Environment Canterbury

Oamaru to Timaru Coastal Report
Status of Gravel Resources and Management Implications

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1. Introduction

As part of Environment Canterbury's wider "Regional Gravel Management Investigation" MWH were commissioned to investigate and report on the potential annual sustainable supply of gravel for the region from the coast for the next 10 years. Three coastal areas were identified by Environment Canterbury for the investigation. These are Oamaru to Timaru, Timaru to Banks Peninsula, and Pegasus Bay.

This report covers the area from Oamaru to Timaru. This area is also known as the South Canterbury coast, and includes three major coastal compartments:

1. Waitaki Fan, comprising the stretch from Oamaru to Waitaki River, and the Morven – Glenavy Cliffs to the Waihao River,
2. Wainono Lowland Coast (Waihao River to Otaio River),
3. South Beach – Port of Timaru (Otaio River to Port of Timaru)

The coastal reach south of the Waitaki River will not be discussed in detail as it is outside of the Canterbury region. However the connection between sediment supply and transport across the regional boundary will be described.

This report initially presents an overview of the South Canterbury coast before reviewing documented changes to the coastal geomorphology based on beach profile and cliff retreat studies and gravel extraction records to assess the available gravel supply. On the basis of the assessed available gravel supply recommendations are made as to future gravel resource management for this section of coast.

2. South Canterbury Coast Description

The coast north of the Waitaki River contains 14 kilometres of alluvial cliffs comprised of glacial outwash gravels and loess deposits. The cliffs are the result of truncating of the Waitaki Fan by coastal erosion due to post-glacial sea level rise. Northwards for 28km from the Waihao River, the coast is comprised of a sand and gravel barrier beach ridge fronting low-lying hinterland. The stretch of shore from the Otaio River to the Port of Timaru is composed of sand and gravel beaches backed by loess cliffs dissected by small rivers and creeks. The northernmost 4km of this stretch encompasses beaches on a bay and headland coast associated with the basalt cliffs of Patiti Point. The beach sediments are sand and gravel and form an aggradational feature built up against the Timaru Harbour breakwater.

The beach and alluvial cliff sediments are derived from greywacke (indurated sandstone) outwash gravels and sands. The plains and fan hinterland are crossed by major rivers, streams and artificial drainage channels. The alluvial fan sands and gravels are poorly consolidated and extend more than 50km out to sea to the edge of the continental shelf. In the nearshore they are covered by a thin layer of fine sand.

It has been estimated (Hewson 1977) that as much as 4.5km of retreat of the Waitaki Fan has occurred in the last four to six thousand years. The coast is almost entirely erosional, with long term rates of shoreline retreat in the range of 0.5 to 4.0 metres per year.

The process environment is dominated by storm and swell waves from the south to south-east. The waves break close to the shore, generally in a single line of breakers, and form a line that delineates the beach from the nearshore seabed. The mixed sand and gravel beaches are different to sand beaches in that there is minimal transfer of gravel sediments on and offshore, and nearly all of the coarse sediment (sands and gravels) is transported in the swash zone. Fine sand is transported in the nearshore and on the seabed, and removed from the beach, but is not transported or resident on the beaches.

The dominant storm and swell waves are generated in the Southern Ocean and result in significant net longshore transport of sediment from the south to north. The main sources of transported sediment are the Waitaki River and erosion of the alluvial cliffs. Short duration storms from the north-east can transport sediment to the south, but the net northward transport is about 60,000m^3/yr. The volume of fine sand transported northward on the seabed is in excess of 600,000m^3/yr.

