Design of a Cross-Section Network for Low-Cost Monitoring of Gravel Extraction Impacts, Nelson City

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Summary

Project and Client

Nelson City Council requested Landcare Research to design a practical, low-cost method for monitoring bed-level trends in Nelson rivers. The work was carried out between April and June 2007.

Objectives

- Develop a low-cost method for surveying river cross sections and implement it in two local rivers (Wakapuaka and Whangamoa)

Methods

The location of cross-sections was determined from river morphology, historical gravel extraction, and location of gravel beaches. Cross sections were surveyed by stretching a tape across the river between benchmarks to measure distance, and recording elevation by levelling. All distances were recorded relative to the left-bank benchmark, and all levels relative to the ground at the right-bank benchmark. The position of all benchmarks was recorded using a GPS to allow accurate re-location of the cross-sections if the benchmarks are lost. At each cross-section photographs were taken looking across the cross-section, and looking upstream and downstream from the cross-section.

Results

In the Wakapuaka River 22 cross-sections were established between the coast and Hira, and in the Whangamoa River 10 cross-sections were established between the coast and State Highway 6. Cross-sections were numbered consecutively upstream from the coast. In the Wakapuaka River the distance between cross-sections ranged from 100 to 820 m, with an average of 305 m, and active channel widths ranged from 12 to 83 m. In the Whangamoa River the distance between cross-sections ranged from 260 to 905 m, with an average of 570 m, and active channel widths ranged from 18 to 48 m. The tape-and-level survey has provided baseline data which can be used to monitor future changes in bed levels, both in areas where gravel typically accumulates and in areas where gravel does not appear to deposit. Distances and levels were accurate to ±0.02–0.05 m. It is estimated that the 32 cross-sections could be surveyed in 5 days in future.

Conclusions

The tape-and-level survey is an efficient, cost-effective method for monitoring changes in bed levels on small rivers. The survey has provided quantitative baseline data to calculate future bed-level change.

Recommendations

- The rivers should be surveyed annually or after significant flood events.
- Surveys should be carried out when the wind is not blowing strongly and when the willow trees have lost their leaves.
- NCC needs to accurately record the location and amount of gravel extracted from the river while the bed-level monitoring is undertaken to allow assessment of the relationship between bed-level trends and gravel extraction.

- The cross-section data should not be used to provide information on gravel volumes stored in the river.
- NCC should consider whether more permanent benchmarks are needed.

1. Introduction

Nelson City Council (NCC) controls the amounts of gravel extracted from local rivers and requires an assessment of environmental effects as part of the resource consent process. One of the major potential effects from overextraction is bed-level degradation and consequent effects on bed and bank stability. Conversely, underextraction can lead to aggradation and loss of flood carrying capacity. Determining the appropriate amount of gravel extraction is most commonly guided by information on bed-level trends. Currently NCC undertakes no quantitative bed-level monitoring in any of the local rivers and relies on expert judgement to assess how much gravel can be extracted. NCC are concerned that resource consents are issued for gravel extraction without an adequate understanding of the available gravel resource. In addition, there is uncertainty about the amounts of gravel being extracted.

Following a previous Envirolink project for NCC (Basher 2006a) that recommended NCC establish a system for investigating bed-level trends Landcare Research was requested to design a practical, low-cost method for monitoring bed-level trends. The work was carried out between April and June 2007 under an Envirolink grant.

2. Background

Many regional councils maintain river-cross-section monitoring networks. Most were intially established for flood management purposes and the bed level monitoring was primarily aimed at ensuring long-term maintenance of flood carrying capacity (Basher 2006b). These same networks have been used to calculate changes in gravel volumes stored in river beds and help guide decisions about (usually) annual volumes of gravel extraction that are allowed through the resource consent process. River-cross-section monitoring networks are the most widely used method for determining bed-level trends, although increasingly councils are looking towards more sophisticated methods such as GPS and LIDAR surveys.

Most of the cross-section networks have been established on large rivers (e.g. Motueka, Takaka, Waimea, Wairau, Waimakariri), have permanently located benchmarks, surveys are tied in to local datum levels, and are carried out by contracted surveyors at regular intervals. Such networks tend to be expensive to maintain and survey, and are beyond the resources or needs of NCC.

The Nelson rivers where extraction occurs tend to be relatively small and have a very simple morphology. Basher (2006a) suggested surveyed cross-sections would be easy to establish on these rivers, and that NCC should consider either establishing a cross-section network or permanently located sites where regular (at least annual) visual inspection was made and ground-based photographs taken. Following further discussion with NCC staff (Paul Sheldon, Reuben Peterson) it was decided to proceed with a low-cost cross-section network following the methodology outlined in Harrelson et al. (1994).

3. Objective

- Develop a low-cost method for surveying river cross-sections and implement it in two local rivers (Wakapuaka and Whangamoa).

4. Methods

The length of river to be surveyed was defined by considering historical gravel extraction, river morphology, and location of current beaches with gravel likely to be considered for extraction in the near future (Stocker 2002). The locations of cross-sections were designed to encompass areas potentially likely to be subject to both aggradation and degradation, and to cover the Wakapuaka as far upstream as Hira and the Whangamoa to State Highway 6. Within the defined river reach, cross-sections were sited in both:

- areas where aggradation appears to have occurred (wide channel with low channel banks, gravel beaches present),
- long straight reaches with an incised channel where there is no current evidence of gravel deposition.

More cross-sections were established in the Wakapuaka River than the Whangamoa River because there were more gravel beaches and more pressure for gravel extraction (both historically and currently).

At each site builders pegs were used to establish benchmarks on both banks of the river and to align the cross-sections perpendicular to the river channel. In a few cases it was not possible to establish benchmarks on both banks so two benchmarks were established on one bank to ensure the same cross-section alignment in future surveys. The position of all benchmarks was recorded using a GPS, with horizontal location accurate to ±<1 m. Wherever possible the location of more permanent features (usually fence posts) was also recorded by GPS, and the elevation of these features recorded by levelling. This should allow relatively accurate re-location of the cross-sections if the benchmarks are lost.

A tape was stretched horizontally between the benchmarks and used to record distance across the stream channel. Because the tape was sometimes up to 4 m above the stream bed all distances are only accurate to within ±0.05 m. However, in most cases they would be accurate to within ±0.02 m. All distances were subsequently corrected to distance from the true left bank (i.e. left looking downstream). Vertical height was recorded by levelling using a Leica NA824 level, with heights read to ±0.001 m. Because of the roughness of the river bed heights are also probably accurate to ±0.02–0.05 m. Elevations at each cross-section were subsequently corrected to relative level with respect to the height of the ground surface at the right benchmark, defined as zero[1]. Level readings were irregularly spaced across the channel, with enough points to adequately establish the cross-section shape. At each cross-section photographs were taken looking across the cross-section and looking upstream and

[1] Note that all levels are relative (RL) and not absolute. RLs cannot be compared between cross-sections and for future comparison each cross-section will have to be corrected to the same equivalent RL for the ground surface at the right benchmark (i.e. 0).

downstream from the cross-section, to provide a permanent record of the morphology of the cross-sections. Relative levels from the cross-section surveys were used to calculate a mean bed level (MBL) with respect to the right bank benchmark in the active channel.

5. Results

In the Wakapuaka River between the coast and Hira 22 cross-sections were established, and in the Whangamoa River between the coast and State Highway 6 ten cross-sections were established. Cross-sections are numbered consecutively from the coast upstream[2]. Benchmark locations are compiled in Appendix 1 and the cross-section data in Appendix 2. Plots of the cross-sections are shown in Figs 1–5.

