THE ECONOMIC IMPACT OF ROAD CLOSURES CAUSED BY NATURAL HAZARDS – CASE STUDY KAIKOURA

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By Joshua Clydesdale

The New Zealand road network is vital to the economic wellbeing of the nation. The road network is, however, vulnerable to closure from a host of natural hazards. Road closures caused by natural hazards adversely effect the movement of freight and people between nodes. Link security is of particular importance to communities separated from major urban centres, particularly when alternative road links (if any) condition costly deviations.

This research investigates the vulnerability of the road network in the Kaikoura District to closure from natural hazards and estimates the costs of road network disruption for road-users and non-users. The road network in the Kaikoura District is sparse and has historically been disrupted by natural hazards. The 'potential' cost of road network disruption for road-users and non-users exceeds $0.25 million per day when road-users are required to detour to the Lewis Pass route. However, total disruption costs are significantly lower when a low-cost alternative route (Highway 70) is available.

Link reinstatement priorities are provided according to road-user cost and non-user cost minimisation and the strategic importance of the State Highway 1 link to the north of Kaikoura has been emphasised. It is recommended that a New Zealand wide risk analysis study be conducted to provide a cohesive and comprehensive information base applicable to the management of the New Zealand road network.

Keywords: road network, natural hazard, road closure, Kaikoura District.

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Chapter 1: Introduction

1.1 Background

The road network is of vital importance to the economic wellbeing of communities in New Zealand (Transit NZ, 1993). The New Zealand road network is, however, vulnerable to closure from natural hazards. 'The combination of steep terrain, high rainfall, and frequent earthquakes mean that most of New Zealand is subject to natural events that may close roads' (Whitehouse and McSaveney, 1992:27).

'One may consider a road network as a system of points and lines as in a graph, the points (or nodes) being the urban centres or road junctions and the lines the individual road links via which inter-nodal interaction takes place' (Kissling, 1969:113). Road closures caused by natural hazards do not allow the road network to function to its full potential because a change in the network's linkages brings about a change in the accessibility of each node in the network (Taaffe et al., 1996). The closure of some links (eg. state highways) may have significant impacts on nodal accessibility, 'principally where there is no alternative route, or where the alternative route is prohibitively expensive' (Butcher, 1985a:11). Links in a network can, therefore, be assigned importance values, for example, in terms of distance, time, or the cost of travel (Kissling, 1969). By quantifying linkage importance, the cost of changes in network accessibility can be measured.

'Network theory is concerned with alternative links and describes the options, the probability of options being simultaneously closed, and the costs of using various network options' (Butcher, 1985a:17). However, network theory only addresses the costs to road-users of detouring to alternative links and does not account for other costs associated with road network disruption.

The costs of road closures caused by natural hazards include:

1. Road-user costs - which refer to the additional costs incurred by road-users (eg. travel time costs, vehicle operating costs and accident costs) as a result of vehicles being required to detour to alternative links;
2. Link reinstatement costs - which refer to the cost of restoring a safe, trafficable link; and
3. Non-user costs (or costs to other parties) - which refer to the costs of interruption and disruption of economic activities as a result of changes in nodal accessibility (Green et al., 1983). A road closure may, for example, isolate a community, thereby affecting the input (eg. supplies) and output (eg. sale of goods) requirements of that community.

This research focuses on road-user costs and non-user costs of road network disruption in the Kaikoura District. Additional time costs, vehicle operating costs and accident costs incurred by road-users as a result of road closure events are easily measured using established methodologies (see Transfund NZ, 1997a). However, non-user costs have received little research attention because of the complex and diffuse nature of these costs (Green et al., 1983). In New Zealand, for example, only anecdotal reports of non-user costs are normally reported (eg. see Birch, 1998), even though much of the impact of network disruption may be felt by non-users (Butcher, 1985a). Impacts on 'local economies and communities, although potentially quite disruptive, have for the most part been overlooked by planners' (Monroe and Ballard, 1983:23).

1.2 Goal and objectives of study

Road closures caused by natural hazards adversely effect the economic benefits the road network provides (Transit NZ, 1998a). The goal of this study is, therefore, to:

Investigate the economic impact of road network disruption in the Kaikoura District.

The objectives of this study are:

1. To identify the costs of past network disruptions in New Zealand and internationally.

2. To conduct a historical review of road network disruption in the Kaikoura District and identify the risk of future disruption.

3. To identify the importance of road links servicing Kaikoura based on current traffic flow and costs of diversion.

4. To identify the costs of road network disruption for businesses in the Kaikoura District, including the length of time businesses can sustain road dislocation.

There is a statutory obligation to provide a safe and efficient road network that contributes to the economic wellbeing of communities in New Zealand (Transit NZ, 1993). Adverse effects, including any actual or potential effects of natural hazards, need to be avoided, remedied or mitigated (ibid). This research provides a greater awareness of the risk of closure in the Kaikoura District. 'Identification of hazards and assessment of their frequency of realisation provide an aid in planning improvements to, or relocation of, highways to minimise maintenance costs and traffic disruption through highway closure' (Whitehouse and McSaveney, 1992:27). Complementing this perspective, this research provides a greater understanding of the costs of road closures caused by natural hazards. The output of this research establishes priorities for the reinstatement of links providing access to Kaikoura according to road-user cost and non-user cost minimisation. Few studies in New Zealand have systematically explored these topics.

1.3 Location of study area

The Kaikoura District is located along the East Coast of the South Island (see Figure 1.1). The District stretches from just north of the Conway River to just north of Kekerengu (Kaikoura District Council, 1996). The Inland Kaikoura Range forms the western boundary of the District, while the Pacific Ocean forms the eastern boundary of the District (ibid).

State Highway 1 is the principal highway in the Kaikoura District (see Figure 1.1). Kaikoura is located 132km south of Blenheim and 189km north of Christchurch. Highway 70 (Inland Road) joins State Highway 1 just south of Kaikoura and provides an alternative route south. No alternative link is available in the Kaikoura District for State Highway 1 to the north of Kaikoura.

1.4 Research framework

Any research into the effects of natural hazards involves consideration of risk analysis (Centre for Advanced Engineering, 1997). Risk analysis is defined as 'the systematic use of available information to determine how often hazards may occur and the magnitude of their consequences' (Helm, 1996:2). The first stage of this research involved the natural hazard assessment. The objective of the natural hazard assessment was to provide insights into the vulnerability of the road network in the Kaikoura District to closure. The consequences (or costs) of road network disruption for road-users and non-users were then estimated (stage 2 and stage 3).

A range of methodologies were applied in this research. For ease of interpretation, the methodologies applied in each of the three stages of this research are described in later chapters.

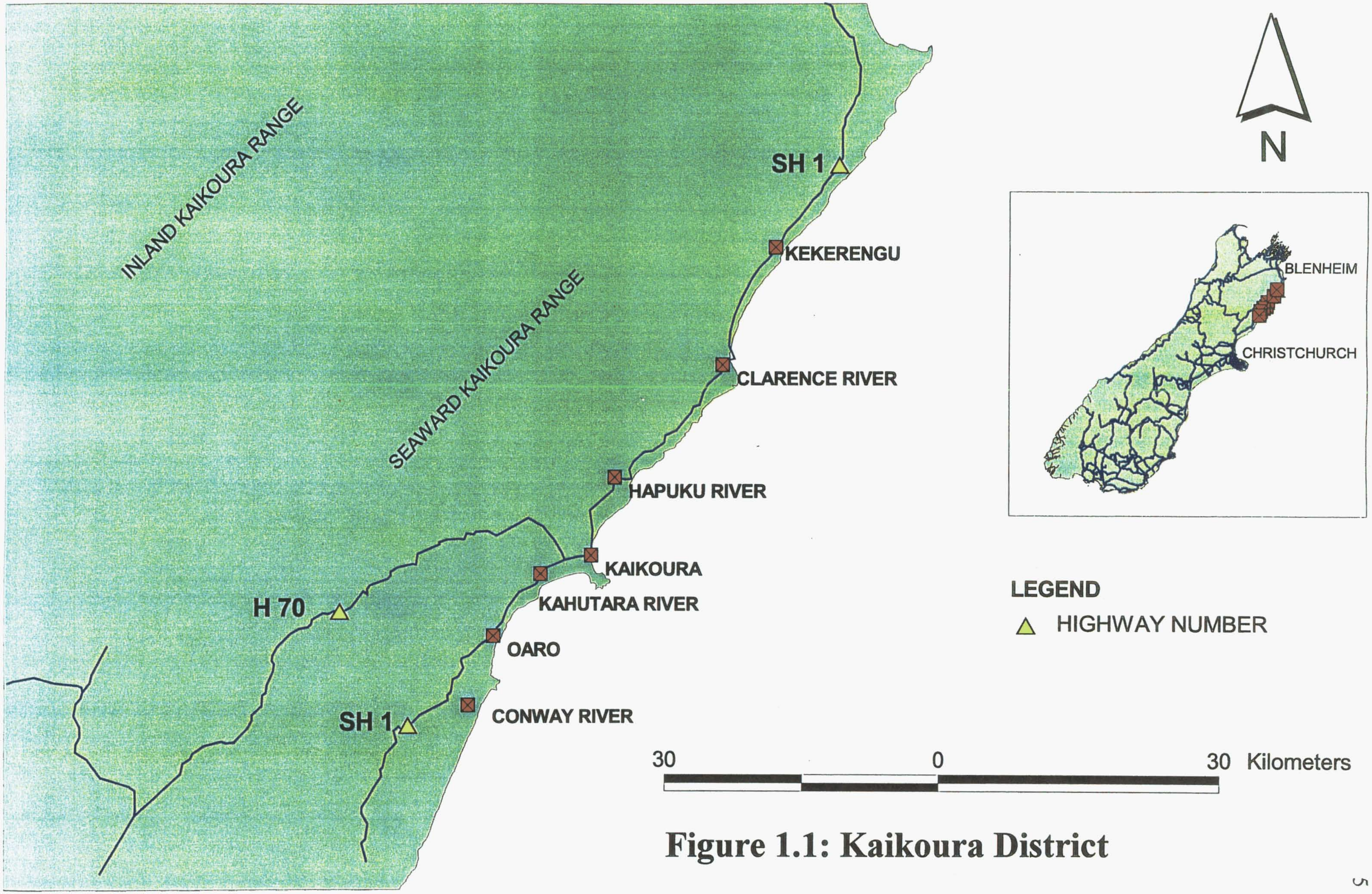


Figure 1.1: Kaikoura District

1.5 Chapter outlines

Chapter 2 describes the costs of past road closure events both internationally and within New Zealand. Chapter 3 describes the risk of road network disruption in the Kaikoura District, including the methodology applied. Chapter 4 estimates the additional costs incurred by road-users as a result of road closure events in the Kaikoura District. The road-user cost methodology is also described. Chapter 5 estimates non-user costs of road network disruption in the Kaikoura District through a survey of local businesses. The non-user cost methodology is also described. Chapter 6 concludes this research.

Chapter 2: Literature review

2.1 Introduction

This chapter describes the costs of past road closure events both internationally and within New Zealand. A review of annual link reinstatement costs (or emergency work expenditure) summarises the extent of road network disruption in New Zealand.

2.2 Past disruptions internationally

2.2.1 Kobe Earthquake, Japan

On January 17, 1995 a Magnitude 7.2 earthquake struck the city of Kobe, Japan (Chung, 1996). Most of Kobe City is built on a narrow coastal plain that is heavily urbanised and industrialised (ibid). The physical environment constraints conditioned a series of tightly compressed transport networks often adjacent to, or above one another (Buckle et al., 1996). Unfortunately, the coastal corridor 'lay directly above the ruptured fault zone, so all major transportation networks in Kobe were severely damaged' (ibid:164).

'The massive simultaneous failures of virtually all of Kobe's major transportation networks - highways, local railways, the Shinkansen (Bullet Train) and port facilities imposed an economic paralysis on the region' (Chang and Taylor, 1995:334). The cost of disruption also had nation-wide repercussions because 'Kobe sits astride the principal transportation corridor between the central and south-western part of Japan's main island, Honshu' (EQE Engineering, 1995:1). In addition, the extensive damage to the port of Kobe 'disrupted shipping throughout Asia because of the critical role the city's port played as a transhipment point' (Tobin and Montz, 1997:250). Several industries (including some computer components manufacturers) were affected around the world (ibid).

Road network damage in Kobe was extensive. 'The worst damage was to the elevated Hanshin Expressway' (Macaulay and Clay, 1996:60). A 'half-kilometre length of four-lane highway toppled at a forty-five degree angle after fifteen huge reinforced concrete supporting pillars broke off at their bases' (ibid). The total repair cost for the Hanshin Expressway Public Corporation was estimated to be US$4.6 billion (Buckle et al., 1996).

Non-damaged surface streets provided the only land access along the coastal corridor and these streets became heavily congested (EQE Engineering, 1995). 'The supply of materials and staff on-site for reconstruction was gravely hampered by damage to, and congestion in, the transport system' (McLean, 1998:29).

Due to the extent of damage to the transport infrastructure, 'the cost of disruption in Kobe seems likely to entail economic consequences of a sort previously not experienced in a modern urban area' (Chang and Taylor, 1995:334). The total economic loss 'is estimated to reach US$200 billion, making it the costliest earthquake in the world thus far' (Chung, 1996:1).

2.2.2 Tasman Bridge collapse, Australia

In January, 1975 the Tasman Bridge, which 'formed the only direct road link across the Derwent River in Hobart, collapsed after being hit by an ore carrier' (Wood and Lee, 1979:1). The bridge closure effectively isolated 30 per cent of Hobart's population resident in the eastern shore from accessing the Central Business District (CBD) (ibid).

Between January and December, 1975 cross-river movement of people and goods was limited to ferry transport or a lengthy road journey of approximately 50km (Lee and Wood, 1981). However, at the time of the collapse, only two small ferries with a capacity of four-hundred people operated on the Derwent River and there was a shortage of infrastructure (eg. car parking) to support increased ferry use (Lee and Wood, 1981). Ferry transport necessitated a multi-modal trip and significant extra time costs for cross-river movement. In addition, the alternative road links were mostly unsealed rural roads that were not designed to support increased traffic volumes (Wood and Lee, 1979). Road-users incurred additional time costs, vehicle operating costs and accident costs by diverting the additional 50km.

After the bridge collapse, many CBD businesses 'found it necessary to devise new delivery and servicing arrangements so that they could continue to operate on a metropolitan-wide basis' (Lee and Wood, 1981:128). However, a small number of businesses refused to deliver goods across the river (because of the additional costs), while other firms reduced the frequency of service and imposed substantial delivery charges (ibid).

For almost twelve months, the normal functioning of many aspects of city life was severely disrupted (Lee and Wood, 1981). In December, 1975 a temporary bailey bridge (with a limited vehicle capacity) was constructed 5km upstream from the Tasman Bridge (Wood and Lee, 1979). However, it was not until thirty-four months after the bridge collapse, when the Tasman Bridge was reopened, that regular transportation movements were again established (ibid).

2.3 Past disruptions in New Zealand

2.3.1 State Highway 3, Taranaki and Waikato regions, North Island

On March 12, 1997 a '35 metre section of the northbound lane of State Highway 3, 94km north of New Plymouth, slipped into the Awakino River and severed the link for one week' (Taranaki Regional Council, 1997:1). The cost of the week-long disruption was considerable because 'State Highway 3 north of New Plymouth is the only major road link between Taranaki and the northern half of the North Island' (ibid).

Average annual daily traffic (AADT) passing through this section of State Highway 3 is approximately 1637 vehicles, of which 23 per cent are heavy commercial vehicles (Harris Consulting, 1997). Road-users had six alternative routes available. Three state highways south of the slip site required extra travel distances of 120km, 325km and 375km (ibid). Three shorter detour routes were available. However, these routes were mostly unsealed and were unsuitable for use by heavy commercial vehicles (Taranaki Regional Council, 1997).

Harris Consulting (1997) estimated that the majority of vehicles that opted for the shorter detours were cars and light or medium commercial vehicles. Road-users opting for shorter detours faced difficult driving conditions, with anecdotal reports identifying numerous minor accidents and delays (Taranaki Regional Council, 1997). Accident costs on each of the two northern unsealed routes were estimated to be $21,600 for the duration of the closure (Harris Consulting, 1997).

Harris Consulting (1997) estimated that the greatest detour costs ($396,816) incurred by road-users during the week-long closure resulted from the additional 325km (4 hours) travel on State Highway 4. The majority of heavy commercial vehicles detoured to State Highway 4 because it was the closest link that was sealed along its entire length (ibid). One transport company alone incurred costs in excess of $80,000 during the period of the closure by diverting its trucks to State Highway 4 (Taranaki Regional Council, 1997). Total detour costs for the week-long closure were estimated to be $1.03 million (ibid).

An incomplete and approximate estimate of business losses was made for the week-long closure, which totalled $0.14 million for the region (Harris Consulting, 1997). 'Businesses noted that the supply of stock, materials, equipment, parts and produce into and out of the region was severely disrupted' (Taranaki Regional Council, 1997:14).

Transit NZ reported costs of $220,000 for the initial bailey bridge to bypass the slip (Taranaki Regional Council, 1997). In addition, the Road Transport Association advised that ongoing costs for heavy vehicle diversions were approximately $5,000 to $10,000 per month owing to heavy vehicle weight restrictions in place on the bailey bridge (ibid).

A detour route to restore two-way access was provided in June, 1997. The detour route involved construction of a second bailey bridge over the Awakino River (for northbound traffic) upstream of the slip site. Construction of 400 metres of temporary highway through farmland and a second bailey bridge cost a further $700,000 (Transit NZ, 1997). A permanent solution involved realigning the road by constructing two new bridges (Cox, pers. com.). The cost of this realignment was a further $4.2 million (Transit NZ, 1998b).

North of the Awakino Gorge slip site, two major slips in July and October, 1998 again severed State Highway 3. Ten days of heavy rain triggered a giant slip in July, 1998 that took approximately 100 metres of State Highway 3 down a slope (NZPA, 1998). State Highway 3 was closed to all traffic for two days and to heavy commercial vehicles for three days (Beca Carter Hollings and Ferner, 1999). The road network of the Waikato region was extensively damaged in July. Thirty-nine road closures were recorded in the region in July, with the combined duration of disruption totalling 841 hours (an average of 21.5 hours per event) (derived from information provided by Runciman, pers. com.).

Storms in October, 1998 resulted in further costs to road-users and non-users. The second major slip on State Highway 3 occurred in close proximity to the July slip site. The region's rail link to the central North Island was also closed in October as a result of a mudslide (Holdom and Maetzig, 1998). According to media reports, business losses from network disruption were widespread. The Taranaki Motel Association, for example, reported that moteliers were receiving cancellations because of the uncertainty that prevailed over the condition of the transport network (Birch, 1998).

In December, 1998 a project to rebuild State Highway 3 at the two slip sites commenced (Beca Carter Hollings and Ferner, 1999). A sealed 26km bypass route was established to enable full highway reconstruction works to be carried out (Cox, pers. com.). Transit NZ spent approximately $7 million on highway reconstruction at the main slip sites and improving and maintaining the detour route (Transit NZ, 1999a). State Highway 3 was reopened on March 20, 1999 (ibid).

2.3.2 State Highway 3, Manawatu region, North Island

The Manawatu Gorge is located between Palmerston North and Woodville on State Highway 3 and provides a key link to the Hawkes Bay region (Kitchin, 1998). The highway has been closed for an average of two in every one-hundred days in the past eleven years (ibid).

Disruption in the Gorge was particularly severe in 1995, when the link was closed for a total of sixty-nine days over a fifteen-week period (Morgan, 1995). Initially, the link was closed on July 27 following a large slip (see Photo 2.1) and was reopened briefly on August 3 before a second (and larger) slip severed the link (Transit NZ, 1995a). The latter slip closed the link for nearly three weeks.

Photo 2.1: Large slip on State Highway 3, Manawatu Gorge

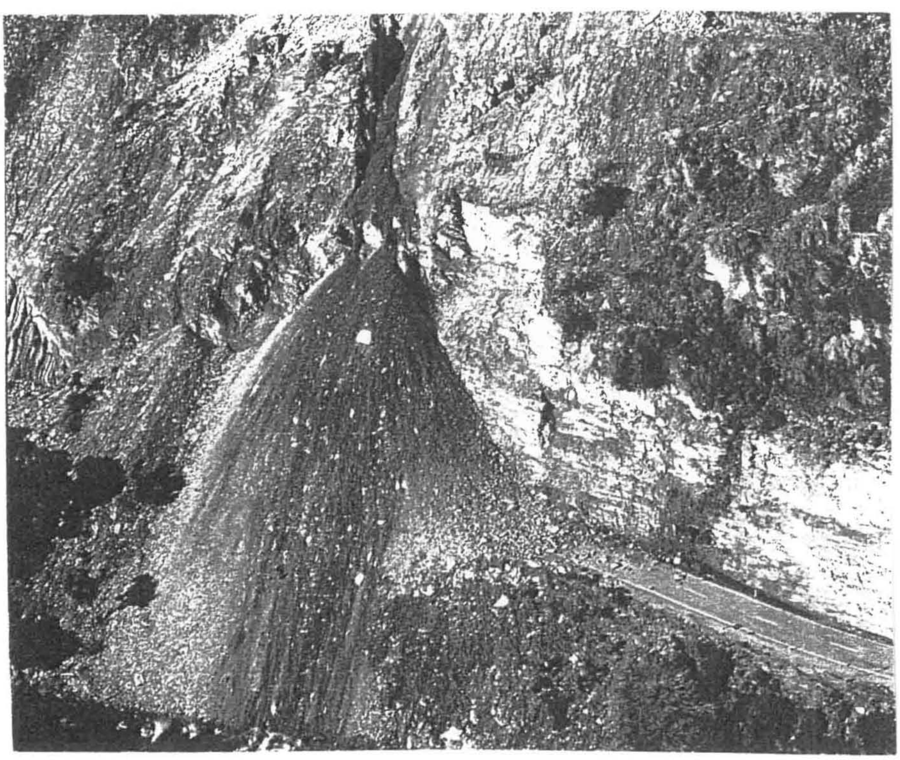
Source: Transit NZ (1995a)

Approximately 5500 vehicles used this link daily in 1995 (Morgan, 1995), with a high proportion of heavy vehicle usage (generally over 600 heavy commercial vehicles per day). Nearby alternative links were available, although these links were severely damaged by increased traffic volumes (ibid). Highway reinstatement costs exceeded $3 million in 1995 (ibid). However, no account of road-user costs or non-users costs was undertaken. More recently, slips closed the link for six days in July, 1998 (Mildenhall, pers. com.). Link reinstatement costs in July were approximately $500,000 (ibid).

2.3.3 State Highway 6, West Coast region, South Island

On August 19, 1998 a large slip 20km south-west of Haast Pass closed State Highway 6 for one week (Transit NZ, 1998c) (see Photo 2.2). The area bordering Lake Wanaka is prone to regular slips that are triggered by heavy rainfall (ibid). One-way access was established seven days after the initial event (Jarvis, pers. com.). Full link reinstatement was completed twenty-three days after the initial slip (ibid).

