

Channel morphology of the Waianakarua River, North Otago

Technical Summary

Changes in the channel morphology of the Waianakarua River have been assessed using visual inspections, aerial and ground photography, and cross-section data collected in June 2004, February 2008, and October 2013. Cross-section data has been collected at 19 locations in the North and South branches, and in the main stem of the river (Figure 4). This assessment provides an update on the changes in channel morphology that have been observed since the last catchment wide analysis of long term trends in 2008. This report is designed to inform decisions relating to the management of the Waianakarua River, including gravel extraction, floodwater conveyance and asset management.

The North Branch of the Waianakarua River has shown bank erosion of both the left and right banks between February 2008 and October 2013. The surveyed reach exhibits areas of both aggradation and degradation with changes in morphology affected by gravel extraction at Sharps Bend (Figure 11).

Erosion of both the left and right banks was an ongoing process in the South Branch of the Waianakarua River between February 2008 and October 2013. Sediment movement (in the form of both erosion and deposition) and gravel extraction activities in the surveyed reach has led to the channel becoming wider in some locations but narrower and deeper in others.

Between February 2008 and October 2013 the main stem of the Waianakarua has shown bank erosion of both the left and right banks. The surveyed reach shows a trend of sediment deposition and channel widening.

The surveyed reaches of the Waianakarua River experienced noticeable amounts of bank erosion between 2008 and 2013. Generally the largest observable change occurred in the South Branch, with the North Branch showing small change in the width of the active channel between 2008 and 2013. The surveyed sections of the main stem are located in an area of braiding and contain numerous flow channels that show a general trend of sediment deposition between 2008 and 2013.

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1 Introduction

1.1 Overview

The physical processes that have shaped the Waianakarua catchment in North Otago (Figure 1) are still at work today. These processes include landslides and land instability (Figure 2), flood events, bank erosion, sediment transport, and deposition. This report identifies what effects these processes have had on the channel morphology¹ of the Waianakarua River, particularly over the short term (since 2008), and also places these recent changes within the context of longer term trends. Changes in channel morphology are primarily determined by comparing cross-section data collected in October 2013 with earlier survey data collected in 2008 as well as through visual inspections of the lower catchment.

The report is intended to inform decisions relating to the management of the Waianakarua River including gravel extraction, floodwater conveyance, and asset management. A previous report² describes the geology and geomorphology of these catchments, and describes changes within the river channel up to 2008. Although this information is not reproduced in detail, where appropriate, earlier records have been used to help describe and understand changes in channel morphology. A description of the Waianakarua catchment is provided below, and a summary of the most recent changes in channel morphology is provided in section 2.1.

A more detailed description of the changes that have occurred at each section since they were last surveyed in 2008 is provided in Appendix 1. Appendix 2 describes the methods used to collect and analyse morphological data.

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¹ The form and structure of topographical features within the river channel

² ORC. 2008: Channel morphology and sedimentation in the Waianakarua River

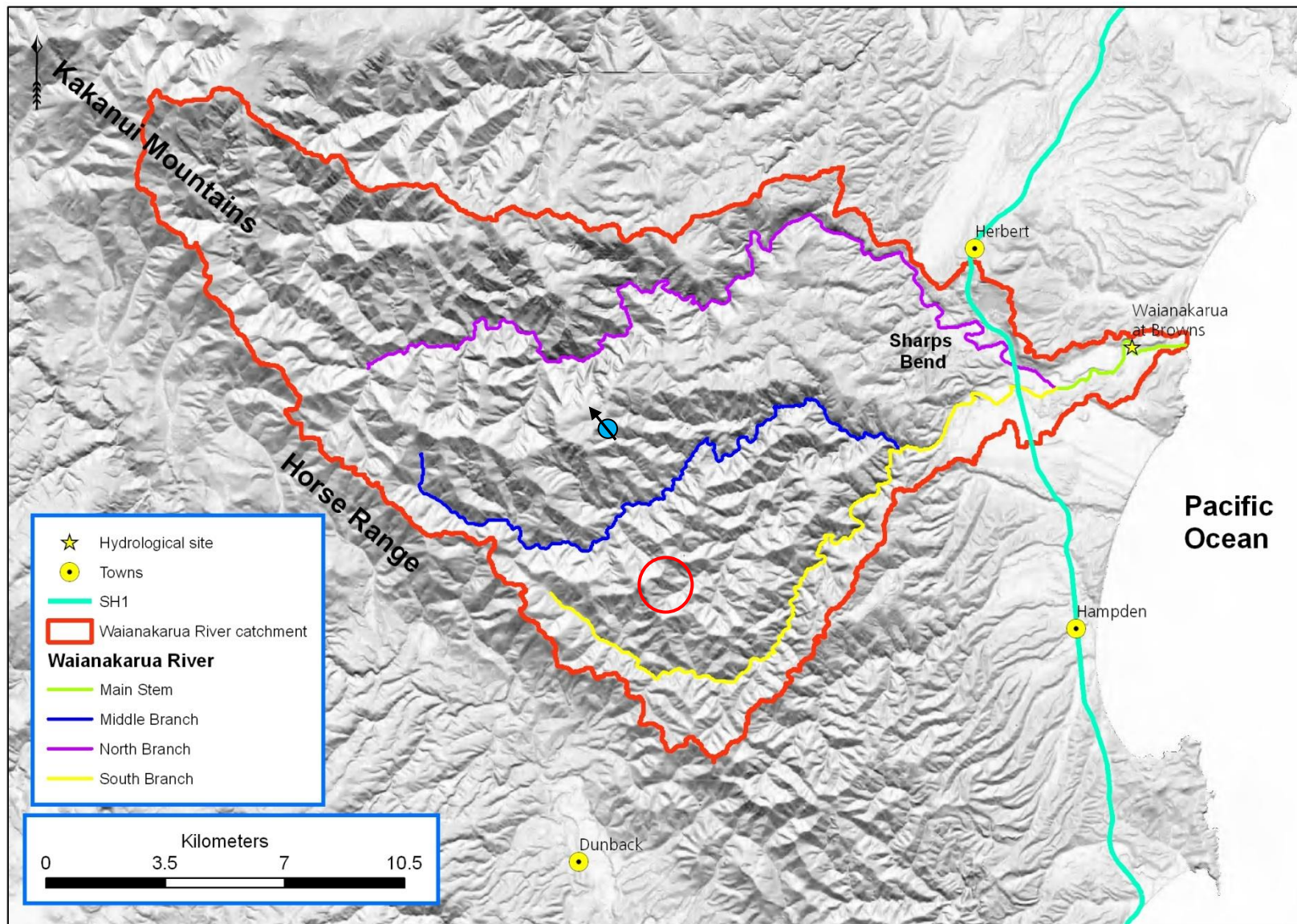


Figure 1-Waianakarua River catchment map. The red circle shows the location of the image in Figure 2, the blue circle shows the location of Figure 3.



Figure 2-Evidence of land instability in the upper reaches of the North Branch of the Waianakarua River image date June 2012 (Google Earth). This location is shown on Figure 1 (red circle).

1.2 Catchment description

The Waianakarua River has a catchment area of 262km² and consists of three branches: the South Branch, Middle Branch, and the North Branch (Figure 1). The South and Middle Branches arise in the Horse Range and join about 6km upstream of SH1. The North Branch arises in the eastern Kakanui Mountains and joins the South Branch approximately 1km downstream of SH1, before entering the Pacific Ocean a further 6km downstream.

The upper catchment consists of tussock scrub and native forest with rocky outcrop and deep incised valleys (Figure 3). The geology of the upper catchment consists mainly of semischist (Forsyth 2001)³. The lower catchment consists of river terraces and coastal plains mainly covered with pastoral land with some crop cover. The geology of the lower catchment (upstream of SH1) is mainly sandstones and mudstones with alluvium overlying the bedrock. Below SH1 the geology consists of river gravels/alluvium and volcanics (Forsyth, 2001).

³ Forsyth, P. J. 2001: Geology of the Waitaki Area, Institute of Geological and Nuclear Science 1:250,000 geological map 19, *Institute of Geological and Nuclear Science*, Lower Hutt.



Figure 3-Upper Waianakarua River catchment (GoogleEarth), looking east towards Mount Miserable. The approximate location and direction of the image is shown in Figure 1.

The three branches of the Waianakarua River consist of confined, meandering channels cut into schist bedrock with a mixed gravel and bedrock bed (ORC, 2008). The lower catchment channel is defined as mostly wandering⁴ with sections of braiding that are incised into an elevated gravel floodplain (ORC, 2008).

2 Results

2.1 Changes in channel morphology

The wandering channel and incised floodplain of the lower Waianakarua River is a contributing factor in the areas of large scale bank erosion that are occurring in both branches and the main stem. This is due to the Waianakarua River moving across its floodplain and eroding into the high banks and terraces, causing localised areas of bank instability. Figure 4 shows the locations of the surveyed cross-sections in the Waianakarua River, Figure 10 to Figure 12 show areas where significant bank erosion has been observed through cross-section analysis or site inspections.

⁴ A wandering channel is one that exhibits forms of both meandering and braided channels.

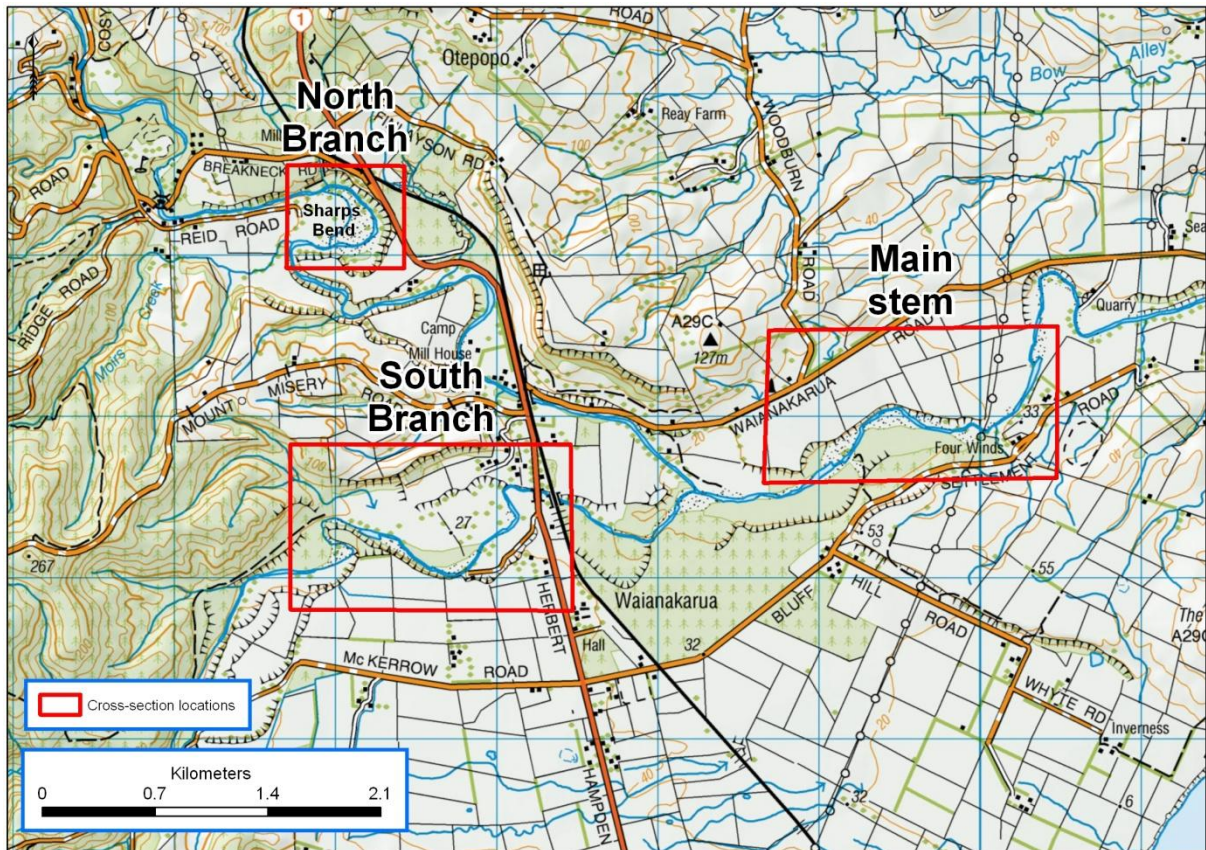


Figure 4- Location of surveyed cross-sections in the North Branch, South Branch, and main stem of the Waianakarua River

Bank erosion is an historic and ongoing issue in the Waianakarua River catchment with records identifying erosion as a problem dating back to the 1940's (Otago Catchment Board, 1949).⁵ To assist in limiting the effects of bank erosion a number of mitigation measures have been attempted including willow planting, rock armouring and channel realignment (Otago Catchment Board, 1980).⁶

In the main stem of the Waianakarua River the channel switches between areas of braiding and single thread channels. The river is actively eroding the bank below Waianakarua Road, approximately 2km from the river mouth (Figure 6 and Figure 7). Between February 2008 and October 2013 survey data shows that the main stem of the Waianakarua has shown erosion of both the true left and true right banks (Figure 10). The upstream sites (WA3 - Figure 25, and WA4 - Figure 27) show aggradation of the bed and widening of the main channel (WA3) and the creation of multiple flow channels (WA4) during this period. The main channel became wider and shallower at the most downstream site (WA1, Figure 21) and narrower and deeper at WA2 (Figure 23) between 2008 and 2013. Cross-sections WA3 and WA4 are affected by gravel extraction activities.

