4	1650	2	3.43
	1690	2	3.38

Flow velocities will be larger than the average cross-section velocity around the outside of bends so that the channel bed will tend to be eroded deeper. Table 7b summarises the results of our scour analysis with the total scour level being as a result of bend scour.

Table 7b: Scour analysis results

Location	Chainage (m)*	Minimum unscored Bed Level (m RL)	Bend Scour Level (m RL)
Point 1	20	6.31	4.6
	40	6.17	4.66
Point 2	270	4.62	2.88
	280	4.59	2.82
Point 3	667	3.3	1.76
	690	3.26	1.72
Point 4	1650	0.5	-1.47
	1690	0.41	-1.62

To counter the effects of high flow velocities on the outside of bends, we have designed a rock riprap protection for the bends (please see Table 7c for details). The bank protection needs to be founded deep enough to prevent undermining by scour and high enough to prevent overtopping by the design flood.

Table 7: Rock Riprap Protection Design Results

Location	Cross Section	Layer Thickness	D_{50}	Foundation Level (m RL)	Top Level (m RL)
Point 1	20	0.36	0.18	5.95	
	40	0.68	0.34	5.49	
Point 2	270	0.72	0.36	3.9	
	280	0.71	0.35	3.88	
Point 3	667	0.63	0.31	2.67	
	690	0.58	0.29	2.68	
Point 4	1650	0.42	0.21	0.08	
	1690	0.41	0.20	0	

Please refer to drawing in Appendix B for typical details for riprap protection. For all bends we have recommended a minimum riprap size of d_{50} = 400mm with a layer thickness of 800 mm.

4.3.3 Contraction Scour

The sheet piled channel section (chainage 100-235m) forms a narrow channel contraction with higher flow velocities. Contraction scour occurs as a result of this channel contraction. The channel transitions from would potentially a trapezoidal channel shape (chainage 80m) to a rectangular channel shape (chainage 100m). The opposite occurs at the end of the sheet piling at chainages 235-250m.

To counter the effects of contraction scour of the stream bed, the stream bed needs to be protected with rock riprap material.

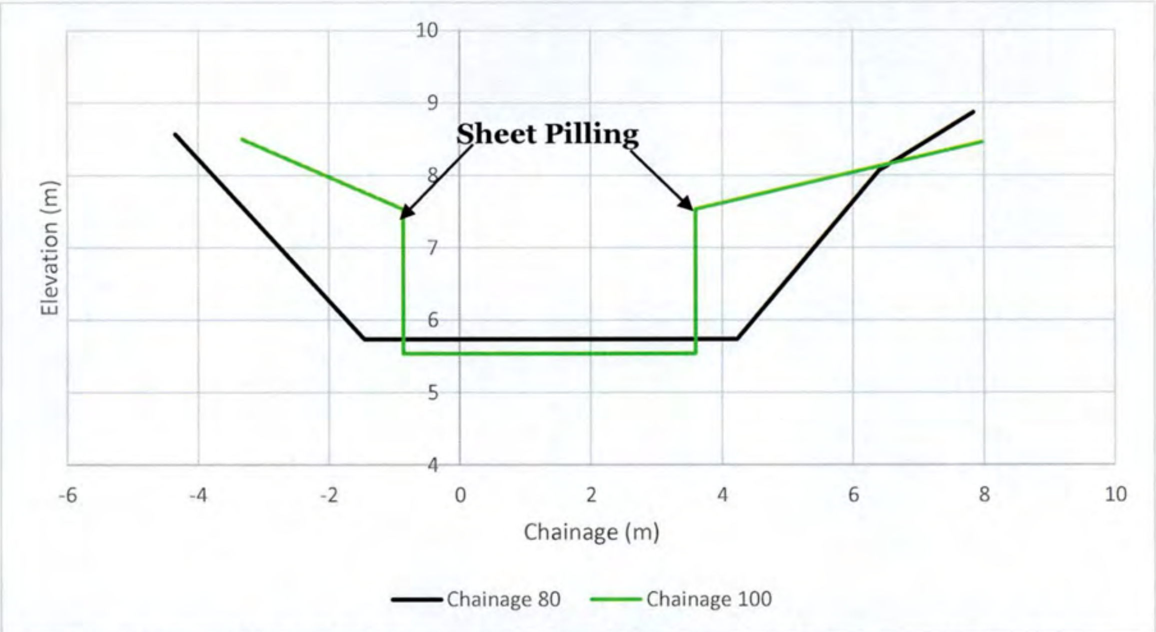


Figure 3 Channel transition from chainage 80 to 100m in proposed modified situation (entrance to channel constriction).

Table 8a shows the predicted velocities and water levels in the vicinity of the proposed modified channel cross-section for a flow of 32 m^3/s.

Table 8a: Predicted water levels and flow velocities through channel constriction in modified channel

Chainage (m)*	Velocity (m/s)	Peak Water Level (RL m)
100	2.32	8.23
120	3	7.94
140	3.41	7.66
160	3.22	7.56
180	3.2	7.43
200	3.48	7.19
220	4.02	6.79
235	3.94	6.66

Table 8b summarises the results of our scour analysis with the total scour level being as a result of the contraction scour. Average scour depth is estimated to be up to 2m due to the high flow velocities through the channel constriction. Maximum scour depths are also likely to be locally larger around the entrance to the channel constriction.

Table 8b: Scour analysis results

Cross Section	Estimated Scour Depth	Min Bed Level (m RL)	Foundation Level (m RL)
100	2	5.53	3.53
120	2	5.38	3.38
140	2	5.25	3.25
160	2	5.05	3.05
180	2	4.9	2.9
200	2	4.8	2.8
220	2	4.8	2.8
235	2	4.75	2.75

To protect the invert of the channel constriction, we have designed an armoured bed protection at channel width (please see Table 8c for details).

Table 8c: Armoured Bed Design Results

Cross Section	Armoured Size (mm)	D_{50}	Armour Layer Thickness
100	100-300 mm	200 mm	400 mm
120			
140			
160			
180			
200			
220			
235			

Please refer to drawing in Appendix B for typical details for riprap protection of the channel invert.

The flanks of the entrance and exit transitions of the channel constriction may also require protection against erosion similar to bridge/ culvert structure entrances and exits. A similar riprap detailed to the latter areas would be appropriate.

5 Conclusions

Considering DHI review on HEC-RAS model in concept design

The results of applying the DHI comments in the concept design model confirmed the suitability of model.

Detailed Design Review

The modified detailed design cross section will largely perform as required and perform within acceptable water level limits, however sections of the channel will require the channel stopbanks to be upgraded.

However, the modified detailed design is not suitable for a channel with significant volumes of debris (same as concept design situation).

Scour analysis and protection design
This study has identified three typical areas where bank erosion and scour would be likely to occur in the modified Wainui Te Whara Stream channel (around bridge and culvert structures, around bends, and through the channel constriction formed by the sheet piled channel reach). Scour protection is required for all of these locations.

In general, the findings of this study confirm that the modified detailed design cross section is suitable for Wainui Te Whara Stream. However, this channel is strictly requires maintenance to remove floating and non-floating debris, particularly following a flood event.

6 References

- Australian Rainfall & Runoff (2015). "Blockage of Hydraulic Structures, Blockage Guidelines", prepared by Engineers Australia Water Engineering, February 2015.

- Francis G, Naude M and Askey P (2015). "Wainui Te Whara Channel Capacity Optimisation-Concept Design Report", Reference 2-34105.75 6th May 2015

- Henderson F M (1966). *Open Channel Flow*, Macmillan, New York.

- McMullan, D and Webby, G (2015), "Wainui Te Whara Stream Lower Channel Investigations", Reference 2-34105.75, Memorandum to Peter Askey sent 16 January 2015.

- Mellville B W and Coleman S E, (2000). *Bridge Scour*, Water Resources Publications, Highland Ranch, Colorado.

- Mellville B W and Coleman S E, (2001). "Case Study; New Zealand Bridge Scour Experiences", ASCE Journal of Hydraulic Engineering, Vol. 127, No. 7.

- Wallace, P (2015), "Wainui Te Whara Stream – Review of HEC-RAS Model", Reference 44800819, 17 September 2015.

Appendix A

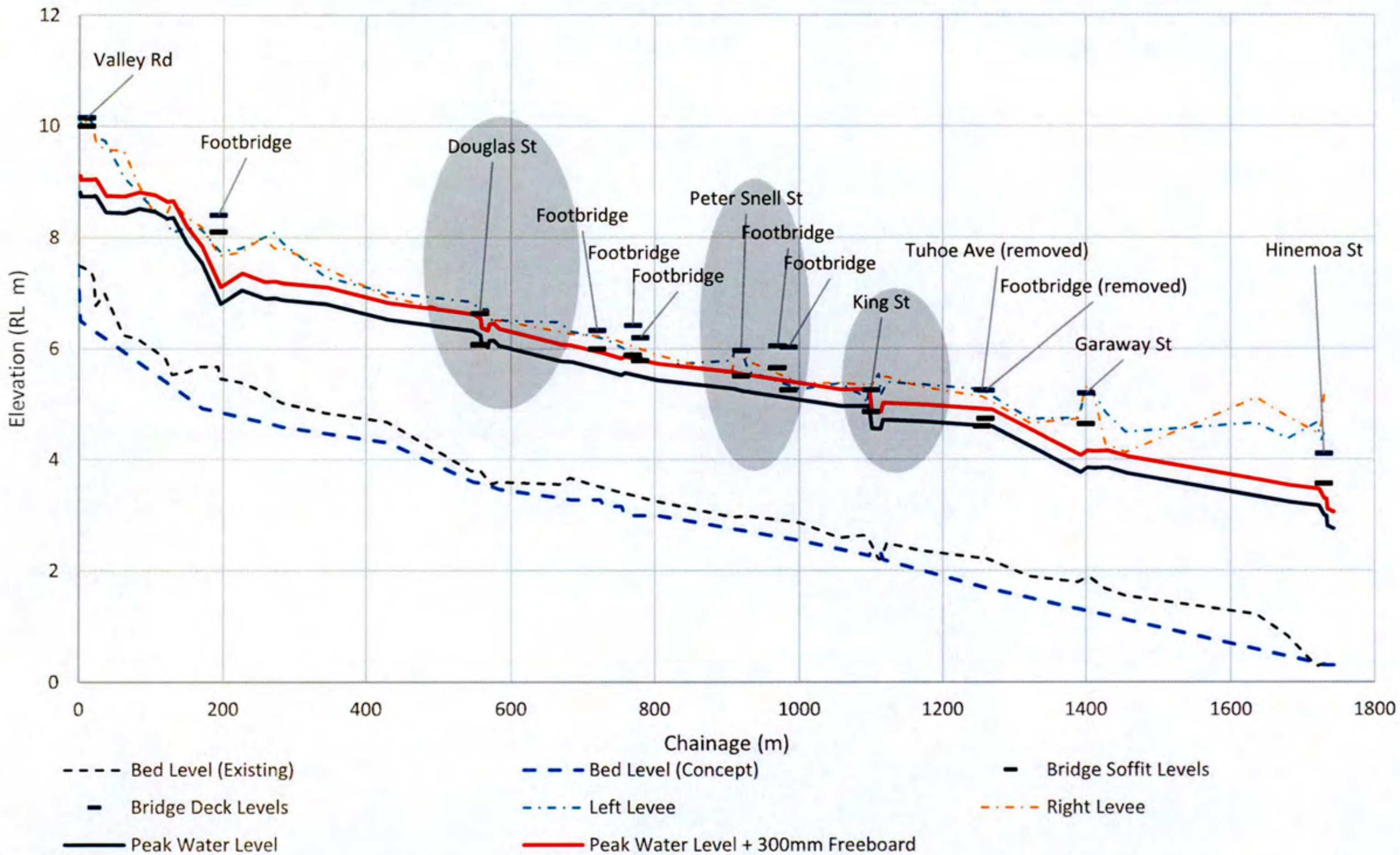


Figure A-1 Flood level profile of the modified Wainui TeWhara Stream, for a discharge of 32 m³/s, (concept design) with 300mm design freeboard allowance

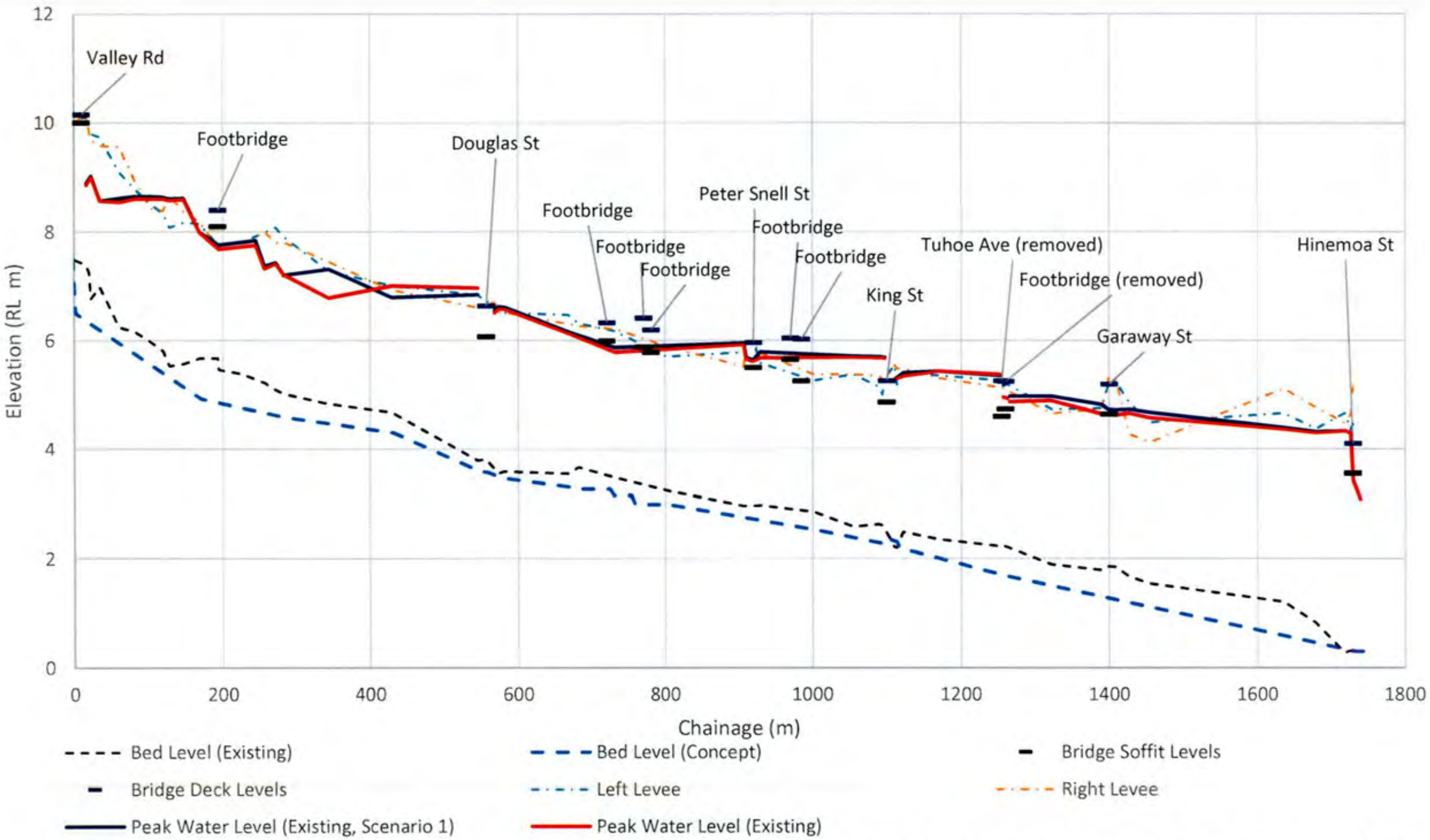


Figure A-2 Flood level profile of the modified Wainui TeWhara Stream (concept design), for a discharge of 32 m³/s, comparing sensitivity test between original results and scenario 1 (to further 0.005 increase in n) based on existing bed profile (Scenario 1).

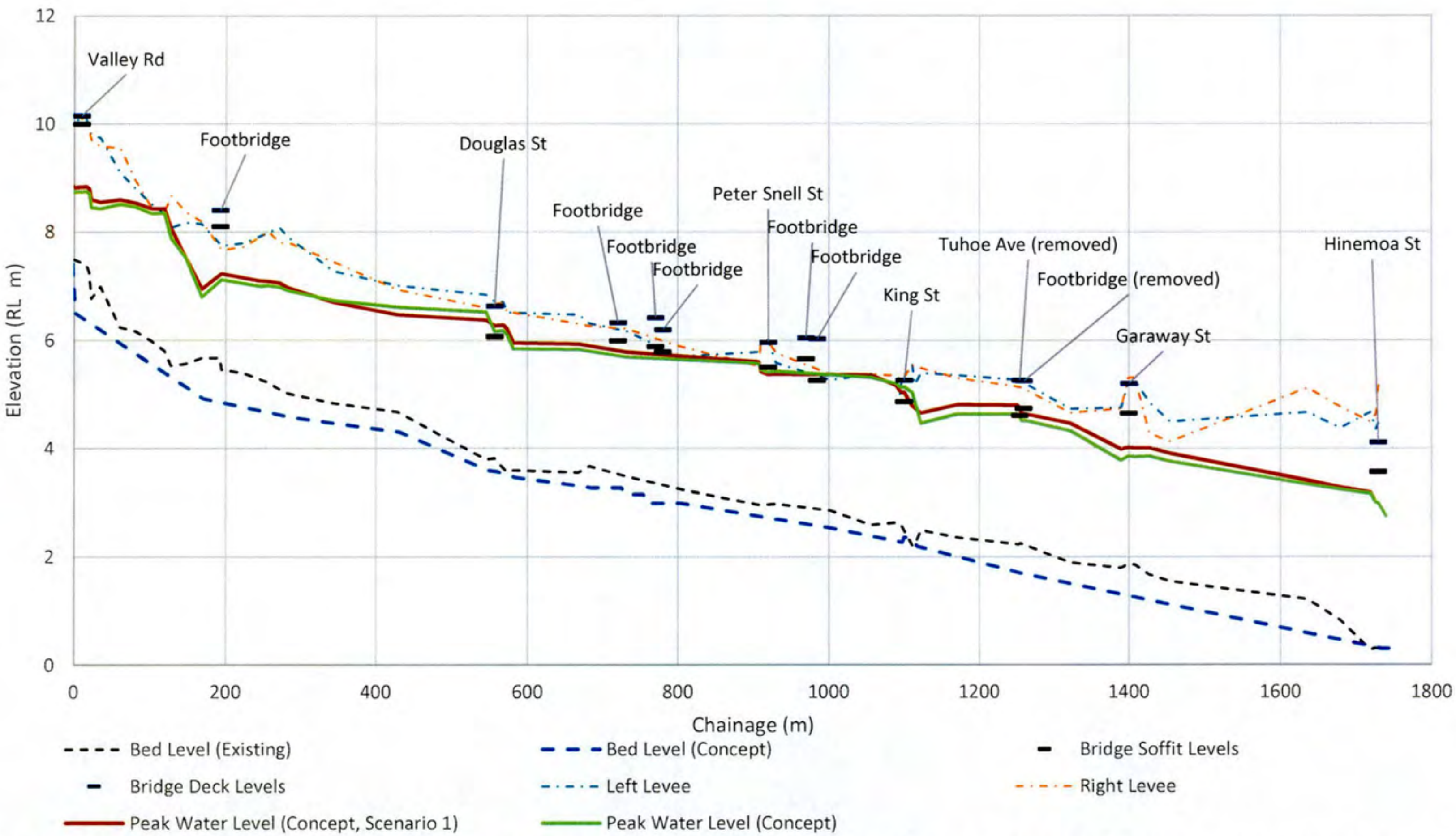


Figure A-3 Profile of the modified Wainui TeWhara Stream, for a discharge of 32 m³/s, comparing sensitivity test between original results and scenario 1 (to further 0.005 increase in n) based on concept bed (scenario 1).

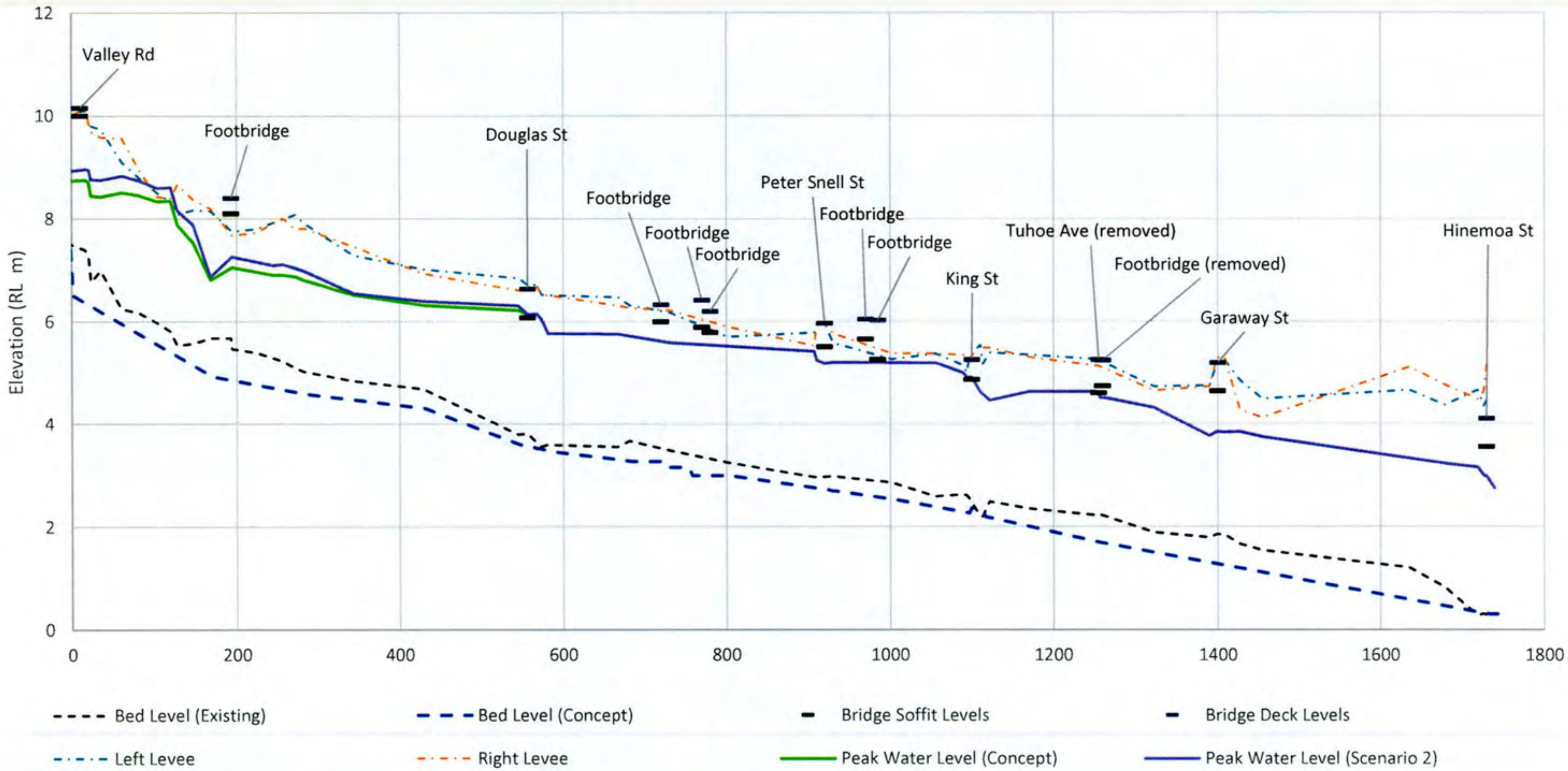


Figure A-4 Profile of the modified Wainui TeWhara Stream, for a discharge of 32 m³/s, showing the effect of debris rafting on the Douglas St, Peter Snell St and King St bridges (scenario 2)

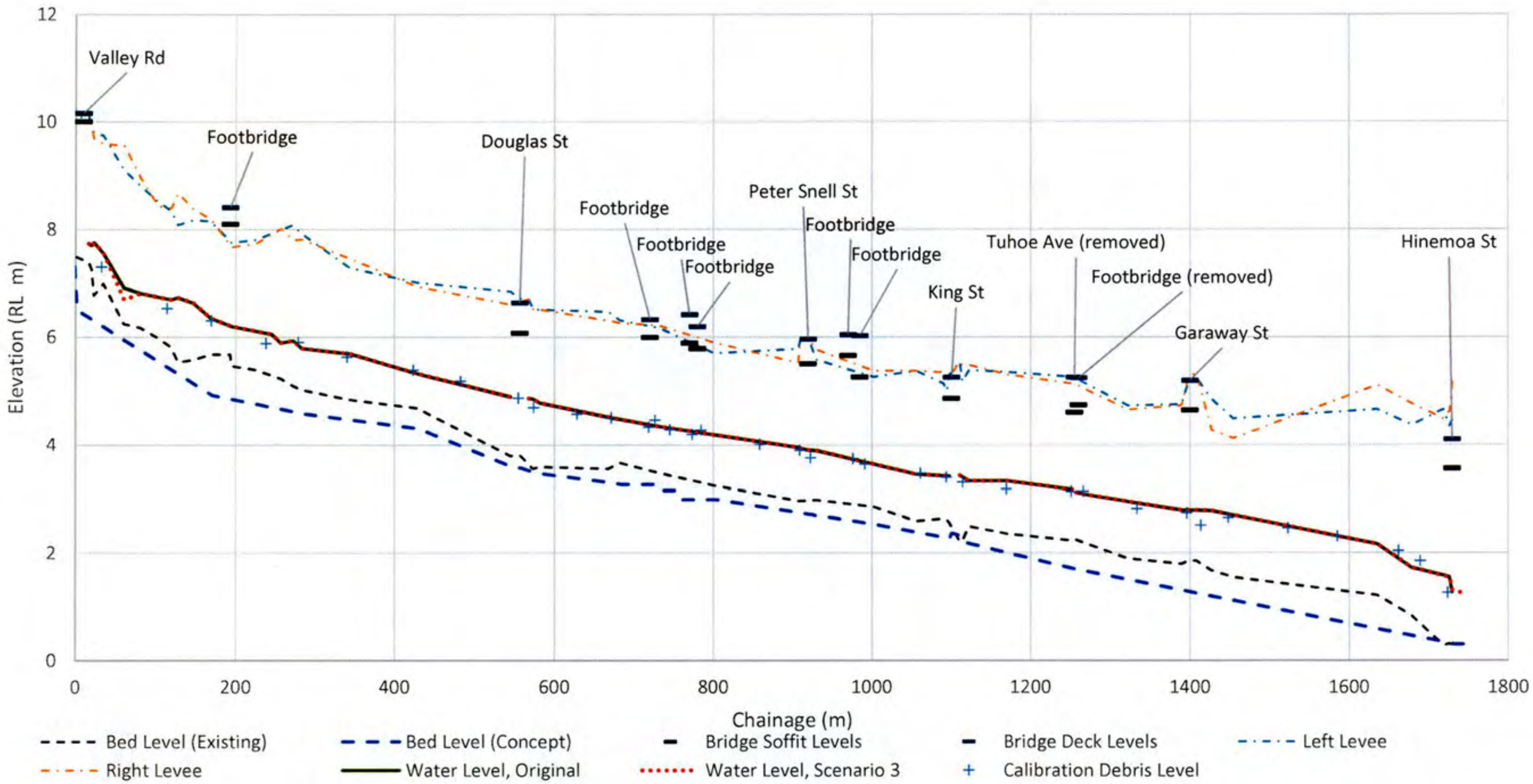


Figure A-5 Profile of the modified Wainui TeWhara Stream, for a discharge of 4.7 m³/s, comparing the original results with re-run scenario 3 (Hinemoa St culvert added).

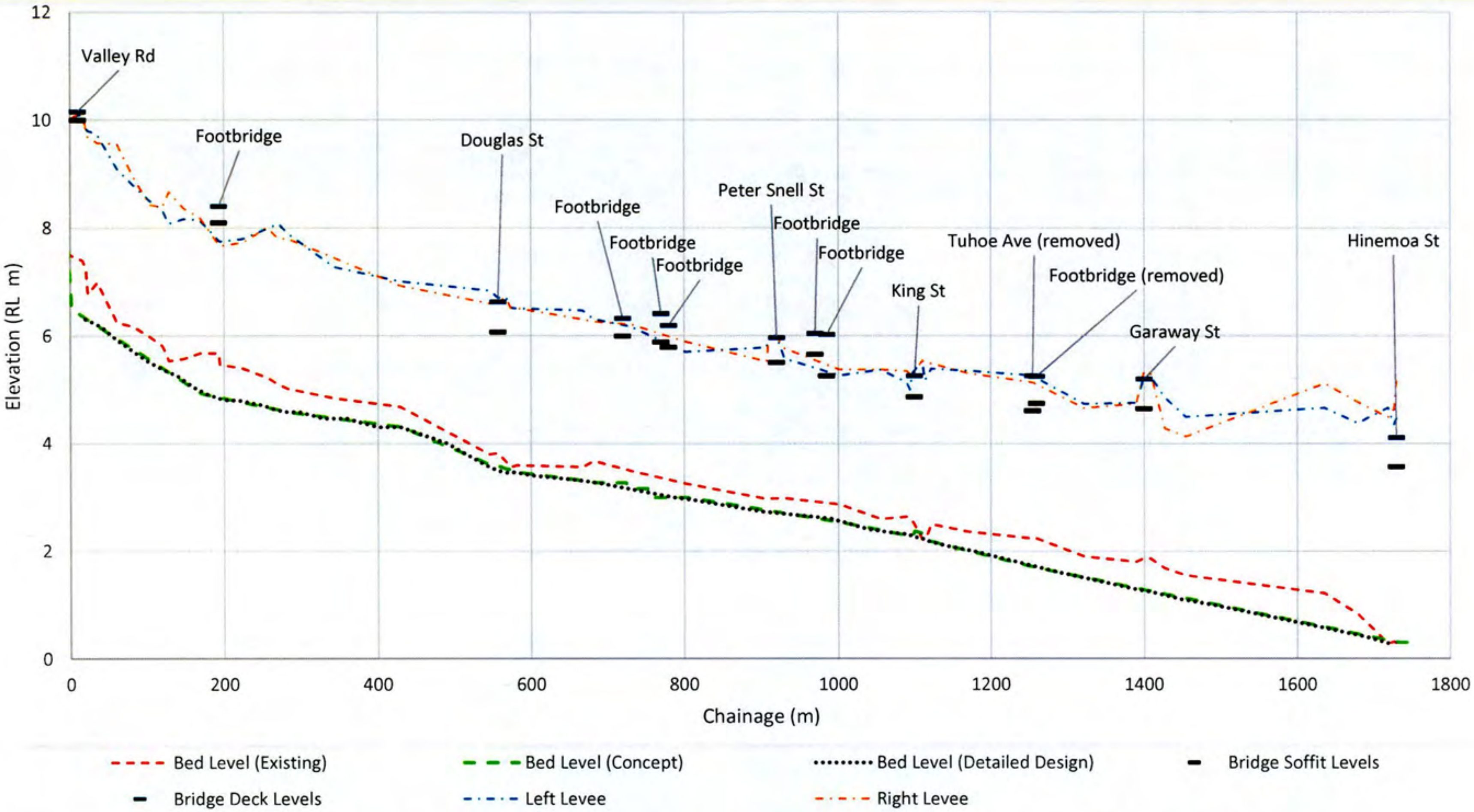


Figure A-6 Comparing minimum bed level between existing situation, concept design and detailed design.

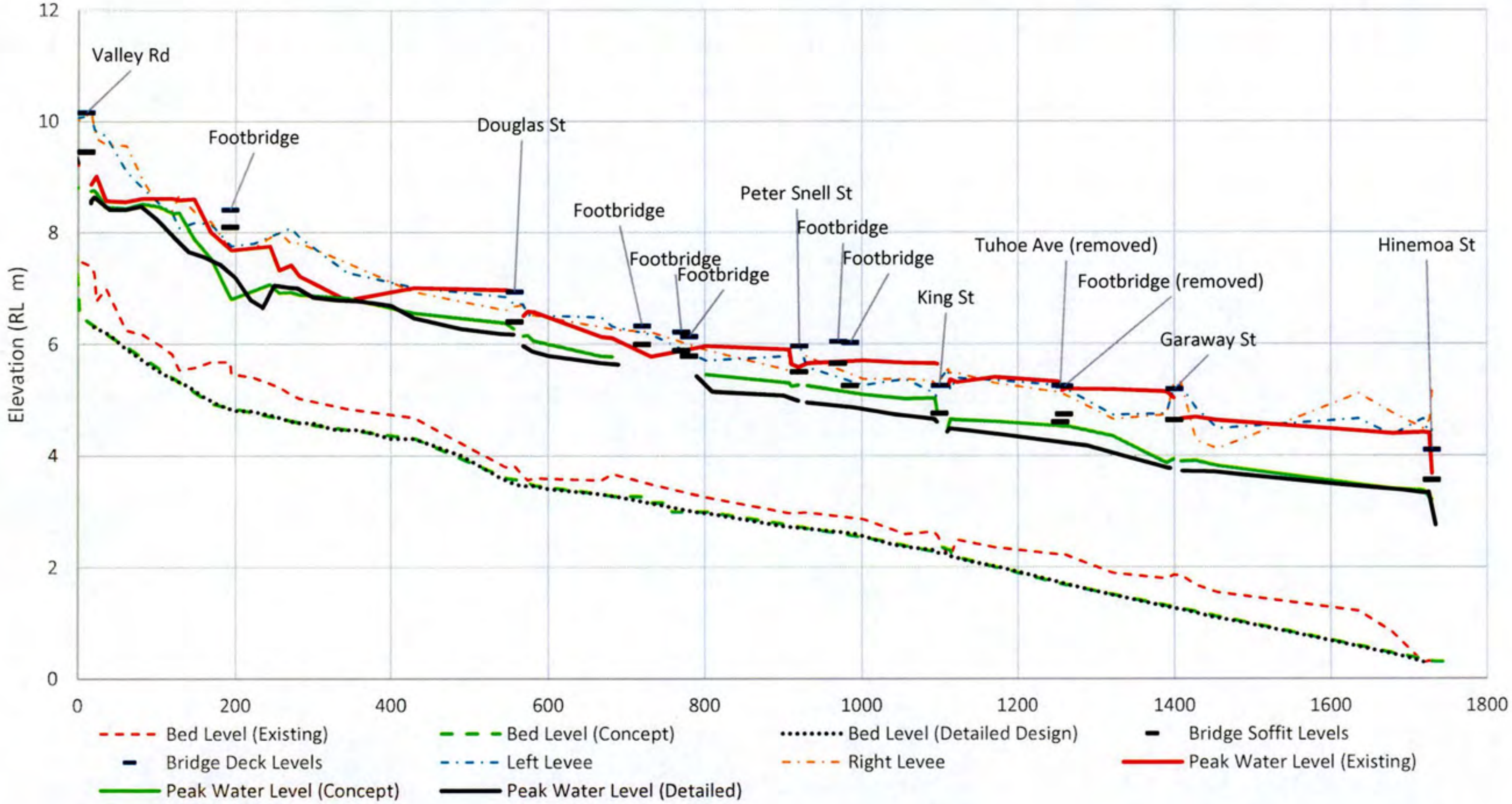


Figure A-7 Profile of the modified Wainui TeWhara Stream, for a discharge of 32 m³/s, comparing existing, concept, and detailed design situations (case A)

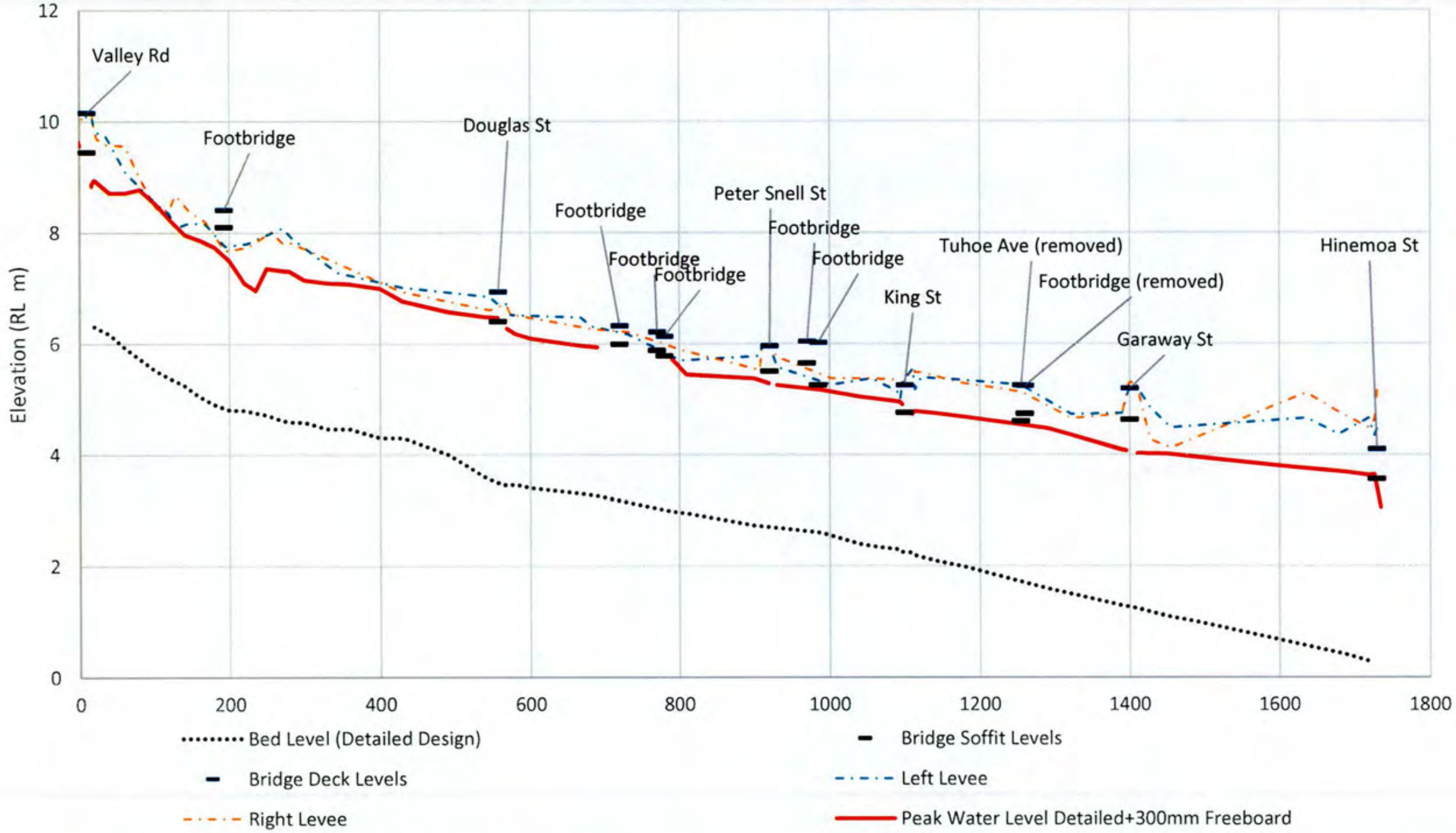


Figure A-8 Profile of the modified Wainui TeWhara Stream, for a discharge of 32 m³/s, showing the peak water level+300mm freeboard (case A+300mm freeboard)

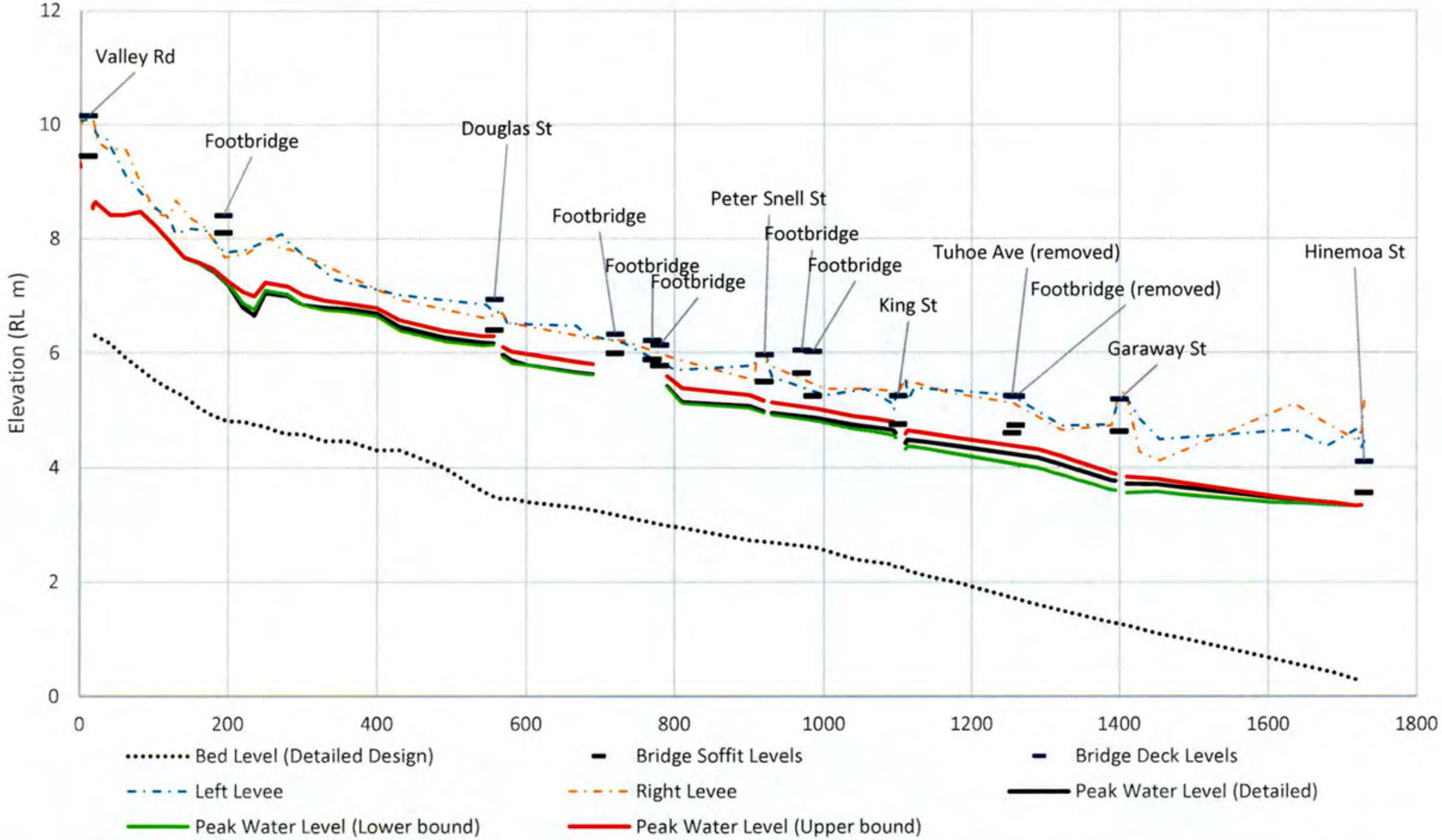


Figure A-9 Profile of the modified Wainui TeWhara Stream, Q=32 m³/s, comparing sensitivity test between original results and upper/ Lower Manning bound (Cases b and c)

