Ashburton River:
Status of gravel resources and management implications

Report U05/34

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Summary

Environmental Management Associates (EMA) were commissioned by Environment Canterbury (ECan) to evaluate the status of the river gravel resources and management implications on several rivers, including the Ashburton River. Some major findings and recommendations regarding gravel management are summarised.

Significant corrections and additions are required in the ECan gravel extraction data base. Following discussions with ECan the 2003 version of the consents data based was used with supplementary information compiled from other reports. This data should be incorporated into a revised data set.

Large volumes of gravel were extracted from the Ashburton River above the SH1 and Rail bridges (~km 18-21: ~20,000 to 66,000 m^3/y); and near Cochranes Road (km 13: 1981-1992 ~33,400 m^3/y). There was no commercial gravel extraction in 2004 and 2005 as bed levels were below critical limits at the bridges. Projecting recent trends (1990-2004), there would be no extraction by 2010.

Undermining of the shallow piled SH1 and Rail bridges on the Ashburton River is inevitable. The question is not if this will occur, but when this will occur. Critical bed levels in the bridge reach will ultimately result from three factors:

- Excessive gravel extraction in the upper Ashburton River.
- Degradation with headward erosion as the river re-grades in response to coastline retreat.
- Degradation as the upper plains entrenched zone migrates downstream into the bridge reach.

The situation has been managed using trigger bed levels at the bridges (Boyle 1996), but this is a temporary measure.

- In channel gravel extraction should be limited to small scale local uses; unless required for river control purposes.
- Alternative sources of gravel are required (e.g. upstream in the aggrading Blands Reach; off channel habitat creation – Hudson 1997; land mining).
- Options to stabilise the bridges should be re-examined (Reynolds 1994).
- A bedload rating relation, calibrated against volume changes, could be established to evaluate variability in bedload; and to guide annual gravel extraction volumes in this and other rivers.

There are some pressing data/analysis gaps:

- Re-survey of the lower reaches of the Ashburton is required to determine when coastal retreat induced incision will affect the bridges. This may require longitudinal surveys in addition to the cross section surveys.
- An analysis of detailed floodplain topographic maps is required to determine the position of the zone of entrenchment in the South Branch and lower North Branch.
- Cross section surveys should be extended into the lower South Branch to determine if the zone of entrenchment is migrating downstream.

Commercial gravel extraction does not occur in the lower North Branch, but the bed degrades in response to extraction downstream in the Ashburton River. Recently, when gravel extraction in the Ashburton decreased (2004), then ceased (2005) the mouth aggraded although large volumes of gravel were extracted upstream in Blands Reach.

North Branch has a major zone of aggradation where there is a break in channel slope in Blands Reach. This reach is perched above the floodplain and threatens to break out into alternative flow paths. The reach has been the focus of channelisation since the 1930s. It is proposed to reinstate the 1982/84 bed levels by removing 320,000 m^3 from the reach to provide greater flood protection. At present consent conditions related to bed levels around the Ashburton Bridges prevent gravel extraction for the flood protection scheme.

Previous analysis indicated there were unlikely to be significant effects on the Ashburton bridges reach from North Branch gravel extraction. The present analysis reinforces this conclusion, particularly regarding recent bed build up near the mouth of the North Branch when gravel extraction of ~50,000 – 60,000 m^3/y occurred in Blands Reach.

- Floodplain management gravel extraction could proceed without adverse effects on the Ashburton bridges reach provided that no further extraction is undertaken in the bridge reach.

Lower South Branch is degrading, not from limited gravel extraction in the reach (~1,600 m^3/y) itself but from over extraction downstream in the Ashburton River. Additional surveys extending from the Ashburton River into South Branch are required to determine if reduced gravel extraction (or cessation of extraction) in the Ashburton results in reduced South Branch degradation near the mouth.

Over the long term the upper plains zone of entrenchment will extend into the lower South Branch and Ashburton River. Surveys are required to verify the position of the zone of entrenchment.

Extraction of 60,000 m^3 for stopbank construction over the 6.5 km reach above Valetta Bridge will lower bed levels 0.07 m on average, but effects were considered to be no more than minor (Hudson 2003). A re-survey of the South Branch is required to examine more recent changes, and to provide a baseline for the proposed stopbank excavations.

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1 Introduction

Environmental Management Associates (EMA) were commissioned by Environment Canterbury (ECan) to evaluate the status of the gravel[1] resources and management implications for gravel extraction in several rivers including the Ashburton River.

The Ashburton River system consists of the South Branch Ashburton River (SBAR; "South Branch"); the North Branch Ashburton River (NBAR; "North Branch"); and the mainstem Ashburton River which forms where the North and South Branches merge about 21 km from the coast.

This report builds on previous investigations on gravel extraction and stopbank construction in the Ashburton River system (e.g. Hudson 2000, 2000b, 2002, 2003). Issues include:

1. River gravels are a preferred source of building materials and sustainable supply is critical. The preferred location for extraction immediately upstream of the Ashburton Bridges (~km 18-21) is unsustainable.
2. Gravel extraction threatens the State Highway 1 (SH 1) and Rail bridges at Ashburton (Reynolds 1994; Hall 2001), with major financial implications and potential liabilities to Environment Canterbury.
3. Gravel extraction and control of gravel supplies are essential components of the Ashburton River floodplain management strategy, particularly in the North Branch (Beck 1937; Stringer 1981; Hudson 2000).

It was recognised that over exploitation of gravel can have significant environmental effects in the rivers themselves (Hudson 1997; Day & Hudson 2001; Kelly *et al.* 2005) and on the coastal zone (e.g. reduced aggregate supplies accelerating coastal erosion – Kirk 1991). These issues were addressed in detail by Sagar *et al.* (1999) and Hudson (2000; 2002; 2003). These studies concluded that excavations back to 1982/84 bed levels to increase fairway flood capacity, and stopbank construction, would have less than significant effects, provided precautions were taken.

This evaluation provides a brief overview of river character and aspects of the flooding problem before evaluating:

- Gravel supplies.
- Rates and location of gravel extraction.
- Affects on the river bed.
- Discussion and recommendations.

[1] "Gravel" is a specific size range of rock fragments (2-64 mm); but is also commonly used to describe riverbed material, largely consisting of sand and gravel sized material, but ranging from very fine material (silt and clay) to cobbles and boulders. Also called "shingle."

2 River character and processes

The Ashburton River has two major tributaries: the North Branch and South Branch Ashburton River (Fig. 1). The South Branch (540 km^2 at Mt. Somers gauge)[2] has its headwaters in the Arrowsmith Range and the Ashburton Glacier and flows in a south-east direction about 100 km to join the North Branch 21 km from the sea. Several peaks in the Arrowsmith Range are over 2000 m (Mt. Arrowsmith 2781 m).

South Branch flows through a steep U shaped valley in the Ranges, through an upper gorge and onto an extensive moraine and outwash plain past the Ashburton Lakes, before the river cuts through a confined reach (the "lower gorge"), and spills onto the Canterbury Plains around Inverary (the Mt Somers gauge site; km 66).[3] In the Ashburton lakes area the river is braided (Fig. 2). Two major streams, Taylors (95 km^2) and Bowyers (64 km^2) flow from the foothills over the plains into the South Branch at km 43.4 (immediately below Valetta; Fig. 1).

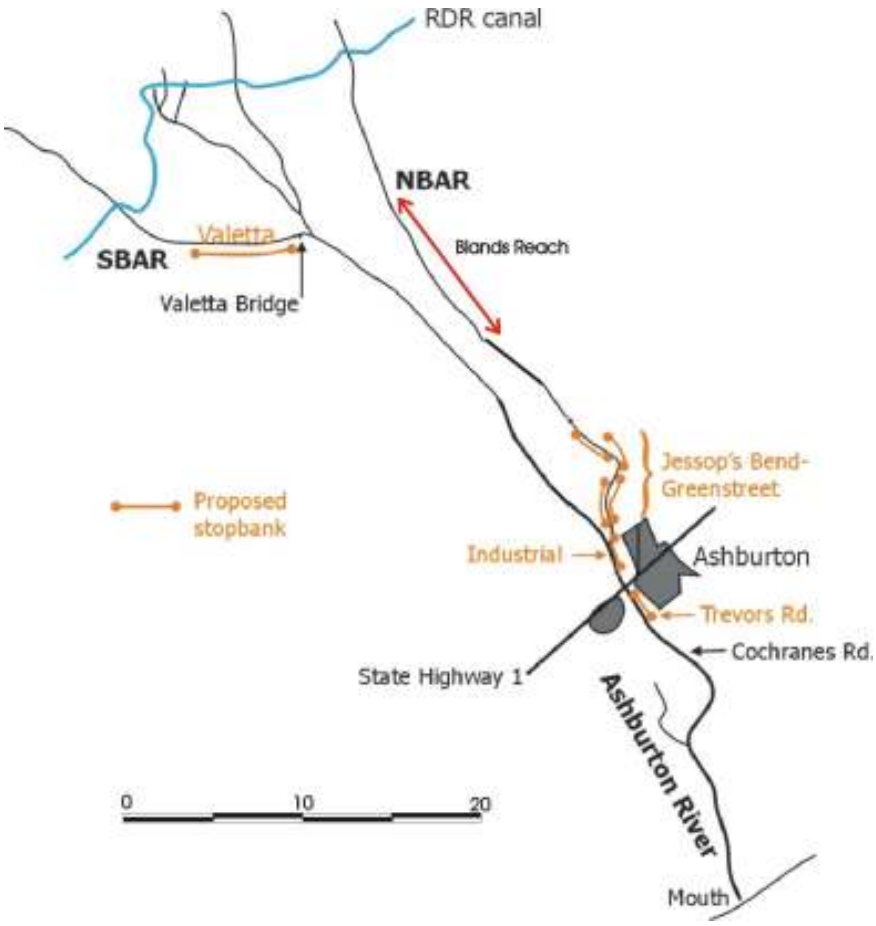


Fig. 1 Lower Ashburton River geography

[2] Catchment areas are from Young (1992).
[3] Distances on the mainstem and South Branch refer to the cross section distances from the sea. North Branch distances re-start at the confluence. Supplementary distances are measured from TopoMap triangulating between way points.