Between February 2008 and October 2013 there was erosion of both the left and right banks of the North Branch of the Waianakarua River (Figure 8, Figure 11). The surveyed reach of the North Branch includes areas of both aggradation and degradation, and an area where multiple

⁵ Otago Catchment Board. 1949. Erosion and recommendation for the Waianakarua River, 5/798.

⁶ Otago Catchment Board. 1980. Waianakarua River (North Branch)-Channel Restoration and Training Bank, 80/170.

channels have developed during the most recent survey period (WA6N, Figure 31). The morphology of the surveyed reach of the North Branch is affected by gravel extraction activities at Sharps Bend (Figure 1).

Erosion of both the left and right banks is an ongoing process in the South Branch of the Waianakarua River (Figure 9, Figure 12). Sediment movement (in the form of both erosion and deposition) in the surveyed reach and has led to the channel becoming wider in some locations (WA5S - Figure 37, and WA7S - Figure 41) but narrower and deeper in others (WA9S - Figure 45, and WA15S - Figure 57). Cross-sections between WA5S and WA9S are affected by gravel extraction activities.

Sediment moves gradually and episodically downstream in the Waianakarua River, usually during flood events, when river energy increases enough to entrain sediment. As flood levels (and river energy) decrease, the ability of the river to carry sediment also decreases and sediment becomes deposited. The rate of sediment transport in river systems is determined by the rate of sediment supply and the number of flood events. Sediment movement and deposition is a natural process in the Waianakarua River with these processes allowing the river to meander across the floodplain and form the banks and terraces alongside the river that are present today.



Figure 5-Area of active bank erosion on the main stem of the Waianakarua River (between cross-section WA2 and WA3), photo taken looking downstream, October 2013



Figure 6-Section of bank erosion on the true left of the Waianakarua River below Waianakarua Road (Google Maps, Street view) (October 2012)



Figure 7-Aerial view of the Waianakarua River looking upstream during a period of high flow in August 2012. The location of Figure 6 is circled in red.



Figure 8-Area of active bank erosion on the North Branch of the Waianakarua River (upstream of SH1), photo taken looking upstream, October 2013



Figure 9-Area of active bank erosion on the South Branch of the Waianakarua River (between cross-section WA7S and WA8S), photo taken looking upstream, October 2013

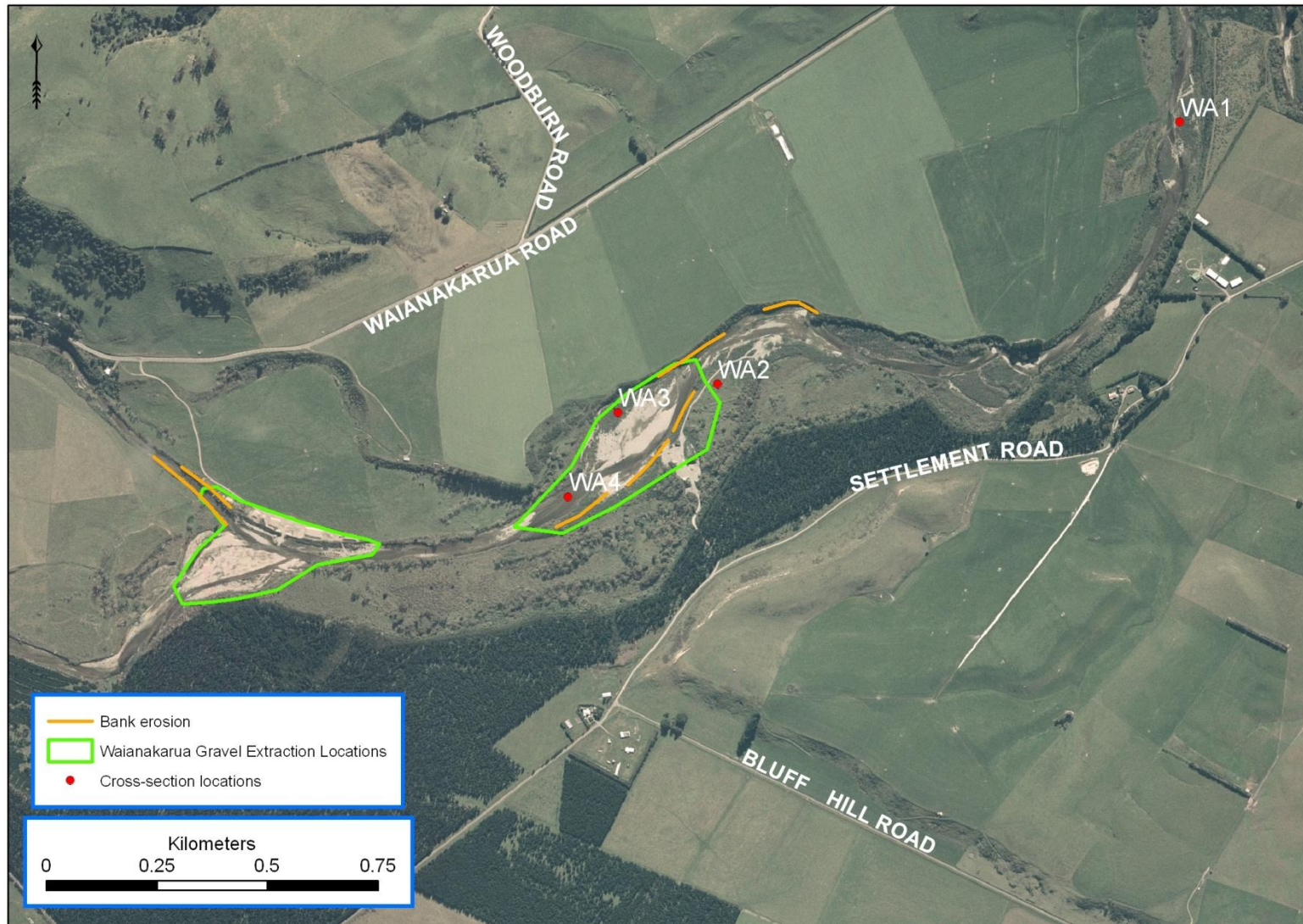


Figure 10-Location of surveyed cross-sections on the main stem of the Waianakarua River, areas where significant bank erosion was observed are shown as orange lines. Locations where gravel extraction has historically taken place are shown as green lines.

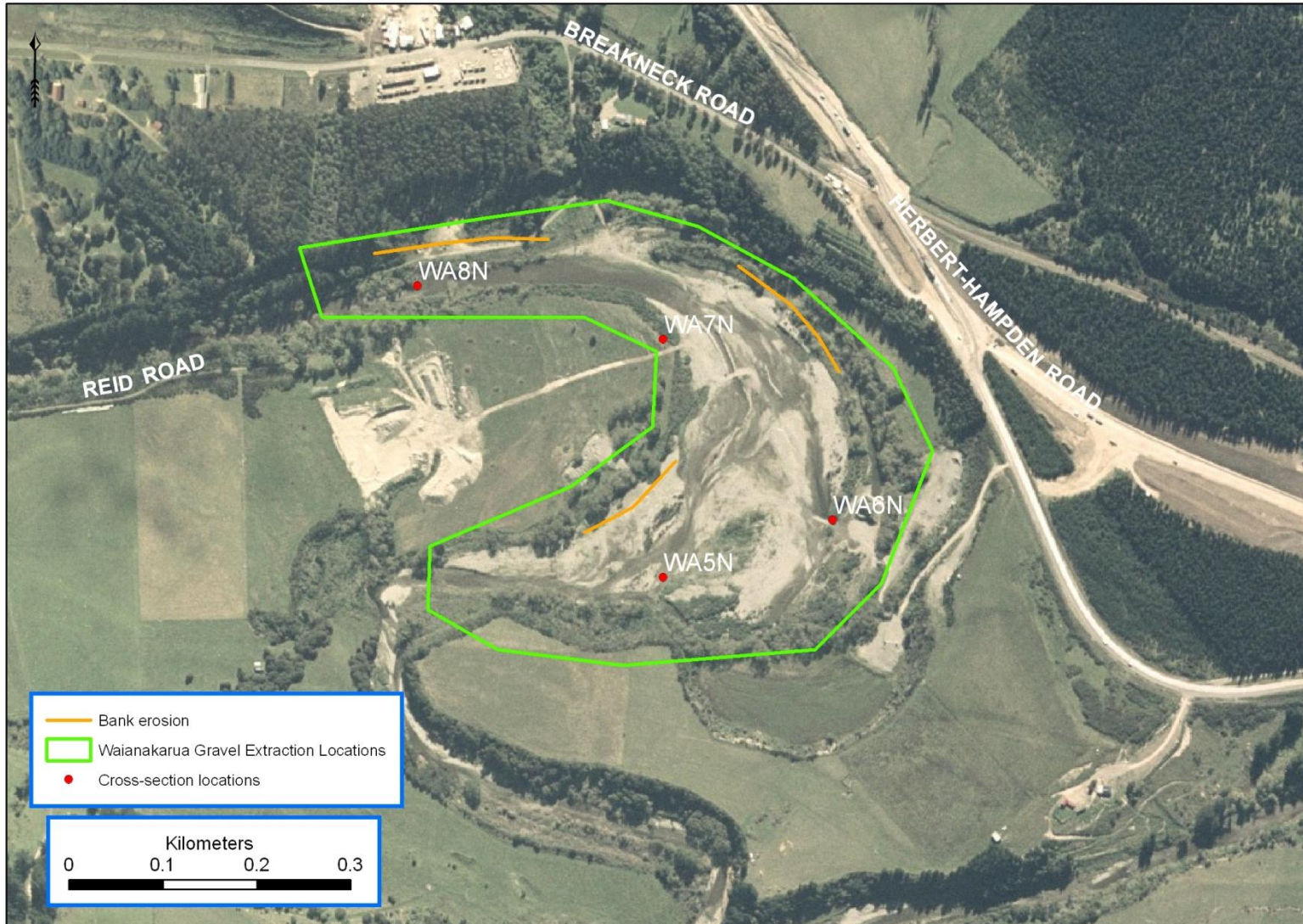


Figure 11-Location of surveyed cross-sections on the North Branch of the Waianakarua River near Sharps Bend. Areas where significant bank erosion was observed are shown as orange lines. Locations where gravel extraction has historically taken place are shown as green lines.