The rivers generally have a narrow, single thread meandering channel with channel banks ranging from < 1 m up to 5 m high. Gravel beaches are common, particularly on the meander bends, but only comprise a small fraction of the length of the river and are usually associated with low channel banks. They tend to be small features with lengths <100 m and widths <30 m. Local farmers suggest the location of the beaches remains constant and that they re-form in the same places following gravel extraction by beach skimming. Typically the bed and the beaches comprise pebbles and cobbles. Bouldery bars and beaches occur rarely within the channel.

In the Wakapuaka River the distance between cross-sections ranged from 100 to 820 m, with an average of 305 m. Active channel widths ranged from 12 to 83 m. At one cross-section (16) there was a distinctive bouldery bar, with far larger clasts than at any other site. Eight of the 22 cross-sections are in reaches where the channel is contained within steep incised banks and there are no gravel beaches. The remainder of the cross-sections are in wider reaches with low channel banks and have gravel beaches adjacent to the channel. In the Whangamoa River the distance between cross-sections ranged from 260 to 905 m, with an average of 570 m, and active channel widths ranged from 18 to 48 m. Four of the 10 cross-sections are in reaches with no beaches and where the channel is contained within steep incised banks, while the remainder have gravel beaches adjacent to the channel. In both rivers gravel beaches become less common upstream and the channel becomes more incised.

The tape-and-level survey has provided baseline data from which to monitor future changes in bed levels, both in areas where gravel typically accumulates and in areas where gravel does not appear to deposit. The method allowed a fairly rapid survey of the river and it will take less time in future as all the benchmarks have been established. It is estimated that the 32 cross-sections could be surveyed within 5 days in future.

Two practical difficulties were apparent during the survey. It would be advisable to carry out the survey after the willows along the river banks have lost their leaves to make it easier to read the staff when levelling. The survey cannot be carried out when the wind is blowing strongly as the tape vibrates making it impossible to read, and in the worst-case scenario it broke. The reaches near the coast cannot be surveyed at high tide.

[2] Note that as a consequence of the consecutive numbering, the cross-section numbers differ from those initially recorded in the field.

It is recommended that the river be surveyed annually or after significant flood events. It is also imperative that NCC accurately record the location and amount of gravel extracted from the river while the bed-level monitoring is undertaken. The requirements in resource consents for reporting of gravel extraction need to be implemented so there is accurate data on extraction volumes and locations. Without this information it will be impossible to assess the relationship between bed-level trends and gravel extraction. It is unlikely that the cross-section data can provide accurate information on gravel volumes (because of the relatively wide spacing of the cross-sections compared to the size of the beaches), but it will provide accurate data on bed-level trends. The photographs will provide additional information on gross morphological change.

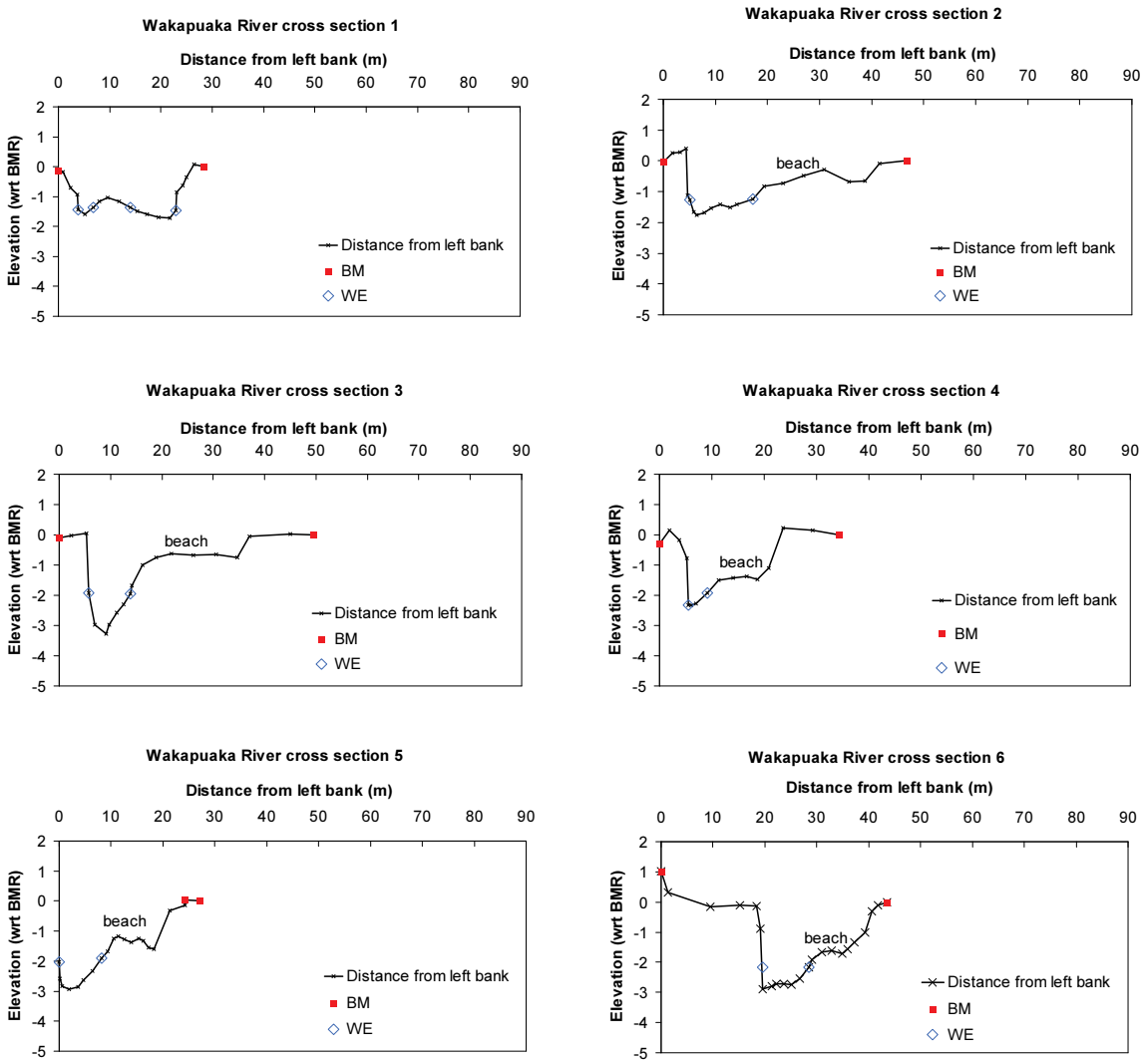

Fig. 1 Plots of Wakapuaka cross-sections 1 to 6 (BM = benchmark, WE = water's edge).