Fig. 2 South Branch view upstream from km 71: braided channel in the moraine and outwash plain

The source of the North Branch is in the Palmer, Taylor, Black Hill, Old Man and Mt Hutt ranges. The river flows in a south-east direction for 98 km to the confluence with the South Branch. The catchment at Old Weir Gauge (km 43.6), which is ~3 km upstream of the Canterbury Plains, is 276 km^2. Pudding Hill Stream is a high energy gravel bed tributary flowing from Mt Hutt into the North Branch below SH 72. Relatively small spring fed streams (notably Harding Creek and O'Shea Creek) flow from the plains into the North Branch. At the mouth the North Branch catchment 490 km^2.

Upper catchment geology is summarised by de Joux (1992). The foothills and ranges are composed primarily of intensely folded, fractured and faulted highly indurated greywacke and argillite. Mt Somers is volcanic and Rhyolite, Andesite, and Mt Somers volcanics occur in the Stour River and Taylors Stream catchments. In the upper catchment the valley floors are underlain by glacial outwash and till deposits (Fig. 2). There are pockets of limestone, siltstone and quartzose coal measures along the fringes of the eastern foothills.

Extensive glacial outwash and alluvial fan deposits from rivers flowing from the foothills and ranges formed the Canterbury Plains. Fans developed from the South and North Branches coalesced with the much larger mountain derived fans of the Rakaia to the north and Rangitata to the south. At present the fan surface extends almost 60 km from the foothills to the sea, where the fan is eroded by coastal wave action.

At State Highway 1 (SH 1) the catchment area is 1,373 km^2; and there is little gain in area downstream to the sea. A catchment map in Young (1992) shows the lower catchment is less than 10 km wide over the lower 40 km and the area above the mouth is 1,520 km^2.

Cuff (1992) described the upper catchment as tall tussock grassland above 900 m elevation, with extensive areas of scree, rock and ice (3,600 ha in the North Branch and 4,990 ha in the South Branch). Below 900 m the short tussock grasslands were extensively modified and hawkweeds are a feature. The eastern portion of the hill country has remnant native forest (~3,000 ha; mainly beech). The Plains are improved pasture with annual crops, and woodlots, being common. The area is extensively irrigated.

The largest centre in the catchment is Ashburton-Tinwald with a population of 18,477 in 2001 (Statistics New Zealand). Other centres include Mt Somers (2,307) and Methven (1,134). Hakatere is a small settlement, primarily holiday baches, on the terrace at the river mouth. The Ashburton District population was 25,433 in 2001.

There are three main river segments in the plains reach of the Ashburton system (Leckie 1994), which are fundamentally important to bed material supply; bed level trends; and the stability of infrastructure, particularly the Ashburton River bridges:

- A degrading upper plains segment.
- A zone of minimal incision.
- A degrading lower segment near the coast.

Leckie (1994) places the downstream end of the upper entrenched segment at about river km 20 (i.e. between the Ashburton bridges and the North and South branch confluence); and the transition between the lower segments around km 13. More detailed analysis suggests are more complex situation.

It is clear that the upper North and South branches are entrenched. Topographic maps show the “lower gorge” of the South Branch at Inverary bridge (km 66) is entrenched ~50 m. The entrenchment progressively shallows downstream. Immediately above SH 72 Bridge (km 56.8) there are multiple terraces on the north and south banks; with the north bank terraces 22 m above the river bed. By km 52 the nearby terrace is ~8 m above the mean bed level, and this decreases to ~4 m at Valetta Bridge (km 46). Terraces are continuous on the north bank and intermittent on the south bank until ~km 30. The north bank terrace extends a further 1.6 km downstream. There are minor stopbanks in the lower 8 km of the South Branch; and stream banks are relatively low.

Continuous north and south bank terraces are mapped on the North Branch from the gorge (~30 m) downstream to above the RDR canal (~km 32). Intermittent distal terraces (~2 km from the river) are mapped downstream to around Thompsons Track (km 22). Nearly continuous stopbanking of both banks occurs from above Thompsons Track downstream to the Ashburton River (km 21.3 from the coast).

Stopbanks suggest shallow incision of the North Branch, but in fact the river is perched about 4 m above the floodplain. This build up, in “Blands Reach”, occurs at a break in slope in the channel and extends from ~km 5 to km 28 (Fig. 1). ECan floodplain topographic maps suggest the channel is entrenched 2.5 near the mouth; and 1 to 2 m in the lower North Branch through the proposed stopbanking reach (Fig. 1). Flood breakouts are a major concern in the lower North Branch.

The zone of minimum erosion is when the rivers historically overtop their banks and flowed in alternative paths to the sea. Ironically, these places are where settlement took place because they were natural fords across the large braided rivers. Upstream of Ashburton, at Jessops Bend, the preferred flow path of the river is straight to the sea via the Ashburton urban area (down the course of what is now Wakanui Stream). There are various

historic channels across about a 3-8 km swath from the confluence of the North and South branches to the sea (McPherson 2000).

Coastline erosion is causing the Ashburton River to re-grade to a new base level. The river is becoming shorter and steeper (section 6.1). At the mouth of the Ashburton River coastal cliffs are 24 m high and decline northward and southward along the coast (Kirk *et al.* 1977, Kirk 1991). Analysis of slopes and cliff heights suggest that 4 to 6 km of land was eroded from the edge of the plains in the last 4,000 to 7,000 years (Kirk 1991).

McPherson (1997) stated that "The first notable change in riverbed gradient, which might mark the position of a knickpoint … commences a short distance down stream of State highway 1 road bridge at the 90 m.a.s.l. contour." The 90 m contour is around km 18, about 200 m downstream of the SH1 Bridge. Leckie (1994) places the transition around km 13; which is where Hudson (2000) shows the bed is no longer deeply entrenched. However, there is no significant discontinuity in the 1984 mean bed levels that identifies a knickpoint at this location. There is a break in thalweg slope (the deepest part of the channel) around km 7.5 which may be the knickpoint.

The Ashburton River discharges into the Canterbury Bight through a lagoon and coastal barrier. Coastal processes overwhelm river inputs - the coast is eroding and deltas are temporary (Browne 2002) although substantial bed material is delivered to the coast (Kirk 1991; Hicks 1998; Hudson 2000).

3 Flooding and flood management

Floods are generated from prolonged high intensity rainfall from two types of weather pattern (Young 1992). From the coast to the eastern foothills, heavy rainfall occurs mainly from south to south west airflows, but some significant precipitation occurs with moist east to north-east air flows. Headwater rains occur with north westerly wind orographic spillover from the main divide. Rainfall is strongly correlated with elevation, with rainfall increasing from 700 mm near the coast to 2,000 mm in the Mt Arrowsmith area. Ashburton Glacier melt enhances spring and summer flows.

Historic flood records are poor in the Ashburton catchment. It is probable that the most severe flood in the Ashburton [since 1888; SCCB 1964] occurred in April 1951: an estimated 2,500 m^3/s was recorded at SH 1 at Ashburton (Young 1992). The bridge approaches and large areas of farmland were flooded when floodwaters breached the stopbanks. The February 1945 flood was of similar magnitude. Other notable floods occurred in January 1934, March 1941, May 1957, January 1965 and March 1986.

Since 1967, when hydrological records were kept at Mt Somers on the South Branch, the average annual maximum flood is 109 m^3/s (ECan data to 2001). The largest recorded event was 1986 (309 m^3/s); with other events exceeding the average annual flood including: 1978 (287 m^3/s); 1994 (184 m^3/s); 1970 (181 m^3/s); 1979 (178 m^3/s); and 2002 (160 m^3/s).

Flood protection from 50 year (rural areas) and 100 year events (Ashburton-Tinwald urban areas) were proposed in the Lower Ashburton River

Improvement Scheme (LARIS: SCCB 1964). Little hydrological data was available at the time; and estimates were largely based on meteorological and topographic data; and slope area computations from the 1951 flood. The mainstem Ashburton 50 and 100 year flood estimates were 47,500 cfs (1,345 m^3/s) and 53,000 cfs (1,500 m^3/s), respectively. The North Branch 50 year flood was estimated as 20,000 cfs (566 m^3/s); and the South Branch above and below Taylors-Bowyer stream as 18,000 cfs (510 m^3/s) and 30,000 cfs (850 m^3/s), respectively.