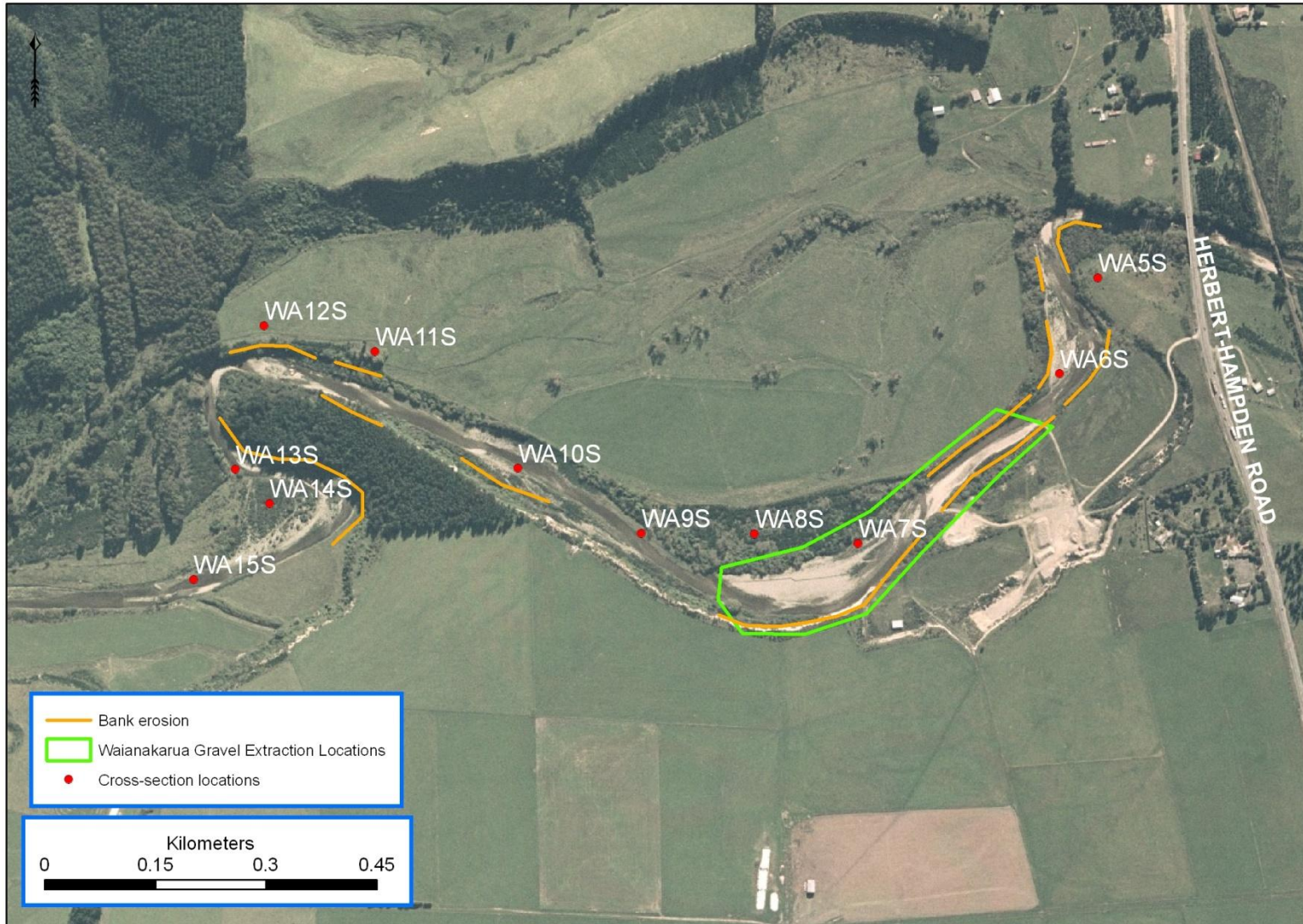


Figure 12-Location of surveyed cross-sections on the South Branch of the Waianakarua River, areas where significant bank erosion was observed are shown as orange lines. Locations where gravel extraction has historically taken place are shown as green lines.

2.2 Changes in thalweg level

Figure 10 to Figure 15 show the longitudinal profile of the North Branch, South Branch and the main stem of the Waianakarua River respectively. The markers represent the thalweg value (minimum bed level of the active channel) at each cross-section in June 2004, February 2008, and October 2013. The lines represent the longitudinal profile of the river between each cross-section and have been included to give an indication of changes in the profile of the river over time.

During the most recent survey period, noticeable increases in thalweg level occurred at the following locations:

- Cross-section WA1 on the main stem
- Cross-section WA8N on the North Branch
- Cross-section WA8S on the South Branch

All the other sections on the Waianakarua showed a decrease in thalweg level or minimal change between 2008 and 2013, with the most noticeable locations being:

- Cross-section WA2 on the main stem
- Cross-section WA7N on the North Branch

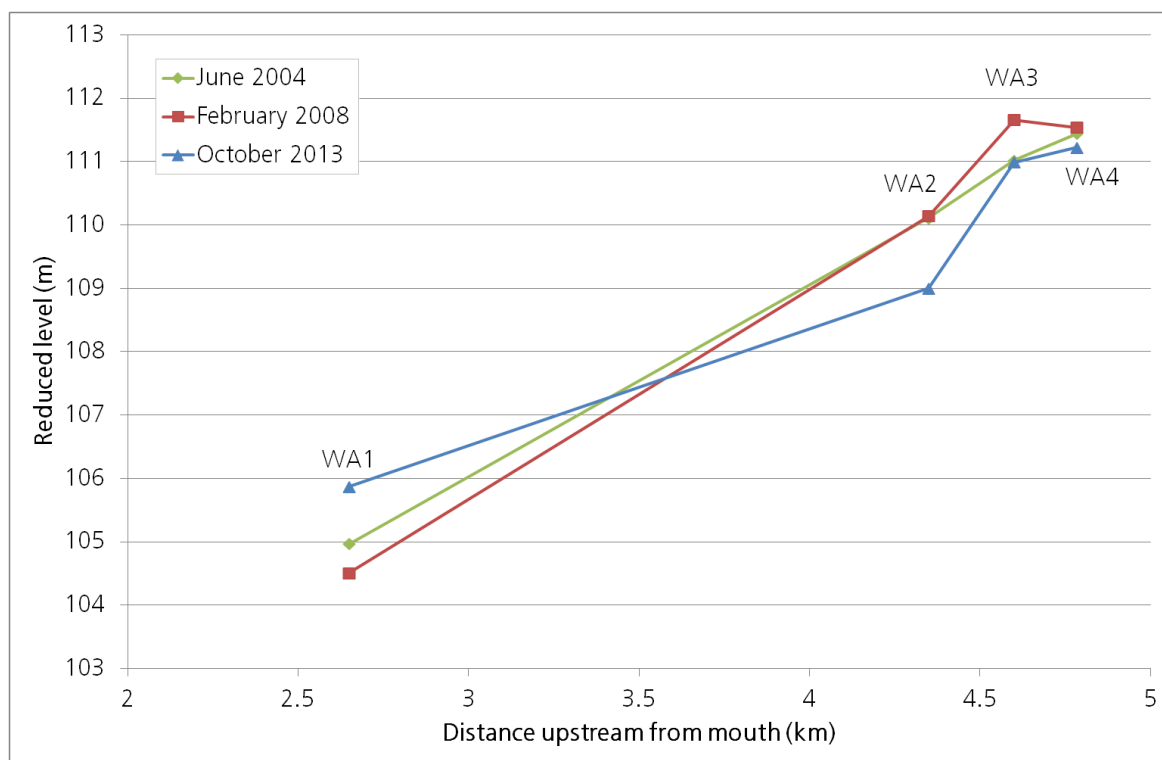


Figure 13-Longitudinal profile showing the thalweg level at cross-section in the main stem of the Waianakarua River

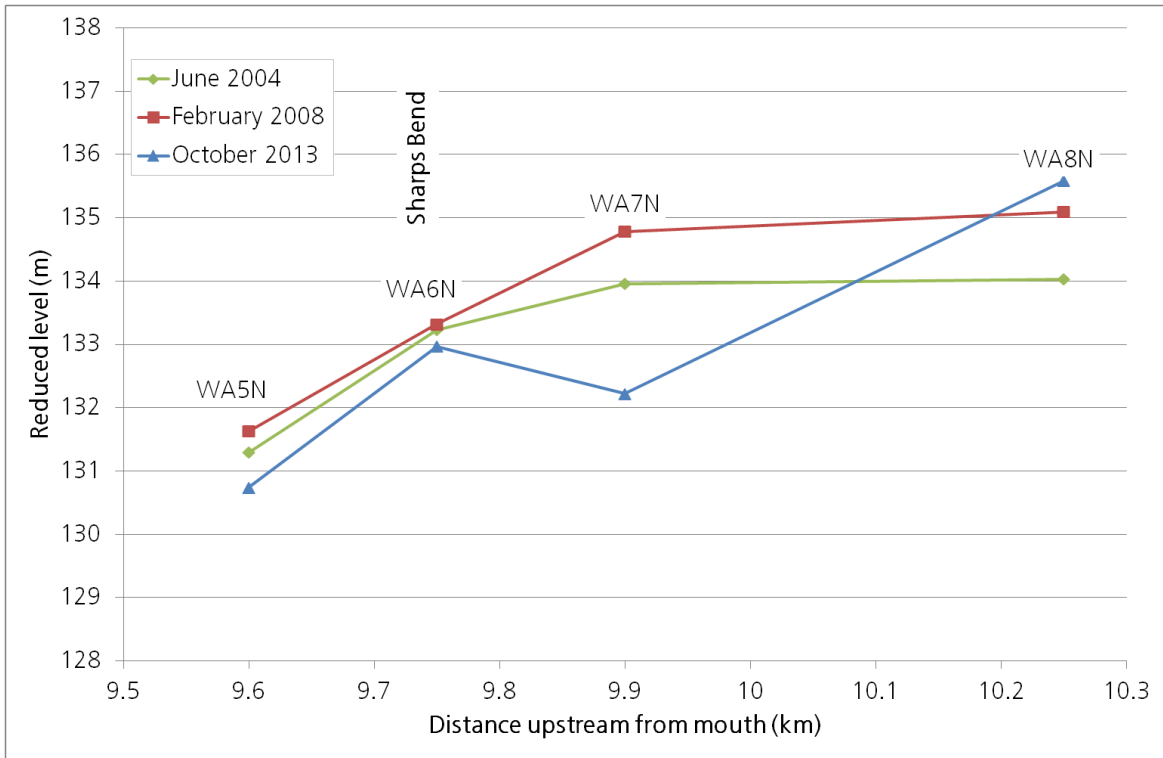


Figure 14-Longitudinal profile showing the thalweg level at cross-section in the North Branch of the Waianakuru River

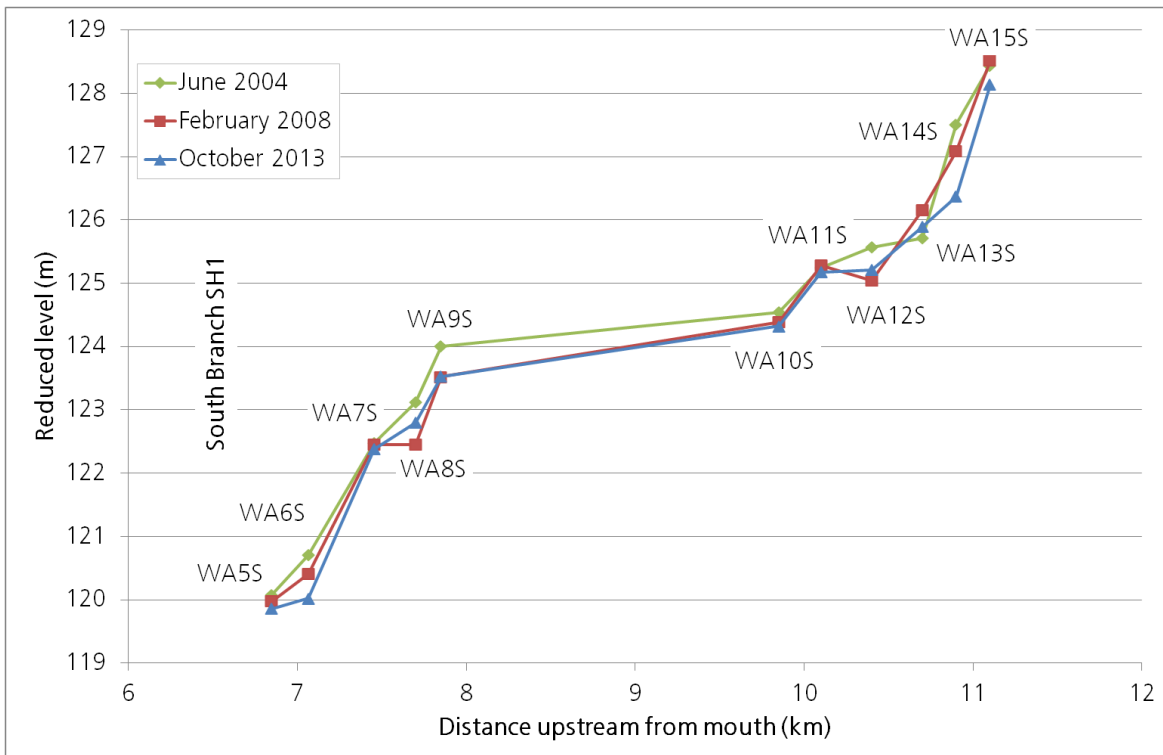


Figure 15-Longitudinal profile showing the thalweg level at cross-section in the South Branch of the Waianakuru River

3 Hydrology and gravel extraction

Changes in the morphology of the Waianakarua River channel are in part driven by the hydrological characteristics of the river, including the magnitude and frequency of flood events, and human activities such as gravel extraction and physical works. A description of these two factors during each of the two most recent survey periods is provided below. Figure 16 shows the flow in the Waianakarua River at Browns hydrological site between February 2008 and October 2013, and for the preceding three year period (the flow record began in April 2005). Three significant floods occurred during the latter period, in June 2013, August 2012, and October 2011 (Figure 16, Figure 17).

