1. FLOODING & RIVERBED AGGRADATION HAZARDS

Reference:
West Coast Regional Council: Natural Hazards Review 2002, DTec Consulting Ltd., Christchurch (the DTec Report)

Flooding and Riverbed Aggradation are caused by:

River floods

River bed aggradation

Avulsion / breakouts

Examples of all of these, both past and projected, can be found at:

Buller River, Westport

Waitangitaona River, Hari Hari

Waiho River, Franz Josef

and most other West Coast rivers

Wanganui River in full flood at the main road bridge, Hari Hari, December 1995
Photograph by M Shearer, WCRC Engineer

FLOODING AND RIVERBED AGGRADATION

Excerpts from DTec Report pp 5-14

Introduction

Floods are by far the most common natural hazard on the West Coast, and occur across the length and breadth of the region. Benn (1990) recorded details of 405 flood events occurring between 1846 and March 1990. Research for this report has added details of a further 69 events between April 1990 and June 2002. The high frequency of floods is not surprising given that in terms of mean annual rainfall, the region is officially one of the wettest places on earth, and unofficially *the wettest.* (Mosley and Pearson 1997). Floods can be generated in a number of other ways besides direct rainfall, and as there is no defined seasonal trend of occurrence, floods occur at any time of the year.

From the earliest known recorded flood event by Thomas Brunner in 1846 (in Brailsford 1984) to the present day, floods have regularly caused inconvenience, and extensive damage in economic, physical and social terms. Floods have also probably caused more loss of life than any other hazard, although establishing the exact number of deaths is difficult due to old reports being vague (especially those up to the early 1900s). In discussing West Coast rivers and flooding. Lord (1928) stated: *the rivers, as will be shown, claimed many victims, so many that drowning became known as the national death*

Given their frequency, and that the region's major settlements are on very active floodplains (e.g. Greymouth, Westport, Hokitika, Karamea, Reefton, Franz Josef Glacier), floods maintain a higher public profile than other hazards. This is particularly true since the disastrous floods of May and September 1988 that devastated Greymouth and many surrounding rural areas, and the potential flood threat at Franz Josef Glacier with recent aggradation changes in the Waiho River. As a result much of the recent flood information relates to these two areas, although flood hazard research has also been extended in other areas of the region.

Causes of Flooding

Although rainfall is ultimately responsible for flooding in most cases, several distinct mechanisms of flooding can be identified. These are described in the following sub-sections.

1. Rainfall — Runoff

Moist westerly airflows travelling across vast tracts of ocean condense upon meeting and ascending over the Southern Alps. The resultant orographic rainfall can lead to extreme precipitation in terms of both intensity and duration. This combined with steep topography and short steep river catchments, leads to very rapid runoff of surface water (Griffiths and McSaveney 1983a), and is the principle cause of flooding in the region.

Mosley and Pearson (1997) described the synoptic conditions leading to heavy rain as: *Heavy rains tend to be associated with slow, eastward moving frontal zones embedded in west or nor west airstreams, where a slow moving anticyclone lies to the north or northeast of the North Island, with a deep depression moving eastwards to the south of the Tasman Sea, and a strong northwest airstream moving ahead of it*.

Some of the historically recorded rainfall figures presented are astounding.

For example:

- In March 1982 at Alex's Knob near Franz Josef, it was estimated that 1810mm (nearly 6ft) of rain fell in three days (Henderson 1993). This estimate was based on the consistency of rain as officially 650mm was recorded for the 3 days, but rain gauges overflowed or were washed out long before it stopped raining (Berm 1990).

- At Franz Josef Glacier township, storms producing 200mm in 24 hrs occur about once a year, and storms producing over 600mm in three days occur every few years (McSaveney and Davies 1998).

- A localised downpour near Lake Kaniere on 21 March 1981 produced 135mm (5.31 inches) in one and a half hours (Benn 1990).

- Otira and South Westland bear the brunt of many storms, and they often receive well in excess of 300mm in 12-24 hour periods (Benn 1990).

- Cropp River Basin, 5-6 October 1993. 800mm in a day (Greymouth Evening Star 6/10/93)

- The maximum daily rainfall recorded at Otira was 413mm and this had a return period of 1 in 100 years (1% chance in any given year) (Whitehouse & Williman 1986).

Annual rainfall figures are equally impressive. For much of the alpine main divide region, Tomlinson (1980) indicated annual rainfall at >8m/yr., and for coastal areas such as Greymouth, around 2.5m/yr. Even more impressive are figures for the Cropp River Basin in the upper Hokitika River Catchment. Griffiths and McSaveney (1983a,b) found the upper Cropp River basin averaged 11.315mm/yr, and the Remarkable Site =11.884mm/yr. Sections of the Southern Alps were estimated to receive between 12 and 15m/yr. It was noted by Mosley and Pearson (1997) that the Guinness Book of Records claims that Mawsynram in India, is the wettest place on earth, with an average annual rainfall of 11.87m/yr. They go on to state: *Sections of the Southern Alps receive an estimated 12 to 15 metres of rain per year but cannot claim the record because the alpine gauges are not part of an official weather station*.

Flood hydrographs and field observations (WCRC 1948-2002, Griffiths and McSaveney 1983b, Lowe 1988), and historical accounts (Cowie 1957, Benn 1990), show that all rivers can rise to very high levels extremely rapidly during high intensity rainfall events.

2. Riverbed Aggradation

Aggradation occurs when the volume of sediment introduced to a channel is more than the flow can remove. Sediment is therefore deposited into the channel. Most aggradation occurs at the head of an active fan, where a river/stream leaves the confines of a narrow valley, and spreads out over the fan, and where changes occur in the channel bed gradient. As the river flows further down the fan, the depth of flow and velocity decreases, leading to sediment deposition. This causes two main problems:

1. As the riverbed rises, the freeboard to the banks is reduced, leading to a corresponding increase in flood risk, as less discharge is needed to overflow the banks.

2. If so much sediment is deposited in a channel, the river may create a new channel or divert to an old channel to bypass the sediment slug.