Photo 2.2: State Highway 6 slip, August 1998



Source: Transit NZ (1998c)

Approximately 411 vehicles use this section of State Highway 6 daily and it is recognised as both a tourist and scenic route (Transit NZ, 1998a). Road-users travelling to or from the West Coast were severely affected. The only detour route available was via State Highway 73, more than 300km north of the slip site. The total cost of link reinstatement was estimated to be $458,000 (Jarvis, pers. com.). However, no account of road-user costs or non-user costs was undertaken.

The road network in the West Coast region is often closed by rain-induced natural hazards. For example, in 1994 State Highway 6 was just one of many highways in the region closed from flooding. 'In just thirty-six hours, 322mm of rain fell over the Milford to Haast catchment area, causing about $7.7 million worth of damage' (Transit NZ, 1995b:1). More than 100km of highway needed to be reinstated, which took more than twelve months to complete (ibid).

2.4 Annual link reinstatement costs

Link reinstatement costs are a significant source of expenditure for road controlling authorities in New Zealand (see Table 2.1).

Table 2.1: Link reinstatement costs in the 1998/99 financial year

Link reinstatement costs	1998/99 ($M)	Percentage of National Roading Programme
Local roads	18.5	2.1
State highways	34.5	4.0
Total	53.0	6.1

Source: Transfund NZ (1999a)

Of the $34.5 million spent on state highways in the 1998/99 financial year, 89 per cent was spent on restoration works in the North Island, while 11 per cent was spent on restoration works in the South Island (Transfund NZ, 1999b). Seventy-five emergency work projects were completed in total, mainly in the Northland, Waikato, Bay of Plenty, Taranaki and Manawatu regions (Transit NZ, 1999b). In the Kaikoura District, there have been no state highway closures in the past two years that have required link reinstatement funding (Hunter, pers. com.).

The level of emergency work expenditure varies considerably on an annual basis because of natural variations in hazard occurrence. The 1998/99 state highway expenditure was, for example, 184 per cent higher than the 1997/98 expenditure (see Table 2.2).

Table 2.2: State Highway link reinstatement costs between 1995 and 1999

Description	Unit	1995/96	1996/97	1997/98	1998/99
Cost	$M	15.64	14.11	12.13	34.5
Single-lane access restored within 12 hours of the substantial end to the event	Percent	78	82	87	79

Source: Transfund NZ (1999a); Transit NZ (1998d); Transit NZ (1999b).

In the 1998/99 financial year, 'expenditure to reinstate storm damage on state highways in the Waikato and Bay of Plenty regions exceeded the national state highway emergency works target of $13.50 million' (Transfund NZ, 1999a:45). Accordingly, other roading projects had to be deferred to offset the additional emergency work expenditure in the 1998/99 financial year (ibid). For example, preventative maintenance expenditure, which is defined as 'non-routine maintenance works to protect the serviceability of the road asset and to minimise the threat of road closure' (Transit NZ, 1999b:20), was deferred to make available funding for emergency work restoration. Preventative maintenance expenditure was $1.6 million less than the forecast $3.1 million expenditure in the 1998/99 financial year (Transfund NZ, 1999a).

The severity of road network damage in 1998/99 is also seen in the lower percentage of closure events having single-lane access restored within twelve hours of the substantial end to the event compared to the 1997/98 year. Of all recorded state highway closure events in 1998/99, thirty-one closures did not have single-lane access restored within twelve hours of the substantial end to the event (Transit NZ, 1999b).

2.5 Conclusion

The impacts of the Kobe earthquake and the Tasman Bridge collapse highlight the importance of link security to road-users and non-users. Changes in network accessibility from simultaneous linkage failures or from failure of a single link can result in significant costs.

In New Zealand, road closures caused by natural hazards can disrupt the road network for extended durations. Road closures often condition significant costs for road-users because the national road network is sparse. Non-user costs are also likely to be significant. However, non-user costs are generally not included in disruption cost estimates. Link reinstatement costs comprise a significant portion of the National Roading Programme budget. In contrast, preventative maintenance expenditure is constrained by limited funding and is significantly lower than post-disruption restoration costs.

The following chapter describes the risk of road network disruption in the Kaikoura District.

Chapter 3: Natural hazard assessment

3.1 Introduction

The *Resource Management Act 1991* defines natural hazard to mean:

'any atmospheric or earth or water related occurrence (including earthquakes, tsunami, erosion, volcanic and geothermal activity, landslip, subsidence, sedimentation, wind, drought, fire, or flooding) the action of which adversely effects human life, property, or other aspects of the environment.'

The road network in the Kaikoura District is vulnerable to closure from a host of natural hazards. The District's climate; steep, small coastal catchments; and its geology all contribute to the hazard threat (Bowring et al., 1978). Earthquakes, tsunami, coastal erosion/inundation, landslides, floods and snow can disrupt the road network. This chapter describes the vulnerability of the road network in the Kaikoura District to these hazards and outlines the methodology applied.

3.2 Natural hazard assessment methodology

Natural hazards literature was reviewed to provide an overview of the hazard threat in the Kaikoura District. Government bodies, tertiary institutions, and private sector organisations were also contacted to obtain supplementary hazards information. However, the acquisition of natural hazards information had various shortcomings. Hazard information is often widely dispersed and little information relating specifically to road network vulnerability is available. For example, road controlling authorities have little coordinated and comprehensive information about natural hazards on principal highway links. In addition, little research has been conducted on some hazard sources. For example, the Institute of Geological and Nuclear Sciences (IGNS) has yet to map landslide hazards in the Kaikoura District.

A historical review of past disruptions was conducted to provide more detailed information about the vulnerability of the road network. Post-1950 editions of the

Kaikoura Star newspaper were reviewed. The newspaper review was complemented by a search of former Ministry of Works and Development (MWD) files held at the National Archives, Christchurch. Flood damage reports between the years of 1951 and 1986 were reviewed (National Archives, 1999). The archive search extended to Opus International Consultants, Christchurch, for the period of 1992 to 1996. Records from 1996 to 1999 were obtained from Montgomery Watson, Christchurch and from Opus International, Greymouth. Appendix 1 lists the dates and locations of all disruptions recorded. This information was used to derive a map depicting sites of past disruptions on State Highway 1 (see Figure 3.1).

Past closure information is in different forms, widely dispersed, and difficult to access. The different reporting styles and quality of information (eg. no specific closure locations or durations are often specified), only allowed a general and incomplete account of past closures to be assessed. No definite closure relationships (eg. probability distributions) could be derived because of the incomplete data set.

In the review of natural hazards on State Highway 73, Whitehouse (1990:47) states that 'the most useful source of information came from the memories of the highway overseer.' Accordingly, past and present highway engineers were consulted to complement the historical review and provide insights into potentially vulnerable areas.

Detailed technical investigations were beyond the scope of this research. Instead, the approach adopted provided a broad overview of the closure threat in the District. As stated by Helm (1996:5), 'regardless of the degree of formal evaluation, there are unquestionable benefits in knowing as much as possible about local hazards.'

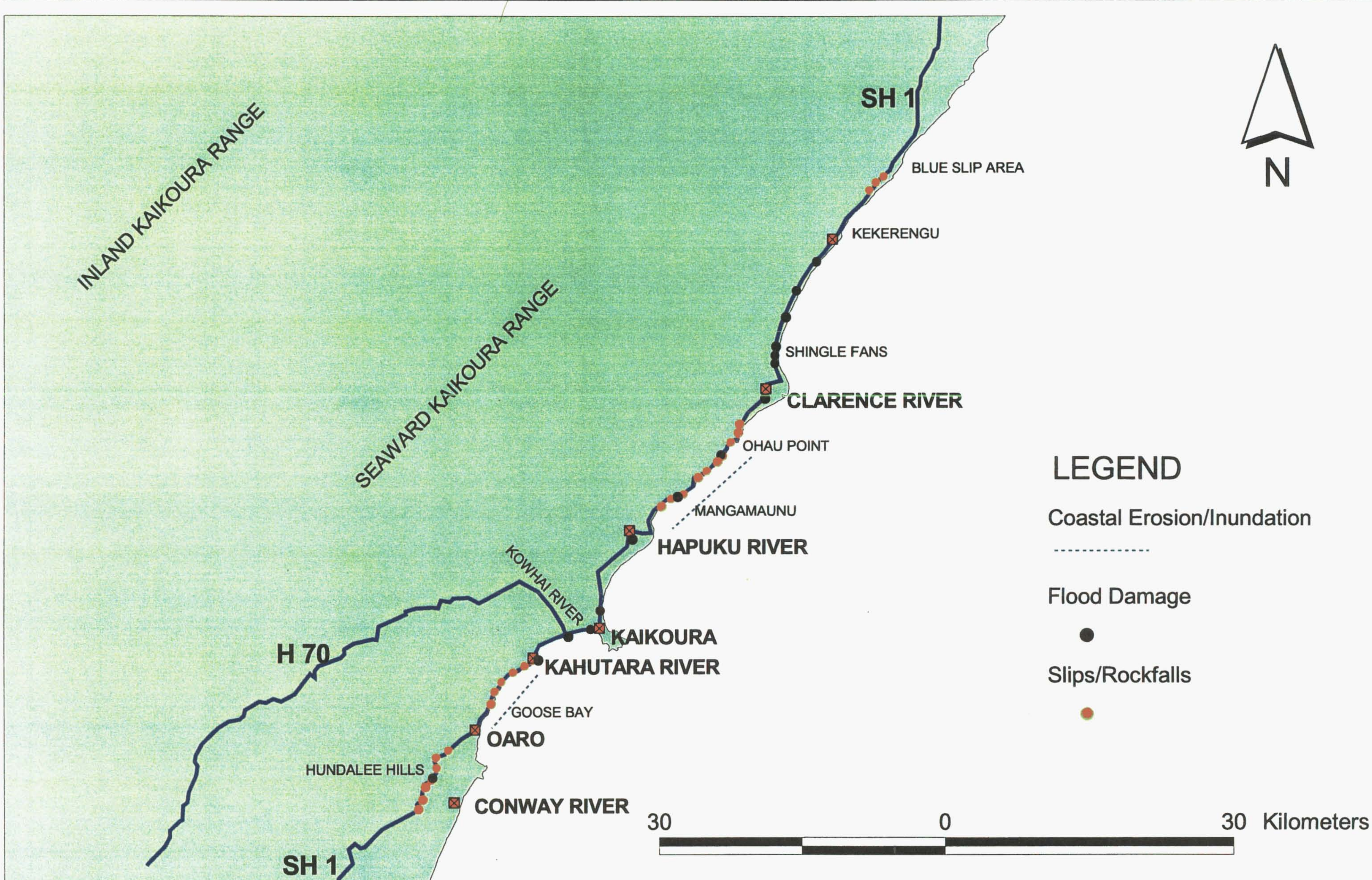


Figure 3.1: Past disruptions on State Highway 1

3.3 Coastal hazards

3.3.1 Coastal erosion and seawater inundation

The Kaikoura Coastline is subject to coastal erosion and seawater inundation because it is exposed to high-energy oceanic swell and storm waves (Kirk, 1985). Large waves may be received at any time of the year and it is common for storms to be attended by surge components which superelevate the sea-level (ibid). Storm surge components of sea-level rise in Canterbury may exceed 1 metre and this results in both greater breaker heights at the shore and greater inland penetration of runup (Kirk and Todd, 1994).

Road network disruption may be caused by:

- erosional encroachment leading to a loss of support and collapse;
- inundation by seawater from the runup of broken waves and/or from ponded fresh water;
- scour by runup and/or fresh water flow;
- damage by direct wave impact; and
- sediment deposition by wave action (Kirk and Todd, 1994:38).

The Canterbury Regional Council (1994) defines a hazard zone that contains land at risk from coastal erosion. In many parts of the Kaikoura District, this hazard zone borders State Highway 1 and in places, this zone encompasses the highway (eg. just north of Oaro). Of greatest concern is the area of State Highway 1 that runs adjacent to the coastline. Approximately 11km of highly exposed coast carrying both State Highway 1 and the South Island Main Trunk Railway (SIMTR) occurs south of Kaikoura between Oaro and the Kahutara River and a further 10km occurs to the north of Kaikoura between the Hapuku River and the Clarence River (Kirk, 1985) (see Figure 3.1). At both Oaro and Goose Bay beaches, wave run-up during storm events is known to flow across State Highway 1 (Kirk, 1985; Kirk and Todd, 1994).

Some 4.7km of seawall protects State Highway 1 against erosion and storm waves along these coastal strips (Kaikoura District Council, 1998). However, the protection structures 'refer' erosion to adjacent unprotected areas and many of the works are inadequate and will fail, either in whole or in part, at some time (Kirk, pers. com.). For example, in 1985 two major sea-storm events caused wide-scale erosion of State Highway 1 (see Appendix 1). The total damage to the highway and coastal works was estimated to be $1.3 million, of which some $500,000 dollars was required to realign State Highway 1 at Ohau Point (Kirk, 1985). 'The storm which occurred in July, 1985 has been estimated to have a return period of 50 years' (Opus, 1999:16).

The historical review of closures indicates that coastal erosion has constituted an ongoing threat to State Highway 1. However, damage from coastal erosion has not conditioned long-term closure events (eg. for periods of three days or more) comparable to rain-induced disruptions (eg. from flooding and slope failures). In addition, disruption from coastal erosion has been less frequent than rain-induced closures. The last major sea-storm damage occurred in 1985. State Highway 1 is, however, subject to a high level of hazard on an ongoing basis (even under normal sea conditions) and more severe disruption in the future is possible (Kirk, pers. com.). Assuming that future damage will occur, it may not be the failure that blocks the highway, but the confined area in which restoration work would need to take place (Bates, pers. com; Kirk, pers. com.).

3.3.2 Tsunami hazard

'A tsunami is a sequence of waves generated by large disturbances below or near the ocean floor' (DeLange, 1998:99). The disturbances that produce tsunami are often associated with earthquakes (ibid). 'A distinction is generally made between far-field tsunami (remotely generated from the target area) and near-field tsunami (created in or close to the target area)' (Kirk and Todd, 1994:47). Ten reports of tsunami (all far-field events) have been recorded in Canterbury between 1840 and 1982 (DeLange and Healy, 1986). However, recent reports indicate that the Kaikoura Coastline is also vulnerable to near-field tsunami (Robson, 1998). It is believed that during the next major earthquake, 200 million cubic metres of silt, gravel, and mud washed into the sea by Canterbury's rivers could avalanche into the 1km deep Kaikoura Canyon, thereby triggering a tsunami (ibid).

The effects of the tsunami hazard are difficult to predict because tsunami wave behaviour at the shore is extremely variable (Kirk and Todd, 1994). For example, 'the 1993 Hokkaido-Nansei-Ohi tsunami in Japan varied in height from 5 metres to 30.5 metres along a short stretch of coast (half a kilometre in length), with the damage it caused varying in different places' (DeLange, 1998:107).

A detailed assessment of the potential damage to the District's road network from the tsunami hazard is beyond the scope of this research. However, it is recognised that tsunami hazards have an enormous potential to damage assets in the coastal environment (Canterbury Regional Council, 1994) and it must be assumed that State Highway 1 is vulnerable to damage. Until further research is conducted, no frequency of occurrence value can be assigned to the tsunami hazard along the Kaikoura Coast (Goring, pers. com.).

3.4 Meteorological hazards

3.4.1 Flooding

Kaikoura lies in close proximity to high mountains that are the source of significant runoff and vast quantities of moving debris (Thomson and Macarthur, 1969). The Seaward Kaikoura Range dominates the District, rising to nearly 2600 metres in just over 10km from the coast (Bowring et al., 1978). Annual rainfall increases from 800mm near the coast to 1600mm on the peaks (ibid).

The major river systems in the Kaikoura District are the Clarence River, the Kowhai River and the Hapuku River, with smaller systems including the Kahutara River, Shingle Fans and the Oaro River (Kaikoura District Council, 1998) (see Figure 3.1). The historical review of closures indicates that all of these river systems may close State Highway 1 and the Kahutara River and the Kowhai River may also sever Highway 70. Just north of the Clarence River, the three Shingle Fans have, for example, frequently disrupted State Highway 1 because of active debris aggradation from their catchments (Bell, 1975). State Highway 1 has been closed at these streams for periods exceeding 48 hours (eg. in January 1961). The concrete fords were supplemented in 1971 by detour bridges that are used during periods of flooding (Bowring et al., 1978). However, in a major flood, these bridges may also be damaged (Bates, pers. com; Sutton, pers. com.).

Many of the lesser coastal rivers and streams crossing State Highway 1 and Highway 70 also have the potential to sever the road network. For example, debris carried by streams throughout the Hundalee Hills (see Figure 3.1) can block culverts and the diverted flows may scour and undermine State Highway 1 (Sutton, pers. com.).

A flood that occurred in 1923 highlights the severity of the flood hazard threat in the District. The flood caused widespread damage to the road network servicing Kaikoura and damaged nearly every bridge in the District (Anon., 1923a). Rain fell heavily for a four-day period, with 25-88 inches of rain recorded (Sherrard, 1998).

'The heaviest flood known in the history of Kaikoura occurred yesterday. On Friday heavy rain began, and continued incessantly throughout Saturday, Sunday, and Monday. Rivers and creeks rose rapidly, heavy seas were running, stemming the rushing waters at the mouths of the rivers and the surplus, surging water inundated the District...Kaikoura is isolated, except by steamer service. From a general observation, it appears as if it would be best to concentrate first on the Inland Route to Waiau, as the difficulties to be experienced are less on this route than the southern road to Christchurch or the road to Blenheim. No doubt, one of these routes will be made available for traffic within a month'(Anon., 1923a:7).

Floodwaters washed away two spans of the Clarence River bridge and for two years a large punt shuttled goods and people across the river (Sherrard, 1998). The river bank was subjected to so much erosion that is was 150 feet wider than it was before the flood' (Anon., 1923b:21).

3.4.2 Snow

The road network in the Kaikoura District is vulnerable to closure from heavy snowfall. The historical review of closures indicates that closures from snowfall are restricted to the links south of Kaikoura, usually through the Hundalee Hills on State Highway 1 or along Highway 70. For example, in 1992 heavy snowfall closed State Highway 1 overnight, while Highway 70 was closed for three days (see Appendix 1).

Research suggests that severe snowfalls in Canterbury occur as often as one in four years (Owens, 1994). However, snow and or ice seldom close the road network for more than three days.

3.5 Landslide hazards

Landslides are caused by a variety of factors, including:

- 'those induced by intense or prolonged rainfall;
- those generated by earthquakes; and
- other (generally slow moving) types' (Bell, 1994:55).

Landslide hazards most commonly occur in areas that have significant relief, and they may either cover the road surface or include the road surface (Bell, 1975). Bell (1976:190) concluded that 'the geologic and geomorphic setting of the Kaikoura District is favourable for extensive mass movements, given the requisite seismic or climatic trigger.'

3.5.1 Rain-induced landslides

In the Kaikoura District, rainstorms originating to the north of New Zealand (usually as extra-tropical cyclones) have historically caused considerable mass movement damage (Bell and Owens, 1979). The predominantly small coastal catchments respond dramatically in intense rainstorms, causing debris flows, aggradation, deposition and flooding (Bell, 1976). 'Debris flows are rapid flows of saturated soil, rock and organic debris down steep mountainous channels' (Paterson, 1996:344). Debris flows 'have the capacity to take out bridges and leave large obstacles on the highway' (Whitehouse and McSaveney, 1992:28).

The historical review of closures indicates that rain-induced slips and rockfalls have been the most frequent source of network disruption in the Kaikoura District. Rain-induced hazards have also caused the longest link severances in the District. Figure 3.1 shows that many slope failures have occurred north of Kaikoura between the Clarence River and the Hapuku River and south of Kaikoura between the Kahutara River and Oaro. In these sections, State Highway 1 is confined to a narrow, rugged area at the foot of steep bluffs and cliffs that rise abruptly to 400 metres (Bell, 1975). In the Hundalee Hills, State Highway 1 is also prone to closure from slope failures. Many areas are affected by slow slumping of the slopes on which they are built (Bowring et al., 1978).

The 1975 Cyclone Alison event best depicts the vulnerability of the road network in the Kaikoura District to rain-induced slope failures. On the night of Wednesday March 12, 1975 State Highway 1 and the South Island Main Trunk Railway (SIMTR) were severely damaged by 'high intensity rainfalls resulting from the passage of Cyclone Alison' (Bell, 1976:189). State Highway 1 and the SIMTR were both closed by 'numerous landslides, flood debris, and washouts' (Bell, 1976:189). In some places, the railway swung freely above 18 feet deep washouts 150 feet long, while at Waipapa Bay the line was pushed 20 yards out of alignment by slips and floodwater (Anon., 1975a). Heavy rainfall caused extensive debris flows within the steep coastal catchments (Bell, 1994). Debris blockages in some streams between the Hapuku River and the Clarence River diverted flows and caused extensive erosion and undermining of the road network (Bell, 1976). Many culverts simply proved inadequate to pass the large quantity of water and debris delivered (ibid). For example, State Highway 1 was severed north of Kaikoura at Ohau Stream as a result of rapid stream aggradation and erosion (see Photo 3.1). Grocott (1977) estimated that damage to road and rail infrastructure amounted to $1.75 million.

Photo 3.1: Damage to State Highway 1 at Ohau Stream following Cyclone Alison, 1975

Source: Barker (1999)

The extent of damage from Cyclone Alison is best described by Barker (1975):

'In the last 9 months, State Highway 1 in the Kaikoura area has been subjected to damage from heavy seas on two occasions and damage from three floods. However, the flood on the 12 March 1975 is the worst in my experience in the District. Torrential rain in the wake of Cyclone Alison wrought tremendous havoc along the East Coast north and south of Kaikoura from Kekerengu to the Conway River.

State Highway 1 was closed at 5.30pm on March 12 when the Shingle Fans broke out of their channels north of the Clarence River. From then on, things became uncontrollable. The worst hit areas were between:

- *Okiwi Bay and Mangamaunu; and*
- *the Kahutara River and Oaro River bridge.*

Unbelievable damage was caused over these sections, especially when coastal streams became raging torrents, overwhelming railway and highway bridges. Huge landslides buried the highway and railway.'

North of Kaikoura, gravel covered both the railway and highway to depths in excess of 5 metres (Bell, 1975) (see Photo 3.2).

Photo 3.2: Debris flow aggradation along State Highway 1 following Cyclone Alison, 1975

Source: Barker (1999)

South of Kaikoura, major flood damage occurred in the Hundalee Hills (see Photo 3.3 and Photo 3.4). Instability problems resulted from combinations of mass movements within steep catchments, rapid stream aggradation, scouring around blocked culverts and active undercutting by the major streams (Bowring et al., 1978).