A large flood occurred in April 2014 (after the latest set of cross-section data was collected) which peaked at XXXX (flow to be inserted – Regional Services to provide next day or so) at Brown's Hydrological site (Figure 19). Additional cross-section survey data would be required to describe any changes in channel morphology which may have resulted from this event.

The flood hazard area for the lower Waianakarua River is shown in Figure 20, this mapping is primarily based on observed flood extents and was not completed using modelling or any topographic information, the accuracy of the flood hazard margins are therefore indicative only. Sedimentation could occur across the flood hazard area during extreme flood events, however, what is described in this report is mainly confined to the active channel and the immediate berm areas. Flood events can move sediment throughout the river system, the size and extent of the flood control where the sediment moves to, and this can potentially be anywhere in the flood hazard area.

Records provided by gravel extractors to ORC show that a total of 9,758m³ was extracted from the Waianakarua River between June 2004 and February 2008 and 31,263m³ was extracted between February 2008-October 2013 (Table 1). The bulk of the gravel extracted from the Waianakarua River (76%) was completed during the latter period. Over both periods of extraction 38% of the total gravel removed was from the South Branch, 39% was removed from the North Branch, and 23% was removed from both the North and South Branches at the confluence and downstream to the river mouth.

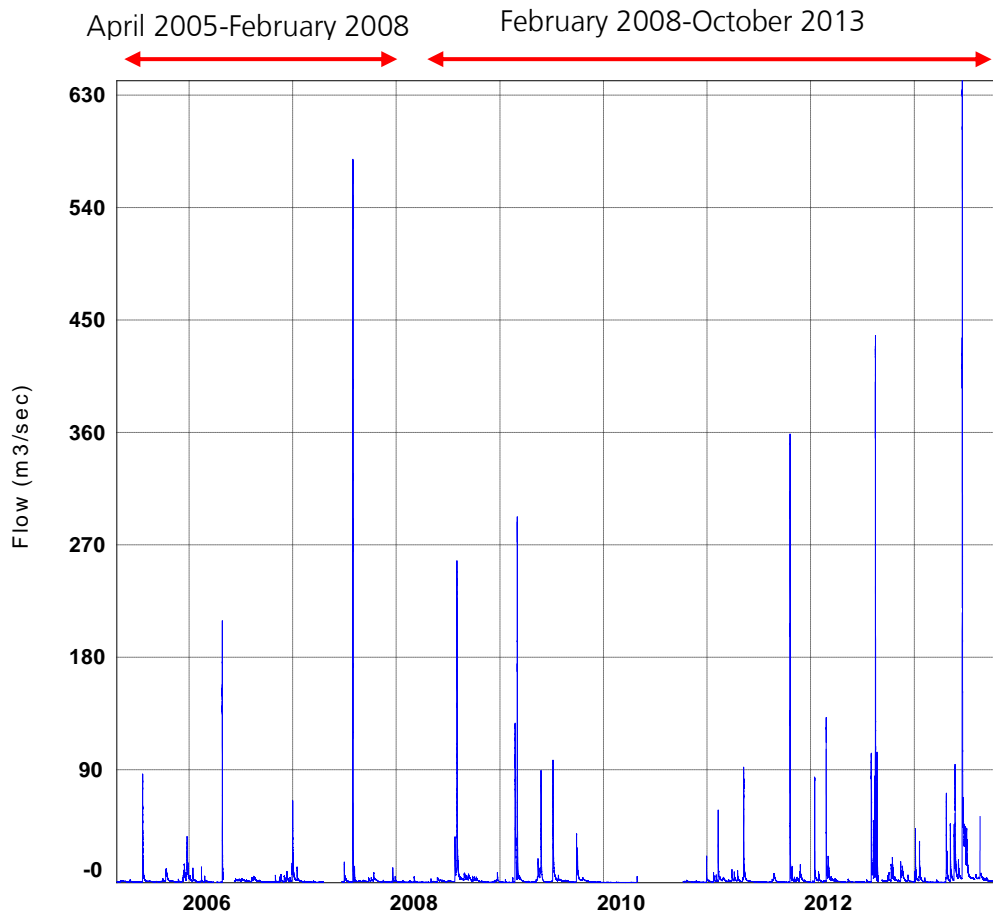


Figure 16-Flow in the Waianakarua River at Browns for April 2005-February 2008 and February 2008 to October 2013. These periods correspond approximately with the timing of the cross-section surveys described above.

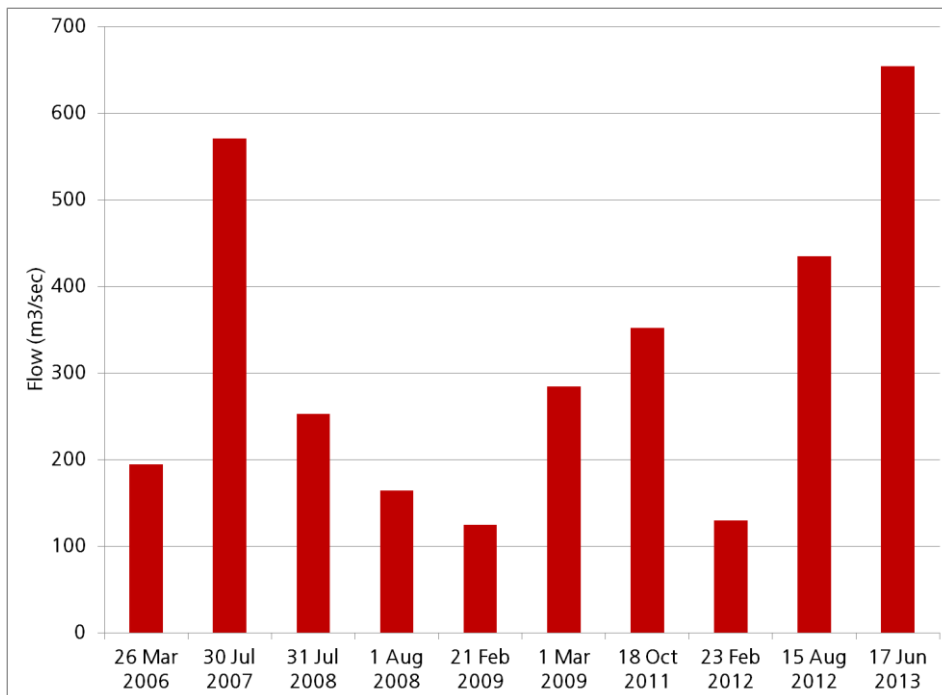


Figure 17- Ten highest flows in the Waianakarua River at Browns since records began in April 2005 (April 2014 flood value to be used when available)

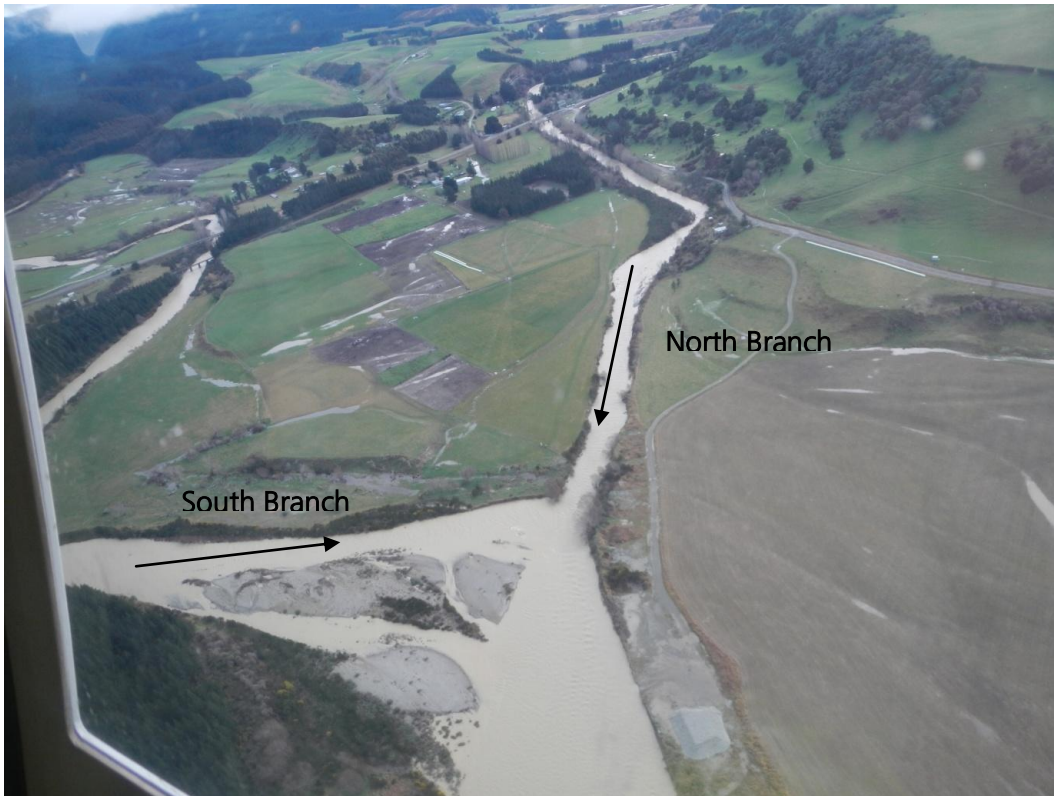


Figure 18-Aerial view of the Waianakarua River catchment in flood looking upstream at the confluence of the North and South branches (August 2012)



Figure 19- Flooding of farmland on the true left bank of the Waianakarua River, below the confluence of the North and South Branches (Photo taken in the morning of 19 April 2014)

Table 1-Summary of extraction records provided to the ORC for consents on the Waianakarua River between June 2004 and October 2013

Extraction location	Amount extracted June 2004-February 2008 (m ³)	Amount extracted February 2008-October 2013 (m ³)	Amount consented (m ³)
South Branch: 500m-1km upstream of SH1 (Figure 12)	5,562	10,155	18,000
North Branch: 200m-600m upstream of Graves Dam	4,196	4,813	10,000
Confluence of North and South Branches:800m upstream and downstream (Figure 10)		2,456	2,000
Main stem: 900m-1800m downstream of confluence (Figure 10)		6,892	20,000
North Branch: Sharps Bend (Figure 11)		6,947	15,000
TOTAL	9,758	31,263	65,000



Figure 20- Flood hazard area for the lower Waiakarua River (ORC, 2002)⁷

⁷ Otago Regional Council. 2002. *Waitaki District Floodplain Report (DRAFT)*.

Appendix 1. Waianakarua River cross-section summaries

Waianakarua: WA1

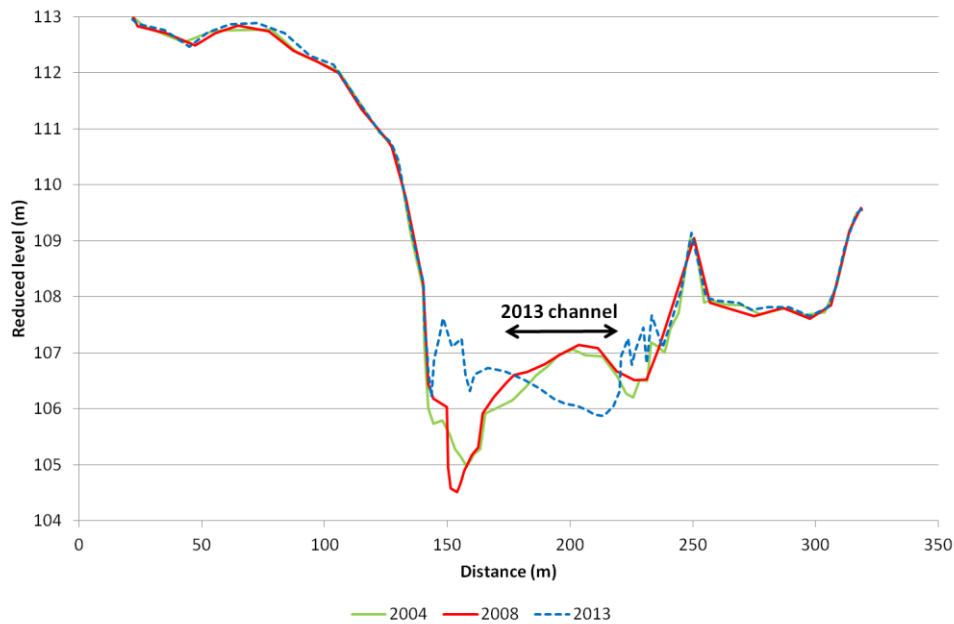


Figure 21- Cross-section WA1, looking downstream



Figure 22-Cross-section WA1, looking downstream, October 2013

Cross-section WA1 is located 2.65km upstream of the Waianakarua River mouth. The channel bed remained similar between June 2004 and February 2008 with a lowering of the main channel occurring. Between February 2008 and October 2013 the main channel has aggraded approximately 2.5m on the true left and degraded by 1m on the true right to create a wider, shallower channel. Minimal change has occurred in the wider floodplain. The thalweg level aggraded by 1.3m between 2008 and 2013 and has changed position (horizontally) from the left to the right bank.