Flood frequencies were computed by Pearson (1996) (Table 1). Boyle (2000) stated these estimates substantially increased the flood peaks that would need to be constrained by proposed works to upgrade flood protection to accommodate 200 year floods for urban areas; 100 year floods in the Greenstreet area[4]; and 50 year events in rural areas. Design flows were 790 m^3/s for the lower North Branch; and 1,965 m^3/s for the mainstem Ashburton (Boyle 2000; Kingsbury 2000).

Historic flood estimates are surprisingly good given the indirect methods used. It would appear if the historic scheme design flood estimates were excessive for the South Branch and the North Branch; with a ~130 m^3/s under-estimate for the mainstem Ashburton.

Table 1 Flood frequencies (Pearson 1996)

Return Period	2.33	10	20	50	100	200	500	1000
SBAR	110	180	226	295	359	432	550	657
NBAR	200	328	410	536	652	786	1000	1194
SH1	500	820	1025	1340	1630	1965	2500	2985
Return period years; Flows m^3/s; SBAR at Mt Somers; NBAR at Old Weir; SH1 Ashburton River at State Highway 1								

Active river channel widths were greatly constricted by the early works proposed by Beck (1937), and with LARIS and subsequent works (Fig. 3; Fig. 4; Fig. 5) (Hudson 2003). SCCB (1964) outline the scheme rationale:

> Fairway Widths: Widths optimum for the dual and somewhat conflicting purpose of keeping stopbanks to reasonable heights while maintaining velocities more than sufficient to transport bed-load were adopted….
>
> Main Stream: 800 feet [243 m]
>
> South Branch: 800 feet [243 m]
>
> North Branch (in the flatter reaches): 275 feet [84 m]
>
> North Branch (in the steeper reaches): 500 feet [152 m]
>
> Channel geometry: It is considered that the channel geometry resulting from the adoption of the above grades, widths and discharges will

[4] SCCB (1964) report the construction of a stopbank at Greenstreet in 1957 to accommodate a 100 year flood for the South Branch, including the proposed North Bank diversion and Dry Creek runoff for a combined flow of 49,500 cfs (1,402 m^3/s) with 1 foot freeboard (30 cm).

control excessive braiding with its loss of transporting power and will not be difficult to maintain.

In the upper plains the Ashburton has a "wandering channel" (Carson 1984) to about the RDR intake and evolves into braided channels that persist to the river mouth. With channelisation vegetated islands were removed, side channels cut off, berms were treed, and the river diverted to flow in a constricted exposed gravel bed. Active river bed channel widths were reduced by 39% in the Ashburton, 50% in the lower 27 km of the South Branch, and 54% in the lower 29 km of the North Branch.

Channelisation was in stages associated with various schemes. For the Ashburton, North and South branches, cumulative channel area reductions were: 1952 <1%; 1958 ~15%; after 1965 ~25%; before 1978 ~39%; between 1981 & 1988 ~44%, and by 2001 ~47%.

4 Gravel supply

Gravel is derived from catchment and channel erosion (river bed and banks, including terraces). Cuff (1974) estimated sediment production from mass movements (e.g. screes, avalanches), gullying and stream bank erosion in the upper catchment yielded 160,000 m^3/y from the North Branch and 120,000 m^3/y from the South Branch. These yields are very high compared with the Opihi catchment (60,000 m^3/y; 404 km^2 at the Saleyards). Erosion is expected to be great because as the Southern Alps are being uplifted, they are simultaneously being eroded (Adams 1980).

Catchment works sought to control sediment inputs (SCCB, 1964, 1973, 1981), but by 1992 only about a quarter of the proposed works were completed (Collins 1999). Connell (1983) noted only 30-40% of the eroding areas could be controlled.

An explicit intent of the channelisation works was to reduce gravel inputs from river bank erosion (SCCB 1964; Stringer 1981). This was largely successful because there are few places where erosion of the berms currently occurs. These changes are superimposed on channel incision into the upper plains in response to uplift (Leckie 1994).

South Branch is expected to contribute less bedload from catchment erosion than North Branch; but there is no large natural sediment trap in South Branch (as there is in North Branch). Upper plains erosion (in response to uplift – Leckie 1994) contributes bedload to the Ashburton River. Degradation is discussed in section 6.3. In addition to material derived from channel degradation, it is estimated that from 1961 to 1997 there was a net contribution from the upper catchment and tributaries of the South Branch of 6,400 to 9,400 m^3/y. Hudson (2000) suggested that with controlled gravel extraction in the Ashburton bridge reach, headward erosion probably ceased, which would reduce net bedload contributions from the South Branch to an average of ~18,000 m^3/y. [5]

[5] Net bedload contribution refers to the material deposited in the channel and does not include material transported through the channel with no net change in mean bed levels.