The mixed sand and gravel beaches which occur at the base of the alluvial and loess cliffs, and comprise the barrier ridge section of the Wainono Lowland Coast varying in width from 20 to 100m depending on the supply of sediment. The height of the gravel barrier ridge ranges from 5 to 7 metres above mean sea level, but the beach is overtopped by storm waves in excess of 2.5m high. The foreshore is very steep (up to 25˚) and so there is very little horizontal translation of the position of the breaking waves across the beach. Unlike composite gravel and sand beaches, there is no exposed sandy intertidal surface at low tide. The beach gravels sit on top of alluvial fan gravels or reworked peat. In most areas it is difficult to determine the depth of the active beach, but it is thought that erosion and retreat of the shore can rework older gravel deposits of the hinterland.

3. Coastal Hazards

Erosion, sea water inundation through storm overtopping, freshwater flooding due to impoundment, and tsunami present hazards to human use of the South Canterbury coast. The barrier beach provides a natural buffer against sea water inundation during high energy storm events. However, it is insufficient to mitigate the hazard completely, and sea water inundation occurs to some extent on the lowland coast during most years. There has been no recorded damage by tsunami waves, but the potential for damage from a far field tsunami is recognised in hazard management and planning for the region.

Erosion is a widespread issue between the Waitaki and Otaio Rivers. Retreat of the cliff coast between the Waitaki and Waihao Rivers has resulted in loss of farmland. Erosion is a result of wave action at the base of the cliffs removing the beach and cliff toe support. The cliff collapses and the resulting tallus sediment is distributed alongshore by wave and swash action. Along the barrier shore, erosion takes the form of landward migration of the barrier beach. The volume and dimensions of the barrier fall within an envelope of dynamic change, but the position of the barrier is moving landward.

4. Gravel Extraction

Environment Canterbury gravel extraction consent information shows five areas of extraction from the coastal environment for the South Canterbury coast. These are upstream of the mouth of the Makikihi River (therefore not strictly in the coastal environment), the beach at Lyalldale Creek, the mouth and beach at Pig Hunting Creek, South Beach in Timaru, and Caroline Bay. Of those areas only three consents are current. Those are:

- CRC970563.1 held by Primeport Timaru Ltd; location - South Beach; term of consent - 1997 to Dec.2006; no annual volume specified.
- CRC022054 held by GJH Rooney; location – Possibly Pig Hunting Creek or Pareoara River, described as landward of MHWS on beach; term of consent 2003 to Feb 2008; 5000m^3/yr.
- CRC052172.1 held by Makikihi Transport Limited; location – Makikihi River at coast; term of consent – 2005 to Dec2009; 2000m^3/yr.

Table 1 shows the returns data for the coastal extraction sites for the period 1 January 1990 to the end of 2004. Extraction sites from the Taitarakihi to Pareora and Waimate Catchment consents have been analysed.

Table 1: Coastal gravel extraction, South Canterbury coast, 1990 to 2004 (m^3).

Year	Site					Volume by Year
	Makikihi River	Lyalldale Creek	Pig Hunting Creek	South Beach	Caroline Bay	
1990		1,486	5,450			**6,936**
1991		410				**410**
1992						
1993						
1994		2,416	424			**2,840**
1995			230	12,089	538	**12,857**
1996		10,969	2,724	2,306	1,254	**17,253**
1997	240	3,993		2,340	733	**7,306**
1998		140	454	6,343	569	**7,506**
1999			1,399	8,126		**9,525**
2000	1,144	693	1,237	12,110		**15,184**
2001	176	2,455	820	837		**4,288**
2002	328	3,176	364	2,278		**6,146**
2003[1]	58		275	1,114		**1,447**
2004				10,160		**10,160**
Total by section	**1,946**	**25,738**	**13,377**	**57,703**	**3,094**	**101,858**

1. Makikihi River, Lyalldale Creek and Pig Hunting Creek returns include extraction described as upstream of the beach crest, but not extraction with other descriptions that place the extraction at a distance from the coast (including Makikihi River near SH1, approximately 1400 m from the coast). There are no returns as yet for 2005.

Those sites where the description of the location is the beach, beach crest, river mouth or upstream of the beach have been included. This may overstate the actual coastal extraction where the descriptions are incomplete for some years.