Photo 3.3: Mass movement and highway instability following Cyclone Alison, 1975

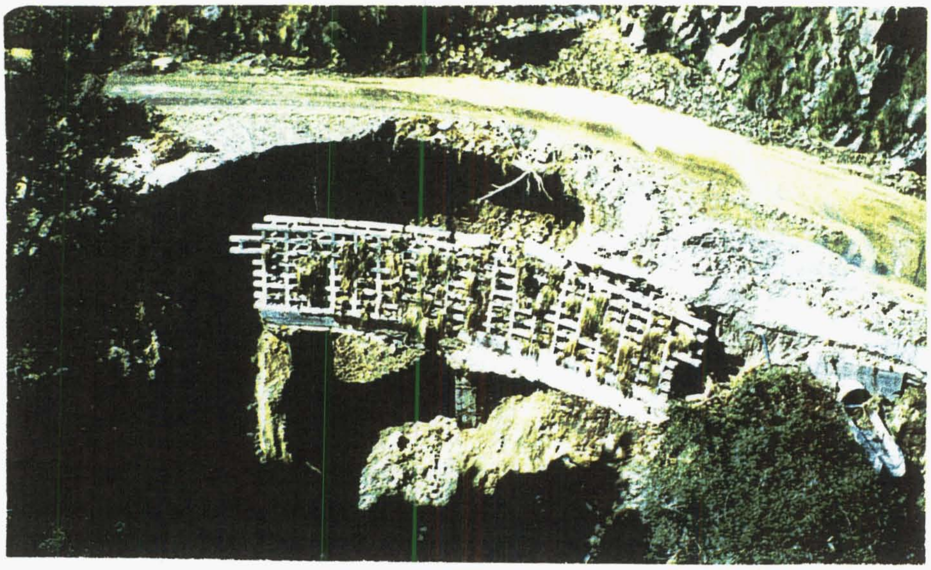
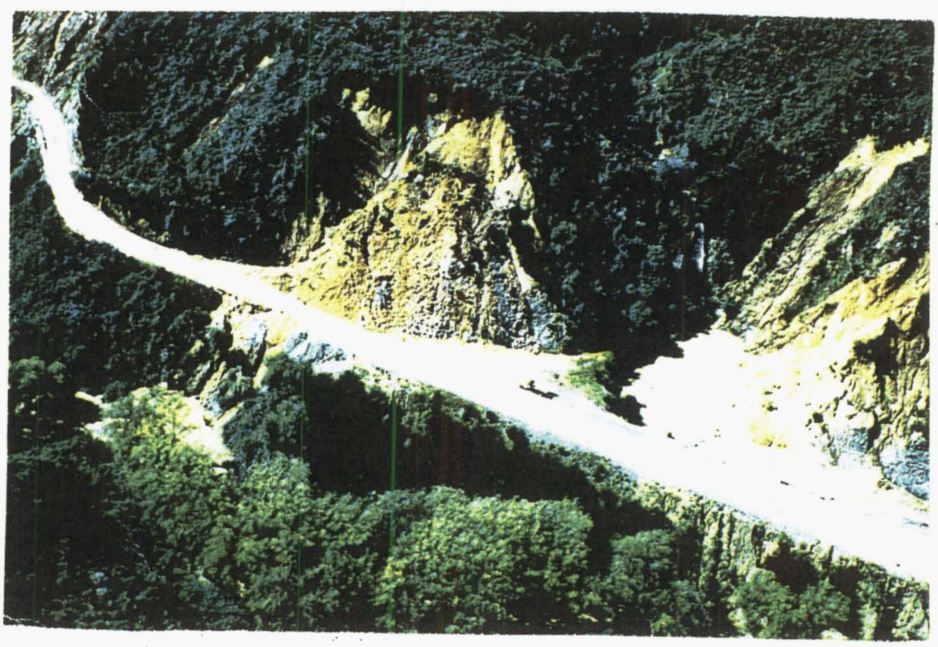


Photo 3.4: Major slip on State Highway 1 following Cyclone Alison, 1975



Source: Barker (1999)

The community of Kaikoura was isolated for two days following the Cyclone Alison event because Highway 70 was also closed. However, damage to Highway 70 was not great and this link was reopened on March 14 (Barker, 1975), allowing foodstuffs to be brought into Kaikoura, as described by Anon. (1975b:1):

'Kaikoura ran out of butter on Friday but a truck with about one ton and a quarter of butter and other food was sent from Blenheim via the Lewis Pass and the Inland Road. The town's milk is also normally delivered from Blenheim, but the Milk Board arranged a supply to be delivered from Christchurch.'

South of Kaikoura, State Highway 1 was opened on March 20 after a bailey bridge was erected in the Hundalee Hills (Barker, 1975). North of Kaikoura, State Highway 1 was opened on March 24, although repairs were not complete (ibid). Rail traffic was operational on March 25 (Bell, 1976).

Few vehicles used Highway 70 while restoration works were being carried out, which adversely effected local businesses in Kaikoura, as described by Anon. (1975c:1):

'Most restaurants have been either closed or working restricted hours and other businesses are well down in their turnover. However, accommodation services have not been affected owing to the influx of workmen brought in to repair damage to road and rail services.'

The major conclusion from post-Cyclone Alison investigations was that 'future damage from such hazards can be minimised, but not prevented' (Bell, 1976:197). Landslide damage during major rainstorm events can be expected to recur every ten to twenty years (Bell, 1994).

3.5.2 Earthquake-induced landslides

Since 1840, at least twenty-two earthquakes in New Zealand have resulted in widespread and damaging landsliding (Hancox et al., 1998). For example, 'the 1929

Murchison earthquake (Magnitude 7.8) triggered countless small slips and at least fifty landslides' (McSaveney and McSaveney, 1998:80). The community of Karamea was isolated by road for several months because of the extent of damage to the road network (ibid). In Canterbury, earthquake generated slope failures 'must be anticipated from any moderate to large seismic event which produces ground shaking intensities of MM6 or greater' (Bell, 1994:63). As described in section 3.6, the Kaikoura District is vulnerable to earthquakes of this magnitude.

During past earthquakes, landslides occur mostly 'on slopes of twenty degrees or more, with the most common failures being rock and soil falls on cliffs, steep escarpments and high unsupported man-made cuts' (Hancox et al., 1998:207). The National Water and Soil Conservation Organisation (1978) classifies much of the area north of Kaikoura between the Hapuku River and the Clarence River and south of Kaikoura between the Kahutara River and Oaro as steep to very steep eroded hills and cliffs with slopes steeper than twenty-one degrees. Most areas have moderate to severe slip potential (ibid). It is reasonable to assume that the slope failure hazard throughout the mountainous sections of State Highway 1 may be acute during the next major earthquake, particularly where faults cross the road corridor (see section 3.6). The Centre for Advanced Engineering (1997), for example, believe that following a major earthquake, damage from slips on State Highway 1 in the Kaikoura District could close the highway for up to three weeks.

The type of instability problems which may result from an earthquake in the Kaikoura District are highlighted by the June 23, 1992 Punchbowl Corner closure, 12km south of Kaikoura. State Highway 1 was closed for a thirteen-day period after the rock face adjacent to the highway was declared to be unsafe (Hide, 1992a). Geologists believed that a minor earthquake might have contributed to the loosening of the rock face (ibid). While remedial works were being carried out, road-users detoured to Highway 70. However, on June 30 Highway 70 was also closed because of ice. Highway 70 became impassable after a heavy frost turned mud to sheet ice on unsealed sections (Hide, 1992b).

The Chairman of the Kaikoura Information and Tourism Council reported that the drop-off in tourism was seriously affecting Kaikoura (Hide, 1992c). As one Kaikoura motelier stated:

'This time of year is our quieter time and with this on top of it is quite a blow. There are parking spaces galore in the township. It is quite dead' (Hide, 1992c:1).

In the Kaikoura District, road network security is also threatened by the damming of rivers. During large earthquakes, many rivers are susceptible to damming by landslides, and consequential flooding when the dam bursts (McSaveney, 1995). Following damming (and later flooding) of the Clarence River, Hapuku River or Kowhai River, the road network in the District may be severed. No feasible mitigation measures are practicable for this type of hazard (ibid).

3.5.3 Slow moving landslides

Slow moving landslides may also disrupt the road network in the Kaikoura District. For example, a 'zone of a kilometre or more of unstable ground occurs in the vicinity of the Blue Slip' (Opus, 1999:14) (see Figure 3.1). Movement does not appear to be directly related to storm events, but is a result of a slow mass movement process (Bowring et al., 1978). The Blue Slip is known to 'lift' the highway (eg. in March 1980 an 80 metre length of highway was uplifted), which may close the highway for a period of 24 hours (Sutton, pers. com.).

3.6 Earthquake hazard

New Zealand is situated between two major tectonic plates and on average, has 17,000 earthquakes each year, six of them greater than Magnitude 6.0 (Hull, 1998). 'The historical and geological record in Canterbury clearly indicates that many active faults within the region are capable of generating earthquakes with Magnitudes greater than 6.0' (Cowan et al., 1994:85). The major fault systems that may be a source of network disruption in the Kaikoura District are the Alpine Fault and the Marlborough Fault system.

3.6.1 The Alpine Fault

The Alpine Fault passes through the Southern Alps and there is 'a greater than 50 per cent probability that it will cause a Magnitude 8.0 earthquake within the next fifty years' (McSaveney and Davies, 1998:75). 'Strong to moderate shaking will occur in most South Island locations within 150km of the Alpine Fault which will trigger landslides over a very large area, particularly in the Southern Alps and on nearby slopes' (Yetton et al., 1998:134). It is reasonable to assume that the road network in the Kaikoura District may be damaged by landslide hazards following rupture of the Alpine Fault because of the mountainous (and unstable) terrain in the Kaikoura District.

3.6.2 Marlborough Fault system

In the Kaikoura District, there are several active faults. These include the:

- Hope Fault - runs parallel to Highway 70 along the base of the Seaward Kaikoura Range. The northerly continuation of the Hope Fault reaches the coast at Ohau Point (see Figure 3.1).
- Clarence Fault - runs along the Clarence River Valley from near the coast south towards the main Alpine Fault.
- Fidget Fault - splays off the Kekerengu Fault and Jordan Thrust Fault near the Clarence River.
- Jordan Thrust Fault - runs along the Seaward Kaikoura Range.
- Kekerengu Fault - connects to the Fidget and Jordan Thrust Faults in the Seaward Kaikoura Range and runs towards the Kekerengu River mouth. Traces of the Kekerengu Fault cross the coast some 3km north of the Blue Slip (Bell, 1975; Cowan et al., 1994; Kaikoura District Council, 1998; and Van Dissen, 1991).

Current understanding of faults in the District suggest that damage to State Highway 1 and Highway 70 could be particularly severe following either direct rupture of the Hope Fault or Kekerengu Fault (where these faults cross the road-rail corridor), or following an earthquake on other nearby faults (McMorran, 1995). Significant damage must be anticipated in the Kaikoura District from these sources (Cowan et al., 1994), which could include distortion of the highway and surface breaks (Opus, 1999).

Based on limited information, McMorran (1995) believes that the Hikurangi Subduction Zone (HSV) (a trench located off the east coast where the Pacific plate dips underneath the North Island) may constitute the greatest seismic hazard in the Kaikoura District. Rupture of this fault, or other faults in the District, may result in shaking intensities of up to MM9 in Kaikoura township (ibid). There is a 10 per cent probability of exceeding MM9 in any fifty-year period (ibid).

3.7 Conclusion

State Highway 1 is vulnerable to closure from landward hazards, seaward hazards, or from both sources simultaneously (Kirk, 1985). Highway 70 is also subject to closure from a host of natural hazards, particularly from flood damage. Heavy rainfall (and associated flooding and slope movements) has been the predominant cause of road network disruption in the Kaikoura District. Simultaneous linkage closures have also occurred in the District because of the geographic coverage of heavy rainfall events. Since June, 1995 the road network in the Kaikoura District has been quite secure. However, the historical record clearly indicates that dislocation of one link (or all links simultaneously) may occur in the future. Extended dislocation of links may occur from rain-induced events, or from a host of other hazards, including potentially 'catastrophic' and poorly understood hazards such as powerful earthquakes and tsunami.

The following chapter estimates the additional costs incurred by road-users as a result of road closure events in the Kaikoura District.

Chapter 4: Road-user cost assessment

4.1 Introduction

Additional costs (time costs, vehicle operating costs and accident costs) incurred by road-users as a result of road closure events in the Kaikoura District are estimated in the following chapter. The road-user cost methodology is also described. The following section describes the road network servicing Kaikoura.

4.2 Road network overview

The road network servicing Kaikoura (including alternative links) is shown in Figure 4.1. The focus of this chapter is the potential costs of closure incurred by road-users when the Waipara to Kaikoura link (State Highway 1 to the south of Kaikoura) or the Kaikoura to Blenheim link (State Highway 1 to the north of Kaikoura) are closed by natural hazards.

In the event of closure, the alternative routes are:

- Highway 70 (Inland Road) - provides an alternative route between Christchurch and Picton (and Kaikoura) *if State Highway 1 to the south of Kaikoura is closed.* This route includes the nodes of Christchurch, Waipara, Culverden, Kaikoura, Blenheim and Picton. In the Hurunui District, approximately 10km of this route is unsealed, although the highway will be completely sealed within a year (Whyte, pers. com.).

- Lewis Pass - provides an additional route between Christchurch and Picton (and Kaikoura) *if State Highway 1 and Highway 70 to the south of Kaikoura are closed or State Highway 1 to the north of Kaikoura is closed.* This route includes the nodes of Christchurch, Waipara, Culverden, Hanmer Junction, Springs Junction, Murchison, Rainbow Junction, Blenheim, Picton (and Kaikoura).

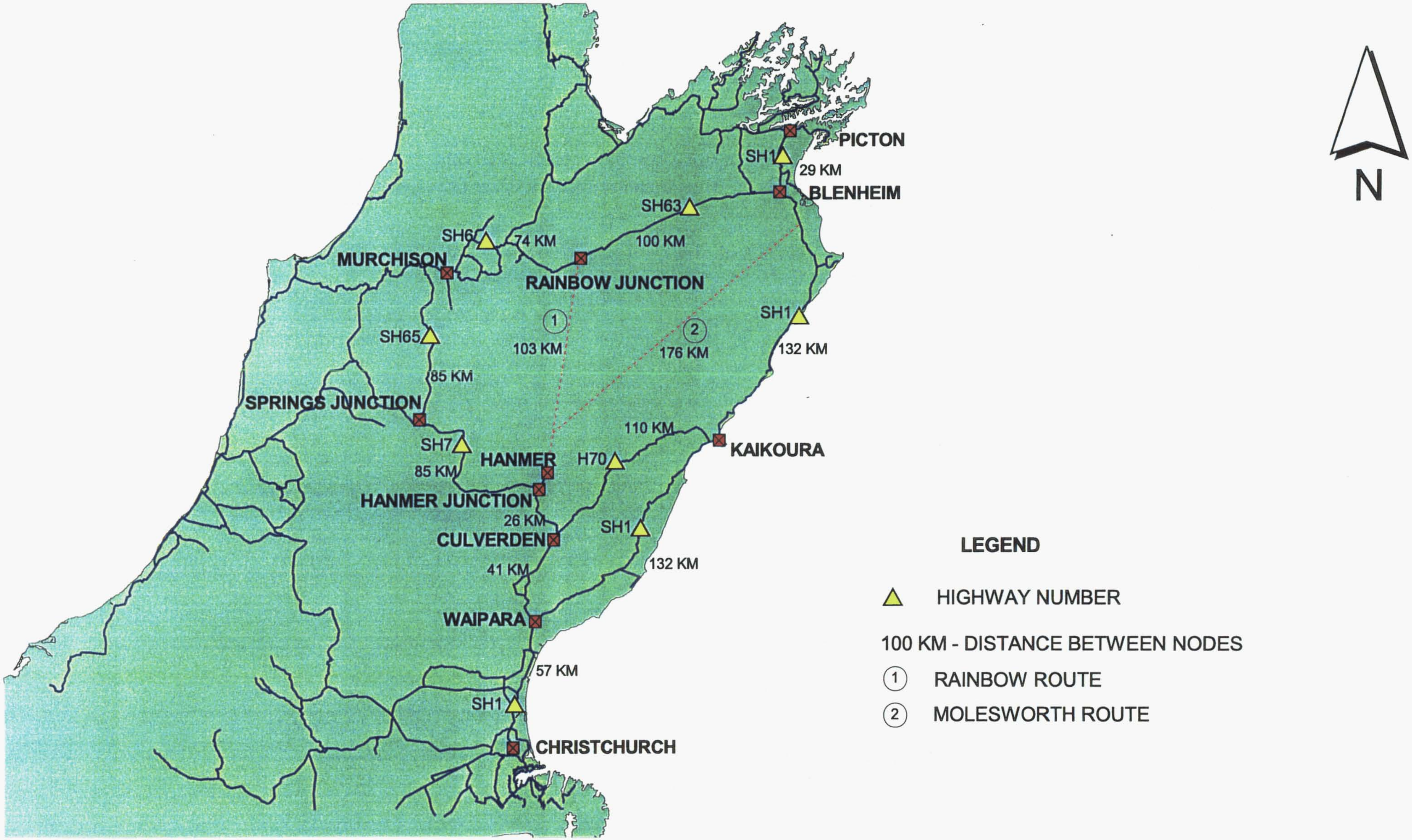


Figure 4.1: Detours due to road closures

In addition, two 'possible' routes are:

- Rainbow route - could be used as an 'emergency' alternative *instead of the Lewis Pass route.* This route includes the nodes of Christchurch, Waipara, Culverden, Hanmer Junction, Hanmer Springs, Rainbow Junction, Blenheim, Picton (and Kaikoura). Between Hanmer Springs and Rainbow Junction the Rainbow route is unsealed (103km) and is recommended for use by four-wheel drive vehicles because it crosses many unbridged streams and is narrow in places (Department of Conservation, 1996). Conversations with the Department of Conservation indicate that the link conditions a trip time of approximately three hours and can be completed by cars, but is unsuitable for use by other vehicle classes. The Rainbow link is vulnerable to closure from natural hazards, particularly heavy snowfall (ibid).

- Molesworth route - could also be used as an 'emergency' alternative *instead of the Lewis Pass route.* This route includes the nodes of Christchurch, Waipara, Culverden, Hanmer Junction, Hanmer Springs, Blenheim, Picton (and Kaikoura). Between Hanmer Springs and the Molesworth route turnoff west of State Highway 1 (22km south of Blenheim) the Molesworth route is unsealed (176km) and conditions a trip time of approximately five hours. Conversations with the Department of Conservation indicate that the link is used by heavy commercial vehicles to transport cattle, although the route is narrow and passes through difficult terrain not favourable for trucking use. The Molesworth link is also prone to closure from natural hazards.

Both 'possible' routes have various limitations, including operational difficulties that would need to be overcome because both routes pass through private land. However, cost estimates are included to provide insights into 'potential' cost structures compared to existing alternatives.

4.3 Road-user cost assessment methodology

Travel time costs and vehicle operating costs (VOC) combined were estimated for each vehicle trip for each link in the road network. Costs were estimated for each of the six vehicle classes (defined in Table 4.1).

Table 4.1: Description of the six vehicle classes

Vehicle class	Vehicle class composition
Passenger cars	cars and station wagons, with a wheelbase of 3.0 metres or less
Light Commercial Vehicles (LCV)	vans, utilities and light trucks up to 3.5 tonnes gross laden weight
Medium Commercial Vehicle (MCV)	two axle heavy trucks without a trailer, over 3.5 tonnes gross laden weight
Heavy Commercial Vehicle I (HCVI)	rigid trucks with or without trailers or articulated vehicle with three or four axles in total
Heavy Commercial Vehicle II (HCVII)	trucks and trailers and articulated vehicles with or without trailers with five or more axles in total
Buses	buses, excluding minibuses

Source: Transfund NZ (1997a:A2-1)

Accident costs were also estimated for each vehicle trip for each link in the network. However, it was not possible to calculate accident costs for individual vehicle classes.

4.3.1 Assigning time costs and VOC (per vehicle trip) for each link in the network

Transfund NZ (1997a) composite time costs (which include occupant time, vehicle time and freight time) for roads designated Rural Other are $20.80 per vehicle per hour for standard traffic mixes (for all periods). However, State Highway 1 typically has a higher percentage of HCV than standard, so travel time costs for Rural Strategic Roads ($21.60) have been used to approximate the costs incurred by this mix of vehicles (Harris Consulting, 1997).

Travel times for each link are based on those reported in Transit NZ (1998e). However, based on HCV travel times associated with the Clifford Bay project, it is assumed that HCV incur an additional 18 per cent travel time (Kerr, pers. com.).

VOC (along rural highways) for each vehicle class were derived from Transfund NZ (1997a). Changes in VOC are dependent on speed and gradient. Following Harris Consulting (1997), link distances were divided by link travel times to derive average speeds for each link in the road network. Average speed information was used in conjunction with highway gradient information to assign VOC along each road link. Highway gradients were estimated from topographic maps and highway information sheets. Mean uphill and downhill VOC (cents/km) for various gradients were multiplied by the length of 'sloping' highway (km) to derive VOC through rolling/mountainous terrain. Total VOC along each link were obtained by combining VOC through rolling/mountainous terrain with VOC through flat terrain (0 per cent gradient).

Road roughness costs were included as additional VOC. Using the roughness count figures suggested by Harris Consulting (1997), unsealed roads were assumed to be 200 NAASRA counts. However, roughness counts on unsealed roads can vary significantly, depending on factors such as weather conditions and frequency of grading (Whyte, pers. com.). Costs are, therefore, approximate and subject to variation. Sealed highways were assumed to be 70 NAASRA counts (Harris Consulting, 1997).

For ease of interpretation, a worked example for the Christchurch to Waipara link is provided below. The information required to assign time costs and VOC (per vehicle) is shown in Table 4.2.

Table 4.2: Information required to assign time costs and VOC (per vehicle) for the Christchurch to Waipara link

Link distance	Time of travel (Cars, LCV, MCV, Buses)	Time of travel (HCV)
57km (sealed)	55 minutes (average speed of 62km/hr)	64.9 minutes (average speed of 53km/hr)

Using this information, Table 4.3 shows the time cost and VOC calculations (including roughness costs) for the six vehicle classes.

Table 4.3: Assigning time costs and VOC (per vehicle trip) for the Christchurch to Waipara link (assuming flat terrain)

	α	A	B	C	D	E
Vehicle class	Time of travel (mins)	Time cost ($/hr)	Total time cost (A*α/60)	VOC (cents/km)	Total VOC (C*57km)	Total cost (B+D)
cars	55	$21.60	$19.80	27.57	$15.72	$35.52
LCV	55	$21.60	$19.80	22.53	$12.84	$32.64
MCV	55	$21.60	$19.80	40.81	$23.26	$43.06
HCVI	64.9	$21.60	$23.36	51.11	$29.13	$52.49
HCVII	64.9	$21.60	$23.36	58.23	$33.19	$56.55
Buses	55	$21.60	$19.80	57.54	$32.80	$52.60

The per vehicle cost estimates for each link were incorporated into the State Highway network model. The model calculated the cost of travel for each vehicle class between different nodes in the network.

4.3.2 Assigning accident costs (per vehicle trip) for each link in the network

Accident histories for each link in the road network for the 1994 to 1998 period were obtained from the Land Transport Safety Authority accident database (LTSA, 1999). Accident histories were then incorporated into the Transfund NZ Accident Analysis Programme (Transfund NZ, 1997b). The programme calculated annual accident costs. Annual accident costs were divided by annual vehicle numbers obtained from Transit NZ (Chesterfield, pers. com. and Harcourt, pers. com.) to provide per vehicle accident costs. However, cost estimates are conservative because intersection accidents (with an estimated cost of $2,659,148 per year) and non-injury accidents are not included in the analysis.