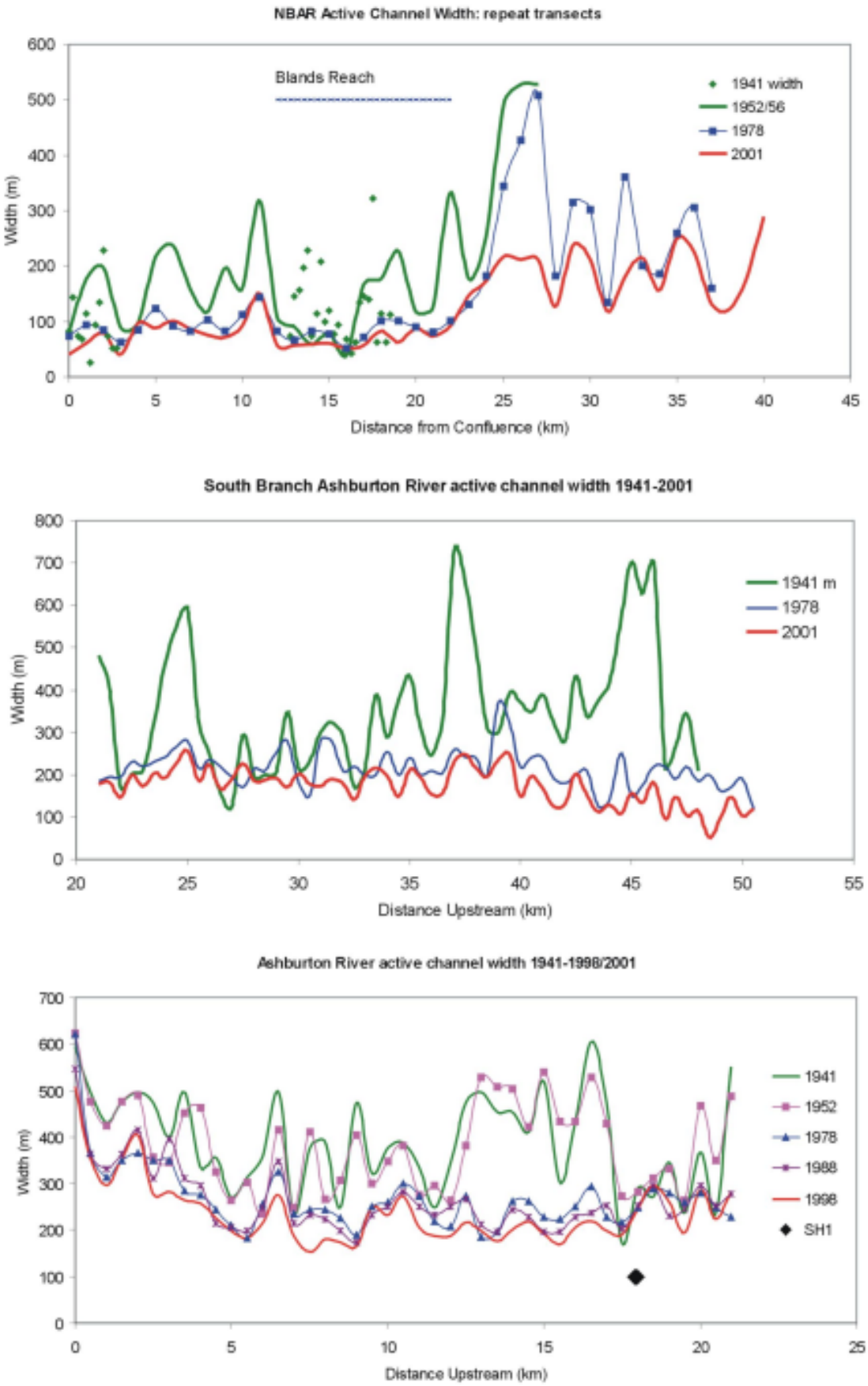


Fig. 3 Ashburton River system active channel widths

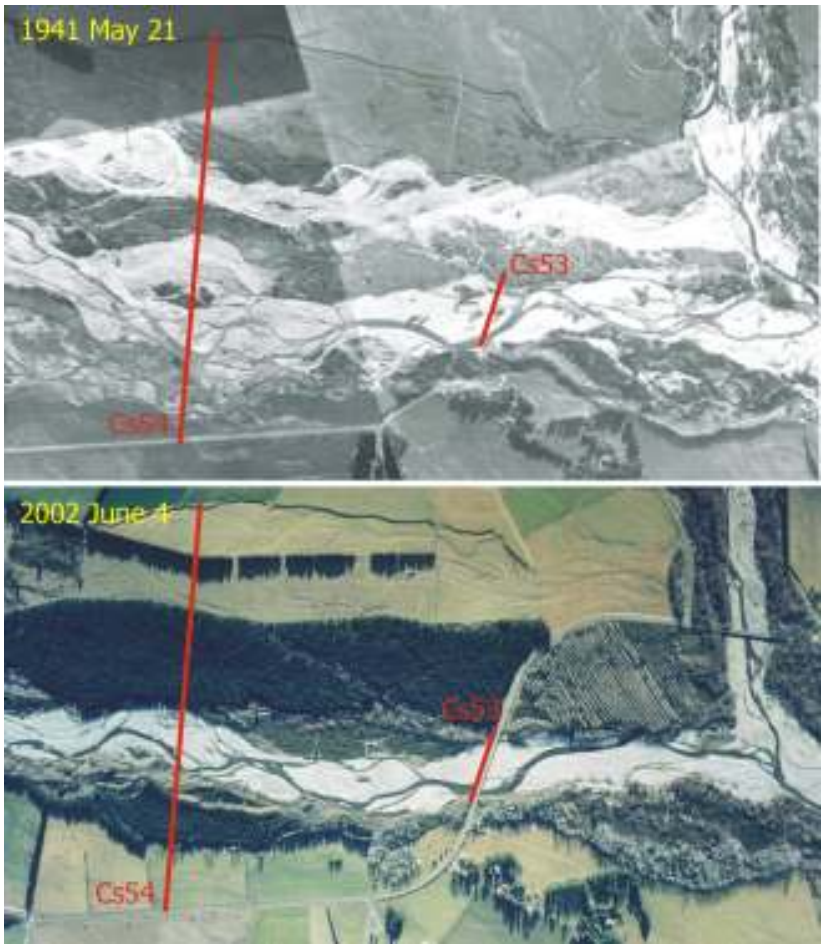


Fig. 4 South Branch at Valetta Bridge (km 45): 1941 and 2002

Fig. 5 North Branch view upstream at Digbys Bridge (~24 km from the sea) (ECan photograph March 2001)

Substantial bedload trapping occurs where the slope decreases in Blands Reach of the North Branch (Connell 1983). Accounting for gravel extraction, the average net annual bedload inputs were:

- 1982 to 1987/88: ~75,000 m^3,
- 1982 to 1997: ~65,000 m^3
- 1987/88 to 1997: ~60,000 m^3

For shorter periods, greater variability is evident – net losses to significant gains occur in the annual surveys. (However, only segments of the NBAR are surveyed this intensely - Hudson 2000).

Over the relatively short term there does not appear to be a reduction in bedload supply from the upper plains reach of the North Branch. Connell (1983) estimated that 80% of the shingle was derived from the upper North Branch catchment with the remaining 20% coming from the river above Blands Reach to the gorge (i.e. ~15,400 m^3/y). Hudson (2000) estimated that up to a third of the bedload was derived from the river between Blands Reach and the gorge for different periods from 1982 to 1997. The overall bed material load was lower from 1990 to 1997 (66,000 m^3/y) than from 1957 to 1982 (77,000 m^3/y). However, the proportion and amount derived from channel erosion was larger (30%, ~19,800 m^3/y from 1990-1997 vs. 20%, ~15,400 m^3/y from 1957-1982).

On average, less than 10% of the volume of gravel deposited in Blands Reach moves downstream to the lower North Branch. From 1982 to 1997 average bedload deposition in the lower North Branch below Blands Reach was 5,900 m^3/y. Further downstream the lower North Branch degraded as the result of excessive gravel extraction in the Ashburton bridge reach contributing ~6,000 m^3/y in the period 1982-1997.

Contrary to the expectations of the scheme, channel confinement and development of a single thread channel probably decreased rather than increased sediment transport because the major mechanism of gravel transport appears to be bank scour along braids (Carson & Griffiths 1989).[6] In the North Branch, where channels have been highly confined, aggradation may be worsened by the smaller width of channel available for deposition (Carson 1997).

Connell (1992) estimated bed material input into the Ashburton River to be 30,000 m^3/y, and suggested that half of this could be sustainably excavated. However, more recent records indicate net bedload inputs into the Ashburton River over the longer term are about half the input used to guide current gravel extraction (Hudson 2003: ≤16,700 m^3/y).

5 Rates and location of gravel extraction

5.1 Data issues

Connell (1983, 1988, and 1991) reported historic gravel extraction and ECan provided a summary of consent records since 1990. The most recent

[6] This observation is supported by time-lapse photography in the Waimakariri River at Crossbank: Hicks *et al.* (2000).

consents records data base is inconsistent with previous versions and is not complete. Discrepancies are significant:

- South Branch: Total extraction was previously reported as 21,207 m^3; the updated data base for the same period is 134,793 m^3.
  Reported sites of extraction are inconsistent with the river distances (they start several km downstream of the South Branch).
- North Branch: More than 20% of the record (127,985 m^3) is missing (mainly from the 1990s).
- Ashburton River: Over 10% of the record is missing from the updated data set (26,020 m^3). This includes 15,500 m^3 of gravel extracted from the Ashburton River (spreadsheet attached to Pinfold letter of 3 July 1992), that was documented in previous reports but not included in the revised consents data base. Reported sites of extraction are inconsistent with earlier records.

Some of the apparently "minor" errors are significant. For example Ashburton extraction that took place downstream of the highway bridges in the 1990s is now reported as occurring above the bridges. The downstream shift in extraction allowed the bed to build up in the bridge reach. This is of fundamental importance.

In all cases the latest data set is incorrect. Following discussions with ECan (Kevin McFall) the 2003 version of the consents data based was used with supplementary information compiled by Hudson (2003).

If any sense is to be made of river channel changes over time, it is imperative that the gravel extraction records are accurate to within ±10%. Also it is important to know if volumes or tonnes are being reported by contractors and the conversions used to calculate loose and extracted volumes.

5.2 Ashburton River

More than one million m^3 of gravel was extracted from the Ashburton River between the bridges and confluence of the North and South branches (~km 18-21) from 1961 to 1997 (Fig. 1). From 1966 to 1980 ~66,000 m^3/y was extracted from the bridge-confluence reach. From 1981 to 1992 extraction occurred downstream (near Cochranes Road; ~km 13). There are no estimates of extraction for earlier periods.

In mid 1992 commercial extraction moved back to the bridge-confluence reach and averaged 16,400 m^3/y to 2002. There was little extraction in 2003 (4,944 m^3) and none in 2004 because critical bed levels were reached at the Ashburton bridges (Boyle 1996). Projecting recent trends (1990-2004), there would be no extraction by 2010.

Stopbank construction in 2005 at Trevors Road (Fig. 1) involved gravel removal of 11,500 m^3 from the riverbed near the stopbank.[7] This was not expected to induce headward retreat into the bridge reach (Hudson 2003).