For the South Canterbury coast, the total volume of gravel (and sand from Caroline Bay) extracted over the period of record was 101,858m^3, at a rate of 6,790m^3/yr. This breaks down to 98,764m^3 of gravel and sand mix from the beaches south of the Port of Timaru breakwater at a rate of 6,584m^3/yr, and 3,094m^3 of sand from Caroline Bay at an annual rate of 206m^3. This latter figure does not accurately reflect the extraction rates as for eleven of the fifteen years there is no recorded extraction. The average rate of extraction for the four years of activity is 773m^3/yr.

The temporal distribution of the extractions has not been even over the 15 years of return records. However there is no temporal trend. The variability is linked to changes in the extraction volumes from South Beach and a large volume extracted from Lyalldale Creek in 1996.

Extraction at South Beach reflects other aspects of the Port of Timaru operations. The addition of a spur groyne to the harbour breakwater in 1987 to trap northward moving sediment resulted in the accretion of about 14ha of beach in front of the breakwater (Kirk 1992). Gravel extraction from South Beach was halted during the period of build up of the "artificial" beach. Prior to 1980, a total of 760,000m^3 of sand and gravel had been extracted from South Beach (Neale 1987). Gravel passing the breakwater to the north is trapped in the harbour channel, from where it is dredged and placed as close as possible to Washdyke Beach (north of Timaru) to nourish the eroding shore. There is no natural transport of gravels from south of the breakwater to the beaches north of Timaru. However sand is transported northwards on the nearshore seabed. Some of the fine sand accumulates in the lee of the

harbour and has formed Caroline Bay. Otherwise the sand component of longshore transport does not contribute to beach sediments.

5. Beach Profile Changes

Environment Canterbury monitor the South Canterbury coast by surveying beach cross-sections on a regular basis. Hicks and Todd (2003) and Hicks, Wild and Todd (2003) presented an analysis of the profile data, maps and aerial photography for the area around the Waitaki River mouth as part of studies into the potential effects of "Project Aqua". Preliminary results were also presented to the Waitaki Water Allocation Board as part of the hearings process on the proposed Waitaki River water allocation plan.

The changes to the 39 beach cross sections monitored by Environment Canterbury have not been summarised and assessed to date in a form which enables a full gravel budget to be calculated for the South Canterbury Coast. However Hicks *et al*. (2003) present in tabular form, erosion rates for beach profiles between Oamaru and Patiti Point (south of the Port of Timaru). Neale (1987) presents an analysis of the profile data between Patiti Point and the breakwater.

Except for one profile at Saltwater Creek, all of the profiles south of Patiti Point show long term erosion. Rates of retreat of the beach crest or cliff top range from -0.45 to -1.97m/yr south of the Waitaki River, -0.59m/yr near the Waitaki fishing village, -0.32 to -0.76m/yr along the alluvial cliffs, about -1.0m/yr along the Wainono Lowland coast, and -0.02 to -0.61m/yr north of the Otaio River, with progradation of 0.57m/yr at Saltwater Creek.

Neale (1987) presents a volumetric accumulation rate for South Beach of 51,288m^3/yr based on data between 1906 and 1954. This rate is based on a period without extraction at South Beach, as he noted a drop in the rate of accumulation in the period after 1954.

Although a detailed analysis of gravel volume changes for the whole section of coast has not been prepared at this time, it can be concluded that south of Patiti Point, the coast is in chronic gravel budget deficit which is reflected in erosion of cliff volume and retreat of the cliffs and beach crest.

The area north of Patiti Point, South Beach, is accreting in volume at the northern end, but the shoreline has retreated in the middle part of the bay as the beach realigns in adjusting to the artificial beach built in front of the breakwater.