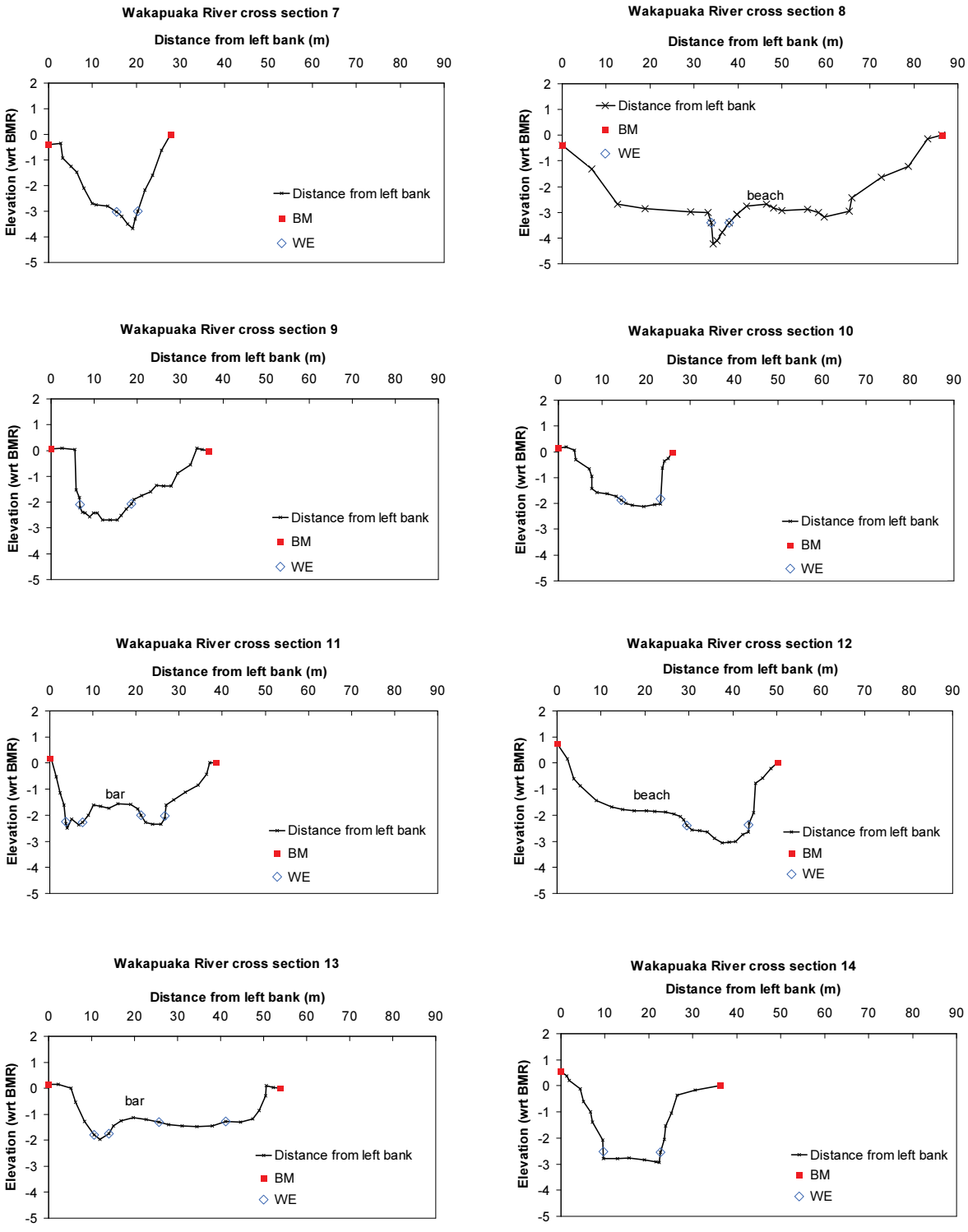

Fig. 2 Plots of Wakapuaka cross-sections 7 to 14 (BM = benchmark, WE = water's edge).

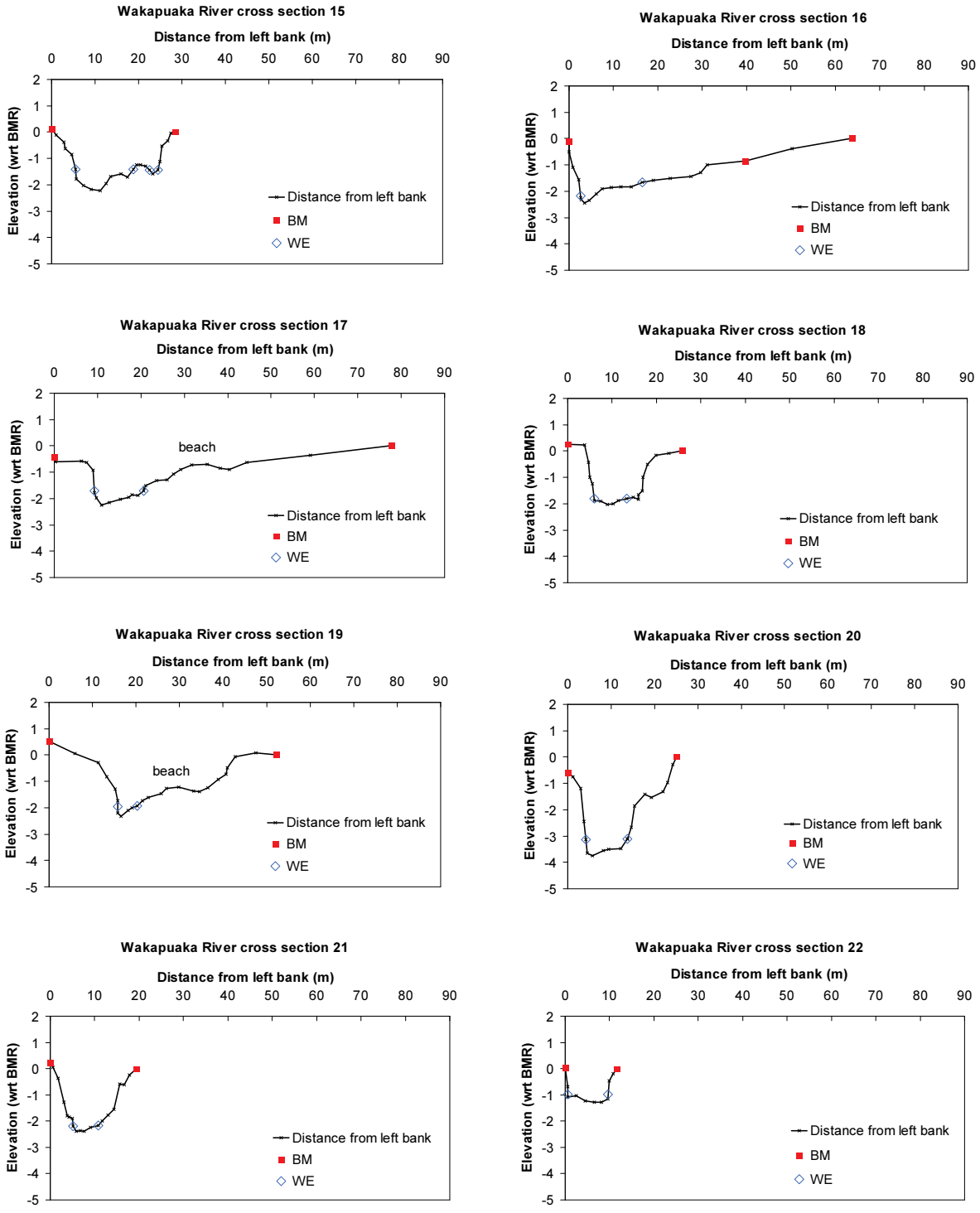

Fig. 3 Plots of Wakapuaka cross-sections 15 to 22 (BM = benchmark, WE = water's edge).