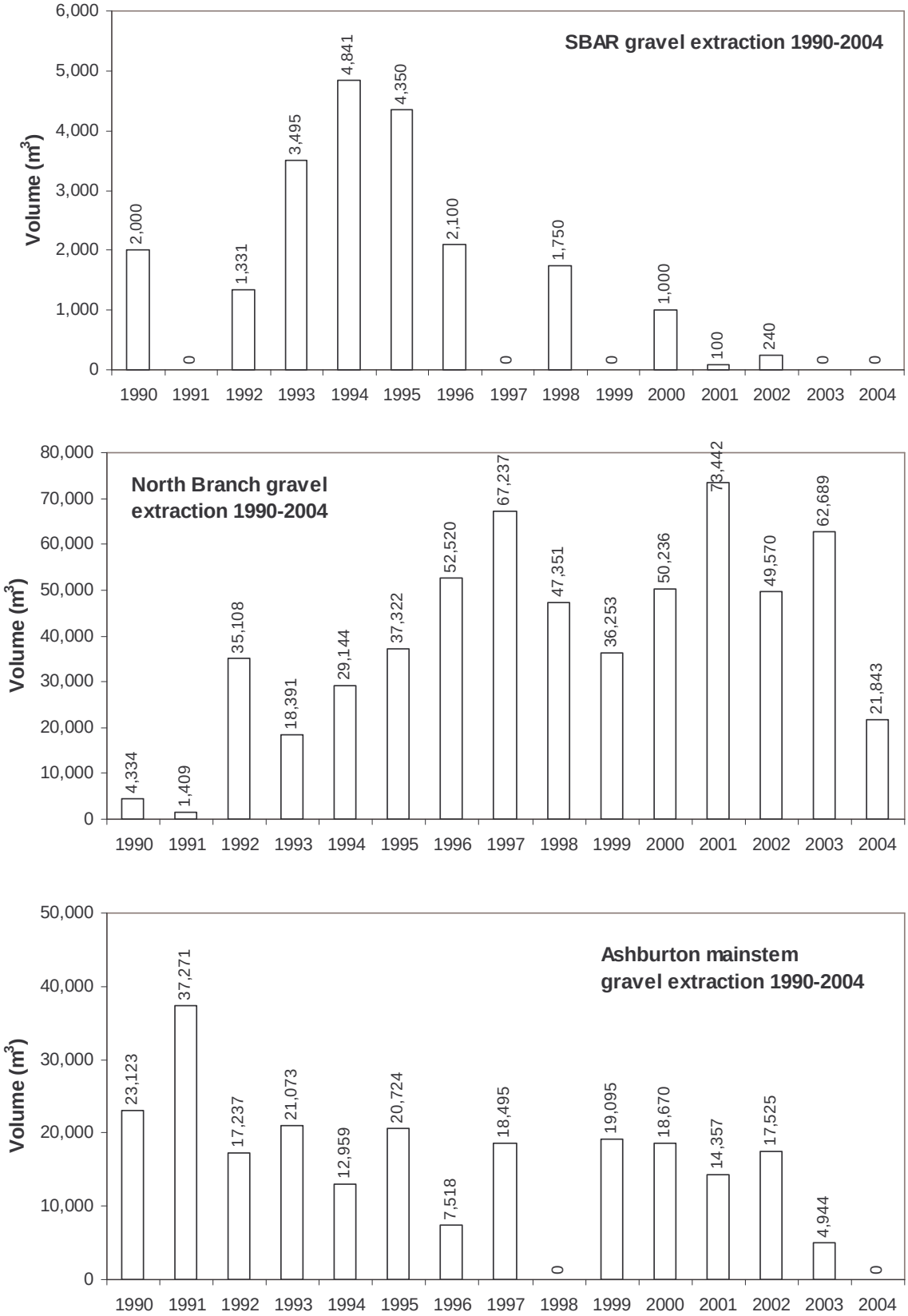


Fig. 6 Gravel extraction 1990-2004 (note scale difference)

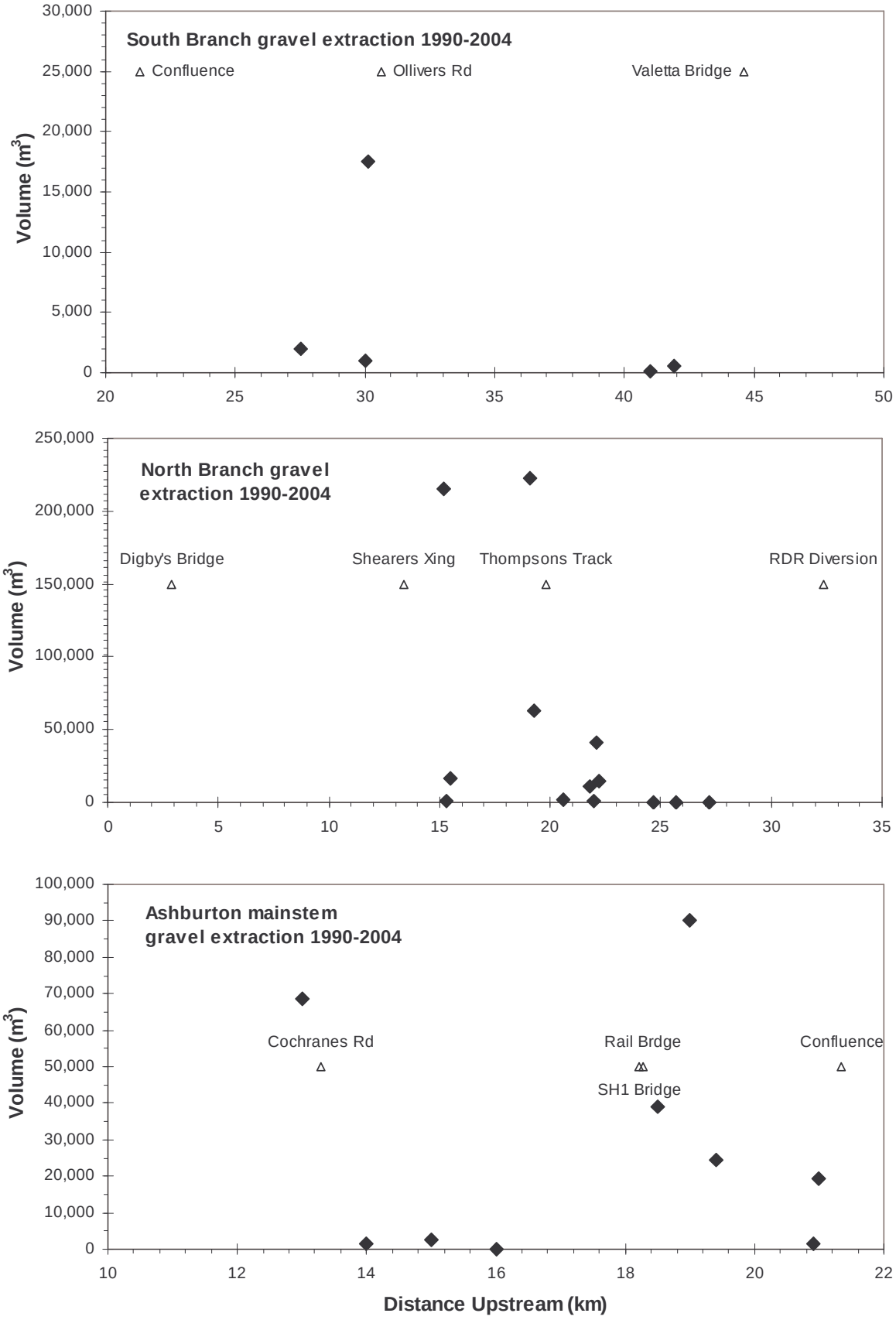


Fig. 7 Gravel extraction 1990-2004 (note scale differences)

5.3 North Branch

Large volumes of gravel were extracted from the North Branch primarily for stopbank building in the period 1966 to 1968 (600,000 m^3 from the confluence to cross section 31) (km 25.92; revised). River aggregate extraction and stopbank construction removed over 176,800 m^3 from Blands Reach in the period 1976 to 1981 (~35,000 m^3/y) (Connell 1983).

From 1990 to 2004 commercial gravel extractors removed ~586,500 m^3 from km 15 to 23 (39,100 m^3/y) (Fig. 6 & Fig. 7). There is a strong trend of increasing gravel extraction with time in the period 1990-2004. If these trends continue, by 2010 extraction will equal or exceed the long term rate of bedload input into Blands reach. By 2020 the projected rate of extraction is ~110,000 m^3/y.

Gravel extraction for the "Industrial" stopbank (Fig. 1) was undertaken from the confluence to cross section 2 of the North Branch (revised km 1.13) (3,600 m^3); but no gravel has been removed by ECan for the planned floodplain management bed level lowering.[7] This involves extraction of more than 320,000 m^3 of gravel from Blands Reach to achieve 1982/84 bed levels (Hudson 2000b).

5.4 South Branch

Limited gravel extraction occurred in the South Branch. Stopbanks built in the 1930s and 1940s were not extended in the 1960s (SCCB 1964) or subsequently (Connell 1988). There are plans to construct a new 6.5 km long stopbank on the true right bank above Valetta Bridge (~river km 45) (~60,000 m^3 of gravel required) (Fig. 1).

Consent records since 1990 show that ~21,200 m^3 of gravel was extracted up to 2002; with no further extractions reported in 2003 and 2004[7] (Fig. 6 & Fig. 7). Almost all of the gravel was extracted from around km 30 (Ollivers-Shearers Road); with ~600 m^3 from ~3 km below Valetta Bridge. Little extraction (15%) occurred since 1996; with a tendency to zero extraction in the short term.

6 Effects of river processes and gravel extraction

6.1 Ashburton River

The Ashburton River has two distinct segments (section 2):

- An entrenched segment near the coast.
- An upper reach where the river bed is weakly incised into the floodplain.

Over the long term the river mouth degraded 24 m in response to coastline retreat (3 to 6 mm/y). From 1937 to 1960 the lower 12.6 km degraded on average 0.55 m (24 mm/y); and from 1960 to 1984 this reach degraded on average 0.45 m (19 mm/y) (Fig. 8). No significant gravel extraction occurred below Cochranes Road (km 13), thus degradation is attributed to river re-grading to a lower base level at the coast; possibly accelerated by sediment starvation due to upstream gravel extraction.

[7] ECan (Matt Surnam, pers. comm.).

