West Coast Regional Council

Hokitika Township

Hokitika River Design Flood Levels

December 2010

Good Earth Matters
Consulting

Client:	West Coast Regional Council
Project Name:	Hokitika Township
Report Title:	Hokitika River Design Flood Levels
File Reference:	32007\2010.12.09 Hokitika River Design Flood Levels.doc
Report Issue:	Draft — Date: June 2010
	Final — Date: December 2010

A P P R O P R I A T E S O L U T I O N S ◆ A P P R O P R I A T E T E C H N O L O G Y

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APPENDICES

1. INTRODUCTION

The town of Hokitika is situated at the mouth of the Hokitika River. The river drains a catchment of approximately 1040 km^2, much of which is located in the Southern Alps where there is exceptionally high rainfall. The Hokitika River is therefore prone to rapid changes in flow and flooding. However, the rise in river level for a given storm event is currently unknown. This is important information in planning for the flood protection around Hokitika.

The West Coast Regional Council (WCRC) has engaged Good Earth Matters Consulting to estimate design flood levels for the right and left bank of the Hokitika River downstream of the Kaniere Bridge for the following return periods:

- 1 in 50 year flood
- 1 in 100 year flood
- 1 in 400 year flood

WCRC plan to use this information to assist in determining if the existing banks are sufficient in containing the Hokitika River, and in determining the need for further modelling work and/or appropriate upgrade options if necessary.

2. EXISTING FLOOD PROTECTION AND PERFORMANCE

The existing flood protection consists of a combination of constructed stopbanks and natural raised banks, running from the mouth of the river upstream to the Kaniere Bridge. There are also a number of groynes along the river, including:

- Five spur groynes on the true left bank, approximately 300m upstream from the State Highway 6 (SH6) bridge
- Three rock spur groynes and rock riprap for 270m on the true right bank immediately upstream from Kaniere Bridge
- Rock protection of the true left bank approximately 1.5km upstream from the SH6 bridge.

An aerial photograph of the area is given in Appendix A, while the levels along the banks are shown on drawings 1 - 6 in Appendix B.

2.1 SITE VISIT

On 28 April 2010, Good Earth Matters Consulting made a site visit to the Hokitika River. This included inspection of the river and surrounding area, a meeting with Westland District Council's Operations Manager (Rob Daniel), and meetings with long-term local residents Norm Gallop and Harry Collett. The key outcomes from the visit and meetings are summarised below:

- At low river flows the tidal influence can reach as far up river as the Kaniere Bridge
- During large storms the sand bar at the mouth of the river tends to get washed out
- The large floods in 1991 reached the underside of the arches at the Kaniere Bridge, a level of 7.3 - 7.5m
- Norm Gallop's lower paddocks along Arthurstown Road flood reasonably often, and flooded 3 - 4 times in the previous year.

2.2 REPORTS AND DATA RECEIVED

The following reports and data were reviewed as part of this study:

- Kaniere Bridge staging 1976 to 1994 (source: WCRC)
- Cross sections and long sections from the mouth of the river to Kaniere Bridge (source: WCRC, Chris Coll Surveying Limited)
- Flow measurement at Kaniere Bridge, 1999 (source: WCRC)
- NIWA estimates of flood frequencies at the Hokitika Gorge, including WCRC data recorded at Colliers Creek, plus flow data recorded at Hokitika Gorge from 1996 to present (source: NIWA)
- NIWA report "Review of Hokitika River flood frequency at Kaniere Bridge", 2009 (source: NIWA. Herein referred to as "the NIWA report")
- Aerial photographs from 1990, 1992, and current.

The aerial photographs show that the river has changed channel over the period of the photographs, and that some of the 'islands' are slowly being eroded away, despite the cross sections showing that two of the main islands have not changed in the eight years since the first cross sectional survey. Information received from Rob Daniel was that the bed was constantly changing. This is supported by the cross sections.

The river over the scheme reach has a varying active channel width of between 240m and 750m. The river has an average grade over the scheme reach of 1.85m fall per 1000m.

A sand bar is present at the mouth of the Hokitika River. The precise depth of the bar is unknown, but historical records ("Cyclopaedia of New Zealand", 1906) indicate that the bar was "…generally safe for vessels drawing eight to ten feet of water".

3. HYDRAULIC MODEL

XP-SWMM v9.0 hydrological/hydraulic software was used for modelling the flood flows. XP-SWMM uses St. Venant one dimensional flow equations.

3.1 SURVEY DATA

WCRC regularly commissions a survey (every 2-4 years) of the Hokitika River adjacent to Hokitika. The survey data provided consists of six river cross sections and long sections of the banks on both sides of the river. This data is presented in terms of NZ Map Grid and the Lyttelton MSL datum, which is approximately 0.18m above the Hokitika Bar datum.

3.2 INFLOWS

Peak flood flows for the 50, 100, and 400 year return period events were modelled.

The NIWA report calculated return periods for the flow at Kaniere Bridge, and is based upon an analysis of flood flows conducted in 1987 as part of the design of the SH6 bridge adjacent to Hokitika. The author of that report, E. B. Williams, undertook a frequency analysis of flood flows on the Hokitika River at Colliers Creek, then correlated this data with flow data at Kaniere Bridge to provide a linear regression of peak flows for Colliers Creek and Kaniere Bridge. In 1996 the Colliers Creek gauge was replaced by a gauge at the Hokitika Gorge. The NIWA report applies the linear regression to maximum annual flows at Colliers Creek and the Hokitika Gorge, to provide a timeline of annual maximum flows, from 1974 to 2008. This data was then used to estimate flood peaks and frequencies. Table 3.1 summarises the findings of that report.

Table 3.1
Hokitika River Design Flood Flows, with 95% Confidence Limits

Return Period (years)	Flood Flow (m^3/s)
50	4390 ± 530
100	4720 ± 630
400	5400 ± 710*

* Note - the 1 in 400 year event has been found by extrapolating the data presented in the NIWA report. The largest return period event documented in the NIWA report is the 1 in 200 year event.

It should be noted that the Hokitika River catchment experiences very high rainfall, in parts an average of over 10m per year. There has been little historical flow measurement downstream of Colliers Creek and Hokitika Gorge. As such, the flows given for the Kaniere Bridge above are approximate only, demonstrated somewhat by the high level of error at 95% confidence. In the absence of hard flow data for the lower Hokitika River, however, these flows are considered acceptable. It should also be noted that Groves Swamp, approximately 15km upstream from the Kaniere Bridge, can flood at high flows and this is likely to provide some buffering. For the purpose of modelling, however, it has been assumed that the swamp is full and there is no buffering effect.

3.3 HYDRAULIC MODEL

The model was established to route a steady state (constant) flow through the channel. The model was created over the project area, constructed using the six surveyed river cross sections representing the 2010 bed levels. The model was set up to follow the river channel and berm areas represented on the aerial photograph shown in Appendix A.

The purpose of the hydraulic model is to estimate design flood levels for the left and right banks. The bank crests were notionally raised to a level of 20m to ensure the routed design flows were contained, producing a representation of the flood levels if the river was restrained by a raised stopbank crest.

The river varies considerably in width over the reach. As the cross section surveys are spaced at large distances, significant changes in channel cross section properties occur between adjacent cross sections. Large changes in cross sectional area may affect the model continuity computation. However, validation of the model showed that reasonable results could be obtained. This is described in Section 4.

3.4 MODEL PARAMETERS

Channel and berm roughness were represented using Manning's roughness values (n). These values were estimated using information from the site visit, aerial photographs, and knowledge of 'n' for other similar river beds in New Zealand (using "Roughness Characteristics of New Zealand Rivers" (1991), D.M. Hicks and P.D. Mason).

The following roughness values (Manning's n) were used in the model:

- Active channel downstream of cross section 2 0.025
- Active channel upstream of cross section 2 0.027
- Berm vegetation 0.05

In terms of setting the downstream boundary conditions for the model, sea level was set at a maximum level that could reasonably be expected to be seen within the next 100 years. The level was taken as 2.1m above the Lyttelton mean sea level (MSL) datum, which includes 1.2m for a mean high water spring (MHWS) tide, 0.6m for a large storm surge (equating to atmospheric pressure of 954 millibars, a very low pressure system) and an allowance of 0.3m for sea rise due to climate change.

4. VALIDATION

Validation of the model is a necessary step in any modelling process. Given the uncertainty and variability in the data, a reasonable match was found between the modelled levels and actual observations. This match lends confidence to the use of the model for estimating flood levels for 1 in 50, 1in 100, and 1 in 400 year floods. The validation process is detailed below.

4.1 VALIDATION DATA

The validation data used is described in Table 4.1.

Table 4.1
Data Used for Validation

Source	Location	Observation
Harry Collett	Kaniere Bridge	1991 flow came to just under the arches at the Kaniere. This level is approximately 7.3 - 7.5m.
Norm Gallop	Between cross sections 3 and 4	Norm Gallop's lower paddocks regularly flooded, and had flooded 3-4 times in the previous year. Upper paddocks had never flooded.
Norm Gallop	Downstream of SH6 Bridge on true left bank	These lower paddocks regularly flood.
West Coast Regional Council	Kaniere Bridge	One-off low flow measurement and stage on 11 February 1999.
The Greymouth Star	SH6 Bridge	1 September 2009 photo shows river at similar level as Good Earth Matters Consulting site visit in April 2010.
Westland District Council	Kaniere Bridge	Staging data at the bridge, 1976 - 1993, flow data for Kaniere bridge as derived flows at Colliers Creek and Hokitika Gorge.