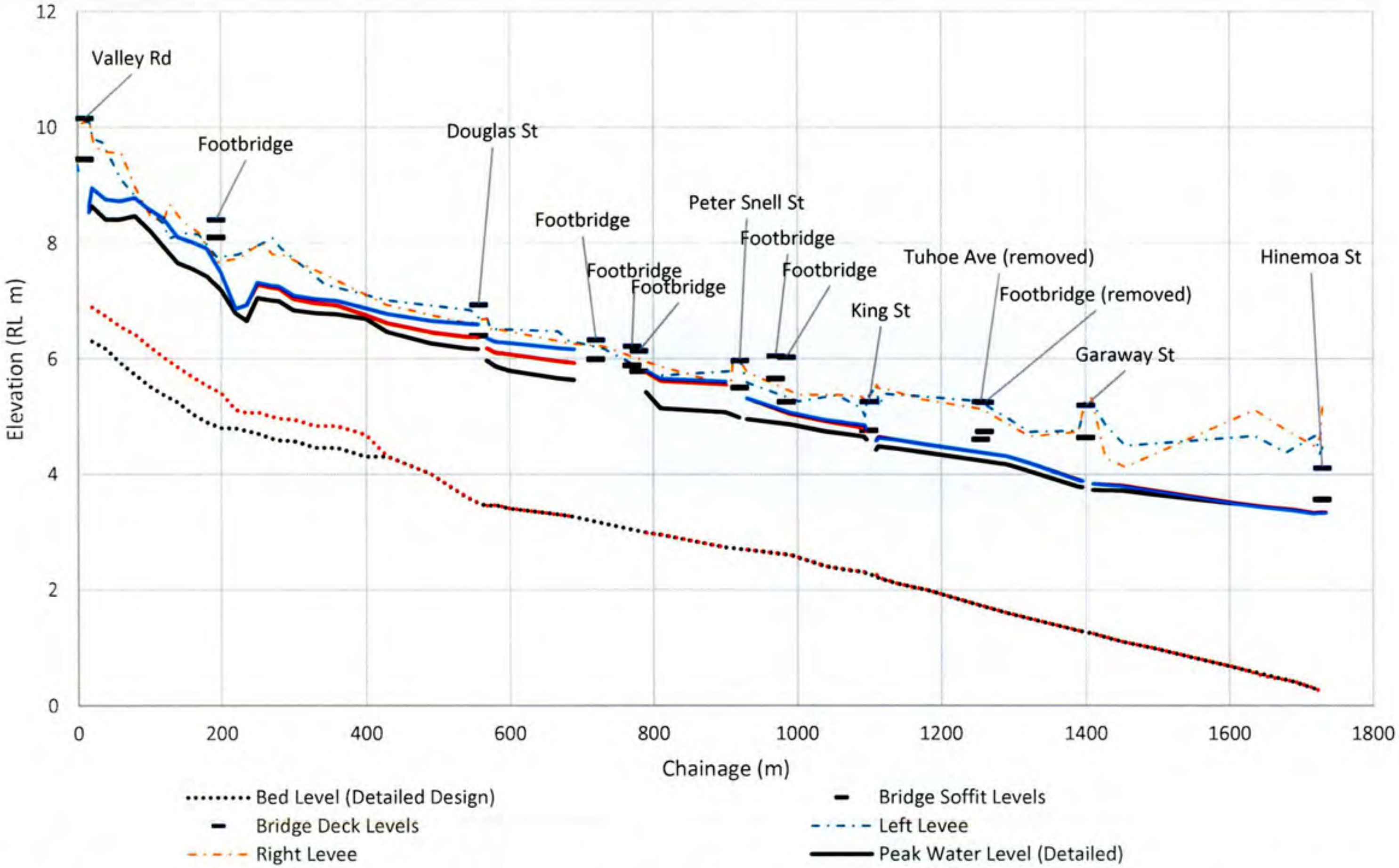


Figure A-10 Profile of the modified Wainui TeWhara Stream, for a discharge of 32 m³/s, showing the effect of debris (cases d and f)

Table A-1 Summary of hydraulic structure details in model

			Bridge						Culvert				
			Deck Soffit Level (m)	Deck Dimension (m)			Bed Level		Box Culvert Dimension (m)			Bed Level	
No.	Structure No.	Distance from Valley Rd (m)		W	H	L	U/S	D/S	W	H	L	U/S	D/S
1	Valley Rd Box Culvert	0							7.66	2.05	16.3	7.5	7.4
	Douglas St Box Culvert	556.89							6	2.8	9	3.596	3.461
2	Foot Bridge	720	5.99	5	0.33	12	3.256	3.22					
3	Foot Bridge	750	5.99	5	0.33	12	3.099	3.099					
4	Foot Bridge	775	5.99	5	0.33	12	3	2.982					
5	Peter Snell St Bridge	925	5.5	5	0.46	12	2.73	2.69					
6	King St Box Culvert	1100							6	2.5	12	2.347	2.205
7	Garaway St Box Culvert	1400							7.25	3.35	9.5	1.28	1.24
8	Hinemoa St Ellipse Culvert	1730							5.66	3.66	8	0.3	0.3

Appendix B

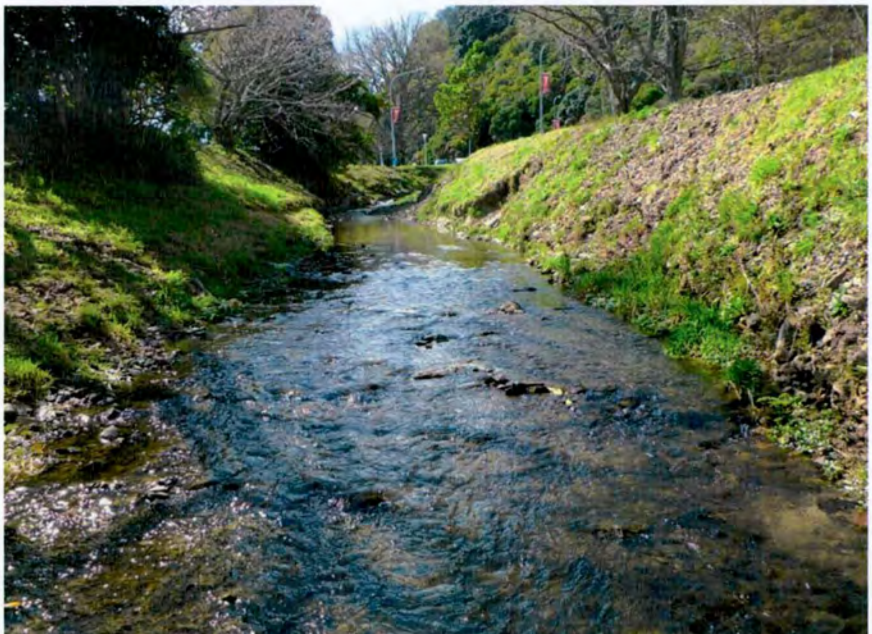
S4 Ecological report - prepared by River Lake Ltd

RiverLake

Wainui Te Whara Stream survey 2015

Prepared for:

Whakatāne District Council



Wainui Te Whara Stream Survey 2015

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Cover photo: Wainui Te Whara Stream below Valley Road

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1 Introduction

1.1 Background

The Whakatāne District Council is seeking resource consent to undertaken work on the Wainui Te Whara Stream in order to alleviate flooding. Works are proposed to lower and widen the bed allow Wainui Te Whara to discharge a 32 m^3/s flood with 300mm freeboard. The summary of works is shown in Appendix 3 (as described in Opus 2015) includes:

- Valley Road and Douglas Street: widen and deepen the channel base and batter slopes. Install about 140m of retaining wall structure. Add rip-rap downstream of Valley Road bridge. Replace Douglas Street bridge with a box culvert.
- Douglas Street to King Street: widen and deepen the channel base and batter slopes. Replace private bridges.
- King Street to Hinemoa Street: widen and deepen the channel. Batter channel slopes and realign channel to accommodate the battered slopes. Replace King Street bridge with box culvert.

River Lake was commissioned to undertake an ecological survey of the Wainui Te Whara Stream. The purpose was to assess the potential impacts of the proposed work and recommend options to mitigate these effects. Field work was undertaken by River Lake and Opus staff. The results of this survey are described in this report.

1.2 Site description

The Wainui te Whara Stream has a catchment size of 5.75 km^2. The upper catchment consists of steep hillside predominantly covered by forest (64%) and farmland (35%). It cascades steeply down Mokoroa gorge and at the base of the hill, downstream of Valley Road, the gradient flattens. The lower catchment is dominated by urban landuse. Through this section the steam is highly modified and flows about 1.75km through Whakatāne urban area into the Awatau Lagoon and the Whakatāne River. Several roads cross the stream including Valley Road, Peter Snell Street, Douglas Street, King Street, Garaway Street and Hinemoa Street (see Appendix B).

The hydrology of the Wainui Te Whara Stream is flashy, with rapid runoff from the hill and urban area. The current stop banks of the lower section (below Valley Road) are capable of containing a 18 m^3/s flood (with no freeboard); this equates to a 1 in 20 year flood event (Opus 2015).

2 Methods

2.1 Sites

Three sites were surveyed on the Wainui Te Whara Stream within its urban catchment: downstream of Valley Road (upper), downstream of Douglas Street (middle) and Garaway Street (lower) (see Table 2.1 and Figure 2.1). Aquatic macroinvertebrates were collected at all three sites; fish were surveyed using electric fishing at the Valley Road and Garaway Street sites. In total about 21% of the stream length between Valley Road and Awatapu Lagoon was fished using electric fishing.

Bay of Plenty Regional Council (BOPRC) collect annual macroinvertebrate samples at three sites in the Wainui Te Whara Stream – Gorge Road, Gorge Road foot bridge (above Valley Road), and King Street. For the purpose of comparison, recent data from these BOPRC sites is presented with macroinvertebrate results from this survey.

Table 2.1: Location of sample reaches on Wainui Te Whara Stream

Reach on Wainui Te Whara Stream	Location	Length (m)	Lat. / Long (degrees) Bottom	Lat. / Long (degrees) Top
Valley Rd reach (upper)	Downstream of Valley Road and upstream of Douglas Street	200	-37.965419 / 176.990778	-37.963716 / 176.991218
Douglas St reach (middle)	Downstream of Douglas Street and upstream of the first private bridge	30	-37.967194 / 176.986531	-37.967211 / 176.986970
Garaway St reach (lower)	Both sides of Garaway Street bridge	175	-37.966351 / 176.977738	-37.966452 / 176.979679

2.2 Timing

Electric fishing was under taken on 17 September 2015 and aquatic macroinvertebrate samples were collected on 18 September 2015. The flow at the time of the survey was about 0.045 m^3/s and the last flood had occurred about two weeks previously on 2 September 2015 (6.6 m^3/s).[1]

[1] BOPRC flow gauge, Wainui Te Whara at Mokorua Gorge.

Figure 2.1: Location of sample sites on Wainui Te Whara Stream, Whakatāne. The upper site was located between Valley Road and Douglas Street, the middle site was between Douglas Street and a private bridge; the lower site was either site of Garaway Street.

2.3 Habitat

Habitat was assessed over the reach using the site characterisation Protocol (P1) of Harding et al. (2009). Substrate size was assessed using the Wolman Pebble count method with size measured at a minimum of 50 points. The percent cover of streambed substrate was visually assessed using substrate cover classes of: clay / silt (<0.063mm), sand (0.063-2 mm), gravel (2-16 mm), pebble (16-64mm), cobble (64-256 mm), boulder (>256 mm) and bedrock (>4000mm). An estimate was made of the percentage to which gravels and cobbles were embedded in fine sediment.

The percentage of macrophyte cover and filamentous periphyton cover were visually estimated across the wetted width of the stream.

2.4 Macroinvertebrates

Aquatic macroinvertebrate samples were collected using the semi-quantitative method for soft bottomed streams – Protocol C2 of Stark et al. (2001). A 0.5mm hand-net was used and the proportion of bank margin, woody debris and macrophyte habitat was sampled according to their occurrence.

All macroinvertebrate samples were preserved in alcohol and processed using Protocol P2 (200 fixed count and scan for rare taxa) of the Protocols for sampling macroinvertebrates in wadeable streams (Stark et al. 2001).

The following ecological indices were calculated to assess the biological health of the river and potential effects on the stream ecology:

- Taxa Richness: This is a measure of the types of invertebrate taxa present in each sample.
- EPT richness and EPT abundance (Ephemeroptera-Plecoptera-Trichoptera). This measures the number of pollution sensitive mayfly, stonefly and caddisfly (EPT) taxa in a sample excluding *Oxyethira* and *Paroxyethira* sp..
- Macroinvertebrate Community Index (MCI). The MCI is an index for assessing the water quality and 'health' of a stream using the presence/absence of macroinvertebrates (Stark 1985).
- Quantitative MCI (QMCI). The QMCI is similar to the MCI but is based on the relative abundance of taxa within a community (Stark 1993, Stark 1998).

The MCI and QMCI reflect the sensitivity of the macroinvertebrate community to pollution and habitat change, with higher scores indicating higher water quality. Generally accepted water quality classes for different MCI and QMCI scores and soft-bottomed version are shown in Table 2.2.

Table 2.2: Suggested quality thresholds for interpretation of the MCI & QMCI from Stark (1998)

Quality Class	Description	MCI	QMCI
Excellent	Clean water	> 120	> 6.0
Good	Doubtful quality or possible mild pollution	100 – 120	5.0 - 6.0
Fair	Probable moderate pollution	80 – 100	4.0 – 5.0
Poor	Probable severe pollution	< 80	< 4.0

2.5 Fish

Fish were surveyed at the upper site (Valley Road) and lower site (Garaway Street) using the backpack electric fishing technique. Sampling was done in accordance with the New Zealand Freshwater Fish Sampling Protocols (Joy et al. 2013). A 200m reach was surveyed at the upper site (Valley Rd) and a 175m reach was surveyed at the lower site (Garaway St). Each reach was fished from downstream to upstream in ca. 10 sub-sections. About 3m lengths were fished from upstream to downstream towards a pole-netter. This was repeated on both sides of the stream before moving upstream and repeating the procedure. Captured fish were stored in a container for identification and measurement after each sub-reach was fished.

The electric fishing machine was setup with a small anode, 300 volts, a pulse rate of 60 pps, and a pulse width of 2.5 ms.

A spotlight survey was undertaken on the middle reach of stream (Douglas Street) on 19 October 2015 using methods in accordance with the New Zealand Freshwater Fish Sampling Protocols (Joy et al. 2013).

3 Results

3.1 Habitat

The urban catchment of the Wainui te Whara Stream, below Valley Road, is a straightened and channelised urban stream confined within stop banks. The riparian margin is mown grass and there is little or no riparian cover. As the Wainui te Whara flows through the town the stream substrate size reduces and the gravels become more highly embedded by sand. There is more macrophyte cover at the downstream reaches, resulting in a narrower channel for base flows and more diversity in flow regimes and habitat (Table 3.1).

The upstream (Valley Road) reach was straight and channelised. Just over half the upper reach that was surveyed had wooden retaining wall structure on both sides of the stream (110m length). The stream width in this section was about 2.9m wide and the substrate was dominated by large gravels. Filamentous diatoms were common on the gravel substrate. There were small (10cm) drop structures along this reach that increased substrate and flow diversity. The section with retaining wall had no riparian cover or undercutting and very little macrophyte cover. The section with grass embankments had a small amount of overhanging vegetation and undercutting of banks, and there was some macrophyte cover in the downstream portion of the reach.

The lower reach was straightened and had embankments covered in short grass. There was very little bank undercutting (about 3m), little riparian shade, and little over-hanging vegetation (limited to grasses) to provide riparian cover for fish. However fish cover was provided by boulder rip-rap on the stream margin and within macrophytes on the stream margin. The macrophytes in the downstream reach narrowed the base flow channel, causing deeper water, faster water velocities and more variation in water velocities. Where the channel had been narrowed by macrophytes a slight meander pattern had started to develop within the confines of the channel (width about 1.5 m, wave length of about 15m).

Substrate in the downstream reach was dominated by small gravels and was highly embedded in sand. Aquatic macrophytes covered about 10-25% of the stream. There was little cover of filamentous algae – probably due to lack of suitable stable substrates and the timing of the survey (in early spring). Observations taken on 18 October 15 (about three weeks since the last flood) found prolific algae growth at all sites in the stream where there was stable substrate.

The middle reach had features intermediate between the upper and lower reach. As with the other reaches it was straightened, confined and the grass embankments provided on riparian cover. The substrate was dominated by small gravel and sand with occasional large gravels and boulders. There was some bank undercutting on the outside bends that provided some fish cover.

Table 3.1: Habitat features of sample reaches of the Wainui te Whara Stream, 17 September 2015.

Reach	typical wetted width (m)	depth max. (m)	water velocity (m/s)	% macrophytes	% filament algae	Dominant substrate	% substrate	Comments
Upper	2.9	0.19	0.34	3%	20%	LG	Riffle: S 14%, SG 29%, LG 52%, SC 5% Run: S 11%, SG 37%, LG 43%, SC 9%	Filamentous diatoms on cobbles.
Middle	2.7	0.19	0.28	<1%	0%	SG	S 40%, SG 43%, LG 9%, SC 7%	Gravels 50-75% embedded in sand
Lower	1.8	0.21	0.70	10-25%	0%	SG	S 20%, SG 80%	Gravels >75% embeddd in sand

Notes
Substate codes are: SC=small cobble, LG=large gravel, SG=small gravel, S=sand.
Water velocity based on measured mid-stream.

3.2 Fish

3.2.1 Previous fish surveys

Erin Broker used fyke nets and gee minnow traps were used to survey the Wainui Te Whara Stream at the base of the hill, upstream of Valley Road in March 2014. The trapping method followed the fish sampling protocols in Joy et al. (2013) and set 6 fyke nets and 12 gee-minnow traps over a 150m reach. The survey found common bully (173), redfin bully (13), inanga (204), longfin eel (3), and shrimp (*Paratya* sp.) (3).

In a follow up survey the Wainui Te Whara Stream was electric fished by Kelly Hughes and Erin Brocker on 12 January 2015 at the same location. This survey caught the same species, i.e. common bully, redfin bully, inanga, longfin eel and shrimp. Electric fishing near the top of the gorge (off White Horse Drive) caught a giant kokopu (ca. 20cm long) and several small eel.

3.2.2 Electric fishing and spotlight survey, spring 2015

Electric fishing the two reaches of the Wainui te Whara below Valley Road on 17 September found shortfin eel, longfin eel, giant bully, common bully, redfin bully, brown trout, inanga and one *Paratya* sp. shrimp. (Table 3.2). Several of these species are classified as threatened, i.e. longfin eel, inanga, and redfin bully are all classified as 'At Risk – Declining' (Goodman et al. 2014).

Eel were the most abundant fish (93% of all fish caught), with similar proportions of longfin and shortfin. Just over half (55%) of the eel caught were elva, but several large eel were also caught including a 62 cm shortfin, a 65cm longfin and a ca. 75 cm unidentified eel that escaped capture. Various bully species were more abundant in the upstream reach where the substrate size was larger.

The 200m long upstream (Valley Road) reach included about 110m of wooden retaining wall. The section with the retaining wall had very low abundance of fish (only 6 elva, 3 bully, 1 galaxiidae and 1 trout). There was less than 1 fish per 10m in the section with retaining wall structure, compared to 8.4

fish per 10m in the section of the reach without the retaining wall structure, i.e. fish abundance along the retaining wall structure was about 12% of the fish abundance in the adjacent section with grassed embankments.

The lower reach (Garaway Street) had higher fish abundance (12.5 fish per 10m) compared to the upstream reach outside the retaining wall structure (8.4 fish per 10m). Furthermore, all the large eel were caught in the downstream reach (Garaway Street). This was due to the presence of more cover within and riprap, macrophyte beds. The amount of cover from over-hanging riparian vegetation was small at both sites.

A spotlight survey of the middle reach (downstream Douglas Street) was done on 19 October 2015. This found shortfin eel (9), unidentified eel (2), inanga (6), and small unidentified *Galaxias* sp. (7). Three of the eel were large and the largest inanga was ca. 8cm long.

Table 3.2: Fish caught in Wainui Te Whara Stream on 17 September 2015 using electric fishing. In the upper reach over half the length fished had a vertical retaining wall structure, where this was present there was very low density of fish (<1 fish /10m where there was retaining wall compared to 8.4 fish /10m where there was not a retaining wall). One shrimp was caught at the lower site.

Upper reach, 200m fished

Species	Scientific name	0+	Small	Medium	Large	Total
shortfin eel	*Anguilla australis*	0	6	0	0	**6**
longfin eel	*Anguilla dieffenbachii*	0	2	3	0	**5**
eel unidentified	*Anguilla* sp.	38	15	3	0	**56**
brown trout	*Salmo trutta*		2			**2**
common bully	*Gobiomorphus cotidianus*			4	2	**6**
giant bully	*Gobiomorphus gobioides*		4	1		**5**
redfin bully	*Gobiomorphus huttoni*			2		**2**
Galaxias unidentified	*Galaxias* sp.	3				**3**
TOTAL						**85**

Lower reach, 175m fished

Species	Scientific name	0+	Small	Medium	Large	Total
shortfin eel	*Anguilla australis*	0	14	3	3	**20**
longfin eel	*Anguilla dieffenbachii*	10	16	6	3	**35**
eel unidentified	*Anguilla* sp.	107	44	5	3	**159**
common bully	*Gobiomorphus cotidianus*	0	1	2		**3**
Inanga	*Galaxias maculatus*		1			**1**
TOTAL						**218**

Eel sizes: 0+ <100mm; small < 101-300cm, Medium 301-500mm, Large >501mm
Common bully sizes: 0+ <20mm; small < 21-40cm, Medium 41-60mm, Large >61mm
Giant bully sizes: 0+ <20mm; small < 21-60cm, Medium 61-115mm, Large >115mm
Inanga sizes: 0+ <40mm; small < 41-60cm, Medium 61-80mm, Large >81mm
Trout: 0+ <80mm; small < 81-220cm, Medium 221-500mm, Large >501mm

3.3 Benthic macroinvertebrates

Benthic macroinvertebrate sampling found the urban section of the Wainui te Whara Stream had good to fair water quality/habitat. The MCI score was indicative of 'good' condition at each site sampled in September 2015, while the QMCI score indicated 'good' conditions in the upper two sites and 'fair' condition in the lower (Garaway Street) site.

Along the stream's 1.75km of urban catchment, there was little change in the number of sensitive EPT macroinvertebrate species but there was a substantial decline in the relative abundance of EPT taxa (Table 3.3). The Garaway Street site had lower abundance of mayfly (Ephemeroptera) and stonefly (Plecoptera), but considerably higher abundance of snails (*Potamopyrgus* sp.). To some extent this reflects a change in habitat and substrate, i.e. more fine sediment and a greater proportion of macrophytes at the downstream site.

The two most dominant macroinvertebrate species were *Zelandobius* sp. stonefly (69%) and *Deleatidium* sp. mayfly (8%) at the upper site, *Zelandobius* sp. stonefly (67%) and *Potampyrgus* snails (9%) at the middle site, and *Potampyrgus* snails (61%) and *Zelandobius* sp. stonefly (21%) at the lower site.

The results from the BOPRC macroinvertebrate monitoring sites indicate a similar pattern of change along the urban section of the Wainui te Whara Stream, i.e. good conditions near Valley Road and good to fair conditions further downstream. The results from the BOPRC sites should not be directly compared with the results from this survey because they were collected at different times of the year and under different flow conditions. The September sampling was done only two weeks after a flood event and there was little periphyton cover, however prolific periphyton growth is common in the stream after more extended periods of low flow in spring and summer.

The BOPRC data had a lower relative proportion of stonefly (e.g. *Zephlebia* sp. 6% and 3% at Gorge Road and King Street respectively), and a higher relative proportion of Potamopyrgus snails (8% and 51% at Gorge Road and King Street respectively) and chironomidae midge larva (22% and 8 % respectively). This probably reflects warmer water and more periphyton in the stream during summer low flows.

The two most dominant macroinvertebrate species at the Gorge Road site were *Deleatidium* mayfly (30%) and chironomidae midge larva (22%); the two most dominant macroinvertebrate species at the King Street site were *Potampyrgus* snails (51%) and chironomidae midge larva (22%).

Table 3.3: Benthic macroinvertebrate metrics for the current survey (18 September 2015) and BOPRC summer sampling (2015). The BOPRC data and the current survey data are not directly comparable because they are sampled at different times of year.

Index	BOPRC (Gorge Rd)	Upper (d/s Valley Rd)	Middle (d/s Douglas St)	BOPRC (King St)	Lower (Garaway St)
No. taxa	45	23	20	47	22
No. EPT taxa (excl. *Oxyethira*)	23	10	8	21	12
% EPT taxa (excl. *Oxyethira*)	51%	43%	40%	45%	55%
% EPT abundance	54%	86%	80%	17%	27%
MCI	116	110	103	108	109
QMCI	5.4	5.2	5.0	3.2	4.1

Calculations of EPT taxa exclude *Oxyethira* sp.

Table 3.4: Aquatic macroinvertebrates in the Wainui Te Whara Stream, 18 September 2015.

TAXON	MCI score	Wainui Te Whara Upper (d/s Valley Rd)	Middle (d/s Douglas St)	Lower (Garaway St)
ACARINA	5		6	1
COLEOPTERA				
Elmidae	6	42	66	36
Ptilodactylidae	8	1		1
CRUSTACEA				
Ostracoda	3		18	1
DIPTERA				
Aphrophila species	5	1		
Austrosimulium species	3	6	1	1
Empididae	3	6		
Eriopterini	9	6		
Hexatomini	5			1
Maoridiamesa species	3	6		
Mischoderus species	4	6		
Molophilus species	5	1		
Orthocladiinae	2	42		24
Tanypodinae	5		6	
EPHEMEROPTERA				
Austroclima species	9	12	24	24
Coloburiscus humeralis	9	12		12
Deleatidium species	8	96	72	12
Neozephlebia scita	7			12
Nesameletus species	9		6	
Zephlebia species	7	24	120	48
MEGALOPTERA				
Archichauliodes diversus	7	1	1	
MOLLUSCA				
Lymnaeidae	3		1	
Potamopyrgus antipodarum	4	30	174	1956
ODONATA				
Xanthocnemis zealandica	5		6	
OLIGOCHAETA	1	24	102	324
PLATYHELMINTHES	3		6	
PLECOPTERA				
Acroperla species	5	30		12
Zelandobius species	5	834	1320	660
TRICHOPTERA				
Aoteapsyche species	4	6		1
Hydrobiosella species	9	1		
Hydrobiosis umbripennis group	5	1		
Oeconesidae	9			1
Oxyethira albiceps	2		18	12
Psilochorema species	8		1	12
Pycnocentrodes species	5	30	24	60
Triplectides species	5		6	1
Number of taxa		23	20	22
No. of EPT taxa		10	8	12
% EPT taxa		43	40	55
MCI score		110	103	109
QMCI score		5.2	5.0	4.1

Calculations of EPT taxa exclude *Oxyethira* sp.

4 Discussion and potential effects of proposal

4.1 Aquatic biota values

The urban catchment of the Wainui te Whara Stream, below Valley Road, has been highly modified to improve flow and reduce flooding. It is straightened, channelised and confined within stop banks. The riparian margin is mown grass and there is very little riparian vegetation suitable for fish cover. Despite the modifications the aquatic macroinvertebrate community is in reasonable condition. Sensitive species such as mayfly, stonefly and caddisfly were present at all sites and the Macroinvertebrate Community Index (MCI) score indicated 'good' conditions.

There was also a reasonable diversity and abundance of fish in the stream. Seven fish species were found in the stream, including three threatened species - longfin eel, inanga and redfin bully which are all classified as 'At Risk – Declining'. Longfin eel and shortfin eel were the most abundant fish found in the stream, most were elva (55%) but a number of large eel were also caught (the largest was 75cm long). The presence of elva and inanga whitebait indicates that the fish friendly flapgates installed at the Awatapu Lagoon outlet are being effective at providing fish passage to the Whakatāne River.

The presence and abundance of fish in any particular stream section was strongly related to the amount of cover available. The section of stream with retaining walls and little cover had only 12% the fish abundance compared to the adjacent sections with grassed embankments (1 fish per 10m compared to 8.4 fish /10m). The lower reach near Garaway Street had more cover for fish within macrophytes and stream bank rip-rap and higher fish abundance (12.5 fish per 10m).

4.2 Potential effects of proposal

The proposal to straighten and widen the Wainui te Whara is unlikely to have a significant long term impact on the aquatic macroinvertebrate community. There will be some short term adverse effects on aquatic macroinvertebrates and increased suspended sediment at the time when construction works are occurring and when sediment removal occurs.

In the absence of mitigation, the proposal is likely to reduce the amount of habitat suitable for fish and reduce fish abundance in the stream. Construction activities and sediment removal may result in some direct fish mortalities (e.g. by removal and or burial), but most impact will result from the loss of fish habitat.

There is very little fish habitat in the section with retaining wall structure. Installing 140m of retaining wall structure will increase the current length of retaining wall by 30m. Based on the results of the September 2015 fish survey this could result in about 40 fewer fish.

Widening and deepening the stream will result in a short term loss of fish cover from macrophyte beds and may result in a long term loss of fish cover from rip-rap boulders unless an alternative habitat is provided. A wider stream channel will be shallower. Shallow water can restrict habitat and fish passage for larger fish so consideration should be given to installing features than help a narrower base flow channel to form.

The deepening work may extent into clay below the stream gravels. A change in stream substrate from gravel to clay would reduce the abundance of many of the sensitive aquatic macroinvertebrate species (e.g. stonefly and mayfly). It may also reduce the streams suitability for some fish species (e.g. bully). This potential effect could be avoided by placing the surface gravels back onto the streambed after the base has been deepened.

Removal of sediment and macrophytes will reduce fish and invertebrate habitat in the short term. Frequent disturbance within the channel can have a significant influence on the ability for the aquatic system to recover its structure and ultimately the biodiversity it can support. There are options to reduce the impact of stream 'maintenance' activities on stream structure and biota; these are discussed below.

4.3 Potential mitigation

There are several actions that could be taken to mitigate the loss of fish habitat while retaining hydraulic capacity. These include:

- Install fish habitat devices or "tuna town houses". Tuna town houses are constructed habitat within stream banks that provides cover for eel and other fish. They can be small e.g. 160mm diameter nova flow pipe bent in a U-shape through two cinder blocks; or large e.g. 2m sections of 450mm diameter Farmboss pipe (stuffed with 160mm nova flow pipe) and installed within stream banks (e.g. rip-rap) and perpendicular to the stream.

- Install large boulder rip-rap within the bank at the level of the stream base flow (e.g. within sections of the stream above King Street). The rocks should be installed to have fish sized gaps between them and /or integrated with fish habitat devices.

- Establish features to encourage the formation of a narrow base flow channel within the main 3m wide channel. One option is to install boulders projecting from alternate stream banks every 8 metres to deflect water and help establish a small base flow meander within the channel (wave length about 16 m). The boulder structures should be >0.5 m high and project about 40cm to still allow a digger to pass.

- Stream surface gravels and sands should be retained and placed back on the stream bed after the bed has been deepened. This will ensure that the natural substrate present in the stream is retained and material is available for the stream to form a meander pattern. I suggest that the installed gravel depth is a minimum of 30 to 40 cm.

- The frequency for stream clearing should be minimised to what is necessary to maintain hydraulic capacity. Clear and robust guidance should be developed to identify what change in bed level will trigger any future sediment removal. Sediment removal should not be triggered simply because the base flow has established more natural meander morphology (i.e. variable depth across the stream width) or macrophytes are present in the stream.

- Stream restoration and riparian planting. Council own reserve land between King Street and the Awatapu Lagoon; in this section there is potential to widen the stream flood channel to create a mini-flood plain within the stop banks, increase the amplitude of the base flow channels meander and plant riparian vegetation beside the base flow channel to provide overhanging vegetation e.g. tussock grasses (e.g. *Carex* sp.). This would have multiple benefits for macroinvertebrates, fish, reduced water temperature, shading to reduce periphyton growth, aesthetics and improving people's connection to the stream.

- The invert of any box culverts (e.g. King Street) should be installed below the stream bed level to allow river substrate to cover it. Not installing box culverts below stream bed level can result in a shallow flow which reduces potential habitat and fish passage.

- The stream deepening and widening will result in sediment disturbance and more turbid water while it is occurring. In order to minimise the period of time downstream sections might have reduce water clarity I suggest that the work occur in upstream sections (e.g. above Douglas Street) prior to downstream sections (e.g. downstream King Street).
- During any earthworks and macrophyte removal use protocols to rescue and relocate any fish caught by the digger (e.g. WRC fish recovery protocols in Appendix 2).

5 Conclusions and recommendations

The urban catchment of the Wainui te Whara Stream is highly modified but the macroinvertebrate communities remain in 'fair' to 'good' condition and there is reasonable fish abundance along much of its length. The current proposal will reduce habitat for fish in both the short term and long, however there is opportunity to sufficiently mitigate and compensate for this potential habitat loss so as to increase the overall habitat values in the stream.

It is recommended that mitigation is provided by:

- Installing fish habitat devices (natural and artificial) within the stream banks.
- Installing structures to help form a meandering base flow channel within the stream banks.
- Replacing stream gravels in the stream once the stream has been deepened.
- Considering stream widening and riparian planting to improve habitat in the section below King Street.
- Ensuring box culverts are installed below the level of the stream bed.
- Applying fish recovery protocols during stream earthworks and sediment removal.
- Minimise the frequency of future sediment removal by developing robust criteria relevant to flood flow capacity.

References

Goodman JM, Dunn NR, Ravenscroft PJ, Allibone RM, Boubee JAT, David BO, Griffiths M, Ling N, Hitchmough RA, Rolfe JR 2014. *Conservation status of New Zealand freshwater fish, 2013*. New Zealand Threat Classification Series 7.

Harding J.S., Clapcott J.E., Quinn J.M., Hayes J., Joy M., Storey R., Greig H., Hay J., James T., Beech M., Ozane R., Meredith A., Boothroyd I. 2009. *Stream habitat assessment protocols for wadeable rivers and streams of New Zealand.* University of Canterbury, NZ.ISBN 978-0-473-15151-5

Joy M., David B. & Lake M. 2013. *New Zealand Freshwater Fish Sampling Protocols: Part one – wadeable rivers and streams*. Massey University, Palmerston North.

Opus International Consultants 2015. *Wainui Te Whara channel capacity optimisation Concept Design Report.* Prepared by Gareth Francis for Whakatāne District Council.

Stark JD; Boothroyd IKG; Harding JS; Maxted JR; Scarsbrook MR 2001. *Protocols for sampling macroinvertebrates in wadeable streams. New Zealand Macroinvertebrate Working Group Report no. 1.* Prepared for the Ministry for the Environment. Sustainable Management Fund Project No. 5103. 57p.

Stark J. D. 1985: *A macroinvertebrate community index of water quality for stony streams*. Water and soil miscellaneous publication 87.

Stark J.D. 1998. SQMCI: A biotic index for freshwater macroinvertebrate coded abundance data. *New Zealand Journal of Marine and Freshwater Research 32*: 55-66.

Stark J.D., Maxted J.R. 2007. A user guide for the Macroinvertebrate Community Index. Prepared for the Ministry for the Environment. Cawthron Report No.1166. 58 p.

Appendix 1: Site photographs

Photo A4.1: Wainui Te Whara upper site, downstream of Valley Road. Very few fish were caught in the section with the retaining wall seen in the top of this photo.

Photo A4.2: Wainui Te Whara upper site, catching a juvenile trout

Photo A4.3: Wainui Te Whara middle site, facing upstream from private bridge

Photo A4.4: Wainui Te Whara lower site, facing upstream towards Garaway Street

Appendix 2: Waikato Regional Council Aquatic Life Recover Protocols for instream works (8/4/2015)

This document sets out how to undertake Bankside and Instream recovery of aquatic life as required under the comprehensive consent mitigation plan for some instream works sites (Doc# 2873674). All recovery activities must be carried out in accordance with all relevant WRC health and safety policies and procedures.

Where species sensitive to low dissolved oxygen (DO) are present both instream and bankside fish recovery is required. Staff should be prepared to undertake both bankside and instream fish recovery at any site where recovery is required in case DO sensitive species are found.

Bankside recovery

Objective: Quickly return as many fish/crayfish/mussels to the water as practical

Equipment

- Sacks (hessian or plastic weave)
- Bucket (large painting or nappy buckets are best)
- Garden gloves (rubber lined cloth appears to work best)

Process

1. Follow behind working machinery and collect fish/crayfish/mussels from the spoil and adjacent areas. Eels can be temporarily held in wet sacks but other species should be held in water filled buckets.
2. Return all living animals to the watercourse as soon as possible
3. Once the works have been completed undertake at least one more search through the entire works area for eels and crayfish that may have initially been missed

Do's

- Give priority to recovering and releasing non-eel fish species as they have the shortest life-span out of water
- Fish are easiest to spot immediately after being removed from the water so remain as close behind the machinery as it is safe to do so.
- When the machinery stops for any reason use that opportunity to search back through the spoil for any animals that may have been missed.
- Mussels tend to occur in patches so if you spot one search the nearby spoil for others
- Keep all animals as cool and moist as possible.
- Euthanaise badly injured animals rather than return them to the water
- Change the water in holding buckets regularly using water unaffected by instream works

- Use garden gloves when handling animals as these make gripping eels easier and reduce the risk of injury to fish.

Don'ts

- Keep any aquatic animal of water for any longer than necessary.

Instream recovery

Objective: Recover and hold sensitive fish species before releasing them where they will not be affected by the works.

Equipment

1 x	Holding tank or fish bin
2 x	Buckets
1 x	Long handled dip net
1 x	Short handled dip net

Process

1. Identify appropriate release site prior to commencing works. These may be upstream of the works or in an adjacent connected waterway. A fish must be able to readily move between the works site and the release site **to avoid the need for permits from DOC or MPI**.

2. Prepare holding tank using water from the watercourse before works begin

3. Recover any DO sensitive fish species observed struggling at the water surface using dip nets.

4. Transfer fish to the recovery tank/bin

5. Release the fish at the identified release site.

Do's

- Carry out bankside recovery simultaneously with instream recovery but make the recovery of struggling instream fish a priority.

- Fish are easiest to spot immediately after being removed from the water so remain as close behind the machinery as it is safe to do so.

- When the machinery stops for any reason use that opportunity to search back along the drain or through the spoil for any animals that may have been missed.

- Maintain water quality in the holding bin by changing it frequently if necessary. Water quality will deteriorate if large numbers of fish are held or if water temperatures are high

- Euthanaise badly injured animals rather than return them to the water

- Use garden gloves when handling animals as these make gripping eels easier and reduce the risk of injury to fish.

Don'ts

- Keep eels in the holding tank with DO sensitive fish

Appendix 3: Summary of proposed works on the Wainui Te Whara Stream

S4A Supplementary Ecological report, prepared specifically for stage two works - prepared by River Lake Ltd

Wainui Te Whara Stream morphology survey and design options 2016

Prepared for:

Whakatāne District Council

Wainui Te Whara Stream morphology survey and design options 2016

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Cover photo: Wainui Te Whara Stream meandering through watercress upstream of Douglas Street (16 April 2016)

RiverLake

Contents

1 Introduction

1.1 Background

The Whakatāne District Council is seeking resource consent to undertaken work on the Wainui Te Whara Stream in order to alleviate flooding. Works are proposed to lower and widen the bed to allow a peak discharge of 32 m^3/s flood with 300mm freeboard. The works are described in Opus (2015) and includes:

- Valley Road and Douglas Street: widen and deepen the channel base and batter slopes. Install about 140m of retaining wall structure. Add rip-rap downstream of Valley Road bridge. Replace Douglas Street bridge with a box culvert.
- Douglas Street to King Street: widen and deepen the channel base and batter slopes. Replace five private bridges.
- King Street to Hinemoa Street: widen and deepen the channel. Batter channel slopes and realign channel to accommodate the battered slopes. Replace King Street bridge with box culvert.

The replacement of the culverts and bridges has been consented and is partially completed (referred to as Stage 1). Resource consent is now being sought to undertake the stream works (Stage 2). River Lake Ltd undertook an ecological survey of the Wainui Te Whara Stream in September 2015, this included and assessment of potential ecological effects from the project and potential recommendations to mitigate these effects. It was concluded that in the absence of ecological design features the works propose in Stage 2 would reduce habitat for fish. However there is opportunity to sufficiently mitigate and compensate for this potential habitat loss so as to increase the overall habitat values in the stream (Hamill 2015).

One concern was the effect of widening the stream on water depth and it was recommended to install structures to help form a meandering base flow channel within the stream banks. River Lake was commissioned to build on the previous report and provide a more detailed assessment on the effects of stream widening and mitigation options.

This report describes the results of a stream morphological survey. It assesses the potential effects on ecology of widening the stream and proposes options to not only avoid / mitigate adverse effects, but also to enhance overall ecological values.

1.2 Site description

The Wainui Te Whara Stream has a catchment size of 5.75 km^2. The upper catchment consists of steep hillside predominantly covered by forest (64%) and farmland (35%). It cascades steeply down Mokoroa gorge and at the base of the hill, downstream of Valley Road, the gradient flattens and the catchment is urban. From Valley Road bridge the stream flows about 1.7km through Whakatāne urban area into the Awatapu Lagoon and the Whakatāne River. This section has been highly modified to improve flow and reduce flooding. It is straightened, channelised and confined within stop banks.

The 2015 ecology survey found that in the urban section of the Wainui Te Whara Stream, the riparian margin is mown grass and there is very little riparian vegetation suitable for fish cover. Despite the modifications the aquatic macroinvertebrate community is in reasonable condition. Sensitive species such as mayfly, stonefly and caddisfly were present at all sites and the Macroinvertebrate Community Index (MCI) score indicated 'good' conditions. There was also a reasonable diversity and abundance of fish in the stream but the spatial distribution was strongly related to the amount of riparian cover available (i.e. undercuts and overhanging vegetation) (Hamill 2015).

2 Method

The methodology described in this section was developed in consultation with Alastair Suren (Freshwater Ecologist) from Bay of Plenty Regional Council.

Morphology and habitat features of the lower Wainui Te Whara Stream were surveyed on 14 April 2016. The length of the stream was walked on from Hinemoa Street to Valley Road and measurements were taken at a total of 75 transects, each located about 20 metres apart. Transects were not located within about 5m of bridges or culverts.

The stream length was divided into sections based on the roads that crossed the stream, i.e. Hinemoa Street, Garaway Street, Tuhoe Street, King Street, Peter Snell Drive, Douglas Street and Valley Road (Figure 1.1, Appendix 1).

At the time of the survey the Wainui Te Whara Stream was flowing at 31 L/s. Prior to this time there had been a series of small floods on 26 March (peak flow 1000 L/s), 2 April (peak flow 800 L/s), and 4 April (peak flow 500 L/s)[1].

At each transect the following measurements were made:

- Full width full (m): a measure of bankfull width during a small flood and was approximated as the width at about 0.5m height.
- Wetted width (m): the wetted width during base flow.
- Flowing width (m): the width of channel with flowing water. This was only measured where aquatic macrophytes or sediment had confined the channel and quiescent water was either side. Also referred to as 'width confined'.
- Water depth (cm): This was measured at five points across the transect, true left, true right and three locations between. The edge measures were within 10cm of stream bank.
- Velocity (m/s). The water velocity at near the centre of flowing water, i.e. close to the maximum water velocity. This was measured using the ruler method described in Harding et al. (2009). The method is sensitive to about 0.14 m/s. Where the water velocity was too low for applying the method a velocity of 0.1 m/s was recorded.
- Soft Sediment (cm). Soft sediment was recorded at three locations across each transect by measuring the depth that a metal ruler could be pushed into the substrate.
- Undercut (cm). This was defined as undercuts or holes in the bank occurring less than 10cm from the water surface. The maximum depth of bank undercut within a two metre band of

[1] Flow data from Bay of Plenty Regional Council flow site at Mokoroa Gorge.

each transect was recorded. Where vegetation obscured the stream bank it was probed using a metal ruler. Large undercuts were generally due to gaps in boulders and were often not obvious to a casual observation.

- Overhang (m). This was a measure of over-hanging vegetation within 15cm of the water level The maximum depth of vegetation within a two metre band of each transect was recorded.

- Dominant substrate size. A visual estimate of substrate size was made across each transect. The two most dominant substrate sizes were recorded according to size categories in Clapcott et al. (2011), i.e.: silt (si) <0.6mm; sand (s) 0.6-2mm; small gravel (sg) 2-8mm; small medium gravel (smg) 8-16mm; medium large gravel (mlg) 16-32mm; large gravel (lg) 32-64mm; small cobble (c) 64-128mm; large cobble (lc)129-259 mm; boulder (b) >259mm.

- Percent plant cover (%). The percent of aquatic macrophyte cover in a two metre wide band across each transect.