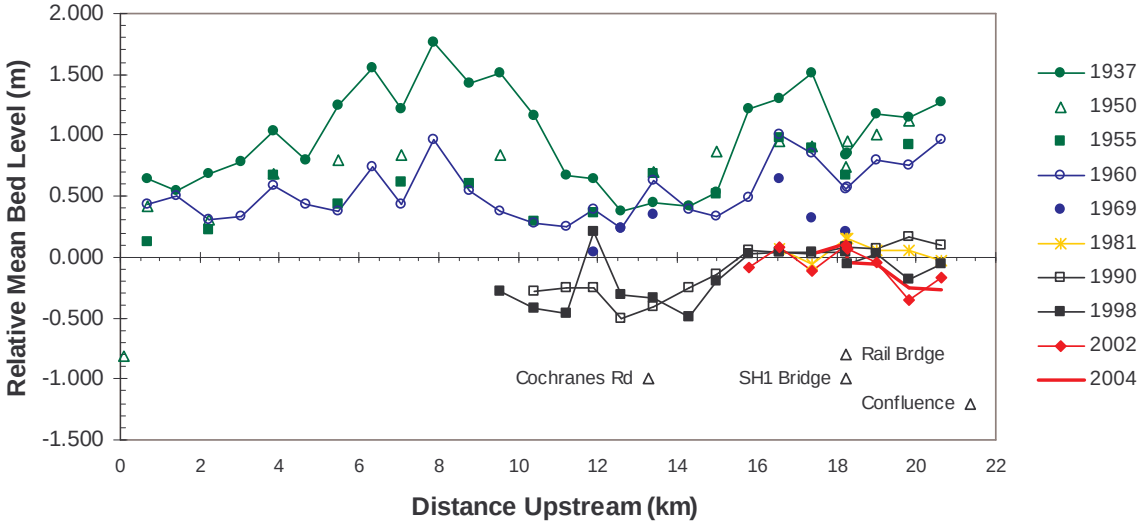


Fig. 8 Ashburton River mean bed levels relative to 1984

Degradation in the lower river provided ~80,000 m^3/y of bed material to the coast from 1937 to 1960; and ~63,000 m^3/y from 1960 to 1984. Decreased rates of incision over the lower 12.6 km suggest recent channel confinement[8] and upstream gravel extraction are not dominating influences. Lower reach surveys are required to evaluate changes since 1984.

The position of the hinge point between the entrenched lower reach and the weakly incised upper reach is of basic importance to long term bridge stability. The road and Rail bridges are at risk of being undermined because they have shallow piers. In 1979 rock rip-rap was placed around active channel road bridge piers and other options were evaluated (Reynolds 1994). Controls on gravel extraction and trigger bed levels were implemented (Boyle 1996), but these are a temporary measure.

A resurvey of the lower reaches of the Ashburton River is a high priority because the knickpoint will ultimately cut back and undermine the bridges irrespective of gravel extraction management. Also the entrenched segment of the upper plains is migrating downstream into the bridge reach and surveys should be extended into the South Branch to determine when incision into the bridge reach from upstream will occur.

In the upper reaches of the Ashburton River (~km 12.6 to 21.6) the bed degraded on average by 0.97 m from 1937 to 1984 (21 mm/y), but this was not constant (Fig. 8). In the period 1937 to 1960, an average of 0.31 m of degradation occurred (13 mm/y). An unknown proportion of the 25,400 m^3/y loss is attributable to gravel extraction, but it is unlikely that large volumes of gravel were removed for river works.[9] Bed levels decreased on average by 0.67 m (28 mm/y) from 1960 to 1984 (53,550 m^3/y). From 1966 to 1980 ~66,000 m^3/y was extracted from the bridge-confluence reach; requiring a net bedload input of ~12,500 m^3/y to balance the budget.

[8] Over the lower 10 km the average active channel width was ~400 m in 1941 & 1952; 290 m in 1978; and 260 m in 1998-2002 (Fig. 3); versus 3-8 km during recent fan development.

[9] In the 1941 aerial photography the bridge reach was highly confined (average width ~220 m) and there has been little net change since then. Above the bridges to the confluence the river was confined from ~330 m (1941) to ~260 m (1978) with little net change in 1988 and 2001. Below the bridges substantial berm planting was undertaken in the 1960s and 70s (Fig. 3).

When gravel extraction moved to Cochranes Road (~km 13) in the period 1981 to 1992, there was a shift in the location of erosion and deposition. With extraction of ~33,400 m^3/y at Cochranes, the reach above SH1 aggraded from 1984-1990 by ~16,700 m^3/y (using revised distances).

When extraction shifted upstream of the bridges in 1992, bed levels decreased. In the survey period 1990-1998 the bridge to confluence reach mean bed level decreased 0.18 m on average (~15,400 m^3/y); with reported gravel extraction of 11,100 m^3/y. The excess loss may be underreporting of gravel extraction, or general degradation because of large floods in 1994.

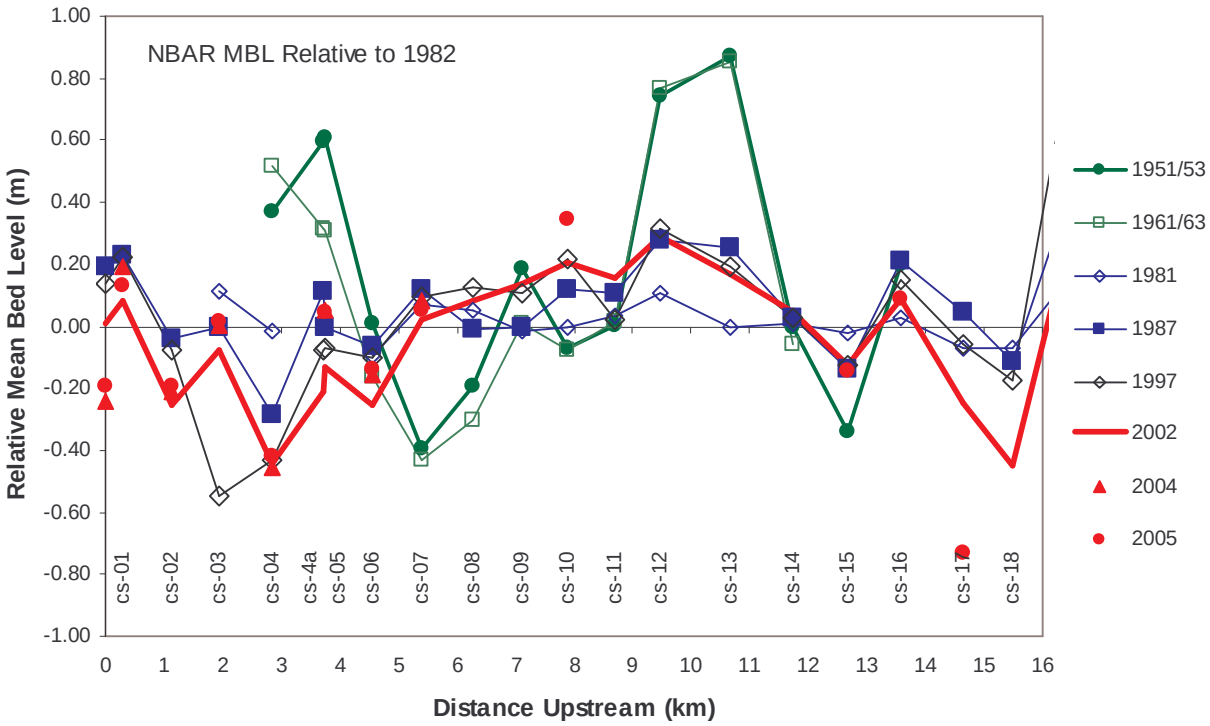
From 1998 to 2002 the bridge-confluence reach degraded 0.12 m on average (30 mm/y; ~17,000 m^3/y) with gravel extraction of 16,700 m^3/y. From 2002-2004 a bed loss of 16,648 m^3 occurred in the bridge to confluence reach; which is close to the reported extractions of 15,264 m^3 between the March 2002 and October 2004 surveys.

6.2 North Branch

Degradation in the upper reaches of the North Branch is attributed to long-term channel entrenchment related to uplift (Leckie 1994). Bed levels fluctuate around the 1982 baseline (Fig. 9), in the upper reaches (above cross section 34; km 27.70) to the gorge; and net degradation is a significant source of bed material:[10]

- 1982-1987/88:125,400 m^3 (22,800 m^3/y).
- 1987/88-1997: 172,600 m^3 (18,200 m^3/y).

Fig. 9 North Branch selected cross section MBLs relative to 1982



[10] Little gravel extraction occurs in this reach (Fig. 7). Over various periods 20 to 34% of the bedload transport into Blands Reach was derived from upper plains channel degradation (section 4).

Blands Reach has a long history of channel aggradation. Since records began in 1937 aggradation of up to ~3 m has occurred and the mean bed level is now up to ~4.2 m above the surrounding floodplain (Fig. 9). Blands Reach is often specified as cross sections 18 to 26 (km 15.47-22.56); but systematic aggradation occurred from cross section 7 to 34 (km 5.39-27.7):

- 1982-1987/88: 41,360 m^3/y.
- 1987/88-1997: 26,005 m^3/y.

Data for 2002 is incomplete[11] (finishing at cross section 28); but from 1997 to 2002 the mean bed level decreased by 0.07 m (~14 mm/y); for a net loss of ~20,000 m^3/y. Average annual gravel extraction from this reach was 54,000 m^3/y for the period 1997-2002. The minimum net bed material input would be in excess of 34,000 m^3/y (deposition in the reach from cross section 28 to 34 is unknown).

Large volumes of gravel were extracted from the North Branch primarily for stopbank building and more recently for commercial gravel extraction (section 5.3). To restore the floodway capacity of the North Branch to the rural protection standard of a 50 year flood, it is proposed to extract 320,000 m^3 of gravel from the river between Shearers Crossing to about Springfield Road (~km 15.5-24.5), thus returning the channel to approximately the 1982/84 bed level (Hudson 2000b).