The technical term for this second process is avulsion, but it is more commonly called a breakout. This process is one of the major hazards threatening Franz Josef at the present time (McSaveney and Davies 1998, Davies 1999, Hall 2000), and SH73 between Jackson s and the Otira Gorge (Whitehouse 1986, Whitehouse and McSaveney 1986, Whitehouse and Williman 1986,Paterson 1996).

Sediment injections into a river causing aggradation originate from landslides (all types e.g. debris flows, rock avalanches etc), bank collapses, and glacial input, and can range from small to huge volumes. Depending on how the sediment is introduced to the river system, downstream aggradation can be gradual (e.g. sediment introduced by riverbank erosion) or extremely rapid (e.g. sediment introduced by landslides). Sediment injections occur at irregular intervals forming sediment pulses or slugs that are moved through the system entirely by river flow. Smaller sediment slugs may be washed away in the next flood, whilst larger ones may need many large floods to disperse them (McSavaney and Davies 1998).

3. Backwater Effects (Back-Up)

River levels can be increased upon meeting an obstruction that restricts the flow, and creates a backwater effect. Such obstacles can include high tide/rough seas, river confluences, landslip dams, in-channel sediment slugs, culverts, and bridges. In Greymouth, river back up against high tides/rough seas has been attributed to increasing the level of several historic floods in the town (Cowie 1957, Benn 1990, Carson 1990, Benn, in prep). Connell (2001) found from hydraulic models, that maximum flood levels are almost always associated with maximum tide levels (see Section 2.5.6.).

Historical evidence also shows that when river levels are high, the major rivers can back up when entering narrow gorges: Tributary channels can also back up upon meeting a major channel that is in high flow. In both of these situations, considerable areas of farmland upstream of the gorge or tributary stream can be flooded. Information on the WCRC s flood hazard maps show this to be common at places like Walker’s Flat, just upstream of the Buller Gorge, where the Buller River (when above normal level) backs up upon meeting the gorge and floods the flat. When the Grey River is high, Stillwater Creek backs up against it and floods adjacent farmland and SH7. In fact, it was the regular occurrence of this phenomenon in pioneering times that lead to the place becoming known as Stillwater.

Rivers can also flood when a landslide blocks the channel, creating a dam. Flooding occurs upstream of the dam as a lake forms, and down stream when the dam breaches. This is discussed in more detail in the following chapter dealing with landslides. Numerous instances of backup water flooding roads and paddocks in rural areas have been recorded when small diameter culverts have become blocked with a variety of debris.

4. Local Surface Impoundment (Ponding)

Localised intense showers commonly cause surface flooding. This can be due to storm water systems in towns, and culverts in rural areas, being unable to cope with rapid inflow (either due to design or blockages with debris). Ponding also occurs when the ground is already saturated and water table levels are high, restricting subterranean drainage. Ponding may also occur where obstacles such as stopbanks impede return flow to a channel. This is one of the main reasons why pumping stations have been included in the Greymouth Flood Protection Scheme since it was built.

5. Back Up Through Urban Stormwater/Sewage Systems

High river flow levels may impede the drainage of stormwater/sewage flows, causing back up in the systems and subsequent surface flooding of streets. In the past this has been a particular problem in Greymouth, and to a lesser extent Hokitika, Franz Josef and Karamea. To help mitigate the problem, automatic floodgates are installed on the stormwater outfalls at these locations and pumps are used when necessary, at Greymouth and Hokitika (Mike Shearer, WCRC, pers.comm.).

6. River Mouth Blockages By Beach Sediments

Backwater flooding can occur when rough seas deposit beach sediment across river mouths, or ironically by lack of rainfall, leading normal coastal processes becoming dominant over low river flows. This process was responsible for major flooding in Hokitika in 1947 (Cowie 1957, Benn 1990), and has occurred on numerous occasions at many of the smaller river mouths such as Saltwater Creek (near Paroa, Appendix 1), Okarito (Westland Catchment Board 1986, Benn 1990) and Punakaiki/Pororari River (Kirk 1988, Benn 1990). Little is known about river mouth dynamics on the West Coast. This phenomenon is discussed in more detail in the Coastal Hazards chapter.

7. **Snowmelt**

Although attributed to being the cause of numerous floods, and adding to already high river levels in many cases (Cowie 1957, Benn 1990), very little quantitative data exists on the contribution of snow melt to floods. Mel Sutherland (GDC, pers.comm.) considered that the relationship between snowmelt and river discharge and levels needed investigating.

8. Jokullhlaup (Glacier Burst)

This process caused by temporary blockages or changes in sub-glacial drainage system leads to a pressure increase at the terminal ice face. This can cause the ice to collapse and create rapid floods and massive rapid aggradation. The exact processes are little understood. Resultant floods inevitably contain huge quantities of ice and sediment. Ice blocks can be huge and boulders extremely large. The term Jokullhlaup is Icelandic, but such events are commonly called Glacier Bursts.

At least five glacier bursts have been recorded on the Franz Joseph Glacier, and they pose a real threat to Franz Josef township and the Waiho Valley in general. As glacier bursts are a relatively rare phenomenon on the West Coast, it is considered that the accounts of these events, recorded in Sara (1968), Marcus *et al.* (1985), Benn (1990), and McSaveney and Davies (1998), are worth presenting in Appendix 2 (on computer disc in the back of the report), to emphasise the magnitude of these hazards. The account of Marcus *et al.* (1985) is particularly interesting as it was actually observed and measured as it occurred.

9. Seiches

Landslides of terrestrial or submarine origin, fault ruptures disturbing the water body, or intense ground shaking can form large seiches on lakes. Seiches can cause general flooding and structural damage, and both have been recorded on the West Coast. This is discussed in the earthquakes chapter.

10. Tsunami and Storm Surge

Both have been recorded in the region and are discussed in the coastal hazards chapter.

11. Artificial Dam Failure

Many artificial dams are scattered throughout the region and some are of considerable size, containing large reservoirs. A number of these have failed in the past causing considerable damage. However this is classed as an anthropogenic hazard by the WCRC and thus it is not referred to further in this report. This type of hazard has been covered previously by the WCRC, in a report by Benn (1995a).

Effects of Flooding

As stated at the beginning of this chapter, floods have probably killed more people on the West Coast than any other natural hazard. There are also a number of other significant effects on the West Coast communities.

