Environment Canterbury

Kowhai River Report
Status of Gravel Resources and Management Implications

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Contents

1. Introduction 1

2. Kowhai River Description....1

3. River Processes....2

  3.1 Flooding....2

  3.2 Bed Profile....2

4. Gravel Extraction....3

5. River Bed Changes....3

  5.1 Mean Bed Level Changes....4

  5.2 Gravel Volume Changes....4

6. Gravel Supply....6

7. Discussion and Recommendations....8

8. References....8

1. Introduction

As part of Environment Canterbury's wider "Regional Gravel Management Investigation" MWH have been commissioned to prepare reports on the Status of Gravel Resources and Management Implications for ten "Priority One" rivers within the Canterbury Region.

The Kowhai River (located near Kaikoura) is one of the ten "Priority One" rivers. Investigation of the Kowhai River's gravel resources is important because:

- River gravels are used extensively throughout Canterbury as a construction material for roads, buildings and other infrastructure.
- Gravel aggradation in the Kowhai River is a crucial aspect of flood management. Allowing gravel to accumulate in the channel has the effect of reducing the channel capacity and increases the likelihood of a flood escaping the main channel.
- Extracting too much gravel risks damage to infrastructure such as stopbank collapse and bridge pier undermining. These types of events are hazardous to life and property.

This report provides an initial overview of the Kowhai River before reviewing its changing bed profile and gravel extraction records to assess the available gravel supply. On the basis of the assessed available gravel supply recommendations are made as to the river's future gravel resource management.

2. Kowhai River Description

The Kowhai River runs for around 27km from its headwaters in the Seaward Kaikoura Range, where it drains the valleys bounded by Uwerau (2,213m), Gables End (1,592m), Mt Fyffe (1,602m), Mt Saunders (2,146m), Snowflake (1876m) and Swyncombe (826m). The catchment area of the Kowhai River is estimated to be 90km^2.

The top 16km of river drains the mountainous Seaward Kaikoura Range formed predominantly by greywacke and argillite with some volcanics, limestone and conglomerates also present.

The lower 11km of the river runs across alluvial and glacial outwash, mainly sands, silts and gravels.

The Kowhai River catchment does not include any towns. Habitation is limited to isolated dwellings. State Highway 1 and the main trunk railway cross the Kowhai River within 2km of the sea.

3. River Processes

3.1 Flooding

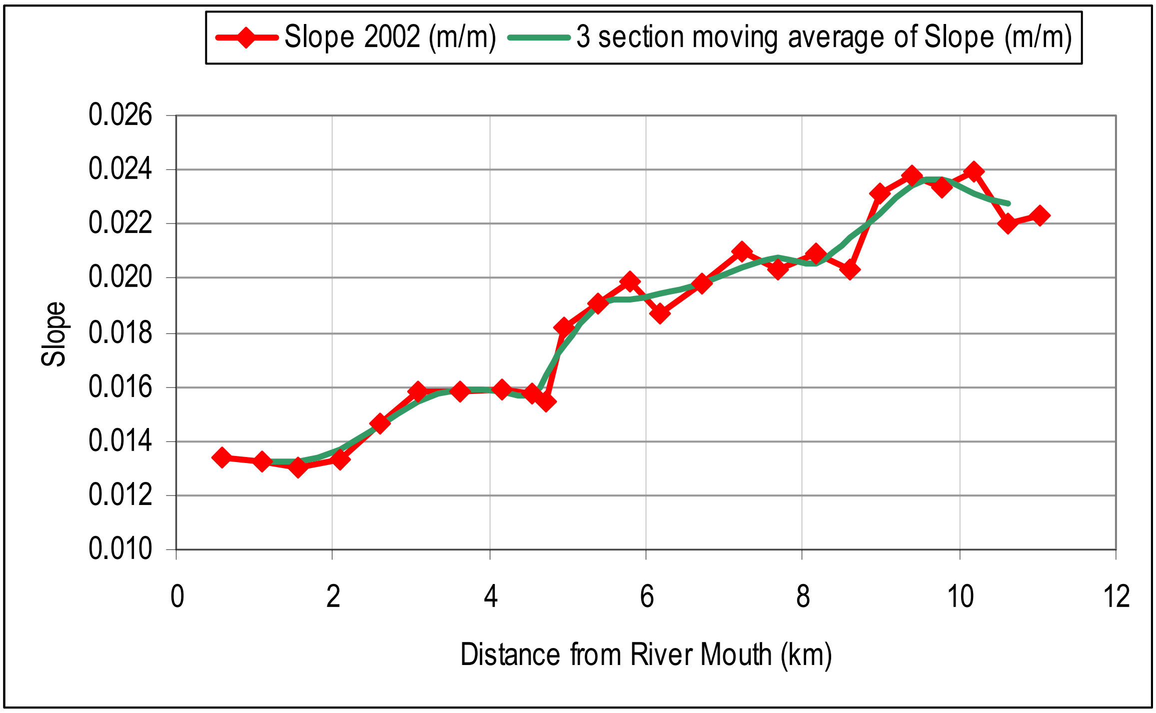
The Kowhai River has a river control scheme that is designed to carry, within its bed without exceeding the banks, the 20-year return period flood. The scheme has a series of echelon stopbanks (a series of stopbanks that return water to the main channel) rather than a continuous stopbank due to the high-energy nature of this river.