For ease of interpretation, a worked example for the Springs Junction to Murchison link is provided below (see Table 4.4).

Table 4.4: Assigning accident costs (per vehicle) for the Springs Junction to Murchison link

		A	B	C
Road segment	Accident history 1994-1998	Annual accident cost	Annual vehicle numbers	Cost per vehicle (A/B)
Springs Junction to SH6 intersection	0 fatal 6 serious 31 minor	$2,064,356	273,750	$7.54
SH6 intersection to Murchison	0 fatal 2 serious 2 minor	$445,486	562,465	$0.79

Table 4.4 shows that the mean accident cost (per vehicle) between Springs Junction and Murchison is $8.33.

The per vehicle accident costs for each link were incorporated into the State Highway network model. The model calculated accident costs between different nodes in the network.

4.3.3 Estimating the daily cost of road closure events

To estimate the daily cost of road closure, the additional per vehicle costs (time costs, VOC and accident costs) incurred along the alternative routes were multiplied by the number of vehicles expected to be affected by road closure events. The number of vehicles expected to be affected by closure events was estimated from AADT information provided by Transit NZ (Harcourt, pers. com.) (see Table 4.5).

Table 4.5: Daily vehicle numbers expected to be affected by the closure of State Highway 1 in the Kaikoura District

	AADT	
Vehicle type	SH1 north of Kaikoura	SH1 south of Kaikoura
Cars	1304	1520
LCV	302	192
MCV	76	76
HCVI	57	94
HCVII	132	96
Buses	19	22
Total	1890	2000

However, it was not accurately known where vehicles in the Kaikoura District were travelling to or from or how traffic movement would change following disruption, both of which influence the magnitude of daily cost estimates. Various assumptions were made to address this uncertainty (see below). Accordingly, daily cost estimates are approximate and subject to error.

State Highway 1 is the South Island's main north/south route and provides an important link (particularly for freight flows) between Christchurch and

Blenheim/Picton (Centre for Advanced Engineering, 1997). It is assumed that the majority of vehicles using State Highway 1 in the Kaikoura District are travelling between Christchurch and Blenheim/Picton (the largest centres in the network under consideration) and a minority of vehicles travel from these larger centres to Kaikoura. These assumptions are supported by comments made by Harcourt (pers. com.) suggesting that Christchurch, Blenheim and Picton (and Kaikoura to a lesser extent) are key origin and destination points. Many road-users are, however, likely to be travelling between other origins and destinations (eg. between local centres in close proximity) and would incur different costs to those assumed above. However, the inclusion of all 'possible' vehicle movements in the cost analysis is too complex. Accordingly, ten per cent of vehicles shown in Table 4.5 were excluded from the cost analysis. This exclusion is likely to result in an under-estimate of road-user costs because the additional costs incurred by 10 per cent of vehicles from link closure are not captured in the analysis.

For vehicle movements included in the analysis, it is assumed that:

'Best' estimate: 80 per cent of cars, LCV and MCV and 95 per cent of HCV and buses are travelling between Christchurch and Blenheim/Picton, independently of Kaikoura as a destination. It is assumed that all other vehicles travel to Kaikoura (from Christchurch or from Blenheim/Picton).

However, because the 'best' vehicle movement assumptions are not precise, alternative assumptions were made to see how road-user costs change (see section 4.3.4).

Assumptions were also made about changes in traffic movement following closure events. Vehicles may delay, detour or cancel their trip. For the purposes of this research, road-users are assumed to either detour or cancel their trip based on prior knowledge of link availability. The exclusion of delay costs is likely to result in an under-estimate of road-user costs because of link closure.

To estimate the number of car-users who may cancel their trips when State Highway 73 is closed, Butcher (1985a) used a demand elasticity value for car travel of 0.34.

This demand elasticity value was derived from traffic count information collected by former Ministry of Works and Development staff during a State Highway 6 closure event (ibid). An alternative route to State Highway 6 via Reefton was available and traffic counters recorded the number of cars detouring, which allowed demand elasticities to be calculated (ibid). Multiplying the demand elasticity value for car travel by the percentage cost increase of the alternative route yields the percentage of car-users who may cancel their trip. Cars travelling between Christchurch and Picton via the Lewis Pass, for example, incur a 45 per cent cost increase. The 45 per cent cost increase multiplied by the demand elasticity value of 0.34 equates to 15 per cent of car-users cancelling their trip. For the various route alternatives, the percentage of car-users expected to cancel was calculated using the elasticity value of 0.34. The percentage of LCV expected to cancel was estimated using the same elasticity value because it is assumed that some LCV (eg. vans and utilities) also have flexible transport schedules.

Following Butcher (1985a), it was assumed that all commercial vehicles, other than LCV, would detour to alternative routes in the event of State Highway 1 closure because of freight and passenger commitments. However, conversations with freight transport companies based in Kaikoura and bus operators contacted by phone suggested that vehicles originating from or destined for Kaikoura would be unlikely to continue regular services if vehicles were required to use the Lewis Pass route. If, for example, State Highway 1 to the north of Kaikoura is closed, operators would be unlikely to continue regular Kaikoura to Blenheim/Picton services by detouring to the Lewis Pass route. Accordingly, all commercial vehicles, other than LCV, originating from, or destined for Kaikoura were assumed to cancel trips if required to detour to the Lewis Pass route.

For all road-users who cancel trips, costs are also incurred. Following Butcher (1985a), the loss of benefits is assumed to be half the cost of detouring (excluding accident costs). However, because the cancellation assumptions are not precise, alternative assumptions were made to see how road-user costs change (see section 4.3.4).

For ease of interpretation, a worked example of calculating daily disruption costs (either because of detour or cancellation) when the Kaikoura to Blenheim link is closed is provided as Appendix 2 (assuming vehicle movements are the same as those outlined in the 'best' estimate).

4.3.4 Sensitivity analysis

The 'best' daily closure cost estimate outlined above is subject to much uncertainty, particularly when road-users are required to detour to the Lewis Pass route. Accordingly, a range of different assumptions were made to determine how daily road-user costs differ to the 'best' estimate.

The alternative assumptions made for pre-disruption vehicle movements are:

'High' estimate: 70 per cent of cars, LCV and MCV and 85 per cent of HCV and buses are travelling between Christchurch and Blenheim/Picton, independently of Kaikoura as a destination. It is assumed that all other vehicles travel to Kaikoura (from Christchurch or from Blenheim/Picton). The 'high' estimate assumes that a higher percentage of vehicles travel to Kaikoura and a lower percentage of vehicles travel between Christchurch and Blenheim/Picton than the 'best' estimate.

'Low' estimate: 90 per cent of cars, LCV and MCV and 100 per cent of HCV and buses are travelling between Christchurch and Blenheim/Picton, independently of Kaikoura as a destination. It is assumed that all other vehicles travel to Kaikoura (from Christchurch or from Blenheim/Picton). The 'low' estimate assumes that a lower percentage of vehicles travel to Kaikoura and a higher percentage of vehicles travel between Christchurch and Blenheim/Picton than the 'best' estimate.

Alternative assumptions were also made about the number of road-users that may cancel their trip in the event of link closure. In addition to the cancellation assumptions made in section 4.3.3, costs are estimated when all vehicles are assumed to detour to alternative routes (ie. no cancellations) for the 'best', 'high', and 'low' vehicle movement estimates.

The sensitivity analysis allows a range of 'possible' daily road-user costs to be presented.

4.4 Results

4.4.1 Additional distance, time and cost of travel (per vehicle) via route alternatives

The additional distance, time and cost of travel (per vehicle) between the nodes of Christchurch and Kaikoura when State Highway 1 is closed south of Kaikoura or Highway 70 and State Highway 1 are closed south of Kaikoura are shown in Table 4.6.

Table 4.6: Additional distance, time and cost of travel (per vehicle) between Christchurch and Kaikoura via the route alternatives

	Existing routes		Possible routes	
Item	Highway 70	Lewis Pass	Rainbow route	Molesworth route
Additional length (km)	19	411	280	231
Additional time* (mins)	50	390	330	340
Distance unsealed (km)	10	-	103	176
Additional time and VOC for:				
cars	$24.91	$254.32	$210.68	$210.89
LCV	$23.46	$234.01	*($196.61)*	$199.31
MCV	$27.98	$313.49	*($261.21)*	$283.09
HCVI	$36.62	$387.58	*($344.85)*	$366.20
HCVII	$38.11	$430.64	*($368.29)*	*($386.79)*
Buses	$30.36	$384.98	*($302.70)*	$291.54
Additional accident cost	-$3.22	$67.74	Not estim.	Not estim.

* It is assumed that HCV incur an additional 18 per cent travel time than times indicated.

Vehicles that are unlikely to be able to use 'possible' routes.

When State Highway 1 is closed south of Kaikoura, Highway 70 requires an additional 19km (50 minutes) travel and conditions moderate time cost and VOC increases (between $23 and $38 per trip). However, accident costs on Highway 70 are $3.22 less per vehicle than on State Highway 1 because a relatively high number of accidents have occurred on State Highway 1 between the Kowhai River and the Waiau River (9 fatal, 29 serious, 68 minor) between 1994 and 1998.

When both southern links providing access to Kaikoura are closed, the Lewis Pass route conditions significant time costs and VOC (an additional $234 to $430 per trip). HCV incur the greatest cost increases. Additional accident costs are also significant, which is largely attributable to the mountainous State Highway 7 stretch. Both 'possible' routes are more direct than the Lewis Pass route. However, the unfavourable terrain of both 'possible' routes conditions trip times that are only 50 minutes to 60 minutes quicker than the Lewis Pass route. Both 'possible' routes provide lower cost alternatives than the Lewis Pass route. If, for example, cars used the Rainbow route, time costs and VOC would be $43 less per vehicle than the Lewis Pass route. The Molesworth route could cater for other vehicle classes than the Rainbow route and provide lower cost travel than the Lewis Pass route (up to $93 less per trip). However, HCVI would only save $21 per trip by using the Molesworth route instead of the Lewis Pass route, primarily because roughness costs for HCV are more than $0.50 per km.

The additional distance, time and cost of travel (per vehicle) between the nodes of Blenheim/Picton and Kaikoura when State Highway 1 is closed north of Kaikoura are shown in Table 4.7.

Table 4.7: Additional distance, time and cost of travel (per vehicle) between Blenheim/Picton and Kaikoura via the route alternatives

	Existing route	Possible routes	
Item	Lewis Pass	Rainbow route	Molesworth route
Additional length (km)	348	217	212
Additional time* (mins)	370	310	360
Distance unsealed (km)	-	113	186
Additional time and VOC for:			
cars	$231.51	$187.87	$214.62
LCV	$213.67	*($176.57)*	$203.35
MCV	$282.51	*($230.23)*	$284.79
HCVI	$352.56	*($309.83)*	$371.30
HCVII	$391.39	*($329.04)*	*($391.58)*
Buses	$342.60	*($260.32)*	$289.36
Additional accident cost	$59.16	Not estim.	Not estim.

* It is assumed that HCV incur an additional 18 per cent travel time than times indicated.
Vehicles that are unlikely to be able to use 'possible' routes.

When State Highway 1 is closed north of Kaikoura, the only existing alternative, via the Lewis Pass, conditions significant distance, time and cost increases. Additional time costs and VOC are between $213 and $391 per trip. Additional accident costs are also high ($59.16 per trip).

Again, the Rainbow route would provide a lower cost alternative for cars than the Lewis Pass route. The Molesworth route only provides a lower cost alternative for cars, LCV and buses compared to the Lewis Pass route.

The additional distance, time and cost of travel between Christchurch and Blenheim/Picton (independently of Kaikoura as an origin or destination) when both links are closed south of Kaikoura and/or State Highway 1 is closed north of Kaikoura are shown in Table 4.8.

Table 4.8: Additional distance, time and cost of travel (per vehicle) between Christchurch and Blenheim/Picton via the route alternatives

	Existing route	Possible routes	
Item	Lewis Pass	Rainbow route	Molesworth route
Additional length (km)	147	16	11
Additional time* (mins)	150	90	140
Distance unsealed (km)	-	103	176
Additional time and VOC for:			
cars	$95.08	$51.44	$78.19
LCV	$87.71	*($50.61)*	$77.39
MCV	$117.35	*($65.07)*	$119.63
HCVI	$146.86	*($104.13)*	$165.60
HCVII	$166.38	*($104.03)*	*($166.57)*
Buses	$143.74	*($61.46)*	$90.50
Additional accident cost	$30.76	Not estim.	Not estim.

* It is assumed that HCV incur an additional 18 per cent travel time than times indicated.
Vehicles that are unlikely to be able to use 'possible' routes.

The Lewis Pass route requires an additional 147km travel than the preferred State Highway 1 route. The additional 150 minute travel time via the Lewis Pass route is likely to be problematic for commercial vehicle operators on return trips (eg. shuttle buses) because of driving hours regulations. Law permits a maximum of 11 hours driving time per day. Return trips via the Lewis Pass route exceed permitted regulations. Some commercial operators may, therefore, incur other additional costs (eg. accommodation costs).

When road-users are required to use the Lewis Pass route, road-users incur additional time costs and VOC of $87 to $166 per trip than the preferred State Highway 1 route. Additional accident costs are also high ($30 per trip).

If all vehicle classes could use the Rainbow route, road-users would incur time costs and VOC of between $37 and $82 less than the Lewis Pass route. Again, if the Molesworth route were available for use, only cars, LCV and buses would incur lower costs compared to the Lewis Pass route.

4.4.2 Daily cost of road closure events

The daily cost of road closure events is presented in the following section. Costs are based on the 'best' vehicle movement estimate and assume that some road-users cancel their trip because of the cost increases incurred along the route alternatives (see section 4.3.3 for a description of the assumptions used to derive cost estimates).

Closure of State Highway 1 north of Kaikoura

There is currently an average of 1890 vehicles per day using the Kaikoura to Blenheim link. However, when the Kaikoura to Blenheim link is closed, additional road-user costs are estimated for only 90 per cent of these vehicles (1701 vehicles per day) to account for vehicle movements outside the scope of the analysis (eg. local vehicle movements). The additional daily costs incurred by road-users via the Lewis Pass route (either because of detour or cancellation) are shown in Table 4.9.

Table 4.9: Additional costs incurred by road-users (per day) when State Highway 1 is closed north of Kaikoura

	Lewis Pass
	Detour and cancellation costs*
Additional time costs and VOC	$177,153
Additional accident costs	$40,242
Total additional costs	$217,395

* A worked example of this cost estimate is provided as Appendix 2.

A 13-day closure north of Kaikoura would, for example, condition additional road-user costs of $2.83 million ($217,395*13).

Closure of State Highway 1 and Highway 70 south of Kaikoura

There is currently an average of 2000 vehicles per day using the Waipara to Kaikoura link. However, when the Waipara to Kaikoura link is closed, additional road-user costs are estimated for only 90 per cent of these vehicles (1800 vehicles per day) to account for vehicle movements outside the scope of the analysis (eg. local vehicle movements). The additional costs incurred by road-users via the Lewis Pass route (either because of detour or cancellation) are shown in Table 4.10. Highway 70 traffic volumes are not considered in the analysis. The exclusion of Highway 70 vehicle numbers results in conservative cost estimates of link closure.

Table 4.10: Additional costs incurred by road-users (per day) when both links south of Kaikoura are closed

	Lewis Pass
	Detour and cancellation costs
Additional time costs and VOC	$194,671
Additional accident costs	$44,681
Total additional costs	$239,352

A 13-day closure of both links south of Kaikoura would, for example, condition additional road-user costs of $3.11 million ($239,352*13).

Closure of State Highway 1 south of Kaikoura

There is currently an average of 2000 vehicles per day using the Waipara to Kaikoura link. However, when the Waipara to Kaikoura link is closed, additional road-user costs are estimated for only 90 per cent of these vehicles (1800 vehicles per day) to account for vehicle movements outside the scope of the analysis (eg.

local vehicle movements). The additional costs incurred by road-users via Highway 70 (either because of detour or cancellation) are shown in Table 4.11.

Table 4.11: Additional costs incurred by road-users (per day) when State Highway 1 is closed south of Kaikoura

	Highway 70
	Detour and cancellation costs
Additional time costs and VOC	$46,156
Additional accident costs	-$5,567
Total additional costs	$40,589

A 13-day closure of State Highway 1 south of Kaikoura would, for example, condition additional road-user costs of $0.53 million ($40,589*13).

4.4.3 Sensitivity analysis

Different assumptions about the percentage of vehicles travelling between nodes and the percentage of road-users cancelling trips were made to allow a range of 'possible' daily closure costs to be presented (see section 4.3.4 for a description of the different assumptions). A range of 'possible' daily costs are presented in Table 4.12 when State Highway 1 is closed north of Kaikoura or both links south of Kaikoura are closed and vehicles detour to the Lewis Pass route. A range of 'possible' costs is not included for the Highway 70 alternative because 'possible' costs show little (or no) variation under different assumptions (eg. if all road-users are assumed to detour to Highway 70 the cost for the 'low', 'medium' and 'best' estimate is $41,239, only $650 more than the estimate provided in Table 4.11).

Table 4.12: Total additional road-user costs incurred (per day) under alternative assumptions

		Lewis Pass		
		'Low' estimate	*'Best' estimate*	*'High' estimate*
SH1 North CLOSED	*Detour and cancellation cost*	$213,092	$217,395	$221,853
	All detour cost	$250,324	$277,747	$307,181
SH1 and H70 South CLOSED	*Detour and cancellation cost*	$229,639	$239,352	$249,078
	All detour cost	$269,888	$304,294	$341,262

When a higher percentage of road-users travel to Kaikoura and a lower percentage of road-users travel between Christchurch and Blenheim/Picton (ie. the 'high' estimate), total additional road-user costs are higher than the 'best' estimate. This may be attributed to the 'backtracking' required to access Kaikoura via the Lewis Pass route. When a lower percentage of road-users travel to Kaikoura and a higher percentage of road-users travel between Christchurch and the north of the South Island (ie. the 'low' estimate), total additional road-user costs are lower than the 'best' estimate.

The greatest differences in costs are, however, seen when all road-users are assumed to detour during closure events (ie. no cancellations). For example, when a high percentage of road-users are assumed to travel to Kaikoura (ie. the 'high' estimate) and no road-users cancel their trip, additional road-user costs exceed $300,000 per day. However, because the cost increases incurred by road-users via the Lewis Pass route are substantial, it is likely that some road-users would cancel their trip when

State Highway 1 is closed. Therefore, it is assumed that the detour and cancellation cost estimates are most feasible (see shaded boxes in Table 4.12).

4.5 Conclusion

The road network in the Kaikoura District is sparse. There is only one alternative route (Highway 70) available in the Kaikoura District when State Highway 1 is closed south of Kaikoura. There is no alternative route in the Kaikoura District for State Highway 1 to the north of Kaikoura. Road-users (particularly HCV) incur significant costs by detouring to the Lewis Pass route. The Rainbow route would provide the lowest cost 'emergency' alternative to the Lewis Pass route. However, if the Rainbow route were to be made available to all vehicle classes, significant (and costly) link improvement works would be required.

Additional road-user costs exceed $200,000 per day when State Highway 1 is closed and road-users detour to the Lewis Pass route. When an immediate alternative route is available (Highway 70), additional daily costs are significantly lower.

State Highway 1 to the north of Kaikoura is the most important single link in the Kaikoura District because no low-cost alternative route is available. The lack of a low-cost alternative route reinforces the importance of retaining (and promptly reinstating) the Kaikoura to Blenheim link. State Highway 1 to the south of Kaikoura is the second most important link because it is more cost-effective than Highway 70.

The following chapter investigates non-user costs of road network disruption in the Kaikoura District.

Chapter 5: Non-user cost assessment

5.1 Introduction

A survey of businesses in the Kaikoura District was conducted to provide insights into non-user costs of road network disruption. This chapter presents the results of the survey and describes the methodology applied. The economic structure of the Kaikoura District is also presented in the following section.

5.2 Economic structure of the Kaikoura District

'At the time of the 1996 census, the Kaikoura District had a usually resident population of 3,516 people and the township itself had a usually resident population of 2,208 people' (Horn et al., 1998:19). Kaikoura township is the primary residential and commercial centre in the Kaikoura District (Canterbury Regional Council, 1999). Outside the township, the District is predominantly rural in focus (ibid).

The 1996 census indicated that total employment in the District was approximately 1,386 full-time equivalent persons (see Table 5.1).

Table 5.1: The number of persons employed in the Kaikoura District

Sector	1996
Agriculture	267
Restaurant and accommodation	180
Wholesale and retail trade	150
All other services	144
Not identified	138
Health and education	126
Construction	81
All other manufacturing	77
Fishing	69
Recreation and culture	60
Fish processing	42
Other transport	36
Business and professional services	21
Dairy processing	18
Hunting, forestry and mining	15
Railways	15
Communications	6
Electricity, gas and water	3
Total	1386

Source: Butcher et al. (1998:2)

The major sources of employment in the Kaikoura District are 'agriculture and the various service industries (which incorporate the various aspects of tourism)' (Butcher et al., 1998:2). Almost 30 per cent of all jobs in the Kaikoura District depend either directly or indirectly on tourist spending (ibid:27).

5.3 Non-user cost assessment methodology

5.3.1 Scenario methods

Non-user costs of road network disruption in the Kaikoura District were estimated using scenario methods. Scenario writing is a technique of futures research that provides descriptions of potential events in order to show how, under present conditions and assumptions, a future state might evolve (Vlachos, 1981). In this research, scenario writing involved painting a picture of what could happen to the road network servicing Kaikoura to investigate the degree to which local businesses may be disrupted by road closure events (Ericksen, 1990).

Non-user costs of road network disruption can be assessed by first establishing the degree of hazard and then relating the hazard threat to realistic closure scenarios (Glade and Crozier, 1996). The historical review of natural hazards formed the basis from which the three closure scenarios were created (see Appendix 3). Scenario 1 is based on the 1992 Punchbowl Corner closure event. Scenario 2 and Scenario 3 are based on 'possible' closure events. The 13-day closure durations used in Scenario 2 and Scenario 3 are based on the most severe closure durations of past events (eg. following the 1975 Cyclone Alison event).

Semi-structured interviews were the preferred research tool because in-depth accounts of potential costs, based on the three scenarios presented to respondents, were sought. 'Semi-structured interviews are used when some of the flexibility and detail of qualitative research is required, in conjunction with the opportunity to aggregate answers (the hallmark of quantitative research)' (Morton-Williams, 1985:28). The methodology used focused on potential turnover losses arising from the three closure scenarios presented to respondents.