1. Rural Effects

The most obvious effect of river flooding is direct inundation from rivers overflowing their banks. This is most commonly seen in rural areas where stretches of river have little or no protection works along their banks. In most cases little damage is done, besides a short period of inconvenience. Conversely, in rarer larger magnitude events, river bank erosion, scouring, deposition of thick silt/debris, and high flow velocities and depths can cause serious damage (and destruction) to pastures (e.g. be put out of production for long periods or destroyed), fences, farm buildings/houses, and equipment. Floods also take their toll on farm animals — many get washed away and/or drowned, or get trapped on islands where they are unable to be fed or get milked.

Many of the region's community rubbish dumps and septic tank discharge sites are located in flood hazard zones (Benn 1995b), and this can lead to visual pollution and contamination of the ground water and river channels as rubbish and septic tank discharge is scattered during flood events.

Aggradation effects are closely related to flooding but can be more long term (e.g. floodwaters drain away in a few hours or days — sediment deposited by aggrading streams stays until something removes it (heavy machinery, subsequent floods, dredging, gravel extraction). A good recent example is this is the McKenzie farm on the banks of the Poerua River, where floods and thick debris deposition originating from the Mt Adams Landslide, has destroyed 80% of the farm (The Press 13/04/02).

2. Urban Effects

In the urban centres, direct inundation can be more devastating due to the concentration of people and assets. This is demonstrated in the numerous cases of severe flooding in Greymouth, culminating in the May and September 1988 floods, where millions of dollars of damage occurred. Effects of the 1988 floods in Greymouth included:

- Isolation of Greymouth due to flooded roads in and out of the town
- Structural damage to homes and businesses, streets, rail tracks
- Damage to business stock and personal property/possessions
- Mass evacuation of people
- Contamination of the town water supply
- Sewage back-up in the streets
- Permanent closure of some businesses
- Numerous homes permanently condemned and subsequently demolished.
- Large financial losses (insurance companies refusing flood cover)
- General social disruption to the town for weeks after each flood (e.g. shops and services such as banks closed, structural repairs of streets and buildings, residents having to boil drinking/washing water etc).

It is worth noting that the Greymouth Flood Protection Scheme is designed to contain around $8500m^3s^{-1}$ before overtopping of the stopbanks occurs. For comparison, a one in a hundred year flood for the Grey River, is calculated at $7082m^3s^{-l}$ (Bowis & Faulkner 2000). It is considered likely that a flood of greater magnitude than this will occur at some future date. Rob Daniel (WDC, pers.comm.) noted that little had been done in Greymouth to prepare for a super-design flood.

Westport has a unique potential flood threat, as the town is surrounded by two river channels (Buller and the Orowaiti), and the sea. If flood levels are high enough to flow down the Orowaiti overflow channel, Westport effectively becomes an island, making access difficult (if the low lying roads nearby are flooded as well, or bridges are damaged).

Major aggradation in the Waiho River has the potential to cause the river to break out of its current channel and create a new course, probably down the Tatare River. Such a break out directly threatens residents on the south bank of the river, and millions of dollars of assets including SH6 (and bridge), the holiday park, and sewage oxidation ponds. If aggradation does continue and the Waiho River changes course, mass relocation of people, houses and assets may be the only feasible solution to avoid or mitigate the hazard.

3. Transport and Communication Effects

Floodwaters and aggradation can isolate communities from one another when transport and communication links get inundated/buried. Road and rail links are frequently cut by direct inundation and streambed aggradation, and power and telecommunication links get damaged frequently, by poles being washed away (Cowie, 1957, Benn 1990, Appendix 1). The whole West Coast Region can become isolated when the three alpine road passes are closed, and rail and communication links are cut. Westport and Greymouth airfields are prone to direct flooding although the risk has been reduced at Greymouth, with the Greymouth Flood Protection Scheme.

Rapid aggradation of steep mountain streams regularly causes damage to State Highways, district roads and rail links, by causing streams to breakout of their channels and bury the transport links.

At river mouths, aggradation can be a hazard to shipping, for example the river port of Westport needs regular dredging at considerable expense. To control aggradation at the Buller River Mouth, Buller Port Services have dredged a total of $2,242,875m^3$ since 1991, at an annual average rate of $320,410m^3$/yr (annual figures from Connell Wagner Ltd 2000). A large flood on the 2nd January 1868 provides possibly the earliest account of aggradation and avulsion being directly responsible for damage. The West Coast Times (06/01/1868 *m* Bonn 1990), reported that on the south side of the river at Westport, a large shingle bank was thrown up , partially filling the channel formed by the islands: consequently the river changed course, flowed to the north, and washed away the bank south of the bonded stores, and wharves on this side were also destroyed.

The Karamea harbour/wharf became operationally redundant after the 1929 Murchison Earthquake partly due to structural damage, but mainly because of the harbour basin aggrading from earthquake debris (KDSCC 1975).

Magnitude and Frequency of Events

Establishing the relationship between flood magnitude and frequency reliably for the West Coast is difficult as the hydrological records are short and in many case non existent. River level recorders are only present on the major rivers, being established on the Karamea in 1978, the Buller in 1963, the Grey in 1968, the Hokitika in 1975, the Poerua in 1982, the Waiho (SH6 bridge) in 2000, and the Haast in 1973 (Bowis & Faulkner, 2000).

Determining the magnitude of flood and aggradation events is relative straight forward compared to determining the frequency. For magnitude, direct quantifiable, physical measurements can be made, whereas frequency determination is usually based on averaging known historical/pre-historical events over a certain time period, or by using predictive numerical models to estimate future events. Both methods have inherent flaws.

1. Flood Magnitude and Frequency

From all sources of flooding, Benn (1990) recorded details of 405 West Coast flood events occurring between February 1846 and March 1990. Research for this report has added details of a further 69 events between April 1990 and March 2002. This makes a total of at least 471 events over a 156 year period. In simple terms, this implies that flood damage/disruption occurs on average three times per year in the West Coast region.

Table 1 shows the maximum-recorded discharges at some of the major rivers in the region.

Table 1. Maximum Recorded Discharges for Major Rivers (Bowis & Faulkner 2000)

River	Date	Max. Discharge (m^3s^{-1})
Karamea	19/10/98	3 166
Buller	25-26/05/50	12460
Grey	16/12/97	5951
Hokitika	09/01/94	2447
Whataroa	09/01/94	3952
Haast	12/05/78	6330

Note: Buller figure from Come (1957), Benn (1990).