The results were summarised as averages across each transect and as averages or proportions within individual sections of the stream.

Figure 2.1: The lower Wainui Te Whara Stream between Hinemoa Street and Valley Road, Whakatāne. The current length of sheet piling downstream of Valley Road is indicated on the map by the yellow line.

3 Results

3.1 Stream width, depth and velocity

The stream width at the base of the banks varied from about 2m to 4.8m; wetted width varied from about 1.2m to 3.6m. The wetted width was often reduced as a result of past bank slumping or boulders in the waterway (see photos in Appendix 1).

Base flow water depth was mostly less than 20cm but the stream becomes deeper in the Garaway and Hinemoa Street section, with six out of the 14 transects having an average water depth across the transect of >30cm. The deepest pools in this section were 55cm deep (Table 3.2, Figure 3.1 and 3.2). Generally the stream bed had a relatively consistent depth across the transect with the below water profile occasionally more V-shaped or angled due to slumping of soil from one bank.

A section of stream between Tuhoe and King Street had a wide wetted width (>3m) and very shallow water depth (<9cm). The maximum channel velocity in this section was reasonably high (0.2 m/s to 0.54 m/s) – probably due to the shallow water (mean <10cm) (Figure 3.1 and 3.2).

Generally the water velocity was quite variably between transects and in any particular section tended to be faster when the water was shallower (Figure 3.2). This reflects a very subtle riffle-run pattern within the stream. Water velocity also corresponded to stream width and was highest when the effective channel width for flowing water was narrow.

Where the flowing channel was constrained by watercress to less than a meter width the water velocity ranged from 0.31 m/s to 0.67 m/s, with the higher velocity corresponding to more shallow water depths (e.g. 14cm).

Downstream of Garaway Street the effective channel in which water flowed was narrowed to less than a metre by both the stream banks and macrophytes (usually watercress). Macrophytes also narrowed the effective channel for flowing water upstream of Douglas Street. This created more diversity of flow (e.g. fast runs, pools) and deeper water during base flow. Often the flowing channel was narrowed to a width of 0.8m with quiescent water on either side. The meander wavelength created by the macrophytes was between about 8 and 15m. The presence of macrophytes is seasonal, with much less cover during winter resulting in less flow diversity and shallower water depths for the equivalent flow.

3.2 Substrate and soft sediment

The dominant substrate size in the Wainui Te Whara Stream tends to decrease with distance downstream from Valley Road. Near Valley Road the substrate is predominantly small cobbles and large gravel, large gravels remain the dominant substrate until Douglas Street after which there is a gradual size reduction, with sand the most dominant cover downstream of Tuhoe Street. About 100m upstream of Hinemoa Street the current stream gradient increases and there are sections with large gravel and boulders (possibly from past stream protection works) (Table 3.1, Figure 3.3, and Appendix 3).

Sand was very common around the gravel substrate from downstream of Douglas Street (Appendix 2).

The depth of soft sediment increases downstream until Peter-Snell Street. There was high variability in the depth of soft sediment within and between transects which reflects the variability in the amount of the stream bed covered by gravels or compacted sand. Downstream of Peter Snell Street the stream is close to its clay base. Between King Street and Tuhoe Street the clay base forms the stream bed and sections like this had a high soft sediment depth (see Photo A3, Appendix 1). Where areas of deep soft sediment occurred at upstream sites these were often located on the stream edge and probably related to slumping of the stream banks.

The change in substrate size probably reflects a combination of reducing stream gradient and a change in sediment supply to the stream, with gravels coming from the upper catchment and finer sediment from the urban catchment. It may also reflect past sediment removal practices.

3.3 Aquatic macrophytes

There was considerable (>50%) cover of aquatic macrophytes (predominantly watercress) downstream of Garaway Street and upstream of Douglas Street to the start of the retaining wall; in contrast there was very low (3%-7%) macrophyte cover between Douglas Street and Garaway Street (Table 3.1, Figure 3.3). The reason for the different amount of macrophyte cover is not clear, but may reflect differences in stream substrate affecting resistance to floods. For example, upstream of Garaway Street large gravels provide a stable substrate but close to Valley Road the stream gradient is steep which may result in more shear force on plants during floods.

There was considerably more macrophyte cover in the stream and longer grass over-hanging the stream during the April survey compared to the September survey. The presence of watercress improved the stream ecology. Aquatic macrophytes help to process nutrients within streams and provide cover and food for fish and invertebrates. They also had a direct effect on hydrology during base flow conditions by narrowing the channel, increasing water depth upstream and increasing the diversity of flow conditions.

3.4 Overhanging vegetation and undercuts

Overhanging vegetation and stable undercuts or holes within the stream bank provide potential cover for fish. Of particular value for large fish are deep holes (e.g. >20cm). Shallow undercuts and overhanging vegetation (e.g. <10cm) assist with stream shading but are probably of limited value as fish cover. Deep undercuts were generally caused by gaps between large boulders in the stream bank. Deep undercuts occurred along the stream length but were much more common from about King Street downstream (Figure 3.4). This will be due in part to the channel works occurring upstream of King Street after the Easter 2014 floods.

Along both banks of the full length of stream surveyed (about 1500m excluding bridges), there were 13 undercuts of 20cm deep or greater and 41 of 10cm deep or greater. That corresponds to 8.7% and 27% of measurements for undercuts >20cm deep and >10cm deep respectively[2]. In the section with most undercuts (Hinemoa Street to Garaway Street), the frequency of undercuts was 14% (4/28) and 39% (11/28) for undercuts >20cm deep and >10cm deep respectively. It should be noted that we recorded the maximum depth of undercut or overhang found in a two metre length at each transect and most of the stream bank length did not have an undercut present.

Overhanging vegetation consisted mostly of rank grass that had not been mown during the summer. Most of this overhanging vegetation would not remain throughout the year because of mowing and reduced grass growth during winter (e.g. the banks had been mown prior to the September 2015 survey).

[2] This is based measurements at on both stream banks at 75 transects.

Stream sections with no vegetation overhang or undercuts occurred between Tuhoe Street and King Street (transects 22-26) and adjacent to the current retaining wall downstream of Valley Road (transects 67 to 70). These are examples of current stream morphology that should aim to be minimised after the proposed works.

Table 3.1: Stream morphology characteristics averaged across transects and stream sections

Stream section	No. transects	width full (m)	width wet (m)	width confined (m)	Depth (cm)	Velocity max (m/s)	Sed depth (cm)	undercut (cm)	overhang (cm)	% plants	dominant substrate
Hinemoa-Garaway	14	2.75	2.15	20% (0.8)	28.6	0.29	6.2	7.6	13.9	51.4	s
Garaway-Tuhoe	6	2.75	2.27		19.8	0.21	6.8	11.5	12.9	7.5	s
Tuhoe-King	7	4.03	2.97		12.5	0.26	8.4	3.6	3.2	3.6	sg/smg
King-Peter Snell	8	3.13	2.24		17.4	0.33	8.6	7.6	14.1	3.1	smg/mlg
Peter Snell-Douglas	16	2.77	2.07		14.0	0.36	3.7	3.8	12.1	3.0	mlg
Douglas-Valley Rd (ds wall)	15	3.20	2.62	80% (1.1)	18.3	0.41	2.4	3.2	17.8	55.1	lg/mlg
Douglas-Valley Rd (walled)	4	3.25	3.14	25% (2)	15.3	0.21	1.3	0.0	0.0	5.0	lg/mlg
Douglas-Valley Rd (us wall)	5	4.31	2.71		17.9	0.32	0.2	5.5	4.3	8.2	sc/lg

Width confined = % transects (and width) where flowing water was confined due to macrophytes or sediment.

Table 3.2: Stream morphology characteristics, range along stream sections after averaging across each transect.

Stream section	width full (m)	width wet (m)	width confined (m)	Depth (cm)	Velocity max (m/s)	Sed depth (cm)	undercut (cm)	overhang (cm)	% plants
Hinemoa-Garaway	1.9 - 4	1.2 - 3.1	0.6 - 1	13.8 - 47.2	0.1 - 0.66	1 - 16	0 - 29	0 - 29	10 - 90
Garaway-Tuhoe	2.6 - 2.9	1.4 - 2.9		14.2 - 23.4	0.1 - 0.44	1 - 10.3	0 - 26	6 - 20	0 - 15
Tuhoe-King	3 - 4.8	2.5 - 3.6		6.2 - 22	0.1 - 0.54	4.67 - 14	0 - 13	0 - 10	0 - 25
King-Peter Snell	2.7 - 3.5	1.6 - 3.3		12.8 - 24.2	0.1 - 0.56	1.7 - 15.7	0 - 28	10 - 23.5	0 - 10
Peter Snell-Douglas	2.1 - 3.6	1.3 - 2.5		8.6 - 21.4	0.1 - 0.64	0.7 - 9.3	0 - 14	5 - 27.5	0 - 15
Douglas-Valley Rd (ds wall)	2.9 - 3.7	1.8 - 3.3	0.8 - 1.8	11.6 - 26.2	0.1 - 0.67	0 - 9.7	0 - 8	2.5 - 31	10 - 90
Douglas-Valley Rd (walled)	3 - 3.4	3 - 3.3	2 - 2	11.6 - 21.4	0.1 - 0.44	0.7 - 2.3	0 - 0	0 - 0	0 - 20
Douglas-Valley Rd (us wall)	3.8 - 4.9	1.8 - 3.5		10.6 - 28	0.1 - 0.40	0 - 0.7	0 - 13	0 - 10	0 - 20

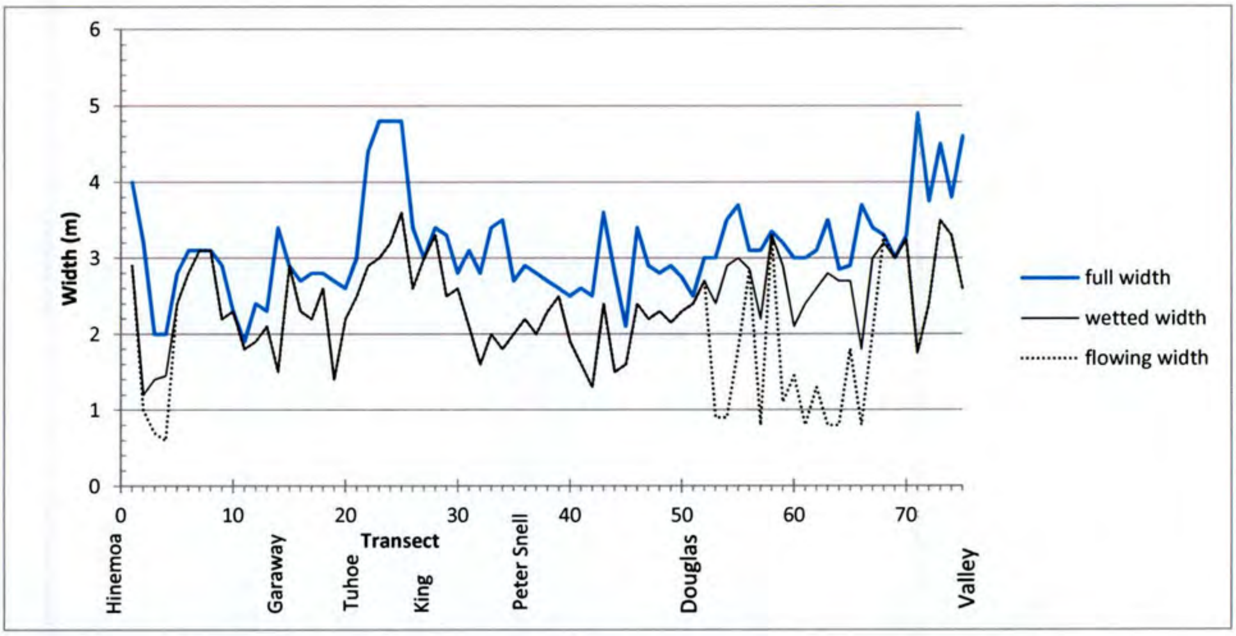


Figure 3.1: Width of the Wainui Te Whara Stream from Hinemoa Street to Valley Road (transects ca. 20m apart). Full width refers to the full width at the base of the stop banks.

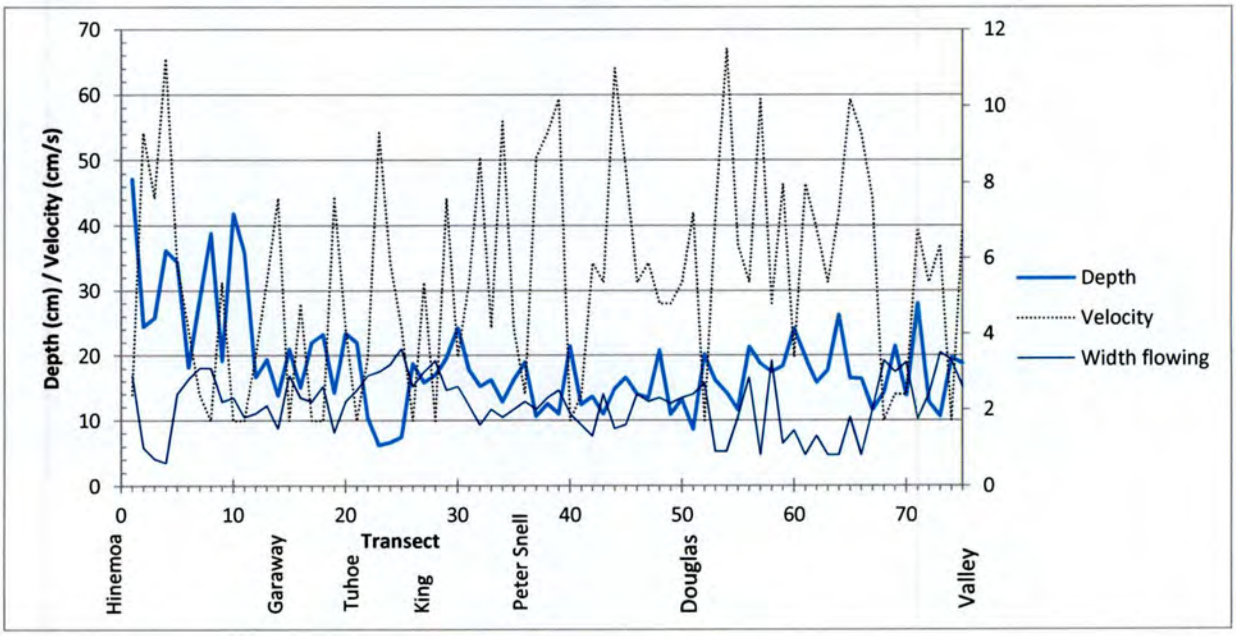


Figure 3.2: Velocity (mid-flow) and depth (transect mean) in the Wainui Te Whara Stream from Hinemoa Street to Valley Road (transects ca. 20m apart).

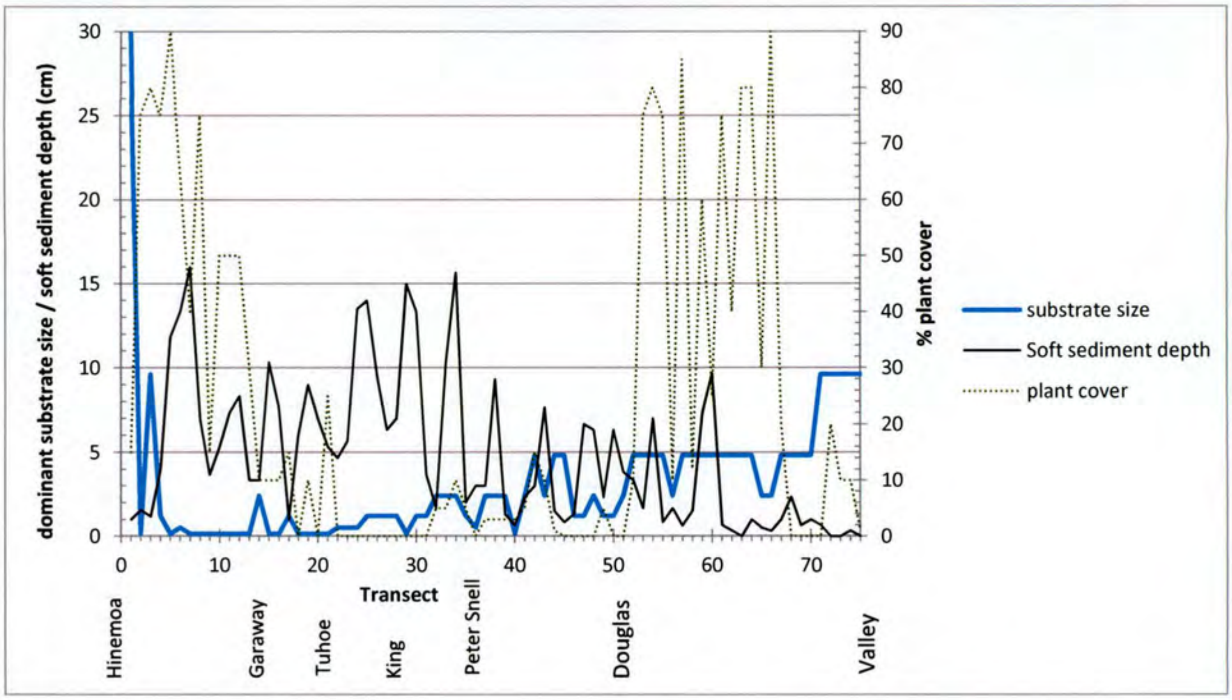


Figure 3.3: Dominant substrate size and aquatic plant cover in the Wainui Te Whara Stream from Hinemoa Street to Valley Road (transects ca. 20m apart).

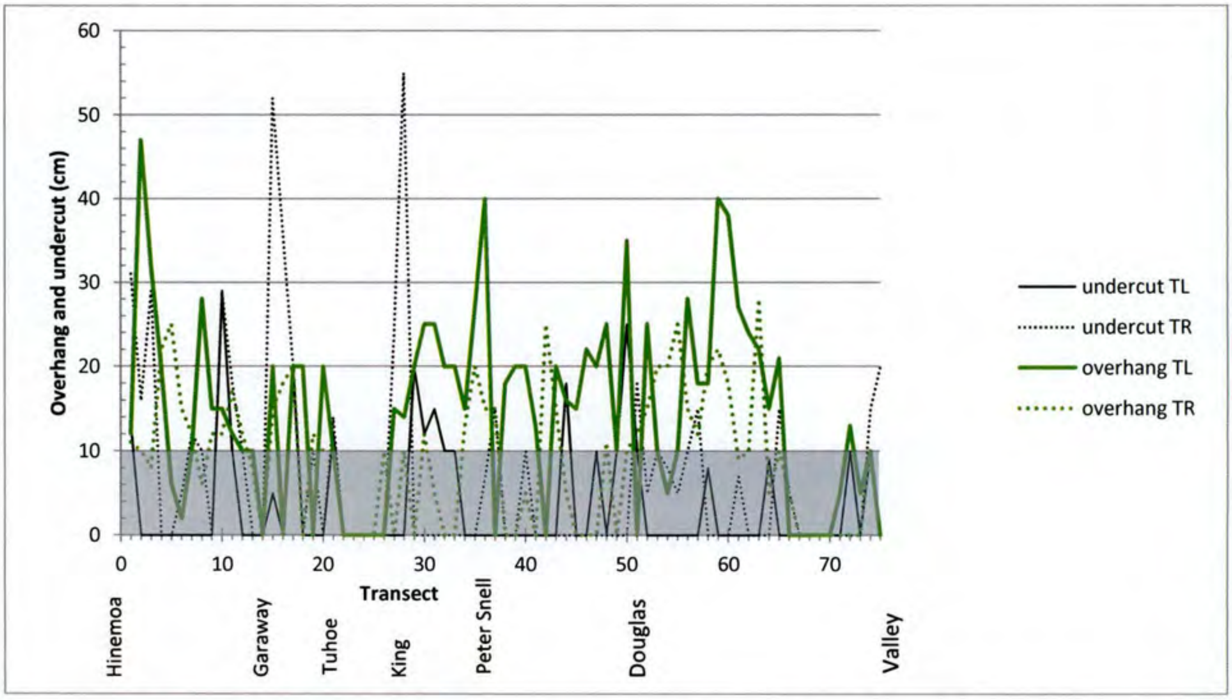


Figure 3.4: Maximum overhang and undercut at transects in the Wainui Te Whara Stream from Hinemoa Street to Valley Road (transects ca. 20m apart). Undercuts and overhangs less than 10cm (greyed area) have more limited value as fish cover.

4 Discussion

4.1 Potential effects of the works

The Wainui Te Whara Stream is highly modified but it still has a reasonably good macroinvertebrate community, and there is reasonable fish abundance along much of its length. Potential ecological effects from the proposed works were discussed in Hamill (2015). Apart from short term effects that occur during construction, a number of long-term ecological effects were identified that potentially could occur in the absence of any mitigation. These included:

- Loss of riparian fish habitat due to the works removing unconsolidated boulders within the stream bank and increasing the length of vertical retaining wall.
- Shallower water depth during base flow which may limit potential fish habitat and/or restrict fish passage.
- Potential reduction in substrate size or covering of gravels by fine sediments unless the gravel is replaced or augmented as part of the works.

The information collected as part of this report allows us to better quantify the effects of the works on fish habitat, water depth and flow regimes. The report also identified measures to avoid and mitigate these effects.

4.1.1 Depth and diversity of flow

A diversity of water depths and flow helps ensure a diversity of habitat for aquatic fauna. Most of the lower Wainui Te Whara Stream has relatively uniform and shallow water depths except where the flow has been constrained by macrophytes (e.g. upstream of Douglas Street) and in steeper sections upstream of Hinemoa Street where pools occur. Any further reduction in base flow water depth (and depth variation) is undesirable for ecology as it reduces habitat features and shallow water restricts fish passage.

The proposed works will widen the base of the stream and result in potentially shallower water depths from about 550m downstream of Valley Road Bridge. Between this location (downstream of the retaining walls) and King Street the cross sectional profiles indicate a 10% increase width, however if a comparison is made with the wetted width from this report the stream width will increase 47% on average. These are likely to result in a corresponding decrease in water depth (Table 4.1).

The actual effect on base flow water depth will depend on the extent to which the stream can form a new base flow channel, slumping of the newly form banks (if any) and the extent to which summer macrophyte growth can confine the flow. The current base flow channel is very subtle and partially due to the slumping of banks and boulders in the stream (Appendix 1). Aquatic macrophytes also help to constrain the flow during summer upstream of Douglas Street and downstream of Garraway Street. Following the works the depth across the channel could be very uniform and without assistance a new base flow channel is likely to take a long time to form. However, installing flow concentration features and profiling the stream after the initial widening and deepening work will considerably improve flow diversity and depth, and result in a corresponding improvement in stream habitat.

The Stream will be deliberately widened between Garaway Street and Hinemoa Street and (to a less extent) between Tuhoe Street and King Street to allow for a restored stream meander.

Table 4.1: Current and proposed average stream width at its base. Stream widths are shown for the 75 transects described in this report and 43 cross sections from Opus (2015) excluding the box culverts. The proposed increase width was calculated as a percentage from current as measured from Opus cross sections and as a percentage from current wetted width as measured from our April 2016 survey.

		from transects (this report)			from profiles (Opus 2015)				
Stream section	Chainage	mean width full (m)	mean wetted width (m)	mean depth (cm)	mean width current (m)	mean width proposed (m)	mean difference (m)	increase from current profile (%)	increase from wet width (%)
Hinemoa-Garaway	to 1730	2.8	2.2	28.6	2.8	3.5	0.8	29%	64%
Garaway-Tuhoe	to 1400	2.8	2.3	19.8	2.8	3.1	0.3	12%	37%
Tuhoe-King	to 1250	4.0	3.0	12.5	3.5	3.7	0.2	5%	23%
King-Peter Snell	to 1100	3.1	2.2	17.4	3.2	3.5	0.3	8%	54%
Peter Snell-Douglas	to 910	2.8	2.1	14.0	3.0	3.3	0.3	9%	59%
Douglas-Valley Rd (ds wall)	to 550	3.2	2.6	18.3	3.0	3.4	0.4	13%	29%
Douglas-Valley Rd (walled)	to 220	3.3	3.1	15.3	3.1	3.2	0.1	3%	2%
Douglas-Valley Rd (us wall)	0-130	4.3	2.7	17.9	4.0	3.9	-0.1	-3%	44%

Based on 43 profiles from Opus (2015) excluding culverts. Culverts are 5 to 6.8m wide.

4.1.2 Bank side cover for fish

Deep undercuts and holes within the stream bank provide important cover in the Wainui Te Whara Stream for large fish such as eel (see Hamill 2015). Large undercuts/bankside holes (>20cm deep) currently occur along 9% of the stream bank. These are typically caused by gaps between large boulders within the stream bank.

It is expected that the proposed works (in the absence of mitigation) will significantly reduce the frequency of undercut because most of the existing rocks that create them will be removed. Where rock protection is planned for the new embankment, this will be engineered to ensure stability and unlikely to contain large gaps suitable for fish. Over time, small undercuts may develop on the new embankment but the intent is that the channel embankments remain stable.

To maintain the current level of large eel holes along the stream, then features will be needed to provide for about 150 eel holes[3]. There are a several options for how fish habitat / eel holes are reinstated within an engineered channel. They could be built into the rip-rap wall as 'tuna town houses', or base-flow concentration structures could be designed to provide gaps within them or incorporate eel habitat devices. Providing 150 eel holes corresponds reasonably well with the number of features needed to drive a base flow meander pattern with a 16m wavelength along the stream.

Over-hanging vegetation on the Wainui Te Whara Stream banks also provides cover for fish. Most of this cover consists of unmown exotic grasses and is largely removed when the stream banks are mown (e.g. as was the cause during September 2015). The stream banks will have similar vegetation after the project works because there are constraints on what can be planted on the stream banks so as to ensure sufficient flood capacity. However, where the flood plain can be widened (e.g. downstream of

[3] Calculated as 9% of 1630m of stream = 147. The 1630m length of stream is the estimated stream length excluding the length currently in culverts or bridges. This assumes large hoes (>20cm deep) are of most ecological value and there was only one of these per 2m section surveyed – which was predominantly the case.

Garaway Street), the stream can be naturalised and more extensive riparian planting can occur. This will provide a net positive effect in terms of fish cover and food.

4.1.3 Substrate

Gravels and cobbles provide an important function in streams by providing a stable substrate for macroinvertebrates to live and biofilms to form. The proposed works will remove and replace gravels onto the stream bed so as to ensure that a gravel base remains in the stream. It is recommended that the stream is also augmented with additional gravels (predominantly large and medium large). The reasons for this are:

- The stream will be widened so additional gravel will be needed to achieve the current depth.
- Gravels should be sufficiently deep to allow for the formation of riffles and pool sections. Very thin layers of gravel can increase bed erosion.
- The stream gradient will be changed by the works (e.g. steeper downstream of Garaway Street) so the current substrate does not necessarily reflect what will be appropriate after the works. Gravel traps upstream of Valley Road means that it may take a long time for gravel to be supplied naturally. To account for this, gravels should be provided as substrate along the stream length and allowed to come to equilibrium over time.
- Watercress growth upstream of Douglas Street corresponds to large gravel substrate. Providing this more stable substrate along the stream length may allow more watercress cover downstream of Douglas Street. This would be positive for habitat diversity.

Fine sediment deposition on a stream bed has significant detrimental effects on biota by clogging the interstitial spaces used as refuges by benthic invertebrates and fish, by altering food resources and by removing site for laying eggs (Clapcott et al. 2011). The works requires digging into the silty-clay base material and will release fine sediment. This will have a short-term adverse effect on the stream. It is recommended that the release of fine sediment is minimised by incorporating fine sediment traps that are regularly clear out (e.g. the new box culvert at Douglas Street is currently acting as fine sediment trap). Also, work should be timed so that replacement of gravels occurs after upstream works that will release fine sediment.

4.2 Stream design features to avoid and mitigate adverse ecological effects

There are several design features that can be included within the proposed works that could avoid and mitigate adverse long term ecological effects while still retaining the intended hydraulic capacity. There is always some uncertainty in exactly how a stream will respond to river restoration activities and it is good practice to focus on long lengths of stream rather than short segments, and to focus more on restoring river functions rather than installing individual structures (Shields et al. 2003). In this context I have used the estimates of potential lost fish cover as a guide to inform mitigation and restoration.

Upstream of King Street the features that can be incorporated in the stream design are constrained by the width of the flood channel and the need to maintain hydraulic capacity. More room is available in the section downstream of Garaway Street and between King Street and Tuhoe Street. In these areas the flood channel can be made wider to allow greater meander amplitude, a wider flood plain, and larger, overhanging riparian vegetation.

This section describes the stream design features in broad terms. It is intended that the information provided is suitable for the purpose of resource consenting, with more detailed design needed for many of the features prior to construction.

4.2.1 Stream design principles

The proposed stream design features have been guided by providing features that mimic or restore natural stream functions that fit within the room available and still allow sufficient hydraulic capacity during floods. Channel widths and meander wave lengths have been based on what currently occurs in the stream after a period of being undisturbed.

Some good and bad examples of stream habitat and functions are already found in the stream. An example of reasonably good flow diversity is the meanders occurring between macrophytes in the section of stream above Douglas Street in April 2016 (see cover photo and Photo A6). There were a range of flow types, substrate sizes and water depth, also the watercress provided good fish cover. However, proper pools or riffles were absent and the features were only seasonally present. An example of poor habitat and low diversity is the wide shallow section of stream about 50m downstream of King Street. The section had uniform flow, few gravels, very shallow water (<10cm) and no instream of riparian cover for fish. This is an example of what the stream should <u>not</u> look like after the works.

The proposed features aim to:

- Increase the diversity of the flow regime. This will be done by concentrating the base flow, use of vanes, and augmenting gravel in riffles. These structures will help form riffles, runs, and pools within the stream.
- Increase habitat diversity for aquatic life. This will occur through use of fish habitat devices, increased diversity of the flow regime, and increase riparian cover and adding wood (the last two downstream of King Street).
- Maintain stream substrate diversity and stability. Substrate will be appropriately sized to resist erosion and allow the formation of a riffle/pool sequence. Fine sediments from works needs to be minimised to ensure open interstitial spaces in the gravels.

Additional restoration features are proposed for the sections downstream of King Street. In this section there are additional restoration aims to:

- Provide for a mini-flood plain within the stop banks in sections that can be widened (i.e. between King and Tuhoe and between Garaway and Hinemoa Street);
- Provide riparian plant cover overhanging the stream and within the flood plain (but not on the stop bank embankments).

The extra space downstream of Garaway Street also allows for creating a bigger base-flow meander (increasing flow diversity) and providing habitat diversity through use of wood.

4.2.2 Flow Concentration Structures – meanders, depth and diversity of flow

Flow concentration structures aim to provide a diversity of base-flow, increased base-flow water depth and create a base-flow meander. Slower water behind the features may help macrophytes to resist floods. This would add further benefit for habitat and flow diversity but direct planting is not intended for most of the stream.

Upstream of King Street flow concentration structures are intended to have a low profile and will not be planted so as to not minimise their impact on channel flood capacity, and allow for future removal of any accumulated sediment. Downstream of King Street, where the channel can be widened, meanders can be larger, grade into a mini-flood plain and incorporate riparian plants.

Meanders help to increase complexity of the instream habitat and hydraulic regimes, and improve hydraulic functions. A natural meander wavelength is typically about 7-14 times the bank-fill width, but can be less (Madsen 1995, Harman and Starr 2011). The meander wavelength observed in Wainui Te Whara Stream in areas with bank slumping is about 16m and the channel meandering through the watercress has a wavelength of about 8 to 10m.

The proposed design for flow concentration structures are:

- Structures should be long (about 2.5 to 3m) so as to minimise erosive forces and increase the influence of faster flows between structures. The front edge should be lower than the downstream end.

- The height of the structure should be about 40cm above the stream bed (grading lower on the upstream and inner edges).

- Narrow the base-flow channel to about 1 to 1.7 metres wide. The channel will need to be narrower (closer to 1m) if holding back water rather than forming a meander pattern. It is proposed to use a range of widths rather than a single repeated pattern.

- Structures should be placed on alternative stream banks with centres of the channel section about 8 m apart so as to help form a meander wavelength of about 16 m.

- The structures are not expected to cause any bank scouring due to relatively low base flow velocities and their low profile. However, if there is concern about erosion then the opposite bank could be protected by either rock or fascines. Fascines are bundles of brushwood or small poles. They can be useful features in streams because they diffuse flow and provide habitat for koura and small fish.

- Channel profiling should be considered to augment what is created by meanders (Figure 4.1). This might include deepening by about 30cm in the channel immediately downstream of the structure and adding additional gravel to create a small riffle about halfway between structures.

There are a number of options for constructing flow concentration structures. The proposed option is to use boulders (e.g. 600mm diameter) and half bury them in the stream bed. Ideally the boulders should be placed so that they are in compression (e.g. leaning on each other in a downstream orientation). This approach allows gaps can be left between large boulders to provide fish habitat. Structure design and initial construction supervision may be needed to ensure that gaps provided.

Ideally the flow concentration structures are installed from about 250m downstream of Valley Road Bridge. The section upstream of this (i.e. the retaining wall and upstream) has a reasonably steep gradient and it is recommended that boulders are placed throughout this section to provide flow diversity (as provided for in the Stage 1 resource consent).

Installing these structures along the full length of stream will more than account for the effects of widening. It is a higher priority to install flow concentration devices downstream of Douglas Street compared to upstream because summer macrophyte cover tends to concentrate flow upstream of Douglas Street anyway. Also this section is has greater natural gravel replenishment.

Installing flow concentration structures in the section between King Street and Tuhoe Street will significantly improve the habitat over its current situation. Installing flow concentration structures in the section downstream of Garaway Street will help ensure a similar diversity of flow regime is maintained, however widening the stream in this section and providing a planted flood plain within the stop banks will improve the habitat quality in this section.

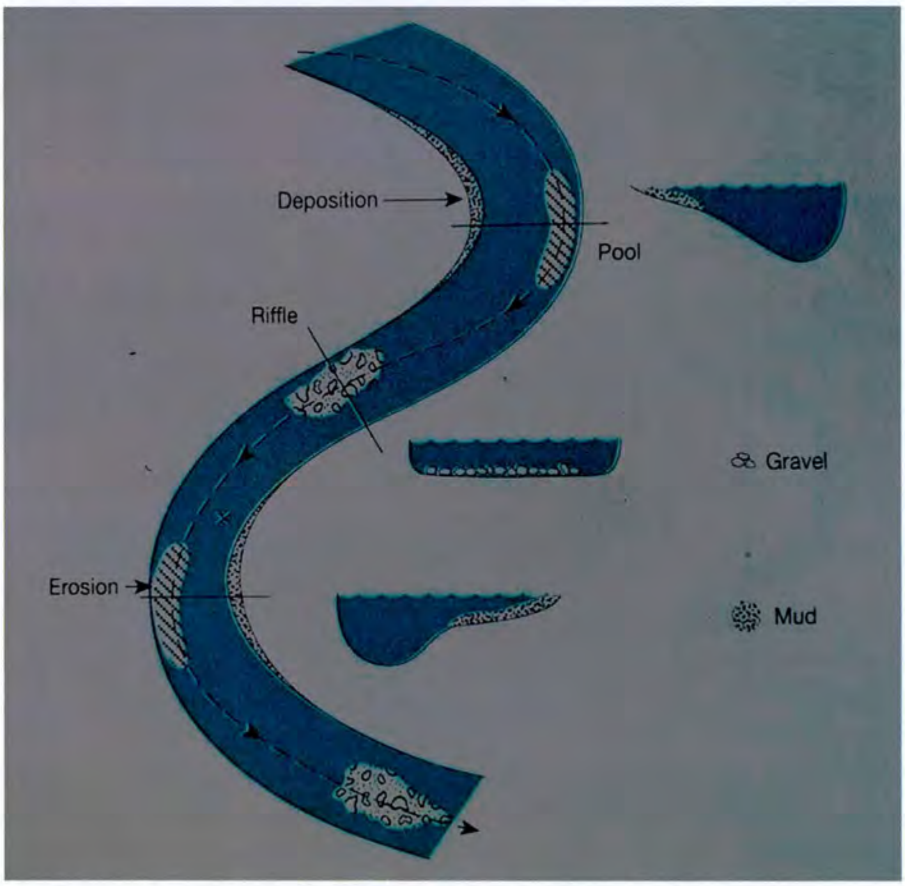


Figure 4.1: Formation of regular current, bend and depth conditions with a meander pattern (from Madsen 1995)

4.2.3 Vanes – gradient control and protecting corners

The stream bed level below Valley Road will be lowered by about 1 metre from its current level. The concrete base of the bridge currently has a drop-off that would restrict fish passage to some degree during base flows. Grade control features will be required downstream of the bridge to ensure that fish passage through the Valley Road culvert becomes better rather than worse. V-vanes are one way to achieve this while also reducing the risk of bank erosion. Multiple V-vanes can be used to create a step-pool sequence or they can be used in combination with rock ramps.

A V-vane (or cross-vane) could also be considered downstream of King Street culvert to hold back water depth in the culvert as the new stream gradient will increase downstream. It may also be a useful way to channel water into the Douglas Street culvert.

J-hook vanes help direct and channel flow around a corner and protect the stream banks. The use of this type of structure should be considered on the corner downstream of Valley Road Bridge; and on the corners 280m upstream of Douglas Street Bridge and 100m downstream of Douglas Street Bridge. In this situation they are intended to augment the rock bank protection rather than replace it.

The benefit of V-vanes and J-hooks is that they are very effective at achieving a stable channel form. They decrease near bank velocity and shear stress and reduce scour. In addition they maintain fish passage, create fish habitat by providing refuge during floods, create pools for fish habitat during base flow and create fish feeding lanes in flow separation zones (Rosgen 2006).

Vanes and J-hooks are more than just a pile of rocks. In order to protect stream banks, direct flow, stay in place during floods and not be 'out flanked' during floods they need to be properly designed and constructed. Details designs should be made prior to construction including the grade of material. In general they should look like the diagrams in Figure 4.2 and 4.3.

Vanes provide fish habitat in their own right but also work very well in combination with fish habitat structures placed adjacent to pools created on the downstream end of the structures.

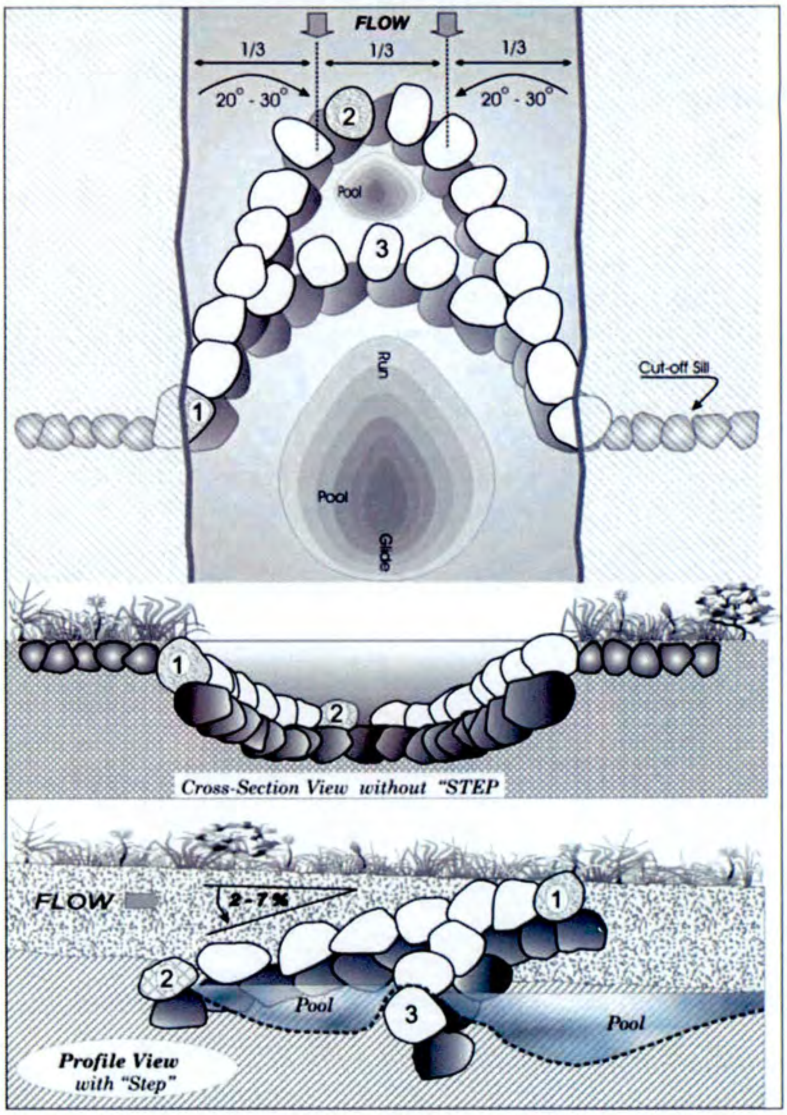


Figure 4.2: Cross Vanes in cross-section, profile and plan view (from Rosgen 2006)

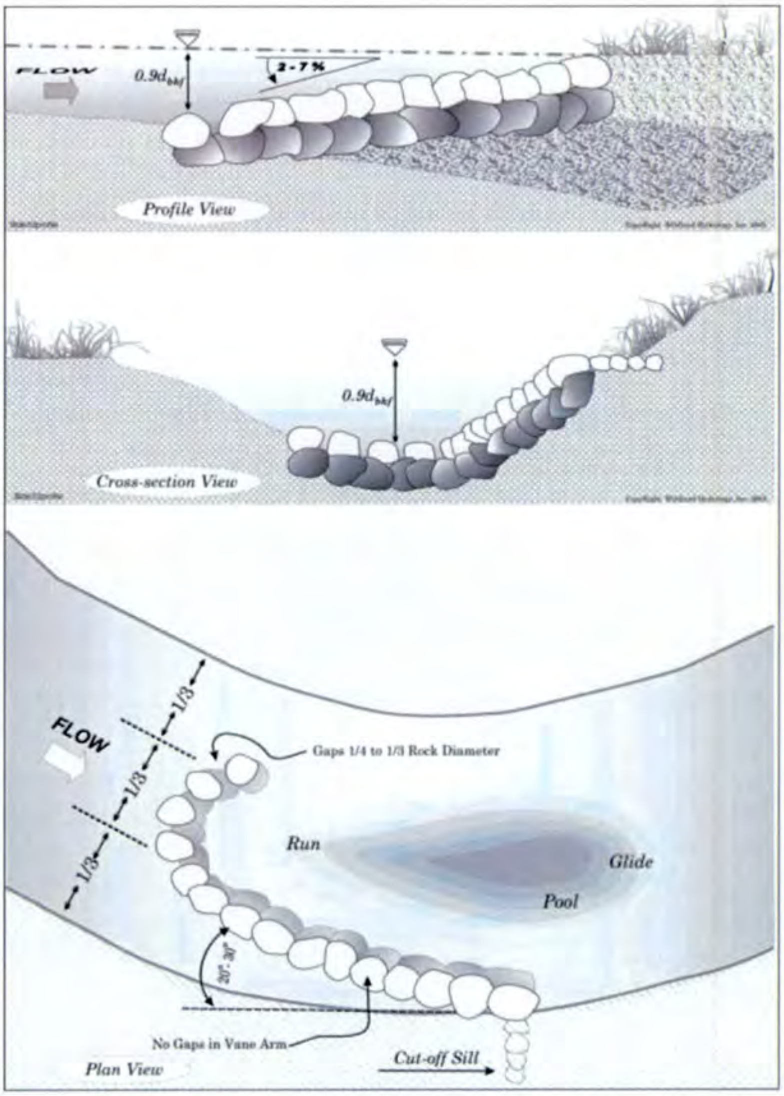


Figure 4.3: J-Hook vane in cross-section, profile and plan view (from Rosgen 2006)

4.2.4 Fish habitat (e.g. holes for eels)

Flow concentration structures constructed from boulders will provide fish cover if constructed so as to allow voids between some rocks. The degree to which rocks create cover and habitat for larger fish depends on their placement and size. They need to be placed so as to allow voids between boulders adjacent to the water.