The asset management plan also notes that reduced channel capacity caused by shingle deposition is also possible. The river has broken out of its course about once every ten years, however since the last major flood in 1993, further works, including another echelon stopbank, have been constructed to increase the design standard to the 20-year return period flood.

3.2 Bed Profile

The bed profile of the Kowhai River shows a drop in slope over the lower 11km of river. The 2002 river bed slope derived from the 2002 mean bed levels is shown in the Figure 3.1.

Figure 3.1: Kowhai River Bed Slopes 2002 (m/m)



It is significant that despite the flattening of the bed slope as the channel gets closer to the sea, there remains a considerable slope at the mouth. Therefore a throughput to the coastal budget is expected.

As the sediment size is very large at the upstream end of the 11km reach it was not possible to estimate the likely aggradation with a simple sediment transport model. To be able to give an estimate would require a much larger study. The best guide to use with the present information is the gravel budget prepared in Section 6.

4. Gravel Extraction

Environment Canterbury monitor gravel extraction from the Kowhai River by requiring extractors to submit returns indicating how much, when and where gravel is taken.

There is a single "live" resource consent for gravel extraction from the Kowhai River allowing the removal of 1,500m^3/yr until 2008. Environment Canterbury gravel extraction return records from 1998 to 2005 for Kowhai River and its tributary Floodgate Creek are shown in Table 4.1. The locations of the extractions are not included in the extraction records.

Table 4.1: Kowhai River Gravel Extractions (m^3)

Year	Floodgate Creek	Kowhai River
1998/99	8,331	
1999/00	300	396
2000/01	7,250	2112
2001/02	7,186	
2002/03	3,263	
2003/04	1,556	532
2004/05	8,651	250
Totals	**36,500**	**3300**

On average over the seven years of record 5,200 m^3 of gravel was extracted per year from Floodgate Creek and 470 m^3 of gravel was extracted per year from the surveyed reach of the Kowhai River.

5. River Bed Changes

Environment Canterbury monitor the Kowhai River channel by surveying cross-sections on a regular basis. The reduced data from the cross-section monitoring has been made available to us. Table 5.1 includes the cross-section data.

Table 5.1: Cross-sectional Data

River Section	River Distances (km)	Number of Cross-Sections	Number of Surveys and Survey Dates
Kowhai River[1]	0 to 11.24	25	3 –1987, 1995, 2002

Notes to table:
1. Environment Canterbury data file: *Kowhai River (Kaikoura) MBL.xls*

Environment Canterbury cross-section data used in our analysis is:

- The cross-section locations measured from the Kowhai River mouth.
- The cross-section fairway widths calculated as the difference between the left and right channel offsets.

- The cross-section fairway mean bed levels (MBL).