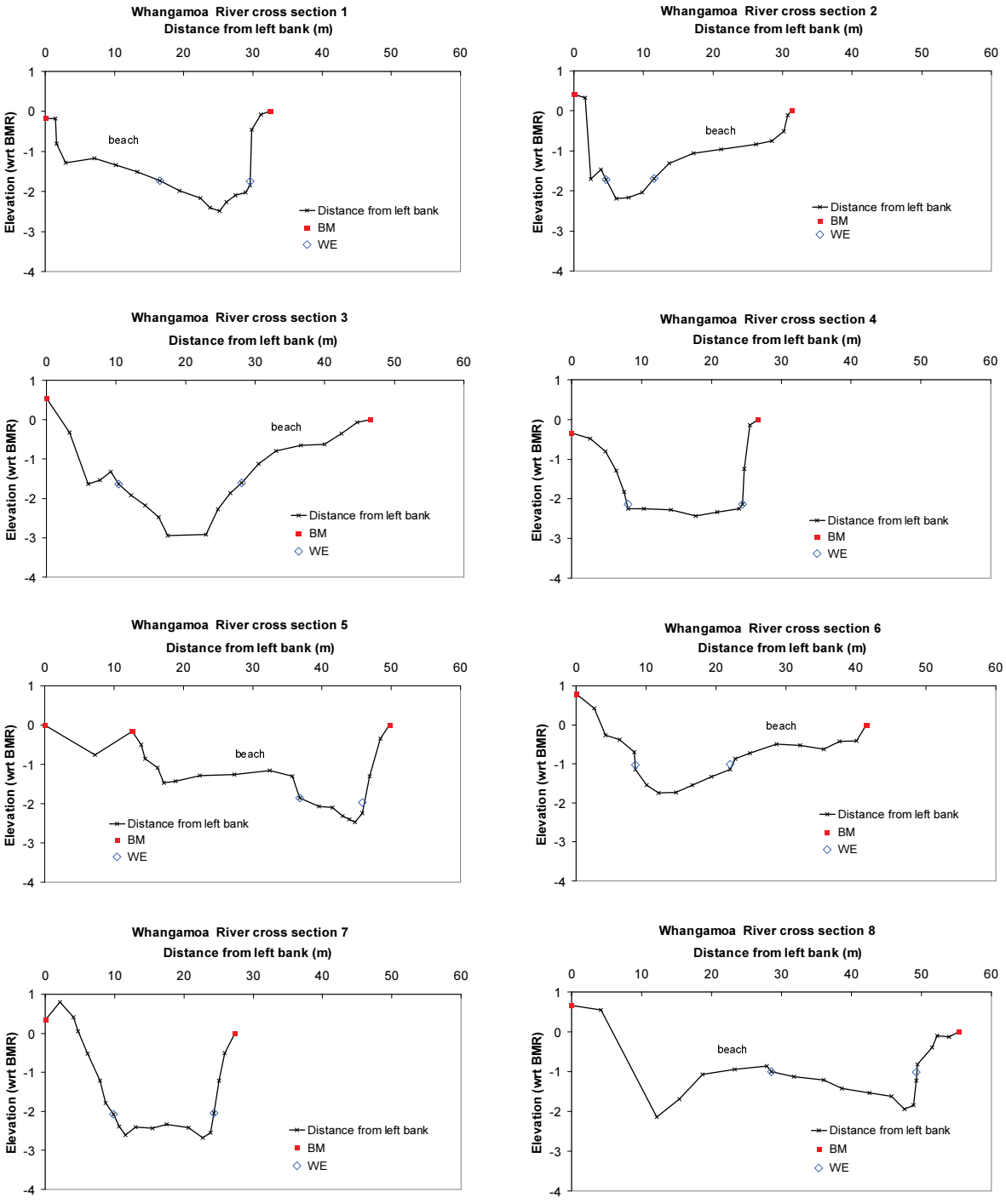

Fig. 4 Plots of Whangamoa cross-sections 1 to 8 (BM = benchmark, WE = water's edge).

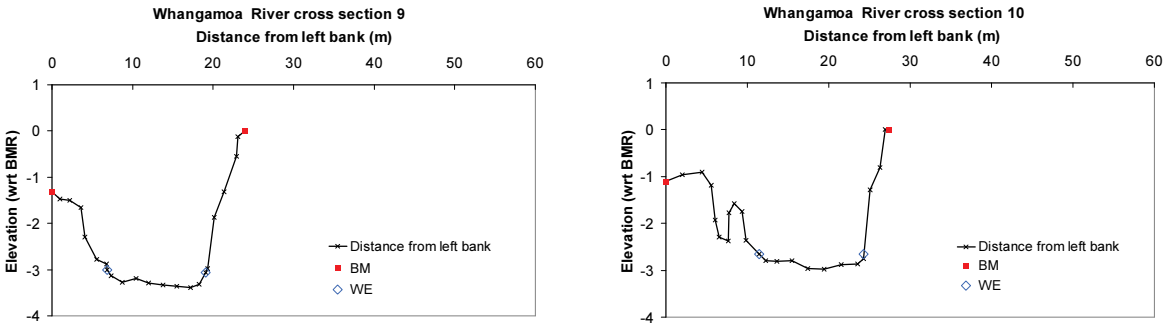

Fig. 5 Plots of Whangamoa cross-sections 9 and 10 (BM = benchmark, WE = water's edge).

6. Conclusions

The tape-and-level survey is an efficient and cost-effective method for monitoring changes in bed levels. The survey has provided quantitative baseline data to calculate future bed-level change in the Wakapuaka and Whangamoa Rivers.

7. Recommendations

- The river should be surveyed annually or after significant flood events.
- Surveys should be carried out when the wind is not blowing strongly and when the willow trees have lost their leaves.
- NCC needs to accurately record the location and amount of gravel extracted from the river while the bed-level monitoring is undertaken to allow assessment of the relationship between bed-level trends and gravel extraction.
- The cross-section data should not be used to provide information on gravel volumes stored in the river.
- NCC should consider whether more permanent benchmarks are needed.

8. Acknowledgements

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9. References

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Appendix 1 Locations of benchmarks and other permanent features at the cross-sections (L left bank; R right bank)

Wakapuaka River

Cross-section no.	Location	Comment	N	E
1	R		6003354.3	2545684.2
1	L		6003377.0	2545668.7
1	R-fencepost	Level to top of post 0.366 m, height of post 1.18 m	6003357.8	2545688.2
2	R		6003095.0	2545553.2
2	L		6003108.8	2545508.3
2	R aux	In fence line	6003076.0	2545568.2
3	R		6002872.5	2545552.4
3	L		6002915.6	2545529.2
3	R-fencepost	Fencepost at stile, level to top of post 0.468 m, height of post?	6002868.9	2545549.0
4	R		6002824.2	2545540.3
4	L		6002793.4	2545524.6
4	R-fencepost	Level to top of post 1.075 m, height of post 1.004 m	6002823.8	2545540.1
5	R		6002705.9	2545584.1
5	R aux		6002707.4	2545581.7
5	R-fencepost	Level to ground beside gate fence post 0.191 m	6002692.6	2545626.3
6	R		6002273.4	2545332.9
6	L		6002263.9	2545290.0
6	L-waratah	Adjacent BL, level to ground beside waratah 1.109 m, height of waratah 1.015 m	6002263.9	2545290.0
7	R		6001994.7	2545401.6
7	L		6002006.8	2545376.5
8	R		6001873.5	2545190.8
8	L		6001884.2	2545105.4
8	L-fencepost	Level to ground beside fencepost −0.346 m, height of post 1.12 m, post 24.5 cm u/s BML	6001884.2	2545105.4
9	R		6001711.4	2545195.9
9	L		6001650.2	2545180.8
9	L-fencepost	Fencepost road edge, level to ground 0.886 m, height of post 1.18 m	6001680.9	2545155.1
10	R		6001536.7	2545450.6
10	L		6001522.1	2545428.5
11	R		6001371.6	2545479.8
11	L	Edge of track	6001369.3	2545442.0
12	R		6001254.2	2545441.0
12	L		6001287.0	2545403.0
13	R		6001170.6	2545210.3