This report estimated needing to reinstate about 150 large eel holes along the length of the stream. This would be achieved if there was only one large hole within the boulders of each flow concentration structure. Based on 8m spacing's (and excluding culverts) there would be about 130 structures downstream of Douglas Street and about 31 between Douglas Street and the retaining wall.

In practise some structures will provide multiple deep holes. The precise number will depend on boulder placement and how the level of the stream bed moves over time. It is recommended that a specimen design is developed for the structures and the construction of the initial structures is supervised to ensure that they are installed with appropriate gaps while still being stable.

There are several options for creating structures to provide additional fish habitat. These are not proposed as part of Stage 2 works, but 'tuna town houses' are being installed as part of Stage 1 works and further structures could be considered as part of any additional stream restoration measures.

Tuna town houses are constructed habitat within stream banks or structures that provides cover for eel and other fish. They can be small e.g. 600mm sections of 110mm nova flow pipe, medium (e.g. 160mm diameter nova flow pipe bent in a U-shape through two cinder blocks); or large (e.g. 2m sections of 450mm diameter Farmboss pipe and stuffed with 160mm nova flow pipe). They are generally installed within stream banks (e.g. rip-rap) and perpendicular to the stream flow.

Habitat devices can also be installed parallel to the water flow along stream banks or within culvert. An example of this configuration would be using 160mm pipe, blocking the upstream end and drilling holes in the side to allow fish to enter. They need to be anchored to the stream bank or bolted to concrete within culverts.

4.2.5 Substrate

Stream gravels should be removed and stored prior to deepening works and replaced after the works are completed. The gravel size tends to reduce with distance downstream so gravels should be returned to a similar location from which they were taken (e.g. gravel taken from upstream of Douglas Street are returned to upstream of Douglas Street).

In addition, additional gravel should be added to augment what is already in the river system. The gravels should be a mix of medium-large gravel to large gravel, with a bias to large gravel further upstream. The stream will naturally try and form riffles between bends (e.g. between flow concentration features). The additional gravel should be added to help create riffle sections between flow augmentation devices. The gravel depth should be about 30 to 40 cm deep, but this may not be evenly distributed across the stream.

4.2.6 Riparian vegetation on flood plain downstream of King Street

The Whakatāne District Council owns reserve land between King Street and the Awatapu Lagoon and there is potential to widen the stream between King Street and Tuhoe Street, and between Garaway Street and Hinemoa Street. In these sections the stream should be further widened and a meander created using flow concentration structures. Unlike further upstream, the meanders should have larger amplitude and the structures should grade to a higher profile and a mini-flood plain will be formed within the stop banks. Native riparian vegetation should be planted within the flood plain but the stop bank embankments are intended to in grasses.

Consideration should be given to incorporating wood material within the stream and anchoring it to the stream bed or within structures. Wood increases the retention of leaves and provides habitat for fish but should be placed so as to avoid scouring. This restoration would have multiple benefits for macroinvertebrates, fish, reduced water temperature, shading to reduce periphyton growth, aesthetics and improving people's connection to the stream.

The width of the stream-belt (i.e. flood plain) should be at least 3.5 times the bank-fill width to allow a stream to properly meander. For the section downstream of Garaway Street it is expected that the base of the stop banks will be greater than five metres apart.

Riparian vegetation is an important part of stream ecosystems. It helps to stabilise banks, provides hanging habitat for aquatic life, shade the stream, reduce high water temperatures, provide leaf and woody debris to the stream, acts as a filter, reduce flow velocities, provide habitat for adult insects that use the stream.

It is not proposed to plant any vegetation within the channel upstream of King Street although it is likely that grasses will colonise some areas narrowed by flow concentration structures, as currently occurs on areas of slumped stop bank. However in sections downstream of King Street it is proposed to plant vegetation within the stop banks (i.e. within the flood channel).

It is recommended that tussock like plants are densely planted in groups close to the water edge to over-hang the water (e.g. *Carex secta*). On higher ground (but still within the flood channel) plant species might include *Juncas* spp. (e.g. *J. gregiflorius* and *J. sarophorus*). Where possible, the plants should be eco-sourced. A more detailed planting plan should be developed prior to planting.

4.2.7 What to do and where

The key features to avoid and mitigate adverse ecological effects and to improve overall ecology in the Wainui Te Whara Stream are summarised below in Appendix 4.

5 Conclusions and recommendations

The proposed works on the Wainui Te Whara Stream offers the opportunity to not only increase hydraulic capacity during floods but to also to improve the aquatic ecology. Widening the deepening the stream on its own will reduce aquatic habitat and fish values, however applying stream restoration principles to incorporate habitat features would significantly improve stream ecology values in the long term. The project will have short term adverse ecological effects during construction, but if the project incorporates the proposed mitigation and stream design features then the long term ecological effects will be positive. Given this caveat, I expect that the ecological effects will, overall, be less then minor.

Actions recommended in this report and by Hamill (2015) to avoid or mitigate adverse effects from stream works are:

- Install structures to constrain base flow and create a base flow meander within the channel (wavelength about 16m). Detailed design can be provided prior to construction.
- Incorporate gaps to act as fish habitat between boulder of flow concentration structures.
- Incorporate vanes below selected culverts and on stream corners. Detailed design can be provided prior to construction.
- Replace stream gravels in the stream once the stream has been deepened, deepen pool sections and add additional gravels in riffle sections.
- Widen the stream flood plain in the section below Garaway Street and between Tuhoe Street and King Street. In these widened sections allow for an increased amplitude of stream meander and riparian planting of native vegetation within the flood channel. Detailed design can be provided prior to construction.
- Apply fish recovery protocols during stream earthworks and sediment removal.

- Minimise the frequency of future sediment removal by developing objective and robust criteria to trigger sediment removal that corresponds to flood flow capacity.

References

Clapcott, J.E., Young, R.G., Harding, J.S., Matthaei, C.D., Quinn, J.M. and Death, R.G. 2011. *Sediment Assessment Methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values.* Cawthron Institute, Nelson, New Zealand.

Goodman JM, Dunn NR, Ravenscroft PJ, Allibone RM, Boubee JAT, David BO, Griffiths M, Ling N, Hitchmough RA, Rolfe JR 2014. *Conservation status of New Zealand freshwater fish, 2013.* New Zealand Threat Classification Series 7.

Hamill KD 2015. *Wainui Te Whara Stream survey 2015.* Prepared for Whakatāne District Council by River Lake Ltd.

Harding J.S., Clapcott J.E., Quinn J.M., Hayes J., Joy M., Storey R., Greig H., Hay J., James T., Beech M., Ozane R., Meredith A., Boothroyd I. 2009. *Stream habitat assessment protocols for wadeable rivers and streams of New Zealand.* University of Canterbury, NZ.ISBN 978-0-473-15151-5

Harman W.R., Starr 2011. *Natural Channel Design Review Checklist.* US Fish and Wildlife Service, Chesapeake Bay Field Office, Annapolis, MD and US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Wetlands Division. Washington, D.C. EPA 843-B-12-005

Madsen BL 1995. *Danish watercourses – ten years with the New Watercourse Act.* Danish Environmental Protection Agency. Ministry of Environment and Energy, Denmark.

Opus International Consultants 2015. *Wainui Te Whara channel capacity optimisation Concept Design Report.* Prepared by Gareth Francis for Whakatāne District Council.

Roisgen DL 2006. *The cross-vane, W-Weir and J-Hook Vane structures (updated 2006), and their description, design and application for stream stabilization and river restoration.* Wildland Hydrology. Colorado.

Shields FD, Copeland RR, Klingeman PC, Doyle MW, Simon A 2003. Design for stream restoration. *Journal of Hydraulic Engineering* 129:8 575-584

Appendix 1: Site photographs

Photo A1: Wainui Te Whara Stream upstream of Hinemoa Street (facing upstream 14 April 2016). The stream section is relatively steep with potential fish cover amongst boulders.

Photo A2: Wainui Te Whara Stream downstream of King Street (facing upstream 14 April 2016).

Photo A3: Wainui Te Whara Stream downstream of King Street (facing upstream 14 April 2016). In this section the stream is wide and shallow.

Photo A4: Wainui Te Whara Stream upstream of King Street and private bridge (facing downstream 14 April 2016).

Photo A5: Wainui Te Whara Stream downstream of Douglas Street (facing downstream 14 April 2016).

Photo A6: Wainui Te Whara Stream at bend upstream of Douglas Street (facing downstream 14 April 2016).

Photo A7: Wainui Te Whara Stream downstream of Valley Road during a small flood (18 April 2016).

RiverLake

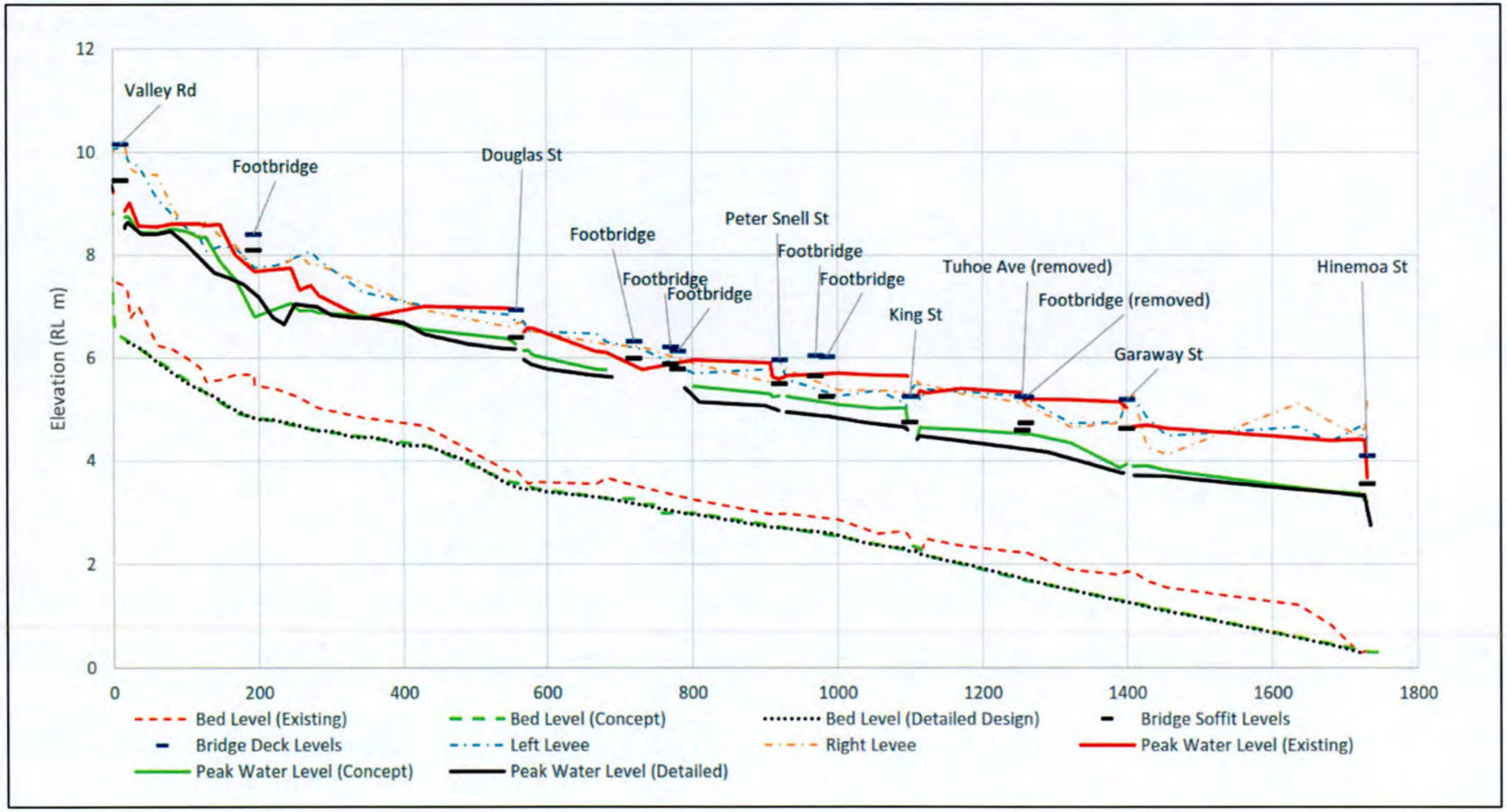
T	section	width full	width wet	width active	Depth TL	Depth a	Depth b	Depth c	Depth TR	Velocity max (m/s)	Sed depth 1	Sed depth 2	Sed depth 3	under-cut TL	under-cut TR	over-hang TL	over-hang TR	substrate 1	substrate 2	substrate 3	% plants
52	Douglas-Valley Rd (ds wall)	3	2.7		19	25	25	20	12	0.10	1	8	1	0	5	25	15	lg			10
53	Douglas-Valley Rd (ds wall)	3	2.4	0.9	10	15.5	19	20	16	0.42	0	0	5	0	10	10	20	lg	mlg		75
54	Douglas-Valley Rd (ds wall)	3.5	2.9	0.9	12	15	16	15	13	0.67	6	3	12	0	8	5	20	lg	mlg		80
55	Douglas-Valley Rd (ds wall)	3.7	3	1.8	13	12	10.5	13.5	9	0.37	1	1	0.5	0	5	10	25	lg	mlg	s	75
56	Douglas-Valley Rd (ds wall)	3.1	2.85		22.5	24	22	18	20	0.31	2	2	1	0	10	28	15	mlg			10
57	Douglas-Valley Rd (ds wall)	3.1	2.2	0.8	15	26	25	18	10	0.59	0.7	0.5	0.7	0	15	18	12	lg	sg		85
58	Douglas-Valley Rd (ds wall)	3.35	3.3		17	18	18	16	18.5	0.28	2	0.5	2	8	0	18	20	lg	sg	si	12
59	Douglas-Valley Rd (ds wall)	3.2	2.9	1.1	21	18.5	17.5	18	17	0.46	20	1	1	0	0	40	22	lg	mlg		60
60	Douglas-Valley Rd (ds wall)	3	2.1	1.45	22	27	23	25	23.5	0.20	5	5	19	0	0	38	18	lg	smg		25
61	Douglas-Valley Rd (ds wall)	3	2.4	0.8	18.5	19	19	23	19	0.46	2	0	0	0	7	27	9	lg	sg		75
62	Douglas-Valley Rd (ds wall)	3.1	2.6	1.3	11	15	16	15	22	0.40	0	1	0	0	0	24	10	lg	smg		40
63	Douglas-Valley Rd (ds wall)	3.5	2.8	0.8	12	16	24	25	12	0.31	0	0	0	0	0	22	28	lg			80
64	Douglas-Valley Rd (ds wall)	2.85	2.7	0.8	27	36	28	26	14	0.42	0.5	2	0.5	9	0	15	5	lg			80
65	Douglas-Valley Rd (ds wall)	2.9	2.7	1.8	15	19	16	14	18.5	0.59	0	0.5	1	0	15	21	10	mlg	s		30
66	Douglas-Valley Rd (ds wall)	3.7	1.8	0.8	14	15.5	19	20	13.5	0.54	1	0	0	0	5	0	5	mlg			90
67	Douglas-Valley Rd (walled)	3.4	3	2	15	14	13	10	6	0.44	1	1	1	0	0	0	0	lg	mlg		20
68	Douglas-Valley Rd (walled)	3.3	3.2		14	13	11	14	19	0.10	1	2	4	0	0	0	0	lg	mlg		0
69	Douglas-Valley Rd (walled)	3	3		20	20	20	22	25	0.14	1	1	0	0	0	0	0	lg	mlg		0
70	Douglas-Valley Rd (walled)	3.3	3.25		17	13	9	14.5	15.5	0.14	0	1	2	0	0	0	0	lg	mlg		0
71	Douglas-Valley Rd (us wall)	4.9	1.75		11	16	30	40	43	0.40	2	0	0	0	0	5	0	sc	lg		0
72	Douglas-Valley Rd (us wall)	3.75	2.4		18	11.5	12	12	10	0.31	0	0	0	10	0	13	0	sc	lg		20
73	Douglas-Valley Rd (us wall)	4.5	3.5		11	10	13	13	6	0.37	0	0	0	0	0	5	0	sc	lg		10
74	Douglas-Valley Rd (us wall)	3.8	3.3		17	17	19	20	25	0.10	1	0	0	10	15	10	10	sc	lg		10
75	Douglas-Valley Rd (us wall)	4.6	2.6		10	18	23	24	19	0.40	0	0	0	0	20	0	0	sc			1

Notes: Where the velocity was too small to measure it was recorded as 0.1 m/s.

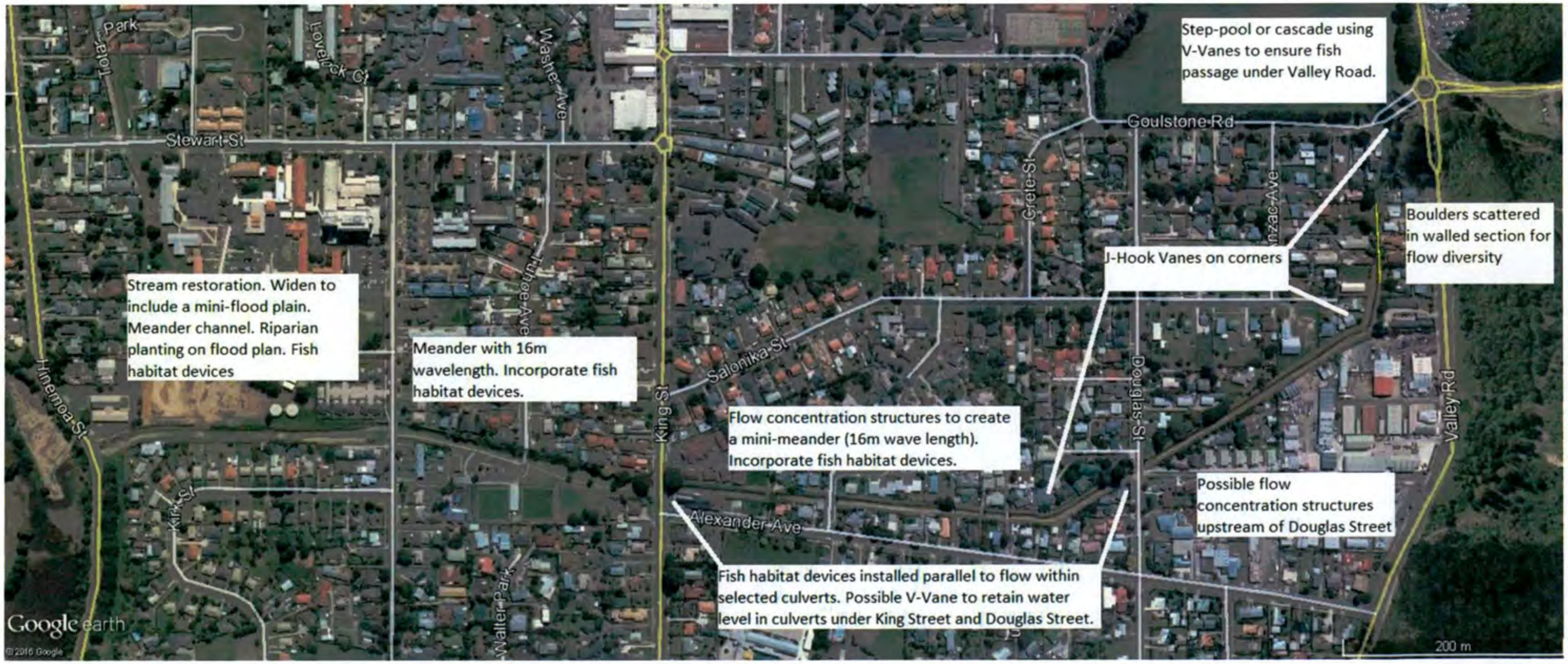
Transect 56: The mid-stream water velocity at this transect was influenced by watercress narrowing the stream 2m upstream to 0.8m wide and a velocity of 0.46m/s.

Appendix 3: Current and proposed profiles for Wainui Te Whara Stream

Reproduced from Opus (2015) Flood level profile of the modified Wainui Te Whara Stream, for a discharge of 32 m3/s, comparing existing, concept, and detailed design situations (case A).



Appendix 4: Key features proposed for Wainui Te Whara Stream to maintain and improve stream ecological functions.



S5 NES/contaminated land assessment - prepared by Opus International Consultants

Preliminary Site Investigation (PSI)

Wainui Te Whara Stream Whakatane

Preliminary Site Investigation (PSI)

Wainui Te Whara Stream Whakatane

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Date: November 2015
Reference: 2-34250.06
Status: Final

Contents

1 Executive Summary

Site history, anecdotal evidence, historical aerial photography site investigations and site inspections have identified HAIL activities (Market Gardening and Waste Disposal to Land) within the area of works. Potential contaminants of concern are persistent pesticides and metals from historic market gardening and dioxins and PCPs from woodwaste disposal.

Discussion with BOPRC staff indicate that woodwaste is unlikely to be present within the development footprint, but the exact extent of woodwaste buried may extend further than currently thought. It is not considered that the past market garden activity will result in modern day contamination levels that will exceed the Soil Contaminant Standards (SCSs) identified. This has been established reviewing scientific case studies completed by PDP (2007) and Gaw et al (2005)[1].

It is therefore considered to be *highly unlikely* that the area to be disturbed represents a significant risk to human health or the environment, but due to the slight unknown with the woodwaste extents it would be prudent to have an unexpected discoveries protocol for those areas potentially affected.

It is recommended that this report is forwarded in full to:

- Whakatāne District Council Regulatory Department for the purpose of compliance with the NES.
- Bay of Plenty Regional Council to confirm that they agree with the conclusions in this report and that the site is not subject to Rule 35 in the Regional Water and Land Plan and is not in need of a resource consent.

2 Scope of Work

Development of the Wainui Te Whara stream to improve flood defences is due to be undertaken and a provisional search indicated that HAIL activities were present on or adjacent to the stream. Disturbance was also deemed to exceed the limits within the National Environmental Standard (NES) Regulations for assessing and Managing Contaminant in soil to protect human health. Opus International Consultants were therefore requested to complete an investigation to assess the potential for contamination (hazardous substances) that may be present to ensure the work meets the requirements of the NES and the Contaminated Land Management Guidelines No1 Reporting on Contaminated Land Sites in New Zealand (CLMG1).

[1] Gaw, S. K., Kim, N. D., Wilkins, A. L., & Palmer, G. T. (2005). *Contaminated Horticulture Land, A Developing Issue for New Zealand.* Auckland: Unknown.
PDP. (2007). *Contamination of Horticultural Land in Canterbury - A Scoping Study.* Christchurch: PATTLE DELAMORE PARTNERS LTD.

3 Site Identification

3.1 Legal Descriptions

Investigations were completed on the following land parcels. Each site is depicted in Figure 1:

- Part Lot 6A DP14175 South Auckland – Whakatāne Hospital
- Pt Lot 60 Deposited Plan South Auckland 582 – 32 Garaway Street, Whakatāne
- Allotment 686 Waimana Parish – 34 Garaway Street, Whakatane
- Lot 37 DP 582 South Auckland – 164 King Street, Whakatane
- Lot 3 DP 76293 South Auckland – 42 Valley Road, Whakatane
- Lot 62 DP 11056 South Auckland – 24 Valley Road, Whakatāne

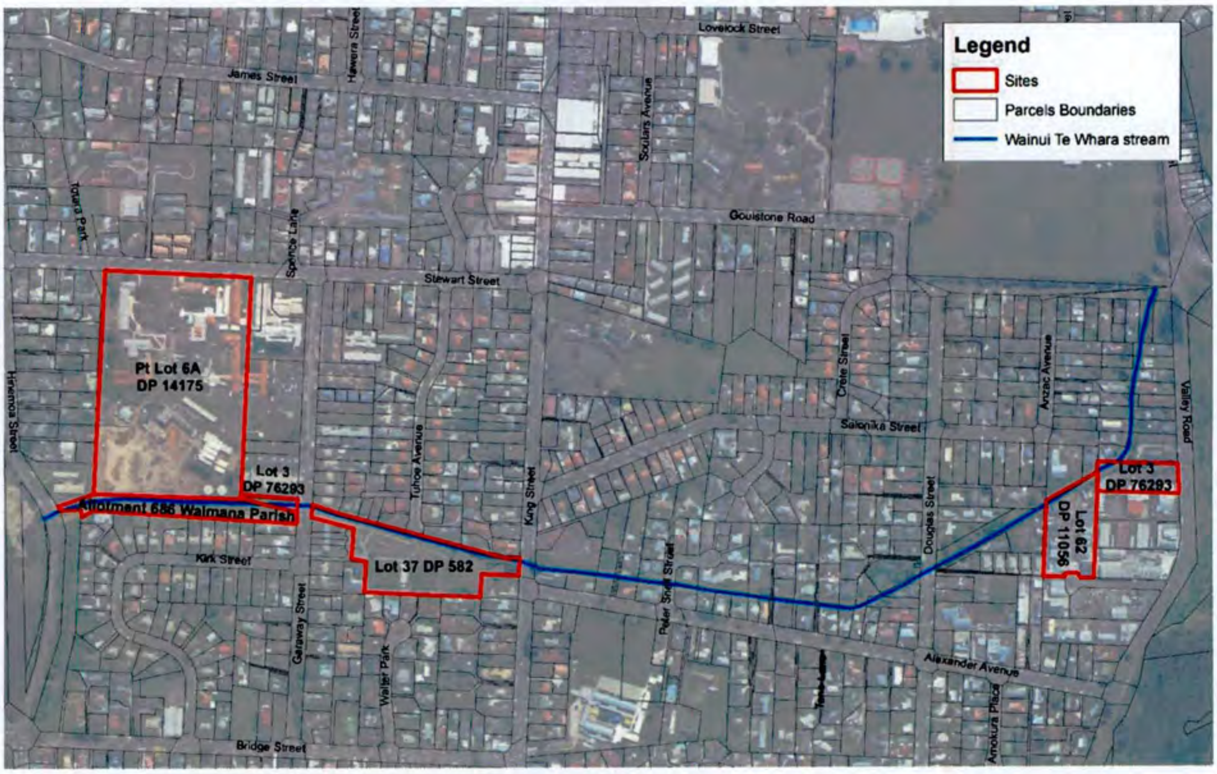


Figure 1 - Investigated sites

The proposed development is to improve flood defence by raising the stopbanks. The development fits the NES Commercial / industrial outdoor worker (unpaved) scenario during development and Parks/ recreational once works are completed.

3.2 Proposed Activities

The proposed activities on the site as defined by the NES Regulations are:

- Disturbing soil (Construction Activities)

4 Site History

In order to determine the site history, property files held by Whakatane District Council (WDC) have been interrogated for the subject site. A review of Historic Aerial Photography held by Bay of Plenty Regional Council (BOPRC) has also been completed.

4.1 Whakatāne District Council (WDC) Property Files

4.1.1 Pt Lot 6A DP 14175 (Whakatane Hospital)

Whakatane District Council property files were requested on 21 October 2015. Opus was informed that the details of the files were confidential and at the time of writing approval to view the files was still to be given.

4.1.2 Allotment 686 Waimana Parish (34 Garaway Street, Whakatane)

Whakatane District Council property files were requested on 21 October 2015. There was no file for the property.

4.1.3 Lot 37 DP 582 (164 King Street, Whakatane)

Whakatane District Council property files were reviewed on 22 October 2015. A summary of the pertinent points of the file has been presented below:

July 1967 – Building permit application for extensions to the Whakatane Women's Bowling Club pavilion. Specifications suggest that asbestos is present in the building.
July 2002 – Memo noting that the site is designated as "King Street Recreation Reserve". Users of the reserve are noted as "the bowling club, garaway kindy, the girl guides and the dog obedience club".
February 2005 – Memo regarding amalgamation of bowling clubs notes that "the property contains four large buildings, two bowling fields, a sealed carpark, grassed areas and a playground."
Unknown – Building consent application for construction of a bridge across Wainui Te Whara stream from Tuhoe Avenue to the King Street Reserve.

4.1.4 Lot 3 DP 76293 (42 Valley Road, Whakatane)

Whakatane District Council property files were reviewed on 22 October 2015. A summary of the pertinent points of the file has been presented below:

April 1991 – Building permit for alterations to commercial paint shop and addition of a workshop and truck storage. Application in name of Bruce Shaw.
November 1996 – Application to erect a new workshop building for Haddock Spraypainters.
November 1999 – Resource consent to establish and operate a motor vehicle dealer sales yard. File notes that no engine bay or degreasing work was to be carried out on site.
April 2006 – Resource Consent for Haddock Spraypainters for the discharge of particulate matter and volatile organic compounds to air from spray-painting booths.
May 2006 – Application to erect an industrial shed at Haddock Spraypainters. Plans show that the shed is located alongside the boundary with the Wainui Te Whara drainage easement.

2008 – Trade Waste Certificate issued to Haddock Spraypainters and Panelbeaters. Discharge characteristics of concern are noted as being emulsions/paint, adhesives, tar, plastic and rubber.
May 2010 – Consent compliance sheet. Notes that lead blasting has now ceased at the site. Site compliant.
April 2011 – Site inspection notice. Notes that new spray booth was inspected and is fully compliant. No lead paints were used.

4.1.5 Lot 62 DP 11056 (24 Valley Road, Whakatane)

Whakatane District Council property files were reviewed on 22 October 2015. A summary of the pertinent points of the file has been presented below:

March 1980 – Site plan showing locations of buildings and other facilities on site. These include cement stores, aggregate storage, precast factory and mixers, other sheds/workshops and a diesel tank and fuel line. These activities appear to have been located away from the boundary with the Wainui Te Whara stream.
September 1985 – Factory registration application for K & J Panels (motor vehicle panel beating and spray painting business).
July 1990 – Application to erect a new workshop at K & J Panels.
May 1993 – Certificate of Compliance confirming that the following activities can be established at the site: sale yard for cars, boats and caravans; sale of ancillary good (e.g. oil packs, petrol tanks); storage and resale of demolition materials.
May 1998 – Trade Waste Consent for Eastern Bay Sprayers for chemical storage.
March 1999 – Application to erect a new storage shed at K & J panels.
June 2003 – Letter from Whakatane District Council (WDC) noting that oily water had been discharging from the site into a stormwater cesspit. Valley Road Wreckers acknowledged that this discharge was the result of a waste oil drum overflowing during rain events.
August / September 2004 – Trade Waste Consent Certificate for K & J Panels. Certificate notes that the site contains an automotive/services workshop, chemical storage/sales and paint products. Hazardous products stored on site include used batteries, used antifreeze, used oil and solvents/organics. There is a wash-down pad and oil interceptor located on the site. Renewed annually until 2006.
2010 – Land Information Memorandum notes that:

> *"It is not known whether the current activities undertaken on this property have resulted in any contaminated site issues. Investigation into this potentially may be required should redevelopment of the site be proposed."*

October 2011 – Oil interceptor trap installed.

4.2 BOPRC Records

The BOPRC online maps service indicates that there are two land parcels adjacent to the Wainui Te Whara that meet the classification of the Hazardous Activities and Industries List (HAIL). These are commonly referred to as HAIL sites and are shown as yellow triangles in figure 2.

Figure 2 - Registered HAIL sites near the Wainui Te Whara (source BOPRC Bay eXplorer website).

Two HAIL sites located on the western end of the Wainui Te Whara are registered as "Contamination Managed" and "Waste disposal to land (excluding where biosolids have been used as soil conditioners)".

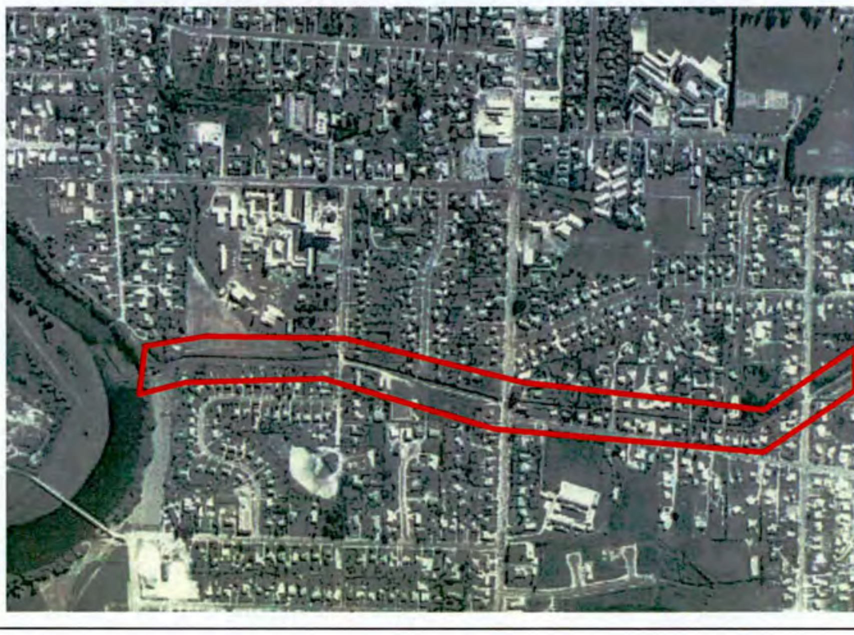
The SLUR (Selected Landuse Register) Reports were therefore requested and a discussion was held with Paul Futter at BOPRC. Reports confirm that the sites are both woodwaste contaminated when the original course of the Wainui Te Whara was filled in sometime between 1961 and 1974. These sites therefore represent a risk to human health from dioxin and PCP contaminated woodwaste. The SLUR report for 32 Garaway Street actually details the contamination as being on 20 Garaway Street, but discussion with Paul indicate that some woodwaste may be present on number 32. Both SLUR reports have been provided in appendix 1.

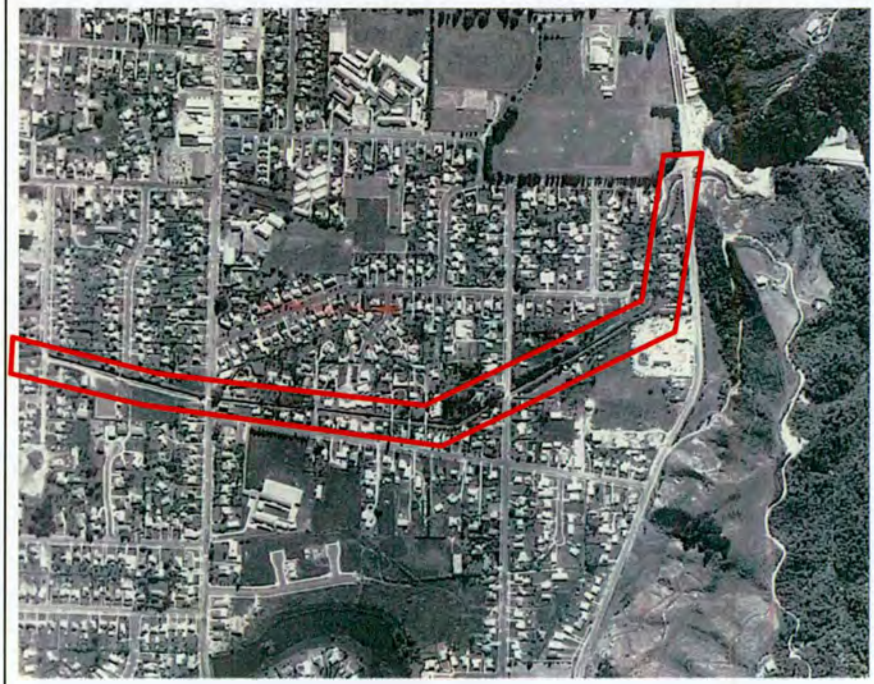
4.3 Historic Aerial Photographs

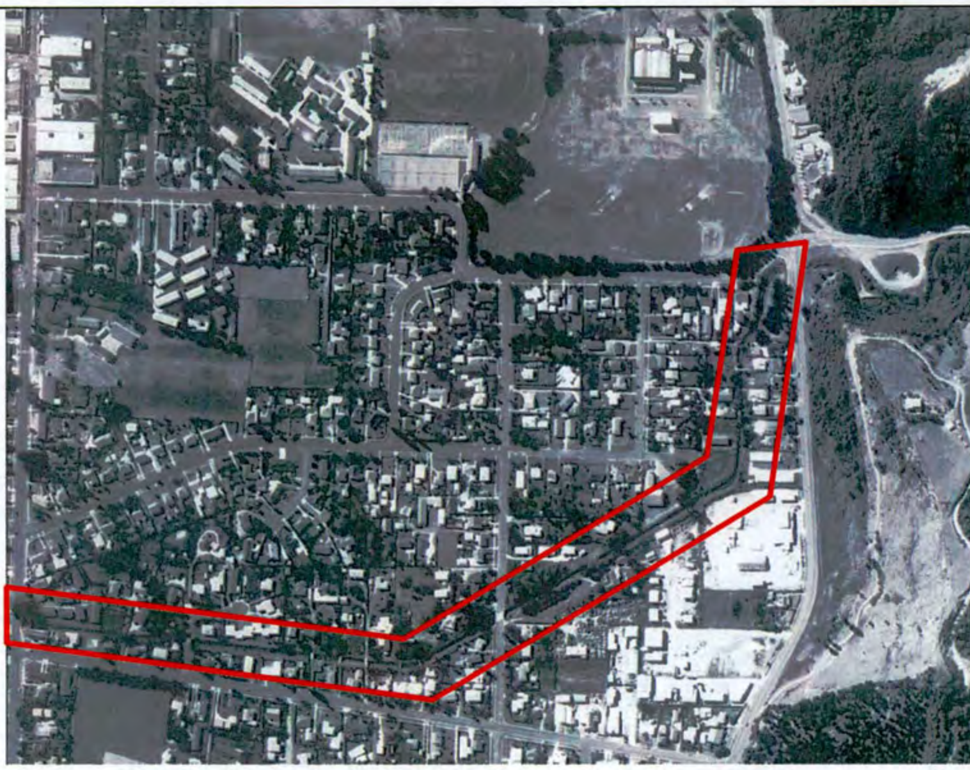
Historic aerial photographs from BOPRC have been reviewed. Table 1 summarises the relevant features of the site and surrounds for each aerial. The Google Earth Pro licence prevents Opus using imagery within reports, but the aerials used by the program show that the use of the land near the Wainui Te Whara stream remained generally the same from 2002 to 2013, with further development of the hospital site in 2011-2013 and various industrial activities present at properties along Valley Road including the storage of many vehicles. The red box represents the approximate location of the Wainui Te Whara stream.

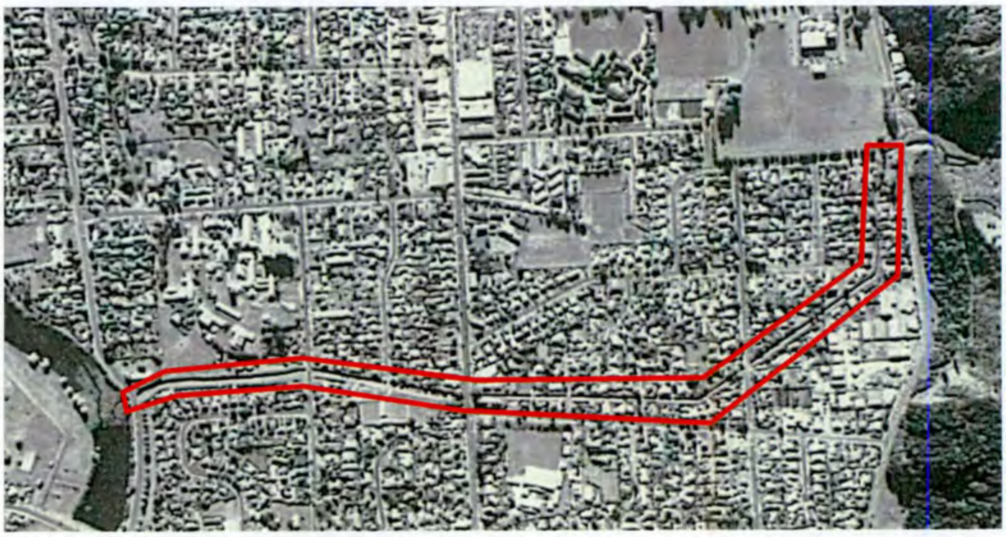
Table 1 : Summary of Aerial Photography

Photograph	Observations / Photo
1944 (678_44 & 45 - 26/9/1944)	Site is predominantly in pasture to the south of the stream with residential development to the north of the stream. Surrounding areas are of a similar nature, in pasture with some residential buildings. Hospital located north of the stream between Garaway and Hinemoa Streets. The Wainui Te Whara stream discharges to the Whakatane River near the site of the present day SH30 bridge. Possible market garden activity present towards the south-west of the site where the present day stream currently runs. 
1961 (3331_47, 48 & 49 - 21/11/1961)	Significant residential development surrounding the sites with some industrial development to the east of the site along Valley Road. Bowling green present to the south of the stream between King and Garaway Streets. Market garden activity present towards the south-west of the site where the present day stream currently runs. Stream discharges as per 1944, near SH30 bridge which is under construction.

	
1974 (SN3580_4523_20 & 22 - 26/4/1974)	As per 1961 aerial with some further residential development. Stream course altered, now discharging to the west as per present day. Previous stream channel filled in. Market garden activity appears to have ceased. 

	
1987 (170419)	As per 1974 aerial. A second bowling green has been developed adjacent to the existing green. Further industrial development to the east of the stream along Valley Road. 

	
1992 (194929)	As per 1987 aerial. 

1995 (12378)	As per 1992 aerial. Some materials stored adjacent to bank in the industrial properties to the east. 
1997 (1180)	Image less clear. Appears to be similar to 1995 aerial. 

4.4 Site Condition and Surrounding Environment

A site visit was completed on 26 October 2015. Investigations were completed upstream to downstream. The majority of the Wainui Te Whara runs through residential areas, this investigation made note of the site condition and surrounding land use that was not residential. All site photos are contained in appendix 2

Table 2: Description of Site Photographs

Photos	Description
1 to 3	Wainui Te Whara Stream looking upstream and downstream at the furthest point accessible from Douglas Street and downstream from the car wreckers (Lot 62 Deposited Plan 11056).
4 to 7	Car wreckers (Lot 62 Deposited Plan 11056) showing activity is currently away from the boundary that is shared Wainui Te Whara. Embers of a small fire were still present in the mid to foreground of photo 4.
8 to 10	Some recent ground disturbance, presumably associated with maintenance of a stormwater drain in photo 10. Ground appeared to have some rubble and concrete.
11	Debris in the Wainui Te Whara. Appears to be a partially buried barrel.
12 to 15	Boundary of Lot 3 Deposited Plan South Auckland 76293 shows some scrap metal on the or just intruding into the Wainui Te Whara boundary. This represents more of a health and safety nuisance than contamination issue.
16 and 17	Upstream and downstream photos of the Wainui Te Whara taken from the south western boundary of 3 Salonika Street.
18 and 19	Douglas Street pumpstation and associated control cabinets.
20 to 25	Wainui Te Whara downstream from Douglas Street bridge, downstream from the north west boundary of 42 Alexander Avenue, upstream from Peter Snell Street bridge, downstream from Peter Snell Street bridge, upstream from the King Street bridge and downstream from the King Street bridge.
26	Electrical cabinet on the southern bank at the King Street bridge.
27 and 28	Bowling green taken from the pathway that runs parallel to the Wainui Te Whara
29 to 32	Wainui Te Whara upstream of the Tuhoe Avenue bridge, downstream of the Tuhoe Avenue bridge, upstream of the Garaway Street bridge and downstream of the Garaway Street bridge.
33	Electrical transformer on sothern bank at the Garaway Street bridge.
34	Area of land registered as HAIL on the BOPRC Online Maps service.
35	Above Ground Storage Tanks (ASTs) just inside hospital boundary. Probably for water storage, but unconfirmed.
36 and 37	Wainui Te Whara looking upstream with the new hospital car park and temporary buildings to the left (north).
38 and 39	Wainui Te Whara looking downstream to the Hinemoa Street culvert from the hospital boundary and upstream to the Hinemoa Street Culvert from the Awatapu Lagoon.