As far as is known the May 1950 discharge for the Buller of 12,460m^3 s^{-1} remains the largest *recorded* flood discharge in New Zealand. This recording was based on gaugings and cross section analysis at Berlin s swing bridge. However, the 1926 flood in the Buller River is presumed to have had a discharge significantly greater than this, based on known flood levels (Cowie 1957).

Fauth (1988b) presented Grey River flood magnitude/return periods for the September 1988 event (5 768m^3 s^{-1} at Dobson) and assigned a 121+ year return period for the event. However this appears to have been based on the historical fact that the September event was the largest recorded in Greymouth to that date. More creditable calculations of discharges at certain return periods for a number of rivers were presented by Bowis & Faulkner (2000), and are shown in Table 2.

Table 2. Calculated Flood Discharges and Return Periods (Bowis & Faulkner 2000)						
Return Period (Years)	Karamea Gorge	Buller /Te Kuha	Grey/Dobson	Whataroa/SHB	Hokitika/Colliers	Haast/R'Billy
	Discharge (n^s")					
1	2042	4894	3827	2822	1 749	3720
5	2488	5963	4573	3403	1 930	4632
10	2852	6833	5 180	3876	2077	5374
20	3200	7668	5763	4330	2218	6066
50	3652	8749	6517	4918	2401	7007
100	3990	9559	7082	5358	2538	7698

Return periods calculated by Connell Wagner Ltd (2000) for the Buller River are shown in Table 3, and generally agree with the figures in Table 2, although the 1988 discharge should be assigned as at least >20 years.

Table 3. Buller River Discharge Return Periods at Te Kuha (Connell Wagner 2000)		
Date	Discharge (mY)	Return Period years
21/10/83	6838	>10
20/05/88	7778	>10
13/06/93 (?)	7800	>20

Note: Discharges and dates from Benn (1990), and GES 13/06/93, return periods from Connell Wagner. Connell Wagner only specified the year: dates and discharges in Table 3 are assumed to correlate to Connell Wagner return periods of the floods they discuss.

Having more accurate flood return periods and levels, and being able to plot such data on flood probability maps is the most recognised gap in hazard information in the region (see district council responses in Chapter 7).

2. Aggradation Magnitude and Frequency

Besides predicting basic trends of aggradation and degradation phases, predicting the magnitude and frequency of such processes with any certainty is effectively impossible. This is due to the large number of variables involved, which themselves are hard enough to predict (e.g. extreme rainfalls, snowmelt, river discharges, landslide occurrence and magnitude, glacial behaviour etc).

Riverbed aggradation in the region in most cases is gradual, with a steady supply of sediment from bank erosion or other minor sources leading to a gradual rise in bed levels. This process was demonstrated for the Buller River below Te Kuha, where aggradation has been occurring since 1972 (Connell Wagner Ltd 2000). Fluctuations in this trend have occurred as floods periodically scour the channel.

In contrast, aggradation can also occur very rapidly (within minutes/hours) and be extreme in terms of bed level elevation changes, and sediment volumes involved. For example, during an intense rainstorm in December 1957, a landslide fell into the Otira River channel, aggrading the riverbed level between 6 and 8m, buried sections of the highway and diverted the river through the town causing serious damage (McSaveney 1982, Whitehouse 1986, Whitehouse and McSaveney 1986, 1989, Benn 1990). McSaveney (1982) also recorded aggradation of 3 to 4m in the Otira River bed during the December 1979 storm.

A similar event occurred in the Waitangitaona River in March 1967. After intense rain, debris from the Gaunt Creek landslip aggraded the Waitangitaona River bed, causing the river to divert from one side of its alluvial fan to the other. The river switched from its historical route to the sea to the north of Okarito Lagoon, to a more easterly direction, across SH6, via Lake Wahapo (6km away), Zaias Creek, Okarito River and Okarito Lagoon (Soons 1982, Griffiths and McSaveney 1986). The change in direction of the Waitangitaona River had the following effects (Soons 1982):

- Changed Lake Wahapo from a clear lake to a turbid lake
- Killed a large stand of native forest by burying the tree root system
- Increased stream flow leading to an increase in bank erosion down stream of Lake Wahapo
- Increased stream flow may have been responsible for changes at the outlet of Okarito Lagoon
- SH6 was blocked

For small creeks in the Otira —Arthur's Pass section of SH73, Whitehouse and Villiman (1986) stated that the principle hydrological factor affecting bridge design was aggradation, and noted that recent bridge renewals all had an allowance of around 3m for aggradation incorporated into their designs. Many sections of SH73 and bridges between Griffin's Creeks and Otira Gorge have been buried by rapidly aggrading creeks during rainstorms over the years (Cowie 1957, Benn 1990, Appendix 1). Rapid aggradation is also a common problem at creeks crossing SH6 between Harihari and Fox Glacier, Haast Pass, between Greymouth and Westport, and SH67 Granity-Ngakawau and the Karamea Bluffs.

The most spectacular aggradation in the region in both long and short-term has occurred in the Waiho River channel, at Franz Josef Glacier. When settled by Europeans the Waiho River was contained in a deep incised channel. This channel was so deep the settlement was originally called Waiho Gorge.

In the last 140 years the river has aggraded so much it now threatens much of Franz Josef township by breaking out and flowing down into the Tatare River — something that it has never done in the past. Glacier bursts have been responsible for the greatest magnitude of aggradation recorded. Appendix 2 [of the Dtec Report] provides a detailed account of the aggradation that occurred in 1965 after a glacier burst: The river aggraded 9.1m (30ft) for a distance of 2km downstream of the terminal face. McSaveney and Davies (1998) considered short term aggradation of about 4m to be normal.

Waiho River River at Franz Josef:

By 1996 the Waiho River had aggraded so much there was very little clearance under the highway suspension bridge for river flow. When the river was flowing with ice melt off the Franz Josef Glacier, ice and boulders were coming very close to the underside of the bridge. In the end the suspension bridge was removed and replaced by a bailey bridge, these being easier to relocate or extend.

