Environment Canterbury

Ashley River Report
Status of Gravel Resources and Management Implications

Report No R06/3
ISBN 1-86937-584-X

Prepared by:

Neil Sutherland

MWH New Zealand Ltd
Christchurch

January 2006

Environment Canterbury
Your regional council

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MWH New Zealand Ltd
Tower 2, Deans Park,
7 Deans Avenue
P O Box 13 249
Christchurch
Tel: 64-3-366 7449
Fax: 64-3-366 7780

58 Kilmore Street
P O Box 345
CHRISTCHURCH
Phone: (03) 365 3828
Fax: (03) 365 3194

75 Church Street
P O Box 550
TIMARU
Phone: (03) 684 0500
Fax: (03) 684 0505

Website: www.ecan.govt.nz
Customer Services Phone 0800 324 636

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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 Ashley River in North Canterbury is one of the ten "Priority One" rivers. Investigation of the Ashley River's gravel resources is important because:

- River gravels are used extensively throughout Canterbury (including from the Ashley River) as a construction material for roads, buildings and other infrastructure.
- Gravel aggradation in the Ashley 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 Ashley 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.

Environment Canterbury monitoring of the riverbed levels has been done separately for the Ashley River above and below the Okuku River confluence. This requires some separate analysis for the two river reaches. For the purposes of this report the following definitions are used:

- Lower Ashley River -- the river from the Okuku River confluence to the coast.
- Upper Ashley River –the river from Ashley Gorge to the Okuku River confluence.

2. Ashley River Description

The Ashley River flows from its headwaters in the Puketeraki Range, through Lees Valley and the Ashley Gorge before crossing the Canterbury Plains to the North of Rangiora before reaching the coast at Waikuku. Over its approximately 95km length the river falls around 1,000m. The catchment area at the coast is 1,340km^2 and the mean annual flood at the Rangiora Traffic Bridge is about 900m^3/s.

The reach of interest to this report is the 43km from the gorge to the coast. It is along this reach where:

- the vast majority of gravel extraction occurs
- the risks from flooding at greatest
- key national infrastructure crosses the river.

The upper part of the river's catchment is typified by "strongly indurated, mostly graded-bedded greywacke and argillite with beds of basic volcanics with associated sediments" of the Torlesse Group. The Lees Valley and Canterbury Plains geology consists of glacial outwash and river aggradation gravels in part overlain by dunes sands (NZGS Geological Map Sheet 18).

The river's major tributaries (Okuku River at 21.5km, Makerikeri River at 12km and the Garry River at 28km) originate in and flow through country of generally similar geology to the mainstem.

Environment Canterbury lists the following key statistics on its website for the Ashley River at the Gorge.

- Catchment area 472km^2
- Mean flow 12.3m^3/s
- Mean annual flood 298m^3/s
- 10-year flood 539m^3/s

Landuse in the upper catchment includes native forest in upper valleys and tributaries and non-intensive cattle and sheep grazing in the downlands. On the lower catchment landuse is more intensive and includes cropping and dairying.

Rangiora is by far the largest settlement (population around 11,000) within the catchment. Other communities of significance are Waikuku and Ashley. All of these communities are protected from Ashley River floods by stopbanks.

The key transportation links, State Highway 1 and the main trunk railway cross the Ashley River at around 3km and 11km from the coast, respectively.

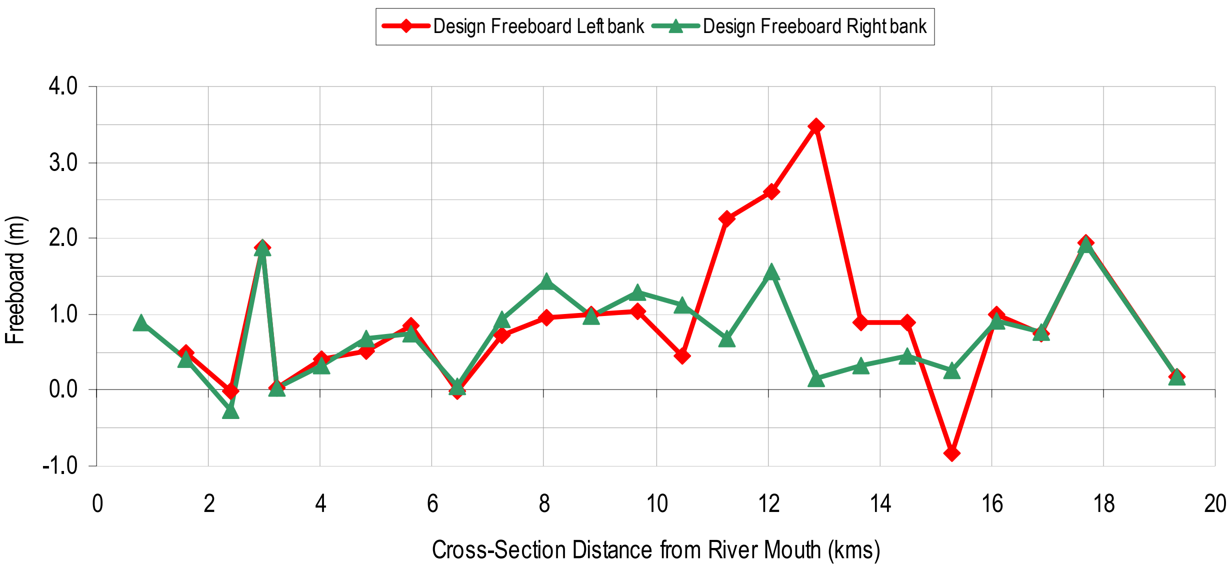
3. River Processes

3.1 Flooding

The Ashley River flood protection scheme includes stopbanks from the Ashley-Okuku confluence to the sea on both banks of the river. The scheme was designed in 1976 to contain the estimated 100-year flood of 2,400m^3/s with 600mm freeboard. Since 1976 the flood hydrology has been reviewed and the 100-year discharge is now estimated to be about 3,600m^3/s. Based on the revised hydrology a 2,400m^3/s flood has a return period of about 25 years.