4.5 Augers

Considering the contamination risk at 32 Garaway Street from woodwaste it was considered appropriate to complete some augers to see if woodwaste was present in the areas of works. Three augers were completed along the stopbank. No woodwaste was detected. It is likely that if there is woodwaste on this land parcel then it will be close to the boundary it shares with 20 Garaway Street. Photographs and logs have been provided in Appendix 3.

5 Geology and Hydrology

5.1 Geology

S-Maps online indicates that the Wainui Te Whara is located on predominately Flaxton Typic Orthic Gley Soil with the lower 370m on Galtymore Weathered Fluvial Recent Soil. Both are Loamy in texture, well drained with no significant barrier within 1m.

NZ 1:250k Geological Units are identified as Holocene ocean beach deposits, consisting of marine gravel, sand and mud on modern beaches.

Data on soils and geology has been presented in Appendix 4.

5.2 Hydrology

The Wainui Te Whara flows from a hilly catchment to east that is predominately a mixture of forestry and native bush. The stream then flows through predominately residential suburbs and into the Awatapu Lagoon before this feeds into the Whakatāne River. The stopbank are approximately 3 to 4 metres above the stream bed. No other significant water bodies are nearby. Groundwater is likely to be shallow and flow in a north-west direction towards the Whakatāne River.

The area surrounding the Wainui Te Whara is serviced by mains water. Groundwater contamination is not considered a threat to human health.

6 Conceptual Site Model

The source pathway receptor linkages are discussed below and take into account the proposed site use.

6.1 Potential Sources of Contamination

Soil contamination is associated with and results from the manufacture, storage, use and disposal of hazardous substances. Potential sources of contamination or Contaminants of Concern (COC) have therefore been identified from analysing the site history summarised in section 4 of this report.

6.2 Migration Pathways

6.2.1 Migration Pathways

Migration pathways are defined as the courses potentially hazardous substances may take from a source to an exposed organism or sensitive receptor. The exposure pathway can be direct (i.e. stays within the same exposure media) or indirect, where transport from one medium to another takes place.

The following potential migration pathways have been identified for the site.

6.2.2 Inhalation / Ingestion

Eating, swallowing or breathing of contaminated dust/soils either by deliberate consumption (children in particular), indirectly by eating or smoking with dirty hands or by ingestion of fugitive dust.

6.2.3 Dermal Contact

Direct contact with contaminated residues on the ground surface, causing skin conditions such as dermatitis etc. Certain contaminants can be absorbed into the body through the skin or enter directly through open cuts or abrasions.

6.2.4 Leaching and Sediment Runoff

Infiltration of water could potentially leach out soluble contaminants. Sediment erosion can also move contaminants bound to the soil structure. Both can result in pollution of controlled waters as likely migration to the stream networks, with the former potentially impacting on groundwater.

6.2.5 Migration of Contaminated Water

Contaminated groundwater can migrate laterally or vertically dependent on permeability and preferential pathways such as drains or man-made voids. Such migration from the documented landfill wastes are likely to have impacted on groundwater quality.

Surface water runoff can carry sediment bound contamination into local waterways.

6.3 Receptors

Receptors are defined as human or non-human organisms that have the potential to experience adverse effects from direct or indirect exposure to contaminated material.

The following potential human health and environmental receptors have therefore been identified for the site.

Site Development – Possible Receptors:

- Construction workers
- Nearby Public / Residents
- Ecology in waterways (e.g. macro invertebrates and fish) from surface water, groundwater percolation and groundwater flow into the stream.

Site Use – Public Walkway – Possible Receptors:

- General public from the use of the site.

6.4 Source-Pathway-Receptor Linkages

Table 3 shows the potential source-pathway-receptor relationships that have been identified for each site bearing in mind the proposed land use and development.

Table 3 - Source-Pathway-Receptor Relationships

Source	Pathway	Receptor	Potential Risks During Development	Potential Risks once Developed
Potential contaminants associated with historic market garden - Pesticides, metals	Ingestion - Soil	Human – Contractors / maintenance workers, General Public and residents	Low potential risk to construction workers – COCs are likely to have leached since 1960's.	Highly unlikely – areas with public access will be landscaped stopbanks.
	Inhalation		Low potential risk to construction workers. Low potential risk to general public and residents who are regularly close to the perimeter of the site during construction – COCs are likely to have leached since 1960's.	Highly unlikely – areas with public access will be landscaped stopbanks.

	Dermal		Low potential risk to construction workers – COCs are likely to have leached since 1960's. Low potential risk to general public as the site will be fenced off during construction.	Highly unlikely – areas with public access will be landscaped stopbank.
	Leaching / Sediment Erosion	Human / Ecology	Low potential risk to ecology as a result of contaminated dust migration and eroded sediment – COCs are likely to have leached since 1960's.	Low potential risk of dust migration and sediment erosion once landscaped.
	Migration of contaminated Water		Low potential risk to ecology – COCs are likely to have leached since 1960's.	Low potential risk – COCs are likely to have leached since 1960's.
Potential contaminants associated buried woodwaste - Dioxins, PCPs	Ingestion - Soil	Human – Contractors / maintenance workers, General Public and residents	Low potential risk to construction workers.	Highly unlikely once areas with public access are landscaped.
	Inhalation		Low potential risk in to construction workers. Low potential risk to general public and neighbouring staff who are regularly close to the perimeter of the site during construction.	Highly unlikely once areas with public access are landscaped.
	Dermal		Low potential risk to construction workers, low potential risk to general public as the site will be fenced off during construction.	Highly unlikely once areas with public access are landscaped.

7 Basis for Guideline Values

Soil Contaminant Standards (SCSs) were selected from the Ministry for the Environment's "Contaminated Land Management Guidelines – Methodology for Deriving Standards for Contaminants in Soil to Protect Human Health" and the "User's Guide – National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health".

The "commercial / industrial / outdoor worker" and "Recreation" values found in "Table B2 – Soil Contaminant Standards for health (SCS (health)) for inorganic substances" and "Table B3 – Soil Contaminant Standards for health (SCSs (health)) for organic compounds" have been provided in Table 4 and 5 respectively. The SCSs have been selected on the basis that the construction workers are to be the primary receptors at risk along with recreational users of the stop banks once the works are completed.

Table 4 – "Soil Contaminant Standards for health (SCS (health)) for inorganic substances".

	Arsenic	Boron	Cadmium (pH 5)[1]	Chromium III	Chromium VI	Copper	Inorganic lead	Inorganic mercury
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Rural residential / lifestyle block 25% produce	17	>10,000	0.8	>10,000	290	>10,000	160	200
Residential 10% produce	20	>10,000	3	>10,000	460	>10,000	210	310
High-density residential	45	>10,000	230	>10,000	1,500	>10,000	500	1,000
Recreation	80	>10,000	400	>10,000	2,700	>10,000	880	1,800
Commercial / industrial outdoor worker (unpaved)	70	>10,000	1,300	>10,000	6,300	>10,000	3,300	4,200

Table 5 – "Soil Contaminant Standards for health (SCS (health)) for organic compounds"

Scenario	BaP[1]	DDT	Dieldrin[2]	PCP	Dioxin TCDD	Dioxin Dioxin-like PCBs
	mg/kg TEQ	mg/kg	mg/kg	mg/kg	µg/kg TEQ	µg/kg TEQ
Rural residential / lifestyle block 25% produce	6	45	1.1	55	0.12	0.09
Residential 10% produce	10	70	2.6	55	0.15	0.12
High-density residential	24	240	45	110	0.35	0.33
Recreation	40	400	70	150	0.6	0.52
Commercial / industrial outdoor worker (unpaved)	35	1,000	160	360	1.4	1.2

8 Site Characterisation

Site history, anecdotal evidence, historical aerial photography and site inspections as detailed in section 4 have been used to determine if HAIL activities are or have been present within the Wainui Te Whara development. Based on the information reviewed it is considered that the following HAIL activities are likely to have occurred on the development site:

A10 – Persistent pesticide bulk storage or use including sports tufts, ***market gardens***, orchards glass houses or spray sheds.

G5 – Waste disposal (specifically woodwaste) to land.

Other HAIL activities such as A10 – Persistent pesticide bulk storage or use including ***sports turfs***, market gardens, orchards glass houses or spray sheds and G4 – Scrapyards including automotive dismantling, wrecking or scrap metal yards were identified nearby, but these were considered to be outside the development site.

9 Conclusions and Recommendations

The assessment of the Wainui Te Whara under the NES is required as a result of the proposed soil disturbance. Site history, anecdotal evidence, historical aerial photography and site inspections have identified HAIL activities within the area of works. The Regulations within the NES are therefore applicable at these sites.

Primary contaminants of concern are pesistant pesticides and metals from historic market gardening and dioxins and PCPs from woodwaste disposal. These contaminants of concern are related to specific activities at specific locations, i.e. they are not all applicable at all of the sites.

9.1 Market Gardening

Gaw et al (2005) identified that a range of persistent organochlorine and metal based pesticides were used in New Zealand up until the mid-1970s. However, control of the use of organochlorine pesticides came into effect in 1970, with only limited quantities allowed to be used under permit until their total phase out in 1989. Arsenic based pesticides were also phased out during the 1970s. This means the sites that pose the greatest risk with regards to organochlorine pesticides are those with horticulture, market garden or orchards pre 1975.

The market gardening activity was located in the bottom 350m section of the Wainui Te Whara, before the stream was diverted to the Awatapu Lagoon. Historic aerials show market gardens in the 1944 and 1961 imagery, indicating at least 17 years of activity. This time frame covers metal based pesticides and organochlorine based pesticides meaning that their use was likely. However, two documents, one written by Gaw et al (2005) on contaminated horticulture land, and a study into the contamination of horticultural land completed by Pattle Delamore Partners Ltd (PDP) (2007) have been reviewed to assess the risk to human health in relation to the land use and development described in this report[2].

In both reports horticultural land similar in use to the described areas was investigated. Tables 3 and 4 in Gaw et al (2005) (tables 6 and 7 of this report) show readings for Arsenic Copper, Lead, Mercury, Tin, Zinc and ΣDDT found in the cropping soils and locations of potential hotspots. Despite sample G being contaminated with paint flakes giving elevated readings for lead none of the levels exceed those specified by the selected SCS in this PSI.

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[2] Gaw, S. K., Kim, N. D., Wilkins, A. L., & Palmer, G. T. (2005). Contaminated Horticulture Land, A Developing Issue for New Zealand. Auckland: Unknown.
PDP. (2007). Contamination of Horticultural Land in Canterbury - A Scoping Study. Christchurch: PATTLE DELAMORE PARTNERS LTD.

Table 6: Table 3 from Gaw et al 2005 providing descriptions from potential hotspots sampled in the investigations.

Sample code	Property type	Land use duration	Hotspot description
A	Glasshouse	Long-term	Compost disposal area
B	Multi-use	Long-term	Boiler ash disposal area
C	Multi-use	Long-term	Concrete storage pad
D	Vineyard	Recent	Spray shed
E	Vineyard	Long-term	Spray shed
F	Orchard	Long-term	Spray shed
G	Glasshouse	Long-term	Bare soil around the outside of a grape glasshouse
H	Orchard	Historic	Possible location of a spill from stationary spray system

Table 7: Table 4 from Gaw et al showing trace element results for potential hotspots on selected horticultural properties and the range for cropping soils completed as part of the investigation.

Sample	Arsenic	Copper	Lead	Mercury	Tin	Zinc	ΣDDT
A	59	46	10.6	<0.1	1	86	0.05
B	22	94	191	<0.1	1	117	
C	11	74	208	<0.1	2	273	<0.03
D	4	41	26.2	<0.1	<1	131	<0.03
E	24	917	159	18.8	12	433	270
F	11	11800	86.1	0.1	14	1050	10.2
G	13	375	2000	0.2	7	671	74.8
H	3	85	86.1	<0.1	1	44	0.43
Cropping soils	<2-34	7-490	2.7-1250	<0.1-0.4	<1-8	9-510	<0.03-289

The study completed by PDP provides information on levels of metals, Dieldrin and DDT in near surface soil samples. Their results (Table 8) indicate that market gardening, orchards, glasshouses and vineyards are unlikely to result in concentrations of these contaminants that are in exceedance of the *"commercial / industrial / outdoor worker"* or "*Recreation*" SCSs as identified in section 7 of this report.

Based on this information, the similarity in land uses found in the studies to the investigation site and that fact there has been around 50 years since the site was last used as a market garden, it is considered that it is *highly unlikely* that the activity will have resulted in modern day contamination in excess of the *"commercial / industrial / outdoor worker"* or "*Recreation*" SCSs.

Table 8 - Selected near-surface soil sampling results from horticultural land3

Former Land Use	Arsenic	Copper	Lead	Zinc	Dieldrin	Total DDT [2]
Orchard (N=1; n=9)[3]	6 – 40	14 – 334	17 - 135	-	0.06 – 0.15	<0.03 - 24.1
Market Gardening (N=3; n=19)	3 – 14	9 – 961	18 – 293	-	0.001	0.03 – 0.74
Glasshouse (N=5; n=63)	6 – 64	11 - 129	42 - 797	82 - 562	<0.01 - 2.82	0.005 – 8.38
Vineyard [4] (n=4)	6 - 11	19 – 47	32 - 771	-	-	0.225 - 10.09

Notes:
1. The sum of DDT, DDD and DDE.
2. N = number of properties; n = total number of samples
3. A single historic vineyard not expected to be typical of modern vineyards.

9.2 Woodwaste Fill

BOPRC records indicate that two HAIL sites located towards the western end of the Wainui Te Whara are registered as "Contamination Managed" and "Waste disposal to land (excluding where biosolids have been used as soil conditioners)". The SLUR reports and discussion with Paul Futter at the council confirm that the sites are both woodwaste contaminated. Although the chances of woodwaste on the development site are slim, the disposal field just borders 32 Garaway Street (Pt Lot 60 Deposited Plan South Auckland 582) and augering did not find any evidence of woodwaste, it is considered prudent that provision be made for unexpected discoveries (woodwaste) within the area of 32 Garaway Street. The greatest chance of woodwaste being uncovered is close to the retaining wall along 20 Garaway Street (Lot 1 Deposited Plan 404258).

9.3 General

Based on the information reviewed it is considered that the risks posed to human health from the development can be appropriately managed, namely construction workers using appropriate site controls, management of personal hygiene and Personal Protective Equipment (PPE). It is therefore recommended that in general that works proceed with this in mind, but this report be made available to the contractor(s) involved.

It is recommended that this report is forwarded to:

- Whakatāne District Council Regulatory Department for the purpose of compliance with the NES

[3] PDP. (2007). *Contamination of Horticultural Land in Canterbury - A Scoping Study.* Christchurch: PATTLE DELAMORE PARTNERS LTD.

- Bay of Plenty Regional Council to confirm that they agree with the conclusions in this report and that the site is not subject to Rule 35 in the Regional Water and Land Plan and is not in need of a resource consent.

10 Applicability and Limitations

This report has been prepared solely for the use by Whakatāne District Council and/or agent. This report is not suitable for any other circumstances than the purpose for which it was prepared. This report has been prepared for the purpose of providing an assessment of the qualitative risk posed to human health by potential soil contamination on the development identified in this report.

This report has used publicly available information, information provided by others, discussions with site owners, regulatory authorities and past occupiers/operators together with a site walkover. Opus cannot and does not accept any responsibility for errors or omissions in, or the currency or sufficiency of the provided information.

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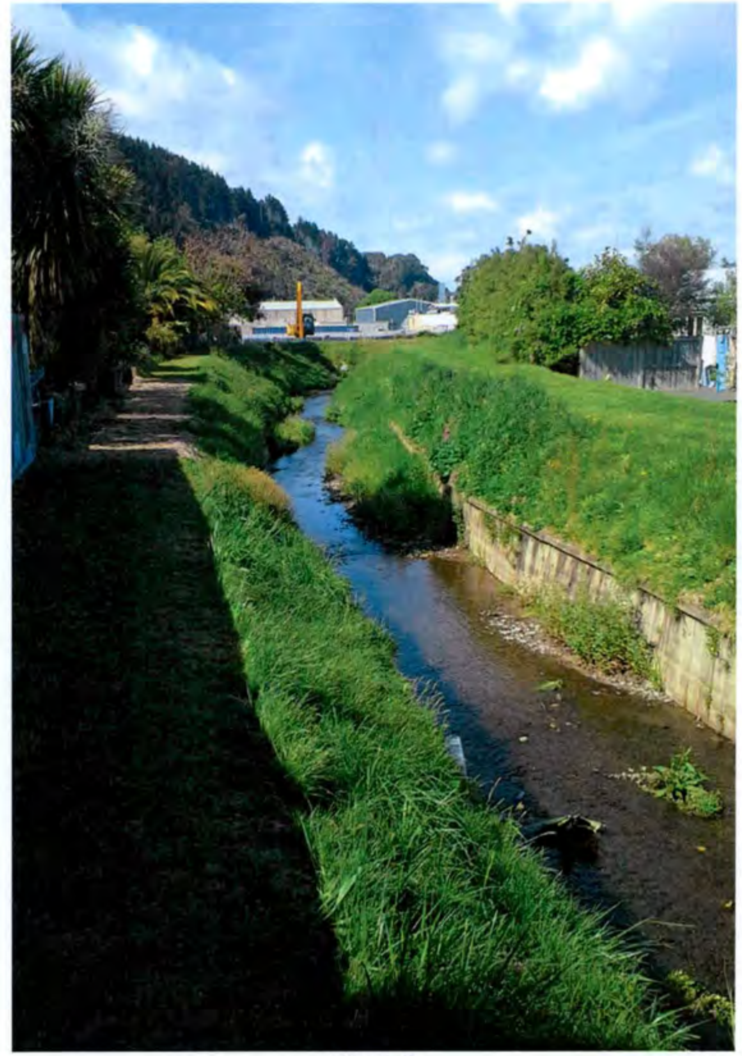
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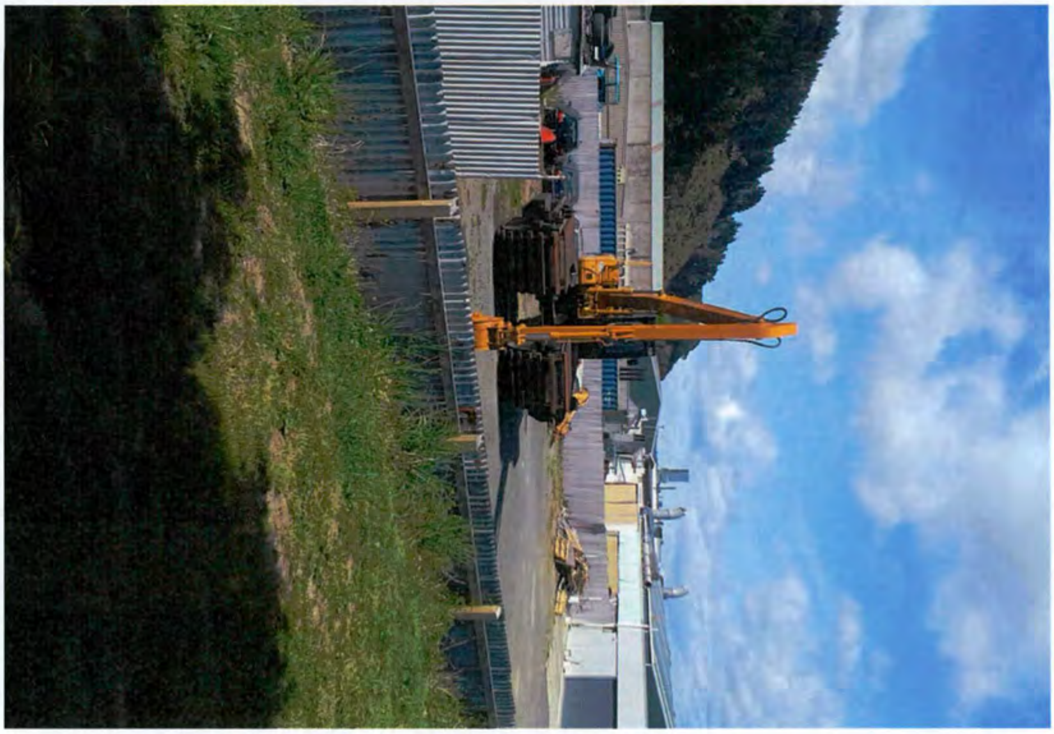

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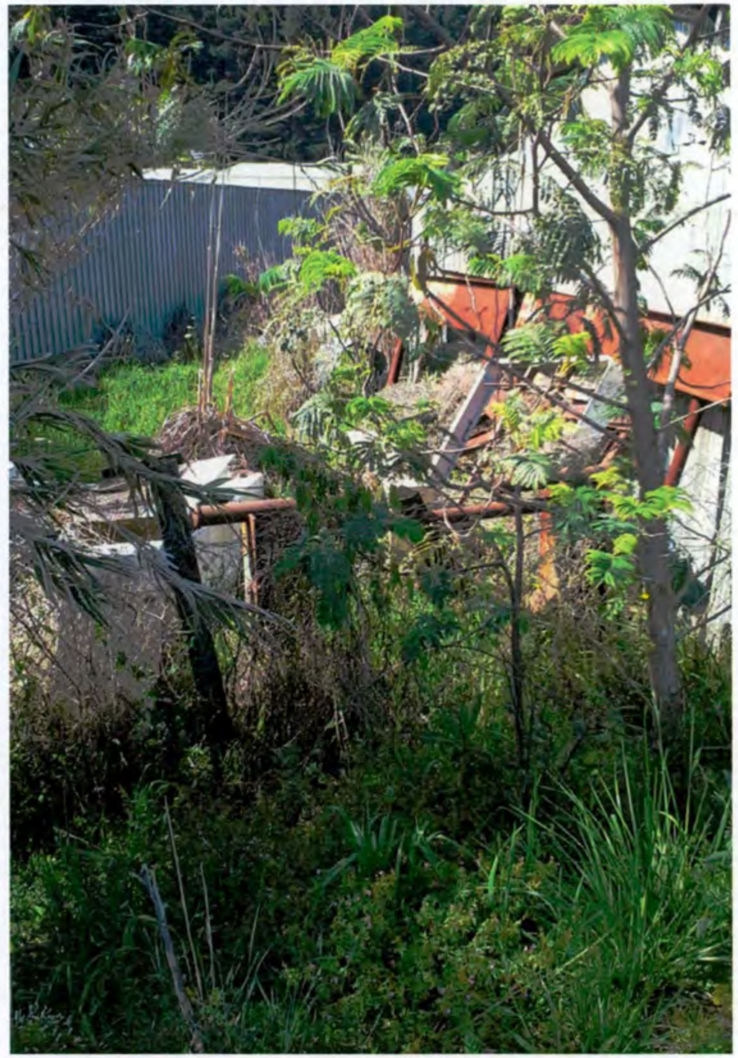
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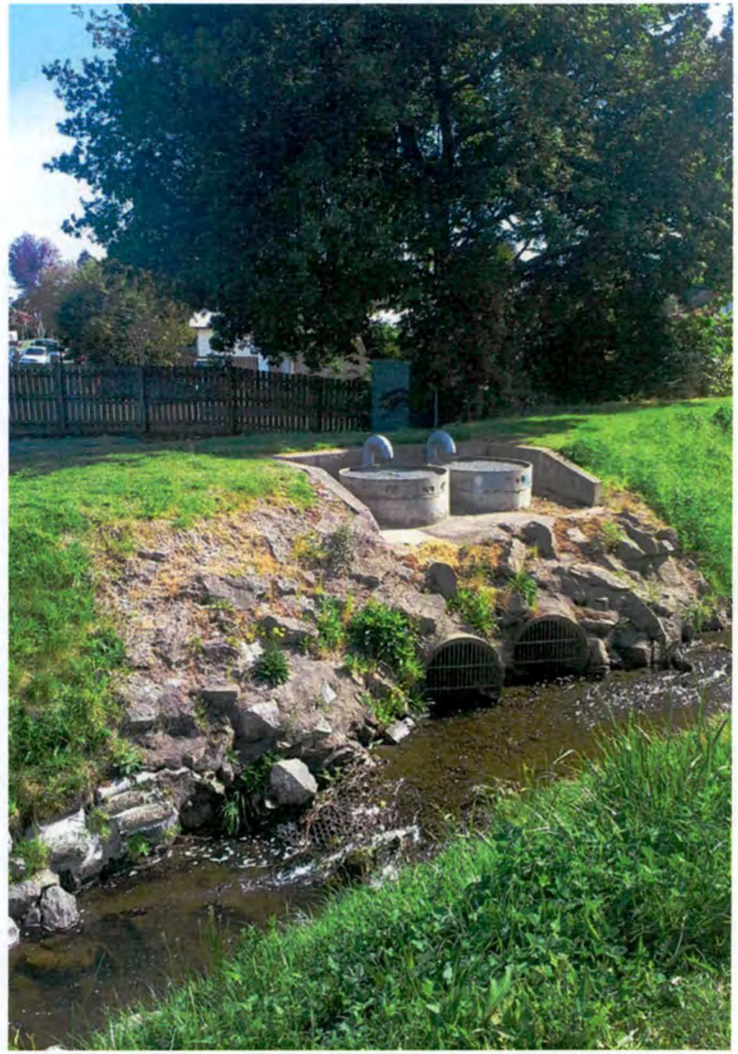

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Photo 20

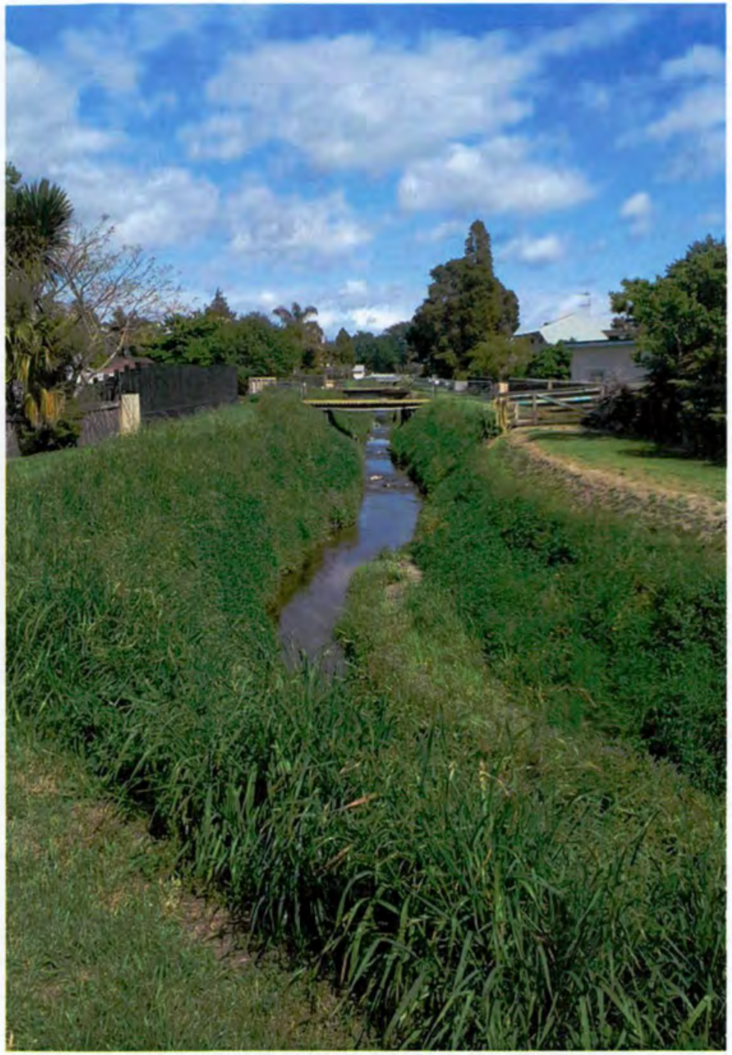
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Photo 27

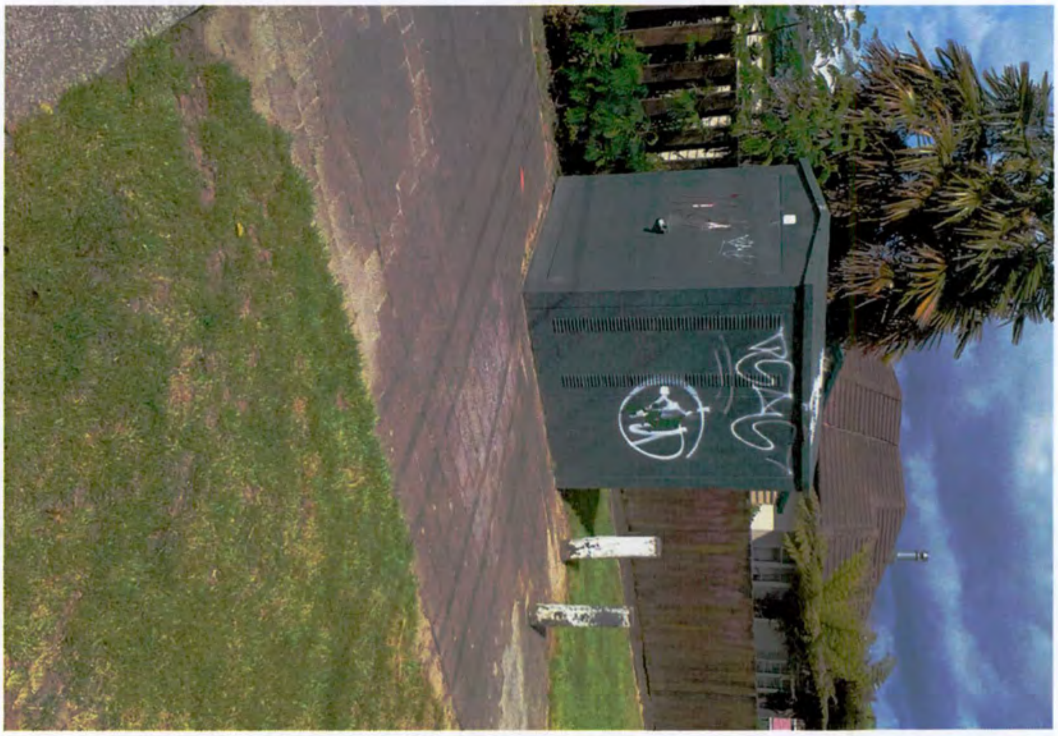

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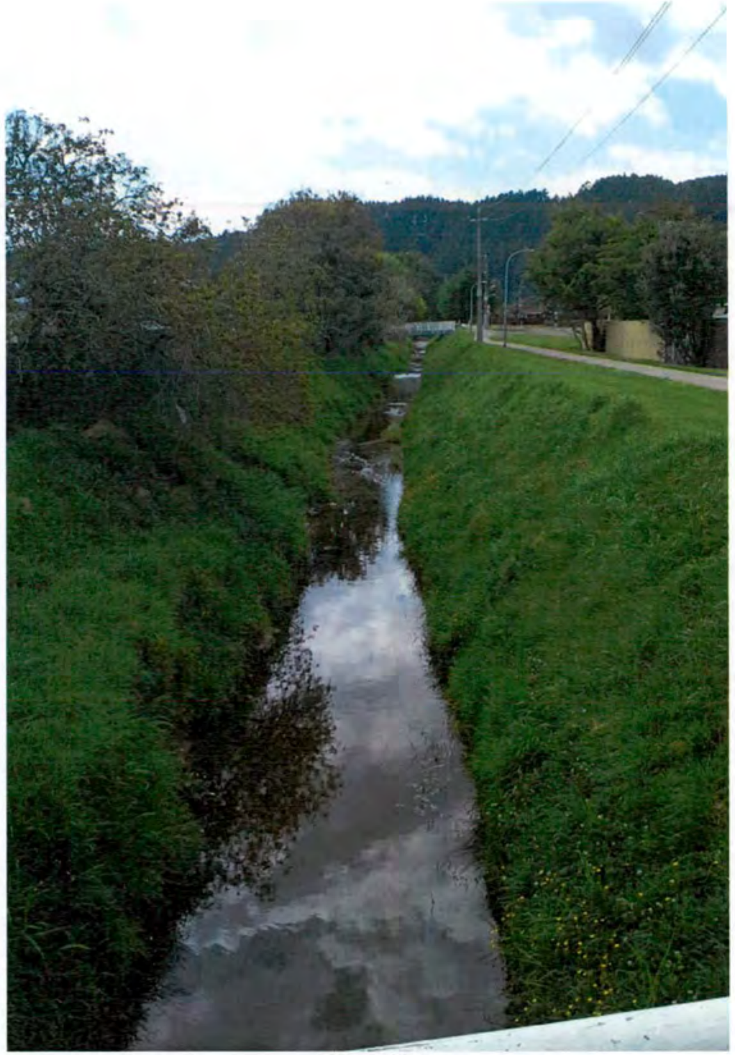
Photo 31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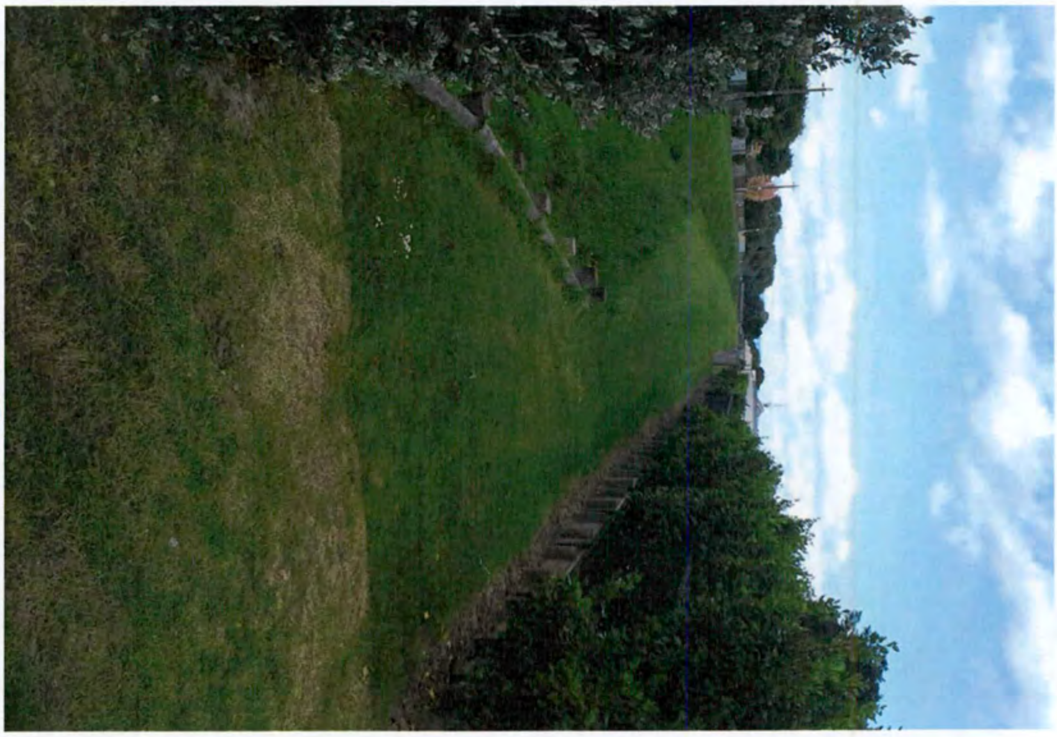

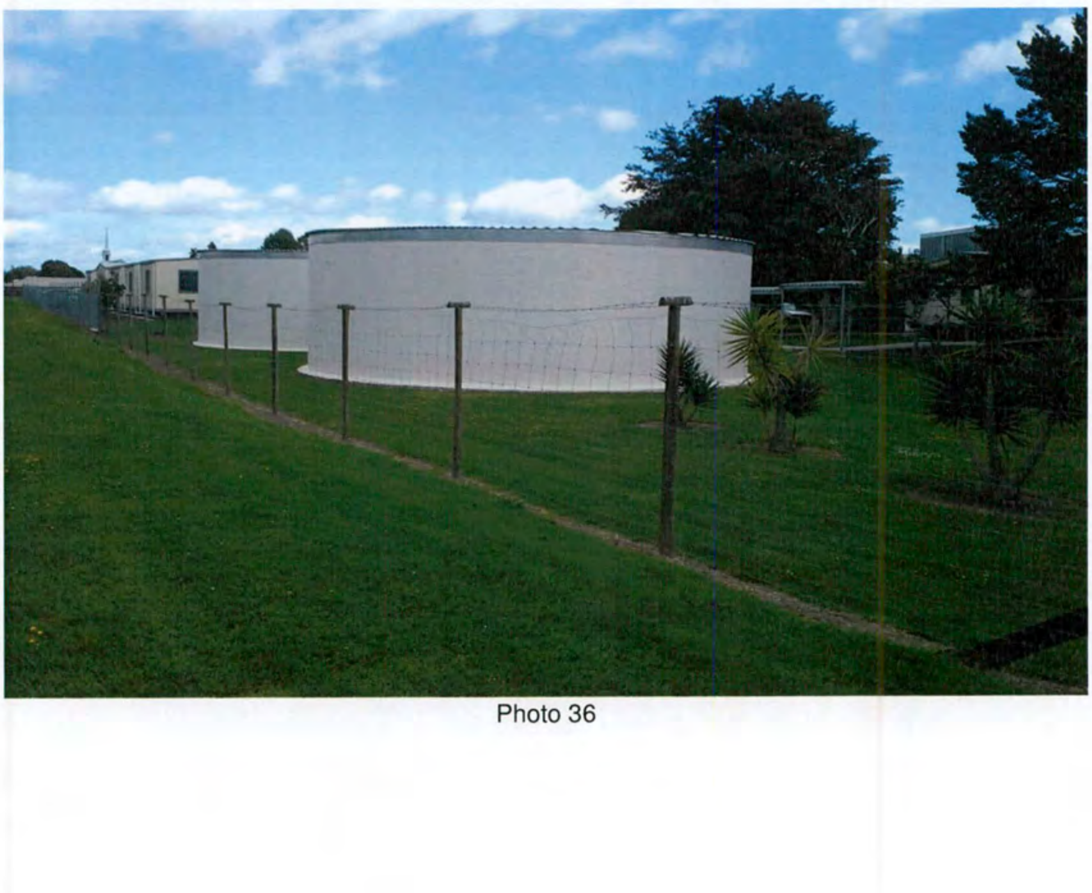

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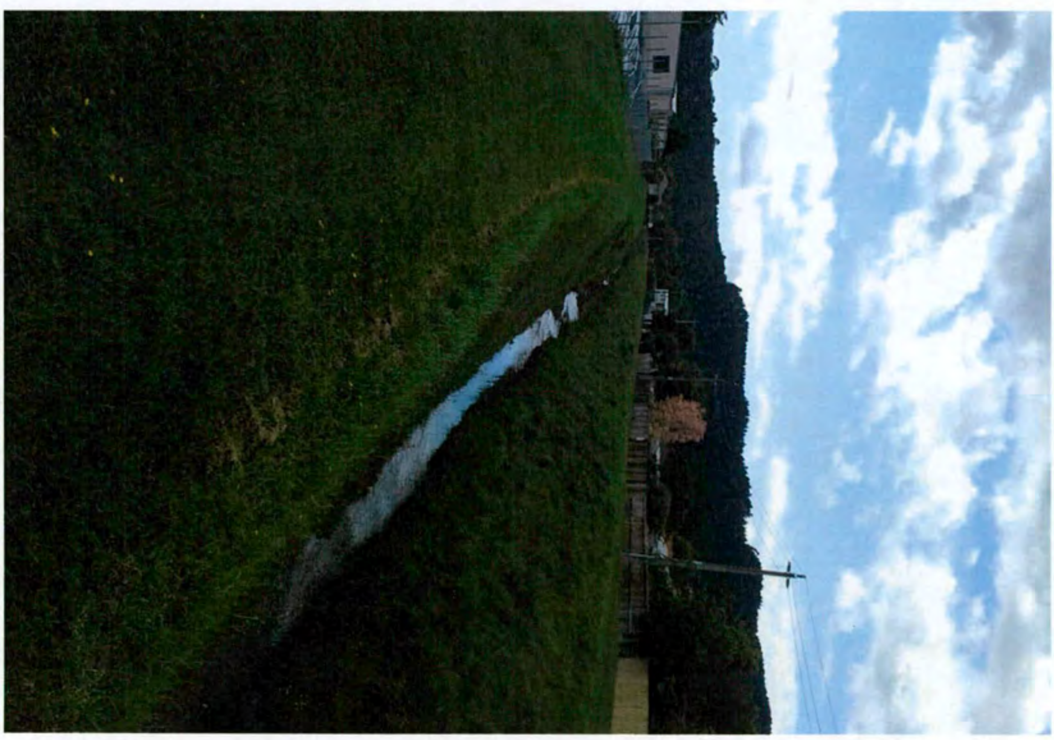

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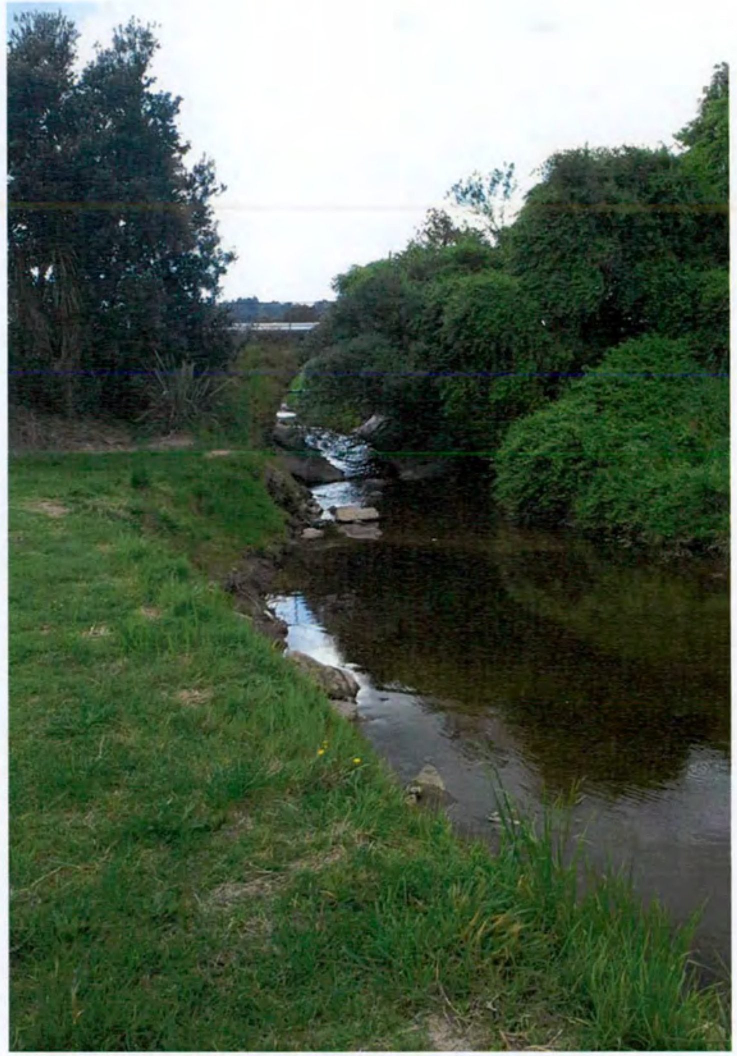

Photo 40

13 Appendix 3: Auger Logs

	0-90 Sandy silt 90-120 Sand w/ silty clay 120-150 Silty clay 150-165 Sand 165-180 Silty clay 180-200 Clay
	0-60 Sandy silt 60-110 Sand w/ clay 110-170 Silty clay 170-200 Clay
	0-55 Sandy silt 55-100 Sand w/ clay 100-115 Silty clay 115-130 Sand 130-170 Sandy silt 170-200 Pumice, sandy silt

14 Appendix 3: Soils and Geology

Wainui Te Whara

S-mapOnline
Fast, simple access to New Zealand soils data

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Scale: 1:10,000

0 100 200 300 400m

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Printed: 16:05:06 PM Thu, 29 Oct 2015

Legend

S-map Polygons &
Labels

S-map soil data

S-mapOnline
Fast, simple access to New Zealand soils data

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S-map Soil Report

Report generated: 29-Oct-2015 from http://smap.landcareresearch.co.nz

This information sheet describes the typical average properties of the specified soil to a depth of 1 metre, and should not be the primary source of data when making land use decisions on individual farms and paddocks.

S-map correlates soils across New Zealand. Both the old soil name and the new correlated (soil family) name are listed below.