The primary concern is perceived costs, or the subjective value to which businesses react and respond to the closure scenarios presented (Tobin and Montz, 1997). Realistic estimates of economic disruption are at best difficult to obtain and are the weakest link in any study of natural hazards (Monroe and Ballard, 1983). However, subjective judgement is a practical and useful way to understand potential costs, despite the lack of exact predictive power (Vlachos, 1981). Scenarios have the potential to generate new information that can be used as a device to educate and communicate to decision-makers (Ericksen, 1975). The Disaster Research Centre at the University of Delaware has, for example, conducted a number of studies focusing on the vulnerability of businesses to natural hazards (Disaster Research Centre, 1998). Studies have provided insights into potential economic losses, hazard mitigation priorities, disaster preparedness and recovery planning (ibid). Similarly, a number of studies (eg. see the University of Colorado Natural Hazards Database, 1998) have estimated potential costs arising from natural hazards (eg. following a major earthquake in San Francisco) using scenario methods.

5.3.2 Survey framework

A copy of the survey used to guide each interview is included as Appendix 4. The survey structure is based on a framework put forward by Green et al. (1983:3) to estimate non-user costs.

Non-user costs = f (dependence, susceptibility, transferability), where:

- Dependence is the degree to which a business requires a particular good as an input, or to output that good, in order to function normally.
- Susceptibility (estimated through the use of the closure scenarios) is the extent to which the physical presence of the disruption (on a temporal and spatial basis) will affect inputs or output.
- Transferability is the ability to respond to disruption.

Disruption awareness was also included in the framework because of the lack of recent long-term closure events in the District.

'Open-ended questions were used extensively to give a greater freedom for respondents to answer in their own terms, rather than within the tramlines of set alternatives in closed questions' (Jones, 1985:49).

Pilot interviews were conducted with three businesses in Kaikoura to ensure that the scenarios presented to respondents were easily interpreted. Following the pilot interviews, it was decided to tape interviews when respondents did not object. In addition, the 1975 Cyclone Alison scenario was omitted because of time constraints in the interview process.

5.3.3 Sample design and survey implementation

'Sample design in qualitative research is usually purposive; that is, rather than taking a random cross section of the population to be studied, small numbers of people with specific characteristics are selected to facilitate broad comparisons between groups that the researcher thinks likely to be important' (Morton-Williams, 1985:30). Costs were assessed on an industry basis because different industries depend on the road network to varying degrees (Chang et al., 1995).

An input-output table was recently constructed (see Butcher et al., 1998) which simultaneously describes the supply and demand relationships of the Kaikoura District economy (Miernyk, 1965). The table was used to help determine which industries should be included in the interview sample. Industries (eg. mining) producing little output (generally less than $1 million) were omitted from the target sample. In addition, it was assumed that a number of larger industries (eg. business and professional services) would be little affected by closure events. The industries surveyed were construction, other food/bakery, wholesale and retail, restaurant and accommodation, freight transport, recreation and culture and two primary producing industries.

The industries surveyed only account for 40 per cent of total industry output in the Kaikoura District. However, as stated by Morton-Williams (1985:29), 'because of time and cost constraints, a qualitative study can never cover the whole population in such a way that all different sub-groups that may be important can be looked at in detail.' Costs incurred by excluded industries have not been included in estimates of disruption costs. Accordingly, non-user costs of road network disruption in the Kaikoura District are likely to be conservative.

As stated by Babbie (1998:195), it is appropriate to select a sample 'on the basis of your own knowledge of the population; its elements and the nature of your research aims.' Business owners and managers in Kaikoura were non-randomly approached in person and informed about the interview purpose. Businesses in operation during the 1992 Punchbowl Corner closure were first approached in an attempt to obtain more reliable turnover loss estimates for Scenario 1 than loss estimates made by respondents not operating in 1992. When respondents indicated that they were willing to be interviewed, a meeting time was arranged. The level of cooperation was high. Five businesses visited were not willing to participate. Twenty interviews were conducted in total. Fifteen of the twenty interviews were recorded (and later transcribed) and interviews lasted for approximately 30 minutes on average.

5.3.4 Survey analysis

The process of survey analysis was largely a search for patterns of similarities and differences in responses followed by an interpretation of those patterns (Babbie, 1998). An important component of the analysis was the calculation of potential turnover losses for each closure scenario, based on information provided by survey respondents. Survey respondents estimated the percentage of daily turnover that may be lost during each closure scenario. The percentage turnover loss estimates, in conjunction with gross annual turnover information provided by respondents, allowed turnover losses for each closure scenario to be calculated. However, twelve respondents did not disclose their gross annual turnover upon which turnover losses for each closure scenario could be calculated. The commercial sensitivity of financial information, particularly in a small community where businesses may be identifiable, often makes data collection difficult (Kerr, 1995). Estimates of annual turnover for these businesses were based on national employment to output ratios (Statistics NZ, 1998) or ratios of employment to output based on information provided by other respondents in the same industry. Loss estimates for twelve respondents are, therefore, subject to this additional source of error.

Turnover losses predicted by respondents for each closure scenario were adjusted to derive direct industry losses in the Kaikoura District, based on output information contained in the input-output table. However, the output information contained in the input-output table is based on 1990/91 data and does not accurately reflect the current level of economic activity in the District. The adjusted industry losses are likely to be conservative primarily as a result of the recent growth of tourism in the Kaikoura District that is not captured in the 1990/91 table. The growth in tourism is seen, for example, in the increase in employment in the wholesale and retail industry (up 28 per cent since 1991) and the recreation and culture industry (up 100 per cent since 1991) (Butcher et al., 1998).

The direct industry turnover losses for each closure scenario do not, however, account for total disruption costs. The total impact 'can only be determined after consideration of flow on (indirect and induced) effects' (Kerr, 1995:159). Indirect impacts arise from decreased spending at other businesses as a result of the initial impact (Butcher et al., 1998). If, for example, a tourist does not purchase food at a cafe (the direct impact), the cafe may purchase fewer products from the bakery, so the bakery output also drops. In addition, the bakery uses less electricity, so the electricity provider also loses turnover, and so on. The induced impact is the result of decreased household income (eg. wages and profits) being spent at other businesses, leading to a further ripple effect of decreased output (ibid).

Multipliers are used to compare the size of the flow on effects with the size of the direct impact and can be calculated by mathematical manipulation of the input-output table (see Butcher, 1985b:3-5). Type II output multipliers (the ratio of direct plus indirect plus induced impacts to direct impacts) were provided by Butcher (pers. com.). The Type II output multipliers allowed the total effects of road network disruption on all sectors to be estimated.

Type II output multipliers (for industries expecting direct turnover losses) are shown in Table 5.2.

Table 5.2: Type II output multipliers used to calculate total non-user costs

	Industry				
	Other food/ bakery	Recreation/ culture	Freight transport	Wholesale/ retail	Restaurant/ accommodation
Direct impact	1.00	1.00	1.00	1.00	1.00
Indirect impact	0.28	0.35	0.30	0.30	0.37
Induced impact	0.17	0.20	0.21	0.21	0.18
Type II output multiplier	1.45	1.55	1.51	1.51	1.55

Using the restaurant and accommodation industry as an example, every $1 not spent has flow on effects of $0.55 and the total change in District output is $1.55. The multipliers used in this research are, however, subject to error because the Kaikoura District input-output table is not constructed from primary data, but is modified from an existing national table using a process called GRIT (generation of regional input-output tables) (see Butcher, 1985b). The Kaikoura District input-output table assumes, for example, that local trade patterns within the Kaikoura District are similar to trade patterns at the national level (Kerr, 1995). However, this is unlikely to be true because more trade is likely to occur across boundaries in the Kaikoura District because of the limited business support infrastructure (Butcher et al., 1998). The multipliers derived from the Kaikoura District input-output table are likely, therefore, to overestimate the flow on effects. The GRIT process can, however, be improved by incorporating into the table local business expenditure information and household consumption information, as performed by Butcher et al. (1998:7) in their study of the economic impact of tourism in Kaikoura.

5.4 Results

5.4.1 Disruption awareness

Nine survey respondents (predominantly from the restaurant and accommodation industry) have been in business for only three years (on average) and have not been affected by long-term closure events. However, all survey respondents were aware, prior to being interviewed, that State Highway 1 and the Inland Road are vulnerable to closure. Most new business owners recalled the effects of short-term closures (of less than a day) caused by road accidents or temporary closures caused by natural hazards. The impacts have, however, been insignificant and largely unnoticed because of the short duration of the closures.

The majority of respondents (11) were in business during the 1992 Punchbowl closure and four of these respondents were also in operation during the 1975 Cyclone Alison event. These respondents were able to draw on past long-term closure events in their determination of potential impacts.

Despite the limited number of recent closure events (and the high proportion of new business owners), all respondents believed that future closure events are likely, as described below.

'We are due for a hit. The road will be closed again because of the natural volatility of the area.'

'Without a doubt. It is just the way we are situated. There are always going to be problems.'

'Our last one where they had to blow a lot of rock off on that corner [the Punchbowl Corner], there will be trouble with slips and things like that definitely around that area again I'd say. It is not that stable. There are always rocks falling on our roads.'

The majority of respondents believed that rain-induced hazards (eg. slips, rockfalls and flooding) would be the most likely cause of future closures.

'I would imagine that weather would be our biggest [threat]. You see, even though we only have a small amount of rain per year, we can get a lot in a one day or two day period. Then we can go without rain for weeks or a month.'

'Rain. If it rains long enough and hard enough. We've had it here in the past and we will get it here again.'

Several respondents, often with reference to more direct business impacts, mentioned earthquakes as a potentially disruptive hazard.

'The other thing is us sitting on a bloody earthquake fault. They keep telling us it is not if but when. So if we had a really good earthquake which flattens the road we are going to have that much infrastructure damage here that we are going to be in trouble anyway.'

Several respondents were also aware that coastal erosion threatened State Highway 1.

'When the sea is rough it undermines the road. There is quite a few places where it is happening.'

The vulnerability of the road network to natural hazards is well recognised. However, three respondents believed that a one-day closure would be the longest disruption in a worst case event. A further two respondents did not know how long a highway could be closed in a worst case event. Four of these five respondents were new business owners. These respondents were also less likely than longer established business operators to expect all highway links providing access to Kaikoura to be closed simultaneously.

Another respondent answered the questions about possible closure lengths with reference to link reinstatement policies, which again reflected a lack of closure awareness among a limited number of respondents.

'Well, isn't there a law or something that a highway can't be closed for any more than twenty-four hours or something? There is a law that a state highway can't be closed for more than a certain time which means that while work is being carried out they will always have one lane [open] at some stage.'

Given the geographical constraints in the Kaikoura District, the objective of restoring single-lane access on highways within twelve hours of the substantial end to the emergency event may not always be achievable (Transit NZ, 1998d).

The majority of respondents (15) (including several new business owners) believed closures of several days or more are likely.

'Weeks wouldn't it be? There is no where to go. The steep faces are only on the other side of the road.'

'A week to a fortnight, especially around the tunnels [south of Kaikoura on State Highway 1] and the other way around the Blue Mud [Blue Slip].'

'The length of closure would be hard to say. Like the snow one, it could be three or four days, but you get Cyclone Alison or a big sea and it could be weeks.'

The majority of respondents also believed that all highways providing access to Kaikoura could be closed simultaneously. One respondent, for example, referred to the Cyclone Alison closure event, as described below.

'Cyclone Alison was one of the worst ones we have had.

[Do you think that type of event could happen again?]

Easy. Of course it could. These cyclones come down the coast and then straight in here. They come out of the Pacific and go across the top of the North Island and circle around in here and get us. And that is what Cyclone Alison was. It was a cyclone that came down from up north and gave us rain.'

Most respondents felt that Kaikoura would only be isolated for short periods (one to three days). However, several respondents believed that a major earthquake or flood might isolate Kaikoura for a week or more.

'I suppose anything is possible in an earthquake or something like that. I would think you would at least have to look at a week.'

'I am not really sure about the Inland Road but it could [also be closed] by an earthquake or flooding. An earthquake could be the most serious which is feasible with the plates we have around here. If it was a bad earthquake, it [isolation] could be for weeks.'

Six respondents believed that the simultaneous closure of all links providing access to Kaikoura was unlikely because the Inland Road is more secure than State Highway 1. However, five of these six respondents did not discuss earthquakes as a potentially disruptive hazard.

'The Inland Road is always open if State Highway 1 is closed.'

'I don't know about the Inland Road. It is probably a wee bit safer not being coastal but certainly north and south could be closed [simultaneously] yes. Anything up to three or four days.'

'Get a decent southerly storm in here and you could be [isolated], but not so much the Inland Road. I think you'd always get out through there, unless there was snow involved.'

The recent historical record indicates that the Inland Road has been quite secure. However, all links have been closed simultaneously in the past and future simultaneous disruption is possible.

Despite the generally well recognised closure threat in the Kaikoura District, no respondents currently compensate for the possibility of road closure. Monetary constraints (eg. the expense of carrying higher levels of inventory) or the inability to provide adequate compensatory measures (eg. for businesses which derive 100 per cent of turnover from tourist purchases) prevents the adoption of cost prevention practices. Accordingly, most respondents are greatly dependent on the road network.

5.4.2 Transport Dependence

Road transport is the most important mode of transport among respondents. No respondents rely directly on rail transport or air transport to source inputs. A limited number of tourists travelling by rail do, however, contribute to the turnover of tourism oriented businesses (10 per cent or less of total turnover). Accordingly, rail transport is not seen as an essential mode of transport among respondents.

State Highway 1 is the most important highway for respondents and is used (or relied on) frequently (several times weekly to daily). The Inland Road is less important than State Highway 1 for the majority of respondents, although increasing numbers of tourists travelling between Kaikoura and Hanmer Springs contribute to the turnover of tourism oriented businesses. Several respondents expected the number of tourists using the Inland Road to increase when the highway sealing programme is complete, as described below.

'You will get a lot more coming through the Inland Road when it is sealed because they [tourists] are not allowed to come through the Inland Road in rental cars because it is unsealed.'

Only a limited number of respondents (eg. from the other food/bakery, freight transport and construction industries) are strongly supported by local community purchases. The majority of respondents depend more greatly on direct tourist purchases than local community purchases.

All respondents (except primary producing businesses) do much (or all) of their buying out of the Kaikoura District. However, most small goods (eg. basic cleaning supplies) and services are sourced locally. The limited size of the Kaikoura economy (eg. the small manufacturing base) necessitates road links with larger centres of commerce.

5.4.3 Scenario 1: 1992 Punchbowl Corner closure

The majority of respondents (17) believed that the Punchbowl closure would condition direct turnover losses. However, three respondents believed that the closure would not condition direct turnover losses.

No loss in turnover

Primary producing businesses were little affected by the Punchbowl closure because almost all inputs are sourced locally and the export of produce can be delayed or redirected, as described below.

'If we have to, we just hold the product. When the Punchbowl was closed we just worked around it. Sometimes we went through the Inland Road and sometimes we just waited until they opened it [temporary openings were in place to allow further remedial works to be carried out] and put it [the product] through.'

This respondent recalled that any loss in turnover was minimal and expected impacts to be similar now.

A respondent from the construction industry could not accurately recall the effects of the Punchbowl closure, but believed that the event could be inconvenient in the future because only 10 per cent of supplies are sourced locally.

'Some of the things, like for me, I have got a kitchen arriving on Tuesday but I don't need it until next week, that is the scenario I operate under. I like to have things sitting here in Kaikoura two or three days, or maybe a week ahead. But if you are cutting things fine and this sort of thing happens sure, that could affect me and you could get caught out.

You realise that a larger builder can't have a lot of stock lying around, they are virtually hand to mouth because they can't afford to have a lot of money outlaid so they would be affected a lot more.

We get excellent service now. I can ring up a freight company up until about 2.00pm today and I can have materials here tomorrow when you need it, but normally we are well ahead. A lot of builders rely on that scenario, but if this happened...'

This respondent did not believe the business would lose turnover. However, the respondent discussed the additional costs likely to be incurred by accessing supplies from alternative markets, if required.

Turnover losses

Eight respondents (three of whom were in operation in 1992) believed that business wellbeing would be seriously affected by the Punchbowl closure, after approximately four days (on average). However, seven respondents expected disruptive, but not serious impacts.

Three retailers were seriously affected by the 1992 event and expected similar turnover reductions now. Turnover losses of between 25 per cent and 50 per cent were incurred because customer numbers dropped markedly. However, one retailer estimated that turnover dropped by 80 per cent, which seriously affected business wellbeing immediately, as described below.

'People just didn't come to Kaikoura. People that came through the Inland Road were not shoppers. They just wanted to get through [to their destination]. People just shot up north because they were brassed off with delays. They didn't shop and wander...You can't replace those tourists. They don't come again. It is lost trade and profit.'

Similarly, four respondents in the accommodation sector unaffected by past closures also believed business wellbeing would be seriously affected (losses of 45 per cent on average were predicted) because of the reluctance of road-users to detour to the Inland Road.

'We get most of the people just driving through and a lot of them wouldn't bother coming through the Inland Road.'

'It [the closure] would have a considerable impact because tourists from the south would be turned off coming.'

In contrast, the majority of respondents from the restaurant sector and recreation and culture industry, for example, expected to incur more moderate turnover losses (between 5 per cent and 25 per cent) because it was believed that tourists would detour to the Inland Road.

'People would come via the Inland Road [during the Punchbowl closure] so there would not be much disruption. People will get through. People on holidays will find their way.'

'That [the Punchbowl closure] would be disruptive to a moderate degree. Some tourists would just go the longer way because they come from the other side of the world. Often, the whales and dolphins are what motivates them to choose Kaikoura

as a destination. These people would still travel the extra distance. That's why I am thinking the impacts would be moderate.'

There is clearly a mixed perception among respondents about the value of the Inland Road as an alternative route, which is also related to the varied opinions about Kaikoura's appeal as a destination in its own right.

All respondents who incurred losses during the 1992 Punchbowl closure expected losses to be greater in the future, primarily because of the recent growth in tourism. A respondent from the freight transport industry, for example, obtains 70 per cent of freight from Christchurch and incurred significant costs during the Punchbowl closure event. However, the respondent believed that the impacts of disruption would be far greater now because the company is moving more freight for tourism oriented businesses. Similarly, a respondent from the other food/bakery industry noted that the impacts of disruption would be greater now, as described below.

'The Punchbowl was and wasn't disruptive. Like it was for the fact that the day wasn't as busy, but then again we were supplying the men that worked on it [the remedial works]. It would be worse now though because the turnover has just been getting better and better every year.'

A motelier in operation during the 1992 Punchbowl event also discussed the costs and benefits of the 1992 closure, but noted that impacts may be more severe in the future, as described below.

'When the Punchbowl was closed it was in the winter time and it was quite good for us because people weren't keen on driving through the Inland Road at night with the ice and conditions. It probably did affect us as far as people coming up from Christchurch, they might have gone up through the West Coast or whatever, but we found at night time people would get here and wouldn't go through the Inland Road at night.

[So your business didn't lose turnover?]

It all sort of balanced out. It was our quiet time of year anyway and it might have even helped us a bit...If it [the closure] occurred during the busy periods though we would lose because people wouldn't come. People are very funny you see, as soon as they hear of something going wrong they don't want to know about it.'

5.4.4 Scenario 2: Closure of both links south of Kaikoura

The majority of respondents (16) believed that Scenario 2 would be more disruptive to business operations than the Punchbowl closure. However, four respondents believed that the impacts of Scenario 1 and Scenario 2 would not be different. Average turnover losses predicted for Scenario 2 are approximately 150 per cent higher than losses predicted in Scenario 1.

Similar disruption to Scenario 1

Primary producing respondents would not lose turnover in Scenario 2 because produce could be stored on site or alternative export arrangements could be made, as described below.

'That [Scenario 2] would pretty much have the same impact [as Scenario 1]. If we had to and the northern route was open we'd organise to whip the product through to Blenheim and fly them down [to Christchurch] or whip them out of Wellington or Auckland. There are just heaps of different alternatives. I just don't think the road could ever be closed long enough to give us a noticeable loss.

[So you have enough packaging and materials to see you through?]

We have a good supply of packaging here to last for two to three weeks. If we can't get supplies in, we obviously can't get product out so what is the point of the packaging anyway? It is a double edged sword isn't it?'

Two other respondents expected the impacts of Scenario 2 to be similar to the Punchbowl event because both respondents believed that tourists would not detour to the Inland Road during the Punchbowl closure event. For both scenarios, turnover losses of 70 per cent and 80 per cent were predicted.

Greater disruption than Scenario 1

The accommodation sector predicted the greatest turnover losses for Scenario 2 (between 70 per cent and 100 per cent). Three accommodation sector respondents estimated turnover losses of 100 per cent for Scenario 2.

'This [Scenario 2] would be much worse obviously [than Scenario 1] because they [tourists] have no alternative whatsoever and if the traffic from the ferry couldn't get through the Inland Road they wouldn't come this way. We wouldn't get any business unless we already had people in town that had to stay, which I doubt... I would think that 100 per cent of our business would be gone. I think it would be pretty devastating.'

Respondents from the recreation and culture industry also predicted considerable turnover losses (between 50 per cent and 90 per cent), as described below.

'That [Scenario 2] would impact markedly on our operations. In the tourist industry you are faced with whatever happens. You can't do anything about it. It is like when Kaikoura flooded and trips were cancelled and you don't get any help from anywhere. You just have to sit and bear it through...As soon as the road was closed the trips the following day, well maybe not the following day because the tourists are always in Kaikoura the night before, but definitely the day after that you'd be down to...well all the bookings that were made...you'd be down I'd say within two days and you'd be cancelling trips...We wouldn't know what was going to come from the north. They might fly people into Kaikoura but I doubt it. In the end, I think you'd just about have to close up shop.'

Of concern for most respondents dependent on tourist purchases would be the loss of visitors originating in Christchurch, including many on return trips. The loss of the

Christchurch market, in conjunction with the reluctance of southbound tourists to travel to Kaikoura, may seriously affect the wellbeing of many businesses.

The majority of respondents in the retail, restaurant and other food/bakery sectors also expected to be seriously affected by Scenario 2. The predicted turnover losses (50 per cent to 80 per cent) are, however, lower than those estimated by accommodation sector respondents because these industries are more strongly supported by local community purchases than accommodation sector respondents. Disruption among retailers, restaurants and other food/bakery respondents would largely be a result of the drop in tourist spending, rather than the inability (or need) to source supplies. Supplies are generally held in sufficient quantities to last a week or more (particularly for larger businesses). However, some businesses (eg. food oriented retailers and restaurants) would need to source fresh produce from alternative markets in order to continue normal operations. The need to make alternative input arrangements largely depends on timing, as stated by one other food/bakery respondent.

'At the moment, with current levels of stock, if it was closed tonight we'd only last tomorrow because the order [from Christchurch] arrives tomorrow. We would need to get the supplies from somewhere else if it was closed tonight. If it happened tomorrow after the stock arrived then we'd get away with probably a week.'

However, with these adjustments come new costs to businesses, as stated by a respondent in the freight transport industry.

'It [Scenario 2] would be extremely disruptive...Marlborough itself hasn't got the expertise to supply what Christchurch can supply, goods wise I mean. Plus, the cost factor comes into it...There is money lost into the town because businesses have to pay more for their goods.'

The freight transport respondent believed that it would not be cost-effective to 'back track' to Christchurch via the Lewis Pass to pick up freight, unless clients were prepared to pay the additional costs. This respondent estimated that up to 70 per cent of turnover could be lost because Christchurch is the main centre serviced by the company.