A review of the river control scheme performance with the 1986 bed levels shows that the river can pass 2,400m^3/s with 600mm freeboard except in a two places. In many places the capacity is significantly greater than 2,400 m^3/s. The results are shown in Figure 3.1 below.

Figure 3.1: Ashley River -design freeboards (freeboard less 600mm) for the design discharge of 2,400m^3/s.



The first river location where the freeboard in less than the design 600mm at a flow of 2,400 m^3/s is at river km 6.44 where the freeboard is 580mm. The second is at river km 2.41 where the freeboard is 330mm. These freeboards will have changed and the following is an assessment of the likely change in freeboards as a result of the bed level changes since 1986.

At river km 6.44 the bed level has dropped by 0.07m since 1986. However it has risen by 0.23m at river km 5.63. It is unlikely the freeboard has changed significantly since 1986.

At river km 2.41 the bed level has dropped by 0.17m. However the bed level at river km 1.61 has risen by 0.05m. The freeboard will still be less than the 600mm design value.

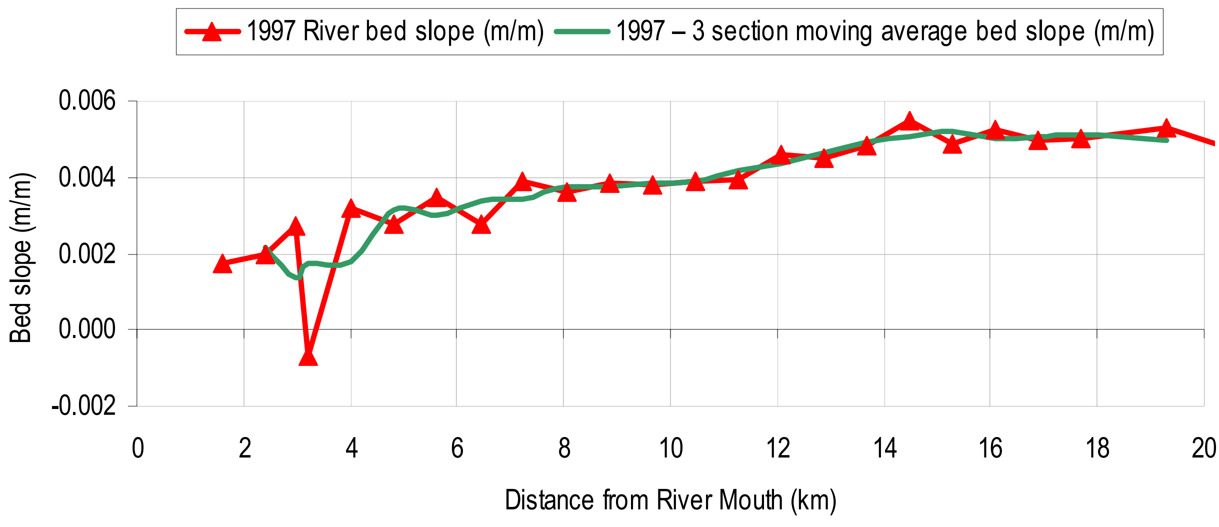
The left bank freeboard is negative at river km 15.29. There is a terrace at this point outside the cross-section survey bench mark that would act to contain any stopbank overtopping at this point.

The Ashley River is likely have the capacity to pass greater flows than the design flow of 2,400m^3/s. The Ashley River Flood Plain investigation estimates a 50% probability that a discharge of 3,000m^3/s (or about the estimated [2002/3 hydrology] 50-year return period flood) could be passed. This assessment takes into consideration all facets of possible failure scenarios, such as localised river bar build up and stopbank integrity.

3.2 River Bed Slope and Bed-load Transport

The river bed slope derived from the 1997 mean bed levels is shown in Figure 3.2 below.

Figure 3.2: Ashley River Bed Slopes 1997 (m/m)



This shows that the river drops off in slope from about 0.005m/m at km 15, to close to 0.002m/m at the mouth. There is a large drop off in slope at 5km, which corresponds to the bed build up in the river. This means that there is potential for extraction in this area.

A very approximate analysis (Connell 1992) using Yalin's formula (Henderson (1966) p444) and calibrated using the aggradation on the North Branch Ashburton River, indicates that a maximum of over 70,000m^3/yr could be deposited in this reach below per year as a result of this drop in slope. The model assumes that the sediment is moved by a 50% of mean annual flood discharge flowing for 0.5% of the year over about 50% of the fairway width. However, as the river catchment is in reasonably good condition, the river is probably not transporting its potential bed load and therefore actual figure will be much less than this.