Flaxton*f*

Typic Orthic Gley Soil

S-map ref: Flax_17a.1

Flax1l (100% of the mapunit at location (5790306, 1950328), Confidence: High)

Key physical properties

Depth class (diggability)		Deep (> 1 m)
Texture profile		Loam
Potential rooting depth		50 - 60 (cm)
Rooting barrier		Anoxic conditions
Topsoil stoniness		Stoneless
Topsoil clay range		15 - 20 %
Drainage class		Poorly drained
Aeration in root zone		Limited
Permeability profile		Moderate Over Slow
Depth to slowly permeable horizon		60 - 70 (cm)
Permeability of slowest horizon		Slow (< 4 mm/h)
Profile available water	(0 - 100cm or root barrier)	High (246.9 mm)
	(0 - 60cm or root barrier)	Very high (153.5 mm)
	(0 - 30cm or root barrier)	Very high (83.5 mm)
Dry bulk density, topsoil		0.94 g/cm³
Dry bulk density, subsoil		1.22 g/cm³
Depth to hard rock		No hard rock within 1 m
Depth to soft rock		No soft rock within 1 m
Depth to stony layer class		No significant stony layer within 1 m

Key chemical properties

Topsoil P retention	Medium (38%)

About this publication

- This information sheet describes the *typical average properties* of the specified soil to a depth of 1 metre.
- For further information on individual soils, contact Landcare Research New Zealand Ltd: www.landcareresearch.co.nz
- Advice should be sought from soil and land use experts before making decisions on individual farms and paddocks.
- The information has been derived from numerous sources. It may not be complete, correct or up to date.
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Additional factors to consider in choice of management practices

Vulnerability classes relate to soil properties only and do not take into account climate or management

Soil structure integrity

Erodibility of soil material	Slight
Structural vulnerability	High (0.66)
Pugging vulnerability	not available yet

Water management

Water logging vulnerability	High
Drought vulnerability - if not irrigated	Low
Bypass flow	High
Hydrological soil group	B/D
Irrigability	Flat to very gently undulating land with severe drainage/permeability restrictions and soils with high to very high PAW

Contaminant management

N leaching vulnerability	Very Low
P leaching vulnerability	not available yet
Bypass flow	High
Dairy effluent (FDE) risk category	C if slope > 7 deg otherwise B
Relative Runoff Potential	Low

Additional information

Soil classification	Typic Orthic Gley Soils
Family	Flaxton*f*
Sibling number	17
Profile texture group	Loamy
Soil profile material	Stoneless soil
Rock class of stones/rocks	Not Applicable
Rock origin of fine earth	From Rhyolitic Rock
Parent material origin	Alluvium

Characteristics of functional horizons in order from top to base of profile:

Functional Horizon	Thickness	Stones	Clay*	Sand*
Loamy Weak	18 - 20 cm	0 %	15 - 20 %	70 - 80 %
Loamy Fine Slightly Firm	30 - 40 cm	0 %	20 - 25 %	30 - 40 %
Sandy Loose, Acidic Tephric	5 - 8 cm	0 %	0 - 2 %	95 - 98 %
Loamy Fine Firm	35 - 40 cm	0 %	25 - 30 %	30 - 50 %

* clay and sand percent values are for the mineral fines (excludes stones). Silt = 100 - (clay + sand)

Flaxtonf

Flax1l (100% of the mapunit at location (5790306, 1950328), Confidence: High)

S-map ref: Flax_17a.1

Soil information for OVERSEER

The following information can be entered in the OVERSEER® Nutrient Budget model. This information is derived from the S-map soil properties which are matched to the most appropriate OVERSEER categories. Please read the notes below for further information.

Soil description page

Click the 'Soil moisture values' option. Enter in the 'Sibling name': Flax_17a.1

From the 'Soil order' dropdown box select: Gley

Soil water properties	0-30 cm	30-60 cm	> 60 cm	
Wilting point (15 bar)	22	17	23	mm per 10 cm
Field capacity	50	40	47	mm per 10 cm
Saturation	63	58	59	mm per 10 cm

From the 'Natural drainage class' dropdown box select: Poorly drained

Depth to impeded drainage layer: Enter zero (no impermeable layer above 1m)

Maximum rooting depth: Enter zero (no rooting barrier above 1m)

Top soil horizon chemical and physical parameters

Anion storage capacity (ASC) or phospate retention (PR): 38 %

Bulk density: 940 kg/m³

Clay: 17 %

Sand: 75 %

Sub soil [average from 10 to 30 cm]

Subsoil clay: 22 %

Is compacted

(this depends on management so cannot be obtained from S-map)

Considerations when using Smap soil properties in OVERSEER

- The soil water values are estimated using a regression model based on soil order, parent rock, soil functional horizon information (stone content, soil density class), as well as texture (field estimates of sand, silt and clay percentages). The model is based on laboratory - measured water content data held in the National Soils Database and other Landcare Research datasets. Most of this data comes from soils under long-term pasture and may vary from land under arable use, irrigation, etc.
- Each value is an estimate of the water content of the whole soil within the target depth range or to the depth of the root barrier (if this occurs above the base of the target depth). Where soil layers contain stones, the soil water content has been decreased according to the stone content.
- S-map only contains information on soils to a depth of 100 cm. The soil water estimates in the > 60 cm depth category assume that the bottom functional horizon that extends to 100 cm, continues down to a depth of 150cm. Where it is known by the user that there is an impermeable layer or non-fractured bedrock between 100 and 150 cm, this depth should be entered into OVERSEER. Where there is a change in the soil profile characteristics below 100 cm, the user should be aware that the values provided on this factsheet for the > 60 cm depth category will not reflect this change. For example, the presence of gravels at 120 cm would usually result in lower soil water estimates in the > 60 cm depth category. Note though that this assumption only impacts on a cropping block, as OVERSEER uses soil data from just the top 60 cm in pastoral blocks.
- OVERSEER requires the soil water values to be non-zero integers (even though zero is a valid value below a root barrier), and the wilting point value must be less than the field capacity value which must be less than the saturation value. The S-map water content estimates provided on this page have been rounded to integers and may be assigned minimal values to meet these OVERSEER requirements. These modifications will result in a slightly less accurate estimate of Available Water to 60 cm (labelled PAW in OVERSEER) than that provided on the first page of this factsheet, but this is not expected to lead to any significant difference in outputs from OVERSEER.

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S-map Soil Report

Report generated: 29-Oct-2015 from http://smap.landcareresearch.co.nz

This information sheet describes the typical average properties of the specified soil to a depth of 1 metre, and should not be the primary source of data when making land use decisions on individual farms and paddocks.

S-map correlates soils across New Zealand. Both the old soil name and the new correlated (soil family) name are listed below.

Galtymore*f*

Weathered Fluvial Recent Soil

S-map ref: Galt_5a.2

Galt1l (100% of the mapunit at location (5790281, 1949305), Confidence: High)

Key physical properties

Depth class (diggability)		Deep (> 1 m)
Texture profile		Loam
Potential rooting depth		Unlimited
Rooting barrier		No significant barrier within 1 m
Topsoil stoniness		Stoneless
Topsoil clay range		10 - 15 %
Drainage class		Well drained
Aeration in root zone		Unlimited
Permeability profile		Rapid
Depth to slowly permeable horizon		No slowly permeable horizon
Permeability of slowest horizon		Rapid (> 72 mm/h)
Profile available water	(0 - 100cm or root barrier)	High (169.8 mm)
	(0 - 60cm or root barrier)	High (102.2 mm)
	(0 - 30cm or root barrier)	High (51.5 mm)
Dry bulk density, topsoil		1.09 g/cm³
Dry bulk density, subsoil		1.30 g/cm³
Depth to hard rock		No hard rock within 1 m
Depth to soft rock		No soft rock within 1 m
Depth to stony layer class		No significant stony layer within 1 m

Key chemical properties

Topsoil P retention	Low (19%)

About this publication

- This information sheet describes the *typical average properties* of the specified soil to a depth of 1 metre.
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Additional factors to consider in choice of management practices

Vulnerability classes relate to soil properties only and do not take into account climate or management

Soil structure integrity

Erodibility of soil material	Moderate
Structural vulnerability	High (0.69)
Pugging vulnerability	not available yet

Water management

Water logging vulnerability	Very low
Drought vulnerability - if not irrigated	Low
Bypass flow	Low
Hydrological soil group	A
Irrigability	Flat to very gently undulating land with good drainage/permeability and soils with high PAW

Contaminant management

N leaching vulnerability	Low
P leaching vulnerability	not available yet
Bypass flow	Low
Dairy effluent (FDE) risk category	C if slope > 7 deg otherwise D
Relative Runoff Potential	Very Low

Additional information

Soil classification	Weathered Fluvial Recent Soils
Family	Galtymore*f*
Sibling number	5
Profile texture group	Loamy
Soil profile material	Stoneless soil
Rock class of stones/rocks	Not Applicable
Rock origin of fine earth	From Hard Sandstone And Rhyolitic Rock
Parent material origin	Alluvium

Characteristics of functional horizons in order from top to base of profile:

Functional Horizon	Thickness	Stones	Clay*	Sand*
Loamy Earthy Weak	22 - 24 cm	0 %	10 - 15 %	40 - 60 %
Loamy Weak	75 - 80 cm	0 %	20 - 30 %	20 - 40 %

* clay and sand percent values are for the mineral fines (excludes stones). Silt = 100 - (clay + sand)

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Galtymoref

Galt1l (100% of the mapunit at location (5790281, 1949305), Confidence: High)

S-map ref: Galt_5a.2

Soil information for OVERSEER

The following information can be entered in the OVERSEER® Nutrient Budget model. This information is derived from the S-map soil properties which are matched to the most appropriate OVERSEER categories. Please read the notes below for further information.

Soil description page

Click the 'Soil moisture values' option. Enter in the 'Sibling name': Galt_5a.2

From the 'Soil order' dropdown box select: Recent

Soil water properties	0-30 cm	30-60 cm	> 60 cm	
Wilting point (15 bar)	13	15	15	mm per 10 cm
Field capacity	30	32	32	mm per 10 cm
Saturation	51	49	49	mm per 10 cm

From the 'Natural drainage class' dropdown box select: Well drained

Depth to impeded drainage layer: Enter zero (no impermeable layer above 1m)

Maximum rooting depth: Enter zero (no rooting barrier above 1m)

Top soil horizon chemical and physical parameters

Anion storage capacity (ASC) or phospate retention (PR): 19 %

Bulk density: 1090 kg/m³

Clay: 12 %

Sand: 50 %

Sub soil [average from 10 to 30 cm]

Subsoil clay: 25 %

Is compacted

(this depends on management so cannot be obtained from S-map)

Considerations when using Smap soil properties in OVERSEER

- The soil water values are estimated using a regression model based on soil order, parent rock, soil functional horizon information (stone content, soil density class), as well as texture (field estimates of sand, silt and clay percentages). The model is based on laboratory - measured water content data held in the National Soils Database and other Landcare Research datasets. Most of this data comes from soils under long-term pasture and may vary from land under arable use, irrigation, etc.

- Each value is an estimate of the water content of the whole soil within the target depth range or to the depth of the root barrier (if this occurs above the base of the target depth). Where soil layers contain stones, the soil water content has been decreased according to the stone content.

- S-map only contains information on soils to a depth of 100 cm. The soil water estimates in the > 60 cm depth category assume that the bottom functional horizon that extends to 100 cm, continues down to a depth of 150cm. Where it is known by the user that there is an impermeable layer or non-fractured bedrock between 100 and 150 cm, this depth should be entered into OVERSEER. Where there is a change in the soil profile characteristics below 100 cm, the user should be aware that the values provided on this factsheet for the > 60 cm depth category will not reflect this change. For example, the presence of gravels at 120 cm would usually result in lower soil water estimates in the > 60 cm depth category. Note though that this assumption only impacts on a cropping block, as OVERSEER uses soil data from just the top 60 cm in pastoral blocks.

- OVERSEER requires the soil water values to be non-zero integers (even though zero is a valid value below a root barrier), and the wilting point value must be less than the field capacity value which must be less than the saturation value. The S-map water content estimates provided on this page have been rounded to integers and may be assigned minimal values to meet these OVERSEER requirements. These modifications will result in a slightly less accurate estimate of Available Water to 60 cm (labelled PAW in OVERSEER) than that provided on the first page of this factsheet, but this is not expected to lead to any significant difference in outputs from OVERSEER.

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S6 Archaeological assessment report

OPUS

Whakatāne District Council

Wainui te Whara, Whakatāne

Flood Control Project

Archaeological Assessment

Whakatāne District Council

Wainui te Whara, Whakatāne

Flood Control Project: Archaeological Assessment

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Principle Archaeologist

Telephone: 07 838 9344

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Date: July 2015

Reference: 2-34250.06

Status:

Whakatāne District Council

Wainui te Whara, Whakatāne

Flood Control Project: Archaeological Assessment

Contents

Figures

Executive Summary

Opus International Consultants (Opus) was contracted by Whakatāne District Council to carry out an archaeological assessment of the stream Wainui Te Whara, Whakatāne, which runs approximately 1.8 km from Valley Road to its outlet at the Awatapu Lagoon (Figure 2).

Opus was contracted to investigate options as part of developing a solution to resolve flooding issues. This assessment has considered the effects on the archaeological values of the proposed project.

This report was compiled through a combination of desk-based research and fieldwork. Two archaeological sites have been identified within the proposed project footprint, both small, subsurface, middens at Chainage 1225 and 1285. These are likely to indicate further subsurface archaeological remains in these vicinities.

Current information indicates that the number of recorded sites in the area around the project footprint is under-representative of the archaeological landscape. The study area, including the project footprint, was likely heavily used prior to 1900, by both Māori and Europeans, and therefore there is a significant risk of encountering additional archaeological material during the proposed earthworks throughout the entire project footprint.

In the proximity of Chainage 1050 it is reported there was a small Māori village, most likely called Otahuhu, were the Baptist Church is now located on the corner of King Street and Alexander Avenue. This abuts the project footprint (Coates 1956). Thus, there is a high risk of encountering archaeological material in this location.

Between Chainage 1400 and 1730, there is a high risk of encountering archaeological material as there is likely an extensive archaeological site beneath the Whakatāne Hospital. It is likely subsurface features may be exposed during works to upgrade the existing drainage channel in this vicinity.

This report recommends that an application be submitted to Heritage NZ for a general authority to modify/destroy archaeological sites during upgrade works to the existing channel, and associated works on bridges, culverts etc.

This is a legal requirement if the cultural material at Chainage 1225 and 1285 is to be impacted by the earthworks. For the remainder of the project area, having an authority in hand prior to works would enable appropriate measures for archaeological recording etc to be implemented without construction delays if additional unrecorded archaeological material is encountered during works. If material of this sort was encountered during works without an archaeological authority having been obtained in advance, a substantial delay could ensue during works while an authority was being sought from HNZPT.

It is also recommended that an Archaeological Management Plan be submitted with the authority application that includes protocols for monitoring areas with high potential for encountering subsurface archaeological remains. This is in accordance with HNZPT guidelines for applications for general archaeological authorities.

1 Introduction

1.1 Purpose

Opus International Consultants (Opus) was commissioned by Whakatāne District Council to carry out an archaeological assessment of the stream Wainui Te Whara, Whakatāne, which runs approximately 1.8 km from Valley Road to its outlet at the Awatapu Lagoon (see Figure 1 and Figure 2). Opus has been contracted to investigate options as part of developing a solution to resolve flooding issues (see Appendix 1). Earthworks for this project include the widening of the channel along its length, installing retaining walls and replacing existing bridges.

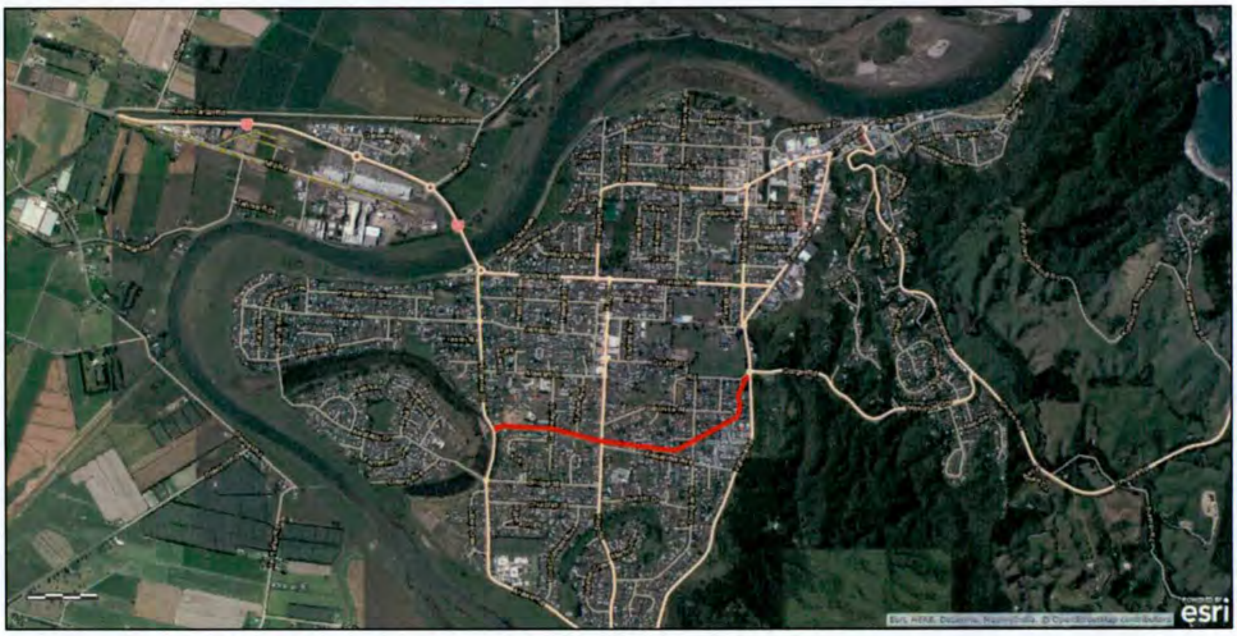


Figure 1: Aerial photograph that shows the approximate location of the proposed area of earthworks (red line) in relation to Whakatāne.

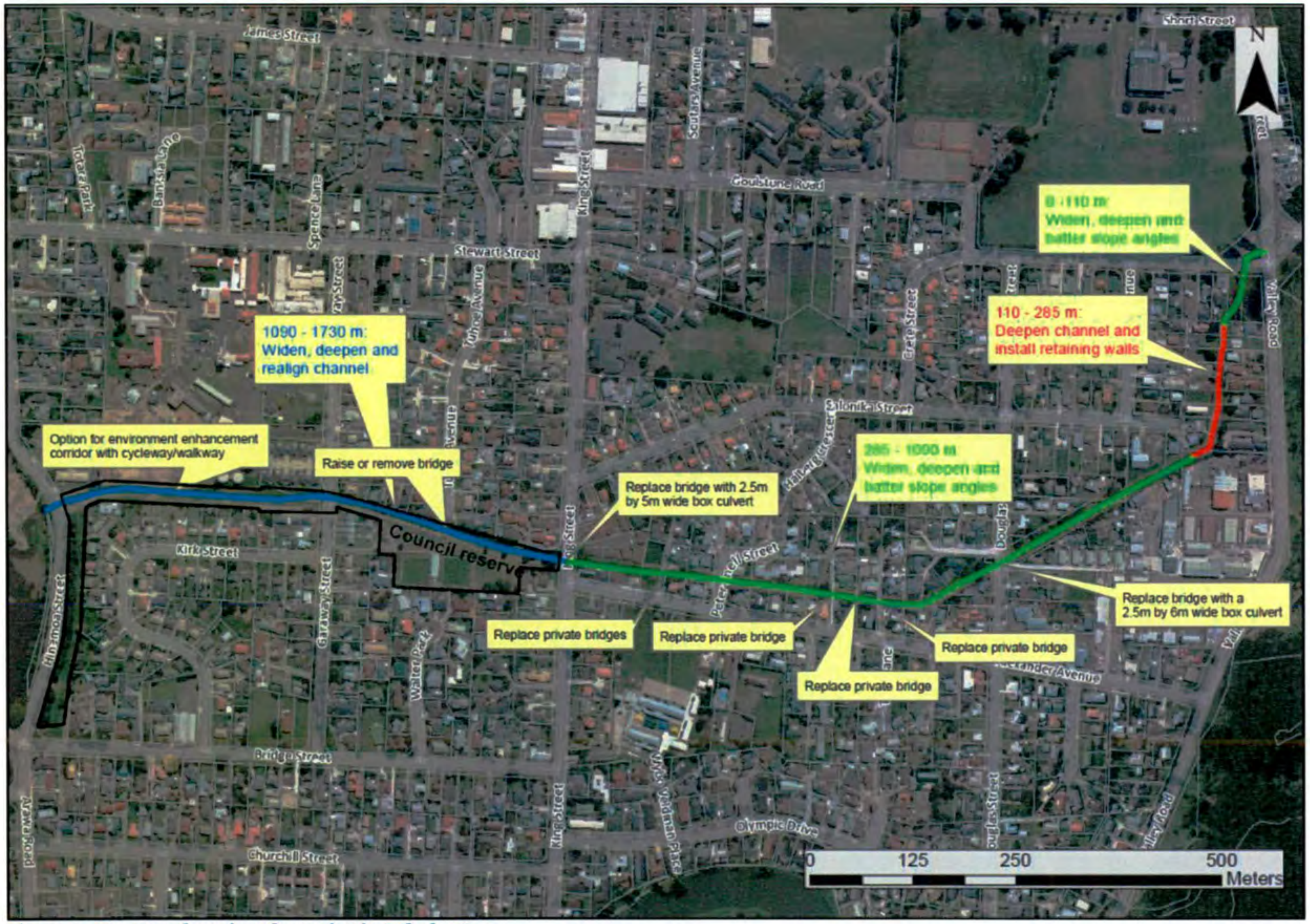


Figure 2: Proposed project footprint in Whakatāne.

1.2 Limitations

This report is an archaeological assessment of the impacts of earthworks within the footprint of the project.

Statements are made as to the location and nature of archaeological sites and their archaeological values. The archaeological information is derived from both published material (i.e. Heritage New Zealand (Heritage NZ) Digital Archaeological Report Library and New Zealand Archaeological Association (NZAA) ArchSite Database) and information from archaeologists who have undertaken research and Heritage NZ authority work in this part of Whakatāne. Archaeological site location data should be regarded as a guide only. The locational accuracy of archaeological sites recorded in ArchSite is variable. Some sites are recorded only to 100 m grid squares and many of these have been recalculated from earlier 100 yard coordinates. Sites that have been visited since the advent of GPS may have more accurate coordinates. Those that have not been GPS marked are indicated on the ArchSite maps with a square and are only accurate to within, at best, 100 m of the actual site location. The full extent of recorded sites is often not known and the single point coordinate provided by ArchSite is often based on the visible surface expression only. This does not necessarily represent the true subsurface extent of a site.

There are no statements on the cultural significance of the project area nor are the views of tangata whenua represented in this report. A statement of cultural values will need to be provided separately to accompany an authority application to Heritage NZ.

If an authority application is to be made using this assessment, archaeological concerns raised by iwi and appropriate mitigation strategies will need to be detailed in an Archaeological Management Plan (AMP). The AMP will need to be written in conjunction with iwi and in consultation with the Regional Archaeologist, and must accompany any application to Heritage NZ for an archaeological authority.

2 Statutory Requirements

There are two main pieces of legislation in New Zealand that control work affecting archaeological sites. These are the *Heritage New Zealand Pouhere Taonga Act 2014* (HNZPTA) and the *Resource Management* Act 1991 (RMA). In addition, statutory planning instruments exist, in this case, those relevant to the project are from the Whakatāne District Council.

2.1 The Heritage New Zealand Pouhere Taonga Act 2014

The purpose of the HNZPTA is to promote the identification, protection, preservation, and conservation of the historical and cultural heritage of New Zealand (HNZPTA section 3), which places emphasis on avoiding effects on heritage.

The HNZPTA provides blanket protection to all archaeological sites whether they are recorded or not. Protection and management of sites is managed by the archaeological authority process, administered by HNZPT. It is illegal to modify or destroy archaeological sites without an authority to do so from HNZPT.

The HNZPTA contains a consent (authority) process for any work affecting archaeological sites, where an archaeological site is defined as:

a. Any place in New Zealand including any building or structure (or part of a building or structure) that:

    i. was associated with human activity that occurred before 1900 or is the site of the wreck of any vessel where that wreck occurred before 1900; and
    ii. provides, or may provide through investigation by archaeological methods, evidence relating to the history of New Zealand (HNZPTA Section 6); and

b. Includes a site for which a declaration is made under Section 43(1) of the Act (such declarations are rare and usually pertain to important post-1900 remains with archaeological values).

Any person who intends to carry out work that may modify or destroy an archaeological site, or to investigate a site using invasive archaeological techniques, must first obtain an authority from Heritage NZ. The process applies to sites on land of all tenure including public, private and designated land. The HNZPTA contains penalties for unauthorised site damage or destruction. For places in which Māori have a particular historical interest, applications for an authority require records of appropriate tangata whenua consultation.

The archaeological authority process applies to all sites that fit the HNZPTA definition, regardless of whether:

- The site is recorded in the NZ Archaeological Association (NZAA) Site Recording Scheme or registered by Heritage NZ;
- The site only becomes known as a result of ground disturbance; and/or,
- The activity is permitted under a district or regional plan, or a resource or building consent has been granted.

Heritage NZ also maintains the List/Rārangi Korero (formerly the Register), which maintains a record of Historic Places, Historic Areas, Wahi Tapu, Wahi Tapu Areas and Wahi Tupuna. The List/Rārangi Korero can include archaeological sites. The purpose of The List/Rārangi Korero is to inform members of the public about such places and to assist with their protection under the RMA.

In considering any application for an authority, Heritage New Zealand Pouhere Taonga may grant fully, or in part, or decline any application. The Act allows for up to 2 months for the Trust to process an authority after the application has been formally lodged although, except in special cases, the time allowed is 20 working days.

2.2 The Resource Management Act 1991

The *Resource Management Act 1991* (RMA) provides guidelines and regulations for the sustainable management and protection of the natural and cultural environment. Section 6(f) of the RMA recognises 'historic heritage' as a matter of national significance, and identifies the need for protection of historic heritage from inappropriate subdivision, development and use.

The definition of 'historic heritage' (RMA s2) refers to those natural and physical resources that contribute to an understanding and appreciation of New Zealand's history and cultures, and includes historic sites, structures, places and areas, archaeological sites, and sites of significance to Māori.

2.3 Statutory Planning Instruments

The study area falls within the boundaries of the Whakatāne District Council. Appendix 1 contains a table of the relevant heritage objectives and policies in the planning instrument relevant to the study area.

2.3.1 Whakatāne District Plan

The Proposed Whakatāne District Plan was notified on 28June 2013 and the heritage section, Chapter 16, of the proposed plan is currently in effect. The prime objective of the plan is the "maintenance and protection of a range of the District's heritage sites, places, features and values from inappropriate subdivision, use and development" (Chapter 16.1 Objective CH1, Proposed Whakatāne District Plan). The plan has seven policies and ten rules to fulfil the objectives. The rules that apply to this project fall under the discretionary category.

2.4 Criteria for Assessing Archaeological Values

The primary purpose of an archaeological assessment is to determine whether or not there are direct impacts on archaeological sites. Heritage NZ provides a series of guidelines to assist in the compilation of reports for assessments of impacts on archaeological sites. In considering authority applications to modify or damage archaeological sites, Heritage NZ requires statements on the following values to assist in determining the significance of the archaeological site, the level of impact and whether an authority can be granted or what mitigation conditions should be attached to an authority decision:

a) *The condition of the site(s)*

b) *Rarity: Is the site(s) unusual, rare or unique, or notable in any other way in comparison with other sites of its kind?*

c) *Does the site possess contextual value?*

d) *Information Potential: What current research questions or areas of interest could be addressed with information from the site(s)?*

e) *Amenity Value: Does the site(s) have potential for public interpretation and education?*

f) *Does the site(s) have any special cultural associations for any particular communities or groups?*

3 Methodology

3.1 Research

This assessment is based on the results of desk-based research and field survey. Research was undertaken of numerous published and unpublished sources including the following:

- ArchSite (New Zealand Archaeological Association (NZAA) national site database);
- The New Zealand Heritage List/Rārangi Kōrero;

- Review of relevant District Plans and associated schedules;
- Published literature;
- Archaeological consultants reports for the wider locality;
- Historic survey plans; and
- Aerial photographs.

3.2 Consultation

A phone conversation regarding this project was held between the author and the Assistant Archaeologist of Heritage NZ. Discussions were held detailing the intention to undertake an assessment for a potential authority application. No concerns were expressed on the project and proposed approach.

This assessment does not express the view of tangata whenua nor does it outline any consultation between them, the client and the archaeologist. This will need to be provided in a separate document for an authority application.

3.3 Fieldwork

On 15 July 2015 a site visit was undertaken by Peter Caldwell of Opus Heritage, Hamilton, to assess the archaeological risk to the project to redevelop the Wainui Te Whara channel within suburban Whakatāne.

The extent of the works was surveyed on foot, where the stream banks were visually inspected for archaeological remains and areas with archaeological potential were hand-probed and, where possible, investigated using a 40 mm hand auger.

Data on the location of all recorded archaeological sites was included in GIS mapping compiled for the project. The purpose of this was to as accurately as possible identify the location of the archaeological features, or possible features in relation to the designation.

4 Project Setting

This section of Wainui Te Whara is approximately 1.8km long and starts to the immediate southwest of the roundabout junction of Valley Road and Gorge Road, Whakatāne (see Figure 1). The channel heads in a broadly western direction, before discharging in to the Awatapu Lagoon. The channel passes through the Whakatāne urban area and there are seven Council road bridges and seven footbridges along the route, of which six are privately owned. These are scheduled for replacement with culverts in some instances, with the remaining works within close proximity to the stream channel.

The areas in the proximity of the stream consist of Opouriao fine sandy loam on the lower reaches emerging from the Mokoroa Gorge, to about 250m from the Valley Road Bridge and changing to recent waterlogged soils consisting of Paroa silt loam towards the exit at Awatapu lagoon. Both of these soil are alluvial in origin and are detailed as overlying buried dunes to a depth of about 3m to 5m below ground level. Soils of the flood plain are mostly mantled with thin deposits of Tarawera ash and naturally poorly drained, but have become moderately well drained, through the implementation of artificial drainage.

5 Historical Background

The following is a very brief history of the pre-European Māori and European settlement of Whakatāne.

5.1 Māori Traditional History[11]

This section is not intended to supplant any Māori values assessment, and relies on secondary sources. It is included as general background only. According to secondary sources on Māori tradition, Toi te Huatahi, later known as Toi Kairakau, landed at Whakatāne in the 12th century AD in search of his grandson, Whatonga (McLintock 1966). Failing to find Whatonga, he decided to settle and built a Pa on the highest point of the Whakatāne Heads, overlooking the present town.

The Rangi-matoru Waka was also said to have arrived at Whakatāne at the beginning of the 14th century A.D (Robertson 1975:11). Rangi-matoru descendants spread along the coast to the Rangitāiki River and travelled inland to Waimana and Ruatoki (Robertson 1975:14).

The area was also associated with Ngahue, who visited the site from Hawaiki. He found moa here and refilled his calabashes before returning to Hawaiki (Whakatāne District Museum & Gallery n.d).

In the 15th century A.D. Ngati Awa began to settle in the Whakatāne District (Robertson 1975:16). Ngati Awa tradition was that the Mātaatua canoe under Toroa had landed at Whakatāne in search of three landmarks identified by Toroa's father Irakewa – Te Wairere (Wairere Stream), Te Ana o Muriwai (Muriwai's Cave) and Te Toka a Irakewa (Irakewa Rock) (Whakatāne District Museum and Art Gallery n.d.).

Toroa established a village beside the stream that was later occupied by Ngati Awa (Te Whara o Toroa). The anchor stone of the Mātaatua canoe, Te Toka a Taiao, was placed near the mouth of the stream on the Whakatāne River.

5.2 Pre-European-Era Landscape

The vast majority of pre-European-era Māori archaeological sites in New Zealand are located in coastal locations. They are particularly densely concentrated where access to the rich coastal resources was supplemented by the presence of navigable waterways. The Whakatāne River provided a navigable waterway in an area dominated by forest, and its adjacent land and stream systems would have provided the rich fertile soils for horticulture and fresh water supply.

Fortified settlements (pa) are in many cases conspicuous archaeological site type -and tend to have been the focus of early archaeological recording, and thus tend to be over represented in existing archaeological records. This is certainly true for pa in the vicinity of the study area. There are extensive pa, earthworks and midden recorded on the hills to the east of the project footprint. Historically, there has been an under-recording of less visible archaeological sites associated with

[11] Reproduced from Cable 2011

day-to-day living activities; for example, garden areas, undefended settlements and food storage locations.

Cultivating Polynesian root crops in New Zealand required horticultural adaptations to improve conditions for plant growth and maturation (Furey 2006). These modifications included the addition of gravel and sand to soil. The project footprint is located on well-drained Galtymore soils and poorly-drained Flaxton soils that may have been suitable for kumara and taro respectively (Harris 2014). Coates (1956) recorded that the flats were used as cultivation grounds for the pa on the hills directly to the east of the project footprint and that Māori inhabited small villages that would have been evacuated in times of hostilities. A number of these small villages have been recorded from the 1840s when the first missionaries visited the Kopeopeo loop, the loop of the Whakatāne River immediately to the north of the project footprint (Coates 1956).

Mature kumara was harvested in autumn and stored in semi-subterranean store pits or in above-ground structures such as pataka or whata (Furey 2006, 11). Mature taro could be left in the ground or stored in the open (Colenso 1880: 15), unlike kumara, which required a very narrow range of temperature and humidity conditions to survive in storage. Storage pits are common in the archaeological record in coastal locations and there are a number recorded in the vicinity of the project area.

Swamps were important resource zones for pre-European Māori. The eastern portion of the project footprint was previously a swamp. Such areas were generally too wet for horticulture, although raised river and stream levees through swamps were often used for horticulture. While no archaeological sites are currently recorded in the area of the former swamp, it is reported that the Pouroto Ngaropa name of the swamp, which was formerly a more open stream, is "Otamakaokao, a site where Ngati Awa warriors prepared for and bathed before and after battle" (Harris 2014).

Archaeological sites tend to be recorded based on those that are easily visible as surface archaeological features (e.g. pa and borrow pits) and those that are uncovered due to private and recent commercial developments. Pits are often infilled due to farming practices such as ploughing and may not be visible as surface features as a result of such practices. The low lying land of Whakatāne, including the project footprint, is therefore considered to have potential for unrecorded archaeological sites. It is thought that the area is likely to have been heavily occupied and the lack of recorded sites on the low lying flats may simply be due to the lack of recent development (Harris 2014). The types of sites that are likely to be located in this area include garden areas, undefended settlements and food storage locations.

5.3 European-Era Historical Background

The first Europeans visitors to Whakatāne in the 1820s were quickly followed by traders who settled in the area in the 1830s (Cable 2011; van der Wouden nd). These settlers tended to settle around Māori villages and traded for items such as flax. By the 1840s central Whakatāne was a permanent settlement (Cable 2011). In the 1860s a mission and store were opened at Kopeopeo, just to the north of the project footprint. In 1868 troops from the Waikato Regiment were sent to Whakatāne and constructed a temporary redoubt several hundred meters to the east of the aforementioned mission before moving to Hillcrest several months later. Kopeopeo thereafter became a large farm on land that was part of a large scale confiscation from Ngati Awa under the *New Zealand Settlements Act 1863* (Cable 2011; Coates 1956; Pullar et al 1978).

Population growth in Whakatāne in the colonial era was slow due to its relative isolation from the main immigration centres. By 1896, the population of Whakatāne had risen to 119. In 1897 the road to Rotorua was complete and a rail between Tauranga and Tāneatua was established in 1928 (Cable 2011; Pullar et al 1978). The population continued to grow slowly until the 1950s when it expanded rapidly due to forestry, paper milling and construction of the Matahina hydroelectric dam (Cable 2011; Pullar et al 1978).

5.4 History of Wainui te Whara

The course of the Wainui te Whara has been modified throughout the 20th century to drain the swamp in the east and prevent flooding. A review of Papers Past (http://paperspast.natlib.govt.nz/cgi-bin/paperspast) produced a number of articles related to flooding events for the Wainui te Whara. It also indicated that the stream was formally known as Maraetotara Stream and Wainui Stream (Worley 1945).

The most eastern portion of the stream as it emerges from the gorge has been left largely unmodified from its natural course, evident through its curving path where it then became a swamp. Plan LT 9702, dated 1915, shows a channel to drain the swamp (see Figure 3). The swampy area emptied into a stream that ran roughly parallel to Hinemoa St before discharging into the Whakatāne River further north than it currently does (see Figure 4). SO 43845 shows land to be taken for these flood control works. The plan was surveyed in 1966.

The majority of plans from the vicinity of the project footprint date from the 1940s through to the 1960s and show the substantial development of the area, including subdivisions of properties and the addition of road (see Figure 5, also DPS 429, DPS 582, DPS 4214, DPS 5131 and DPS 6304). A topographical map of the area, dating 1978, shows that the western portion of the course of Wainui te Whara has been diverted to discharge more directly into the Whakatāne River. The river has also changed course to mitigate flooding, being cut through a former loop in 1970 leaving the former loop as Awatapu Lagoon (see Figure 6).

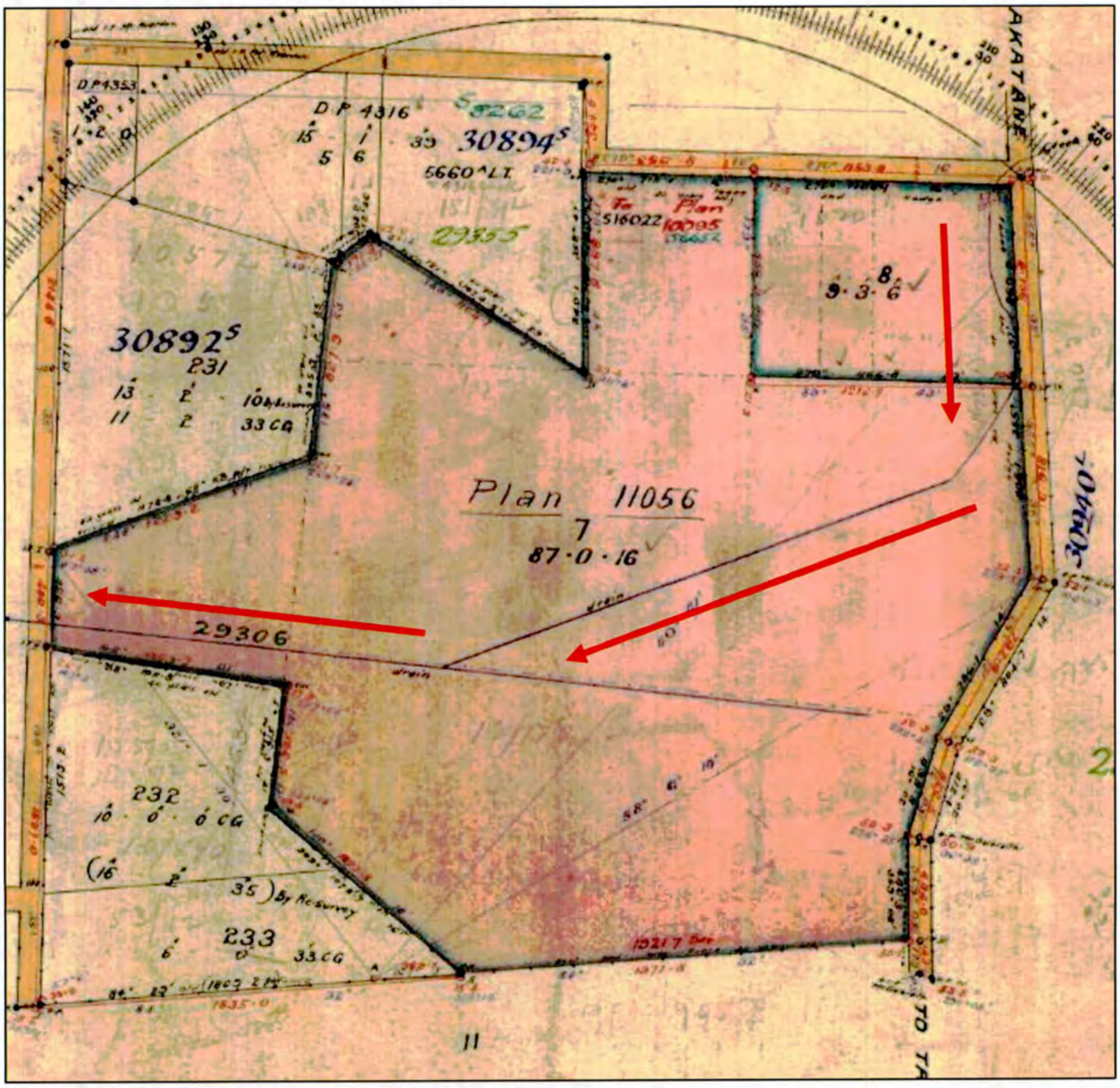


Figure 2: Portion of plan LT 9702, dated 1915, showing drain as indicated by the red arrows in the approximate current location of Wainui te Whara.

Figure 3: Aerial photograph with the 1943 course of Wainui te Whara with the current route indicated approximately by the red line.

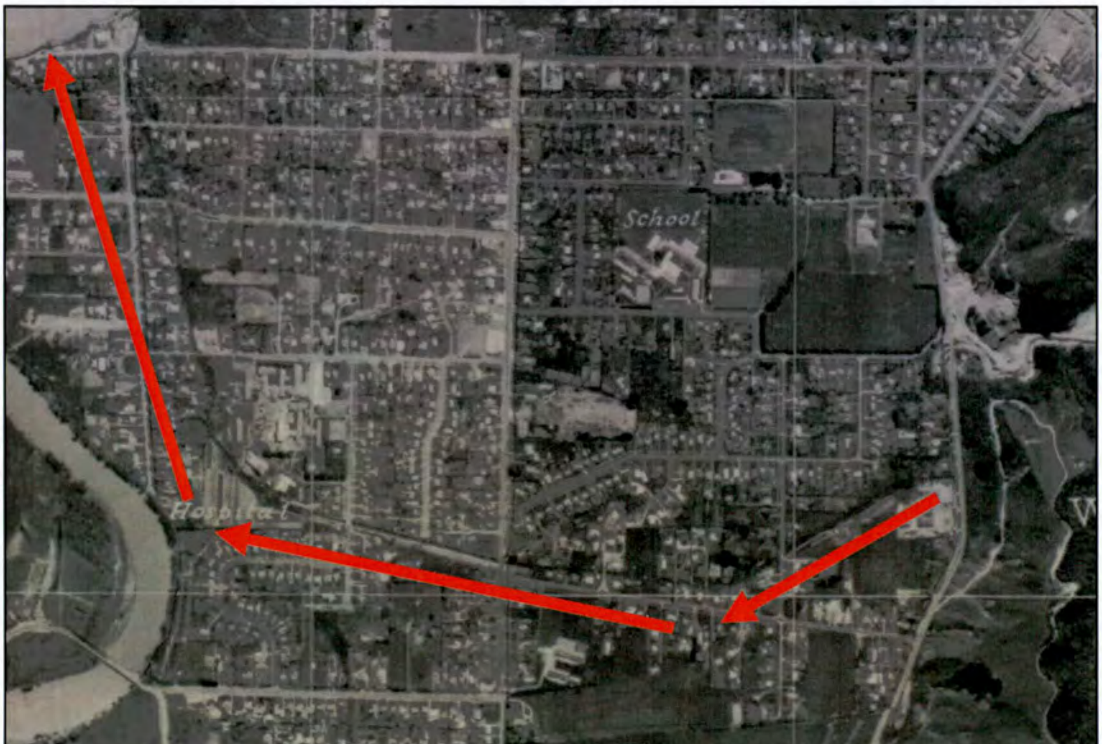


Figure 4: 1964 aerial with the course of Wainui te Whara at that time indicated by the red arrows.