No extractions for the Ashburton floodplain management strategy have been undertaken in Blands Reach to date. However, recent increased gravel extraction, coupled with the smallest recorded net input of bed material into Blands Reach over a period of several years, is achieving the desired result.

An issue to be resolved regarding gravel extraction for the floodplain strategy is that resource consent conditions include provision for bed levels at the Ashburton River State Highway 1 and Rail bridges. As discussed in Hudson (2003), it is unlikely that gravel excavations in Blands Reach would have an adverse effect on the Ashburton Bridge reach bed levels. The immediate problem is historic over-extraction in the bridge reach. The longer term problem is degradation from natural processes in the Ashburton River (coastal retreat and upper reach entrenchment). Gravel by-passing through Blands Reach continues.

Limited volumes of bed material move past the aggradation zone around Blands Reach into the lower reaches of the North Branch. Connell (1983) estimated that bedload by-passing into lower North Branch was 7,700 m^3/y.[12] Net channel degradation of 196,000 m^3 from x-s 1 to 6 in the period 1951 to 1987 is largely due to 120,000 m^3 of gravel extraction in 1966. Connell (1991) attributed the rest of the degradation (76,000 m^3) to headward erosion from the mainstem Ashburton River. (66,000 m^3/y was extracted from the mainstem immediately downstream of the North Branch in the period 1966 to 1980).

[11] 2004 is limited to cross sections 1-7. 2005 data is limited to cross sections 1-7 and 10, 15-17.
[12] The electronic data archive does not include all the bed levels reported by Connell (1983). These levels should be verified and incorporated into the NBAR data set.

In the period 1982 to 1997 (and 1987/88 to 1997 in brackets):

- The mouth of the North Branch (to km 4.55) degraded 5,590 m^3/y (5,982 m^3/y) although there was no gravel extraction in the reach. Degradation is attributed to headward erosion from Ashburton River gravel extraction.
- Aggradation of 5,776 m^3/y (2,259 m^3/y) occurred from km 5.12 to 11.42 as the result of gravel by-passing Blands Reach where gravel extraction of ~30,000 m^3/y occurred.
- Almost half of the total extraction occurs immediately upstream at Shearers Crossing (km 15.1); where bed levels were maintained.
- Above Shearers Crossing (km 15.95 to km 26.77) the bed aggraded 26,600 m^3/y (~26,000 m^3/y). Further upstream the bed degraded.

In the period 1997-2002 the mouth of the North Branch degraded 1,760 m^3 (~350 m^3/y); and km 5.12-11.42 degraded 10,400 m^3 (~2,100 m^3/y). No gravel extraction occurred in this reach of the North Branch. There was probably headward retreat - gravel extraction in the 1997-2002 period in the upper Ashburton totalled 102,000 m^3 (17,000 m^3/y). Gravel extraction in Blands Reach averaged 54,000 m^3/y in this period.

From 2002 to 2004 the mouth aggraded by ~36,400 m^3 (18,200 m^3/y); and by ~4,100 m^3 from 2004 to 2005. There was little gravel extraction in the upper Ashburton in 2003 (4,994 m^3 reported), and none in 2004; but there was 112,260 m^3 extracted from Blands Reach in 2002-2003; and 22,000 m^3 in the fist few months of 2004.

As part of the flood protection scheme stopbanks are proposed in the lower reaches of the North Branch (Fig. 1). Jessop's Bend runs along the true left from river km ~1.6 to ~5.8 and involves removal of ~66,000 m^3 of river bed gravel. Greenstreet stopbank runs along the true right bank from ~km 1.5 to 3.1; and ~km 4.5 to ~5.8 and involves ~40,000 m^3 of river gravel excavation. As discussed in Hudson (2003), it is unlikely that gravel excavations for stopbanks in the lower North Branch would have an adverse effect on the Ashburton Bridge reach bed. To date no gravel has been removed from the lower North Branch for stopbank construction; but recent surveys (discussed above) show bed build up in the North Branch stopbank reach as gravel extraction in the upper Ashburton decreased and eventually ceased. At the same time large extractions occurred in Blands Reach.

6.3 South Branch

Since 1937 the bed in the lower 6 km of South Branch degraded on average by ~13 mm/y (Fig. 10). Between surveys average rates of degradation vary from 2-3 mm/y to 16 mm/y, on average. There is no reported extraction in the lower 6 km.

Over the lower 6 km little net change appears to occur between 1955 and 1961 (average degradation of 2 mm/y) possibly because the fairway was

redefined as the result of extensive channelisation.[13] Little change (average degradation of 3 mm/y) also occurred between 1991 and 1997 (Fig. 10). This may be partially in response to the downstream shift of gravel extraction to Cochranes Road (km 13) in the period 1981-1992 with a time lag as headward erosion into South Branch decreased.

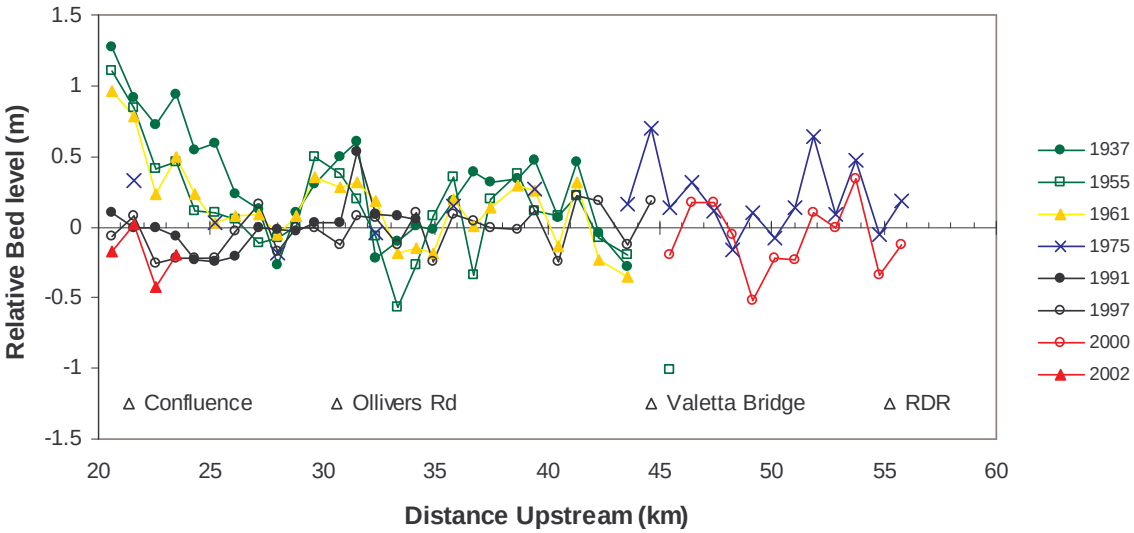


Fig. 10 South Branch mean bed levels relative to 1984/85

Net degradation in the lower 6 km averaged 18,150 m^3/y in the period 1937-1997; but this varies from ~900 m^3/y (1991-1997) to ~25,000 m^3/y (1937-1955; and 1985-1991). Degradation appears to be continuing. From 1997 to 2002 the mouth of the South Branch degraded ~10,000 m^3/y (Fig. 10).

From ~km 27 to 44 (i.e. ~6 to 18 km up South Branch), bed levels fluctuate, with a tendency to degradation. Average bed levels decreased by 0.107 m (6 mm/y) from 1937 to 1955; increased by 2 mm/y from 1955 to 1961; and decreased by 3 mm/y on average from 1961 to 1984/85.

Net degradation averaged 25,000 m^3/y from 1937-1955; and 13,500 m^3/y from 1961-1984/85. Net aggradation occurred in 1955-1961 (~12,800 m^3/y) and 1985-1997 (520 m^3/y). Gravel extraction records are not available for the earlier period; but from 1990 to 2004 almost all the reported South Branch gravel extraction occurred in this reach (Fig. 7) with ~18,000 m^3 (85%) extracted by 1996 (Fig. 6). To balance the net bed material storage required about 18,500 m^3/y of bed material input into the km 27-44 reach.

A re-survey of the South Branch is required to examine more recent changes; but the implication of the available survey data is that gravel

[13] In anticipation of the diversion of the North Branch, Stringer (1981) reports that in 1958 the lower South Branch below Taylors Stream (~km 43) was widened over extensive reaches to a design width of 245 m. This is a simplistic description of change because it refers to the channel fairway. The channel was straightened, vegetated islands removed, stopbanks constructed, channels cut off, and berm land planted. Net effects varied downstream (Figure 3). From the confluence (km 21) to ~km 34 the cleared fairway was widened, but the average active channel width (i.e. including secondary channels through the bermlands) decreased from ~290 m in 1941 to ~220 in 1978. (There are substantial similarities between the 1941 and 1952 aerial photographs).

extraction accounts for recent channel degradation in the km 27-44 reach. Degradation in the lower 6 km is partially accounted for by gravel extraction upstream; and over-extraction in the Ashburton is though to induce headward scour (Connell 1991; Hudson 2000), which could account for the residual degradation.