Studies (McSaveney and Whitehouse, 1989) of the catchment erosion indicate that 600t/km^2/yr is eroded from the catchment which gives a total load (both suspended and bed load) from 1300km^2 of 390,000m^3/yr (assuming 2t/m^3). The bed load, Hicks and Griffiths (1992), is between 3% to 25% of this total or between 12,000 and 97,500m^3/yr.

To be able to give an accurate figure would require a much larger study than has been undertaken here. 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 Ashley River and its tributaries by requiring extractors to submit returns indicating how much, when and where gravel is taken. The Ashley River gravel returns for the period from 1993 to 2005 have been made available to us.

Our analysis of the returns data has been to determine the patterns of where and when gravel has been extracted from the Ashley River over the past 12 years. Table 4.1 breaks the extractions down by year and part of the system where the extractions occurred.

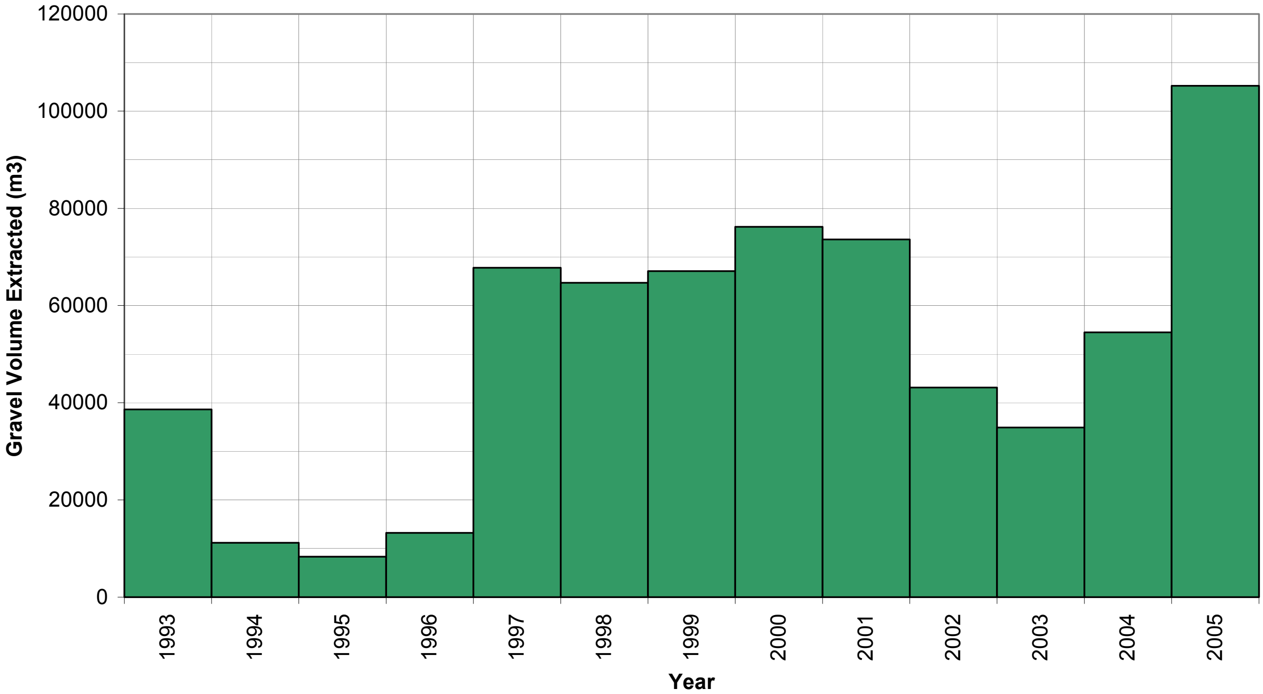
Table 4.1: Gravel Returns by Year for Each Part of the Ashley River System

Year	Part of River / Tributary									Volume by Year
	Lower Ashley[1]	Upper Ashley[2]	Ashley above gorge	Makerikeri	Okuku	Grey River	Karetu	Bullock	Mt Thomas	
1993	36,200			2,400						**38,600**
1994	10,000			1,200						**11,200**
1995	7,900			400						**8,300**
1996	11,600			1,600						**13,200**
1997	55,500			3,700		6,000	800		1,800	**67,800**
1998	60,500			700				500	3,000	**64,700**
1999	64,600		200			1,900			600	**67,300**
2000	49,000	22,000	21,500		3,700	1,000			500	**97,700**
2001	68,500								5,100	**73,600**
2002	40,000		400	100	200				2,800	**43,500**
2003	30,600	1,300							3,000	**34,900**
2004	51,000	500							3,000	**54,500**
2005[3]	104,400	800								**105,200**
Volume by Part/Trib.	**589,800**	**24,600**	**22,100**	**10,140**	**3,900**	**8,900**	**800**	**500**	**19,800**	**680,540**

1. Ashley River from coast up to Okuku confluence
2. Ashley River from Okuku confluence up to Ashley Gorge
3. Returns for 2005 doubled to extend record from June 2005 to end of year.