There are also other problems as a result of this aggradation because the riverbed is also higher than dwellings on the other side of the stopbank on the south side of the river. These dwellings and anyone in them are at extreme risk and as of 2003 the Ministry of Civil Defence & Emergency Management decreed that these dwellings should go. This has caused much friction between the businesses concerned and the Ministry, the Westland District Council and the WC Regional Council. As of July 2004 these issues are not fully resolved (refer West Coast Times and Westland District Council for ongoing information).

Note how low the suspension bridge, since removed, is to the water. Bailey bridge in background
Photograph taken by Mike Shearer, WCRC Engineer in November 1996.

Resource Sample 1.

Flood Data for West Coast for 1968

The following items are a <u>sample only</u> of the WCRC flood records collected by former staff member, John Benn, and held at the council. The list is extensive and runs from 1846 to 1989. Access to all the material is available through the Environmental Information Officer for teachers (for preparing class work), community leaders, students doing Correspondence studies at secondary school and Year 13 or university students doing research.

<u>9 - 12 MARCH 1968</u>

Strong winds with heavy rain brought some surface flooding to Greymouth but caused no damage. All damage reported was due to wind (G.E.S. 09/03/1968). Minor flooding of the Grey River slowed repair work of the Blackball Bridge, and floodwaters washed away another span of the old Waitangi-taona River Bridge (G.E.S. 13/03/1968).

<u>9 - 10 APRIL 1968</u>

The "Wahine Storm" caused much damage to road and rail links on the West Coast. Greymouth recorded 53mm of rain in one hour. Many residents suggested the Grey River was at its highest level in memory (G.E.S. 09/04/1968). Recorded levels show the Grey River was discharging 5100 cumecs and was 5.4m above normal levels. The Hokitika River was 5.4m above normal at the Kaniere bridge and flowed at 3,030 cumecs. Sawyers Creek was at its highest level ever, at 2.9m and discharging 70 cumecs. The Mawheraiti River was also reported by residents to be at record height. The Inangahua River was in heavy flood although no damage was reported from the area. Other rivers in high flood were the Taramakau, Kaniere, Kokatahi, Waitaha and Poerua. All flooded rivers except the Inangahua damaged stopbanks and groynes (W.C.B. File 375). Four spans of the Totara bridge were washed away and residents suggested floodwaters there were the highest ever (G.E.S. 09/04/1968). Spans of the Blackball Bridge were washed away and the whole of the rail track at the end of the Kaimata tunnel fell into the Arnold River. Bridge approaches were washed out between Ahaura and Kopara and the bridge at Bell Hill was washed away completely (G.E.S. 10/04/1968). Approaches to the Canoe Creek Bridge were also washed out. Cemetery Creek and Sawyers Creek both overflowed and flooded parts of Reefton and Greymouth respectively. Greymouth, Cobden and Runanga all received severe surface flooding and slipping. The Denniston Escarpment Mine was badly damaged by a creek bursting its banks and flowing into the mine (G.E.S. 09/05/1968). The Brighton Coal Mine was written off as water and silt swept away all the surface buildings and plant equipment. New road seal at Dobson was destroyed by upwelling from an underground stream.

Although most of the major rivers caused relatively little damage, Ahaura and Totara Flat were severely inundated by the Grey River. The railway in this area was damaged severely by slips (G.E.S. 10/04/1968).

6 MAY 1968

Surface flooding occurred in the Greymouth area as the result of heavy rain produced by a thunder storm. In twenty-four hours, Karoro received 29mm of rain and Greymouth Harbour recorded 31mm.

Slips produced by the April storm were re-activated, one which blocked the Cobden Railway line. Little damage was reported (G.E.S. 06/05/1968).

24 - 25 MAY 1968

The upper Buller River rose considerably after it was blocked by a huge slip triggered by the Inangahua Earthquake. The rock avalanche blocked the river 3km upstream of Lyell. Material on the south bank was brought down from a height of over 600m and was carried about 50m up the north bank.

The river backed up and formed a lake behind the dam, until it eventually broke through. Reports from the Ministry of Works indicated that the river was blocked from 4.30 p.m. on the 24th until 1.00 a.m. on the 25th (Adams, et. al. 1968).

11 - 13 AUGUST 1968

When heavy rain commenced on the night of the 11th, rivers throughout Buller and Westland began to rise and roads were closed because of flooding and slips. The Upper and Lower Buller Gorges were closed because of slips, and State Highway 6 was closed to light traffic when Lake Wahapo overflowed. A number of slips also occurred in the area but these did not block the road. Surface flooding also occurred on a number of county roads throughout the district. In Greymouth drains and smaller creeks backed up onto a number of properties although no damage was reported.

In the twenty-four hours to 9.00 a.m. on the 12th, 69mm of rain was recorded at Greymouth. The Grey peaked later in the day, flowing at 2.25m/s (G.E.S. 12/08/1968), but dropped quite rapidly to a 1m/s velocity by early morning on the 13th (G.E.S. 13/08/1968).

22 - 23 OCTOBER 1968

A north-west storm brought heavy rain to most of the West Coast. Rivers rose to high levels with the Mawheraiti at Ikamatua rising 2.1m above normal, and the Ahaura River approached its 7.4m record level set in March 1967. The Hokitika River was in high flood and parts of Hokitika's business district and lower lying streets were flooded by surface water. Minor slips occurred on road and rail links but these were cleared quickly (G.E.S. 23/10/1968).

A "cloudburst" over the Cascade Mine caused ground shattered by the Inangahua Earthquake to slump and block Cascade Creek; water backed up and flooded the mine causing about $20000 worth of damage. Bins, a compressor, electric pumps and other equipment was lost (G.E.S. 24/10/1968).

Cont …………….

In the twenty-four hours to 9.00 a.m. on the 23rd, the following rainfall recordings were made: Greymouth 51mm, Otira 201mm, Hokitika 88mm, Milford Sound 220mm. From the Greymouth total, 33mm fell in two hours and from the Hokitika total, 58mm fell in three hours (G.E.S. 23/10/1968).