4.2 VALIDATION RESULTS

Four scenarios were selected for validation. These are summarised in sections 4.2.1 to 4.2.4.

4.2.1 Validation Against Previous Flood Data

Annual maximum flood flows for the Kaniere Bridge as well as staging data at the bridge were available for the period 1976 to 1993. There is some inconsistency in the levels at the bridge against the flows. In order to minimise this error, the model was run over a range of annual maximum flows with a specified channel n value, and the modelled levels checked against the recorded levels. The differences between the actual and modelled levels were then summed. The n value was then changed and the exercise repeated. The value of n which gave the smallest sum of differences was chosen as the channel n for the model. This was found to be n=0.027. This method for checking modelled levels against measured levels is therefore also effectively a sensitivity analysis for n.

4.2.2 Validation Against Levels at Norm Gallop's Lower Paddock, Arthurstown Road

Norm Gallop advised that his lower paddocks (lying in the range of 2.0 - 3.5m) had flooded 3-4 times in the previous year. Flood levels were therefore modelled using the three largest flows from the previous year. The model showed that the river levels at Mr Gallop's land were within the acceptable range.

4.2.3 Validation Against Levels at Norm Gallop's Paddocks Below SH6 Bridge

Norm Gallop also stated that his paddocks below the SH6 bridge occasionally flooded. Cross section 1 showed that this was at an approximate level of 1.0 - 1.5m. The model was run as per section 4.2.2, with the result that none of the levels were within the required range. However, the model was re-run with a sea level of 1m above MSL, which showed that the river level comes very close to the paddock level. It is therefore reasonable to expect that, with a high tide and higher flow, the paddocks would occasionally flood, somewhat matching Mr Gallop's description.

4.2.4 Validation Against Flow on 1 September 2009

An article in the Greymouth Star taken on 1 September 2009 showed a picture of the river in high flow. The picture appeared to be taken from the SH6 bridge looking upstream and shows what appears to be a whitebaiting hut. When Good Earth Matters Consulting visited Hokitika on 28 April 2010, a photo was taken from a similar location looking upstream and showing the same hut. Visual inspections of the two photos show that the river is at around the same level. Further inspection of photos taken under the bridge show that some of the river bed was exposed at the bridge supports approximately 200m from the true left bank. While it is difficult to reconcile the photographs with the cross sections, it is estimated that based on the photographs and cross sections, the river level was between -0.5 and 0.5m at cross section 2 (under the SH6 bridge). Good Earth Matters Consulting also observed that the level at the Kaniere Bridge was 3.5m. Flow at the Hokitika Gorge on 30 August 2009 and 31 August 2009 peaked at 900 m^3/s and dropped to 150 m^3/s on the morning of 01 September 2009. Given this information was available, and given the sparseness of other information available for validation, it was decided to use the levels at Kaniere Bridge and SH6 Bridge as a final check on the validity of the model. It is known that the River takes only a matter of a few hours to flow from the hills to the sea - a flow of $400m^3/s$ at the Hokitika Gorge, equating to 539 m^3/s at Kaniere Bridge (using William's formula) was therefore input. This yielded a level of 3.56m at Kaniere Bridge (compared with the observed level of 3.5m on 28 April 2010) and -0.13m at the SH6 Bridge. This matches the observations well.

4.3 SENSITIVITY

Sensitivity tests on channel roughness, sea level, and sand bar level were carried out. Sensitivity to Manning's n was effectively achieved by adjusting the channel n until the model output approximately matched the observed levels, as described in section 4.2.1. This Manning's n was used in all modelling.

Sensitivity to sea level was measured by setting the sea level at 1.25m above MSL and running the model at a nominal flow of 3000 m^3/s. Sea level was found to have a large effect at cross sections 1 and 2 (an increase of 1.16m at cross section 1 and 0.67m at cross section 2), but little or no effect further upstream than this.

Sensitivity to the sand bar height was measured. The depth of the sand bar had negligible effect on water levels at all the cross sections. As the anecdotal evidence suggested that a high sand bar is washed out during large floods, and it was shown that the depth of the sand bar had little effect on river levels, a sand bar depth of eight feet below low tide was used in all modelling.

The model was also run with an increase berm roughness from n=0.05 to n=0.08. The right overbank was adjusted to the left edge of the islands shown on the aerial photographs (rather than the true right bank of the river) on cross sections 3 and 4, as the islands showed different characteristics to the main channel. On this basis the maximum the modelled river level rose was 0.15m at cross section 4. This can be managed within the free-board range of 0.9m.

5. ESTIMATED FLOOD LEVELS

The following estimated flood flows were used during modelling

- 1 in 50 year flow - 4390 m^3/s
- 1 in 100 year flow - 4720 m^3/s
- 1 in 400 year flow - 5400 m^3/s

The design levels include an allowance for freeboard of 0.9m. This freeboard allowance is consistent with the existing design standards as detailed in the Rating District Asset Management Plan for the Hokitika River. Freeboard is a factor of safety that compensates for uncertainties in the estimation of flood levels. These uncertainties include:

- Model assumptions
- Afflux (back water effects caused by obstructions)
- Wave action.

The one-dimensional limitations of the model mean it is imperative to assess the two-dimensional characteristics of the river at high flow. Super elevations occur when high velocity water flows around a radius, causing water on the outside of the bend to elevate its levels. Super elevations may also be 'cancelled' if the water slows due to the presence of groynes, vegetation, or other obstructions. Three areas were identified of being at risk of experiencing super elevations and of these, only the right bank at cross sections 3 and 4 was estimated to have a rise in water level. This was calculated at 0.2m.

Back water effects occur when the river is subjected to extra frictional forces which slow the water velocity. The model was rerun to simulate this effect between cross sections 2 and 4, where two major islands are present. Though water can move around the outside of the island, an effect of restricted flow will be present. This effect was estimated by the model to raise the right bank by 0.10m at cross sections 2, 3, and 4.

The effects of super elevations and backwater have been included in all levels shown in the results. Table 5.1 summarises the results while Appendix B shows the flood levels on long sections of the banks and cross sections of the river bed. All elevations relate to Lyttelton Harbour datum.

Table 5.1
Flood Levels at Cross Sections
(metres above MSL and inclusive of 0.9m freeboard)

	Left Bank Elevation	Right Bank Elevation	50 Year Storm	100 Year Storm	400 Year Storm
Cross section 1	2.72	2.85	2.83	2.85	2.89
Cross section 2	4.43	3.41	3.13	3.17	3.27
Cross section 3	2.82	4.38	3.96	4.05	4.24
Cross section 4	4.49	5.79	4.82	4.92	5.10
Cross section 5	4.70	10.60	6.53	6.68	6.97
Cross section 6	9.66	9.65	8.06	8.25	8.63

6. DISCUSSION

6.1 CURRENT SCHEME CAPACITY

The right bank of the Hokitika River from the Kaniere Bridge to the mouth is a combination of constructed stop banks (largely protecting Hokitika township) and natural banks, while the majority of the left side has no constructed protection. This is immediately clear from the long sections, which shows little variation in the right bank until chainage 2900m, but significant variation across the length of the left bank. It is also immediately clear from the long sections that the left bank levels are considerably lower than the right bank. This is most noticeable at cross section 3, which shows the terrace on the property of Norm Gallop. This acts as a 'secondary stopbank', as the low lying paddocks are frequently flooded, while the upper paddocks do not. The low lying paddocks west of the SH6 bridge are also often flooded. There is little infrastructure along the left bank of the Hokitika River.

The long sections given in Appendix B show that the right bank of the Hokitika has a capacity equal to the 1 in 100 year storm, from the Hokitika Bridge to chainage 400. Below this point (recreation land and tip head) the bank capacity is mostly below the 50 year design level. The stopbank in this area is typically 0.1m below the 50 year design level (inclusive of 0.9m freeboard) between chainages 450 and 150. From chainages 100 downstream (ie at the downstream extremity of the system), the stopbank is approximately 0.25m below the 50 year design level (inclusive of 0.9m freeboard). In this downstream section there is also very little difference between the 50 and 100 year flood event due to the influence of sea level conditions.

Bank protection from the Hokitika Bridge to cross section 4 is adequate to the 1 in 100 year level. Much of this bank is built above the 1 in 400 year level. The bank has an irregular profile upstream of cross section 4 to Ch 4650. Depressions show tributaries and low points surveyed.

The long section shows inadequate protection from Ch 4650 to Ch 6700. It is possible that the 270m of protection works upstream of the Kaniere Bridge, as detailed in section 2, has not been identified in this survey.

The left bank, however, has extended lengths where significant work would be required for protection against a 1 in 50 year storm. Construction of the spur groynes to protect the bank and properties upstream of the State Highway bridge along Aurthurstown Road are the only areas with adequate protection. As previously mentioned, the long sections consider the immediate river banks and not secondary terraces.

No geotechnical work was done as part of this study. No comment is therefore made on the structural soundness of the existing constructed stopbanks.

6.2 CLIMATE CHANGE

The Ministry for the Environment report "Climate Change Effects and Impacts Assessment - A Guidance Manual for Local Government in New Zealand 2nd Edition, May 2008" offers guidance on the assessment of potential climate change impacts on flood flows. Findings for the West Coast region are that for mid range predicted temperature increases of 2.2 degrees (0.9 degree to 5.3 degree range) by 2090, rainfall intensity will be increased and peak flow rates increased by about 20% (7% to 42% range).