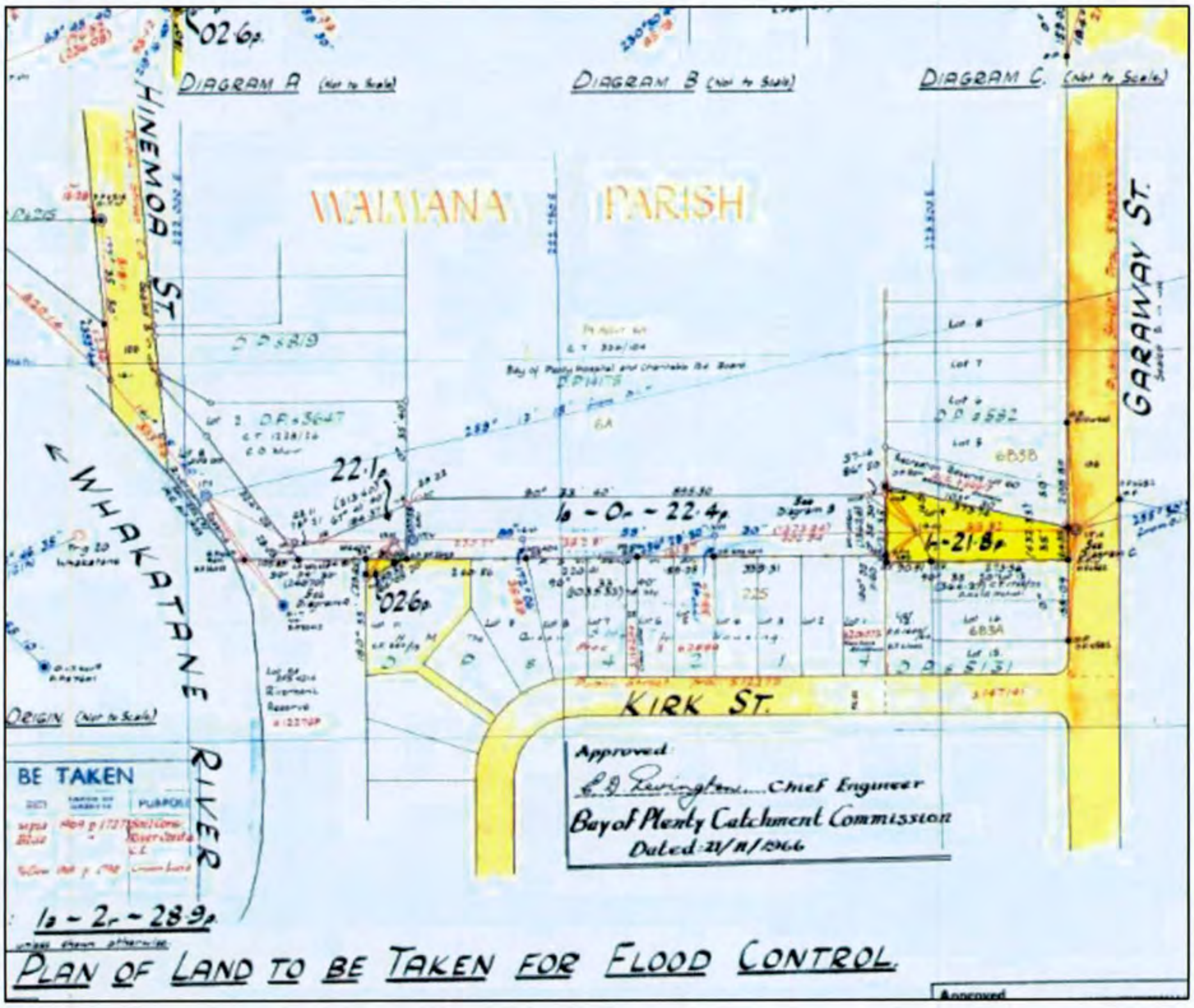


Figure 5: Portion of SO 43845, dated 1966, indicating land to be taken for the western portion of Wainui te Whara.

6 Previous Archaeological Work

6.1 Previous Archaeological Surveys and Recording

Previous archaeological surveys in Whakatāne have tended to previously focused on the commercial centre of town to the north. This is likely to have contributed to the few recorded archaeological sites in the vicinity of the project footprint. These few recorded sites are therefore of interest as they provide the most relevant information for the risk of encountering archaeological material within the project footprint. Archaeological records in ArchSite for the area are shown in Figure 7.

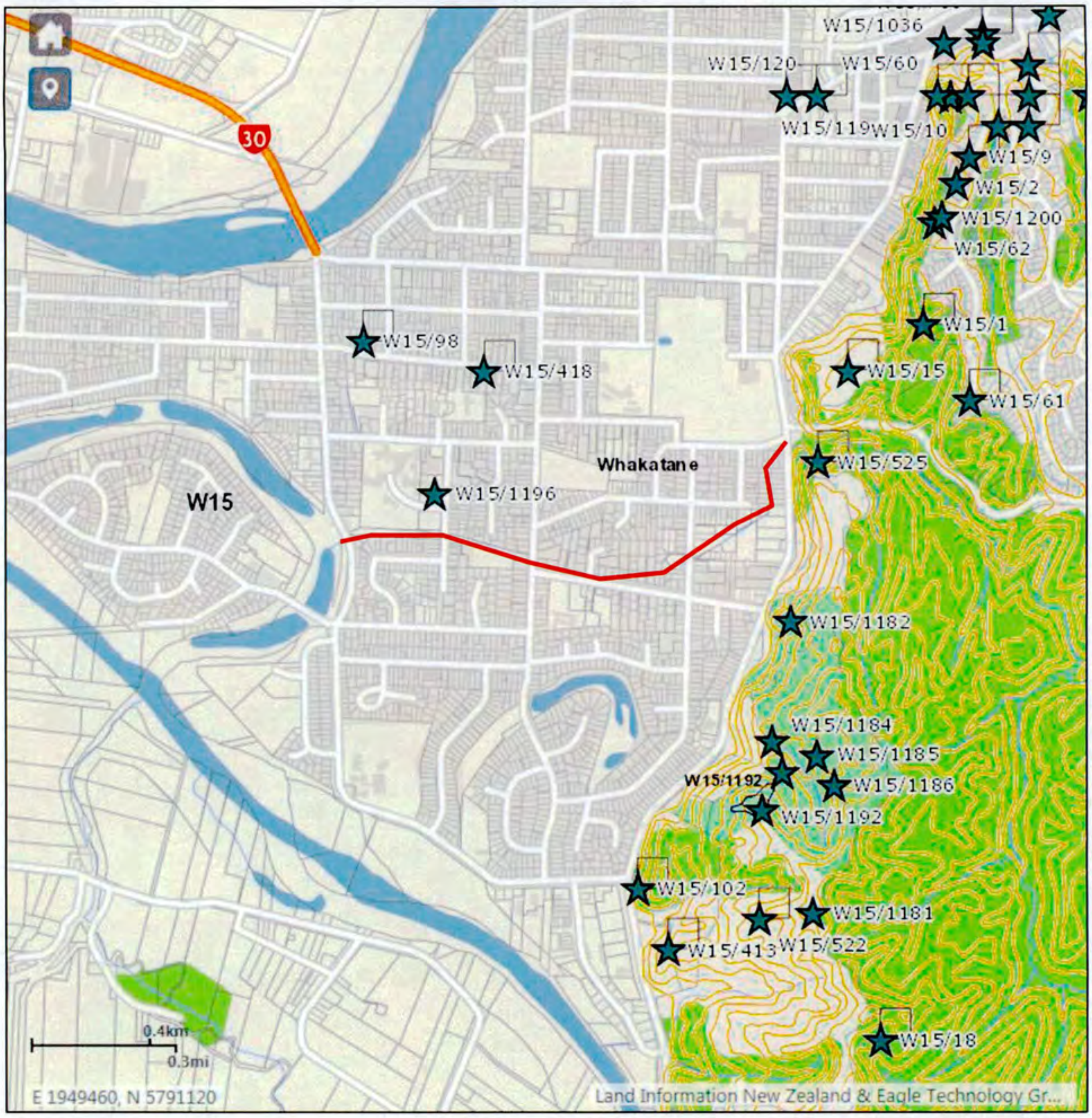


Figure 6: Map of ArchSite in the vicinity of the project (as indicated by the red line) – (source-ArchSite, retrieved 10/07/2015).

6.1.1 W15/15 – Pa – Tupateko

This was recorded as comprising a large platform (80m x 20 m) with lateral scarps and ditches.

6.1.2 W15/98 – Midden

Recorded in 1972 as midden that was "built on" (see Appendix 3). The site record indicates there were midden, umu, obsidian and a kainga at this location. The record also says the kainga site is reputed to have been in the area as evidenced by the material at 55 Victoria Avenue. However, further information as to evidence of this is not provided in the site record.

6.1.3 W15/418 - Pits and find spot

An argillite chisel was found here and six pits were exposed in a section on a building site (see Appendix 3).

6.1.4 W15/525 – Midden

Eroding from flat topped ridge for approximately 10 m. Consists of tuatua, cockle and hang stones. Adzes and obsidian reported to be frequently found in the area.

6.1.5 W15/1182 – Terrace and platform

15-20 x 8 m terrace and an 8 m oval platform. Interpreted as representing either gardening or habitation.

6.1.6 W15/1196 - Te Mara Kai o Taiwhakaea

Recorded as a midden/oven site, Te Maara Kai o Taiwhakaea is reported as the find location of koiwi (cranium and mandible) with disturbed midden and two fire scoops located a further 20 m to the northwest (see Appendix 3).

6.2 Previous Archaeological Investigations in the Area

6.2.1 W15/1196 Te Maara Kai o Taiwhakaea

This is the closest recorded archaeological site to the project footprint. The NZAA grid reference indicates a location approximately 130 m to the north of the project footprint on the west side of Garraway Street.

Koiwi (a cranium and mandible) were identified here in 2013. CFG Heritage Ltd subsequently carried out a detailed archaeological investigation. CFG recorded 233 archaeological features in two areas including three borrow pits, a burial, three caches of stone, 22 ovens, 46 pits, 129 postholes, 6 bin pits as well as various historic and modern features. Harris (2014) concluded that the area examined was a small portion of an intensely occupied location that was likely in use early in the pre-European era of Māori settlement. Harris concluded there was probably a relatively brief single episode of settlement. The site contained borrow and storage pits, indirectly indicating horticulture. Associated gardens were not located although they were surmised to have been somewhere nearby. A similar conclusion was reached regarding houses, with the remains of fire pits and obsidian artefacts indicating habitation. While it was concluded that development of the surrounding area had most likely disturbed the site and impacted on negatively archaeological preservation, Harris (2014) stated that it was likely that the site would formerly have extended in all directions beyond the area investigated.

6.3 Summary

Six archaeological sites have been reviewed within the section as being relevant to the project footprint:

Table 1: Recorded archaeological sites within close proximity to the project footprint.

Site Number	Site Type	Grid Reference
W15/15	Pa – Tupateko	NZTM E 1950898 NZTM N 5790983
W15/98	Midden	NZTM E 1949296 NZTM N 5791081
W15/418	Pits and find spot	NZTM E 1949696 NZTM N 5790981
W15/525	Midden	NZTM E 1950798 NZTM N 5790682
W15/1182	Terrace and platform	NZTM E 1950705 NZTM N 5790158
W15/1196	Midden/Oven- Te Maara Kai o Taiwhakaea	NZTM E 1949534 NZTM N 5790580

7 Research Results

Research results presented below include the results from analysis of historic survey plans and also detail the results of field research.

7.1 Historic Maps and Survey Plans

A search LINZ historic survey plans was carried out via *QuickMaps*. Several historic maps were identified that showed historic land use in the study area.

The earliest plan of the area is SO 480H and is dated 1868 (see Figure 8). Other plans from this time, SO 480H and SO 476, show that Wainui te Whara was not a distinct stream at this time but emerged from the gorge into a large area of swamp (see Figure 8 and Figure 9).

In the 1868 plan, the land transected by the eastern portion of the project footprint, being east of King Road, was at that time within an area shown as swamp. This is not well illustrated on SO 480H, but it is clearly shown on SO 476, which, while undated, is very similar to SO 480H.

Plan SO 480H illustrates that within the project footprint to the west of Kings Road the project transects a number of early town allotments. Some of these have names, including Māori names, written within the property boundaries.

An overlay of the plan with the project footprint illustrates that the current course of Wainui te Whara as modified by previous drainage/flood control works in the late 1960s runs through the back and side portions of four allotments labelled: 6A, 6B, 228– (the latter annotated "Ihaka Taupō") and 31/225 (annotated Hoani Tuhimata) (see Figure 10 and Figure 11). It appears that the drain that has been cut to accommodate the water of the Wainui te Whara follows what was at the time of those surveys a swampy channel through allotment 6, but close to the boundary with allotment 225, to allow drainage into the Whakatāne River. There is a cottage and several other small structures just to the north of the watercourse visible in the 1943 aerial on the block annotated "Ihaka Taupō".

The land affected by this new channel in the 1960s was formerly part of allotments 6A and 31. This area is also 130 m to the south of the location of excavations reported in Harris (2014) excavation within the grounds of the Whakatāne hospital. This area therefore has a high risk for encountering cultural features within the project footprint.

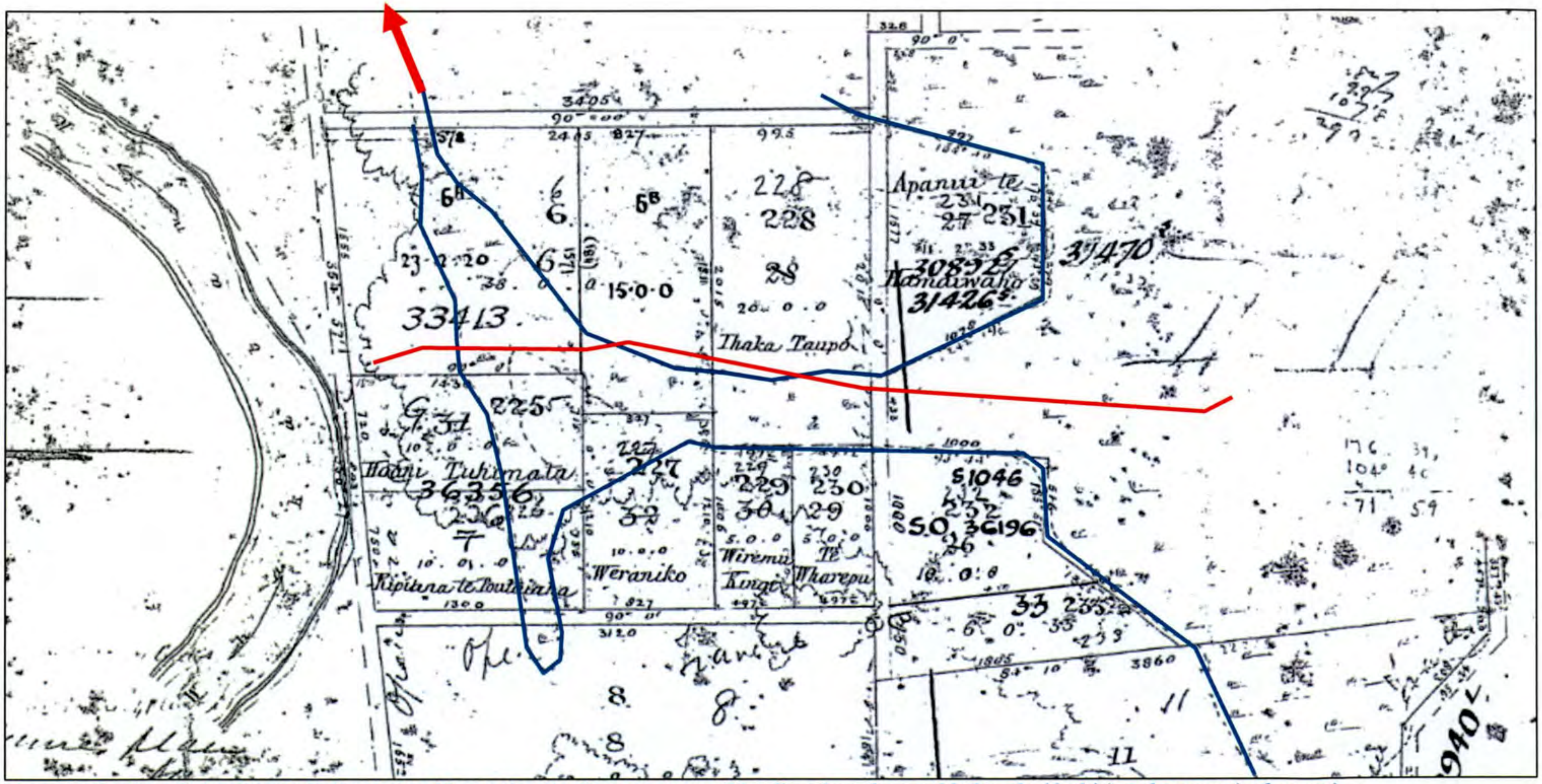


Figure 7: Portion of plan SO 480H dated 1868 illustrating the former swamp (blue lines have been added to clarify this) and stream (red arrow) that drained what is now the Wainui te Whara (red line).

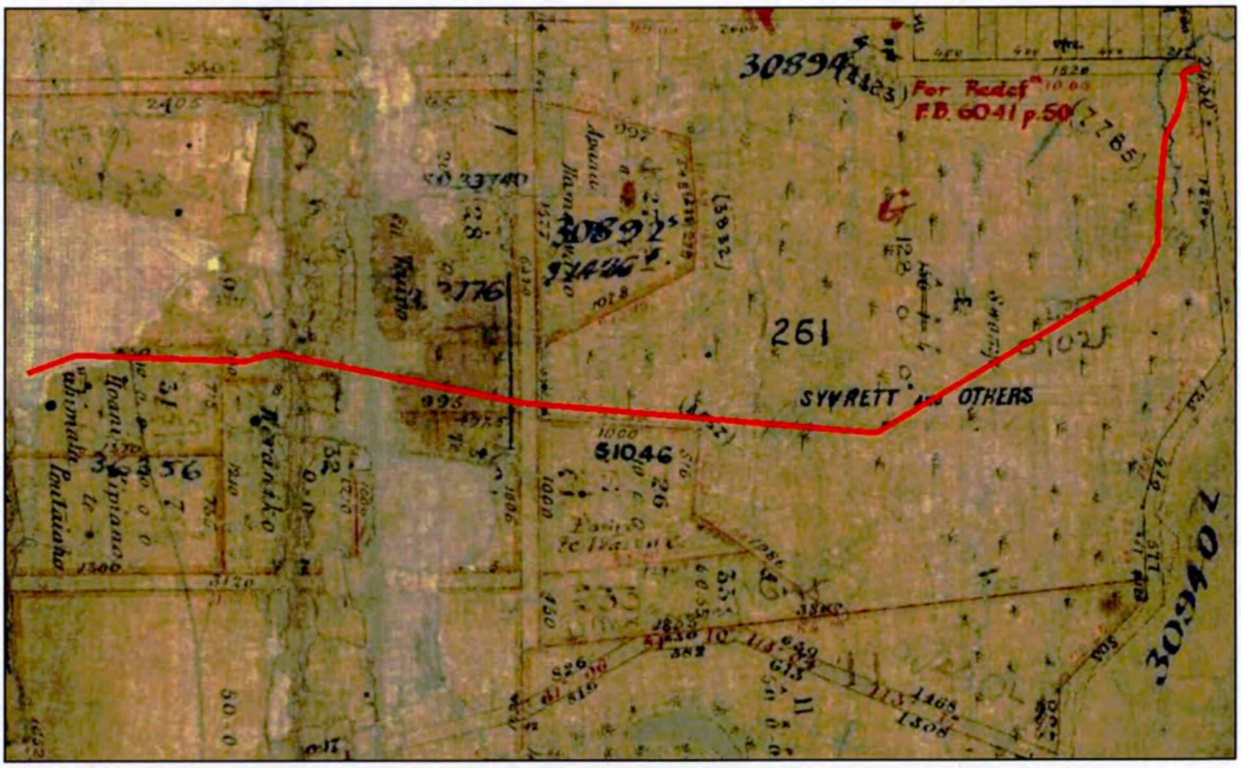


Figure 8: Detail from plan SO 476, undated but showing allotments and names as per SO 480H as well as the eastern portion of Wainui te Whara (indicated by red line).

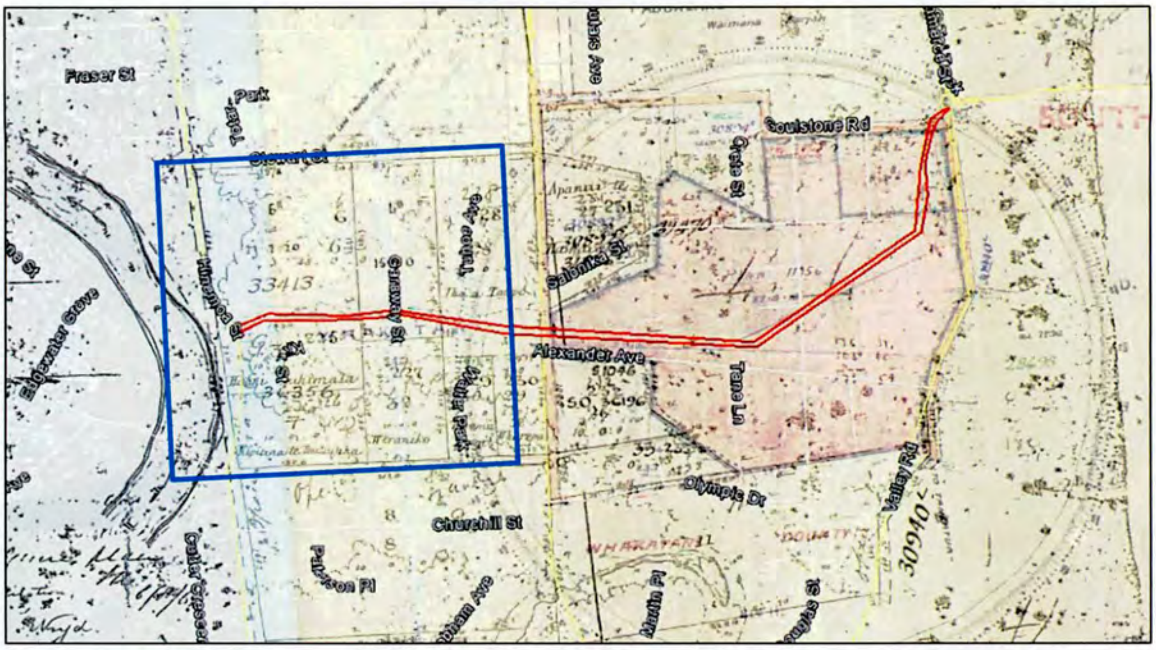


Figure 9: Overlay of SO 480, LT9702, the project footprint (red) and the location of properties of interest (blue box).

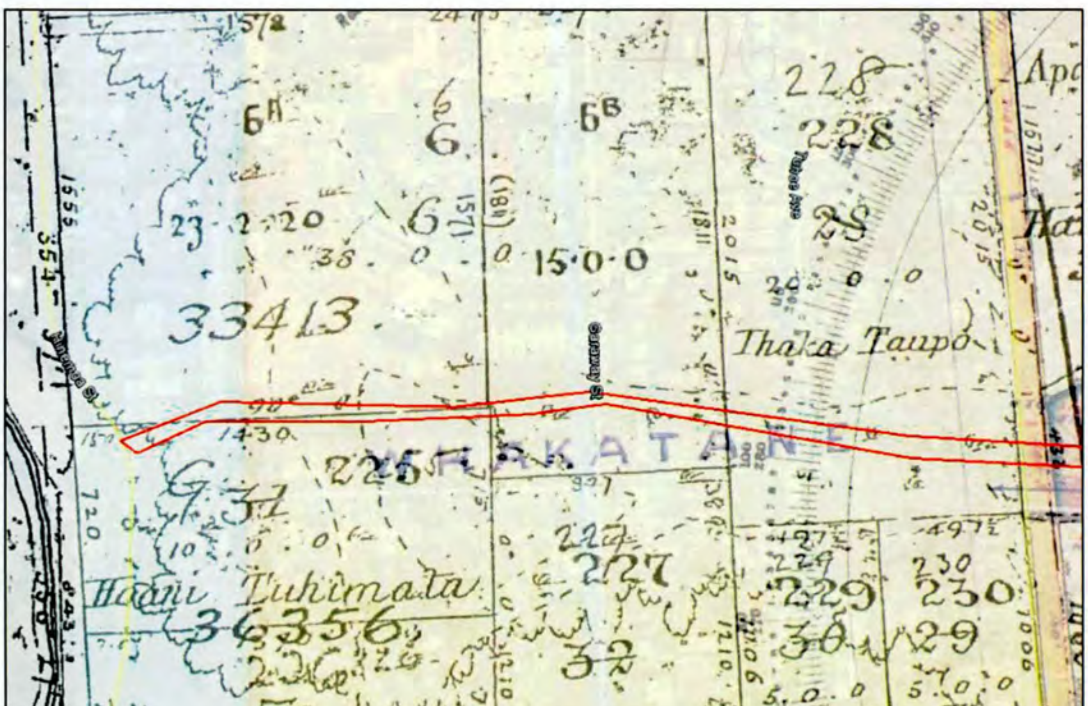


Figure 10: Close up of properties of interest indicated by the blue box in Figure 10)

7.2 Other Resources

A search of the New Zealand Heritage List/Rārangi Kōrero produced no results for archaeological or heritage sites within the footprint of the project. The closest heritage listed site is a Historic Place Category 2 house at 39 Goldstone Road, approximately 350 m from the project footprint.

A brief review of the literature outlines there are a number of Māori villages noted by early missionaries, who established a mission to the north of the project footprint in the 1860s (Coates 1956). Coates notes two of these habitation within close proximity to the project footprint. A pa, which he names as Otamakaukau, is reported to have been located at the "David Hogg Memorial Hostel for Māori Boys, Hinemoa Street", now 68 Hinemoa Street, less than 300 m to the north of the project footprint (Coates 1956:2). This is a very similar name to that given by Ngati Awa representatives during the CFG excavations as "Otamakaokao, a site where Ngati Awa warriors prepared for and bathed before and after battle" (Harris 2014).

Coates further notes that there was a small village, which he calls Otahuhu, where the Baptist Church is located on the corner of King Street and Alexander Avenue, which is immediately adjacent to the project footprint (Coates 1956). A sketch map of the area included in NZAA Site Record W15/418 places "Otamakaukau" at this location. This site has been recorded in ArchSite as W15/1208. There is therefore a high risk of encountering archaeological material in this location.

Coates (1956) produced a plan of the Kopeopeo area from approximately 1890. The edge of the map indicates that "Simpkins" owned an area on the eastern side of the Whakatāne River, close to the area where Wainui te Whara currently discharges into the former river bend. Thus, there is a risk that archaeological material relating to pre-1900 farming activities exist within the project footprint.

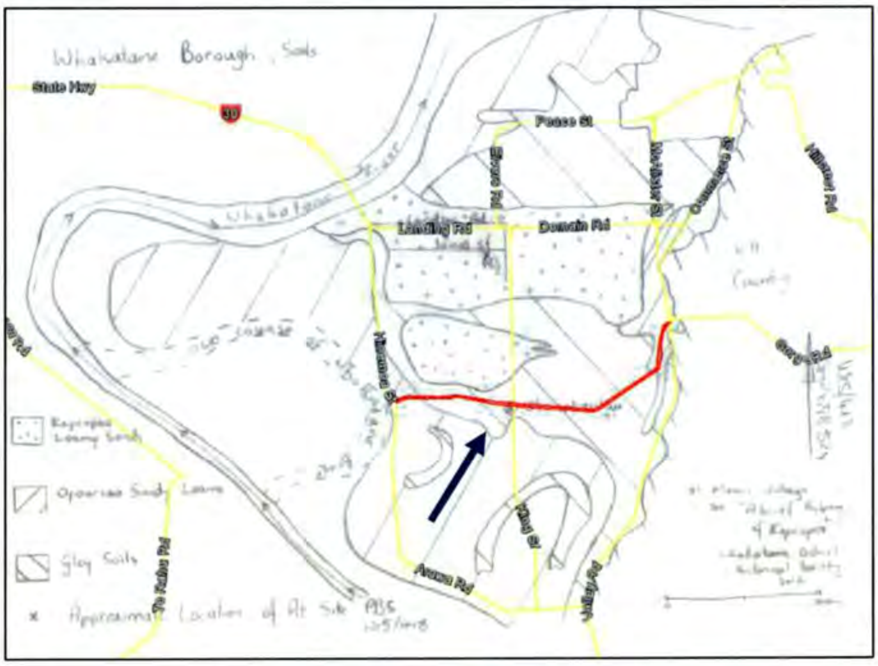


Figure 11: Location of Otamakaukau (indicated by blue arrow) in relation to the project footprint (red line - NZAA Site Record W15/418).

Figure 12: Reported location of Māori village (red box) in relation to the project footprint (blue line) on the corner of King Street and Alexander Avenue.

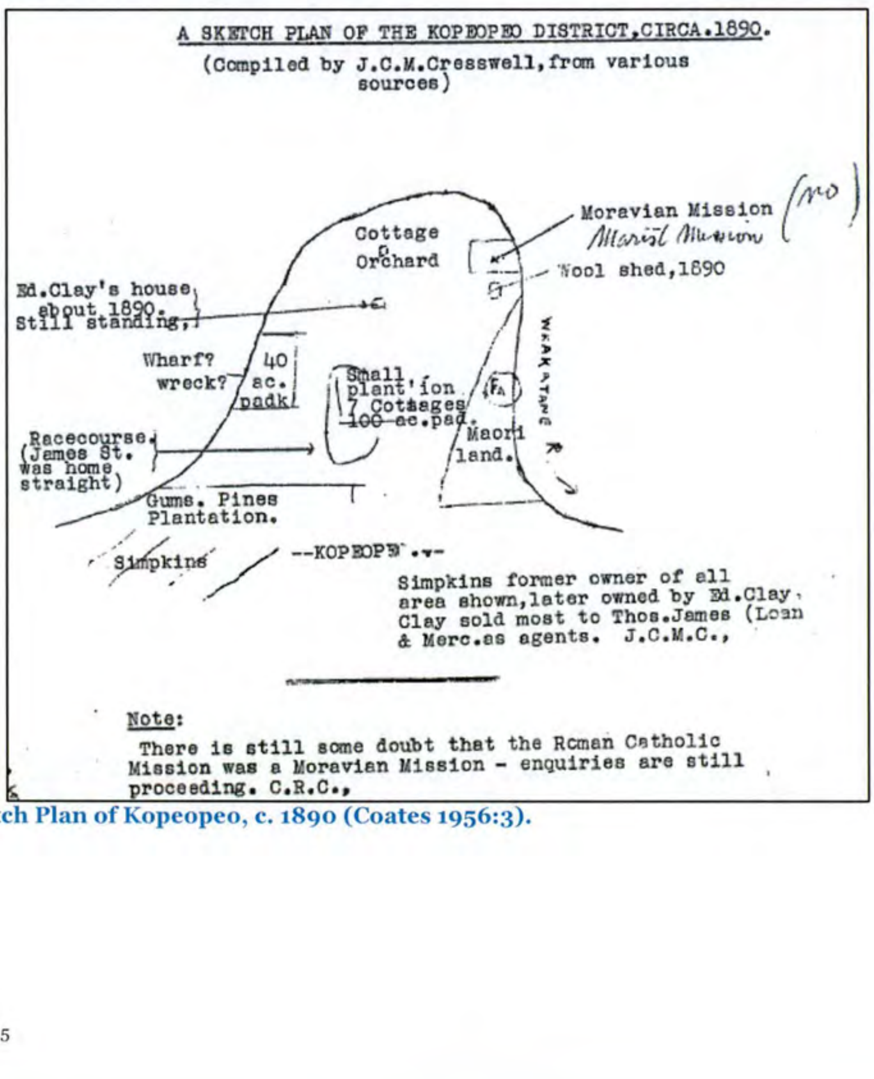


Figure 13: Sketch Plan of Kopeopeo, c. 1890 (Coates 1956:3).

7.3 Fieldwork

Locations will be referred to in terms of Chainage (metres) from the start of works at Valley Road as per the plans (see Figure 15, Figure 16 and Appendix 2).

Figure 14: Chainage relevant to fieldwork in the eastern portion of the project footprint

Figure 15: Chainage relevant to fieldwork in the eastern portion of the project footprint

7.3.1 Chainage 0-70 m

The east bank at this point is bounded by a small reserve and on the west, residential properties (see Figure 17). The reserve is planted in c.35 year old trees and has c.1200 mm subsurface of roading metal. It is likely this metal has been introduced to build up the area as part of the channel modification and subsequent roading development.

The west bank was probed with a steel spear along the property boundary boundaries.

No archaeological remains such as shell midden were seen or detected by probing.

Figure 16: View north of Chainage 0-70m - note depth of roading material.

7.3.2 Chainage 70-260 m

This area was not accessible by foot due to fencing, however, the upper banks were observed to be augmented with c.1000 mm stop banks and the stream banks themselves covered in thick mown grass. The stop banks exist to the margin of adjoining properties. Further archaeological examination was not possible due to the depth of the stop bank and access constraints.

7.3.3 Chainage 260-560 m

A substantial stop bank c.1200 mm high has been built along the entire length of this section (see Figure 18). The stop bank and stream banks are covered in mown grass. Access to this area was gained from the Assembly of God church carpark in Salonika Street.

The church property, along the inside of the fence (see Figure 19) was hand probed, revealing a subsurface of hard packed river gravels. It is possible this material is introduced relating to the construction of the buildings on the property. The stop bank was examined on foot along the northern bank up to Douglas Street (Chainage 560). Again further archaeological examination was not possible due to the depth of the stop bank material and access constraints.

No Archaeological material was observed.

Figure 17: View east of Chainage 260- 360m.

Figure 18: View west of Chainage 360-480m.

7.3.4 Chainage 560-1160 m

Prior to the field visit, NZAA site record forms were examined to indicate possible archaeological activity in the area. A map included in Site Record Form W15/418 (reported by Bristow in 1986) shows the position of a Māori village (not W15/418), reported to be at the present location of the Baptist Church on the corner of King Street and Alexander Avenue (see Figure 20 - Coates 1956).

The riverbank/stop bank was walked along both sides to King Street (Chainage 1160). Again further archaeological examination was not possible due to the depth of the stop bank material stream bank grass cover and access constraints, hence no Archaeological material was observed. Thus, this area continues to have a high risk of encountering subsurface archaeological material.

Figure 19: View east from King St of Chainage 900- 1100m – note the Baptist Church on the far right.

7.3.5 Chainage 1160-1400 m

As archaeological examination of the Baptist Church riverbank/stop bank was not possible, hand auger testing was carried out in the council reserve on the south side of the channel between Chainage 1100 and 1240 m. Five tests were carried out revealing up to 400mm of dark brown sandy soil over grey/brown/ orange silty clays. No archaeological deposits were noted.

At Chainage 1375 m, a shell deposit was noted on the north bank just under the present ground surface. The condition of the tuatua shell was very good with intact periostracum. It is concluded that this deposit in relatively modern in nature and not archaeological.

However, on the north bank two archaeological shell deposits were noted at Chainage 1225 and 1285.

7.3.5.1 Chainage 1225 – NZAA Site W15/1206

At Chainage 1225 a small in-situ cockle and pipi midden deposit was observed c.700 mm below the present ground surface (see Figure 21 and Figure 22). The shell may to be in a buried topsoil context but no charcoal was observed. The condition and position of the shell suggests it may indicate more substantial archaeological remains in the vicinity. The shell midden was entered into ArchSite as W15/1206.

Figure 20: View north of Chainage 1225m. Cockle and pipi shell deposit in channel bank indicated by the red oval.

Figure 21: View north of Chainage 1225. Close up of cockle and pipi shell deposit.

7.3.5.2 Chainage 1285 – NZAA Site W15/1207

At Chainage 1285 shell was noted in sandy soil, c.1000 mm below the present ground surface in an eroded scarp (see Figure 23 and Figure 24). Again as with the prior deposit the condition and position of the shell suggests it is likely to be in an archaeological context indicating further archaeological activity in the immediate area. Further shell was noted on top of the bank and is interpreted as redeposited shell from channel maintenance. The shell midden was entered into ArchSite as W15/1206.

Figure 22: View north of Chainage 1285. Shell midden indicated with red oval.

Figure 23: View north of Chainage 1285. Close up of shell deposit.

Site	Value	Assessment
NZAA Site W15/1208 – traditional site	Condition	As this is only recorded via written records it is condition of the site is unknown.
	Rarity/ Uniqueness	Any intact evidence of a settlement under an urban area is considered rare because of the highly disturbed nature of urban development. In particular, it is extremely rare to find early Māori settlement sites in an urban environment as has been located at the Whakatāne Hospital (Harris 2014). The lack of large scale archaeological investigations in this area gives greater significance to any archaeological material within the project footprint as it would make an important contribution to research in this area.
	Contextual Value	There is evidence that this part of Whakatāne is known to have been occupied by Māori during the early 15th and possibly into the 16th century at the Whakatāne Hospital site to after the arrival of Europeans as recorded by the missionaries (Coates 1956; Harris 2014). As this reported village was reported by missionaries in the early 19th century it is presumed that the site was in use at that time.
	Information Potential	Any archaeological material would contribute immensely to the record of use of this area, particularly the early 19th century.
	Amenity Value	The project footprint is located in the residential zone of Whakatāne and is therefore very accessible to the public and affected community. Should any material be found, there is a significant potential for onsite public education.
	Cultural Associations	The area is associated with Ngati Awa. Statements on the significance of the sites to iwi and Māori Values can only be provided by tangata whenua.

Potentially unrecorded archaeological material	Condition	It is possible that there are further unrecorded archaeological sites within the footprint of the project footprint.
	Rarity/ Uniqueness	Should unrecorded archaeological sites be located during earthworks within the project footprint these are likely to be storage pits, settlements, temporary camps, burials, and European farming related sites. Any of these site types would be considered relatively rare for this landscape and would require careful archaeological investigations.
	Contextual Value	There is evidence that this part of Whakatāne is known to have been occupied by Māori during the early 15th and possibly into the 16th century at the Whakatāne Hospital site to after the arrival of Europeans as recorded by the missionaries (Coates 1956; Harris 2014). European traders occupied areas in close proximity to the project footprint from the 1830s. Should sites be located during the earthworks, they will likely be related to either the pre-European Māori activity or Mid-to-late 19th century farming.
	Information Potential	Should unrecorded archaeological sites be located during these have the potential to add to our knowledge and understanding of Māori settlement patterns, settlement chronology and distribution and land-use prior to intensive farming from the late 19th century. There is also potential for significant information on past environmental changes to be gained if such are encountered during works and investigated. Furthermore, analysis of items such as lithics have the potential to gain information on interactions through studies of the original geological provenance of the lithic material. There is also potential for the location of early 19th century European and Māori sites, particularly from the mid-to-late-19th century settlements, potentially in the context of a Christian mission settlement.
	Amenity Value	If further archaeological material is discovered during works there is potential to enhance amenity value through commemorative signage or some similar measure. The project footprint is located in the residential zone of Whakatāne and is therefore very accessible to the public and affected community.

	Cultural Associations	There are a number of Māori individuals associated with the land that is west of King Street from approximately Chainage 1100. These individuals are named on the land survey from 1868. An overlay of the plan with the project footprint illustrates that Wainui te Whara runs through the back and side portions of four properties labelled: 6A, 6B, 25 – Ihaka Taupō and 31 - Hoani Tuhimata (see Figure 9 and Figure 11). Cultural material found at these locations may relate to these occupations. The area is associated with Ngati Awa. Statements on the significance of the sites to iwi and Māori Values can only be provided by tangata whenua.

9 Assessment of Effects

9.1 Proposed Works

In order to safely discharge flood waters from the lower Wainui te Whara catchment during peak flows, the project proses that the existing channel will need to be significantly up-graded. Opus have undertaken a series of hydraulic assessments, combined with geotechnical investigations and structural assessments of the existing bridges as part of a concept design for the channel up-grade. Based on these studies, the proposed works outlined in Table 2 and Table 3 are recommended to be undertaken, in order to allow the Wainui te Whara channel to safely convey the design peak flow.

Table 1 outlines that the proposed works include widening and deepening the stream channel so the banks are between 35 and 42 degrees in slope (see for Figure 14 and Figure 15 Chainage locations). This equates to up to 2 m of bank removal on both sides in any one place.

Table 2 outlines the upgrade of nine bridges including replacement with box culverts up to 6 m wide and 3 m high (Douglas Street, King Street, Hinemoa Street), removal or raising the current bridge deck (Tūhoe Avenue) and raising the current bridge and increasing the bridge span (5 privately owned bridges). This table also outlines that between Chainage 110 and 285 retaining walls will be installed.

Table 2 Proposed works to Wainui te Whara channel (Francis 2015).

Chainage	True Left Hand Side	True Right Hand Side	Comments
0 – 110	Widen, deepen channel base and batter slope angle no steeper than 35°	Widen, deepen channel base and batter slope angle no steeper than 35°	Top-up existing stop banks on both sides from CH80 – Ch110 to accommodate over topping and free board requirement Placement of rip rap at exit of Valley Road bridge CH20 – CH60, within base of channel
285 – 580	Widen, deepen channel base and batter slope angle no steeper than 42°	Widen, deepen channel base and batter slope angle no steeper than 37°	Height of existing stop bank to be increased slightly to allow for 300mm freeboard
580 – 1090	Widen, deepen channel base and batter slope angle no steeper than 40°	Widen, deepen channel base and batter slope angle no steeper than 40°	Height of existing stop bank to be increased slightly to allow for 300mm freeboard
11115 – 1730	Widen, deepen and realign channel with batter slope angle no steeper than 38°	Widen, deepen and realign channel with batter slope angle no steeper than 34°	Realignment of channel required to accommodate proposed slope angles Height of proposed stop bank to be increased to allow for 300mm freeboard between CH1115 and CH1380 and CH1410 and CH1440

Table 3: Proposed works to the bridges that cross the Wainui te Whara channel (Francis 2015).

Asset	Recommendation
CH110 – CH285	Install retaining walls – See Table 1-5 for recommendations. Retained height to take in to account peak flow and 300mm free board
Douglas Street Bridge	Replace with 6m wide and 2.5m high box culvert
Peter Snell Bridge	No action required
King Street Bridge	Replace with 5m wide and 2.5m high box culvert
Tūhoe Avenue Bridge	Removal of bridge, or raise existing deck level
Garaway Street Bridge	No action required
Hinemoa Street Bridge	Replace with 5m wide and 3m high box culvert
5 privately owned bridges	Raise current bridge decks and increase bridge span

9.2 Archaeological Impacts

Prior to Chainage 1000, there is no evidence of archaeological material. Most of this area was formally a swamp, however, access to portions of the stream channel was difficult with low visibility and thus, there is some low risk of encountering archaeological material remains during works. Although it is not possible to have much confidence on the magnitude of any effects in this area, given the low risk of encountering any extensive archaeological material in the former swamp, effects here are characterised as minimal.

In the proximity of Chainage 1050 it is reported there was a small Māori village, Otahuhu, where the Baptist Church is located on the corner of King Street and Alexander Avenue. This is immediately adjacent the project footprint (Coates 1956). Thus, if archaeological remains are present here, earthworks in the vicinity have a high risk of impacting archaeological material. The extent of works are, however, relatively restricted here. Potential effects are therefor considered to be moderate in scale.

There are two small areas of known archaeological material, archaeological sites W15/1206 and W15/1207 within the project footprint. These are small exposures of shell midden on the north side of the channel at Chainage 1225 and 1285. Earthworks at this locations would impact on these cultural deposits and it is likely there are further subsurface cultural deposits in the vicinity. There is a legal requirement to obtain an archaeological authority from HNZPT to modify or destroy an archaeological site prior to any earthworks on known archaeological sites, or in an area where there is reasonable cause to suspect that there may be unrecorded archaeological sites. Effects in this area would be moderate in scale due to the fairly restricted extent of proposed works, provided that appropriate archaeological management provisions are in place to cover any associated works such as construction depots etc.