Cross-section no.	Location	Comment	N	E
13	L		6001181.9	2545157.3
13	R-fencepost	Level to top of post 0.644 m, height of post 1.17m	6001150.3	2545232.9
14	R		6001026.7	2545113.9
14	L		6001046.6	2545082.9
14	R-fencepost	Level to top of post 1.141 m, height of post 1.18 m	6001025.7	2545111.3
15	L		6000633.4	2544882.9
15	R		6000632.0	2544911.7
15	R-fencepost	Level to ground 0.991 m, height of post 1.195 m	6000627.0	2544926.0
16	R		6000452.4	2544756.1
16	R aux		6000471.1	2544741.0
16	R-fencepost	Fencepost in deer fence, level to ground 1.111 m	6000428.7	2544771.3
17	L		6000217.8	2544563.2
17	R		6000185.2	2544514.8
18	L		6000212.6	2544256.7
18	R		6000190.7	2544243.6
18	R-fencepost	Level to top of post 1.109 m, height of post?	6000190.7	2544243.6
19	L		6000101.6	2543886.7
19	R		6000095.3	2543938.5
19	R-fencepost	Level to top of post 1.010 m, height of post 1.01 m	6000095.3	2543938.5
20	R		5999734.8	2543829.1
20	L		5999744.2	2543803.8
20	L-fencepost	Level to top of post 0.472 m, height of post 1.05 m	5999744.2	2543803.8
21	R		5999344.3	2543488.3
21	L		5999351.5	2543470.3
22	L	Top of staff gauge, 0.625 m above ground	5998919.6	2543158.7
22	R	On steep bank below flax bush	5998916.6	2543167.2

Whangamoa River

Cross-section no.	Location	Comment	N	E
1	L	Tidal reach	6010518.1	2555819.6
1	R		6010503.4	2555848.2
1	R-waratah	Waratah adjacent BMR, level to top 0.999 m, height of waratah 0.98 m	6010503.4	2555848.2
2	L	In bush	6010115.6	2555754.0
2	R		6010085.3	2555746.1
3	L	In willows	6009875.1	2555442.3
3	R		6009835.6	2555465.9
3	L-fencepost	Level to top of fencepost at base of bank 0.932 m, height of post 1.15 m	6009878.4	2555440.0
4	L	Replaced original BML	6009596.4	2555454.1
4	R	Top of bank	6009607.4	2555478.3
4	L-fencepost	By original BML, level to top of post 0.812 m, height of post 1.198 m	6009594.6	2555454.6
5	L	In fenceline by post	6009335.1	2555627.5
5	L aux	Near bank edge	6009347.2	2555629.9
5	R		6009383.9	2555637.6
5	L-fencepost	Fencepost adjacent BML, level to top 1.012 m, height of post 1.043 m	6009335.1	2555627.5
6	L		6009058.5	2555495.0
6	R	On bank	6009037.7	2555531.6
6	L-fencepost	Fencepost adjacent BML, level to ground 0.825 m, height of post 1.255 m	6009058.5	2555495.0
7	L		6008669.3	2555420.8
7	R		6008659.9	2555446.7
7	L-fencepost	Fencepost adjacent BML, level to top 1.348 m, height of post 1.025 m	6008669.3	2555420.8
8	L	In fenceline	6008037.5	2555244.2
8	R	In fendeline	6008043.2	2555300.5
8	L-fencepost	Fencepost, level to top 1.721 m, height above ground 1.245m	6008045.8	2555246.3
9	L		6007274.6	2554948.0
9	R	In trees	6007276.7	2554970.3
9	R-fencepost	Level to top 1.070 m, height above ground 1.125 m	6007275.8	2554973.0
10	L	In fence line	6006488.1	2555066.2
10	R	Beside tree	6006469.7	2555086.4
10	L-fencepost	Level to top of post 0.200 m, height above ground 1.295 m	6006482.7	2555063.5

Appendix 2 Survey data for the cross-sections

Wakapuaka River

Cross-section	Distance (m)	RL (m)	Code
1	0	-0.111	BML
	0.9	-0.179	TOB
	2.32	-0.714	bank
	3.7	-0.944	TOB
	3.87	-1.446	BOB, WE
	5.15	-1.594	Channel
	6.75	-1.372	WE
	7.99	-1.166	Beach
	9.57	-1.029	Beach
	11.79	-1.149	Beach
	14.01	-1.354	WE
	15.39	-1.494	Channel
	17.27	-1.599	Channel
	19.58	-1.685	Channel
	21.72	-1.709	Channel
	22.96	-1.455	BOB, WE
	23.11	-0.843	TOB
	24.29	-0.62	bank
	24.98	-0.342	bank
	26.52	0.091	TOB
	28.37	0	BMR

Cross-section	Distance (m)	RL (m)	Code
2	0	-0.046	BML
	1.75	0.25	berm
	3.25	0.275	berm
	4.39	0.408	TOB
	4.67	-1.13	BOB
	5.06	-1.272	WE
	5.77	-1.655	Channel
	6.46	-1.77	Channel
	7.81	-1.686	Channel
	9.21	-1.528	Channel
	10.9	-1.423	Channel
	12.86	-1.5	Channel
	14.12	-1.413	Channel
	17.19	-1.252	WE
	19.3	-0.835	Beach
	22.96	-0.735	Beach
	26.93	-0.473	Beach
	30.93	-0.276	Beach
	35.64	-0.682	Beach
	38.73	-0.657	edge of gorse
	41.46	-0.082	berm/gorse
	46.81	0	BMR

Cross-section	Distance (m)	RL (m)	Code
3	0	-0.111	BML
	2.4	-0.017	Paddock
	5.38	0.053	TOB
	5.74	-1.919	BOB, WE
	6.9	-2.972	Channel
	9.2	-3.272	Channel
	9.8	-2.982	Channel
	11.17	-2.587	Channel
	12.57	-2.302	Channel
	13.87	-1.942	WE
	14.13	-1.672	BOB
	16.22	-0.992	TOB
	18.95	-0.748	Beach
	21.85	-0.637	Beach
	26.08	-0.674	edge of grass
	30.54	-0.654	berm
	34.65	-0.742	BOB
	37.01	-0.055	TOB
	44.99	0.013	berm
	49.39	0	BMR

Cross-section	Distance (m)	RL (m)	Code
4	0	-0.312	BML
	1.84	0.139	Paddock
	3.72	-0.181	Paddock
	5.16	-0.772	TOB
	5.56	-2.333	BOB, WE
	6.05	-2.328	Channel
	6.95	-2.268	Channel
	9.16	-1.928	WE
	11.32	-1.512	Beach
	14.01	-1.423	Beach
	16.64	-1.379	Beach
	18.7	-1.483	bank
	20.91	-1.096	BOB
	23.65	0.224	TOB
	29.22	0.153	berm
	34.36	0	BMR