Waianakarua: WA2

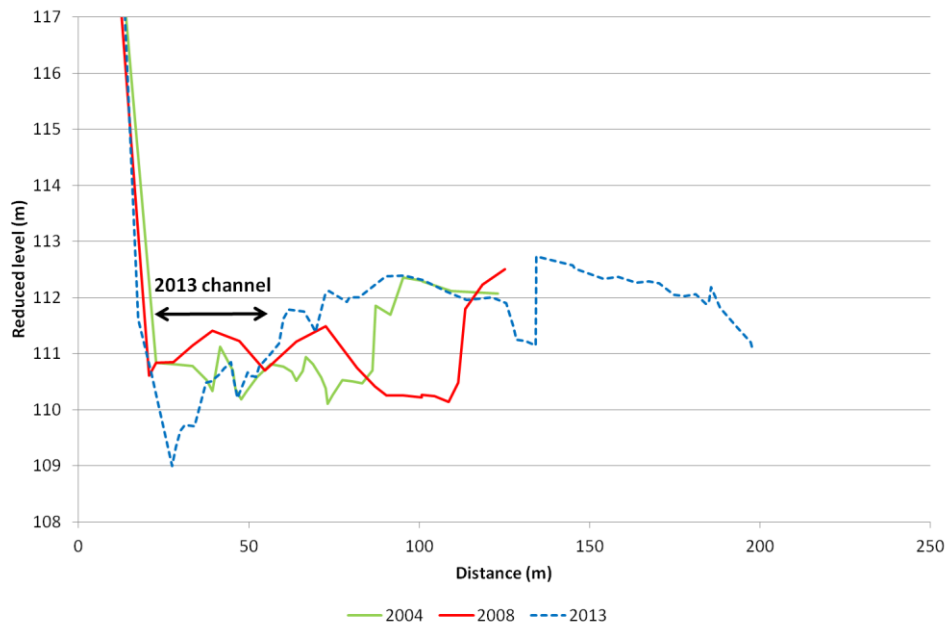


Figure 23- Cross-section WA2, looking downstream



Figure 24-Cross-section WA2, looking downstream, October 2013

Cross-section WA2 is located 4.35km upstream of the Waianakarua River mouth. The channel bed aggraded between June 2004 and February 2008 with erosion of the right bank occurring. Between February 2008 and October 2013 the main channel degraded approximately 2m on the true left and aggraded by 2m on the true right to create a narrower, deeper channel. Changes on the true right wider floodplain cannot be verified, as previous surveys in 2004 and 2008 did not extend as far to the true right as that completed in 2013. The thalweg degraded by 1.1m between 2008 and 2013 and has changed position (horizontally) from the right to the left bank.

Waianakarua: WA3

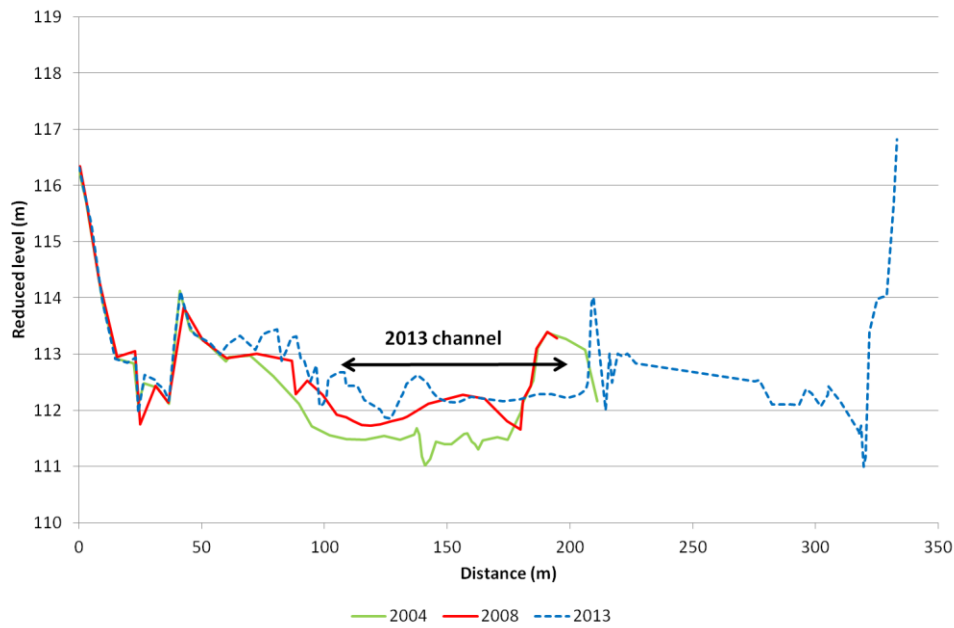


Figure 25- Cross-section WA3, looking downstream



Figure 26-Cross-section WA3, looking upstream, October 2013

Cross-section WA3 is located 4.6km upstream of the Waianakarua River mouth. The channel bed aggraded between June 2004 and February 2008. Between February 2008 and October 2013 the main channel aggraded up to 1m on the true left and eroded the true right bank by approximately 20m. Changes on the true right wider floodplain cannot be verified, as previous surveys in 2004 and 2008 did not extend as far to the true right as that completed in 2013. The thalweg aggraded by 0.6m between 2008 and 2013.

Waianakarua: WA4

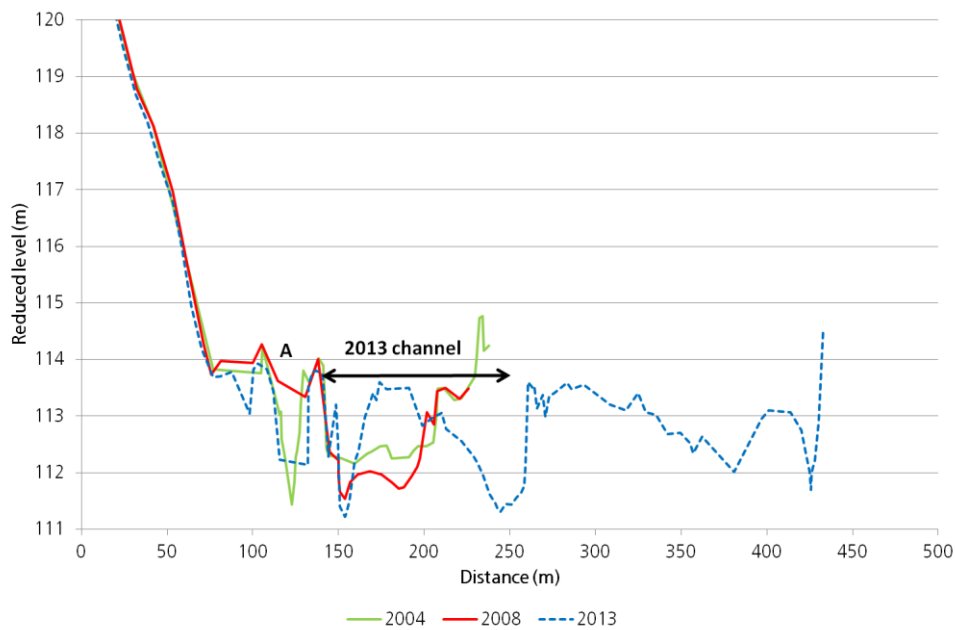


Figure 27- Cross-section WA4, looking downstream



Figure 28-Cross-section WA4, looking upstream, October 2013

Cross-section WA4 is located 4.7km upstream of the Waianakarua River mouth. The channel bed aggraded on the true left secondary channel (point labelled A) with degradation occurring in the main channel between June 2004 and February 2008. Between February 2008 and October 2013 the main channel aggraded approximately 2m, with degradation occurring in the secondary flow channel (point labelled A). The right bank eroded with another channel being created between 2008 and 2013 indicating the dynamic nature of the Waianakarua River at this location. Changes on the true right wider floodplain cannot be verified, as previous surveys in 2004 and 2008 did not extend as far to the true right as that completed in 2013. The thalweg degraded by 0.3m between 2008 and 2013.

Waianakarua: WA5N



Figure 29- Cross-section WA5N, looking downstream



Figure 30-Cross-section WA5N, looking downstream, October 2013

Cross-section WA5N is located 9.6km upstream of the Waianakarua River mouth on the North Branch at Sharps Bend. Sharps bend is an area of historic and recent gravel extraction activity and changes at this location reflect both natural and artificial change. The channel bed both aggraded and degraded between June 2004 and February 2008. Between February 2008 and October 2013 the main channel both aggraded and degraded creating a smoother and lower profile. The top of the left bank shows aggradation and the creation of two levees (at the point labelled A).The right bank aggraded and steepened between 2008 and 2013. The thalweg degraded by 0.9m between 2008 and 2013.

Waianakarua: WA6N

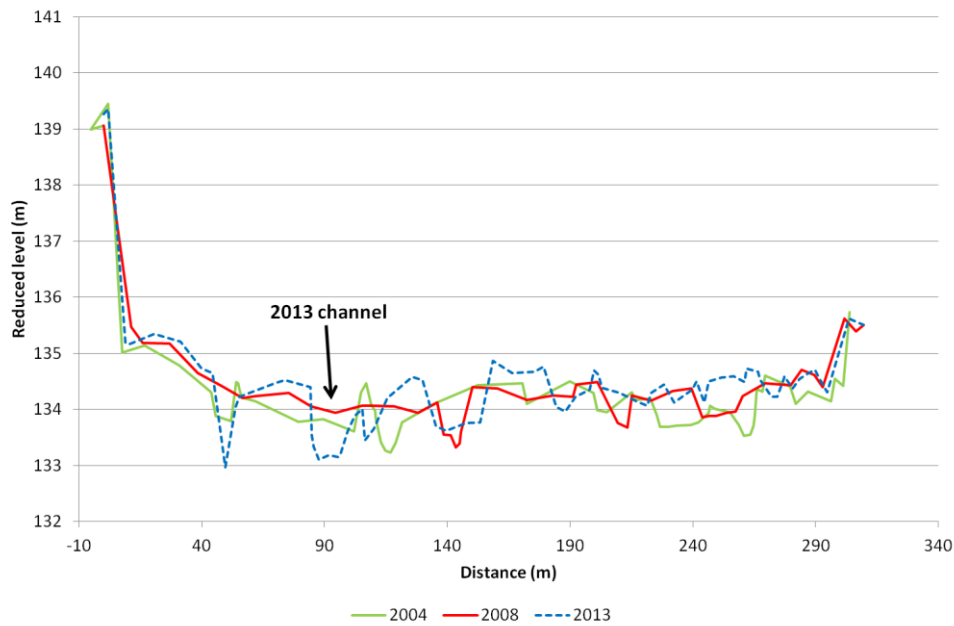


Figure 31- Cross-section WA6N, looking downstream



Figure 32-Cross-section WA6N, looking downstream, October 2013

Cross-section WA6N is located 9.75km upstream of the Waianakarua River mouth on the North Branch at Sharps Bend. Sharps bend is an area of historic and recent gravel extraction activity and changes at this location reflect both natural and artificial change. The Waianakarua River at this location consists of several low flow channels with the bed both aggrading and degrading between June 2004 and February 2008. Three channels were created on the true left of the channel between February 2008 and October 2013 with aggradation occurring on the true left bank. The thalweg degraded by 0.35m between 2008 and 2013.