Only eight respondents expected the wellbeing of their business to be seriously affected in Scenario 1 (and these businesses were more likely to be smaller operators). However, in Scenario 2, fifteen respondents indicated that the wellbeing of their business would be seriously affected, again, after approximately four days (on average). In addition, many respondents believed that Scenario 2 might be detrimental to long-term business wellbeing, as described below.

'We hope to think the loss in turnover would be manageable. We hope we have enough leeway for two weeks. It might mean we make choices in next years budget.'

'We'd survive but you would feel it later on. Although you wouldn't be paying out much because your not getting people in there are still some ongoing costs that would take a long time to recover.'

In response to the potential losses predicted in Scenario 2, many businesses noted that changes would need to be made to minimise outgoings, such as reducing staff hours, as described below.

'Unfortunately staff would miss out for starters. You'd just work yourself. I always keep good stock on hand so you just wouldn't buy anything. You'd just tighten everything up.'

5.4.5 Scenario 3: Closure of State Highway 1 to the north of Kaikoura

The majority of respondents (14) believed that the closure of State Highway 1 to the north of Kaikoura would be less disruptive than Scenario 2. Six respondents believed that the impacts of Scenario 2 and Scenario 3 would not be different. Average turnover losses expected for Scenario 3 are approximately 35 per cent lower than losses predicted in Scenario 2 and approximately 65 per cent higher than losses predicted in Scenario 1.

Similar disruption to Scenario 2

Respondents from the primary producing and construction industries would be little affected by the closure of State Highway 1 to the north of Kaikoura. However, one primary producing respondent believed that the closure could result in minor losses, as described below.

'We would lose income from our fresh produce, but we could negotiate with someone from the south possibly. That would be the biggest inconvenience of the lot financially. It wouldn't leave us stopping production and is not a big margin involved. We could lose $4000 a week if we couldn't get anyone to take our product to the south.'

Other respondents (from the retail and restaurant sectors) believed that the impacts of Scenario 3 would be similar to Scenario 2 because ferry traffic would again bypass Kaikoura.

Less disruption than Scenario 2

The majority of respondents (including all accommodation sector and recreation and culture industry respondents) expected less disruptive impacts in Scenario 3 than in Scenario 2 because of the benefits the Christchurch market provides.

'Closure of the northern route probably would not be as disruptive [as Scenario 2] because we have a lot of tourists coming up from Christchurch that go back to Christchurch. They stay here for the last two or three days and then go back and fly out.'

'A lot of people fly into Christchurch and pick up their campervans. A lesser percentage come across on the ferry than they do from the South Island.'

'No, it [the closure of State Highway 1 north of Kaikoura] wouldn't seriously affect us. All our supplies come from Christchurch and Christchurch people and local trade will keep us going. The turnover may drop 10 per cent.'

One recreation and culture respondent also discussed the impacts of losing north-bound ferry traffic.

'It [Scenario 3] would have less of an impact [than Scenario 2] other than a lot of people travel on to Picton after being here. I think that would have an impact because the people are not so much the dedicated activities people but are there on vacation and passing through and go whale watching or dolphin swimming because it is the thing to do. If these people can't get through to Picton they may decide to fly up from Christchurch and so yes that must impact on us. The greater proportion of our people travel from the south and go up to Picton, so it may cut 25 per cent to 50 per cent of people.'

Fourteen respondents predicted that the wellbeing of their business would be seriously affected in Scenario 3 (one less than in Scenario 2) and many respondents also discussed the long-term costs of link disruption.

'Any loss in turnover would seriously affect us because we are such a small business, irrespective of which closure you are talking about. If it is only the north closed, it is not as bad as southbound, but any loss in turnover is serious. There is no way of retrieving that money. Once it has gone you have lost it and you haven't got any options to say, OK, we are going to do some advertising to grab some quick cash because we are too small. We are totally reliant on any money we receive here. It is not as though we have other incomes coming in so it would be desperate within seven days.'

5.4.6 Seasonal Influence

All respondents (excluding one primary producing respondent) indicated that future closures would be more severe between November and April, as described below.

'These closures would hurt us if they occurred during summer. The southern closure would be the worst one if it was closed. We wouldn't want many days of disruption over summer because that is when we make our money. You wouldn't want more than four or five days.'

Most businesses are sustained through the quieter winter months by the summer profits.

'We just tick over in the winter season and although we are just ticking over all our buying and all our product is arriving for the summer season so your outgoings are high, but there is not a lot of income, so you have to rely on the summer season.'

Non-tourism oriented industries such as the construction industry would also expect impacts to be greater in the summer months because builders work more hours (and hence need more supplies) because the weather is favourable. In addition, one primary producing business exports produce to northern markets over the summer period and the closure of State Highway 1 to the north of Kaikoura would condition greater inconvenience and costs.

The general consensus among respondents is that winter closures would still have considerable impacts, but losses would be more manageable, as described by one motelier.

'It would still affect us in winter because we still don't have many days with nobody in. Even in winter, you would feel the pinch after a few days, just not on such a large scale. It doesn't matter what time of year it is, it would definitely affect business.'

5.4.7 Transferability

Post-disruption compensatory measures would be adopted or 'investigated' by the majority of respondents (12). However, eight respondents (including five accommodation respondents) could not make any adjustments to minimise impacts.

Accommodation sector respondents have sufficient supplies available to last beyond the closure duration of the three scenarios and would not need to source inputs from available markets. Respondents believed that the greatest impacts would arise from the loss of tourist traffic, for which no contingency plans could be provided.

Recreation and culture respondents suggested that bus-pick up arrangements (where tourists could walk around a closure site safely) or an air link may be investigated. However, like other industries largely dependent on tourist purchases, the recreation and culture industry suggested that cost minimisation practices are unlikely to be successful, as described below.

'An air link would be looked into but that straight away adds costs and to get something like that organised and to promote it as an option...your just about back to all the roads being open. I don't think it would be cost-effective.'

A respondent from the freight transport industry would encourage local businesses to source inputs from alternative markets. Invariably, however, freight services would be greatly disrupted because additional road-user costs would prevent all regular services from operating.

Respondents in the retail, restaurant and other food/bakery sectors could source inputs from alternative markets, if required.

'If a closure occurred when our summer stock was arriving [in September and October] that would affect us greatly, but if it happened half way through summer when all our stock is in it wouldn't affect us because we are just relying on top-ups. If our summer stock couldn't get through we'd probably try and get it down [from Blenheim] some other way if we could.'

Similarly, another retailer suggested that they might fly in stock from Wellington if State Highway 1 to the north of Kaikoura is closed because the cost is not excessive.

However, most respondents expect to incur the greatest costs largely as a result of the drop in tourist spending, for which no contingency plans can be provided. Respondents from industries less dependent on tourism (eg. the construction industry and primary producing industries) have the most effective contingency plans and consequently are little disrupted by road closure events. However, all contingency plans condition additional costs.

Most respondents will be unable to overcome the effects of road network disruption by transference. In addition, only one respondent believed that their business could be better prepared for future closures by increasing storage capacity for produce.

5.4.8 Returning to pre-closure levels of activity and income

Six respondents in operation during Scenario 1 (from eleven respondents in total) stated that their businesses returned to normality immediately after link reinstatement works were complete. However, these businesses (eg. primary producing respondents) were little affected by the Punchbowl closure. Businesses with a greater reliance on tourist purchases (eg. retailers) stated that it took several days (on average) for business to return to normality. One respondent also discussed the role of the media in influencing road-users travel plans, as described below.

'What you also have is the effect of bad press. People [locals] thought that when the road closures were happening at the Punchbowl it was bad press that affected it [business] more than anything else...When something is reported in the newspaper it is usually made very dramatic. You know 'road closures' and people think 'goodness me.' It happened up in the North Island when they had the floods...and people just stopped travelling because they see it on the news and they think oh, we're not going there. They don't realise that in a few days time everybody has cleared up and operating again, so that does take quite a while to filter through...It is a bit like when we had the flood in 1993 in Kaikoura. That impacted for quite a while.'

Of the nine businesses unaffected by the Punchbowl closure, five respondents believed that their business would return to its pre-closure level of activity and income immediately after link reinstatement. Other respondents believed it would take between one and three days to return to normality following link reinstatement.

These mixed perceptions showed little variation between the three scenarios. However, based on a limited number of responses, it is reasonable to assume that some businesses (eg. the accommodation sector) may incur residual losses for short periods following link reinstatement.

5.4.9 Turnover loss estimates for closure scenarios

Turnover losses predicted by respondents for the three closure scenarios were adjusted to account for direct industry losses in the Kaikoura District (refer to section 5.3.4). The direct industry losses were multiplied by Type II output multipliers to obtain total non-user costs (refer to section 5.3.4 for the definition of total costs and the multipliers used to derive total costs). Direct non-user costs and total non-user costs arising from the three closure scenarios are shown in Table 5.3 (industry costs are aggregated to preserve confidentiality).

Table 5.3: Direct non-user costs and total non-user costs of road network disruption in the Kaikoura District

	Direct cost	Total cost	Total cost per day of route closure
Scenario 1	$240,288	$367,385	$28,260
Scenario 2	$809,556	$1,241,993	$95,538
Scenario 3	$568,016	$872,568	$67,121

The greatest costs are incurred by the restaurant and accommodation industry, wholesale and retail industry, recreation and culture industry and freight transport industry respectively. The other food/bakery industry incurs the lowest proportion of total costs because respondents are more strongly supported by local community purchases than other industries. Primary producing industries and the construction industry incur no direct turnover losses.

Table 5.3 shows that daily non-user costs are significant for a small rural economy. The loss of inter-regional traffic adversely effects the financial wellbeing of many businesses in the Kaikoura District, particularly when road links with Christchurch are dislocated.

5.5 Conclusion

Business operators in the Kaikoura District are strongly dependent on road links with larger centres of commerce and are, therefore, acutely aware of the vulnerability of the road network to closure. However, a limited number of business owners (particularly new business owners) were unaware of the potential for long-term closure events. The majority of survey respondents would incur significant turnover losses during road closure events (particularly between November and April) and would be unable to provide adequate contingency plans to overcome the effects of road closure events. Accordingly, road closure events would seriously affect the financial wellbeing of many businesses after approximately four days.

The closure of both southern links would condition the greatest non-user costs (approximately \$95,000 per day), which emphasises the importance of the Christchurch market to the vitality of the Kaikoura District economy. When State Highway 1 to the north of Kaikoura is closed, non-user costs are also significant (approximately \$67,000 per day) because respondents expect road-users travelling between Christchurch and the north of the South Island to bypass Kaikoura. However, the cost of Scenario 1 is less than the cost of Scenario 2 and Scenario 3 because a low-cost alternative route (Highway 70) is available for road-users.

Non-user costs are combined with road-user costs in the concluding chapter, and implications for policy are discussed.

Chapter 6: Conclusion

6.1 Introduction

The following chapter summarises the main findings of this research and describes the limitations of the research methodology. Policy implications and recommendations conclude this research.

6.2 Summary of research

The New Zealand road network is vulnerable to closure from a host of natural hazards. Road closure events can occur frequently, depending on natural variations in hazard occurrence. It is not uncommon for road links to be severed for periods of several days or more. The cost of reinstating state highway links in New Zealand has exceeded $12 million annually since 1995.

This research has provided insights into road network vulnerability in the Kaikoura District and the consequential costs of disruption for road-users and non-users. The road network in the Kaikoura District is vulnerable to closure from a range of natural hazards, including potentially catastrophic and poorly understood natural hazards such as powerful tsunamis and earthquakes. The historical review of closures indicates that rain-induced natural hazards (eg. flooding and landslides) have been the most frequent cause of road network disruption in the District, particularly along State Highway 1. However, all links providing access to Kaikoura can be closed simultaneously, thereby isolating Kaikoura from larger centres of commerce.

There is only one alternative route (Highway 70) available to road-users in the Kaikoura District when State Highway 1 is closed south of Kaikoura. No alternative route is available in the Kaikoura District for State Highway 1 to the north of Kaikoura. Table 6.1 shows how daily disruption costs vary by closure scenario and shows that costs are significantly lower when a low-cost alternative route (Highway 70) is available (see Scenario 1).

Table 6.1: The daily cost of road closure events in the Kaikoura District

Type of cost	Closure of SH1 south of Kaikoura (Scenario 1)	Closure of both links south of Kaikoura (Scenario 2)	Closure of SH1 north of Kaikoura (Scenario 3)
Road-user	$40,589 (59%)	$239,352 (71%)	$217,395 (76%)
Non-user	$28,260 (41%)	$95,538 (29%)	$67,121 (24%)
Total	$68,849 (100%)	$334,890 (100%)	$284,516 (100%)

Daily disruption costs are significant when vehicles detour to the Lewis Pass route (Scenario 2 and Scenario 3). The cost of Scenario 2 is greater than the cost of Scenario 3 because of the importance of the Christchurch market to the vitality of the Kaikoura District economy and as a result of disruption to the high traffic volumes on the Waipara to Kaikoura link.

Table 6.1 also highlights the severity and diversity of impacts associated with road closure events. Road-user costs represent the greatest road network disruption costs in the Kaikoura District. However, non-user costs are also considerable, particularly for a small rural economy. Although non-user costs are lower than road-user costs, non-user costs are greater than road-user costs on a cost per person-affected basis. In communities larger than Kaikoura, non-user costs are likely to be more prominent (eg. in New Plymouth when State Highway 3 is closed).

Total daily disruption costs are substantial. For example, closures of four days or more would condition disruption costs in excess of $1 million when road-users are required to detour to the Lewis Pass route. Other disruption costs that have not been included in the analysis (eg. costs to industries not surveyed and delay costs to road-users) would further inflate total disruption costs.

6.3 Limitations of research and opportunities for further research

The major limitation of the research methodology is that road-user costs and non-user costs of road network disruption are not derived from information pertaining to a recent road closure event, but are predominantly based on assumptions about 'potential' road closure events. The road-user cost and non-user cost estimates made in this research are, therefore, subject to error.

Numerous assumptions were employed in assigning road-user costs. For example, pre-disruption and post-disruption vehicle movements were not known with any certainty, which only allowed a general range of 'possible' costs to be calculated. Further research (eg. origin/destination surveys of State Highway 1 road-users) would provide a more accurate picture of vehicle movement patterns and a more accurate estimate of road-user costs.

Inaccuracies in assigning non-user costs also arose because survey respondents were not able to base turnover loss estimates on recent closure events. The diversity of impacts predicted by local businesses for the three closure scenarios suggests that 'potential' costs may not be a very reliable basis for policy development. A more comprehensive post-disruption assessment of non-user costs would provide a richer and more reliable source of information applicable to policy development. For example, an assessment of post-disruption non-user costs (particularly in larger centres such as New Plymouth) may provide a better understanding of the significance of non-user costs on a temporal basis and would be useful in evaluating impacts across a more diverse range of industries (eg. the manufacturing industry).

Further limitations of the research methodology arise from the potential for biases and distortion in the data collection and analysis process. For example, the non-user cost sample selection was biased towards industries more likely to be adversely effected by road closure. If similar research is conducted in the future, it would be beneficial to randomly sample a higher number of businesses (from a more diverse range of industries) to gain insights into the range of costs (and possible benefits) arising from recent road closure events. In addition, the analysis of interview data imposed an artificial structure on the data obtained from survey respondents. Relevant information or interpretations of data may have been excluded from the analysis or may have been presented differently under different conditions or assumptions.

6.4 Policy implications

The estimated costs of road closure events in the Kaikoura District suggest that the reinstatement of a link south of Kaikoura should take precedence if all links are closed simultaneously. It would be preferable to reinstate State Highway 1 before Highway 70 unless Highway 70 could be reinstated significantly more quickly. When one southern link is operational, State Highway 1 to the north of Kaikoura should then be reinstated.

Road closure events condition costs for most businesses in the Kaikoura District immediately after link closure, and the costs of disruption become progressively worse each day of link closure. The compounding costs reinforce the need for prompt reinstatement or, at a minimum, the provision of limited access availability (eg. single-lane openings). An optimal disposition of maintenance resources (eg. bailey bridges) would help ensure that restoration delays are kept to a minimum. Repair strategies will become of utmost importance on busier state highway links connecting larger centres of commerce (eg. New Plymouth and Auckland via State Highway 3), particularly where no low-cost alternative route is available.

After approximately four days, the financial wellbeing of many businesses in the Kaikoura District may be seriously affected by road closure events. Ideally, link reinstatement should be complete within this time frame, pending funding and technology constraints. If closures extend beyond a four-day period, particularly between November and April, losses may cause considerable financial strain and result in long-term impacts for many local businesses.

The availability of low-cost alternative links (eg. Highway 70) minimises the risk associated with the closure of strategically vital links (eg. State Highway 1). The availability of the Rainbow route as an emergency alternative would minimise the risk associated with the closure of State Highway 1 and provides existing traffic flows (eg. Christchurch to Nelson traffic) with an alternative route to State Highway 65. However, the capital costs of upgrading the Rainbow link to cater for all vehicle classes is likely to be significant and may not be economically justified given the low traffic volumes using State Highway 1 (and State Highway 65) and the recent security of State Highway 1. Accordingly, this research highlights the strategic importance of the State Highway 1 link to the north of Kaikoura because no low-cost alternative route is available when this link is closed. If further preventative maintenance works are to be allocated in the Kaikoura District (eg. improved coastal protection works) available funding should be directed to State Highway 1 to the north of Kaikoura. The security of this link is not only critical to non-users in the Kaikoura District, but also to inter-regional traffic (eg. freight flows) travelling between Christchurch and the north of the South Island.

The strategic importance (and vulnerability) of links on a 'network' wide basis needs to be more clearly recognised in New Zealand if long-term road network disruption costs are to be minimised. More comprehensive and co-ordinated information about the risk of road network disruption in New Zealand would help reduce costs for road-users and non-users by providing effective contingency planning information for the road transport industry and enhanced network repair priorities and strategies for road controlling authorities. A New Zealand wide risk analysis study focusing on the vulnerability of state highway links to closure and the consequential costs of disruption for road-users and non-users would also help determine priorities for the allocation of roading expenditure in New Zealand. For example, road controlling authorities could focus on the most vulnerable parts of the road network and determine where highway improvement works (including preventative maintenance works and improvement works to alternative links) would be most beneficial. It is also important that the strategic benefits (and vulnerability) of links from a 'network' perspective are incorporated into the benefit-cost assessment process for highway improvement projects. Continued development and application of newly established methodologies (eg. National Strategic Factors – Security of Access) should be encouraged to ensure that the strategic benefits of links are captured adequately.

6.5 Recommendations

- Further research into the vulnerability of the road network in the Kaikoura District to closure from the tsunami hazard and the earthquake hazard (including earthquake-induced landslides) because these hazards have the potential to sever the road network for extended durations. Of particular concern is the area of State Highway 1 between Oaro and the Kahutara River and the Hapuku River and the Clarence River where State Highway 1 is immediately adjacent to the coast and has historically, been affected by highway instability problems. The Institute of Geological and Nuclear Sciences and the National Institute of Water and Atmospheric research could provide the necessary research expertise to gauge the severity (and probability) of the closure threat.

- Consideration of further preventative maintenance works (eg. coastal protection works) along State Highway 1 to the north of Kaikoura. This research has shown that State Highway 1 to the north of Kaikoura is the most important single link in the Kaikoura District because no low-cost alternative route is available when this link is closed. Future studies, which investigate the benefits and costs of providing improved protection works along this link, is recommended because of the strategic importance of this link from a 'network' perspective.

- Further research into the benefits and costs of opening the Rainbow route to all vehicle classes (perhaps as a toll road), including the benefits the route would provide for existing traffic flows. If State Highway 1 is dislocated for an extended duration, the availability of the Rainbow route would minimise long-term disruption costs. Road controlling authorities, local landowners and the Department of Conservation would need to coordinate if route upgrading was determined to be in the national interest.

- More comprehensive and easily accessible information about road closure events in New Zealand, particularly with regard to the frequency and duration of closure events and the degree of disruption incurred by road-users and non-users. A more cohesive and in-depth information base would improve road network management and provide valuable information for future research projects. It would be beneficial if road controlling authorities could synthesise and report information about road closure events on a regular (eg. monthly reporting) basis.

- The ongoing road closure threat in New Zealand and the sparseness of the national road network warrants consideration of a New Zealand wide risk analysis study, which determines priorities for link reinstatement and the allocation of roading expenditure. The study should also determine if maintenance resources are located optimally. In addition, the study should document those communities most vulnerable to disruption and the likely impacts of network disruption based on past events. It would be beneficial to clearly address (in a systematic and consistent framework) the management of road closures caused by natural hazards.

References

Anonymous (1923a) *The Kaikoura Star.* May 8, page 7.

Anonymous (1923b) *The Christchurch Press.* May 12, page 21.

Anonymous (1975a) *The Christchurch Press.* March 14, page 1.

Anonymous (1975b) *The Christchurch Press.* March 17, page 1.

Anonymous (1975c) *The Kaikoura Star.* March 27, page 1.

Babbie, E. (1998) *The practice of social research.* Eighth edition. Wadsworth Publishing Company, California.

Barker, L. (1975) Report to Resident Engineer Ministry of Works and Development, Christchurch, 9 April 1975 in *13 District flood damage report 1968-1980.* National Archives, Christchurch. Accession 162 72/13/23.

Barker, L. (1999) *Personal communication.* Former Ministry of Works and Development Engineer, Kaikoura.

Bates, D. (1999) *Personal communication.* Transit NZ, Christchurch.

Beca Carter Hollings and Ferner Ltd. (1999) *Economic assessment of the strategic value of State Highway 3 between Taranaki and Waikato.* Report to Taranaki Regional Council, New Plymouth.

Bell, D. (1975) *Geological Society of New Zealand Annual Conference, Kaikoura, November 24-28, 1975 - Notes for Field Trip D.* Unpublished material obtained from author.

Bell, D. (1976) High intensity rainstorms and geological hazards: Cyclone Alison, March 1975, Kaikoura, New Zealand in *Bulletin International Association of Engineering Geology*. Volume 14, pages 189-200.

Bell, D. and Owens, I. (1979) High intensity rainstorms and mass movements. Paper to *ANZAAS Conference*. Auckland, January 1979.

Bell, D. (1994) Landslide hazards in Owens, I. (Ed.) *Natural Hazards in Canterbury*. Canterbury Regional Council, Christchurch. Report 94 (19).

Birch, M. (1998) Contractors battle to reopen link in *The Daily News*. October 30, page 1.

Bowring, L., Cunliffe, J., Mackay, D., and Wright, A. (1978) *East Coast Survey - a study of catchment and stream conditions*. Marlborough Catchment and Regional Water Board, November 1978.

Buckle, I., Cooper, J., Holzer, T., O'Rourke, T., Schiff, A., Sheng, L., Taylor, A., Whitney, M., and Wilcoski, J. (1996) Performance of transportations systems in Chung, R. (Ed.) *The January 17, 1995 Hyogoken-Nanbu (Kobe) Earthquake- Performance of Structures, Lifelines, and Fire Protection Systems*. National Institute of Standards and Technology (US). Special publication 901, Washington DC.