To put this predicted increase into context, by 2090 the current 100 year flood event of 4720 m^3/s increased by 20% will have reached a similar order of magnitude as the 1 in 400 year flood event of 5040 m^3/s. As a minimum, it is recommended that proposed capital work should make allowances for future upgrade work to contain flood risk increases as they are experienced. This includes constructing stopbanks in a manner which ensures there is space and sufficient base width to enable them to be raised further.

6.3 DESIGN STANDARD

There is no defined design standard for the scheme.

Currently, large sections of both sides of the Hokitika River bank do not have constructed stopbanks. One of the concerns of Westland District Council was that the banks of the river should be able to hold a 1 in 50 year flood. This position is based on the requirements of the Building Act (2004) which specifies that surface water from 50 year events shall not enter housing. The District Council consider a 50 year stopbank design standard as a means of achieving the Building Act requirements. It should be noted that the Building Act does not specify a stopbank standard, rather requires buildings not to be inundated in the 50 year event.

6.4 STOPBANK UPGRADE DESIGN

The design flood levels presented in this report enables the crest level to be set to an accepted design standard. In addition to this, the stopbank profile (batter slopes and crest width) and stopbank construction need to be specified. To determine these parameters, the existing stopbank condition and its ability to contain flood flows without failure should be assessed.

The stopbank does not contribute solely to providing a design level of protection. Stopbanks, bank edge protection, and overflow channels all contribute to providing a level of protection and should be considered as a whole when planning upgrade works.

6.5 SUMMARY

Simply upgrading the stopbank crest to a specified design flood level does not guarantee a level of protection to the community as stopbank failure from erosion or piping failure may occur before the flood waters reach the stopbank crest. Accordingly, an assessment of the existing constructed stopbanks should be undertaken to determine its material composition and integrity.

The modelling work to determine the design flood levels has been undertaken with limited survey and flow data. Nonetheless, the estimated design flood levels can be viewed with a moderate level of confidence for the purposes of setting a stopbank crest height.

The left bank requires substantial stopbank works in order to meet 1 in 50 year protection levels.

The right bank is able to meet the 1 in 50 year protection level with some minor raising required below chainage 450m, in order to maintain consistent freeboard levels (0.9m) and in localised low spots between cross-sections 4 and 6.

The right bank is generally able to meet 100 year protection levels (inclusive of freeboard) downstream of cross section 5 at chainage 4350 (approximately 1.2km downstream of Kaniere Bridge).

The flood levels modelled and plotted in Appendix B and C are inclusive of a 0.9m freeboard allowance in accordance with the scheme's Asset Management Plan. No allowance has been made for an increase in flood flows due to climate change. However allowance for a 0.3m increase in sea level due to climate change has been included in the model boundary conditions. To place the potential for increased flood flows due to climate change in to perspective, Ministry for the Environment states that increases in peak flow of 20% could occur by 2090 (as a mid range prediction). This would see the 100 year flood event increase to be a similar order of magnitude as the modelled 400 year flood event. Such considerations should be taken in to account when making any decisions as to the timing and extent of any improvement works for the flood protection scheme.

Appendix A

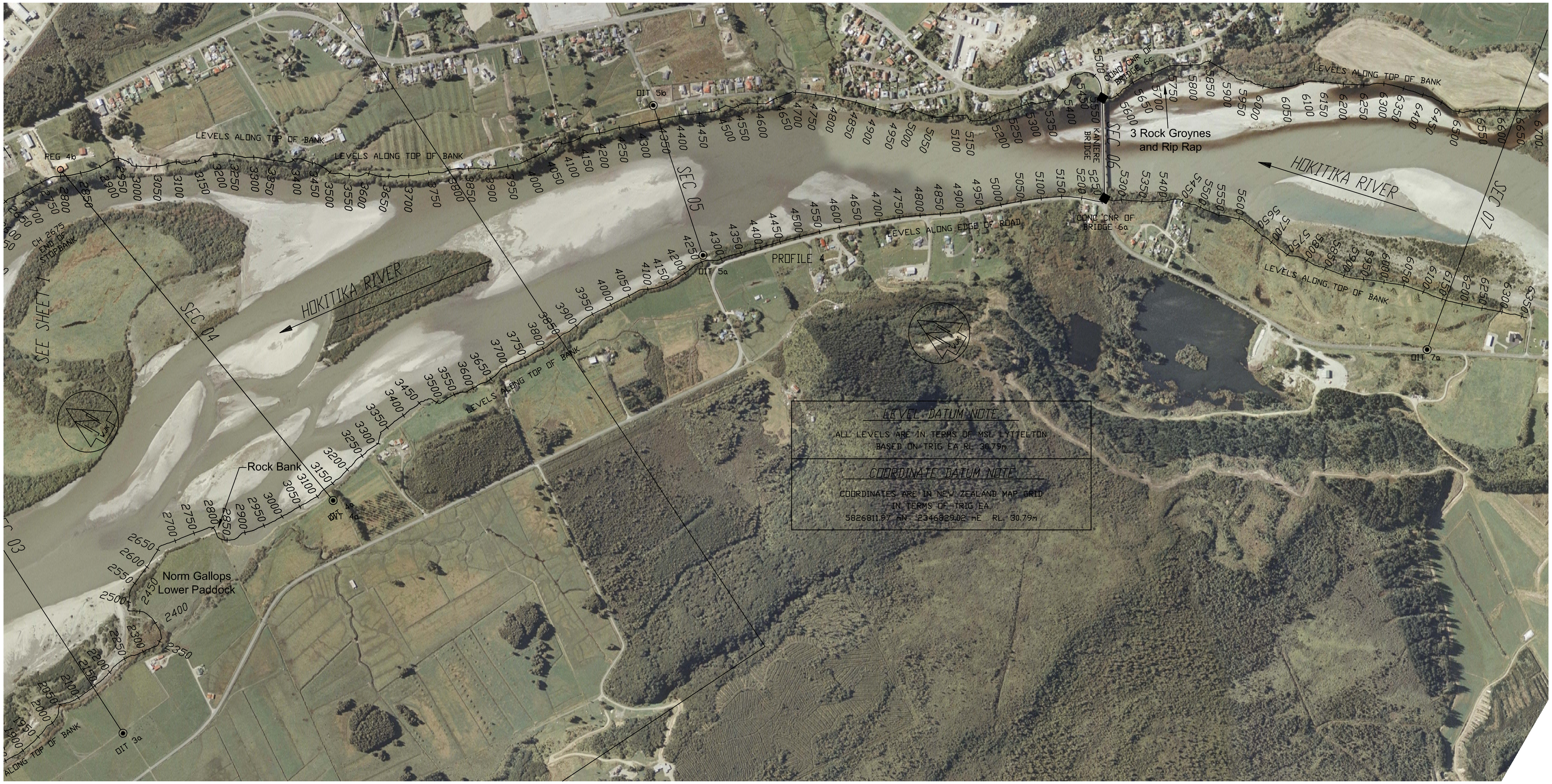
AERIAL PHOTOGRAPH

1

HOKITIKA RIVER RATING DISTRICT
STOPBANK CHAINAGE AND CROSS SECTIONS

June 2010

Scale 1:10 000



2

HOKITIKA RIVER RATING DISTRICT
STOPBANK CHAINAGE AND CROSS SECTIONS

June 2010

Scale 1:10 000

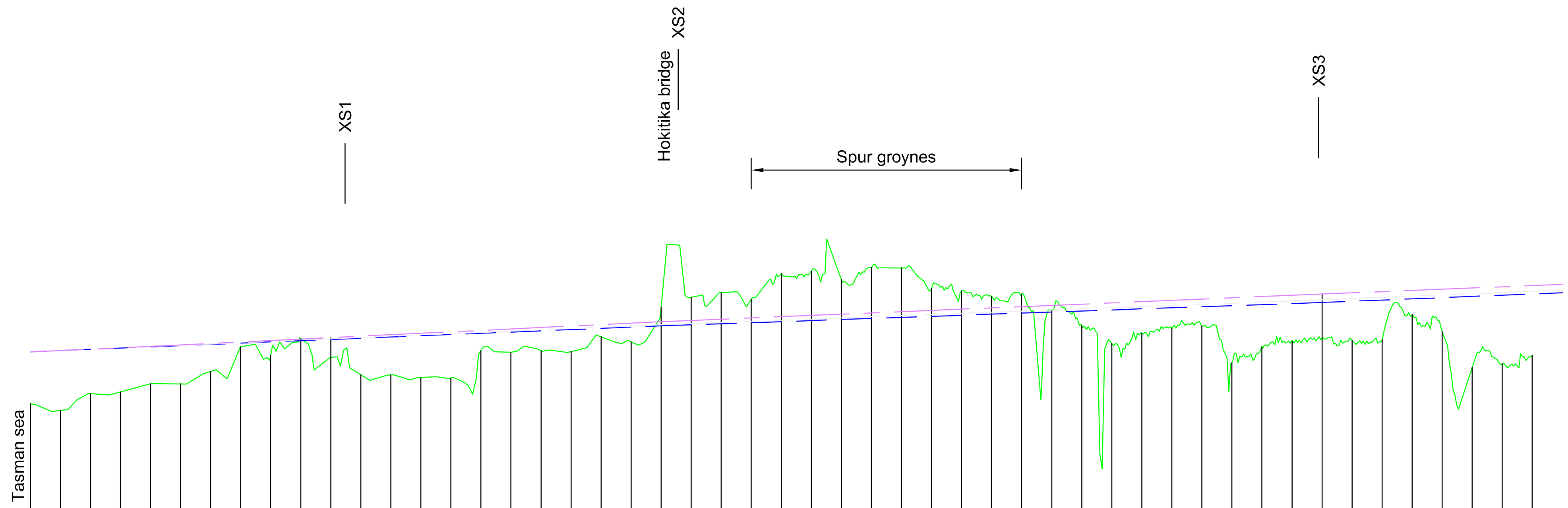
Appendix B

LONG SECTIONS AND MODELLED RIVER LEVELS

KEY:

- 400 Year Design Flood Level (5400 Cumecs + 900mm Freeboard)
- 100 Year Design Flood Level (4720 Cumecs + 900mm Freeboard)
- 50 Year Design Flood Level (4390 Cumecs + 900mm Freeboard)
- Bank height

Scale:
Horiz: 1:10,000
Vert: 1:200



Datum: -3.00

Chainage	Elevation	50 year design flood	100 year design flood	400 year design flood
0				
50	0.47			
100	1.02			
150	1.09			
200	1.36			
250	1.35			
300	1.76			
350	2.58			
400	2.30			
450	2.86			
500	2.24	2.83	2.85	2.89
550	1.66			
600	1.65			
650	1.56			
700	1.55			
750	2.46			
800	2.40			
850	2.46			
900	2.43			
950	2.92			
1000	2.75			
1050	3.91	3.28	3.32	3.42
1100	4.23			
1150	4.38			
1200	4.17			
1250	5.02			
1300	5.10			
1350	4.82			
1400	5.23			
1450	5.21			
1500	4.52			
1550	4.44			
1600	4.26			
1650	4.34			
1700	3.79			
1750	3.29			
1800	2.70			
1850	3.04			
1900	3.21			
1950	3.28			
2000	2.06			
2050	2.58			
2100	2.78			
2150	2.88	4.06	4.15	4.34
2200	2.80			
2250	2.83			
2300	3.66			
2350	3.10			
2400	1.90			
2450	2.02			
2500	2.30			

LEFT BANK LONG SECTION CHAINAGE 0.00 TO 2500.00

REV.	AMENDMENTS	BY.	APPD.	DATE.
1	For final report	DW		June 10

	NAME	DATE
DRAWN.	DW	June 10
DESIGNED.	DBW	June 10
CHECKED.	JM	June 10
APPROVED.		June 10

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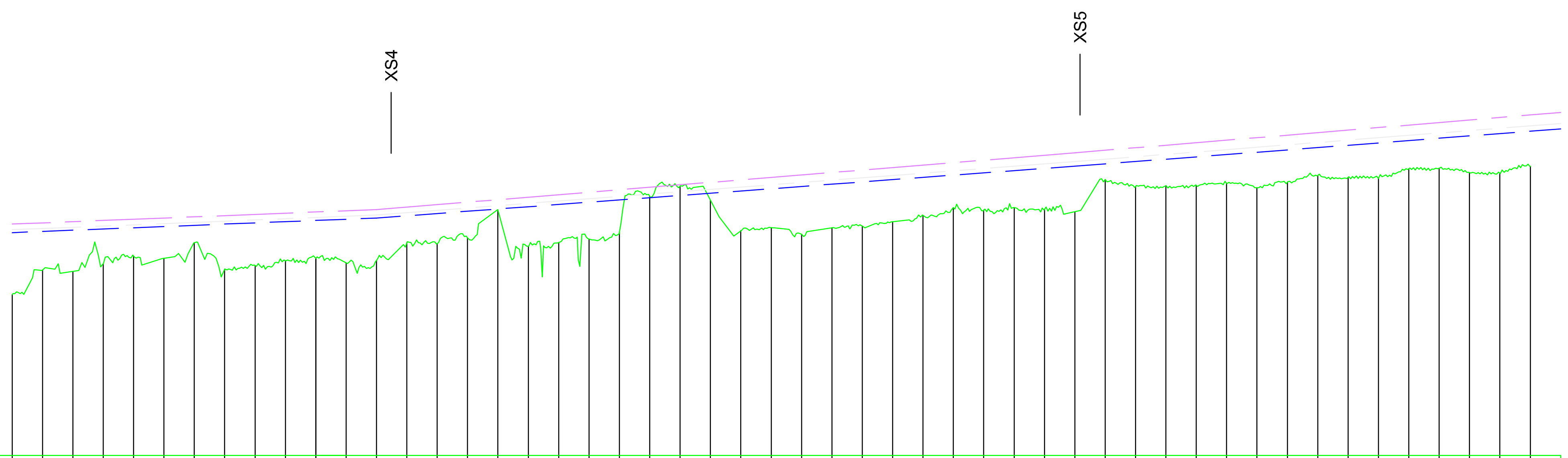
CLIENT: WEST COAST REGIONAL COUNCIL
PROJECT: HOKITIKA RIVER - DESIGN FLOOD LEVELS
TITLE: HOKITIKA RIVER
RATING DISTRICT STOPBANK
(TRUE LEFT BANK)

SCALE.	A1	-	ORIGINAL
	A3	AS SHOWN	A3
PROJECT		32007	DATE ISSUED
SHEET No		1	
REVISION No		1	June 10

KEY:

- 400 Year Design Flood Level (5400 Cumecs + 900mm Freeboard)
- 100 Year Design Flood Level (4720 Cumecs + 900mm Freeboard)
- 50 Year Design Flood Level (4390 Cumecs + 900mm Freeboard)
- Bank height



Scale:
Horiz: 1:10,000
Vert: 1:200

Datum: -3.00

Chainage	Elevation	50 year design flood	100 year design flood	400 year design flood
2500	2.30			
2550	3.11			
2600	3.06			
2650	3.31			
2700	3.57			
2750	3.49			
2800	4.00			
2850	3.14			
2900	3.26			
2950	3.41			
3000	3.49			
3050	3.34			
3100	3.42	4.82	4.92	5.10
3150	4.00			
3200	3.97			
3250	4.17			
3300	5.08			
3350	3.89			
3400	4.01			
3450	4.13			
3500	4.35			
3550	5.53			
3600	5.87			
3650	5.40			
3700	4.40			
3750	4.50			
3800	4.29			
3850	4.50			
3900	4.55			
3950	4.70			
4000	4.90			
4050	5.16			
4100	5.08			
4150	5.16			
4200	5.10			
4250	5.03	6.53	6.68	6.97
4300	6.09			
4350	5.86			
4400	5.88			
4450	5.90			
4500	5.97			
4550	5.82			
4600	6.00			
4650	6.21			
4700	6.16			
4750	6.13			
4800	6.44			
4850	6.46			
4900	6.32			
4950	6.30			
5000	6.52			

LEFT BANK LONG SECTION CHAINAGE 2500.00 TO 5000.00

REV.	AMENDMENTS	BY.	APPD.	DATE.
1	For final report	DW		June 10

	NAME	DATE
DRAWN.	DW	June 10
DESIGNED.	DBW	June 10
CHECKED.	JM	June 10
APPROVED.		June 10

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CLIENT: WEST COAST REGIONAL COUNCIL

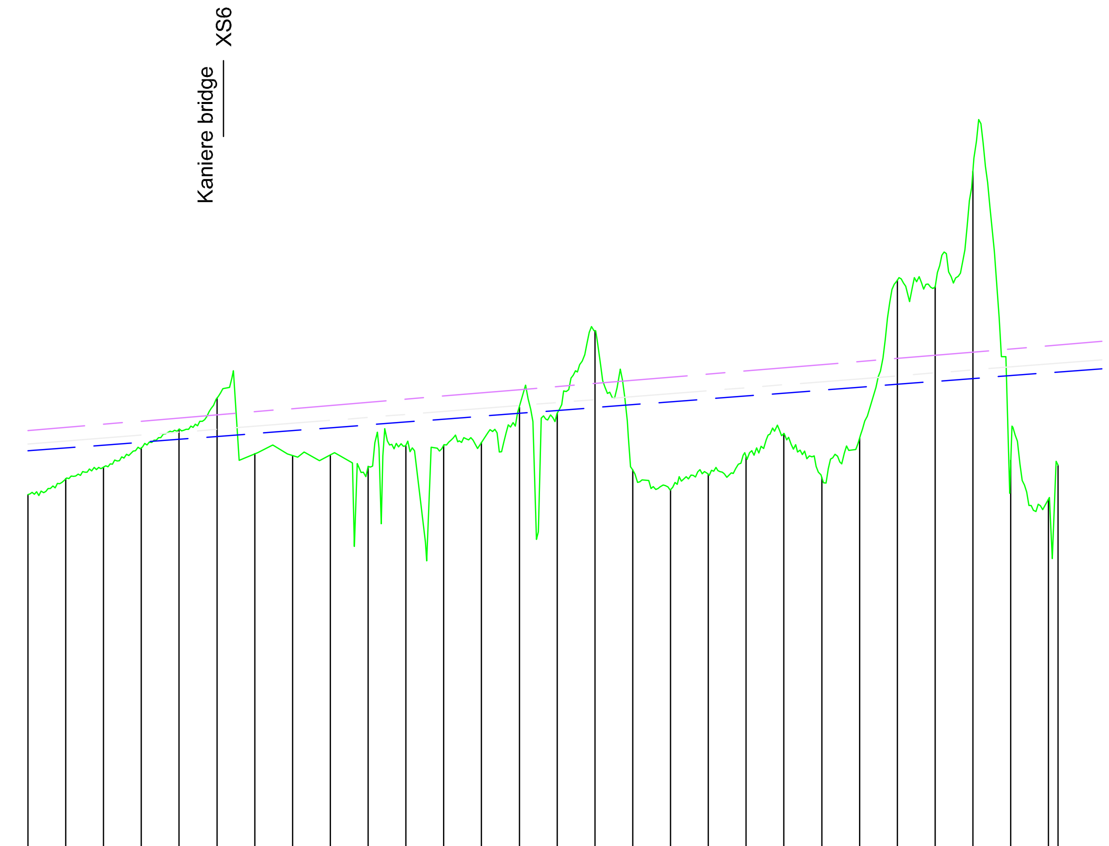
PROJECT: HOKITIKA RIVER - DESIGN FLOOD LEVELS