Cross-section	Distance (m)	RL (m)	Code
5	0	-2.024	WE, BOB
	0.13	-2.576	Channel
	0.61	-2.844	Channel
	1.86	-2.944	Channel
	3.59	-2.872	Channel
	4.73	-2.639	Channel
	6.39	-2.324	Channel
	8.15	-1.915	WE
	9.37	-1.685	Beach
	10.59	-1.251	Beach
	11.4	-1.164	Beach
	12.56	-1.261	Beach
	13.93	-1.382	Beach
	15.34	-1.242	Beach
	16.25	-1.314	Beach
	17.19	-1.546	Beach
	18.23	-1.604	BOB
	21.26	-0.316	TOB
	24.2	-0.148	Paddock
	24.21	0.043	BMRaux
	27.05	0	BMR

Cross-section	Distance (m)	RL (m)	Code
7	0	-0.407	BML
	2.8	-0.349	TOB
	3.16	-0.924	Bank
	5.16	-1.249	Bank
	6.49	-1.468	Bank
	8.07	-2.108	Bank
	9.96	-2.7	BOB
	10.84	-2.742	Beach, edge of grass
	13.46	-2.805	Beach
	15.49	-3.022	WE
	16.68	-3.205	Channel
	18.04	-3.503	Channel
	19.19	-3.668	Channel
	19.78	-3.296	Channel
	20.28	-3.006	WE
	21.85	-2.178	Bank
	23.72	-1.588	Bank
	25.69	-0.622	Bank
	27.72	0	BMR

Cross-section	Distance (m)	RL (m)	Code
6	0	1.012	BML
	1.36	0.311	Paddock
	9.48	-0.157	Paddock
	15.13	-0.095	Paddock
	18.37	-0.126	TOB
	19.08	-0.876	Bank
	19.56	-2.898	WE, BOB
	21.34	-2.794	Channel
	22.2	-2.711	Channel
	23.69	-2.708	Channel
	25.2	-2.731	Channel
	26.72	-2.546	Channel
	28.48	-2.171	WE
	29.06	-1.905	Beach
	30.97	-1.671	Beach
	32.85	-1.618	Beach
	34.91	-1.701	edge of grass
	35.89	-1.56	berm
	37.28	-1.334	berm
	39.33	-1.005	BOB
	40.59	-0.303	TOB
	41.82	-0.104	Paddock
	43.58	0	BMR

Cross-section	Distance (m)	RL (m)	Code
8	0	-0.391	BML
	6.67	-1.311	Bank
	12.58	-2.681	BOB
	18.85	-2.859	berm
	29.28	-2.973	berm
	33.16	-3.011	end of riprap
	33.95	-3.409	WE-on riprap
	34.37	-4.236	Channel
	35.14	-4.101	Channel
	36.38	-3.786	Channel
	37.92	-3.411	WE
	39.7	-3.079	Beach
	41.9	-2.764	Beach
	46.47	-2.676	Beach
	48.01	-2.843	Beach
	49.99	-2.936	Beach
	55.74	-2.874	Beach
	58.27	-2.999	Beach
	59.64	-3.181	edge of grass
	65.36	-2.965	BOB
	65.9	-2.444	TOB
	72.6	-1.629	Paddock
	78.82	-1.209	BOB
	83.13	-0.147	TOB
	86.38	0	BMR

Cross-section	Distance (m)	RL (m)	Code
9	0	0.058	BML
	2.55	0.094	Paddock
	5.45	0.047	TOB
	5.76	-1.533	Bank
	6.51	-1.818	Bank
	6.72	-2.208	WE, BOB
	7.37	-2.385	Channel
	7.98	-2.428	Channel
	8.95	-2.562	Channel
	9.88	-2.408	Channel
	10.72	-2.411	Channel
	11.87	-2.694	Channel
	13.75	-2.703	Channel
	15.33	-2.688	Channel
	16.23	-2.529	Channel
	17.47	-2.259	Channel
	18.73	-2.068	WE
	19.23	-1.891	Beach
	21.09	-1.753	Beach
	23.17	-1.599	Beach
	24.55	-1.359	Beach
	26.13	-1.382	Beach
	27.84	-1.381	BOB
	29.43	-0.878	Bank
	32.33	-0.56	Bank
	33.83	0.092	TOB
	35.03	0.041	Paddock
	36.56	0	BMR

Cross-section	Distance (m)	RL (m)	Code
10	0	0.14	BML
	1.76	0.183	Paddock
	3.58	0.06	TOB
	3.9	-0.301	Bank
	7.06	-0.656	Bank
	7.61	-0.961	Bank
	7.67	-1.417	Bank
	8.76	-1.566	BOB
	11.13	-1.626	Gravel
	13.13	-1.735	Gravel
	14.39	-1.86	WE
	15.4	-2.005	Channel
	16.82	-2.076	Channel
	19.47	-2.113	Channel
	21.85	-2.046	Channel
	23.27	-2.021	BOB, WE
	23.73	-0.621	Bank
	24.11	-0.363	TOB
	25.01	-0.256	Paddock
	25.87	0	BMR

Cross-section	Distance (m)	RL (m)	Code
11	0	0.192	BML
	0.27	0.172	TOB
	1.47	-0.535	Bank
	2.37	-1.148	Bank
	3.31	-1.621	Bank
	3.69	-2.326	WE
	4.09	-2.503	Channel
	5.08	-2.148	Channel
	6.64	-2.383	Channel
	7.67	-2.266	WE
	8.94	-1.998	Beach
	10.11	-1.618	Beach
	11.7	-1.656	Beach
	13.7	-1.729	Beach
	15.78	-1.557	Beach
	18.74	-1.598	Beach
	20.35	-1.751	Beach
	21.14	-2.013	WE
	22.24	-2.272	Channel
	23.8	-2.345	Channel
	25.73	-2.338	Channel
	26.65	-2.131	BOB, WE
	27.04	-1.603	TOB
	28.76	-1.423	Bank
	31.5	-1.115	Bank
	34.39	-0.838	Bank
	36.35	-0.436	BOB
	37.14	0.008	TOB
	38.63	0	BMR

Cross-section	Distance (m)	RL (m)	Code
12	0	0.747	BML, TOB
	2.28	0.165	Bank
	3.85	-0.598	BOB
	5.26	-0.88	Paddock
	8.95	-1.428	Paddock
	12.43	-1.672	berm
	14.88	-1.774	berm
	17.51	-1.825	berm
	20.28	-1.827	edge of grass
	22.28	-1.862	Beach
	24.75	-1.876	Beach
	26.53	-1.95	Beach
	27.98	-2.055	Beach
	28.78	-2.176	Beach
	29.54	-2.39	WE
	30.71	-2.558	Channel
	32.37	-2.583	Channel
	34.18	-2.648	Channel
	35.8	-2.883	Channel
	37.55	-3.06	Channel
	39.19	-3.027	Channel
	40.57	-3.009	Channel
	42.25	-2.733	Channel
	43.61	-2.649	WE
	43.68	-2.3	Bank
	44.77	-1.893	BOB
	45.13	-0.764	TOB
	46.78	-0.578	Paddock
	48.7	-0.201	Paddock
	50.08	0	BMR

Cross-section	Distance (m)	RL (m)	Code
13	0	0.157	BML
	2.29	0.149	Paddock
	5.22	0.009	TOB
	6.3	-0.541	Bank
	8.32	-1.276	Bank
	10.58	-1.785	WE, BOB
	11.98	-1.971	Channel
	13.97	-1.746	WE
	15.09	-1.447	Beach
	16.94	-1.251	Beach
	19.69	-1.126	Beach
	22.7	-1.215	Beach
	25.67	-1.306	WE
	27.93	-1.401	Channel
	31.04	-1.44	Channel
	34.43	-1.466	Channel
	38.02	-1.441	Channel
	41.19	-1.283	WE
	44.61	-1.296	Gravel/grass
	47.43	-1.189	BOB
	48.98	-0.851	Bank
	50.42	-0.301	Bank
	50.64	0.098	TOB
	52.19	0.03	Paddock
	53.91	0	BMR