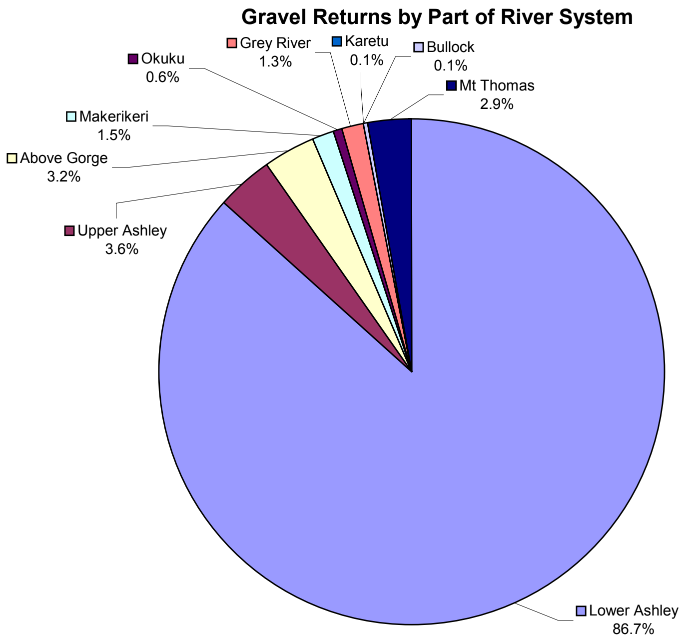
In terms of the bulk extraction, 680,500m^3 will be taken by the end of 2005, at an average rate of around 52,300m^3/yr. The temporal distribution of the extractions has not been even over the 13 years of return records. Figure 4.1 shows a distinct lull of activity prior to 1997, followed by a burst of activity up to 2001 and followed in turn by around average activity up to 2004 and what is a potentially big year in 2005.

Figure 4.1: Ashley River Gravel Extraction by Year



Similarly, the spatial distribution of extractions is not even across the river system. In a reflection of ease of access, proximity to transport links and end use and the perceived benefit of extraction from particular areas, the extractions are primarily from the Lower Ashley (below the Okuku River confluence). 86.7% of the gravel returns by volume are from this part of the river. The other major areas of extraction are the Upper Ashley (from gorge to the Okuku River confluence) and the Ashley River above the gorge with 3.6 and 3.2% of the gravel returns by volume, respectively. Figure 4.2 breaks the gravel returns down by the part of the river system the gravel was taken from.

Figure 4.2: Ashley River Gravel Extraction by Reach



Stopbanking was undertaken in 1968, 1973 and after 1976 when the river was increased to its present design capacity of 2,400m^3/s with 600mm freeboard.

5. River Bed Changes

Environment Canterbury monitors the Ashley 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
Lower Ashley (coast to Okuku River)[1]	0 to 20.92	25	5 – 1960/62, 1976, 1986/88, 1997, 2001[3]
Upper Ashley (Okuku River to gorge)[2]	22.10 to 41.30	10	2 – 1979, 2001

Notes:
1. Environment Canterbury data file: *Ashley River Lower MBL.xls*
2. Environment Canterbury data file: *Ashley 22.1-41.3kmMBL.xls*
3. 2001 survey only includes the 3 most downstream cross-sections.

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

- The cross-section locations measured from the coast.
- 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. Each of the surveys used the same cross-sections with each cross-section having the same width from survey to survey.