28 - 30 OCTOBER 1968

The second peak in a week of stormy weather occurred as the Grey River had been running bank to bank or overflowing its banks since the 23rd (G.E.S. 28/11/1968). At Dobson the river was 5.6m above normal and was only a "few feet" below the Dobson memorial on the island between Dobson and Taylorville. The Omoto Racecourse was flooded to the extent that tops of the power poles were only 1.5m above the water. Houses at Ikamatua and Ahaura were flooded as the Big Grey held its peak for a number of hours and lower parts of Greymouth were affected by surface flooding.

Only the Coast Road to Greymouth remained open out of Westport as all others were closed because of flooding or slipping. The Upper and Lower Buller Gorges were closed as water covered the road. At Fenwick's the road was covered with about 2m of water. Rail and road links throughout the area were also cut by flood waters and slips. At their peaks, both the Buller and Grey Rivers were running at 5m/s (G.E.S. 30/10/1968). The most inconvenient damage during the storm was to telecommunication links, done by high winds and not flood waters.

8 NOVEMBER 1968

Heavy rain produced surface flooding over a wide area. During the night Hokitika received 76mm of rain and winds up to 65 km/h.

The southern approach to the Ford Creek Bridge just south of Blackball was washed out cutting off access to the township except via Ikamatua. On the Otira highway water was up to the road at Harris's Swamp and in Greymouth water was over the footpath at Whall Street and at the Sawyers Creek end of Shakespeare Street. Surface flooding due to stormwater backup occurred in Leonard Street and on the town side of the Cobden Bridge (G.E.S. 08/11/1968). Minor damage was reported to river protection works from a number of areas (W.C.B. File 375). In the Fairdown and Granity areas a number of creeks overflowed onto the road and railway although they remained open (W.C.B. photographs).

25 DECEMBER 1968

Floodwaters washed out 80m of recently constructed stopbank on the Little Man River (Dry Creek), exposing a house and State Highway 6 to flood waters. No other damage was reported (W.C.B. File 375).

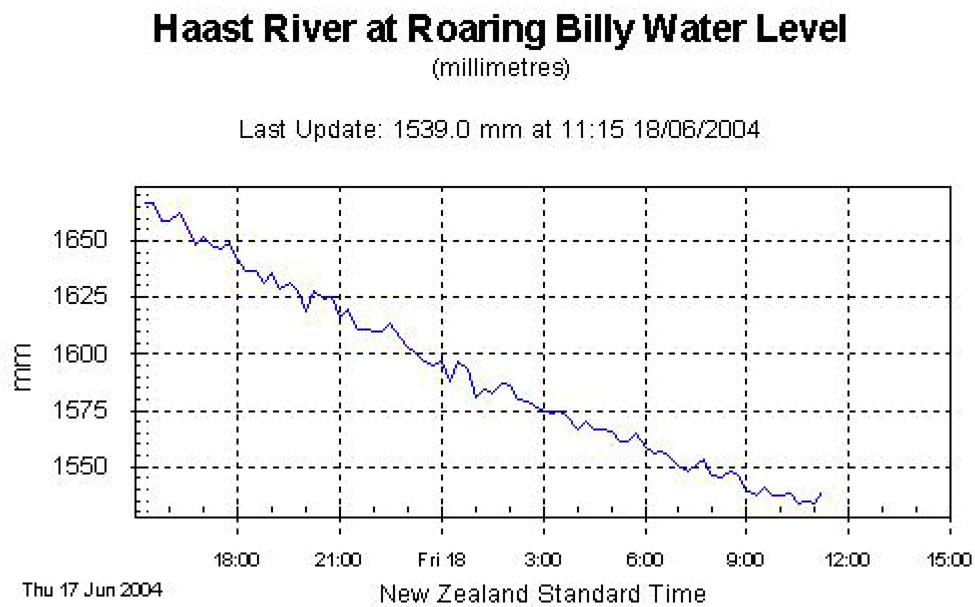
Resource Sample 2.

WCRC River & Rainfall Information:

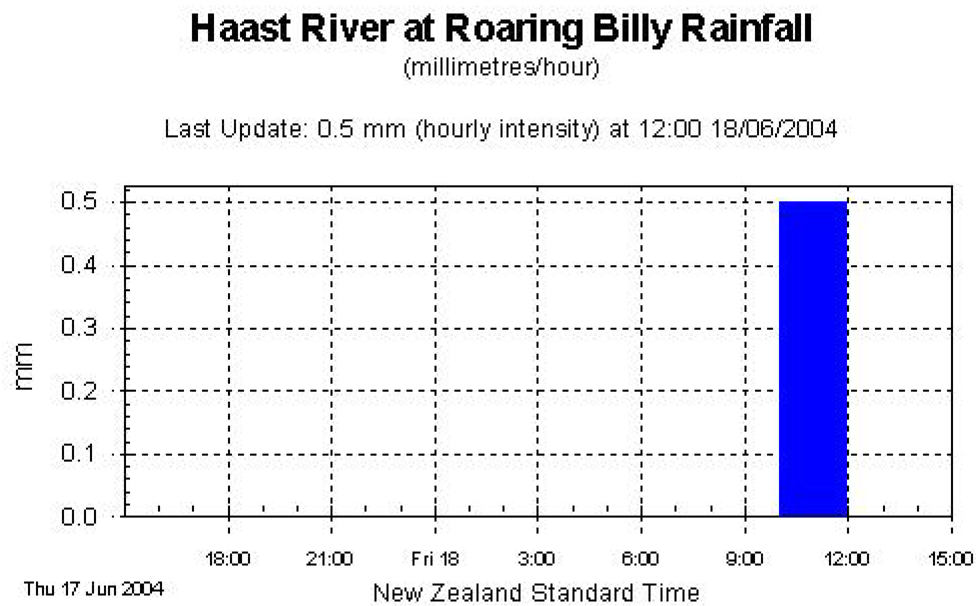
Examples of type of information online at www.wcrc.govt.nz/environment/hydro

1. Haast River Water Level & Rainfall - last 24 hours

Telemetry disclaimer



Water Level last 7 days
Flow last 7 days



Rainfall last 7 days

Monitoring site comments:

The Roaring Billy water level and rainfall recorder is situated on the Haast River in the lower Haast catchment, 47km upstream of the township of Haast. The site has a catchment area of 1020km2. Lowest water levels are recorded during the winter months when levels can fall to 0.6 metres but normal water levels are closer to 1.2 metres. A high flood water level of 7.6 metres was recorded at this site in May 1978.