Cross-section	Distance (m)	RL (m)	Code
14	0	0.547	BML
	1.38	0.378	Paddock
	1.87	0.212	Paddock
	4.43	-0.119	TOB
	5.09	-0.611	Bank
	6.68	-0.994	Bank
	7.16	-1.4	Bank
	9.51	-2.074	BOB
	9.64	-2.795	WE
	12.92	-2.782	Channel
	15.46	-2.767	Channel
	19.01	-2.838	Channel
	21.62	-2.909	Channel
	22.31	-2.949	Channel
	22.59	-2.549	WE, BOB
	23.58	-2.049	Bank
	23.77	-1.537	Bank
	25.2	-1.044	Bank
	26.48	-0.354	TOB
	30.52	-0.159	Paddock
	36.26	0	BMR

Cross-section	Distance (m)	RL (m)	Code
15	0	0.144	BML, TOB
	1.02	-0.111	Bank
	2.77	-0.377	Bank
	3.18	-0.618	Bank
	4.62	-0.842	Bank
	5.56	-1.419	WE, BOB
	5.61	-1.785	Channel
	7.34	-2.031	Channel
	9.08	-2.18	Channel
	11.12	-2.236	Channel
	12.56	-1.943	Channel
	13.63	-1.685	Channel
	16	-1.581	Channel
	17.53	-1.716	Channel
	18.81	-1.416	WE
	19.49	-1.236	Beach
	20.51	-1.23	Beach
	21.68	-1.3	Beach
	22.52	-1.437	WE
	23.32	-1.596	Channel
	24.42	-1.44	WE, BOB
	24.87	-1.111	Bank
	25.43	-0.541	Bank
	26.78	-0.333	Bank
	27.4	-0.036	TOB
	28.49	0	BMR

Cross-section	Distance (m)	RL (m)	Code
16	0	-0.119	BML on rock protection
	0.06	-0.495	Bank
	0.82	-1.083	Bank
	2.12	-1.57	Bank
	2.56	-2.249	WE
	2.81	-2.334	Channel
	3.54	-2.434	Channel
	4.57	-2.339	Channel
	6.08	-2.094	Channel
	7.47	-1.893	Channel
	9.44	-1.857	Channel
	11.66	-1.824	Channel
	14.07	-1.83	Channel
	16.48	-1.659	WE
	19.02	-1.589	bar
	22.84	-1.519	bar
	27.41	-1.429	bar
	29.69	-1.286	bar
	31.11	-0.994	Edge of grass
	39.75	-0.837	BMRaux
	50.28	-0.379	Paddock
	63.72	0	BMR

Cross-section	Distance (m)	RL (m)	Code
17	0	-0.44	BML, top of stump
	0.31	-0.597	Paddock
	6.31	-0.59	Paddock
	7.49	-0.624	TOB
	8.97	-0.918	Bank, riprap
	9.32	-1.785	BOB, WE
	9.73	-1.978	Channel
	10.98	-2.249	Channel
	12.74	-2.156	Channel
	15.27	-2.019	Channel
	17.14	-1.949	Channel
	17.94	-1.845	Channel
	19.35	-1.877	Channel
	20.56	-1.703	WE
	20.77	-1.59	Beach
	21.13	-1.514	Beach
	23.68	-1.325	Beach
	26.01	-1.285	Beach
	27.48	-1.077	Beach
	29.16	-0.893	Beach
	31.67	-0.727	Beach
	35.24	-0.7	Beach
	38.22	-0.844	Beach
	40.32	-0.901	Edge of grass
	44.46	-0.617	Paddock
	58.98	-0.366	Paddock
	77.73	0	BMR, under fence

Cross-section	Distance (m)	RL (m)	Code
18	0	0.256	BML
	3.75	0.24	TOB
	4.63	-0.432	Bank
	4.96	-0.99	Bank
	5.62	-1.246	Bank
	5.94	-1.887	BOB
	7.4	-1.9	Channel
	8.91	-2.019	Channel
	10.3	-2.01	Channel
	11.46	-1.89	Channel
	13.31	-1.818	WE
	14.75	-1.75	Gravel
	15.91	-1.832	BOB
	15.96	-1.66	Bank
	16.73	-1.509	Bank
	17.01	-0.994	Bank
	18.03	-0.494	Bank
	19.81	-0.152	TOB
	22.78	-0.085	Paddock
	25.7	0	BMR

Cross-section	Distance (m)	RL (m)	Code
19	0	0.527	BML
	5.98	0.052	Paddock
	11.31	-0.287	TOB
	13.31	-0.826	Bank
	15.21	-1.297	Bank
	15.76	-1.74	Bank
	15.84	-2.211	BOB
	16.56	-2.332	Channel
	18.16	-2.09	Channel
	19.03	-2.008	Channel
	20.2	-1.937	WE
	21.43	-1.74	Beach
	22.74	-1.604	Beach
	25.71	-1.455	Beach
	26.93	-1.269	Beach
	29.77	-1.213	Beach
	33.25	-1.355	Beach
	34.56	-1.396	berm
	36.55	-1.244	berm
	38.87	-0.917	berm
	40.68	-0.737	BOB
	41.02	-0.486	Bank
	42.71	-0.061	TOB
	47.48	0.075	Paddock
	52.19	0	BMR

Cross-section	Distance (m)	RL (m)	Code
20	0	-0.579	BML
	1.19	-0.758	Paddock
	3.05	-1.205	TOB
	3.71	-2.437	Bank
	4.15	-3.138	WE
	4.53	-3.658	Channel
	5.61	-3.748	Channel
	8.27	-3.543	Channel
	9.43	-3.492	Channel
	12.27	-3.485	Channel
	13.81	-3.119	WE, BOB
	14.72	-2.662	Bank
	15.41	-1.852	TOB
	17.83	-1.417	berm
	19.3	-1.532	berm
	21.99	-1.325	BOB
	23.03	-0.982	Bank
	24.26	-0.294	Bank
	25.11	0	BMR

Cross-section	Distance (m)	RL (m)	Code
21	0	0.229	BML
	0.64	0.064	TOB
	1.7	-0.358	Bank
	3.13	-1.287	Bank
	3.87	-1.8	BOB
	4.22	-1.834	Bank
	5.03	-1.895	bank
	5.05	-2.183	WE
	5.81	-2.396	Channel
	6.65	-2.355	Channel
	7.56	-2.375	Channel
	9.07	-2.235	Channel
	10.77	-2.155	WE
	11.73	-1.984	Gravel
	13.01	-1.78	Gravel
	14.33	-1.547	BOB
	15.59	-0.59	TOB
	16.6	-0.617	Bank
	17.83	-0.231	Bank
	19.45	0	BMR

Cross-section	Distance (m)	RL (m)	Code
22	0	0.018	BML-top of staff gauge, 0.625 m above ground
	0.52	-0.68	edge of concrete
	0.58	-1.09	WE-water depth 0.11M
	2.48	-1.024	Channel
	4.53	-1.222	Channel
	6.51	-1.283	Channel
	8.2	-1.276	Channel
	9.71	-1.153	WE, BOB
	9.95	-0.472	TOB
	10.87	-0.192	Bank
	11.67	0	BMR