5.1 Lower Ashley River (0 to 20.92km)

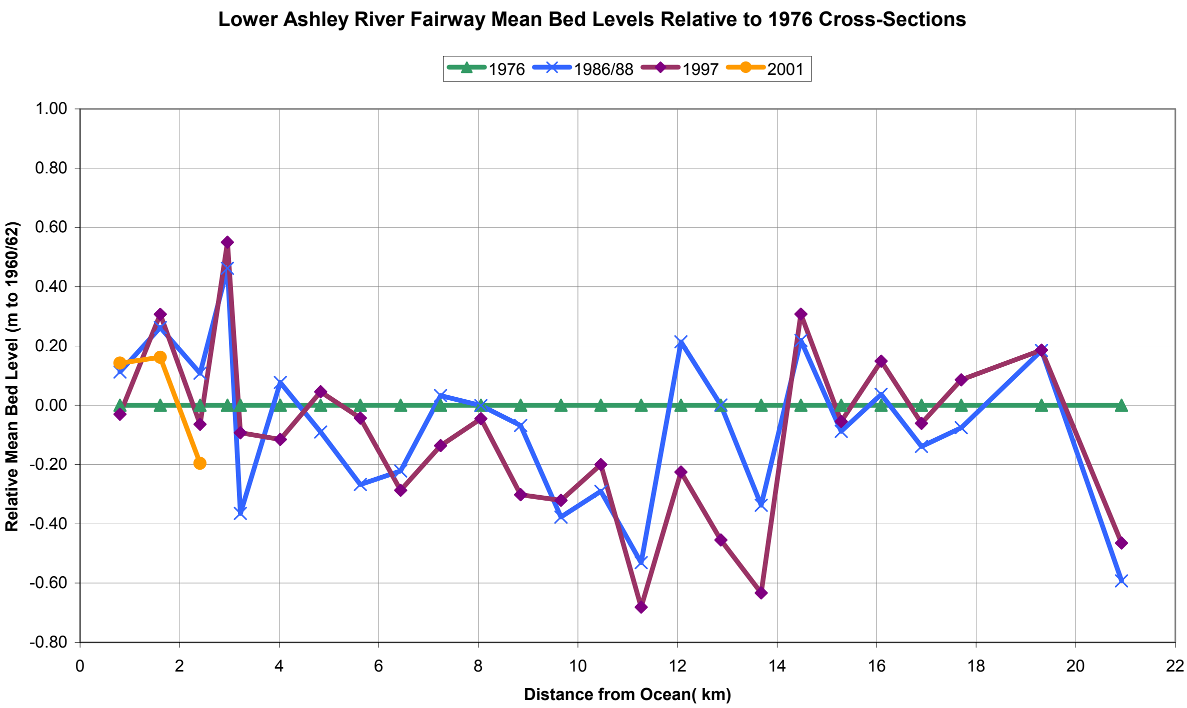
5.1.1 Mean Bed Level Changes

The change in the Lower Ashley River's fairway mean bed level (MBL) over the period from 1976 to 1997 is shown in Figure 5.1. The chart shows a general lowering of the bed level with the average MBL falling by 69mm from 1976 to 1986/88 and an additional 34mm from 1986/88 to 1997.

The river between 8 km to 14 km has experienced the largest fall in MBL. The 1997 survey shows around 5km of river in this area where the MBL has dropped by more than 200mm (and up to 600 mm) relative to the 1976 levels.

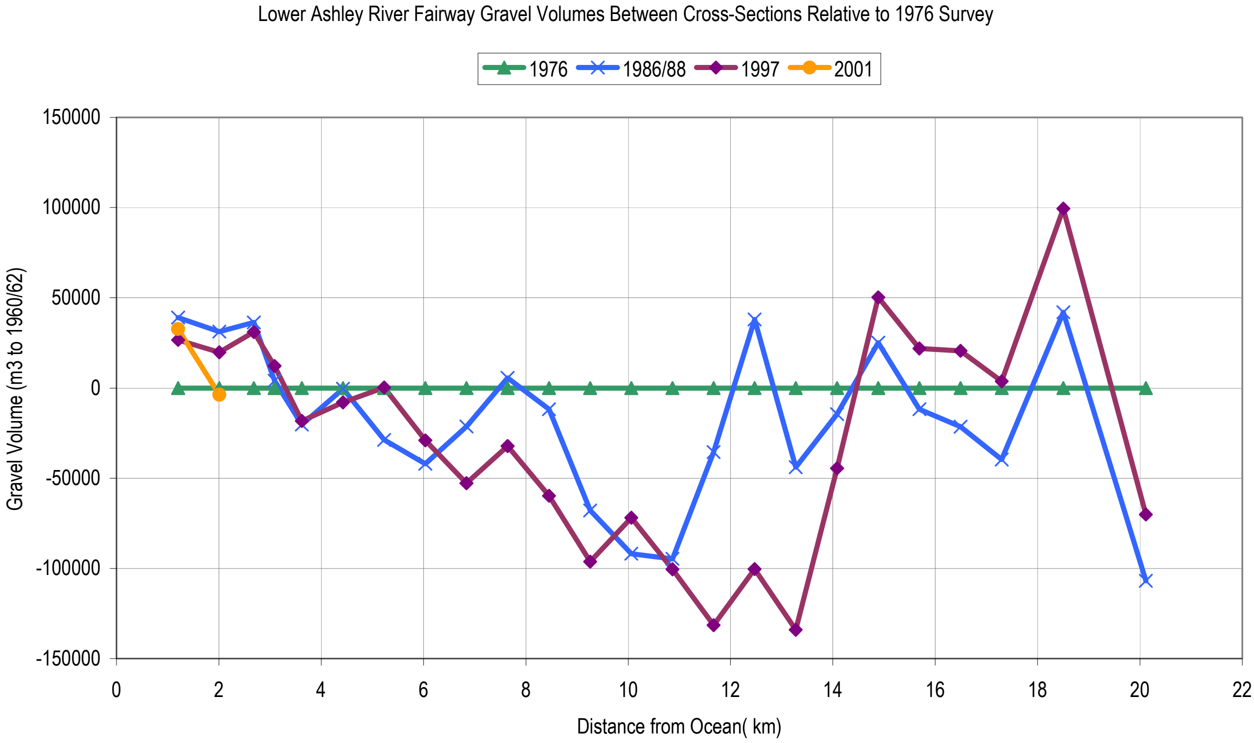
Within the Lower Ashley reach there are some exceptions to the falling MBL trend. Such exceptions are below 3km (where material may build up until a flood of sufficient magnitude can move it out to sea) and between 14 and 19 km.

Figure 5.1: Lower Ashley River Fairway MBL Relative to 1976 Levels



5.1.2 Gravel Volume Changes

Figure 5.2: Lower Ashley River Fairway Gravel Volumes Relative to 1976 Levels



The change in the Lower Ashley River's fairway gravel volumes over the period from 1976 to 1997 is shown in Figure 5.2. The chart describes a similar pattern to that discussed in Section 5.1.1 with some aggradation occurring near the river mouth and other points, but with an apparent overall loss of gravel.

The changing volume of gravel in the Lower Ashley in terms of absolute volumes and rate of loss/gain is shown in Table 5.2.