This site records a mean annual rainfall of 5750mm and daily falls of up to 400mm.

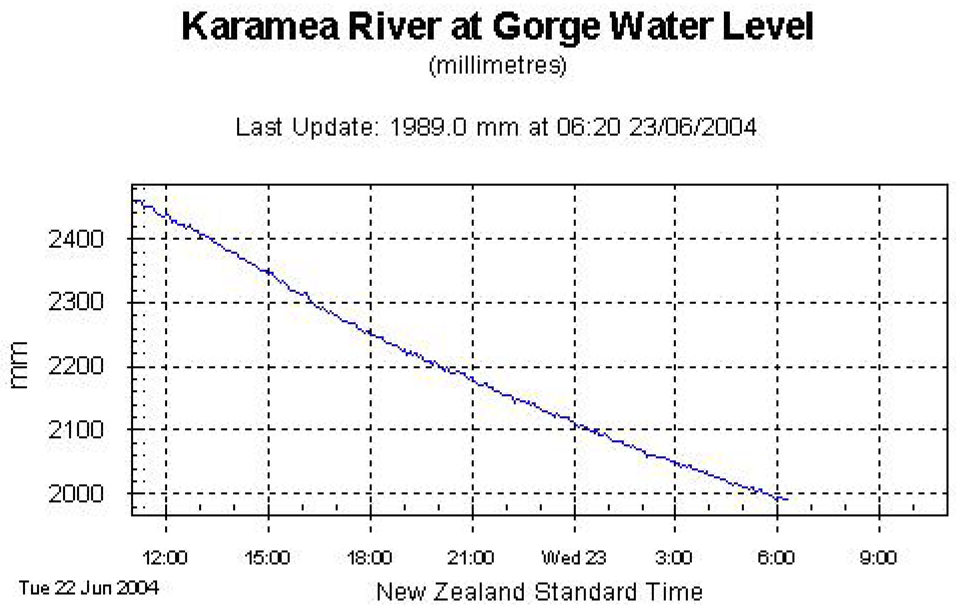
This site is operated by the National Institute of Water & Atmosphere as part of the National Hydrometric Monitoring Network, and is a part of the West Coast Regional Council Flood Warning Network.

Haast: flood prone and remote. Residents in the Haast area of South Westland are hardy individuals whose contacts to the outside world become tenuous when the elements are at their worst. A long road bridge links them to places north while highway up the Haast valley and over Haast Pass is their only road link east. The heavy rain the region is well known for regularly damages these outside links. Repairing roads due to slips and flooding is an ongoing task in this part of the world.

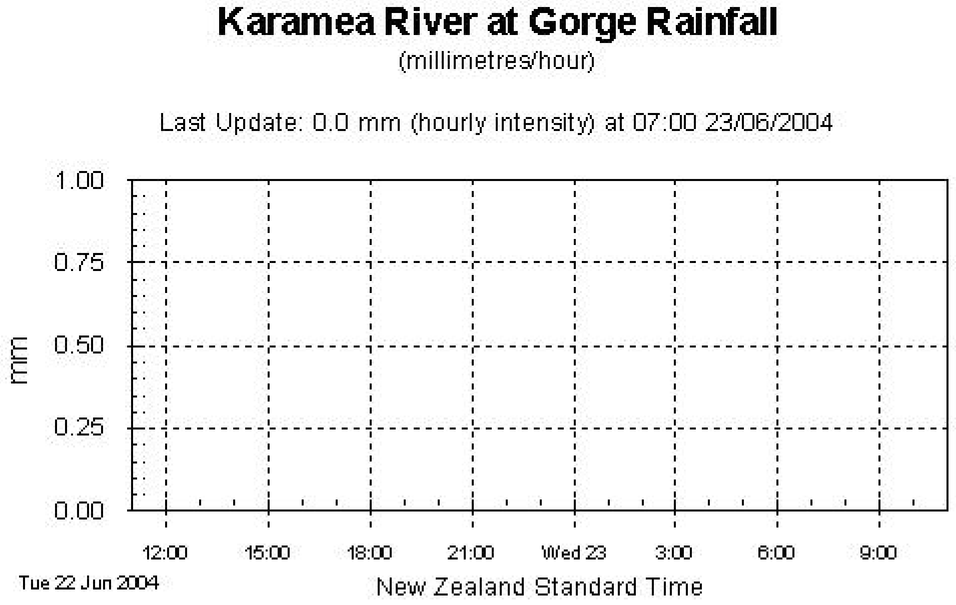
The Haast River in full flood at the highway bridge. *Photograph by G Mackley*

2. Karamea Water Level & Rainfall – last 24 hours

Telemetry disclaimer



Water Level last 7 days
Flow last 7 days



Rainfall last 7 days

Monitoring site comments:

The Gorge water level and rainfall recorder is situated on the Karamea River in the lower Karamea catchment, 12km upstream of the township of Karamea. The site has a catchment area of 1160km2. The site commonly records dramatic rises in water level in response to heavy rain when rates or water level rise of 0.7m per hour are not uncommon. Summer water levels at this site can get as low as 0.7 metres but normal water levels are closer to 1.0 metres. A high flood water level of 5.6 metres was recorded at this site in October 1998. The First Stage Alarm Level for Flood Warning at this site is 4.0 metres.

This site records a mean annual rainfall of 2760mm and daily falls of up to 140mm.

This site is operated by the National Institute of Water & Atmosphere as part of the National Hydrometric Monitoring Network, and is a part of the West Coast Regional Council Flood Warning Network.

Karamea: flood prone and remote. The settled area at Karamea from Little Wanganui through to Karamea and North Beach is divided by the Karamea River. This is a "big river," with big rapids and large flow giving it a Grade 5+ category for commercial river rafting (a Grade 6 is well nigh impossible to raft). Many times in the past the river has flooded, even taking out the bridge, and basically cut off the town (shops, school, Information Centre) from the farming areas further south toward Little Wanganui. Local Civil Defence arrangements take this into account in the event of a flood with the district having separate Civil Defence officers and plans for the north and south areas.