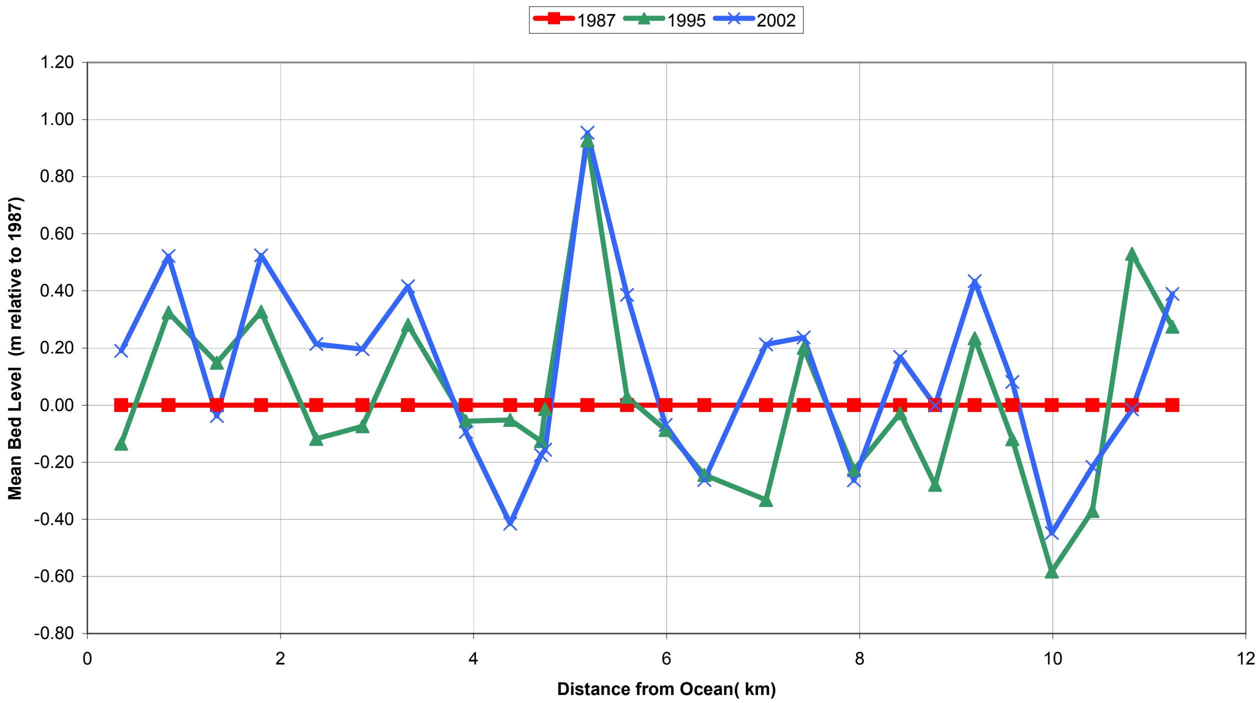
Our analysis includes estimating the gravel volumes (above MSL) by integrating between adjacent cross-sections assuming linear variations of channel width and MBL along the channel between the cross-sections.

5.1 Mean Bed Level Changes

The change in the Kowhai River's fairway mean bed level (MBL) over the period from 1987 to 2002 is shown Figure 5.1. The chart shows the MBLs relative to the MBLs of the 1987 survey.

The charts show a generally increasing mean bed level with the indicative average MBL increasing by around 240mm from 1987 to 2002 in the reach below river km 4 and 50mm from 1987 to 2002 in the reach above river km 4.