Butcher, G. (1985a) *Cost benefit analysis: assessment of project parameter values in the context of a route and the probability distribution of net present values*. Contract research undertaken for Road Research Unit, National Roads Board. Unpublished adjunct to Report AD38, Wellington, 1985.

Butcher, G. (1985b) *Regional income, output and employment multipliers: their uses and estimates of them*. Economics Division, Ministry of Agriculture and Fisheries, Wellington.

Butcher, G., Fairweather, J., and Simmons, D. (1998) *The economic impact of tourism on Kaikoura.* Tourism Research and Education Centre (TREC), Lincoln University. Report number 8.

Butcher, G. (1999) *Personal communication.* Butcher Partners Ltd, Christchurch.

Canterbury Regional Council (1994) *Proposed Regional Coastal Environment Plan.* Report 94 (17).

Canterbury Regional Council (1999) *Kaikoura floodplain management strategy - issues and options for reducing the impacts of flooding and flood sediment deposition.* Report R99/5.

Centre for Advanced Engineering (1997) *Risks and realities - a multi-disciplinary approach to the vulnerability of lifelines to natural hazards.* Report of the Christchurch Engineering Lifelines Group.

Chang, S., Seligson, H., and Eguchi, R. (1995) Estimation of economic losses caused by disruption of lifeline service in O'Rourke, M. (Ed.) *Lifeline earthquake engineering.* Proceedings of the Fourth US Conference, American Society of Civil Engineers, New York.

Chang, S. and Taylor, W. (1995) Economic impact of lifeline disruption: current models and preliminary observations from the Hanshin earthquake in *Proceedings of the 6th US - Japan workshop on earthquake disaster prevention for lifeline systems.* July 18-19, 1995, Osaka. Public Works Research Institute, Japan.

Chesterfield, S. (1999) *Personal communication.* Transit NZ, Wellington.

Chung, R. (1996) Introduction in Chung, R. (Ed.) *The January 17, 1995 Hyogoken-Nanbu (Kobe) Earthquake - Performance of Structures, Lifelines, and Fire Protection Systems.* National Institute of Standards and Technology (US). Special publication 901, Washington DC.

Cowan, H., Pettinga, J., and Bell, D. (1994) Seismic hazards in Owens, I. (Ed.) *Natural Hazards in Canterbury*. Canterbury Regional Council, Christchurch. Report 94 (19).

Cox, I. (1999) *Personal communication*. Transit NZ, Hamilton.

DeLange, W. and Healy, T. (1986) New Zealand Tsunamis 1840-1982 in *New Zealand Journal of Geology and Geophysics*. Volume 29 (1), pages 115-134.

DeLange, W. (1998) The last wave in Hicks, G. and Campbell, H. (Eds.) *Awesome forces: the natural hazard's that threaten New Zealand*. Te Papa Press, Wellington. Published in association with EQC and IGNS.

Department of Conservation (1996) *Molesworth route brochure*. DOC, Nelson.

Disaster Research Centre (1998) *Internet: http://www.udel.edu/DRC/projects.html* November 19, 1998.

EQE Engineering (1995) *Internet: http://www.eqe.com* November 19, 1998. (The January 17 1995 Kobe Earthquake - EQE Summary Report).

Ericksen, N. (1975) *Scenario methodology in natural hazards research*. Institute of Behavioural Science, University of Colorado, Monograph 10.

Ericksen, N. (1990) Natural hazards: an interactive system approach in Crozier, M., Ansell, J., and Speden, I. (Eds.) *Natural hazards 90 - natural hazard assessment in New Zealand*. Research School of Earth Sciences, Victoria University, Wellington.

Glade, T. and Crozier, M. (1996) Towards a national landslide information base for New Zealand in New *Zealand Geographer*. Volume 52 (1), pages 29-40.

Goring, D. (1999) *Personal communication*. National Institute of Water and Atmospheric Research, Christchurch.

Green, C., Parker, D., Thompson, P., and Penning-Rowsell, E. (1983) *Indirect losses from urban flooding: an analytical framework.* Flood Hazard Research Centre, Middlesex Polytechnic. Publication number 52.

Grocott, G. (1977) *Landslide investigation, Main North Line Railway, South Island, New Zealand.* A thesis submitted in partial fulfilment of the requirement for the degree of Master of Science in Engineering Geology. University of Canterbury, May 1977.

Hancox, G., Perrin, N., and Dellow, G. (1998) Earthquake-induced landsliding in New Zealand and implications for MM Intensity and seismic hazard assessment: a summary of a recent study in *New Zealand National Society for Earthquake Engineering - Technical Conference and AGM, Taupo, 27-29 March 1998.* New Zealand National Society of Earthquake Engineering, Lower Hutt.

Harcourt, T. (1999) *Personal communication.* Transit NZ, Christchurch.

Harris Consulting (1997) *Assessment of the costs of the State Highway 3 slip at Awakino, 12-19 March 1997.* A report prepared for the Taranaki Regional Council. Harris Consulting, Christchurch.

Helm, P. (1996) Integrated risk management for natural and technological disasters in Centre for Advanced Engineering (1997) *Risks and realities - a multi-disciplinary approach to the vulnerability of lifelines to natural hazards.* Report of the Christchurch Engineering Lifelines Group.

Hide, S. (1992a) State Highway closed at Punchbowl in *The Kaikoura Star.* June 24, page 1.

Hide, S. (1992b) Another blow for travellers on the Inland Road in *The Kaikoura Star.* July 1, page 1.

Hide, S. (1992c) What happened at the Punchbowl and who (or what) is to blame in *The Kaikoura Star.* July 1, page 1.

Holdom, N. and Maetzig, R. (1998) Crews work through night to clear gorge in *The Daily News.* October 26, page 1.

Horn, C., Simmons, D., and Fairweather, J. (1998) *Evolution and change in Kaikoura: responses to tourism development.* TREC, Lincoln University. Report number 6.

Hull, A. (1998) The big one in Hicks, G. and Campbell, H. (Eds.) *Awesome forces: the natural hazard's that threaten New Zealand.* Te Papa Press, Wellington. Published in association with EQC and IGNS.

Hunter, N. (1998) *Personal communication.* Transfund NZ, Christchurch.

Jarvis, J. (1999) *Personal communication.* Transit NZ, Otago.

Jones, S. (1985) Depth interviewing in Walker, R. (Ed.) *Applied Qualitative Research.* Gower Publishing Company, England.

Kaikoura District Council (1996) *Kaikoura District Civil Defence Plan.*

Kaikoura District Council (1998) *Draft Kaikoura District Plan.*

Kerr, G. (1995) The assessment of impacts on the local and regional economy in Taylor, C., Bryan, C., and Goodrich, C. (1995) *Social assessment: theory, process and techniques.* Taylor Baines and Associates, New Zealand.

Kerr, G. (1999) *Personal communication.* Lincoln University, Canterbury.

Kirk, R. (1985) *Coastal erosion and protection on steep coasts at Kaikoura.* A report to Christchurch Residency, Ministry of Works and Development.

Kirk, R. and Todd, D. (1994) Coastal hazards in Owens, I. (Ed.) *Natural Hazards in Canterbury*. Canterbury Regional Council, Christchurch. Report 94 (19).

Kirk, R. (1999) *Personal communication.* University of Canterbury, Christchurch.

Kissling, C. (1969) Linkage importance in a regional highway network in *Canadian Geographer*. Volume 13 (2), pages 113-127.

Kitchin, P. (1998) Gorge bypass plan scrapped in *The Dominion*. August 7, page 9.

Land Transport Safety Authority (1999) *Accident investigation system computer database*. Available from the LTSA.

Lee, T. and Wood, L. (1981) Adjustment in the urban system: the Tasman Bridge collapse and its effects on metropolitan Hobart in *Progress in Planning*. Volume 15, pages 63-150. Pergamon Press Ltd, Great Britain.

Macaulay, J. and Clay, T. (1996) *Nature fights back - a geography of natural hazards*. Second edition. Longman, NZ.

McLean, I. (1998) New Zealand preparedness for recovery in the light of Kobe and Northridge in *New Zealand National Society for Earthquake Engineering - Technical Conference and AGM, Taupo, 27-29 March 1998*. New Zealand National Society of Earthquake Engineering, Lower Hutt.

McMorran, T. (1995) *Seismic hazard evaluation for the Kaikoura District.* Prepared for Kaikoura District Council, December 1995. Woodward-Clyde, Christchurch.

McSaveney, M. (1995) Managing slope instability hazards in Hull, A. and Coory, R. (Eds.) *Proceedings of the natural hazards management workshop, Auckland 28-29 November, 1995*. IGNS Information Series.

McSaveney, M. and Davies, T. (1998) A hazard assessment for Aoraki/Mt Cook Village in Johnston, D. and Kingsbury, P. (Eds.) *Proceedings of the Natural Hazard Management Workshop.* IGNS information series 45. IGNS and CRC, New Zealand.

McSaveney, E. and McSaveney, M. (1998) Beware of falling rocks in Hicks, G. and Campbell, H. (Eds.) *Awesome forces: the natural hazard's that threaten New Zealand.* Te Papa Press, Wellington. Published in association with EQC and IGNS.

Miernyk, W. (1965) *The elements of input-output analysis.* Random House, New York.

Mildenhall, M. (1999) *Personal communication.* Transit NZ, Wanganui.

Monroe, T. and Ballard, K. (1983) Modelling the economic disruption of a major earthquake in the San Francisco Bay area: impact on California in *Annals of Regional Science.* Volume 17 (3), pages 23-40.

Morgan, J. (1995) Gorge to reopen yet again in *The Dominion.* November 14, page 14.

Morton-Williams, J. (1985) Making qualitative research work: aspects of administration in Walker, R. (Ed.) *Applied Qualitative Research.* Gower Publishing Company, England.

National Archives (1999) *13 District Flood Damage Reports.* Accession 150 72/13/23 Part 1 and 2 (1951-1975), Accession 162 72/13/23 (1968-1980), and Accession 298 72/13/23 Part 3 and 4 (1975-1989). Unpublished National Archives Reports, Christchurch.

National Water and Soil Conservation Organisation (1978) *Land Resource Inventory Worksheet - Kaikoura (s49).*

NZPA (1998) Rain causes slips, floods in *The Press.* July 11, page 8.

Opus (1999) *Transit NZ State Highway 1 Blenheim to Kaikoura Strategy Study - Second Draft Report.* March, 1999.

Owens, I. (1994) Meteorological hazards in Owens, I. (Ed.) *Natural Hazards in Canterbury.* Canterbury Regional Council, Christchurch. Report 94 (19).

Paterson, B. (1996) Slope instability along State Highway 73 through Arthur's Pass, South Island, New Zealand in *New Zealand Journal of Geology and Geophysics.* Volume 39, pages 339-351.

Resource Management Act (1991). Government Printer, Wellington.

Robson, S. (1998) Tsunami danger for Kaikoura in *The Press.* March 3, page 5.

Runciman, L. (1999) *Personal communication.* Transit NZ, Hamilton.

Sherrard, J. (1998) *Kaikoura - a history of the District.* Cadsonbury Publications, Christchurch.

Statistics New Zealand (1998) *Business Activity Statistics 1998.* SNZ, Wellington.

Sutton, D. (1999) *Personal communication.* Works Civil Construction, Kaikoura

Taaffe, E., Gauthier, H., and O'Kelly, M. (1996) *Geography of transportation.* Prentice Hall, USA.

Taranaki Regional Council (1997) *The costs of the slip and closure of State Highway 3 at Awakino, 12-19 March 1997.* TRC, Stratford, NZ.

Thompson, P. and Macarthur, R. (1969) *Major river control, drainage, and erosion control scheme for Kaikoura.* Marlborough Catchment Board, New Zealand.

Tobin, G. and Montz, B. (1997) *Natural hazards: explanation and integration.* Guilford Press, New York.

Transfund NZ (1997a) *Project Evaluation Manual.* 1st Revision, May 1997.

Transfund NZ (1997b) *Accident analysis computer application.* Version 3.0, July 1997.

Transfund NZ (1999a) *Transfund NZ Annual Report 1998/1999.*

Transfund NZ (1999b) *Roading statistics for the year ending 30 June 1999.*

Transit NZ (1993) *Planning for a safe and efficient highway network under the Resource Management Act 1991.* A guideline by Transit NZ.

Transit NZ (1995a) Hazardous conditions close roads in *In Transit.* August 1995, Issue 66.

Transit NZ (1995b) Reflecting on storms havoc 12 months on in *In Transit.* December 1994/January 1995, Issue 59.

Transit NZ (1997) Detour route for Awakino Gorge slip in *In Transit.* May 1997, Issue 80.

Transit NZ (1998a) *National State Highway Strategy.*

Transit NZ (1998b) 'Star Wars' for country's state highways in *In Transit.* November 1998, Issue 97.

Transit NZ (1998c) Large landslip closes southern highway in *In Transit.* September 1998, Issue 95.

Transit NZ (1998d) *Annual report 1997/1998.*

Transit NZ (1998e) *Emergency procedure and contingency plan - Region 11 and 12.* Report 98/32. December, 1998.

Transit NZ (1999a) Stockman's Hill reopened in *In Transit.* March 1999, Issue 100.

Transit NZ (1999b) *Annual Report 1998/1999.*

University of Colorado Natural Hazards Database (1998) *Internet: http://www.Colorado.EDU/hazards/index.html* November 19, 1998.

Van Dissen, R. (1991) An evaluation of seismic hazard in the Kaikoura Region, South-Eastern Marlborough. *New Zealand Geological Survey Record.* Volume 43, pages 93-99.

Vlachos, E. (1981) The use of scenarios for social impact assessment in Finsterbusch, K. and Wolf, C. (Eds.) *Methodology of social impact assessment.* Second edition, Hutchinson Ross Publishing Company, USA.

Whitehouse, I. (1990) Disaster reduction: how can the geomorphologist help in Crozier, M., Ansell, J., and Speden, I. (Eds.) *Natural hazards 90 - natural hazard assessment in New Zealand.* Research School of Earth Sciences, Victoria University, Wellington.

Whitehouse, I. and McSaveney, M. (1992) Assessment of geomorphic hazards along an alpine highway in *New Zealand Geographer.* Volume 48 (1), pages 27-32.

Whyte, J. (1999) *Personal communication.* Hurunui District Council, Canterbury.

Wood, L. and Lee, T. (1979) *The Tasman Bridge collapse and its effects on metropolitan Hobart - disruption of journey to work patterns.* Department of Geography, University of Tasmania. Occasional paper 5.

Yetton, M., Wells, A., and Traylen, N. (1998) *The probability and consequences of the next Alpine Fault earthquake.* New Zealand Earthquake Commission and Geotech Consulting, New Zealand.

Appendix 1: Historical review of past disruptions in the Kaikoura District

June 1950 - SH1 closed, including washouts near Clarence River bridge.

January 1951 - Eleven blockages north of Kaikoura. Slips and washouts between Rakautara and the Clarence River bridge. Cheviot earthquake caused no damage to roads.

August 1952 - Slips at Blue Duck and between Hundalee and Oaro. Washout at Mangamaunu. Flooding at Cheviot. Washout at Oaro River bridge.

December 1952 - Flooding of Kowhai River. Twenty-five feet of the approach to the Kowhai River bridge lost and 5 feet of the approach to Stoney Creek was washed away. At least a 24 hour closure south of Kaikoura.

January 1953 - Slips at Blue Slip and White Slip north of the Clarence River. Clarence River bridge damaged. Shingle Fans closed. Kowhai River bridge approaches were washed out. Cribb Creek bridge underwater on Highway 70.

June 1953 - Slips north of Kaikoura. Major slip between Blue Duck Stream and Rakautara.

August 1954 - SH1 north and south of Kaikoura damaged. Road blocked at Cheviot by floodwater and in Hundalees by slips. Two major slips came down at Okarahia and one at Oaro. SH1 covered by floodwater at Golf Links.

December 1954 - Minor damage to SH1 as the Kowhai River overflowed.

October 1956 - SH1 closed at Shingle Fans.

1959 - Slip between Okarahia and the Black Birch forest south of Kaikoura. SH1 closed for at least 48 hours.

January 1961 - Shingle Fans blocked. Traffic forced to travel via Lewis Pass. At the Ure River, 50 miles north of Kaikoura, 3 feet of water covered the road. Slip 14 miles north of Kaikoura. SH1 closed Monday, January 16 to Wednesday, January 18.

May 1961 - Heavy rain (up to 10 inches in 24 hours). SH1 flood damage from Awatere to Hundalee and flood damage on H70. Major damage in the Hundalees, with 24 major slips between Oaro and Hundalee. Shingle Fans blocked SH1. Slip 5 miles south of Clarence River bridge and at Rakautara. Major slip which buried the highway at Mangamaunu. Slip at Punchbowl. North of Kaikoura, SH1 closed for approximately 24 hours, while to the south, SH1 was closed by a slip just south of Oaro for approximately 36 hours.

24 June 1961 - Snow affected SH1 from Oaro to the Leader River bridge.

July 1963 - SH1 closed in many locations north and south of Kaikoura after 5 days of heavy rain. Slips from Tirohanga to Kekerengu. Slips and debris blocked SH1 between the Blue Duck River and Mangamaunu. Slips at Waipapa Bay. Slips two miles south of the Clarence River. Flood waters from Middle Creek closed SH1. Washout just south of the Waiau River bridge blocked SH1 and railway. Slip between Goose Bay and Kaikoura blocked traffic overnight. Slips in the Hundalees. Slips on the Charwell Cutting and near the Kahutara River bridge on H70. Heavy flood water rising over the Cribb Creek bridge closed H70.

September 1963 - Flood damage to H70 (Kaikoura to Culverden). Lynton River overflowed and crossed the highway on the Kaikoura side of the bridge.

March 1965 - H70 flood damage. Road closed for 36 hours.

April 1965 - Flood damage between Kaikoura and Domett. Numerous slips between the Kahutara River and Oaro. Slips in Hundalees.

May 1966 - SH1 flood damage between the Clarence River and Kaikoura. Traffic forced to divert via Lewis Pass. Slips in the Hundalees and surface water in the Leader River area, resulting in highway closures. Floodwater from the Kowhai River closed H70 briefly. Possible isolation of Kaikoura.

July 1966- Flood damage to H70

16-19 November 1967 - Flood damage to SH1 from Tirohanga to Hurunui. H70 flood damage, including damage at the Mason River bridge and the Lottery River bridge.

August 1967 - Between Tirohanga and Cheviot, extensive damage to SH1. Slips between Tirohanga and Kaikoura. Slips between Kaikoura and Domett. Washout in Hundalees. SH1 closed.

April 1968 - H70 flood damage, including slips (Kaikoura County Section). SH1 flood damage between Tirohanga and Hurunui. Slips between Tirohanga and Kaikoura. Clearing of shingle at Shingle Fans. Damage to sea-wall protection works and highway from heavy seas.

November 1968 - shingle deposition at the Shingle Fans.

April 1969 - Sea coast damage to SH1 between the Clarence River and Oaro, especially north of Kaikoura between Half Moon Bay and Irongate. Damage at Rakautara. Flood damage between the Clarence River and Oaro.

January 1971 - Flood damage between the Blue Slip and the Shingle Fans, Ohau Bluff and Mangamaunu, and the Kahutara River and the Hundalee Hills.

August 1971 - Blue Slip closed SH1 for five and a half hours. SH1 damage also occurred from heavy seas, mainly between Ohau Bluff and Rakautara and between the Kahutara River and Raramai Tunnel.

May 1972 - Slips at Blue Slip and Shingle Fans (short disruptions).

August 1973 - SH1 sea coast damage (north and south of Kaikoura).

April 1974 - Numerous slips in Hundalees (short disruptions).

June 1974 - Very heavy seas (estimated to be 25 feet high) hit the Kaikoura Coast. Damage to SH1, particularly north of Kaikoura between Ohau Bluff and the Irongate River bridge and south of Kaikoura between the Kahutara River and Oaro. Near the Kahutara Bluff, SH1 was reduced to a single lane. Significant damage at Rakautara where the highway was strewn with boulders and seaweed.

August 1974 - Damage to SH1 from heavy seas. At Halfmoon Bay erosion was extensive.

September 1974 - Waiau River bridge damaged. SH1 was closed for 4 days. SH1 closed for 24 hours by a slip in the Hundalee Hills. Numerous other slips in the Hundalees and along the Conway River. Flood damage on H70 washed out Cribb River bridge and the Humbug River bridge. H70 closed from September 4 to September 7.

March 1975 - Extensive damage between Kekerengu and the Conway River. Damage was extensive between Deadman's Stream Bridge to Windy Gully Ford. The worst hit areas were between Okiwi Bay to Mangamaunu and between the Kahutara River and Oaro. Slip at Blue Slip. Slips and washouts between Black Miller Stream and the Hapuku River. The worst slip was at Black Miller Stream where almost 12,000 cubic yards of hillside fell across SH1. Bridge approaches to both Deadman's Stream and Washdyke Stream washed out. Between Oaro River and the Conway River there were extensive slips and washouts. Two miles north of Kaikoura water was two feet deep across SH1. A mile south of Kaikoura there was flood water across SH1. The worst damage was between the Kahutara River bridge to Windy Gully Ford.

June 1975 - SH1 covered by surface flooding in many places. Up to a foot of water across SH1 at Golf Links. Between Oaro and the Kahutara River and at Rakautara, the sea broke over in many places dumping rubble and kelp.

September 1976 - SH1 flood damage between the Clarence River and the Waiau River, particularly in the Hundalee Hills.

July 1977 - SH1 was closed from 11am 21 July to 9.00am 22 July from a washout at Windy Gully and from slips between Oaro and Hundalee. Other areas of SH1 both north and south of Kaikoura were subject to surface flooding. H70 was also closed between July 21 and July 22.

April 1978 - Damage at Shingle Fans and through the Hundalees. SH1 closed 11.00pm 17 April to 10.00am 18 April. Slips and washouts at RS118/08 south of the Clarence River and flood damage between Oaro and Windy Gully Ford (RS195/08).

May 1978 - SH1 was covered by shingle and seaweed at Rakautara.

June 1978 - Rough seas caused erosion to SH1 north and south of Kaikoura, mainly between Okiwi Bay (RP118/09) and Mangamaunu and between the Kahutara River bridge and Oaro.

July 1978 - Rough seas caused further erosion to SH1 north and south of Kaikoura.

March 1979 - Heavy coastal rain damaged SH1 extensively. SH1 was closed between Tirohanga and Mangamaunu from 7.30am 22 March to 11am 24 March and from 10.30pm 30 March to 10.00am 31 March. The worst areas were Blue Slip, Kekerengu, Shades, Shingle Fans, Black Miller bridge, and the North Coast between Waipapa Bay and Mangamaunu and south of Kaikoura between the Kahutara River and Oaro. The White Slip (RP90/5.2 to RP90/5.8) was severely affected, the first serious trouble for approximately 15 years. The bridge approaches to Woodbanks Stream and Deadman's Stream were also washed out.

August 1979 - H70 closed for 3 days.

October 1979 - H70 flood damage. Slip in Kekerengu area on SH1.