Waianakarua: WA7N

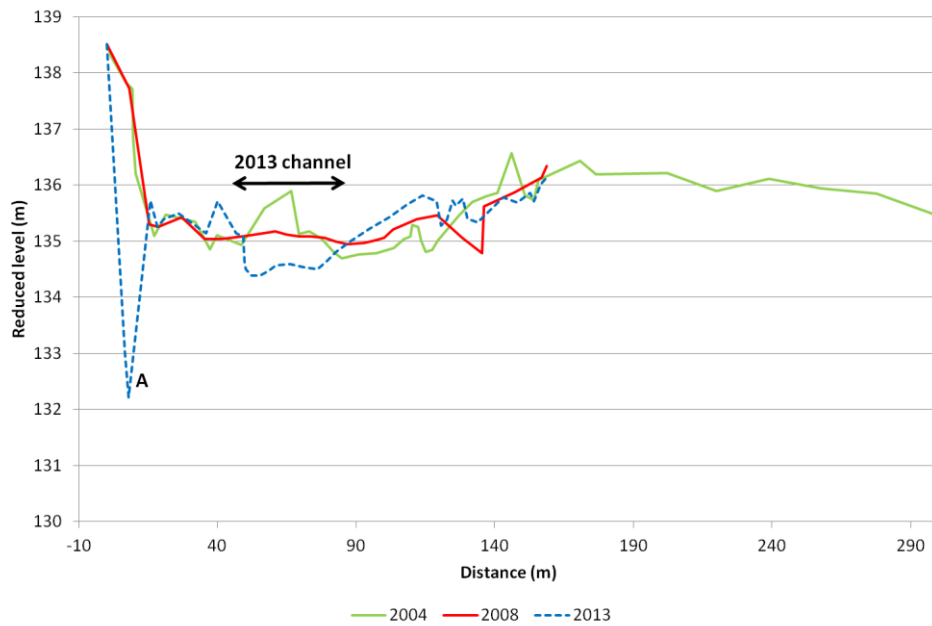


Figure 33- Cross-section WA7N, looking downstream



Figure 34-Cross-section WA7N, looking downstream, October 2013

Cross-section WA7N is located 9.9km upstream of the Waianakarua River mouth on the North Branch at Sharps Bend. Sharps bend is an area of historic and recent gravel extraction activity and changes at this location reflect both natural and artificial change. Between June 2004 and February 2008 the bed both aggraded and degraded with the channel becoming smoother in 2008. Between February 2008 and October 2013 the left bank eroded approximately 9m and degraded 6m creating a deep secondary channel (point labelled A). The main channel degraded with aggradation occurring on the right bank between February 2008 and October 2013 creating a narrower deeper main channel. The thalweg degraded by 0.4m between 2008 and 2013.

Waianakarua: WA8N

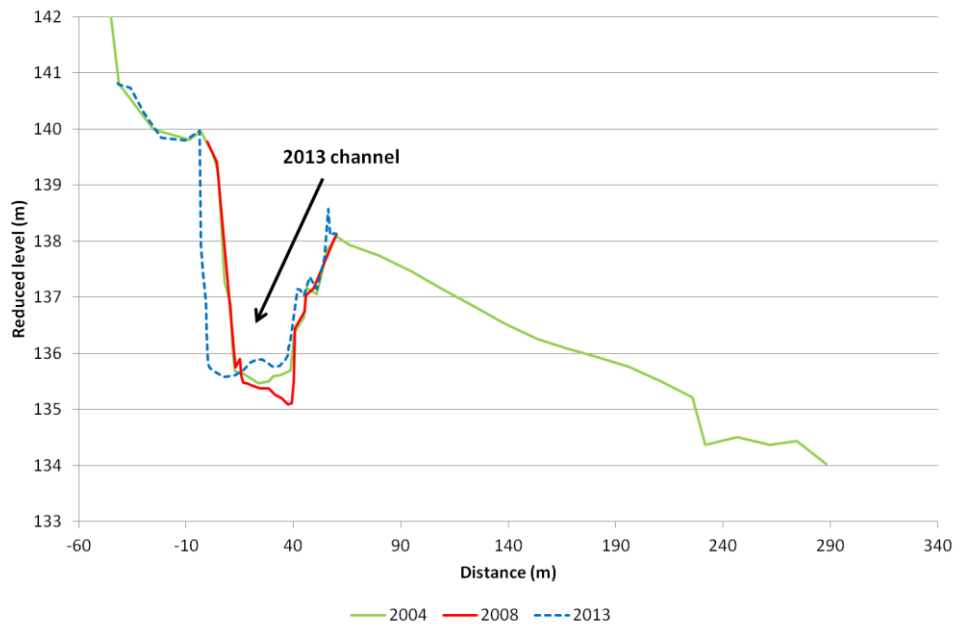


Figure 35- Cross-section WA8N, looking downstream



Figure 36-Cross-section WA8N, looking from true left to true right, October 2013

Cross-section WA8N is located 10.25km upstream of the Waianakarua River mouth on the North Branch at Sharps Bend. Sharps bend is an area of historic and recent gravel extraction activity and changes at this location reflect both natural and artificial change. Between June 2004 and February 2008 the main channel bed degraded by approximately 0.5m. Between February 2008 and October 2013 the left bank eroded by approximately 13m with the main channel aggrading by approximately 0.75m creating a wider shallower channel. Some aggradation occurred on the right bank between 2008 and 2013. Changes on the true right wider floodplain cannot be verified, as surveys in 2013 and 2008 did not extend as far to the true right as that completed in 2004. The thalweg aggraded by 0.49m between 2008 and 2013.

Waianakarua River: WA5S

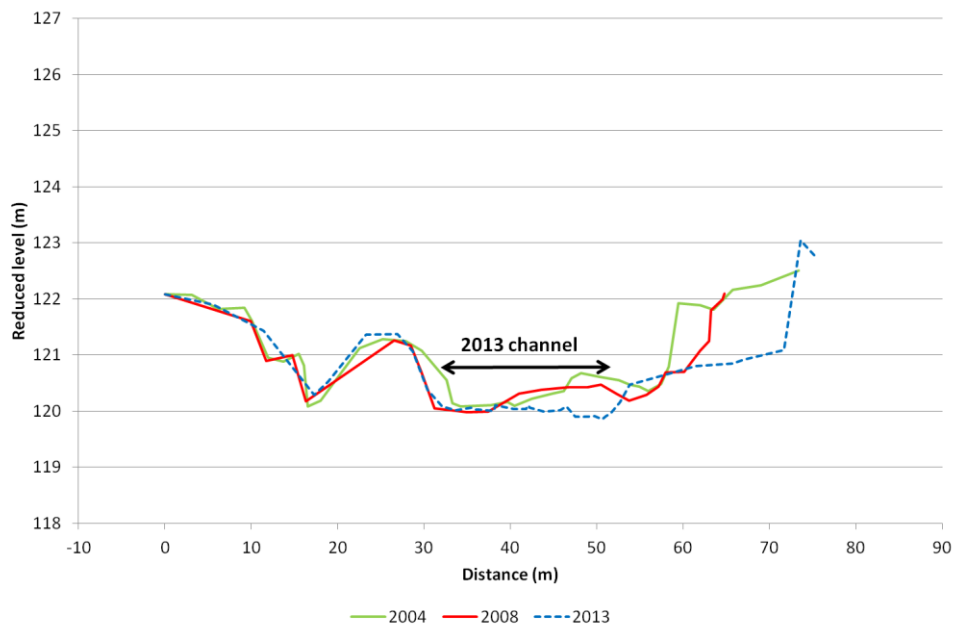


Figure 37- Cross-section WA5S, looking downstream

Cross-section WA5S is located 6.85km upstream of the Waianakarua River mouth on the South Branch. Between June 2004 and February 2008 there was erosion of the left and right banks with the channel bed aggrading in some places and degrading in others. Continued erosion at this location would affect farmland on the right bank. Between February 2008 and October 2013 the wider left floodplain aggraded creating a smoother profile with degradation occurring in the main channel. The right bank eroded approximately 14m between 2004 and 2013. Changes on the true right wider floodplain between 2008 and 2013 cannot be verified, as the 2008 survey did not extend as far to the true right as that completed in 2004 and 2013. The thalweg degraded by 0.12m between 2008 and 2013.



Figure 38-Cross-section WA5S, looking downstream towards the cross-section, October 2013

Waianakarua: WA6S

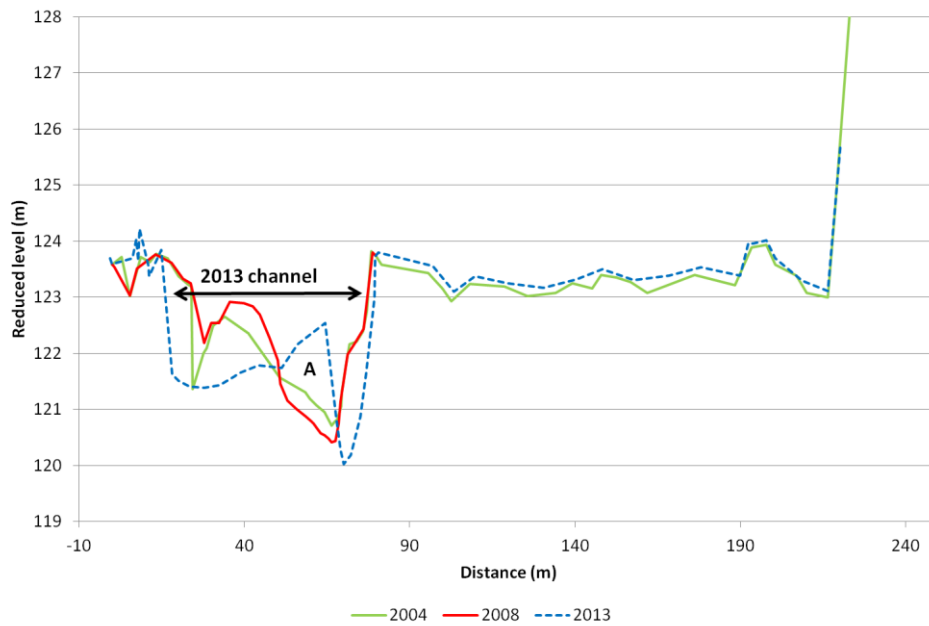


Figure 39- Cross-section WA6S, looking downstream



Figure 40-Cross-section WA6S, looking upstream, October 2013

Cross-section WA6S is located 7km upstream of the Waianakarua River mouth on the South Branch. Between June 2004 and February 2008 there was aggradation of the left bank with the main channel bed degrading. Between February 2008 and October 2013 the left and right banks eroded with aggradation occurring in the 2004/2008 main channel. This has created two channels separated by a gravel bar (Figure 39) (point labelled A). The wider right bank floodplain has aggraded between 2004 and 2013. Changes on the true right wider floodplain between 2008 and 2013 cannot be verified, as the 2008 survey did not extend as far to the true right as that completed in 2004 and 2013. The thalweg degraded by 0.4m between 2008 and 2013.

Waianakarua: WA7S

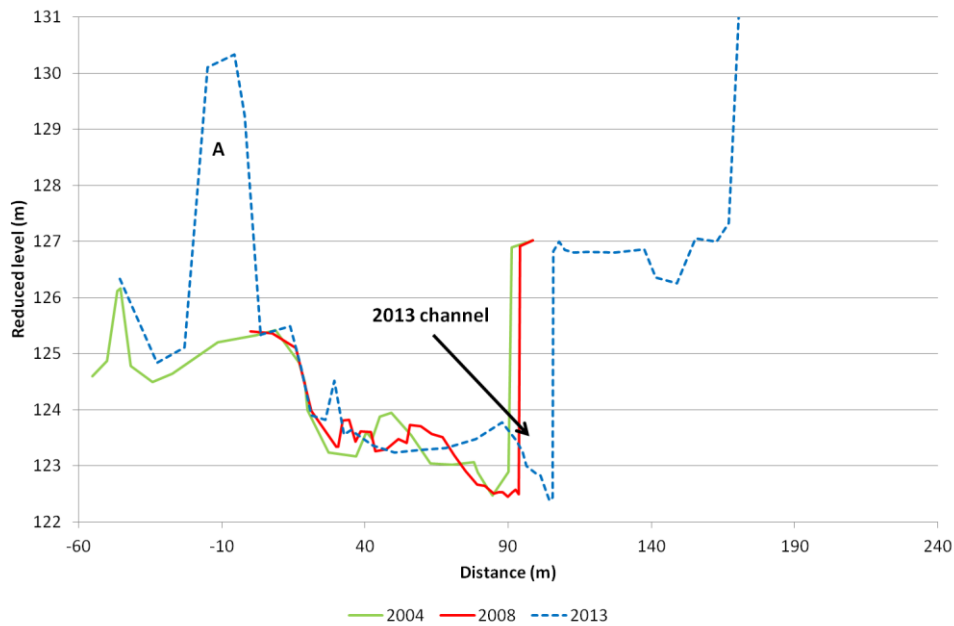


Figure 41- Cross-section WA7S, looking downstream



Figure 42-Cross-section WA7S, looking from true left to true right, October 2013

Cross-section WA7S is located 7.4km upstream of the Waianakarua River mouth on the South Branch. Between June 2004 and February 2008 the right bank eroded causing the main channel to shift towards the right bank. Between February 2008 and October 2013 the right bank eroded with both aggradation and degradation occurring across the main channel. If erosion of the right bank continues, farmland and a farm shed may become affected. Gravel is extracted from this location, the large bank feature (point labelled A) is a gravel stockpile and not a natural feature. Changes on the true right and true left wider floodplain between 2004-2013 cannot be verified, as the 2008 and 2004 surveys do not extend as far on the true right or left banks as that completed in 2013. The thalweg remained at a similar height between 2008 and 2013.