Table 5.2: Lower Ashley River Volume Changes

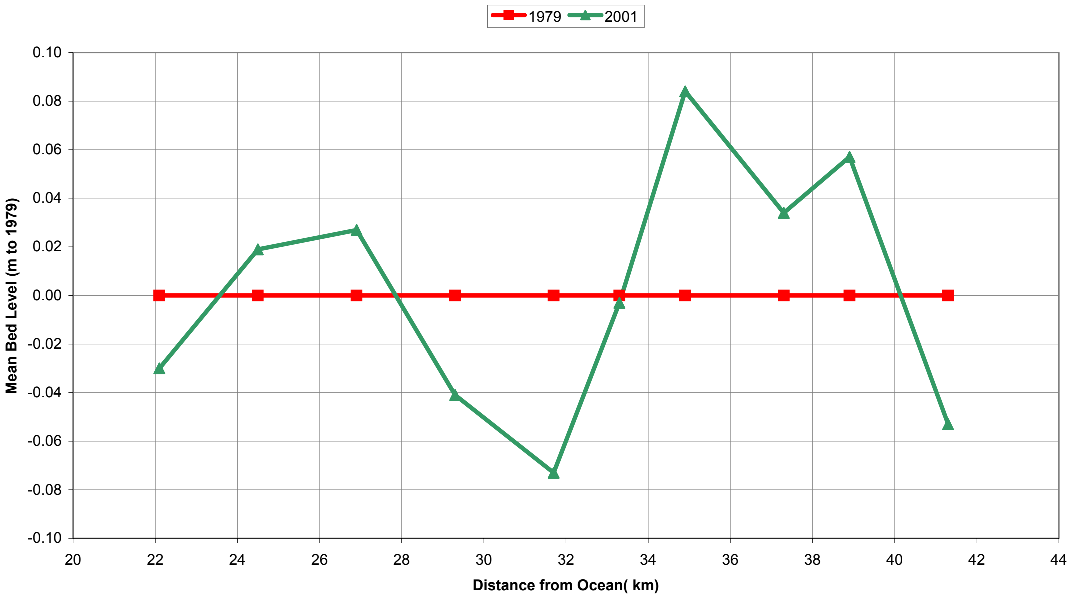
Period	Gravel Volume Change (m^3)	Rate of Change (m^3/year)
1976 to 1986/88	-431,000	-39,200
1986/88 to 1997	-232,000	-23,200

5.2 Upper Ashley River (22.10 to 41.30km)

5.2.1 Mean Bed Level Changes

The change in the Upper Ashley River's fairway mean bed level (MBL) over the period from 1979 to 2001 is shown in Figure 5.3. The chart shows no great variation in MBL with all observed changes being less than 100mm and no general trend being discernible. On average the Upper Ashley MBL has fallen 2mm between 1979 and 2001.

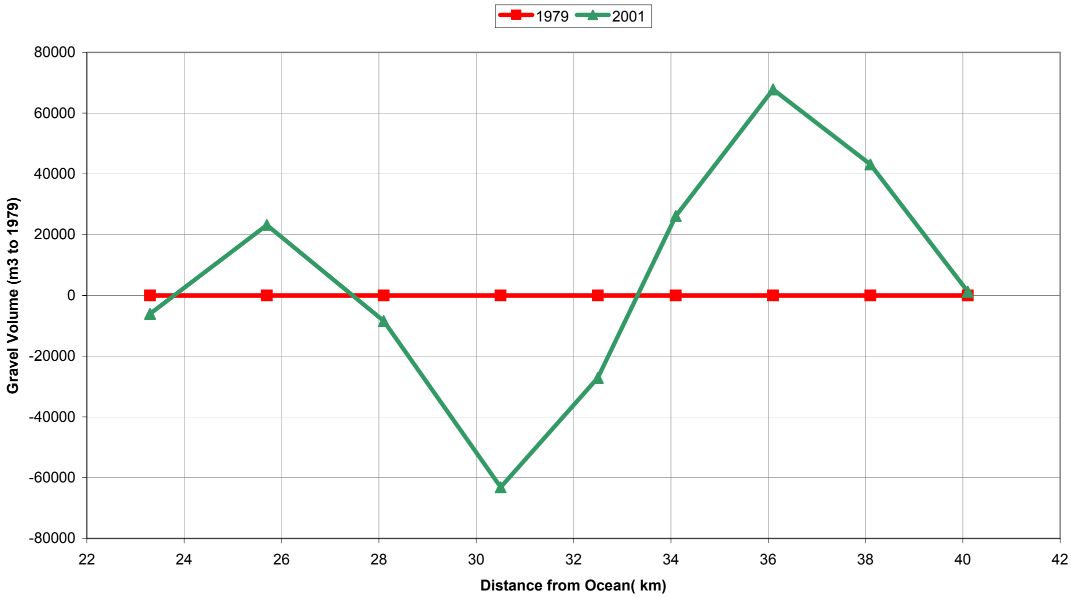
Figure 5.3: Upper Ashley River Fairway MBL Relative to 1979 Levels



5.2.2 Gravel Volume Changes

The change in the Upper Ashley River's fairway gravel volumes over the period from 1979 to 2001 is shown in Figure 5.4. The chart shows some build-up of material above 33km and some loss below 33km.

Figure 5.4: Upper Ashley River Fairway Gravel Volumes Relative to 1979 Levels



The changing volume of gravel in the Upper Ashley, in terms of absolute volumes, and rate of loss/gain is shown in Table 5.3:

Table 5.3: Upper Ashley River Volume Changes

Period	Gravel Volume Change (m^3)	Rate of Change (m^3/year)
1979 to 2001	+57,000	+2,600

6. Gravel Supply

Using the available data the gravel supply in the Ashley 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.