TITLE: HOKITIKA RIVER
RATING DISTRICT STOPBANK
(TRUE LEFT BANK)

SCALE.	A1	-	ORIGINAL
	A3	AS SHOWN	A3
PROJECT		32007	DATE ISSUED
SHEET No		2	
REVISION No		1	June 10

KEY:

- 400 Year Design Flood Level (5400 Cumecs + 900mm Freeboard)
- 100 Year Design Flood Level (4720 Cumecs + 900mm Freeboard)
- 50 Year Design Flood Level (4390 Cumecs + 900mm Freeboard)
- Bank height



Scale:
Horiz: 1:10,000
Vert: 1:200

Datum: -3.00

Chainage	Elevation	400 year design flood	100 year design flood	50 year design flood
5000	6.52			
5050	6.94			
5100	7.25			
5150	7.76			
5200	8.25			
5250	9.08	8.63	8.25	8.06
5300	7.60			
5350	7.55			
5400	7.58			
5450	7.27			
5500	7.83			
5550	7.83			
5600	7.90			
5650	8.84			
5700	8.67			
5750	10.86			
5800	7.18			
5850	6.65			
5900	7.06			
5950	7.53			
6000	8.13			
6050	6.97			
6100	8.01			
6150	12.19			
6200	12.02			
6250	15.07			
6300	7.43			
6350	6.40			
6362	7.30			

LEFT BANK LONG SECTION CHAINAGE 5000.00 TO 6326.81

REV.	AMENDMENTS	BY.	APPD.	DATE.
1	For final report	DW		June 10

	NAME	DATE
DRAWN.	DW	June 10
DESIGNED.	DBW	June 10
CHECKED.	JM	June 10
APPROVED.		June 10

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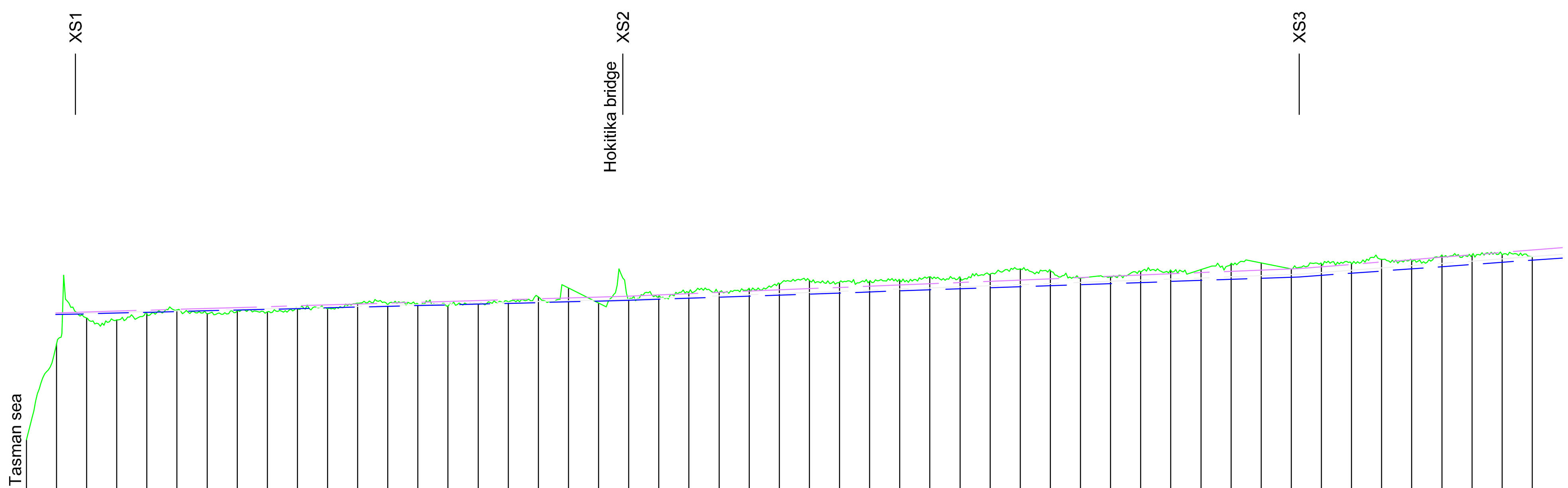
CLIENT: WEST COAST REGIONAL COUNCIL
PROJECT: HOKITIKA RIVER - DESIGN FLOOD LEVELS
TITLE: HOKITIKA RIVER
RATING DISTRICT STOPBANK
(TRUE LEFT BANK)

SCALE.	A1	-	ORIGINAL
	A3	AS SHOWN	A3
PROJECT		32007	DATE ISSUED
SHEET No		3	
REVISION No		1	June 10

KEY:

- 400 Year Design Flood Level (5400 Cumecs + 900mm Freeboard)
- 100 Year Design Flood Level (4720 Cumecs + 900mm Freeboard)
- 50 Year Design Flood Level (4390 Cumecs + 900mm Freeboard)
- Bank height



Scale:
Horiz: 1:10,000
Vert: 1:200

Datum: -3.00

Chainage	Elevation	50 year design flood	100 year design flood	400 year design flood
0	-1.34			
50	1.85	2.83	2.85	2.89
100	2.70			
150	2.64			
200	2.85			
250	2.97			
300	2.85			
350	2.94			
400	2.91			
450	3.01			
500	3.01			
550	3.19			
600	3.14			
650	3.16			
700	3.10			
750	3.16			
800	3.24			
850	3.40			
900	3.69			
950	3.20	3.28	3.32	3.42
1000	3.31			
1050	3.42			
1100	3.56			
1150	3.55			
1200	3.68			
1250	3.84			
1300	3.95			
1350	3.90			
1400	3.93			
1450	3.96			
1500	4.07			
1550	4.05			
1600	4.16			
1650	4.34			
1700	4.28			
1750	4.02			
1800	4.07			
1850	4.24			
1900	4.28			
1950	4.31			
2000	4.51			
2050	4.53			
2100	4.33	4.06	4.15	4.34
2150	4.51			
2200	4.51			
2250	4.65			
2300	4.61			
2350	4.79			
2400	4.78			
2450	4.80			
2500	4.72			

RIGHT BANK LONG SECTION CHAINAGE 0.00 TO 2500.00

REV.	AMENDMENTS	BY.	APPD.	DATE.
1	For final report	DW		June 10

	NAME	DATE
DRAWN.	DW	June 10
DESIGNED.	DBW	June 10
CHECKED.	JM	June 10
APPROVED.		June 10

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Consulting

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CLIENT: WEST COAST REGIONAL COUNCIL

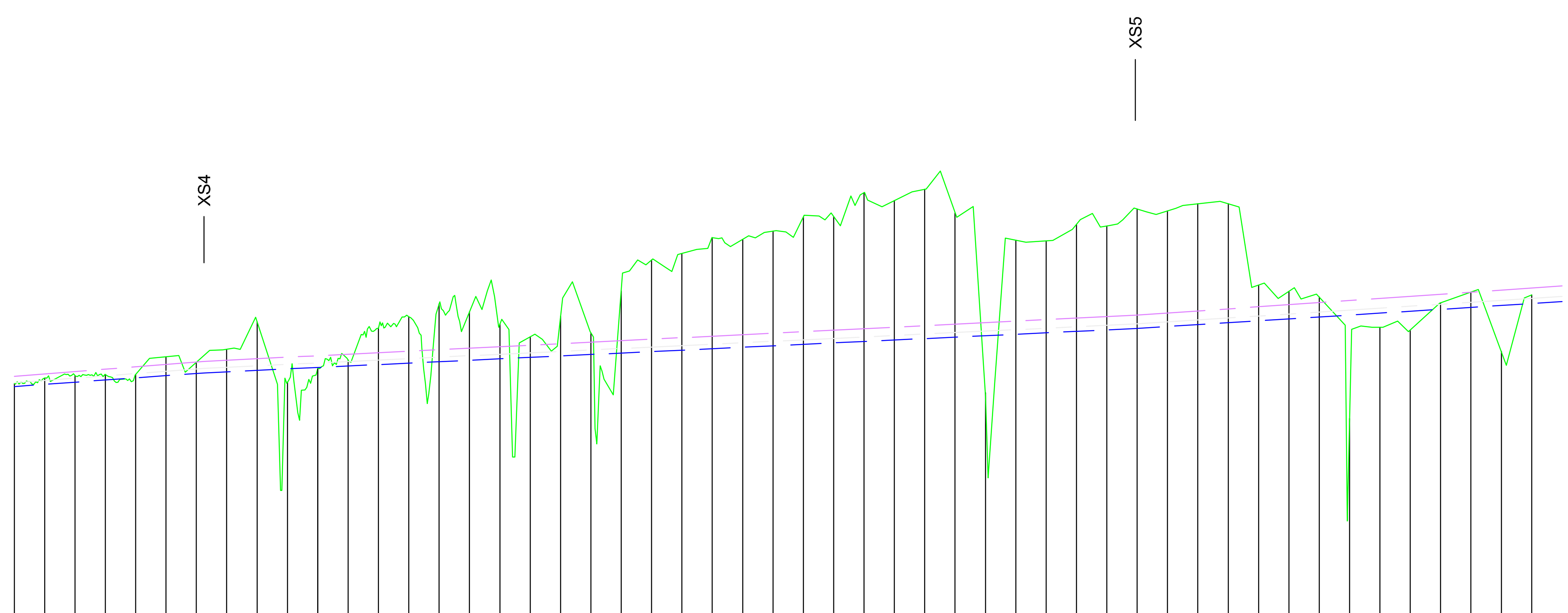
PROJECT: HOKITIKA RIVER - DESIGN FLOOD LEVELS