March 1980 - For a period on March 3 Kaikoura was isolated by road. SH1 was closed between 8pm 2 March to 11am 3 March. Damage extended from RS90 to Windy Gully Ford (RP195/7.93). There was surface flooding, scouring and large slips between Tirohanga and the Clarence River, particularly in the Kekerengu area. The Blue Slip uplifted an 80 metre length of SH1. The Shingle Fans topped the concrete fords, bypass bridge and training channels with shingle. Slips and surface flooding between the Clarence River bridge (RS118) and Kaikoura. Numerous slips and scouring between the Kahutara River bridge and Windy Gully Ford (RP195/7.93). In the Hundalee Hills there were 4 major drop outs. H70 was also closed from March 2 to March 4. Road-users were forced to detour to the Lewis Pass.

April 1980 - Shingle Fans again filled following rain.

June 1982 - H70 closed following heavy rain (closed during weekend of 26 and 27 June). Slip at Mason Hills.

July 1983 - SH1 damage (from high seas) between the Clarence River and Oaro.

May 1985 - SH1 damage from heavy seas. SH1 closed in the Oaro section from 15 May to 16 May. Alternative access was available via H70. Damage occurred on the northern section between RP118/9.1 and RP118/19.0 and on the southern section between RP163/4.5 and RP163/15.2. Damage was virtually continuous over the 21km stretch. The Ohau Point area (RP118/13) was severely affected.

July 1985 - RP90 to RP247/15.3 storm damage, including damage from huge seas.

July 1986 - Storm damage to seawalls and foreshore, Clarence River to Oaro. Very large southerly seas.

August 1986 - slips in numerous locations on SH1. H70 also damaged.

October 1986 - Tirohanga to Greta Village flood damage. Blue Slip blocked traffic for 5 hours and slips occurred in Hundalee Hills.

April 1989 - Slip (300 cubic metres) at Ron's Rock about 10km south of Kaikoura. SH1 partially blocked on the seaward side.

September 1989 - Slip at Oaro (between the road tunnels) caused train derailment which closed SH1 for 4 days. Surface flooding on two other occasions closed the road at various locations.

May 1992 - SH1 closure overnight at Punchbowl Corner.

7 June 1992 - Small slips and falling debris, 6km south of the Conway River, then major slip.

23 June 1992 - SH1 closed at Punchbowl Corner for 13 days because of rock instability. H70 also closed for a day during this period because of ice (30 June).

July 1992 - SH1 and H70 south of Kaikoura closed by snow.

1 July 1992 - Clear sea debris from SH1.

8 July 1992 - Shingle Fans closed. Waipara to Oaro closed.

9 and 10 July 1992 - Slips on Oaro Hill.

13 July 1992 - Clear debris from Shingle Fans. Slips on Oaro Hill. Clear rock and debris (Puketa to Oaro).

23 July 1992 - Clear debris from Shingle Fans.

26 August 1992 - Snow (Omihi and Hawkswood).

27 August 1992 - SH1 closed south of Kaikoura through Hundalee Hills.

11 September 1992 - H70 closed by snow, except for 4WD vehicles.

15 September 1992 - Rocks on highway at Willowa Point, Ohau Point and Seacoast South.

16 September 1992 - Shingle Fans closed (until 17 September). Rocks on highway at Ohau Point, Seacoast South.

18 September 1992 - Surface flooding north of Kaikoura. Rocks on highway at Ohau Point, Seacoast South, Shingle Fans closed (until 21 September). Slips at Mangamaunu and Oaro Hill. Minor slips and flooding Hawkswood to Hundalees and Parnassus to Kaikoura.

21 September 1992 - Slip at Waipapa Bay, rocks on highway Seacoast South.

28 September 1992 - Slip at Waipapa Bay.

18 October 1992 - Slip at Ron's Rock (163/5.12), 10km south of Kaikoura. Three hour closure.

21 October 1992 - Clear slip (179/2.40).

24 October 1992 - Rockfalls at Ohau Point and Seacoast South.

25 October 1992 - Rockfalls at Ohau Point, Irongate Stream, and Punchbowl Corner.

28 October 1992 - Slips at Waipapa and Mangamaunu.

November 1992 - Slip between Hundalees and the Conway River.

22 November 1993 - Slips blocking one lane just north of the Conway River.

23 December 1993 - Slip 2km north of the Conway River. Surface flooding 1km north of Waiau River. Severe surface flooding on SH1 at Greta and Siberia Ford. SH1 closed at Omihi.

23 and 24 December 1993 - Slips at Greta cutting and south of Cheviot. Waipara to Kaikoura closed. Waiau River broken banks and washed out approaches to bridge.

24 December 1993 - H70 closed (1305 hours) from washouts at Lottery Bridge, Upper Mason Bridge, and the Cribb Creek bridge. Traffic diverted via Lewis Pass. Kaikoura isolated for a brief period. NZ Post flew in Xmas mail to Kaikoura.

20 February 1994 - Kaikoura Coast almost impassable because of slips between the two road tunnels.

10 March 1994 - Slip 8km north of Leader River and 2km north of the Conway River.

29 March 1994 - Slip 10km south of Kaikoura (3 hour closure). Northbound lane of SH1 blocked by slip 1km north of Raramai Tunnel.

25-27 July 1994 - Surface flooding at Cheviot. Flooding 3.2km south of the Jed River. Water across SH1 at Siberia Ford. SH1 was closed north of Kaikoura because of water at Middle Creek (138/15.60) and from a slip at Mangamaunu. South of Kaikoura, SH1 was reduced to one lane at various places in the Hundalee Hills. H70 closed.

29 September 1994 - Surface flooding north of the Conway River.

2 May 1995 - Slip at Blue Slip.

6 May 1995 - SH1 closed at Shingle Fans.

19 May 1995 - Slip at White Slip.

2 June 1995 - SH1 and H70 south of Kaikoura closed by snow. Over a metre of snow from a southerly blast forced motorists to stay in Kaikoura until roads were cleared later in the day. Media reports indicated that accommodation was scarce in Kaikoura.

12 June 1995 - In Kaikoura, an estimated 300mm of rain fell over 12 hours. SH1 closed between Cheviot and Kaikoura because of slips and flooding (mainly in the Oaro area). SH1 was single lane in many places. SH1 also closed north of Kaikoura between Kekerengu and the Clarence River. Civil Defence put on alert. SH1 opened 10am June 13. Reinstatement costs exceeded $200,000.

14 June 1995 - SH1 open but single lane access.

15 June 1995 - Between Oaro and Parnassus single lane access because of slips and washouts.

30 June 1995 - Oaro to Waipara Junction closed by snow (4 hours).

2 July 1995 - Snow between Kaikoura and Parnassus. Snow and ice in Hundalees trapped road-users. Vehicles trapped for 4 hours while 30cm to 60cm of snow was cleared.

6 August 1995 -- More than 160mm of rain was estimated to have fallen on the Kaikoura Coast in two days. SH1 (and rail) closed at White Slip for much of Sunday. The hill (roughly estimated to be 1000 cubic metres) virtually moved sideways across SH1 with grass and tussock remaining intact. Slips at Kekerengu (3000 cubic metres), Halfmoon Bay, and shingle aggradation at Shingle Fans (one pile estimated to be higher than a 4WD vehicle). SH1 closed between 7.00am and 3.00pm. Slips also closed SH1 between Kaikoura and Christchurch from 7.21am to 8.46am.

3 October 1995 - Slip (90/3.580).

10 October 1995 - Rockfall and slip (RS90 to RS185).

1 November 1995 - Rockfalls (163/4.00-9.30).

6 November 1995 - Slip (118/19.98). Rockfall (138/0.42).

26 December 1995 - Remove rock and debris (163/4.00-9.10).

6 January 1996 - Remove rock and debris (163/4.00-9.10).

7 January 1996 - Rockfall (118/13.20).

15 January 1996 - Remove rock and debris (118/12.00).

8 February 1996 - Rockfalls (163/4.0).

19 February 1996 - Rockfalls (163/4.0).

20 February 1996 - Rockfalls (118/13.0).

21 February 1996 - Rockfalls (163/3.0).

23 February 1996 - Rockfalls (163/4.0).

6 Aril 1996 - Flooding closed Shingle Fans.

7 April 1996 - Flooding/rockfalls (RP90-185).

9 April 1996 - Rockfalls after heavy rain (163/4-6.5).

30 April 1996 - Rockfalls (163/4-9.1).

8 May 1996 - Rockfall at Punchbowl Corner (163/6.48). Rockfall at Paratitahi Tunnel (163/5.79).

14 May 1996 - Rockfall (163/4.5).

17 May 1996 - Rockfalls (163/4.0 and 9.0).

22 May 1996 - Rockfalls/slips (118/12.78-5.15).

26 May 1996 - Rockfalls (163/4.0-9.4).

12 June 1996 - SH1 closed Greta to Omihi (set up block Kaikoura side). Heavy snowfall (138/12.20). SH1 closed for most of Wednesday, with little or no traffic heading south or arriving in Kaikoura from Christchurch.

23 June 1996 - Shingle Fans closed. Rockfalls (163/4-9.10). Slip (90/3.10).

24 June 1996 - Slip blocking traffic (90/3.10). Rockfalls/slips (163/4.91). Cars diverted to edge of rail.

13 November 1996 - Heavy sea debris on SH1 (118/16.76 and 163/15.80).

29 November 1996 - Rock slip clearing at Ohau Point (118/13.00).
31 December 1996 - Shingle Fans closed (until 2 January 1997). Slips between the Conway River and Siberia Ford (195/10.00). Three large rocks on SH1 at Goose Bay (163/12.50).

11 January 1997 - Shingle Fans closed (until 12 January).

9 February 1997 - Rockfall at Punchbowl Corner. SH1 closed for period in morning and from mid afternoon to midnight.

3 March 1997 - Clearance of rock at Punchbowl Corner (3 hour closure).

8 March 1997 - Clearance of rock at Punchbowl Corner (4 hour closure).

8 July 1997 - Rockfall (200m south of first tunnel, heading south).

3 January 1998 - Small slip between road tunnels.

Appendix 2: Calculation of the additional costs incurred by road-users (per day) when State Highway 1 to the north of Kaikoura is closed

Each of the following 8 steps corresponds with the information contained in Chapter 4 (see section 4.3.3).

1. Estimate AADT (less 10 per cent of vehicles outside the scope of the analysis)

Cars	1174
LCV	272
MCV	68
HCVI	51
HCVII	119
Buses	17
Total	1701 vehicles per day

2. 'Best' estimate vehicle movement assumptions:

- 80 per cent of cars, LCV, MCV and 95 per cent of HCV and buses travel between Christchurch and Blenheim/Picton
- All other vehicles travel to Kaikoura (from Blenheim/Picton). Therefore:

<u>Vehicles travelling to/from Kaikoura</u>:

Cars	235
LCV	54
MCV	14
HCVI	3
HCVII	6
Buses	1

<u>Vehicles travelling between Christchurch and Blenheim/Picton</u>:

Cars	939
LCV	218
MCV	54
HCVI	48
HCVII	113
Buses	16

3. Estimate additional time costs and VOC incurred by road-users via the Lewis Pass route

Multiply the number of vehicles travelling between different nodes (above two tables) by the respective additional time costs and VOC incurred via the Lewis Pass route (see Table 4.7 and 4.8). Therefore:

Vehicles travelling to/from Kaikoura:

Cars	235 * $231.51
LCV	54 * $213.67
MCV	14 * $282.51
HCVI	3 * $352.56
HCVII	6 * $391.39
Buses	1 * $342.60

Vehicles travelling between Christchurch and Blenheim/Picton:

Cars	939 * $95.08
LCV	218 * $87.71
MCV	54 * $117.35
HCVI	48 * $146.86
HCVII	113 * $166.38
Buses	16 * $143.74

The combined cost for Kaikoura traffic and Christchurch to Blenheim/Picton traffic is $216,535, assuming all road-users detour to the Lewis Pass route.

4. Estimate the number of vehicles that may cancel their trip

Vehicles travelling to/from Kaikoura:

83% of cars and LCV cancel
(ie. 244% cost increase via Lewis Pass route * demand elasticity value of 0.34)

100% of MCV, HCV and buses cancel when required to use the Lewis Pass route (based on conversations with road transport operators).

Vehicles travelling between Christchurch and Blenheim/Picton:

15% of cars and LCV cancel
(ie. 45% cost increase via Lewis Pass route * demand elasticity value of 0.34).

All other commercial vehicles are assumed to detour because of passenger and freight commitments.

5. Account for cancellation costs

Multiply the number of vehicles cancelling between different nodes by the respective additional time cost and VOC incurred via the Lewis Pass route (see Table 4.7 and 4.8). The combined costs are $78,764. The loss of benefits for these road-users is assumed to be half the cost of detouring (ie. 0.5 * $78,764 = $39,382).

6. Calculate additional time costs and VOC (either because of detour or cancellation)

Detour costs ($216,535) – Cancellation costs ($39,382) = $177,153

7. Calculate additional accident costs

Multiply the number of vehicles travelling between different nodes (not including road-users who cancel their trip) by the additional accident costs incurred via the Lewis Pass route (see Table 4.7 and 4.8). Total additional accident costs are $40,242.

8. Calculate total additional road-user costs incurred (per day) when the Kaikoura to Blenheim link is closed

Additional time costs and VOC ($177,153) + Additional accident costs ($40,242) = $217,395 (which corresponds with Table 4.9).

Appendix 3: Closure scenarios presented to respondents

Scenario 1

In 1992, a minor earthquake caused rock instability problems at Punchbowl Corner, 12km south of Kaikoura. State Highway 1 was closed for 13 days while the rockface was stabilised. The rail line was not affected. During this period, most traffic diverted to the Inland Road. However, media reports indicated that some businesses in Kaikoura experienced a downturn in business because the town had fewer visitors.

During the 13 day Punchbowl closure, the Inland Road was also closed for one day because of snow. Kaikoura was isolated by road from the south for one day.

The event is summarised in the table below.

Route	Length of closure
State Highway 1 (north)	Not closed
State Highway 1 (south)	13 days
Inland Road (south)	1 day
Rail line	Not closed

Please assume that the event occurs at a time when your business experiences 'average' turnover.

Scenario 2

Assume that during the 13 day Punchbowl closure on State Highway 1, the Inland Road was closed for 7 days (instead of one). Kaikoura would be isolated by road from the south for 7 days. Most northbound and southbound traffic would bypass Kaikoura.

The event is summarised in the table below.

Route	Length of closure
State Highway 1 (north)	Not closed
State Highway 1 (south)	13 days
Inland Road (south)	7 days
Rail	Not closed

Please assume that the event occurs at a time when your business experiences 'average' turnover.

Scenario 3

Within the next 12 months, it is possible that a major earthquake will strike the northern part of the Kaikoura District. The Hope Fault, which crosses State Highway 1 at Ohau Point, will rupture the highway surface and cause major landslides and rock instability problems. North of Kaikoura, State Highway 1 and the rail line are expected to be closed for 13 days. Most northbound and southbound traffic would bypass Kaikoura.

The event is summarised in the table below.

Route	Length of closure
State Highway 1 (north)	13 days
State Highway 1 (south)	Not closed
Inland Road (south)	Not closed
Rail line	13 days

Please assume that the event occurs at a time when your business experiences 'average' turnover.

Appendix 4: Survey used to guide interviews

Introduction

The purpose of this interview is to determine how your business may be affected when the main highways which provide access to Kaikoura (ie. State Highway 1 and the Inland Road) are closed by natural hazards (eg. from slips, flooding, snow, earthquakes etc).

Part A: Disruption awareness

The purpose of the following questions is to find out how aware you are of the closure threat in the Kaikoura District.

1. Prior to me contacting you, were you aware that State Highway 1 and the Inland Road are vulnerable to closure from natural hazards?

☐ Yes ☐ No **If NO, go to question 4.**

2. Has your business ever been affected by a highway closure caused by natural hazards?

☐ Yes If YES, when? ☐ No **If NO, go to question 4.**

3. How disruptive were these closures for your business?

4. Do you think it is likely that your business will be affected by highway closures caused by natural hazards in the future?

☐ Yes If YES, why? ☐ No **If NO, why not?**

5. Which natural hazard (if any) do you believe is most likely to cause the longest road closure(s) in the Kaikoura District?

6. How long (how many hours or days) do you think one of the highways providing access to Kaikoura could be closed (in a worst case scenario)?

☐ Hours ☐ Days

7. How long (how many hours or days) do you think all highways providing access to Kaikoura could be closed simultaneously (in a worst case scenario)?

☐ Hours ☐ Days

Part B: Transport Dependence

The next stage of this interview aims to provide information about the ways in which your business depends on the road network.

1. What percentage of your businesses needs (eg. goods and services) is supplied by the local community?

2. What percentage of your turnover comes from:

the local community	____________%
passing trade (ie. short stop visitors)	____________%
tourists to Kaikoura	____________%
markets outside the Kaikoura District	____________%
TOTAL	**100 %**

3. Can you describe the ways in which your business depends on:

- State Highway 1 to the North of Kaikoura (including how frequently you depend on this route)
- State Highway 1 to the South of Kaikoura (including how frequently you depend on this route)
- The Inland Road (including how frequently you depend on this route)
- Rail transport (including how frequently you depend on rail transport)
- Other forms of transport (if any) (including how frequently you depend on the these forms of transport)

Part C: Closure scenarios

The next stage of this interview asks you about three closure scenarios (ie. three possible closure events). The purpose of the scenarios is to provide insights into the ways in which your business may be affected. To give you an idea of the types of closures I will ask you to consider, I will show you some photos which illustrate the type of damage that can occur. Before I ask the first series of questions, can you please read scenario 1.

Questions about scenario 1

1. How disruptive would this event be for your business?
(or How disruptive was this event for your business? How disruptive would the event be for your business now?)

2. Why?

3. Would your business experience a loss in turnover?
(or Did your business experience a loss in turnover? Would your business experience a loss in turnover now?)

☐ Yes ☐ No **If NO, why not (then go to scenario 2)?**

4. After what length of time (how many hours or days) would your business 'first' experience a loss in turnover? Why?
(or after what length of time (how many hours or days) did your business first experience a loss in turnover? Would it take this length of time now?)

☐ Hours ☐ Days

5. Would further losses in turnover during the 13 day closure period seriously affect the wellbeing of your business (ie. would your business eventually 'feel the pinch')?
(or did further losses in turnover during the 13 day closure period seriously affect the wellbeing of your business (ie. did your business eventually 'feel the pinch')? What about now?)

☐ Yes If YES, please explain the implications of further losses for your business.

☐ No **If NO, why not? (then go to question 7)**

6. After what length of time (how many hours or days) would the wellbeing of your business be seriously affected? Why?
(or after what length of time (how many hours or days) was the wellbeing of your business seriously affected? Would it take this length of time now?)

☐ Hours ☐ Days

7. What percentage reduction in daily turnover would you expect (on average) until all routes were reopened?
(or What percentage reduction in daily turnover did you have (on average) until all routes were reopened? What is your best estimate of the percentage reduction in turnover now?)

8. Why do you estimate this amount?

9. When all routes were reopened, after what length of time (how many hours or days) would you expect your business to return to its pre-closure level of activity and turnover? Why?
(when all routes reopened, after what length of time (how many hours or days) did your business return to its pre-closure level of activity and turnover? Would it take this length of time now?)

☐ Hours ☐ Days

Questions about Scenario 2

1. How disruptive would this event be compared to scenario 1?

2. Why?

3. Would your business experience a loss in turnover?

☐ Yes ☐ **No If NO, why not (then go to scenario 3)?**

4. After what length of time (how many hours or days) would your business 'first' experience a loss in turnover? Why?

☐ Hours ☐ Days

5. Would further losses in turnover during the 13 day closure period seriously affect the wellbeing of your business (ie. would your business eventually 'feel the pinch')?

☐ Yes If YES, please explain the implications of further losses for your business.

☐ **No If NO, why not? (then go to question 7)**

6. After what length of time (how many hours or days) would the wellbeing of your business be seriously affected? Why?

☐ Hours ☐ Days

7. What percentage reduction in daily turnover would you expect (on average) until all routes were reopened?

8. Why do you estimate this amount?

9. When all routes were reopened, after what length of time (how many hours or days) would you expect your business to return to its pre-closure level of activity and turnover? Why?

☐ Hours ☐ Days

Questions about Scenario 3

1. How disruptive would this event be compared to scenario 1 and scenario 2?

2. Why?

3. Would your business experience a loss in turnover?

☐ Yes ☐ No **If NO, why not (then go to general questions)?**

4. After what length of time (how many hours or days) would your business 'first' experience a loss in turnover? Why?

☐ Hours ☐ Days

5. Would further losses in turnover during the 13 day closure seriously affect the wellbeing of your business (ie. would your business eventually 'feel the pinch')?

☐ Yes If YES, please explain the implications of further losses for your business.

☐ No **If NO, why not? (then go to question 7)**

6. After what length of time (how many hours or days) would the wellbeing of your business be seriously affected? Why?

☐ Hours ☐ Days

7. What percentage reduction in daily turnover would you expect (on average) until all routes were reopened?

8. Why do you estimate this amount?

9. When all routes were reopened, after what length of time (how many hours or days) would you expect your business to return to its pre-closure level of activity and turnover? Why?

☐ Hours ☐ Days

General questions about all scenarios considered

1. If these types of scenarios (ie. long-term closures) occurred during your busiest periods (eg. in the high season) would the impacts be any different?

☐ Yes If Yes, in what ways? ☐ **No If NO, why not?**

2. If these types of scenarios (ie. long-term closures) occurred during your quiet periods (eg. in the low season) would the impacts be any different?

☐ Yes If Yes, in what ways? ☐ **No If NO, why not?**

Part D: Transferability

The next stage of this interview aims to provide insights into your ability to overcome the effects of road closures.

1. Does your business currently compensate for the possibility of road closure (eg. by carrying higher levels of stock)?

☐ Yes If Yes, in what ways? ☐ **No If NO, why not (then go to question 3)?**

2. To what extent do these measures help minimise potential impacts?

3. During any of the three closure scenarios considered, would you make any adjustments (eg. would you obtain supplies by rail) to help reduce the impacts?

☐ Yes If Yes, what are they and for which scenarios? ☐ **No If NO, why not? (then go to question 6)**

4. To what extent would these measures help minimise potential impacts?

5. After what length of time (how many hours or days) would you make these adjustments?

6. Is there anything your business could do to be better prepared for future closures?

☐ Yes If Yes, what? ☐ **No If NO, why not?**

7. Is there anything else you would like to say?

Part E: Business information

The purpose of the final series of questions is to provide background information about your business.

1. What type of business do you operate (eg. restaurant, hotel etc)?

2. Do you own or manage this business?

☐ Own ☐ Manage

3. How long have you 'owned' or 'managed' this business?

☐ Months ☐ Years

4. What is the gross annual turnover of this business?

5. How many full-year full-time persons does this business employ (40 hours per week=1 full-time employee)?

6. How many full-year part-time persons does this business employ (and on average, how many hours per week do each of these persons work)?

7. How many seasonal persons does this business employ (and on average, how many hours per week and weeks per year do each of these persons work)?