From around Valetta Bridge (km 44.6) upstream bed levels decreased from 1975 to 1984/84 by 0.200 m (21 mm/y; 35,800 m^3/y); and by 0.069 m (4 mm/y; ~3,800 m^3/y) from 1984/85 to 2000 (Fig. 10). Extraction of 60,000 m^3 for stopbank construction over the 6.5 km reach above Valetta Bridge would result in bed lowering in 0.07m over the average channel width of 133 m (from 2001 ortho-photos).

From a gravel management and bridge stability perspective, effects of Valetta stopbank construction were considered to be no more than minor (Hudson 2003). Limited data suggests bed levels probably significantly aggraded prior to channelisation (e.g. >1 m at cs-54) (Fig. 10), but post channelisation (with bulldozing of a single thread channel) bed levels dropped ~0.10 m over the stopbank reach. Undermining of Valetta Bridge is unlikely. Minor pier cap exposure occurs in two channels, but several other pier caps are buried in gravel.

7 Discussion and recommendations

The most recent consents records data base is inconsistent with previous versions and is not complete. Errors and omissions are significant. Following discussions with ECan the 2003 version of the consents data based was used with supplementary information compiled by Connell (1983, 1988, and 1991) and Hudson (2003).

Sustainable management relies on accurate data, so appropriate procedures must be implemented to obtain accurate extraction information (±10%); locations of extraction should be specified in terms of the ECan river distance/cross section maps; inconsistent gravel returns should be corrected in the data base; and historic information should be incorporated into the data base.

Large volumes of gravel were extracted from the Ashburton River above the SH1 and Rail bridges (~km 18-21: 1966-1980 ~66,000 m^3/y; 1992-2003 ~20,300 m^3/y); and near Cochranes Road (km 13: 1981-1992 ~33,400 m^3/y). There was no commercial gravel extraction in 2004 and 2005 as bed levels were below critical limits at the bridges. Projecting recent trends (1990-2004), there would be no extraction by 2010.

Undermining of the SH1 and Rail bridges on the Ashburton River is inevitable. The question is not if this will occur, but when this will occur. Critical bed levels in the bridge reach will ultimately result from three factors:

1. Excessive gravel extraction in the upper Ashburton River.
2. Degradation with headward erosion as the river re-grades in response to coastline retreat.
3. Degradation as the upper plains entrenched zone migrates downstream into the bridge reach.

The Ashburton bridges were built on shallow piles in a zone where the river bed was weakly incised into the floodplain. Gravel extraction accounts for historic decreased bed levels (~1 m on average since 1937) in this reach. When extraction moved to Cochranes Road the bed upstream of the bridges aggraded (~17,000 m^3/y) and headward erosion into the North and South branches decreased or stopped.

Gravel extraction has been excessive in the Ashburton River. Net bedload inputs over the longer term are less than the figure used to guide gravel extraction consents (i.e. 12,500-16,700 m^3/y vs. the previous estimated input of 30,000 m^3/y). Over shorter time frames bedload inputs are probably highly variable. This could be evaluated with an analysis of streamflows and bedload transport (Carson & Griffiths 1989). This situation can be managed with the present bed trigger levels (Boyle 1996), but this is merely delaying the inevitable.

In channel gravel extraction should be limited to small scale local uses (NRRP Chapter 6; fact sheet 6); unless required for river control purposes.

Alternative sources of gravel are required (e.g. upstream in the aggrading Blands reach; off channel habitat creation – Hudson 1997; land mining).

Options to stabilise the bridges should be re-examined (Reynolds 1994).

A bedload rating relation, calibrated against volume changes, could be established to evaluate variability in bedload; and to guide annual gravel extraction volumes.

Coastline erosion is causing the Ashburton River to re-grade to a new base level as illustrated by the 24 m high alluvial cliffs at the mouth. Rates of incision are now far greater than in the post glacial period when sea levels rose (13-30 mm/y vs. 3-6 mm/y). It is uncertain when headward erosion from coastline retreat will incise into the bridge reach (~km 18). Lechie (1994) places the transition at km 13 and McPherson (2000) identifies a break in slope about 200 m downstream of SH1 Bridge. The most recent survey in 1984 shows a break in thalweg slope (the deepest part of the channel) around km 7.5 which may be the knickpoint.

Re-survey of the lower reaches of the Ashburton is required to determine when coastal retreat induced incision will affect the bridges. This may require longitudinal surveys in addition to the cross section surveys.

Incision into the bridge reach may also occur because of the downstream migration of the zone of entrenchment caused in the upper plains. The transition between the zone of weak incision and zone of entrenchment is not well defined in the South Branch; and recent survey data is patchy. The North Branch is weakly incised at the mouth, and is aggrading upstream in Blands Reach.

An analysis of detailed floodplain topographic maps is required to determine the position of the zone of entrenchment in the South Branch and lower North Branch.

Cross section surveys should be extended into the lower South Branch to determine if the zone of entrenchment is migrating downstream.

Commercial gravel extraction does not occur in the lower North Branch, but the bed degrades in response to extraction downstream in the Ashburton River. Recently, when gravel extraction in the Ashburton decreased (2004), then ceased (2005) the mouth aggraded. In this reach the North Branch is weakly incised and prone to flooding into the Ashburton urban area. Stopbank upgrading and construction are proposed in the lower reaches. Undermining of bridges has not been identified as an issue in the North Branch.

Contrary to Leckie's (1994) model, North Branch has a major zone of aggradation where there is a break in channel slope in Blands Reach. This reach is perched above the floodplain and threatens to break out into alternative flow paths. The reach has been the focus of channelisation since the 1930s. Severe channel narrowing and upstream berm plantings have not alleviated gravel build up. It is proposed to reinstate the 1982/84 bed levels by removing 320,000 m^3 from the reach to provide greater flood protection (Hudson 2000).

Bed material inputs into Blands Reach are derived from catchment erosion; and upstream channel erosion (~20-30% of the total net input) where the river is incising into the upper plains in response to uplift (Leckie 1994). Over a period of several years net bed load inputs range from 30,000 m^3/y to 75,000 m^3/y. Over shorter periods inputs are more variable.

Large volumes of gravel are extracted from North Branch (1966-1968: 600,000 m^3, and 1976-1981: 176,800 m^3 for stopbank construction; and ~40,000 m^3/y since the 1990s for commercial gravel extraction). By 2010 extraction is expected to equal long term inputs (>75,000 m^3/y); and by 2020 the projected rate of extraction is ~110,000 m^3/y. Although a large volume of gravel is extracted from Blands Reach, about 10% of bed material by-passes the excavation reach to be deposited downstream.

At present consent conditions related to bed levels around the Ashburton Bridges prevent gravel extraction for the flood protection scheme. Previous analysis (Hudson 2003) indicated there were unlikely to be significant effects on the Ashburton bridges reach from North Branch gravel extraction. The conclusions are reinforced by this analysis, particularly regarding bed build up near the mouth of the North Branch when gravel extraction of ~50,000 – 60,000 m^3/y occurred in Blands Reach.

It is concluded that floodplain management gravel extraction could proceed without adverse effects on the Ashburton bridges reach provided that no further extraction is undertaken in the bridge reach.

Lower South Branch is degrading, not from gravel extraction in the reach itself but from over extraction downstream in the Ashburton River. Net degradation in the lower 6 km averaged 18,150 m^3/y in the period 1937-1997; but this is highly variable between surveys. Low rates of degradation from 1991-1997 (900 m^3/y) may be attributable to the downstream shift in gravel extraction in the Ashburton (to Cochranes Road); but more information is desirable on this matter.

Additional surveys extending from the Ashburton River into South Branch are required to determine if reduced gravel extraction (or cessation of extraction) in the Ashburton results in reduced South Branch degradation near the mouth.

Over the long term the upper plains zone of entrenchment will extend into the lower South Branch and Ashburton River. (This may already have occurred - Leckie (1994) places the hinge point between the Ashburton bridges and South Branch mouth. However, this is not apparent with available information and analysis). Recommendations for further surveys were made in the discussion of the Ashburton River.

Most of the limited gravel extraction in South Branch (~1,600 m^3/y from 1990-2003) occurs around km 30 (Ollivers-Shearers Road). Little extraction (15%) occurred since 1996; with a tendency to zero extraction in the short term. Recent bed degradation is partially attributable to gravel extraction in the reach, and from over-extraction in the Ashburton River. In addition, there is probably a component of upper plains entrenchment, but this can not be quantified with available data. The reach above Valetta Bridge (km 46) is degrading because of the upper plains uplift induced incision (Leckie 1994).

Extraction of 60,000 m^3 for stopbank construction over the 6.5 km reach above Valetta Bridge will lower bed levels 0.07 m on average, but effects were considered to be no more than minor (Hudson 2003).

A re-survey of the South Branch is required to examine more recent changes, and to provide a baseline for the proposed stopbank excavations.

8 Disclaimer

The information in this report and any accompanying documentation is accurate to the best of the knowledge and belief of the Consultant acting on behalf of Environment Canterbury. While the Consultant has exercised all reasonable skill and care in the preparation of information in this report, neither the Consultant nor Environment Canterbury accept any liability in contract, tort or otherwise for any loss, damage, injury or expense, whether direct, indirect or consequential, arising out of the provision of information in this report.

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