Figure 5.1: Kowhai River MBL Relative to 1987 Levels

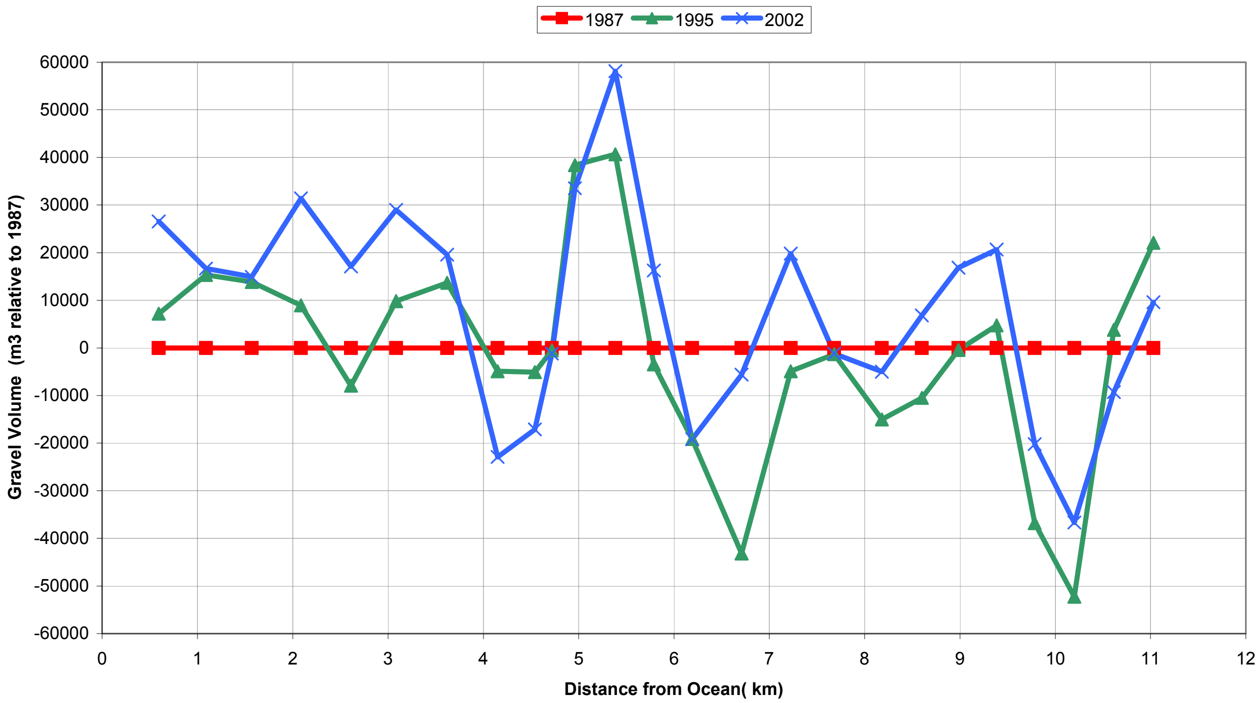


5.2 Gravel Volume Changes

The change in the Kowhai River's fairway gravel volumes over the period from 1987 to 2002 is shown in the following chart.

The chart describes a similar pattern to that discussed in Section 5.1 with an increase in gravel volumes. Over the period 1987 to 2002 volumes have increased by 155,000m^3 below river km 4 and by 43,300m^3 above that point.

Figure 5.3: Kowhai River Fairway Only Gravel Volumes Relative to 1987 Survey



The changing volume of gravel in the Kowhai River in terms of absolute volumes and rate of gain for is shown in Table 5.2.

Table 5.2: Kowhai River Gravel Volume Change

Period	Gravel Volume Change (m^3)	Rate of Change (m^3/year)
1987 to 2002	+198,500	+13,200

6. Gravel Supply

Using the available data the gravel supply in the Kowhai River can be best estimated using a conservation of volume approach over the river reach. Put simply, gravel entering either leaves or remains in the reach. In mathematical terms for a given reach of river (refer also to accompanying schematic below):

$$\frac{\Delta V_g}{\Delta t} = Q_{g.in} - Q_{g.out} \qquad \textit{(Eqn. 1)}$$

where:

ΔV_g	=	change in volume of gravel (m^3)
Δt	=	time elapsed (y)
$Q_{g.in}$	=	total volume rate of gravel into river reach (m^3/y)
$Q_{g.out}$	=	total volume rate of gravel out of river reach (m^3/y)