Whangamoa River

Cross-section	Distance (m)	RL (m)	Code
1	0	-0.183	BML
	1.44	-0.178	TOB
	1.67	-0.803	Bank
	2.95	-1.287	BOB
	7.1	-1.168	grassy beach
	10.16	-1.333	edge of grass
	13.25	-1.505	Gravel
	16.54	-1.738	WE
	19.4	-1.988	Channel
	22.45	-2.162	Channel
	23.81	-2.403	Channel
	25.16	-2.481	Channel
	26.16	-2.261	Channel
	27.5	-2.102	Channel
	28.98	-2.02	Channel
	29.6	-1.837	WE
	29.8	-0.454	TOB
	31.16	-0.078	berm
	32.41	0	BMR

Cross-section	Distance (m)	RL (m)	Code
2	0	0.408	BML
	1.59	0.322	TOB
	2.47	-1.697	BOB
	3.88	-1.466	collapsed bank
	4.63	-1.715	WE
	6.06	-2.199	Channel
	7.84	-2.17	Channel
	9.83	-2.034	Channel
	11.53	-1.689	WE
	13.69	-1.305	Beach
	17.16	-1.06	Beach
	21.18	-0.965	Beach
	26.19	-0.835	edge of grass
	28.49	-0.749	grass
	30.15	-0.519	BOB
	30.74	-0.103	TOB
	31.26	0	BMR

Cross-section	Distance (m)	RL (m)	Code
3	0	0.54	BML, TOB
	3.36	-0.329	Bank
	6.04	-1.637	BOB
	7.7	-1.535	Gravel
	9.23	-1.315	grass
	10.37	-1.63	WE
	12.19	-1.926	Channel
	14.15	-2.18	Channel
	16.13	-2.474	Channel
	17.46	-2.945	Channel
	22.94	-2.915	Channel
	24.68	-2.28	Channel
	26.42	-1.859	Channel
	28.03	-1.61	WE
	30.52	-1.125	Beach
	32.96	-0.795	Beach
	36.57	-0.65	Beach
	39.97	-0.618	Beach
	42.43	-0.347	edge of grass
	44.67	-0.066	berm
	46.55	0	BMR

Cross-section	Distance (m)	RL (m)	Code
4	0	-0.342	BML
	2.65	-0.484	berm
	4.83	-0.804	TOB
	6.4	-1.291	Bank
	7.54	-1.82	Bank
	8.04	-2.245	BOB, WE
	10.36	-2.249	Channel
	14.2	-2.279	Channel
	17.8	-2.439	Channel
	20.81	-2.33	Channel
	24.02	-2.255	Channel
	24.45	-2.134	WE, BOB
	24.69	-1.252	Bank
	25.51	-0.15	TOB
	26.61	0	BMR

Cross-section	Distance (m)	RL (m)	Code
5	0	-0.007	BML
	7.22	-0.755	berm
	12.63	-0.155	BML aux
	13.89	-0.498	TOB
	14.5	-0.857	Bank
	16.25	-1.091	Bank
	17.18	-1.465	BOB
	18.88	-1.424	Beach
	22.42	-1.29	Beach
	27.39	-1.259	Beach
	32.46	-1.15	Beach
	35.78	-1.306	Beach
	36.78	-1.86	WE
	39.53	-2.065	Channel
	41.55	-2.093	Channel
	42.98	-2.32	Channel
	44	-2.4	Channel
	44.78	-2.472	Channel
	45.84	-2.239	WE, BOB
	46.86	-1.303	Bank
	48.4	-0.338	TOB
	49.77	0	BMR

Cross-section	Distance (m)	RL (m)	Code
7	0	0.346	BML
	2.1	0.801	berm
	4.11	0.412	TOB
	4.71	0.046	Bank
	6.1	-0.518	Bank
	7.93	-1.212	Bank
	8.7	-1.791	BOB
	9.83	-2.073	WE
	10.67	-2.388	Channel
	11.52	-2.609	Channel
	13	-2.409	Channel
	15.44	-2.429	Channel
	17.5	-2.34	Channel
	20.67	-2.417	Channel
	22.68	-2.677	Channel
	23.87	-2.555	Channel
	24.38	-2.041	WE
	25.07	-1.208	Bank
	25.89	-0.504	TOB
	27.39	0	BMR

Cross-section	Distance (m)	RL (m)	Code
6	0	0.793	BML
	2.55	0.42	TOB
	4.19	-0.26	BOB
	6.18	-0.375	berm
	8.32	-0.692	TOB
	8.5	-1.146	WE
	10.07	-1.536	Channel
	11.81	-1.747	Channel
	14.24	-1.73	Channel
	16.65	-1.542	Channel
	19.39	-1.324	Channel
	22.05	-1.141	WE
	22.71	-0.871	Beach
	24.85	-0.721	Beach
	28.64	-0.492	Beach
	32.03	-0.523	Beach
	35.44	-0.621	edge of grass
	37.66	-0.416	berm
	40.06	-0.415	BOB
	41.48	0	BMR

Cross-section	Distance (m)	RL (m)	Code
8	0	0.667	BML
	4.16	0.546	Rock protection
	12.2	-2.144	BOB
	15.4	-1.685	Beach
	18.73	-1.064	Beach
	23.29	-0.938	Beach
	27.87	-0.859	Beach
	28.52	-1.005	WE
	31.8	-1.124	Channel
	36.02	-1.212	Channel
	38.65	-1.426	Channel
	42.57	-1.529	Channel
	45.72	-1.613	Channel
	47.6	-1.944	Channel
	48.87	-1.844	Channel
	49.24	-1.225	WE
	49.43	-0.81	TOB
	51.56	-0.393	berm
	52.22	-0.104	berm
	53.92	-0.132	berm
	55.3	0	BMR

Cross-section	Distance (m)	RL (m)	Code
9	0	-1.32	BML
	0.94	-1.478	berm
	2.21	-1.507	berm
	3.55	-1.653	TOB
	4.06	-2.292	Bank
	5.57	-2.777	BOB
	6.76	-2.883	Gravel
	6.88	-3.005	WE
	7.35	-3.13	Channel
	8.69	-3.274	Channel
	10.41	-3.194	Channel
	11.96	-3.291	Channel
	13.74	-3.338	Channel
	15.49	-3.365	Channel
	17.17	-3.387	Channel
	18.29	-3.317	Channel
	19.08	-3.057	WE
	19.31	-2.976	BOB
	20.16	-1.869	Bank
	21.35	-1.314	Bank
	22.93	-0.546	Bank
	23.11	-0.118	TOB
	23.98	0	BMR

Cross-section	Distance (m)	RL (m)	Code
10	0	-1.100	BML
	2	-0.964	berm
	4.42	-0.909	berm
	5.56	-1.184	TOB
	6.05	-1.925	Bank
	6.54	-2.294	BOB
	7.63	-2.38	BOB
	7.73	-1.767	TOB
	8.41	-1.58	berm
	9.34	-1.751	TOB
	9.86	-2.36	BOB
	11.43	-2.651	WE
	12.24	-2.792	Channel
	13.61	-2.816	Channel
	15.5	-2.8	Channel
	17.41	-2.965	Channel
	19.46	-2.975	Channel
	21.5	-2.884	Channel
	23.53	-2.866	Channel
	24.31	-2.753	WE, BOB
	25.12	-1.28	Bank
	26.25	-0.804	Bank
	26.96	0.006	TOB
	27.34	0	BMR

BML = left-bank benchmark;

BMR= right-bank benchmark;

TOB = top of bank;

BOB = bottom of bank;

WE = water's edge