Waianakarua: WA8S

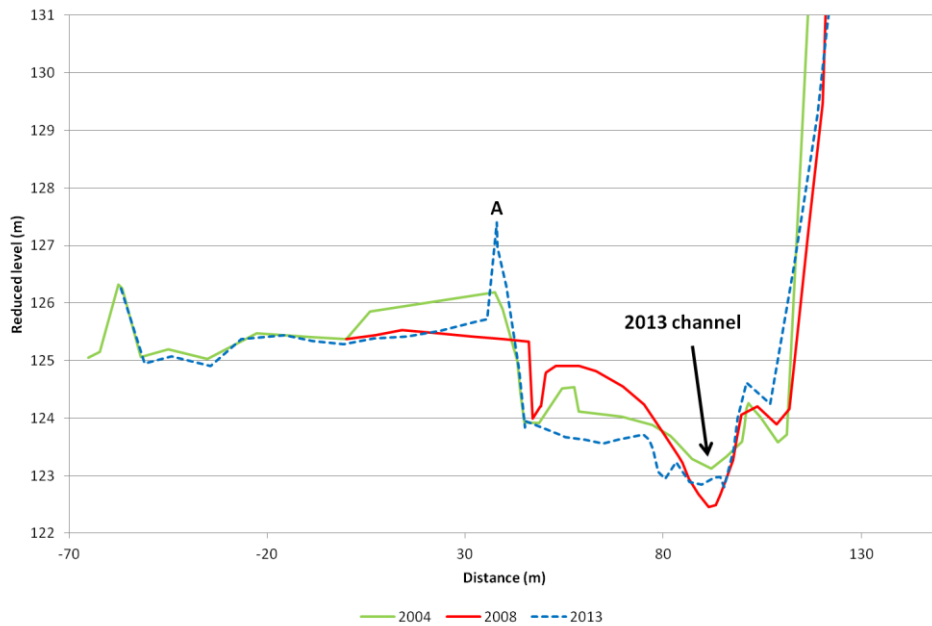


Figure 43- Cross-section WA8S, looking downstream



Figure 44-Cross-section WA8S, looking upstream, October 2013

Cross-section WA8S is located 7.7km upstream of the Waianakarua River mouth on the South Branch. Between June 2004 and February 2008 the right bank eroded, the main channel degraded, and the left bank aggraded creating a narrower deeper channel. Between February 2008 and October 2013 the right bank and main channel aggraded. The left bank of the main channel degraded, creating a wider shallower channel. The top of the left bank has been shaped into a bank feature (point labelled A). Gravel is extracted from this location. The thalweg aggraded 0.35m between 2008 and 2013.

Waianakarua:WA9S

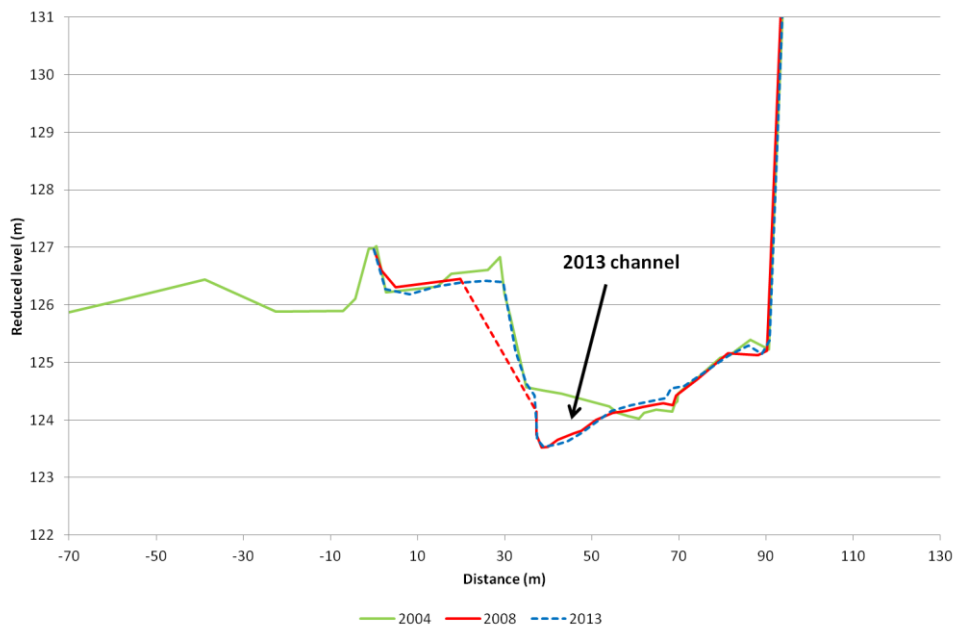


Figure 45- Cross-section WA9S, looking downstream, the dashed line for 2008 represents unconfirmed data



Figure 46-Cross-section WA9S, looking downstream, October 2013

Cross-section WA9S is located 7.85km upstream of the Waianakarua River mouth on the South Branch. Between June 2004 and February 2008 the left bank eroded (although the 2008 data is unconfirmed for the left bank), the main channel degraded, and a small amount of aggradation occurred in the 2004 main channel. Between February 2008 and October 2013 the left bank aggraded to a similar position as 2004, the main channel remained in the same position as 2008. The thalweg level did not move vertically or horizontally between 2008 and 2013.

Waianakarua:WA10S

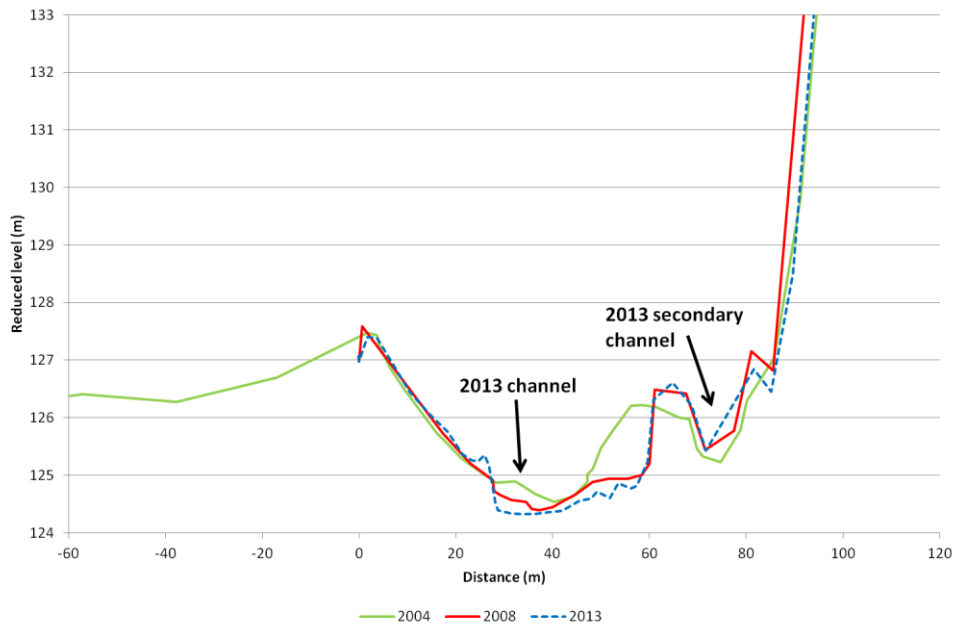


Figure 47- Cross-section WA10S, looking downstream



Figure 48-Cross-section WA10S, looking upstream, October 2013

Cross-section WA10S is located 9.85km upstream of the Waianakarua River mouth on the South Branch. Between June 2004 and February 2008 the right bank of the main channel eroded approximately 10m with aggradation occurring on the right bank of the secondary channel. Between February 2008 and October 2013 the main channel degraded with both aggradation and degradation occurring on the right bank of the secondary channel. The thalweg degraded 0.07m between 2008 and 2013.

Waianakarua: WA11S

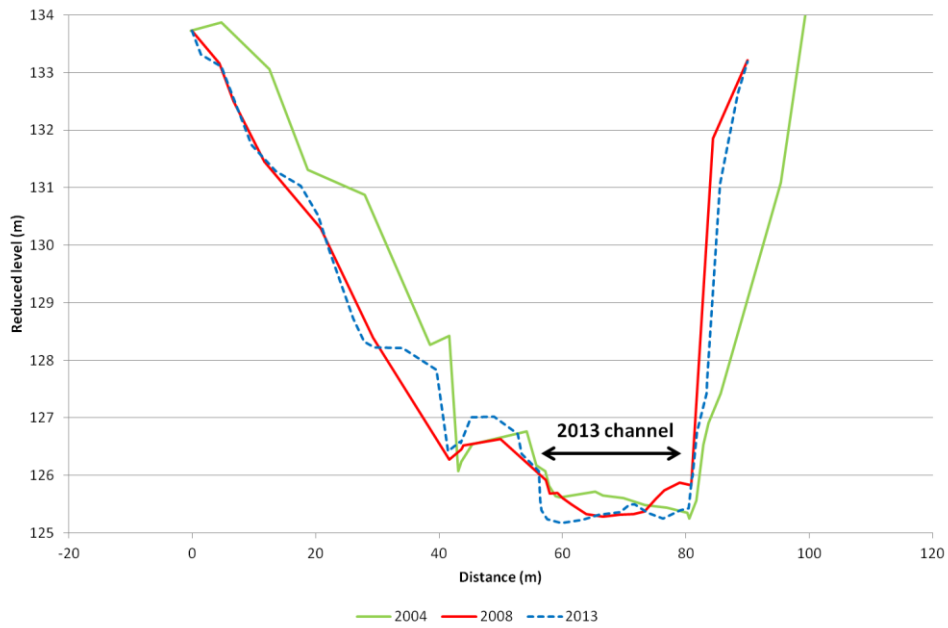


Figure 49- Cross-section WA11S, looking downstream



Figure 50-Cross-section WA11S, looking upstream, October 2013

Cross-section WA11S is located 10.1km upstream of the Waianakarua River mouth on the South Branch. Between June 2004 and February 2008 the right bank of the main channel aggraded, the left bank degraded, and the main channel both aggraded and degraded. Between February 2008 and October 2013 the main channel degraded with aggradation occurring on the left bank and degradation occurring on the right bank. The thalweg degraded 0.11m between 2008 and 2013.

Waianakarua:WA12S

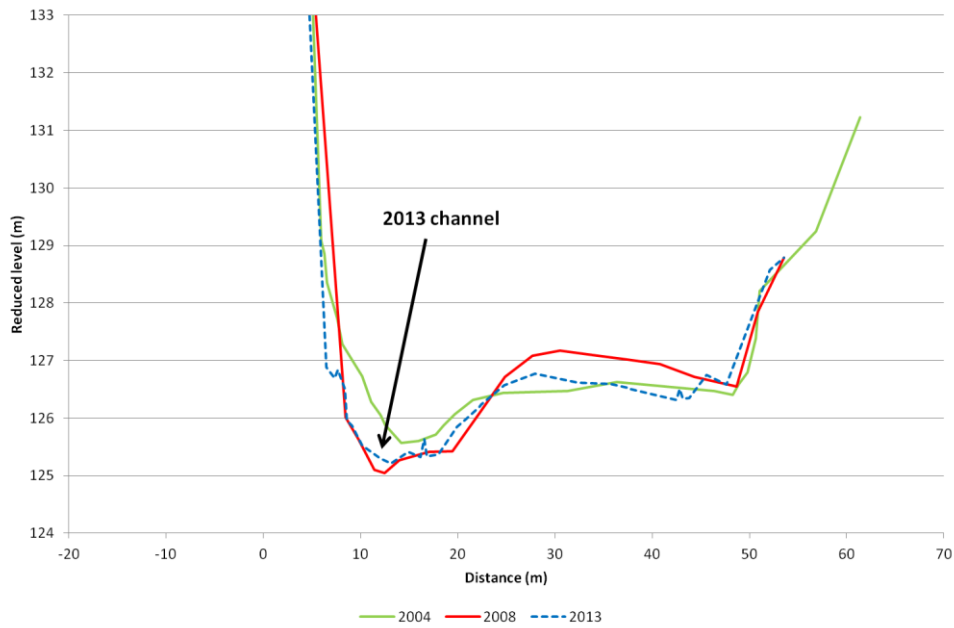


Figure 51- Cross-section WA12S, looking downstream



Figure 52-Cross-section WA12S, looking upstream, October 2013

Cross-section WA12S is located 10.4km upstream of the Waianakarua River mouth on the South Branch. Between June 2004 and February 2008 the main channel degraded by approximately 0.75m, with the right bank floodplain aggrading by approximately 0.5m. Between February 2008 and October 2013 the main channel aggraded, the left bank eroded by approximately 2m, and the right bank floodplain degrading to a similar level as 2004. The thalweg degraded 0.16m between 2008 and 2013.