6. Gravel Supply

6.1 Analysis

A broad approach to determining the gravel supply can be carried out through gravel budget analysis. This approach considers the inputs and outputs of gravel to the system under study, with the outcome a determination of whether the budget is in balance, deficit or surplus. A number of studies have attempted to formulate a gravel budget for the South Canterbury coast. The first came from Hewson's work (1977), while the Hicks studies (2003) consider the area of the Waitaki Fan.

There is temporal and spatial variability to the gravel budget along the coast. The temporal variability arises through the irregular incidence of floods delivering sediment from the rivers, storm waves delivering sediment from cliff erosion, and waves transporting sediment through

the coastal compartment from south to north. Wave action also removes sediment from the budget through abrasion of gravel.
On sandy coasts, sand can be removed from the active beach by winds, forming dunes in the backshore. Gravel is removed from the foreshore due to wave overtopping of the barrier beaches, but it generally remains in the beach system and is counted in calculating beach volume. Sands and gravels are also lost from the budget by extraction.

6.1.1 Inputs

Inputs of gravel to the South Canterbury Coast include point and line sources. The point sources are the rivers (Waitaki, Waihao, Makikihi, Otaio and Pareora), while the line sources are the cliffs. There is also some input of sand and gravel from south of the Waitaki River.

Table 2 shows an estimate of the overall gravel budget for the South Canterbury Coast. Reductions in the Waitaki River source are expected to be accommodated by an increase in the cliff erosion source on the northern Waitaki fan. (From Hicks and Todd, 2003).

Table 2 'Natural' beach material budget for sub-cells of the Waitaki littoral cell.

Cell	Distance N of Waitaki (km)	Cliff supply (m^3/yr)	River supply (m^3/yr)	Abrasion losses in each cell (m^3/yr)	Passing north (m^3/yr)
South fan	-21.4 to -2.6	250151	0	-77948	172203
Waitaki Mouth Area	-2.6 to 3.2	41820	153000	-53530	313493
North fan	3.2 to 13.3	79656	0	-108623	284526
Wainono lowland	13.3 to 36.4	0	0	-160907	123620
Makikihi-Pareora	36.4 to 51.4	5600	17200	-52906	93514
Pareora-Timaru	51.4 to 63.9	0	0	-33887	59627
Sum/net		**371626**	**170200**	**-487800**	**59627**
% of total supply		**69%**	**31%**	**89%**	**11%**

Estimates of gravel inputs to the coast from the rivers and cliffs is subject to a large amount of variation. For example the estimate of bedload from the Waitaki River from Hicks and Todd (2003) has possibly a factor of 2 uncertainty. Total river supply to the coast will vary widely depending on which estimate is used in the calculation. The estimates used below come from a variety of sources, and so provide for a range of uncertainty. In effect the amounts of sediment supply are indicative only, the actual sediment (bedload, suspended or both) arriving at the coast will vary year to year due to supply variability along the river, and flooding variability in transporting the sediment downstream.

The bedload supply from the Waitaki River was calculated by Hicks and Todd (2003) to be between 69,000 and 153,000m^3/yr. Input from the Waihao ranges from 0 to about 7,900m^3/yr, estimates range for the Makikihi from 0 to 6,000m^3/yr (Hicks and Todd 2003, Kirk 1987, MWH studies, 2005), for the Otaio from 0 to about 12,400 (Hicks and Todd 2003, MWH studies, 2005) and for the Pareora from about 11,000 to 17,200m^3/yr (Kirk 1987, Hicks and Todd 2003).

The total river supply is up to about 196,500m^3/yr (using the upper estimates for each river).

Hicks and Todd (2003) estimate that the sand and gravel supply from erosion of the alluvial cliffs north of the Waitaki River is about 120,000m^3/yr, with approximately 172,000 m^3/yr passing north from cliff erosion south of the Waitaki River.

The input of sand and gravel from south of the Waitaki River is uncertain, and has been thought to be small by some researchers (various estimates have been given from 0 to 25m^3/yr by Kirk, 1987 and Gibb and Adams, 1982 respectively). The value from Hicks and Todd (2003) has been used in calculating the total supply.