The Karamea River (left, looking upstream) floods houses and farmland at the Arapito upstream and on true left of the main road bridge, Karamea, 1998.
Photograph from WCRC Collection

Resource Example 3. Photo File

1. The floodwall just holds, Greymouth 1997. Built after the two disastrous floods of 1988 this was the first real test for Greymouth's much vaunted floodwall. Even so there were still major problems upstream at Kaiata and over the river at Cobden. The wall has since had further work because of leaks and it will be raised yet again in 2005 because flood modelling has shown this will be needed.

Looking out to sea with the Grey River awash, December 1997. *Photograph by M Shearer, WCRC Engineer*

2. Cropp River Rain Gauge Site: This rain gauge, sited mid photo on a small rise at the true right of river before it drops into the gorge, records an annual mean rainfall of just over 10m. In February 2004 it recorded a record 99mm in one hour. The site is within the maximum precipitation zone at 860m above sea level and about 20 kms inland.

Looking down the Cropp River into the gorge. *Photograph by J Porteous, NIWA*

3. Poerua River flats below the Gorge: In June 2000 a huge landslide off Mt Adams dammed the Poerua River above the gorge. This then gave way and a large wall of water came down the river, broaching stopbanks at the first farm down the valley. The stopbanks which had been able to contain normal floods over a long period, were no match for this one and a large area of arable farm land was ruined.

The scene on June 29th at the topmost broach of the stopbank on the Poerua River post the Mt Adams landslide flood. *Photograph by M Shearer, WCRC Engineer*

4. Maruia River at the Falls: the Maruia River is a main tributary of the Buller River which has a long history of flooding at Westport. Between Springs Junction and the falls, created in 1929 by the Murchison Earthquake, the Mariua River meanders for much of the time across a wide valley. Many of the farms have stopbanks in place for flood protection.

Maruia Falls in full flood spate, October 23rd 1996. *Photograph by M Shearer, WCRC Engineer*

5. Sawyers Creek at Greymouth: Localised downpours can cause lesser West Coast streams to become raging torrents and when they flow through urban areas major flooding can occur. Sometimes these local creeks will be in major flood while nearby large rivers are not. The term "stormwater" is then aptly deserved.

The scene in Alexander Street, Greymouth on January 24th 2000, after a flash flood down Sawyer's Creek from a localised downpour just east of Greymouth.

Sawyers Creek floodwaters lapping the footbridge in Dixon Park, Greymouth on January 24th 2000. Before major floodworks were completed upstream in the 1970's this creek had been known to top this bridge. *Both photographs by M Shearer, WCRC Engineer*

Flooding & River Aggradation References

General Information

Natural Hazards in New Zealand: compiled by I. Speden and MJ Crozier for NZ UNESCO 1984. Part A: Scientific Topics Weather Related Hazards 1. Flooding

Tephra Magazine, June 1997, Vol.16: All articles on Storms. Excellent technical information but limited West Coast Information.

Regional Information

A Chronology of Flooding on the West Coast, 1846 – 1990: WCRC Report by J Benn, 1990. Access report through WCRC EI Officer.

Major Flood Events in Greymouth, N.Z., 1862 – 1988 (1992): WCRC Report by J. Benn. Access report through WCRC EI Officer.

***Buller and Westland - Report on Major Flooding, May 1988*:** by BJ Fauth, for Westland Catchment Board, Sept. 1988. Access report through WCRC EI Officer.

Westland District Plan 2002: "5.7 Waiho River Severe Flood Hazard Policy Unit." Access at Westland District Council or from EE Officer at WCRC

Landslide Dambreak Floods at Franz Josef Township, Westland, NZ: by TRH Davies, 2002. Published NZ Journal of Hydrology, Vol 41, pp 1-17

Impact Magazine, Dec 2002 issue : "Waiho River Flooding Risk Assessment,"

Impact Magazine, July 2000 issue: "Managing Risk in Franz Josef"

The 1999 Landslide Dam in the Poerua River, Westland, NZ: by GT Hancox, MJ Mc Saveney, MJ Davies & K Hodgson, 2000. Published in "Dams Management and Best Practice", IPENZ.

Inchbonnie Rating Area - Tarakamau River Control: WCRC operational plan in place for Inchbonnie Rating Area. Re aggradation, breakout control. Short history.

Natural Hazards Update, Quarterly Newsletter of NIWA and GNS on all types of NZ Natural Hazards. Sometimes information specific to West Coast. Available online.

Flooding & River Aggradation Websites

General Information Sites

www.hydrology.org.nz-resources	Core body associated with hydrology management throughout New Zealand. Many links to other groups listed on this website
www.niwa.co.nz/ncwr	the National Centre for Water Resources supplies public information on river, lake and groundwater conditions throughout NZ. Has daily flood forecasts in collaboration with Regional councils, e.g. WCRC
www.naturalhazards.co.nz	Expert consultants, engineers re disaster prevention, mitigation, recovery. Look for links to flooding.
www.ew.govt.nz	Environment Waikato has a new flood plan for the Waikato River. Email facility online for accessing flood, other information. A region with similar problems to the West Coast.
www.nwp.rsnz.org	NZ Waterways Project provides facilitators and equipment throughout NZ for school groups to do stream monitoring and allied activities.
www.waterinfo.org.nz	This is the NZ Hydrological's Society's Water Information Directory website. Not organized in terms of natural hazards but much information about NZ's waterways of all kinds.
www.naturalhazards.net.nz	For online versions of *Natural Hazards Update*, joint NIWA and GNS quarterly newsletters

Regional Information Sites

www.wcrc.govt.nz	Excellent site for looking at a flood warning system. Rainfall data figures and river monitoring of WC rivers online. Backdated information also available on application to Council Hydrologist.
www.wcrc.govt.nz	See Flooding & Aggradation Section of Natural Hazards Resource Kit. Prepared from July 2002 DTec Report on West Coast Natural Hazards
www.greydc.govt.nz/annualplan	Relevant section Grey District's Council's 2002 Annual Plan: statement regarding their commitments to Stormwater, River Protection & Soil Conservation.

www.westlanddc.govt.nz/districtplan	Section 5.7, Waiho River Severe Flood Hazard Policy Unit. Major potential flood hazard for WDC.