Waianakarua: WA13S

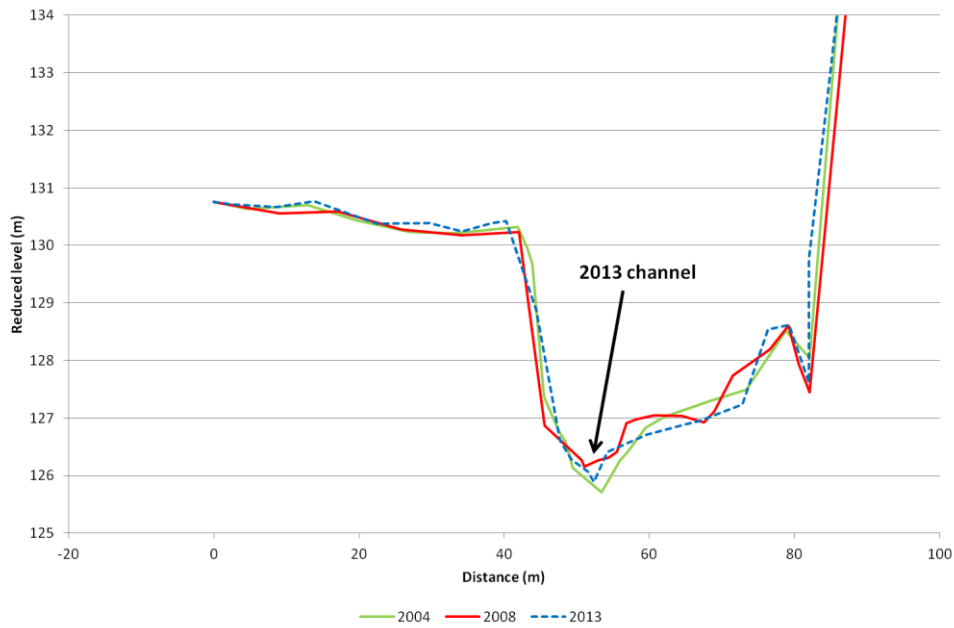


Figure 53- Cross-section WA13S, looking downstream

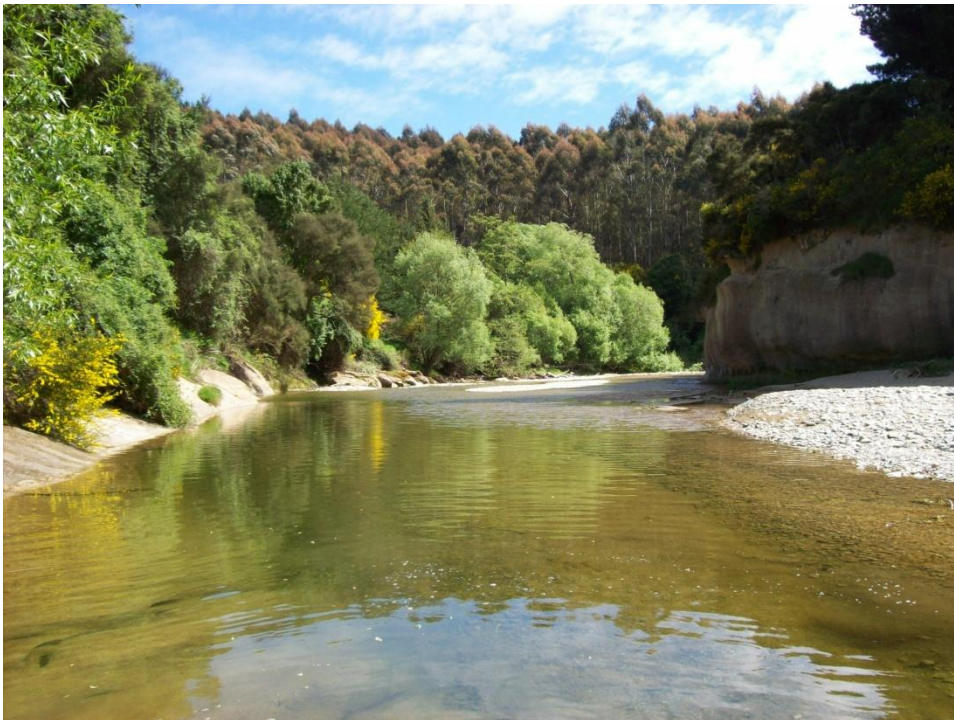


Figure 54-Cross-section WA13S, looking downstream, October 2013

Cross-section WA13S is located 10.7km upstream of the Waianakarua River mouth on the South Branch. Between June 2004 and February 2008 the main channel aggraded by approximately 0.5m, the right bank floodplain both aggraded and degraded, and the left bank eroded by approximately 2m. Between February 2008 and October 2013 the main channel and the true right floodplain degraded and both the left and right banks aggraded by approximately 3m. The thalweg degraded 0.26m between 2008 and 2013.

Waianakarua: WA14S

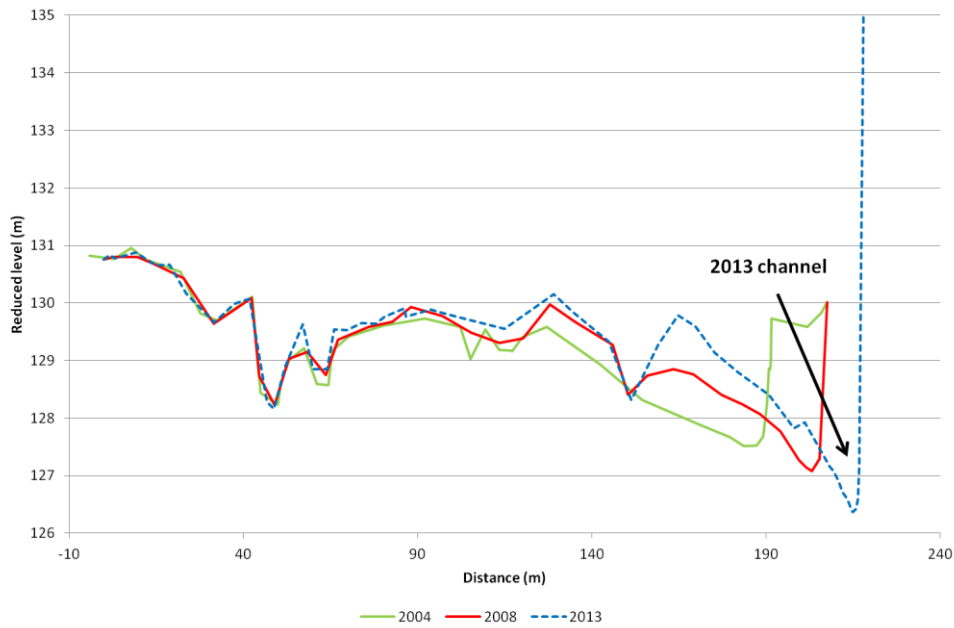


Figure 55- Cross-section WA14S, looking downstream



Figure 56-Cross-section WA14S, looking downstream, October 2013

Cross-section WA14S is located 10.9km upstream of the Waianakarua River mouth on the South Branch. Between June 2004 and February 2008 the main channel degraded by approximately 0.5m, the left bank floodplain aggraded and the right bank eroded by approximately 18m. Between February 2008 and October 2013 the main channel degraded by approximately 0.5m, the left bank floodplain aggraded and the right bank eroded by approximately 13m. This shows that the river is currently continuing to move towards and erode the right bank, if this erosion continues more farmland will begin to be affected. The thalweg degraded 0.70m between 2008-2013.

Waianakarua: WA15S

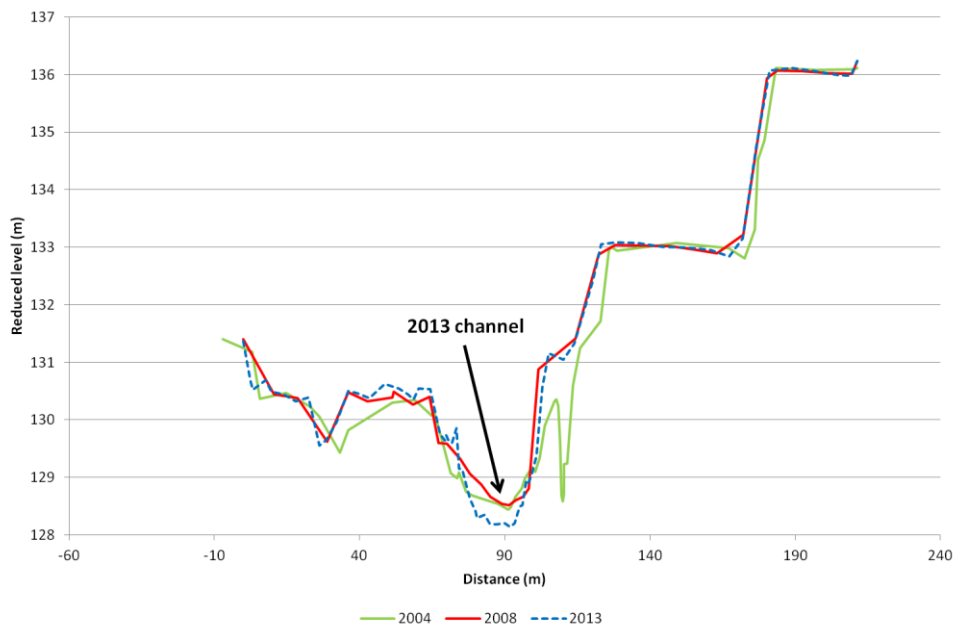


Figure 57- Cross-section WA15S, looking downstream



Figure 58-Cross-section WA15S, looking upstream, October 2013

Cross-section WA15S is located 11.1km upstream of the Waianakarua River mouth on the South Branch. Between June 2004 and February 2008 both banks of the main channel aggraded, with aggradation occurring the on the right bank and the left bank floodplain. Between February 2008 and October 2013 the main channel degraded by approximately 0.4m, the left and right bank floodplains remained similar. The thalweg degraded 0.38m between 2008 and 2013.

Appendix 2. Methods

Background

ORC has collected cross-section survey information on the Waianakarua River, in the North Branch, South Branch, and the main stem. The monitoring programme dates back to 2004. A comprehensive survey of all the existing cross-sections in the Waianakarua was undertaken in June 2004, February 2008, and October 2013.

This analysis is intended to show the changes in morphology that have occurred since the last comprehensive survey was undertaken in 2008. Although changes before this time are described more fully in ORC (2008), this report does place the more recent changes within the context of longer term trends.

Parameters

The minimum (thalweg) bed level of each cross-section and for each survey period were determined. Analysis of thalweg levels between survey periods can indicate whether the gradient of the river has changed over time as a result of sediment movement (aggradation and/or degradation). Thalweg values are shown in graphical form, and the changes that have occurred up till 2013 are discussed in section 2.2.

Limitations

A limitation of the cross-section data is that it shows the river as it was at the time the survey was undertaken; therefore, it provides a snapshot view of the river morphology for that particular time and place. Furthermore, survey methods involve taking an elevation and distance measurement at every major break in slope. This method has limitations in terms of transect resolution. The interpretations should therefore be viewed within the context that the data was collected.

All cross-section graphs are looking downstream, with the true left of the river being on the left side of the graph. All reduced level measurements are expressed in Otago datum, which lies 100m above the Dunedin vertical datum 1958. The horizontal (distance) scale varies between each cross-section. A consistent scale has been used for the vertical axis.

Appendix 3. Timing of cross-section survey's in the Waianakarua River

Cross-section	June 2004	February 2008	October 2013
WA1	X	X	X
WA2	X	X	X
WA3	X	X	X
WA4	X	X	X
WA5N	X	X	X
WA6N	X	X	X
WA7N	X	X	X
WA8N	X	X	X
WA5S	X	X	X
WA6S	X	X	X
WA7S	X	X	X
WA8S	X	X	X
WA9S	X	X	X
WA10S	X	X	X
WA11S	X	X	X
WA12S	X	X	X
WA13S	X	X	X
WA14S	X	X	X
WA15S	X	X	X