TITLE: HOKITIKA RIVER
RATING DISTRICT STOPBANK
(TRUE RIGHT BANK)

SCALE.	A1	-	ORIGINAL
	A3	AS SHOWN	A3
PROJECT		32007	DATE ISSUED
SHEET No		4	
REVISION No		1	June 10

KEY:

- 400 Year Design Flood Level (5400 Cumecs + 900mm Freeboard)
- 100 Year Design Flood Level (4720 Cumecs + 900mm Freeboard)
- 50 Year Design Flood Level (4390 Cumecs + 900mm Freeboard)
- Bank height



Scale:
Horiz: 1:10,000
Vert: 1:200

Datum: -3.00

Chainage	2500	2550	2600	2650	2700	2750	2800	2850	2900	2950	3000	3050	3100
400 year design flood							5.45						
100 year design flood							5.22						
50 year design flood							5.07						
Elevation	4.72	4.90	4.98	5.01	5.02	5.60	5.42	5.85	6.75	4.76	5.22	5.50	6.55

Chainage	3150	3200	3250	3300	3350	3400	3450	3500	3550	3600	3650	3700	3750
400 year design flood													
100 year design flood													
50 year design flood													
Elevation	6.92	7.34	7.08	6.68	6.26	6.93	6.39	7.77	8.79	9.01	9.52	9.47	9.74

Chainage	3800	3850	3900	3950	4000	4050	4100	4150	4200	4250	4300	4350	4400
400 year design flood												6.97	
100 year design flood												6.68	
50 year design flood												6.53	
Elevation	10.20	10.22	11.01	10.75	11.12	10.34	4.41	9.45	9.42	9.97	9.91	10.47	10.41

Chainage	4450	4500	4550	4600	4650	4700	4750	4800	4850	4900	4950	5000
400 year design flood												
100 year design flood												
50 year design flood												
Elevation	10.64	10.64	7.97	7.76	7.57	3.57	6.57	6.48	7.38	7.73	5.77	7.64

RIGHT BANK LONG SECTION CHAINAGE 2500.00 TO 5000.00

REV.	AMENDMENTS	BY.	APPD.	DATE.
1	For final report	DW		June 10

	NAME	DATE
DRAWN.	DW	June 10
DESIGNED.	DBW	June 10
CHECKED.	JM	June 10
APPROVED.		June 10

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CLIENT: WEST COAST REGIONAL COUNCIL

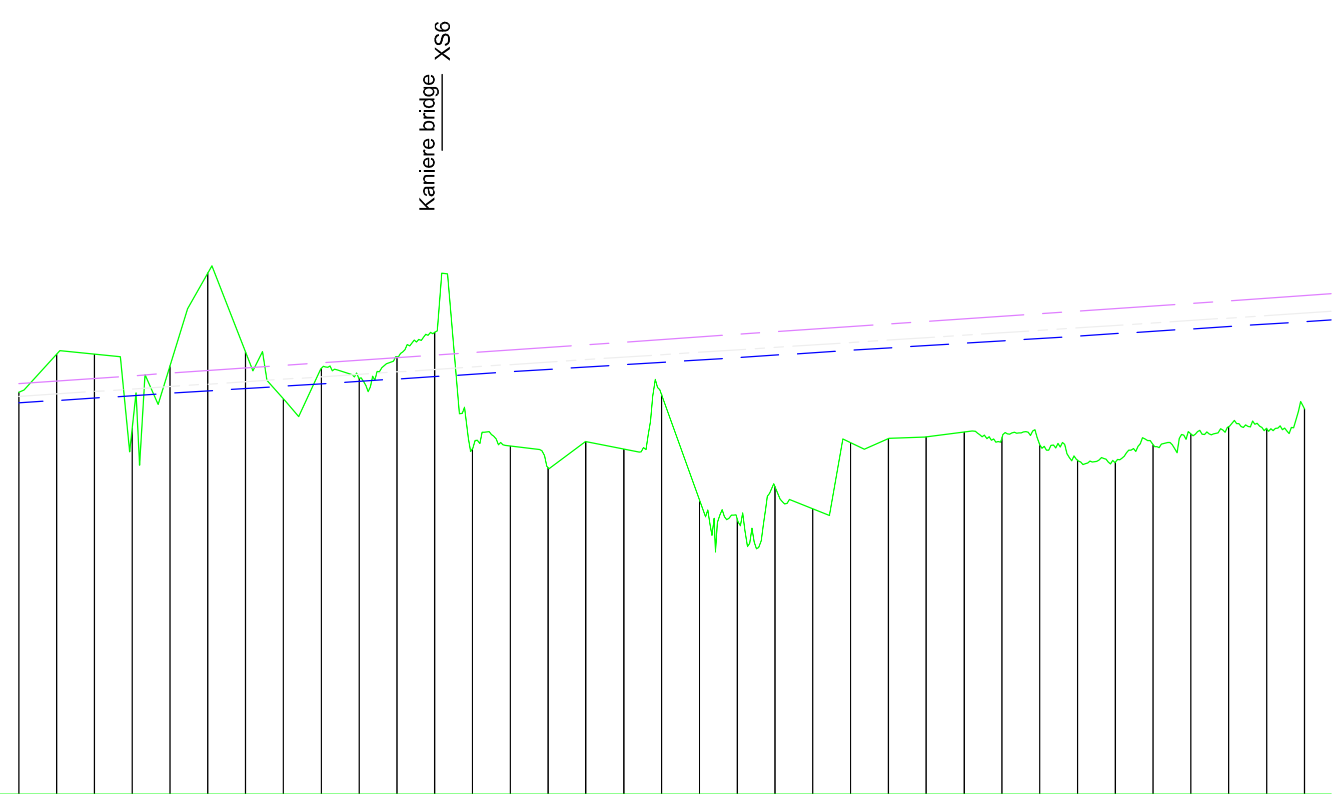
PROJECT: HOKITIKA RIVER - DESIGN FLOOD LEVELS

TITLE: HOKITIKA RIVER
RATING DISTRICT STOPBANK
(TRUE RIGHT BANK)

SCALE.	A1	-	ORIGINAL
	A3	AS SHOWN	A3
PROJECT		32007	DATE ISSUED
SHEET No		5	
REVISION No		1	June 10

KEY:

- 400 Year Design Flood Level (5400 Cumecs + 900mm Freeboard)
- 100 Year Design Flood Level (4720 Cumecs + 900mm Freeboard)
- 50 Year Design Flood Level (4390 Cumecs + 900mm Freeboard)
- Bank height



Scale:
Horiz: 1:10,000
Vert: 1:200

Datum: -3.00

Chainage	Elevation	50 year design flood	100 year design flood	400 year design flood
5000	7.64			
5050	8.64			
5100	8.64			
5150	6.68			
5200	8.33			
5250	10.79			
5300	8.70			
5350	7.46			
5400	8.26			
5450	8.00			
5500	8.57			
5550	9.22	8.06	8.25	8.63
5600	6.14			
5650	6.21			
5700	5.64			
5750	6.33			
5800	6.13			
5850	7.58			
5900	4.80			
5950	4.28			
6000	5.14			
6050	4.55			
6100	6.30			
6150	6.40			
6200	6.46			
6250	6.58			
6300	6.43			
6350	6.25			
6400	5.84			
6450	5.78			
6500	6.24			
6550	6.53			
6600	6.72			
6650	6.67			
6700	7.20			

RIGHT BANK LONG SECTION CHAINAGE 5000.00 TO 6700.00

REV.	AMENDMENTS	BY.	APPD.	DATE.
1	For final report	DW		June 10

	NAME	DATE
DRAWN.	DW	June 10
DESIGNED.	DBW	June 10
CHECKED.	JM	June 10
APPROVED.		June 10

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CLIENT: WEST COAST REGIONAL COUNCIL

PROJECT: HOKITIKA RIVER - DESIGN FLOOD LEVELS

TITLE: HOKITIKA RIVER
RATING DISTRICT STOPBANK
(TRUE RIGHT BANK)