Between Chainage 1400 and 1730, it is considered that there is a high risk of encountering archaeological material. In the adjacent property (Whakatāne Hospital) on the north side of the channel several archaeological excavations have recorded substantial archaeological remains including midden, pits and Koiwi. While no archaeological features were noted during the field visit, visibility was low due to grass. It is likely subsurface features remain within the works' footprint in this area. There is also a reported pa 300 m to the north of the project footprint and west of the hospital indicating the area was heavily used by Māori prior to 1900. Earthworks in this portion of the project footprint could have moderate impact on archaeological material, in that the extent of proposed works is fairly restricted.

The earthworks component of the project poses the greatest risk of impacts on unrecorded archaeological sites within the footprint, provided that appropriate archaeological management is instituted for any enabling works such as construction depots etc.

Earthworks may potentially affect:

- Māori shell midden;
- Pre-European-era crop storage pits;
- Kaianga remains such as house floors and post-moulds;
- Garden soils;
- Colonial-era farming structures (buildings, fences, field boundaries, ditches); and
- Burials.

9.3 Avoidance and mitigation of effects

There is limited scope for the avoidance and mitigation of archaeological material within the project footprint. The allotted easement boundary for Wainui te Whara is fairly narrow and the proposed stream upgrade works are to reduce flooding, which has been a continuous problem in the area. Furthermore, the midden may be of risk of further damage from flooding.

One way of mitigating the removal of archaeological material is thorough archaeological recording and also potentially the establishment of commemorative and/or interpretive materials. It is recommended that consultation with iwi is carried out in this regard.

9.4 Management of Archaeological Sites

To avoid lengthy and costly delays as a result of uncovering archaeological material during earthworks, it is recommended that an authority is sought, for the entire project footprint, from HNZPT to allow for the expedient recording and sampling of archaeological material, should it be present, during the project earthworks. HNZPT (2014) recommends the following be included within a management plan:

a. Methods to protect any archaeological sites or features;
b. Procedures for any archaeological investigation or recording of archaeological information,
c. The role, responsibility and level of authority of the approved archaeologist,
d. Timeframes for archaeological work,
e. Protocols for the unexpected discovery of archaeological material,
f. On-site briefing by project archaeologist for contractors about the archaeological work required and how to identify archaeological sites during works,
g. The responsibilities of contractors with regard to notification of the discovery of archaeological evidence,
h. Requirements for stand down periods to enable archaeological work,
i. Mechanisms for dispute resolution, and
j. Emergency contact details for the project archaeologist, HNZPT Regional Archaeologist and Tangata Whenua.

10 Conclusions and Recommendations

The purpose of this assessment was to identify as far as possible any archaeological values within the project footprint, and to develop recommendations to avoid or mitigate effects as far as possible.

Two archaeological sites, W15/1206 and W15/1207, have been identified within the proposed project footprint, both small subsurface middens at Chainage 1225 and 1285 respectively. These are likely to be small parts of larger sites. In the proximity of Chainage 1050 it is reported there was a small Māori village, most likely called Otahuhu, were the Baptist Church is located on the corner of King Street and Alexander Avenue, which is immediately adjacent to the project footprint (Coates 1956). Thus, there is a high risk of encountering archaeological material in this location.

The study area, including the project footprint, was likely heavily used prior to 1900, by both Māori and Europeans, and therefore there presents a risk for encountering additional unrecorded archaeological material during the proposed earthworks throughout the entire project footprint.

Between Chainage 1400 and 1730, there is a high risk of encountering archaeological material. While no features were noted during the field visit, visibility was low due to grass. In the adjacent property (Whakatāne Hospital) on the north side of the channel archaeological investigations 130 m north of the project footprint have recorded substantial archaeological remains including midden, pits and Koiwi. It is likely subsurface features remain within the works' footprint in this area. This is also a reported pa 300 m to the north of the project footprint and west of the hospital indicating the area was heavily used by Māori prior to 1900.

10.1 Recommendations

Considering the scale of the project and the potential for effect of moderate scale in several locations along the project footprint, the archaeological provisions of the HNZPTA need to be a key part of project planning.

It is recommended that Whakatāne District Council applies to HNZPT for a general Authority (see HNZPT n.d.) to modify or destroy any archaeological sites that cannot be avoided within the project footprint. It is recommended that iwi are consulted regarding their traditional values and associations with the area, and to ascertain any concerns they may have regarding the proposed works on the project. Iwi will need to be consulted and involved as part of the archaeological authority application process.

The following recommendations are made in relation to the possible effects of the construction of the project.

It is recommended:

- That an application be made to HNZPT for an authority under Section 44 of the HNZPTA for all earthworks associated with this project[2];
- That iwi be consulted in preparation for the authority application in accordance with HNZPT guidelines for applicants;
- That a detailed Archaeological Management Plan be submitted with the application for an authority; and
- That the Archaeological Management Plan is consistent with associated construction and project environmental management plans (CEMPs), and that these included relevant archaeological management provisions.

[2] See 16.2 advice note 1 in Appendix 2

References

Cable, N. 2011. *Waste-Water Rising Main Upgrade, The Strand, Whakatāne*. Unpublished report for the Whakatāne District Council.

Coates, C. R. 1956 *A brief History of Kopeopeo*. Unpublished paper read to Whakatāne and District Historical Society. Available from the Whakatāne and District Historical Society.

Colenso, W. 1880. On the vegetable foods of the Ancient New Zealanders before Cook's visit. *Transactions of the New Zealand Institute* 13: 3–38.

Francis, G. 2015. Wainui Te Whara Channel Capacity Optimisation, Concept Design Report. Unpublished report for Whakatāne District Council.

Furey, L. 2006. *Māori Gardening: An Archaeological Perspective*. Science & Technical Publishing, Department of Conservation, Wellington

HNZPT 2014. Assessment Template 04 Jun 2014. Available online at: http://www.heritage.org.nz/protecting-heritage/archaeology/archaeological-guidelines-and-templates

HNZPT n.d. Guide A: Application for a General Archaeological Authority. Available online at: http://www.heritage.org.nz/protecting-heritage/archaeology/archaeological-authorities

Harris, J. 2014 *Archaeological investigations of the Whakatāne Hospital Site*, W15/1196 (HPA authority 2013/692). Unpublished report to the Bay of Plenty District Health Board and The New Zealand Historic Places Trust.

McLintock, A.H. (1966) *Encyclopaedia of New Zealand*. Government Printer, Wellington.

Pullar, W.A., Hewitt S.R. and Heine, J.C. (1978) Soils and the Land Use of Whakatāne Borough and Environs, Bay of Plenty, New Zealand. New Zealand Soils Bureau Bulletin 38.

Robertson, J.B.W. (1975) A consecutive account of the traditional history of the Whakatāne District. *Whakatāne and District Society Monograph* 4, Whakatāne.

van der Wouden, A. n.d. *The Early Ferries in the Whakatāne District*. Whakatāne & District Historical Society journal Historical Review 31/1:43-56.

Whakatāne District Museum & Art Gallery (n.d.) "*Māori History of Whakatāne District*" Unpublished manuscript in library archives.

Worley, R. P. 1945, Borough Water Supply. *Bay of Plenty Beacon*, Volume 08, Issue 91(20):7.

Other sources referred to or reviewed:

- Historic aerial photographs 1943, 1964;
- NZAA ArchSite database;
- HNZPT Digital Library; and

- New Zealand Heritage List/Rārangi Kōrero.

Heritage New Zealand Site Records: W15/15, W15/98, W15/418, W15/525, W15/1182, W15/1196, W15/1206, W15/1207, W15/1208

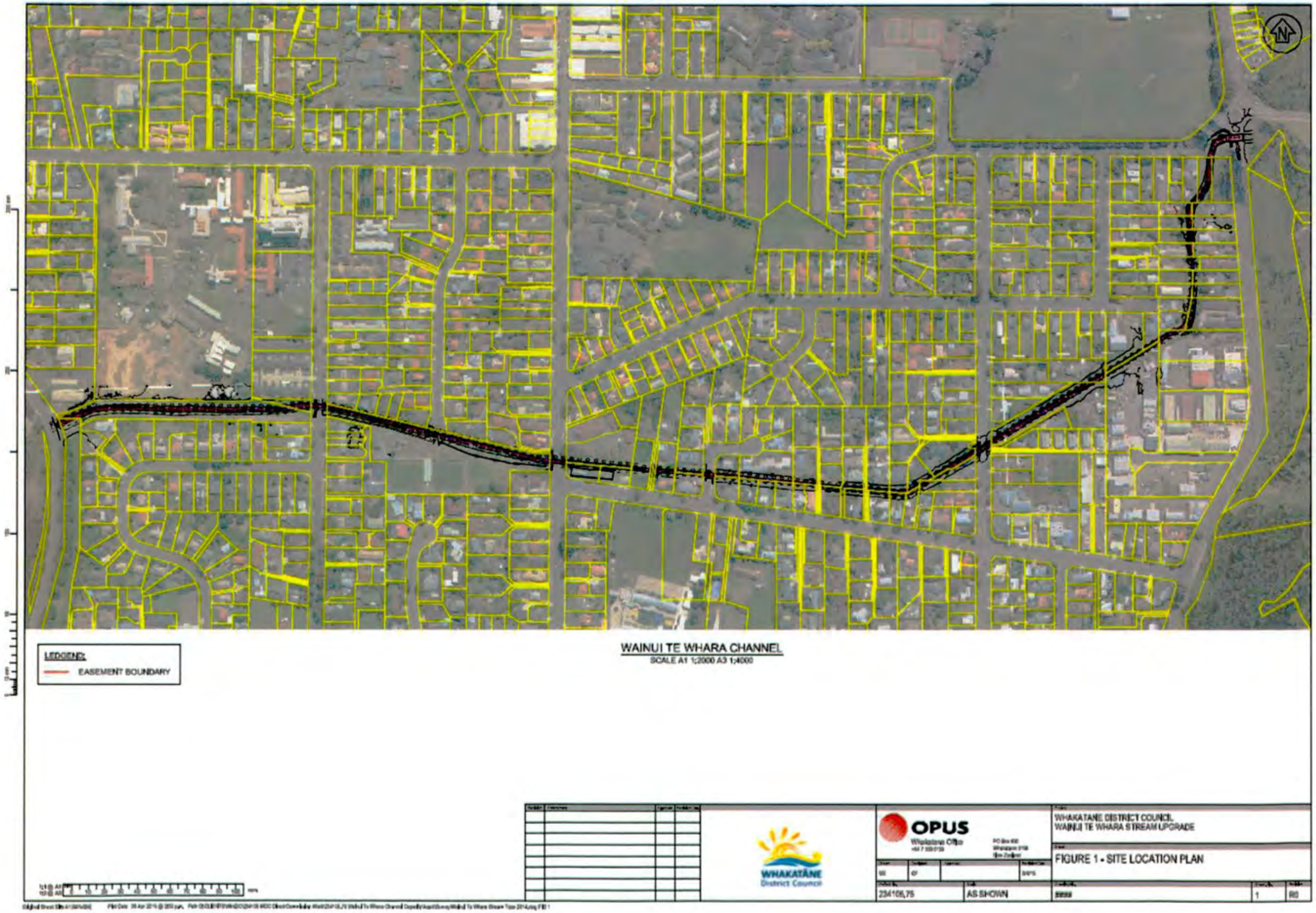
LINZ Historic Maps: SO 480H, 43845, LT 9702, DPS 429, 476, 480, 582, 4214, 5131 and 6304

New Zealand Topographic Maps: NZMS 1 Whakatāne N69 (1978)

Appendices

Appendix 1

Proposed Project Plans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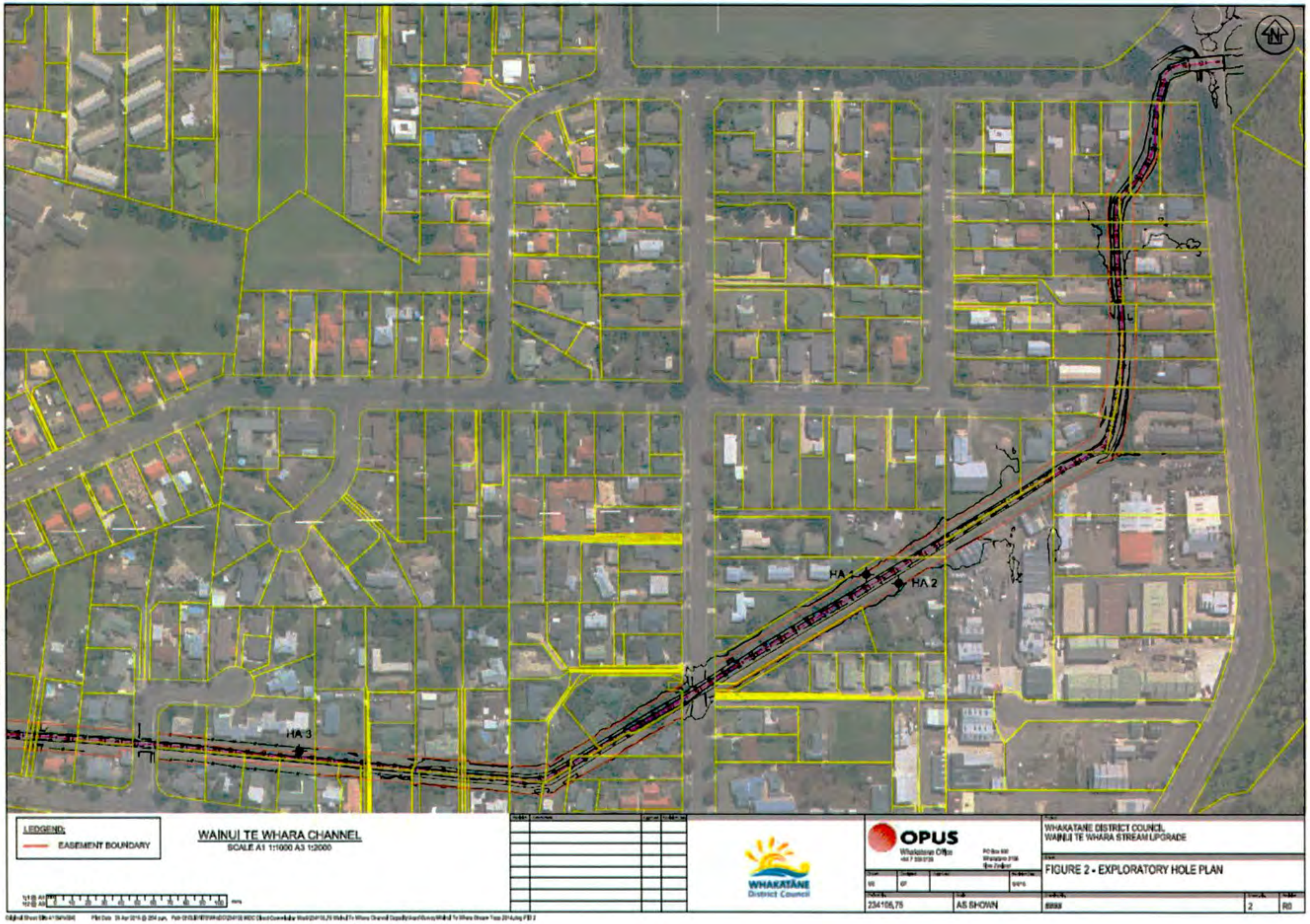
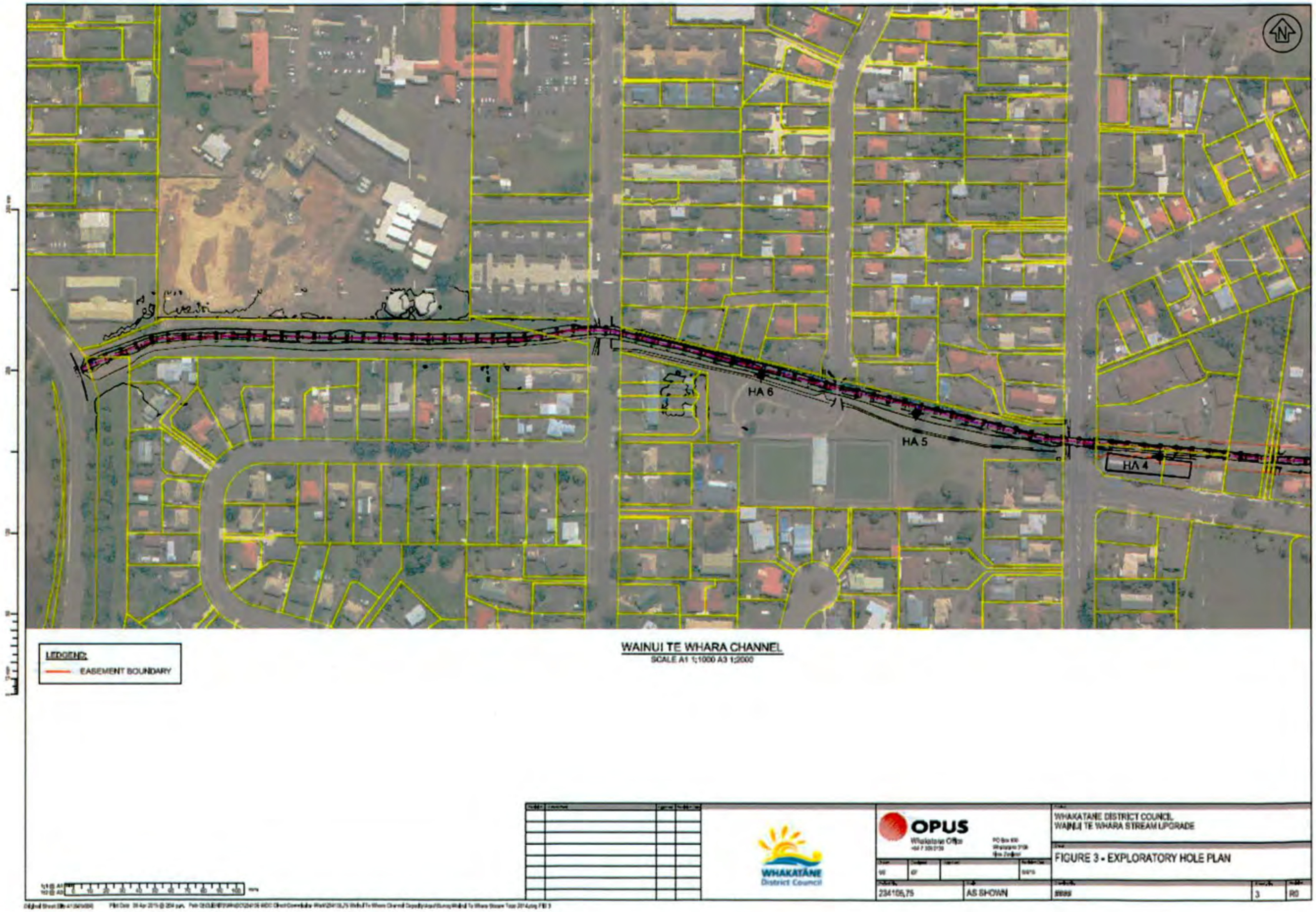
EASEMENT BOUNDARY
WAINUI TE WHARA CHANNEL
SCALE A1 1:2000 A3 1:4000
WHAKATĀNE District Council
OPUS
Whakatane Office
WHAKATANE DISTRICT COUNCIL
WAINUI TE WHARA STREAM UPGRADE
FIGURE 1 - SITE LOCATION PLAN
234106,75
AS SHOWN
1
R0


HA 1
HA 2
HA 3
LEDGEND:
EASEMENT BOUNDARY
WAINUI TE WHARA CHANNEL
SCALE A1 1:1000 A3 1:2000
WHAKATANE District Council
OPUS
WHAKATANE DISTRICT COUNCIL
WAINUI TE WHARA STREAM UPGRADE
FIGURE 2 - EXPLORATORY HOLE PLAN
234106.75
AS SHOWN
2
R0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HA 5
HA 4
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WHAKATANE District Council
OPUS
Whakatane Office
WHAKATANE DISTRICT COUNCIL
WAINUI TE WHARA STREAM UPGRADE
FIGURE 3 - EXPLORATORY HOLE PLAN
234105.75
AS SHOWN
3
R0

Appendix 2

Relevant Heritage Objectives and Policies in the Planning Documents

16.1 OBJECTIVES AND POLICIES

Objective CH1	***The maintenance and protection of a range of the District's heritage sites, places, features and values from inappropriate subdivision, use and development.***
Policy 1	To ensure the effects of activities on, in and around identified significant heritage features identified in Schedule 16.5.1 and 16.5.2 do not result in their destruction or deterioration or the cumulative loss of values.
Policy 2	To enable public access to sites with cultural significance to be retained through co-operative initiatives which do not jeopardise the reasonable operation of activities nor degrade the heritage values.
Policy 3	To encourage and support the protection and restoration of heritage features whilst giving priority to those sites listed in Schedule 16.5.1 and 16.5.2.
Policy 4	To avoid, remedy or mitigate the adverse effects of activities on, in and around heritage features.
Policy 5	To enable and encourage subdivision, land use and development that result in the protection and enhancement of heritage.
Policy 6	To protect identified significant specimen trees and encourage the retention of other mature specimen trees in the **District**.
Policy 7	To identify heritage sites, places, features and values using criteria in Appendix F of the Bay of Plenty Regional Policy Statement (Appendix 22.7), whilst recognising that only tangata whenua can define their relationship with their land, resources and other taonga.

16.2 RULES

The following standards and terms apply to Permitted, Controlled, and Restricted Discretionary activities and will be used as a guide for Discretionary and Non-complying activities.

16.2.1 Activity Status for Scheduled Heritage Features

16.2.1.1 The rules of this section relate to any features listed in Schedules 16.5.1, 16.5.2 and 16.5.3.

Key

P = Permitted	D = Discretionary
C = Controlled	NC = Non-Complying
RD = Restricted Discretionary	Pr = Prohibited

	Activity	Archaeological and Cultural Site Schedule	Building Schedule
1.	Protection and maintenance of the site of an identified feature,	P	P
	but excluding any activity which falls within Rule 4 or 6 below.		
2.	Minor restoration, maintenance, repair and/or alteration to any existing building or structure and which is carried out in a similar manner and design, and with the same or similar materials. This applies to both internal and external work.	NA	P
3.	Works required for the strengthening of any scheduled building to meet the requirements of the Councils Earthquake Prone, Dangerous and Insanitary Buildings Policy.	NA	P
4.	Alterations or additions to any scheduled building excluding works provided for in 2 and 3 above.	NA	RD
5.	The relocation of any Scheduled building.	NA	D
6.	Modification of any natural landform on the site of a feature including earthworks, deposition of fill, or excavation, or the disposal of solid or liquid waste, excluding that provided by (8) below.	D	D
7.	The placement, alteration or construction of any new building or structure (including signs, but not public information signs).	D	NA
8.	Existing cemeteries or urupā.	P	NA
9.	Activities (excluding buildings) on public reserves operating in accordance with an approved Conservation Management Strategy, Management Plan under Conservation Act 1987, National Parks Act 1980 and under the Reserves Act 1977 or Te Ture Whenua Māori Act 1993 or which is provided for in an Iwi Management Plan approved by an Iwi Authority.	P	P
10.	Activities not otherwise provided for in this table including demolition.	D	D

Advice Note 1: All development and subdivision **must** show the location of recorded archaeological sites as held at **Council**, on a resource consent application. The **Council** holds information about the location of all recorded archaeological sites in the **District**. However the absence of a site on this register should not be taken as confirmation that no sites exist in this area and **Council** may require an archaeological and cultural assessment as part of an application.

Evidence of unrecorded archaeological sites uncovered as a result of earthworks may include burnt and fire cracked stones, charcoal, rubbish heaps including shell, bone and/or glass and crockery, ditches, banks, pits, old building foundations, artefacts of Māori and European origin or human burials.

Earthworks affecting archaeological sites (recorded or unrecorded) are subject to a consenting process under the Historic Places Act 1993. An authority (consent) from the New Zealand Historic Places Trust must be obtained for the work prior to commencement and this process will include consultation with iwi. It is an offence to modify damage or destroy a site for any purpose without an authority. The Historic Places Act 1993 contains penalties for unauthorised site damage. The applicant is advised to contact the New Zealand Historic Places Trust for further information.

Appendix 3

Relevant NZAA Site Records

AA AT AE CA AA IY

NEW ZEALAND ARCHAEOLOGICAL ASSOCIATION

SITE RECORD FORM

Map number N 69
Map name WHAKATANE
Map edition 1st
Grid Reference 418 252

SITE NUMBER N 69/ 104

SITE NAME: MAORI
OTHER

SITE TYPE MIDDEN

E441800 N525200

1. Aids to relocation of site
At Kopeopeo a suburb at Whakatane, site is located at 59 Victoria Ave

2. State of site; possibility of damage or destruction
Built upon.

3. Description of site *(NOTE: This section is to be completed ONLY if no separate Site Description Form is to be prepared.)*

This has been recorded to indicate that it is apparent midden, umu and kainga sites exist at this suburb and at 59 Victoira Ave, apart from shell a large piece of obsidion 3" in dia and round was found beside a heavy white calcite stone of 2" dia and can be scratched with the obsidion. It is reputed that a kainga site was hereabouts as evidenced by the material also at 55 Victoria Ave.

4. Owner Mr Sutcliffe
Address 59 Victoria Ave
Attitude Good.

Tenant/Manager
Address
Attitude

5. Methods and equipment used
Photographs taken: Yes/No (Describe on Photograph Record Form)
Date recorded

6. Aerial photograph or mosaic No.
Site shows:
Clearly/badly/not at all

7. Reported by W.A. Pullar
Address
Date

Filekeeper K.W. Moore.
Date May 1972.

NEW ZEALAND ARCHAEOLOGICAL ASSOCIATION

ARCHSITE
archaeological site recording scheme

Site Record Form

NZAA SITE NUMBER: W15/418

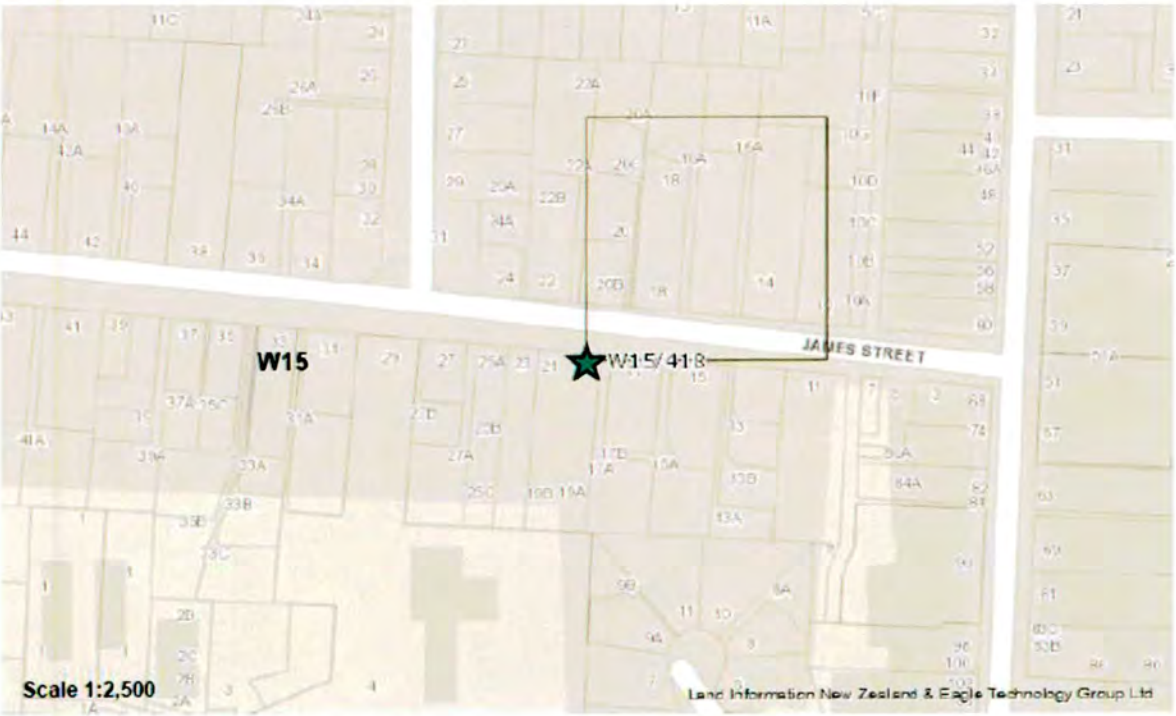
SITE TYPE: Pit/Terrace

SITE NAME(s):

DATE RECORDED:

SITE COORDINATES (NZTM) Easting: 1949696 **Northing:** 5790981 **Source:** CINZAS

IMPERIAL SITE NUMBER: **METRIC SITE NUMBER:** W15/418



Finding aids to the location of the site

James Street, Whakatane.

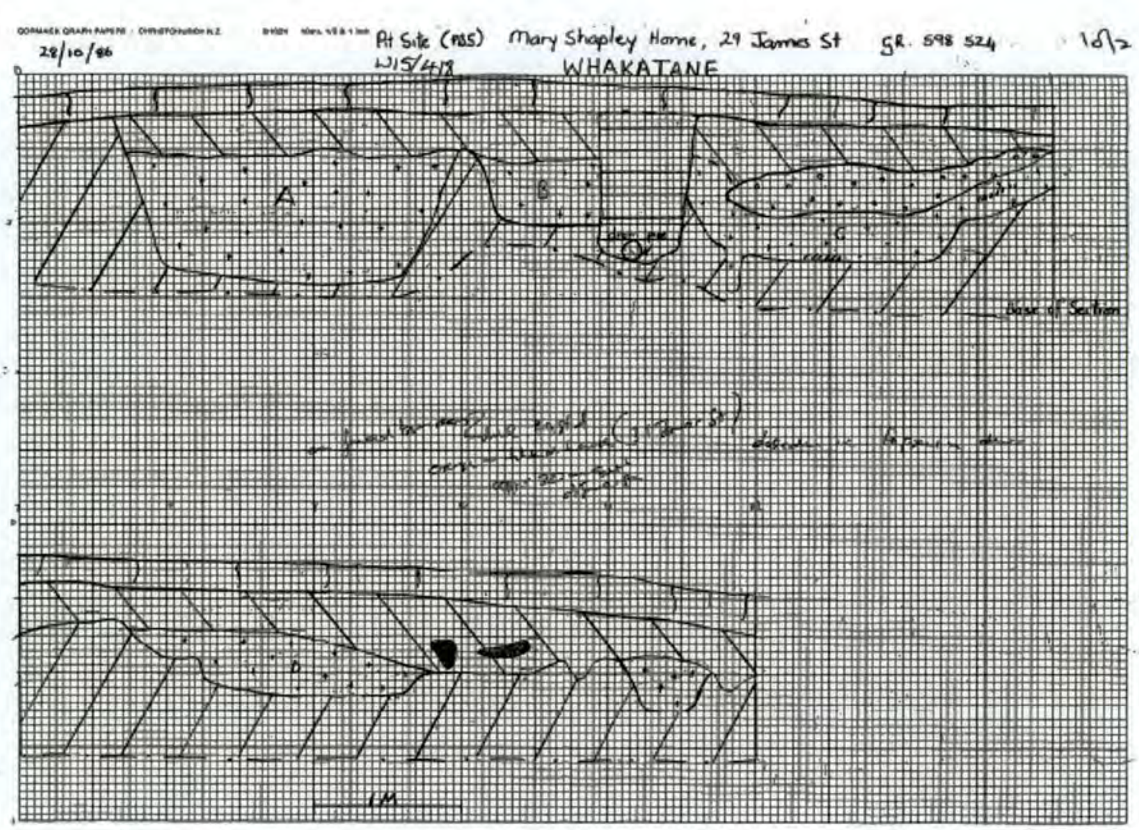
Brief description

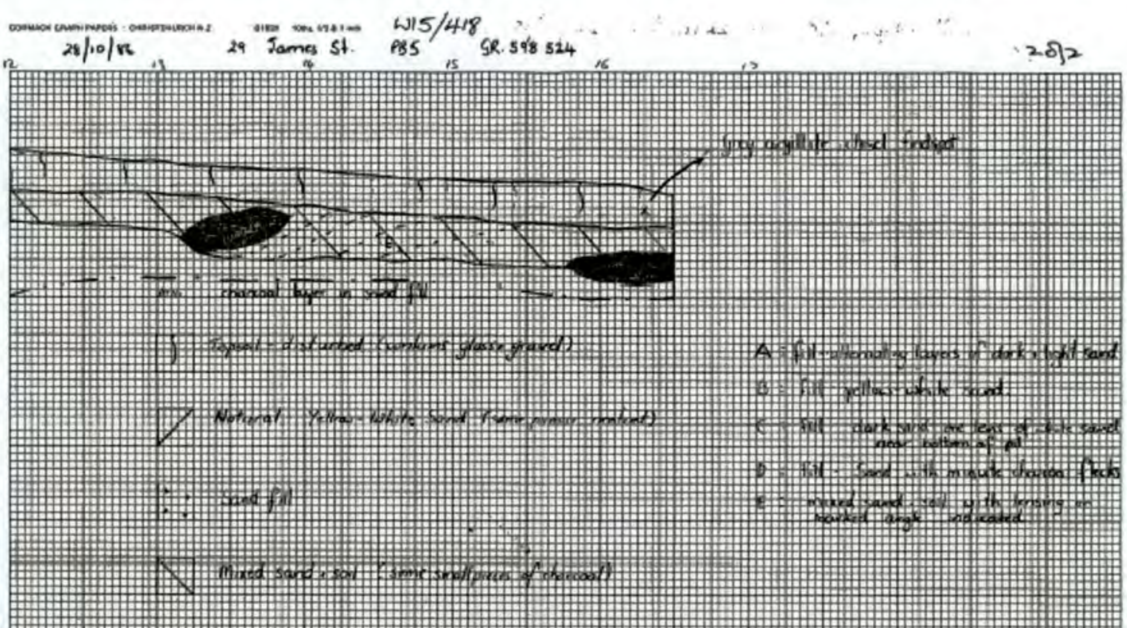
Six pits (exposed in section on building site). Findspot for an argillite chisel.

Recorded features

Pit, Artefact

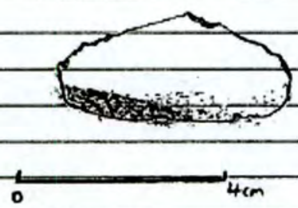
Other sites associated with this site


28/10/86
Pit Site (PBS) Mary Shapley Home, 29 James St
GR. 598 524
W15/418
WHAKATANE
1 of 2
A
B
C
D
Base of Section
1M


28/10/86
29 James St.
PBS
W15/418
GR. 598 524
2 of 2
Grey argillite chisel findspot
charcoal layer in sand fill
Topsoil - disturbed (some glass gravel)
Natural Yellow-White sand (some pumice revealed)
Sand fill
Mixed sand + soil (some small pieces of charcoal)
Ash/Loam fill (some charcoal)
Modern drain trench
Buried top soil (Soil of modern topsoil)
A = fill - alternating layers of dark + light sand
B = fill - yellow-white sand
C = fill - dark sand - one lens of white sand near bottom of pit
D = fill - Sand with minute charcoal flecks
E = mixed sand + soil with lensing in marked angle indicated

W15/ Pits - Findspot (PB5) W15/418

G.R. 598 524



Grey D'Urville Is. argillite chisel.
Found in section of Mary
Shapley Home site, James
St., Whakatane
PB5

Drawn NPO'Keefe
NZHPT 12.12.86.

NEW ZEALAND ARCHAEOLOGICAL ASSOCIATION

SITE RECORD FORM (METRIC)

Metric map number W15
Metric map name
Metric map edition NZMS 270

NZAA METRIC SITE NUMBER W15/418
DATE VISITED Oct. 1986
SITE TYPE Pits / Findspot.
SITE NAME: MAORI
OTHER

Grid Reference Easting 2859800 Northing 6352400

1. Aids to relocation of site *(attach a sketch map)* (29?) James St Whakatane
Mary Shapley Home for Elderly Citizens.
PBS

2. State of site and possible future damage Exposed in section of building site probably will be destroyed after completion of building

3. Description of site *(Supply full details, history, local environment, references, sketches, etc. If extra sheets are attached, include a summary here)*

Six pits exposed in section. Cross section drawn. Pits up to 1m deep. Filled with lower layer of sand overlaid with mixed sand/soil layer with a disturbed Topsoil layer. A grey Durville Is. Argillite chisel was found in topsoil layer.

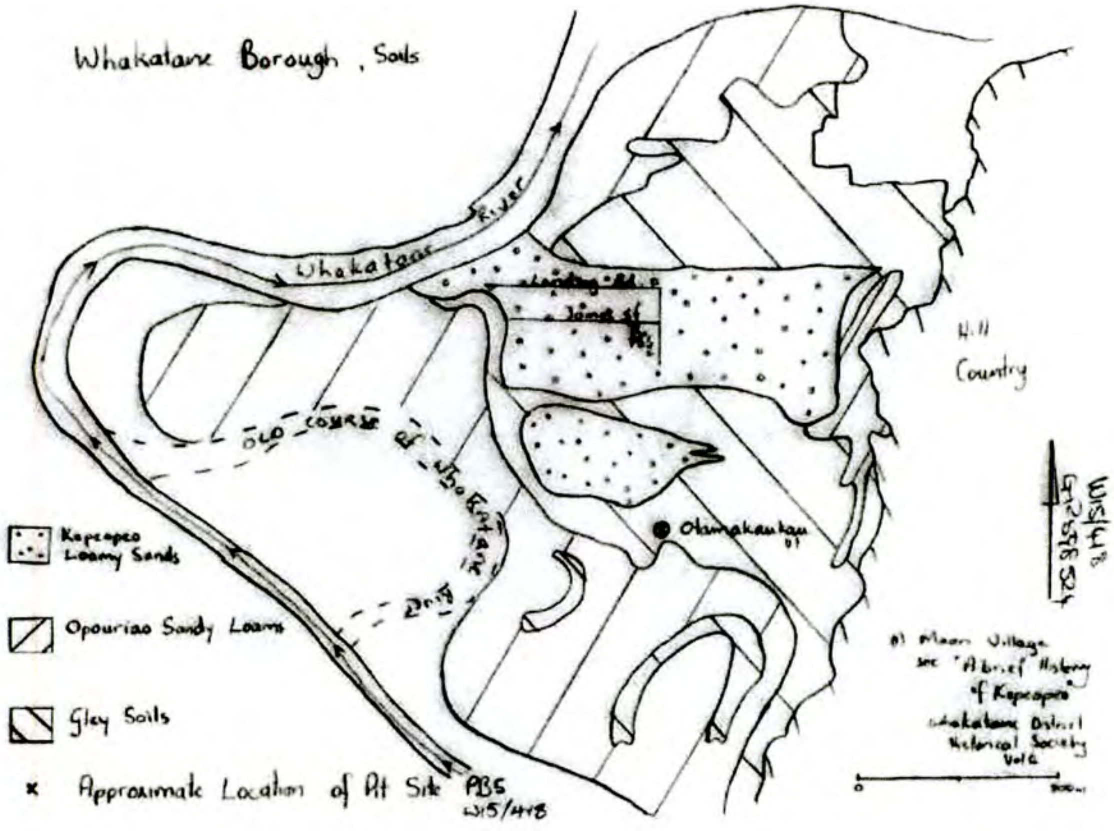
4. Owner Presbyterian Social Services
Address
Tenant/Manager
Address

5. Nature of information *(hearsay, brief or extended visit, etc.)* Brief Visit.
Photographs *(reference numbers, and where they are held)*
Aerial photographs *(reference numbers, and clarity of site)*

6. Reported by P. Bristow
Address N.Z.H.P.T.
Filekeeper
Date

7. New Zealand Historic Places Trust *(for office use)*

A M	Type of site		A C	Present condition and future danger of destruction
– –	Local environment today		I Y	Local body
A I	Land classification			


Whakatane Borough, Soils
Whakatane River
Landing Rd
Hill
Country
OLD COURSE OF
Kopeopeo
Loamy Sands
Opouriao Sandy Loams
Gley Soils
x Approximate Location of Pit Site PBS
W15/448
Maori Village
see "A brief History
of Kopeopeo"
Whakatane District
Historical Society
Vol 6
0

NEW ZEALAND ARCHAEOLOGICAL ASSOCIATION

ARCHSITE
archaeological site recording scheme

Site Record Form

NZAA SITE NUMBER: W15/1196

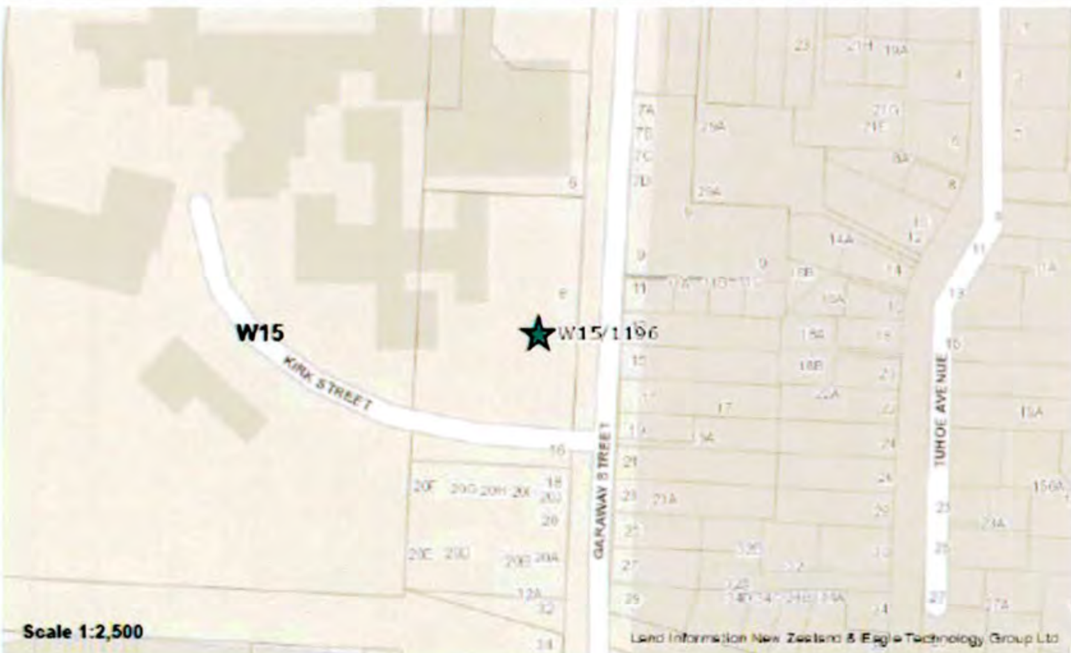
SITE TYPE: Midden/Oven

SITE NAME(s): Te Maara Kai o Taiwhakaea

DATE RECORDED: 04/04/2013

SITE COORDINATES (NZTM) Easting: 1949534 **Northing:** 5790580 **Source:** On Screen

IMPERIAL SITE NUMBER: **METRIC SITE NUMBER:**



Finding aids to the location of the site

Beneath the Whakatane Hospital Carpark off Garaway St.

Brief description

A find of koiwi (cranium and mandible, disturbed) and 20 m to the north west a disturbed midden and the bases of two firescoops.

Recorded features

Burial, Midden

Other sites associated with this site

SITE RECORD HISTORY	NZAA SITE NUMBER: W15/1196

Site description

Updated: 04/04/2013, Visited: 04/04/2013 - NZTM E1949534 / N5790580 (On Screen). A find of koiwi (cranium and mandible, disturbed) and 20 m to the north west a disturbed midden and the bases of two firescoops. Further midden may be present beneath the car park to the north. It is possible that further koiwi may be present. The site has been truncated by former car park construction. Inspected by: Campbell, Matthew.

Condition of the site

Updated: 04/04/2013, Visited: 04/04/2013 - Largely truncated by car park construction, only the base of the midden is currently visible.

Statement of condition

Updated: 02/05/2013, Visited: 04/04/2013 - Poor - Visible features are incomplete, unclear and/or the majority have been damaged in some way

Current land use:

Threats:

Updated: 02/05/2013, Visited: 04/04/2013 - Property development

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