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

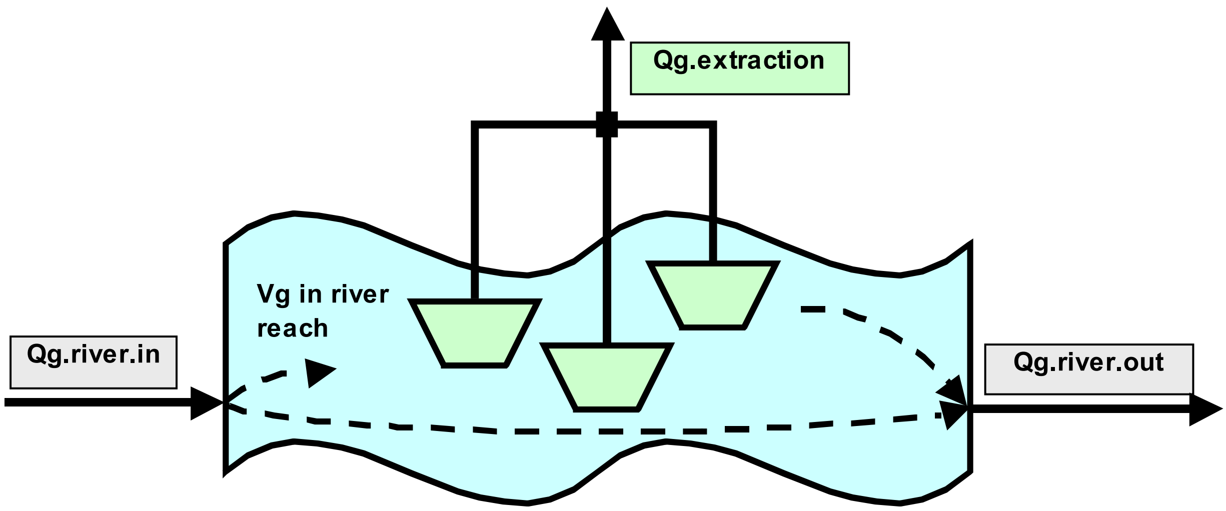
where:

$Q_{g.river.in}$	=	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 6.1 shows a schematic of the gravel volume flows and changes.

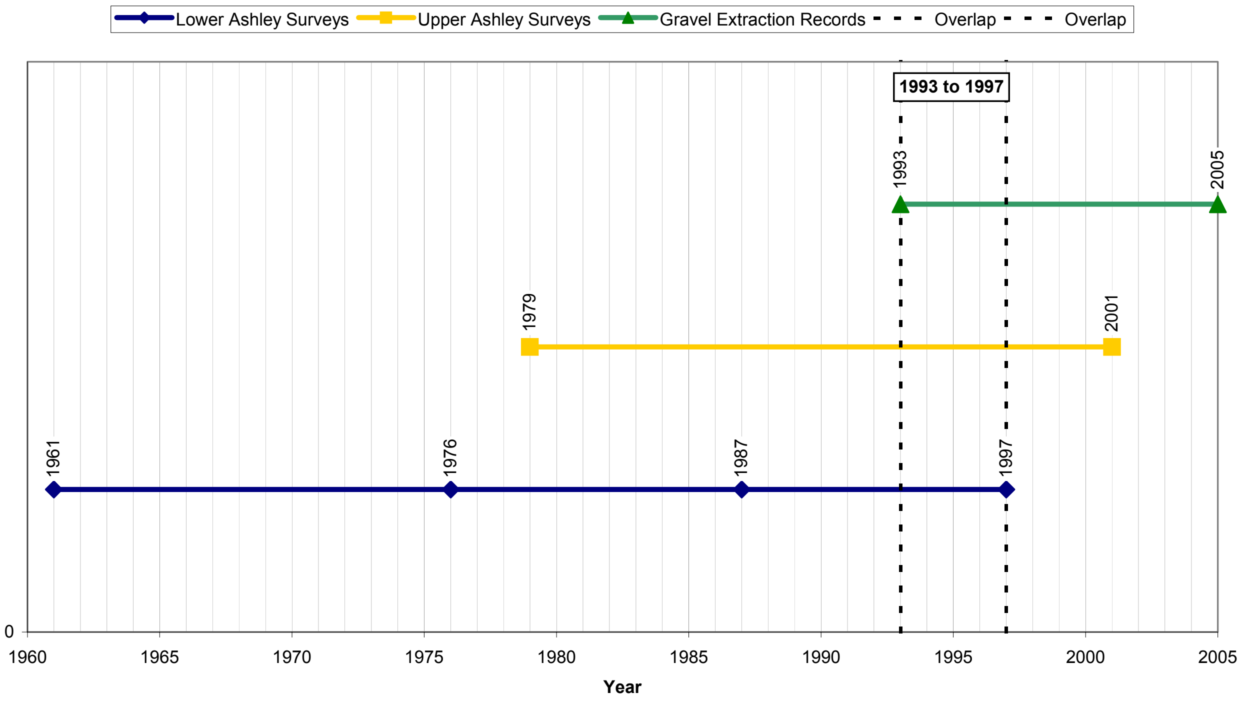
Figure 6.1: Schematic Representation of Change in Gravel Volumes



There are some inherent difficulties arising from the data available. These are associated with the periods of records. Extraction data is available from 1993 to 2005. For the river below the Okuku confluence the river surveys cover 1960/62 to 1997 and above the Okuku confluence from 1979 to 2001. The periods of record do not exactly coincide. Thus some interpretation is required.