SCALE. A1	-	ORIGINAL
SCALE. A3	AS SHOWN	A3
PROJECT	32007	DATE ISSUED
SHEET No	6	
REVISION No	1	June 10

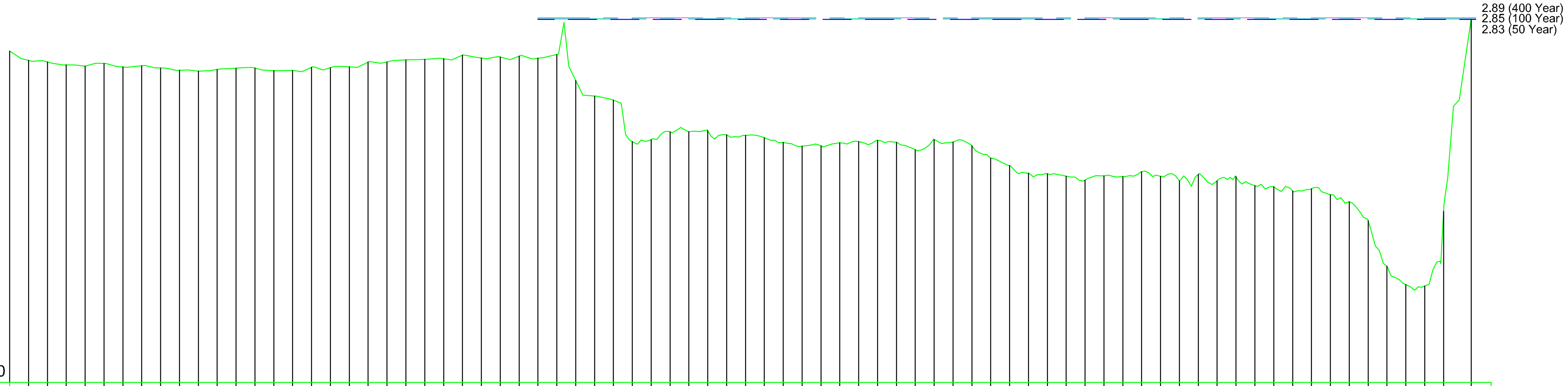
Appendix C

CROSS SECTIONS AND MODELLED RIVER LEVELS

KEY:
400 Year Design Flood Level
100 Year Design Flood Level
50 Year Design Flood Level
Bank height

Horizontal Scale 1 : 1500
Vertical Scale 1 : 100

Section 01 2010



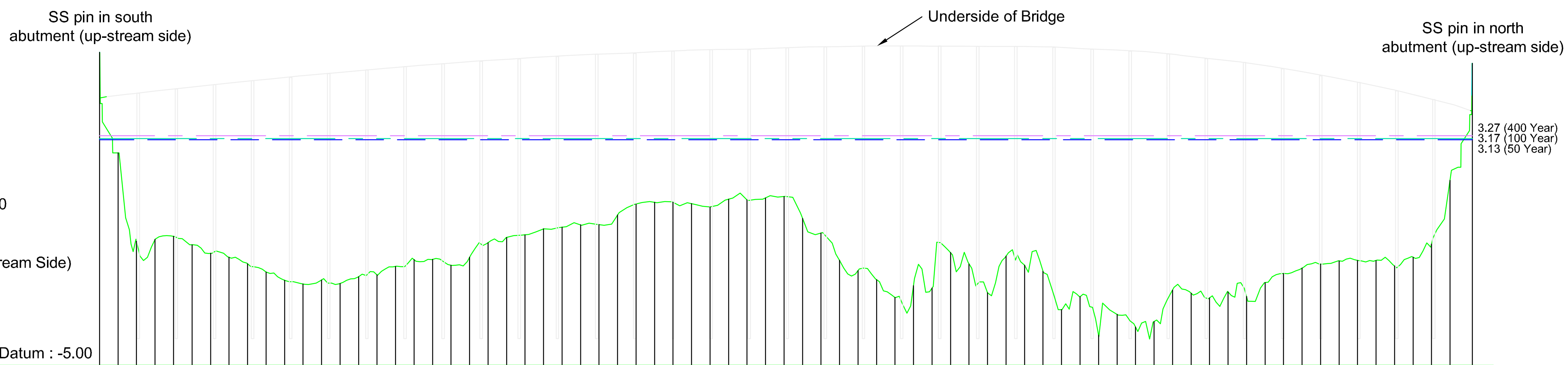
Datum: -10.00

Chainage	Section 1 2010 Elevation
0	1.71
10	1.38
20	1.32
30	1.22
40	1.18
50	1.27
60	1.15
70	1.19
80	1.11
90	1.03
100	1.00
110	1.06
120	1.10
130	1.11
140	1.02
150	1.03
160	1.13
170	1.12
180	1.15
190	1.32
200	1.33
210	1.40
220	1.42
230	1.44
240	1.57
250	1.47
260	1.50
270	1.53
280	1.46
290	1.59
300	0.67
310	0.12
320	-0.03
330	-1.49
340	-1.42
350	-1.14
360	-1.14
370	-1.10
380	-1.25
390	-1.27
400	-1.35
410	-1.51
420	-1.65
430	-1.64
440	-1.53
450	-1.49
460	-1.44
470	-1.51
480	-1.77
490	-1.42
500	-1.50
510	-1.63
520	-2.07
530	-2.34
540	-2.61
550	-2.62
560	-2.71
570	-2.85
580	-2.70
590	-2.72
600	-2.55
610	-2.71
620	-2.88
630	-2.65
640	-2.87
650	-2.73
660	-3.04
670	-3.08
680	-3.23
690	-3.16
700	-3.37
710	-3.62
720	-4.28
730	-5.89
740	-6.54
750	-6.59
760	-3.96
774	2.85

CROSS SECTION ONE

Horizontal Scale 1 : 1500
Vertical Scale 1 : 100

Section 02 2010 (Up-Stream Side)



Datum : -5.00

Chainage	Section 2 2010 Elevation
0	6.28
10	2.65
20	-0.53
30	-0.47
40	-0.35
50	-0.65
60	-0.96
70	-1.11
80	-1.34
90	-1.63
100	-1.94
110	-2.07
120	-1.93
130	-2.05
140	-1.81
150	-1.74
160	-1.43
170	-1.19
180	-1.18
190	-1.39
200	-1.11
210	-0.58
220	-0.39
230	-0.30
240	-0.08
250	-0.02
260	0.06
270	0.07
280	0.42
290	0.81
300	0.87
310	0.88
320	0.83
330	0.71
340	0.99
350	0.96
360	1.03
370	1.08
380	0.29
390	-0.23
400	-1.22
410	-1.59
420	-1.91
430	-2.56
440	-2.13
450	-2.21
460	-0.94
470	-1.35
480	-2.39
490	-1.07
500	-1.39
510	-1.62
520	-2.99
530	-2.53
540	-3.91
550	-3.16
560	-3.62
570	-3.42
580	-2.29
590	-2.40
600	-2.57
610	-2.35
620	-2.52
630	-2.02
640	-1.69
650	-1.50
660	-1.35
670	-1.24
680	-1.22
690	-1.22
700	-1.42
710	-1.11
720	-0.63
730	1.66
742	5.88

CROSS SECTION TWO

REV.	AMENDMENTS	BY.	APPD.	DATE.
1	For final report	MRB	DJB	June 10

	NAME	DATE
DRAWN.	MRB	June 10
DESIGNED.	DBW	June 10
CHECKED.	JM	June 10
APPROVED.	DJB	June 10

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CLIENT: WEST COAST REGIONAL COUNCIL

PROJECT: HOKITIKA RIVER - DESIGN FLOOD LEVELS

TITLE: HOKITIKA RIVER
RATING DISTRICT STOPBANK
CROSS SECTIONS

SCALE. A1	-	ORIGINAL
SCALE. A3	AS SHOWN	A3
PROJECT	32007	DATE ISSUED
SHEET No	7	
REVISION No	1	June 10

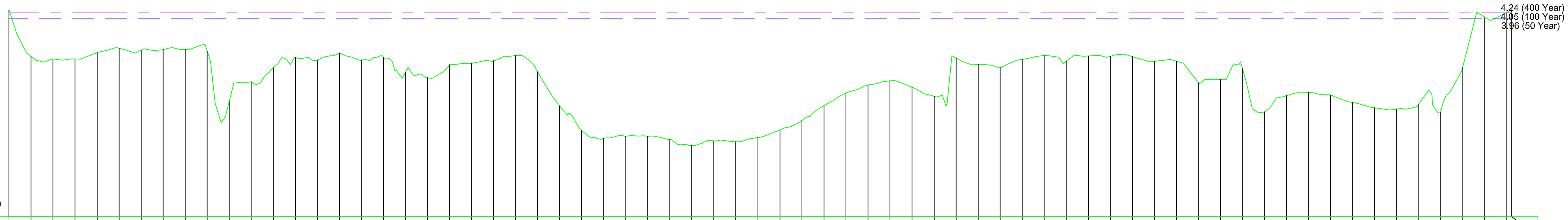
KEY:

- 400 Year Design Flood Level
- 100 Year Design Flood Level
- 50 Year Design Flood Level
- Bank height