The total gravel supply to the coast is therefore 196,500 + 292,000 = 488,500m^3/yr.

This compares to Hicks and Todd's estimate of about 462,400 m^3/yr.

6.1.2 Outputs

Outputs of gravel from the coastal system can occur through losses offshore, alongshore, onshore and through extraction. These losses are extremely difficult to assess, so most often they are calculated from the difference between the inputs to the system and the system balance (erosion or accretion).

Gravel extraction losses can be determined from the records available for this study. The total extraction from the coastal system is about 6,600m^3/yr.

Offshore losses from the South Canterbury coast are due to the winnowing of fine material from the beach. Fine material is the result of abrasion processes. A range of abrasion losses from 9 to 98% has been suggested in different studies.

In recent years there has been very little gravel sized material lost out of the system to the north due to accretion against the spur groyne at the Port of Timaru breakwater. There is also no loss from the system to onshore movement through overtopping of the barrier beach, as this material is included in any estimates of beach volume.

6.1.3 Gravel Budget Balance

The state of the gravel budget balance can be determined for the South Canterbury coast from the accumulation of gravel at South Beach. Although recent accumulation has not yet been determined from the beach profile records, the long-term accumulation rate can be used to assess the general gravel budget balance.

Neale (1987) notes the long-term accumulation (without gravel extraction) to be about 52,000m^3/yr at the Port of Timaru breakwater. Hicks and Todd (2003) present a total accumulation (or arrival) at the Port of Timaru of 59,627m^3/yr.

This total is made up from the known inputs to the system (488,500m^3/yr) minus the known outputs from the system (gravel extraction at about 6,600m^3/yr), minus the unknown outputs (losses offshore due to abrasion). If the total is taken as the accumulation at South Beach, then the unknown losses (including all other uncertainties) can be determined from:

59,600 + 6,600 – 488,500 = -422,300m^3/yr.

This is about 86% of the total inputs, and close to the upper estimates of abrasion from Flatman (1997 for the Canterbury Bight), Hicks and Todd (2003) and Hemmingsen (2004 from studies of greywacke abrasion processes).

Therefore it can be seen that the gravel budget balance for the whole coast is in surplus. However this surplus is only expressed in the field north of Patiti Point. The coast south of Patiti Point (except for a small quantity of accretion at Saltwater Creek) is in gravel deficit and is eroding.

7. Discussion and Recommendations

Analysis of the beach survey monitoring data shows that the South Canterbury Coast is eroding between the Waitaki River and Patiti Point. There is a surplus in the gravel budget at South Beach.

Gravel extraction at Makikihi and other areas of the coast between the Waitaki River and Patiti Point add to the overall deficit but at the existing rates indicated by the returns do not contribute significantly to natural erosion processes. However all extraction from the rivers supplying gravel to this coast contribute to the sediment deficit in the vicinity of the river outlet. Therefore extraction from these rivers should be considered in determining a comprehensive gravel budget for the area to assess the extent of effect at the coast.

Substantial losses from the system due to abrasion may be an indication that river and coastal gravel extraction is a minor effect, limited to the vicinity close to the river mouth. Sites of extraction consents may not have a sustainable source of gravels on an annual basis, but may depend on temporal variability of flooding for gravel supply. Therefore consistent extraction at the consent limit may be unsustainable.

Extraction rates at South Beach of up to 10,000 to 12,000m^3/yr appear to be sustainable, and may mitigate against infilling of the dredged harbour channel.

Further analysis of the beach monitoring surveys is required to analyse volumetric changes to the beach system over time, and to correlate actual extraction against changes to the beach profiles.

Further assessment of the beach profile data for South Beach is also necessary to determine the changes along this stretch of coast in light of the development of the artificial beach in front of the harbour breakwater. Management of the build up of sediment may indicate that there may be a greater amount of gravel available for extraction at South Beach than is currently taken.

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