Gravel leaves the reach either by extraction or by being transported down-river. Gravel enters the reach either from upstream, side tributaries or bank erosion. Building this into Equation. 1 gives us Equation 2.

$$\frac{\Delta V_g}{\Delta t} = Q_{g.river.in} - Q_{g.river.out} - Q_{g.extraction} \qquad \textit{(Eqn. 2)}$$

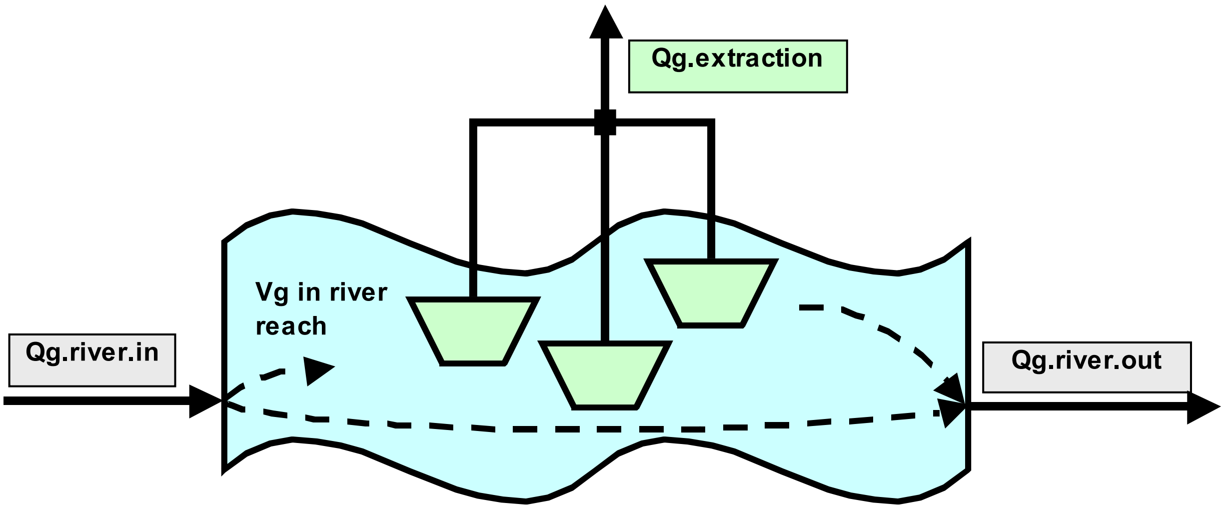
where:

$Q_{g.river.in}$	=	volume flow rate of gravel into river reach from upstream, side tributaries or bank erosion (m^3/y).
$Q_{g.river.out}$	=	volume flow rate of gravel out of river reach by downstream transport (m^3/y)
$Q_{g.extraction}$	=	volume flow rate of gravel extracted from river reach (m^3/y)

Equation 2 can be solved for $Q_{g.river.net}$ (the difference between $Q_{g.river.in}$ and $Q_{g.river.out}$) from the recorded extraction rates and bed level surveys. To estimate the absolute values of $Q_{g.river.in}$ and $Q_{g.river.out}$ we use catchment erosion rate estimates to assess $Q_{g.river.in}$ and then solve for $Q_{g.river.out}$ as the remaining unknown.

Figure 6.2 shows a schematic of the gravel volume flows and changes.

Figure 6.1: Schematic Representation of Change in Gravel Volumes



Gravel extraction data is available from 1998 to 2005 and shows an average of 5,700 m^3/yr extracted. The MBL surveys extend from 1987 to 2002. The following analysis is based on the average observed rates of extraction and gravel volume change.

To estimate the gravel inflow we use a catchment specific suspended sediment yield estimate for North Canterbury rivers as reported by Griffiths (1981) and relate that to a bedload yield. For a catchment of 95km^2 in the Canterbury and Marlborough regions with an estimated mean annual flood runoff of 0.85m^3/s/km^2 (using data for the Ribble Stream as the most similar river to the Kowhai in the Griffiths paper) the estimated suspended sediment yield is 670t/km^2/yr. If bedload is around 40% of the total sediment load then the bedload sediment yield is 440t/km^2/yr.