Horizontal Scale 1 : 1500
Vertical Scale 1 : 100

Section 03 2010

Datum: -5.00



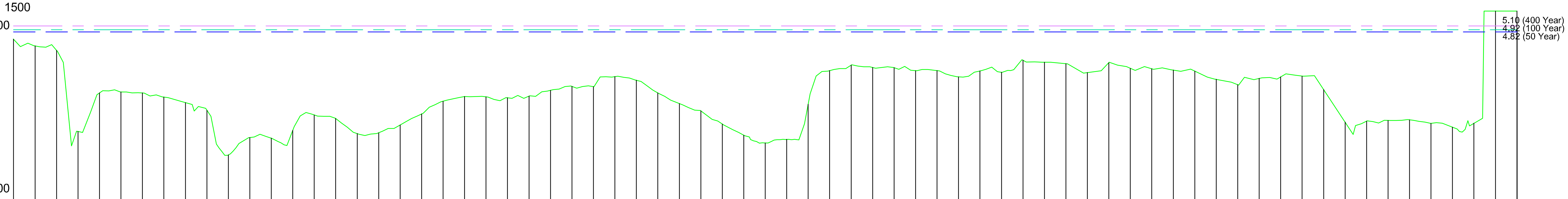
Chainage	Section 3 2010 Elevation
0	4.38
15	2.26
30	2.14
45	2.15
60	2.44
75	2.64
90	2.55
105	2.58
120	2.58
135	2.51
150	0.24
165	1.11
180	1.75
195	2.21
210	2.09
225	2.41
240	2.09
255	2.23
270	1.54
285	1.29
300	1.88
315	1.95
330	2.06
345	2.31
360	1.56
375	0.02
390	-1.10
405	-1.45
420	-1.35
435	-1.35
450	-1.51
465	-1.78
480	-1.57
495	-1.60
510	-1.42
525	-1.07
540	-0.64
555	0.03
570	0.61
585	0.96
600	1.16
615	0.87
630	0.45
645	2.19
660	1.90
675	1.75
690	2.13
705	2.30
720	2.05
735	2.28
750	2.27
765	2.25
780	2.04
795	2.05
810	1.07
825	1.22
840	1.71
855	-0.25
870	0.49
885	0.63
900	0.51
915	0.18
930	-0.07
945	-0.12
960	0.10
975	-0.26
990	1.78
1005	4.05
1020	4.26
1023	4.37

CROSS SECTION THREE

Horizontal Scale 1 : 1500
Vertical Scale 1 : 100

Section 04 2010

Datum: -3.00



Chainage	Section 4 2010 Elevation
0.00	4.49
15.00	4.17
30.00	3.97
45.00	0.18
60.00	1.96
75.00	2.02
90.00	1.97
105.00	1.78
120.00	1.52
135.00	1.18
150.00	-0.93
165.00	-0.11
180.00	-0.13
195.00	0.19
210.00	0.95
225.00	0.79
240.00	0.08
255.00	0.11
270.00	0.47
285.00	0.99
300.00	1.58
315.00	1.80
330.00	1.79
345.00	1.75
360.00	1.82
375.00	2.09
390.00	2.29
405.00	2.26
420.00	2.73
435.00	2.57
450.00	1.98
465.00	1.48
480.00	1.14
495.00	0.53
510.00	0.01
525.00	-0.36
540.00	-0.20
555.00	1.37
570.00	3.01
585.00	3.26
600.00	3.16
615.00	3.16
630.00	3.01
645.00	3.01
660.00	2.72
675.00	2.99
690.00	2.94
705.00	3.50
720.00	3.40
735.00	3.34
750.00	2.92
765.00	3.37
780.00	3.13
795.00	3.10
810.00	3.04
825.00	3.00
840.00	2.61
855.00	2.36
870.00	2.65
885.00	2.71
900.00	2.76
915.00	2.15
930.00	0.63
945.00	0.65
960.00	0.69
975.00	0.72
990.00	0.55
1005.00	0.38
1020.00	0.55
1035.00	5.79
1050.00	5.79
1050.20	5.79

CROSS SECTION FOUR

REV.	AMENDMENTS	BY.	APPD.	DATE.
1	For final report	MRB	DJB	June 10

	NAME	DATE
DRAWN.	MRB	June 10
DESIGNED.	DBW	June 10
CHECKED.	JM	June 10
APPROVED.	DJB	June 10

GOOD EARTH MATTERS
Consulting

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CLIENT: WEST COAST REGIONAL COUNCIL

PROJECT: HOKITIKA RIVER - DESIGN FLOOD LEVELS

TITLE: HOKITIKA RIVER
RATING DISTRICT STOPBANK
CROSS SECTIONS

SCALE.	A1	-	ORIGINAL
	A3	AS SHOWN	A3
PROJECT		32007	DATE ISSUED
SHEET No		8	
REVISION No		1	June 10

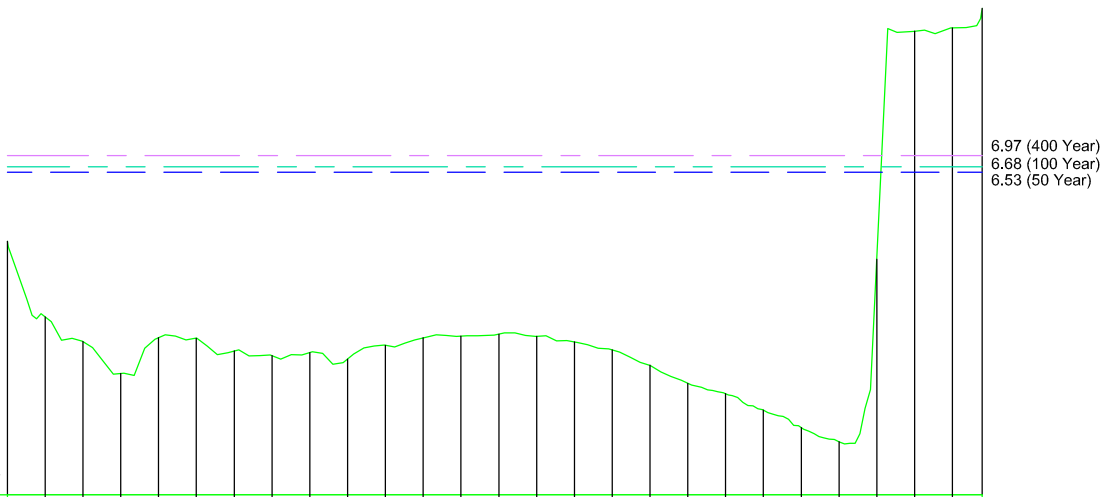
KEY:

- 400 Year Design Flood Level
- 100 Year Design Flood Level
- 50 Year Design Flood Level
- Bank height

Horizontal Scale 1 : 1500
Vertical Scale 1 : 100

Section 05 2010

Datum: -2.00



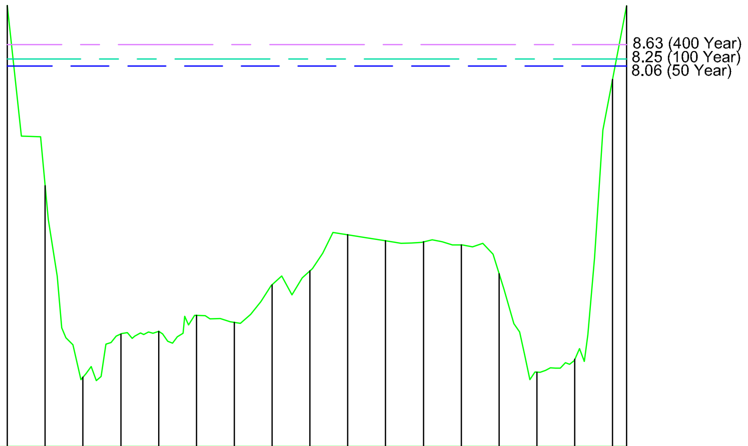
Section 5 2010 Elevation	4.70	2.70	2.05	1.21	2.16	2.14	1.80	1.68	1.76	1.59	1.95	2.15	2.19	2.25	2.19	2.04	1.83	1.43	0.95	0.67	0.24	-0.22	-0.60	4.23	10.26	10.35
Chainage	0.00	15.00	30.00	45.00	60.00	75.00	90.00	105.00	120.00	135.00	150.00	165.00	180.00	195.00	210.00	225.00	240.00	255.00	270.00	285.00	300.00	315.00	330.00	345.00	360.00	375.00

CROSS SECTION FIVE

Horizontal Scale 1 : 1500
Vertical Scale 1 : 100

Section 06 2010

Datum: -2.00



Section 6 2010 Elevation	9.66	4.90	-0.17	0.97	1.04	1.47	1.28	2.27	2.64	3.60	3.44	3.41	3.33	2.57	-0.04	0.30	7.70
Chainage	0.00	15.00	30.00	45.00	60.00	75.00	90.00	105.00	120.00	135.00	150.00	165.00	180.00	195.00	210.00	225.00	240.00

CROSS SECTION SIX

REV.	AMENDMENTS	BY.	APPD.	DATE.
1	For final report	MRB	DJB	June 10

	NAME	DATE
DRAWN.	MRB	June 10
DESIGNED.	DBW	June 10
CHECKED.	JM	June 10
APPROVED.	DJB	June 10

GOOD EARTH MATTERS
Consulting

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CLIENT: WEST COAST REGIONAL COUNCIL

PROJECT: HOKITIKA RIVER - DESIGN FLOOD LEVELS

TITLE: HOKITIKA RIVER
RATING DISTRICT STOPBANK
CROSS SECTIONS

SCALE.	A1	-	ORIGINAL
	A3	AS SHOWN	A3
PROJECT		32007	DATE ISSUED
SHEET No		9	
REVISION No		1	June 10