To develop the volume balance the overlapping period of extraction records and riverbed surveys is used, as shown in Figure 6.2.

Figure 6.2: Ashley River – Periods of Records



Therefore the analysis period is 1993 to 1997 with the inputs for:

- Gravel extraction being the average of the extractions from 1993 to 1997
- Lower Ashley riverbed changes being the average change over the period from 1987 to 1997.
- Upper Ashley riverbed changes being the average change over the period from 1979 to 2001.

To estimate the gravel inflow we use the reported catchment erosion figures from McSaveney and Whitehouse (refer Section 3.2) for the Ashley River of 600t/km^2/yr and make the assumption that 10 percent of the sediment is bedload. Volumetrically this equates to a range of 30m^3/km^2/yr or 40,200m^3/yr (based on a bulk density for wet gravel of 2 t/m^3).

Thus for the Ashley River from the coast to the gorge the following observed quantities are used in Eqn. 2.

$\Delta V_g / \Delta t$	-20,600m^3/yr	(calculated as the sum of the observed rates for the Upper and Lower Ashley)
$Q_{g.ext}$	24,240m^3/yr	(refer Section 4)
$Q_{g.river.in}$	40,200m^3/yr	

to yield $Q_{g.river.out}$ = 36,560m^3/yr.

Of the calculated gravel flux into the mainstem of the Ashley River it is assumed that 25% enters the Lower Ashley River directly from the Okuku and Makerikeri Rivers and other local streams/river banks (based on the roughly estimated combined Makerikeri/Okuku/Lower Ashley River catchment area of around 350km^2 and the overall roughly estimated Ashley River catchment area of around 1,340km^2). The other direct gravel fluxes into the mainstem Ashley River are into the Upper Ashley River, from the gorge and other major tributaries.

For the Lower Ashley River from the coast to the Okuku Confluence the following observed quantities are used in Eqn. 2

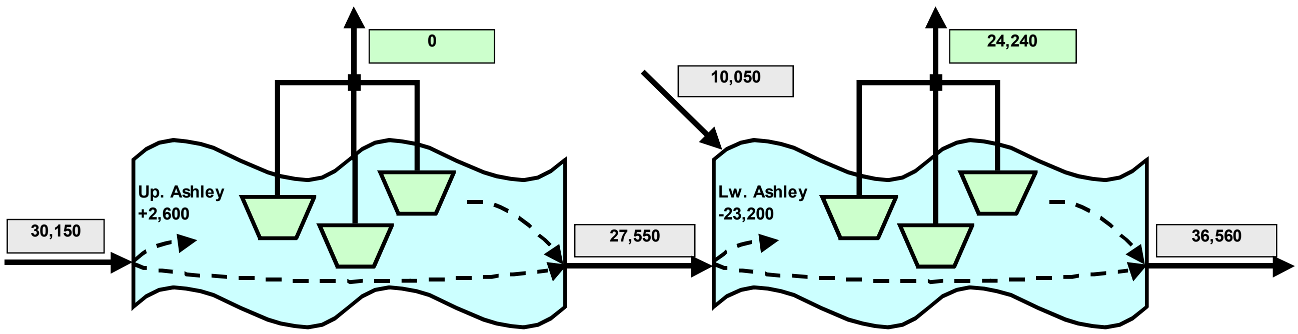
$\Delta V_g / \Delta t$	-23,200m^3/yr	(calculated as the sum of the observed rates for the Upper and Lower Ashley)
$Q_{g.ext}$	24,240m^3/yr	(refer Section 4)
$Q_{g.river.out}$	36,560m^3/yr	
$Q_{g.tribs}$	10,050m^3/yr	(25% of the total catchment yield being the local inflows into the Lower Ashley)
to yield		
$Q_{g.river.in}$	27,550m^3/yr	(the gravel flux between the Upper and Lower Ashley River)

A volume balance crosscheck using the Upper Ashley reach can be used to show the volume balances are maintained for all parts of the system.

The figures indicate some amount of gravel flow through to the coast.

The estimated annual average gravel volume flows, extractions and volume changes (all in m^3/yr) are shown in Figure 6.3. The grey coloured boxes show the river bedloads, the light green shows the gravel extraction and the pale blue box shows the rate of gravel volume change in the river reach.

Figure 6.3: Ashley 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 3,600m^3/yr in the Ashley River, with 2,600m^3/yr available above the Okuku River and 1,000m^3/yr available below the Okuku River.

The proxy design bed level indicated to us by Environment Canterbury is the 1976 bed levels. There are no recorded 1976 bed levels for the Upper Ashley River, so we have used the 1979 survey of that reach as the design level.

The latest complete Upper Ashley River survey (2001) shows around 140,000m^3 of "above design bed level" gravel between 35 and 41km, and around 20,000m^3 of "above design bed level" gravel around 27km. Future extractions could target the sustainable 2,600m^3/yr extraction and some additional extraction to remove the excess material in these areas.

The latest complete Lower Ashley River survey (1997) shows around 90,000m^3 of "above design bed level" gravel within 3km of the river mouth, and around 125,000m^3 of "above design bed level" gravel between 15 and 20km. Future extractions could target the sustainable 1,000m^3/yr extraction and some additional extraction to remove the excess material in these areas.

8. References

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