For the Kowhai River using a catchment area of 90km^2 the corresponding bedload is 19,800m^3/yr. A downward adjustment is made to allow for the 5,200 m^3/yr of gravel extraction occurring in the Floodgate Creek tributary. Thus for the Kowhai River the following observed quantities are used in Eqn. 2.

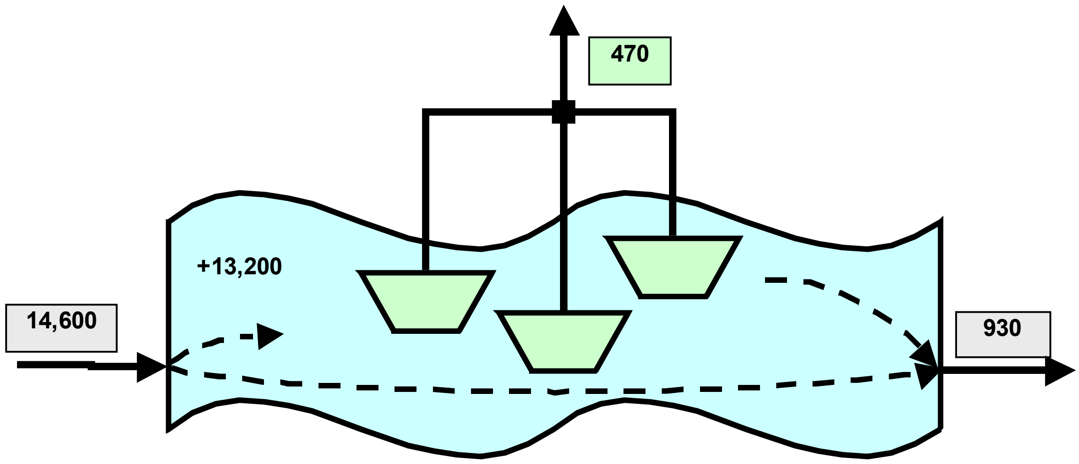
$\Delta V_g / \Delta t$	13,200m^3/yr	(averaged over 1987 to 2002)
$Q_{g.extraction}$	470m^3/yr	(refer Section 4)
$Q_{g.river.in}$	14,600m^3/yr	(as above)

to yield $Q_{g.river.out}$ = 930m^3/yr.

The figures indicate that the river is aggrading and that a limited amount of bedload sediment could be exiting the river mouth to the sea.

The estimated annual average gravel volume flows, extractions and volume changes (all in m^3/yr) are shown in Figure 6.2. The grey coloured boxes show the river bedloads, the light green box shows the gravel extraction and the pale blue box shows the rate of gravel volume change in the river reach.

Figure 6.2: Kowhai River - Schematic Representation of Change in Gravel Volumes



7. Discussion and Recommendations

The gravel budget shows that there is a sustainable gravel supply of around 13,700m^3/yr in the surveyed reach of the Kowhai River. This figure becomes around 19,000m^3/yr when the extractions from Floodgate Creek are added in (using the assumption that the Floodgate Creek rate of extraction is sustainable).

Surveying of the reaches of Floodgate Creek affected by gravel extractions should be included in future Kowhai River surveys.

The proxy design bed level indicated to us by Environment Canterbury is the 1987 bed level.

The latest Kowhai River survey (2002) shows around

- 155,000m^3 of “above design bed level” gravel below 4km
- 110,000m^3 of “above design bed level” gravel between 5 and 6km.
- 20,000m^3 of “above design bed level” gravel around 7km.
- 45,000m^3 of “above design bed level” gravel around 9km.

Future extractions from the surveyed Kowhai River reach and Floodgate Creek could target the sustainable 19,000m^3/yr extraction plus some additional extraction to remove the excess material in these areas.

8. References

Griffiths, G.A.,. (1981), Some Suspended Sediment Yields from South Island Catchments, New Zealand, Water Resources Bulletin, American Water Resources Association, Vol. 17, No 4, August 1981.