West Coast Lifelines

Vulnerability and Interdependency Assessment

Supplement 6:

Transportation Lifelines Assets

West Coast Civil Defence Emergency Management Group

August 2017

IMPORTANT NOTES

Disclaimer

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Hazard Maps

The hazard maps contained in this report are regional in scope and detail, and should not be considered as a substitute for site-specific investigations and/or geotechnical engineering assessments for any project. Qualified and experienced practitioners should assess the site-specific hazard potential, including the potential for damage, at a more detailed scale.

Cover Photo: Road Bridge across railway at South beach, Greymouth

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1 OVERVIEW

The West Coast Region transport systems are described as follows:

a) State Highway (SH) network, of which the major routes are:
- SH 6 running the length of the region from Murchison to Haast Pass via the upper and lower Buller Gorges, Westport, Greymouth, Hokitika, Harihari, and Franz Josef;
- SH 7 linking Greymouth with Reefton, Springs Junction and Christchurch over the Lewis Pass;
- SH 73 linking Greymouth and Hokitika with Christchurch over Arthur's Pass;
- SH 65 from Murchison to Springs Junction, which is an alternative route from Nelson;
- SH 69 between Reefton and Inangahua; and
- SH 67 north from Westport to Mokihinui.

b) District roads, mostly no-exit and interconnected only through the State Highway system, to serve local communities. The more important roads are
- Greymouth to Ikamatua on the west bank of the Grey River (GDC)
- Stillwater to Jacksons as an alternative route to part of SH 73 (GDC)
- Nelson Creek to Bell Hill and Haupiri (GDC)
- Mokihinui to Karamea – the only road to Karamea (BDC)
- Hokitika to Kaniere, Kokatahi and Kowhitirangi farming area (WDC).
- Haast to Jackson Bay (WDC);

c) Railway with lines from Ngakawau and Westport to the north and Greymouth, Runanga and Hokitika to the south linking at Stillwater with the Midland line and through the Otira Tunnel to Canterbury;

d) Hokitika, Westport and, to a lesser degree, Greymouth airports, offering regular airline flights, and four other aerodromes used for local small plane and helicopter operations; and

e) River mouth harbours at Westport and Greymouth servicing fishing boats and bulk export ships and barges, plus a wharf at Jackson Bay.

The West Coast road and rail transport systems are presented in Figures 2.1 and 3.1, which also show the four State Highway road links and the railway link out of the region.

Roading is the key lifeline for the West Coast Region as all the others depend on roads for maintenance access and emergency repairs. The railway is very important to the coal mining and diary industries.

2 ROADING

2.1 Overview

This is a, if not the, key lifeline. The whole economy is dependent on it, and it provides the necessary access to other utilities. We have explored this utility in greater detail and attempted to define the route priority in terms of the functional importance of each section as well as its vulnerability to natural hazards. These two measures can guide decisions about where increased resilience is best focused.

The West Coast Region's road system is characterised by its length, low traffic volumes, frequently mountainous or hilly terrain with high rainfall and the many rivers and streams that cross the main routes. Figure 2.1 shows both State Highways and district roads. There are only four links to the rest of the South Island, all State Highways, with three of them crossing mountain passes. Within the northern part of the region there are some alternative routes such as the coastal and inland routes between Westport and Greymouth, and the Upper Buller Gorge and Maruia Valley routes between Reefton and Murchison. On the other hand, South Westland is characterised by a single State Highway without any alternative linking all the communities between Ross and Haast as well as those on the WDC road south of Haast. This combination of relative lack of redundancy, low traffic volumes holding back major upgrades, and the challenging environment makes the road system particularly vulnerable to natural hazards.

Table 2.1: West Coast Road Length Statistics (km)

Managing Authority:	NZTA[1]	Buller DC[2]	Grey DC[3]	Westland DC[4]
Roads				
Total length	871	605	610	677
Urban sealed		94	148	58
Urban unsealed		9	8	1
Rural sealed		226	242	316
Rural unsealed		276	211	302
Total	871	District roads 1,892		
Bridges				
Number	280[5] / 472[6]	155	206	287[7]
Length (km)		1.8	3.4	-
Longer than 10m		-	-	-
Single lane		-	102	-
Total	280	648		

1. Tai Poutini West Coast Growth Opportunities Report
2. Buller District Council
3. Grey District Council (Roads from Table 2 and Table 22. Bridges Table 25)
4. Westland District Council Transport Asset Management Plan (Table 2.2)
5. West Coast Engineering Lifelines Group Study – Alpine Fault Earthquake Scenario. 2006. Table 7.1
6. NZTA advice with new definition of cross section greater than $2.4m^2$ (i.e, including large culverts)
7. Includes footbridges

Figure 2.1: West Coast State Highway System

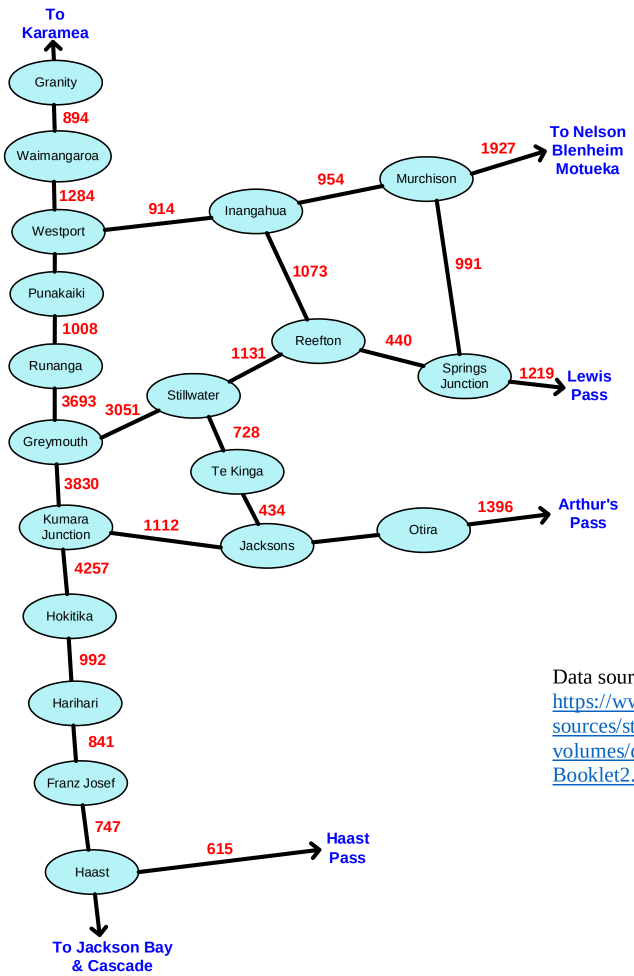
There is also a significant length of road in the region not maintained by the District Councils or NZTA, such as forestry and mining access roads. These may be significant as alternative 4WD routes in some locations for access to other lifelines or to bypass local damage to roads.

2.2 State Highway Network

The New Zealand Transport Agency (NZTA)[1] manages the State Highway network in New Zealand. The West Coast State Highway network accounts for 8% of the total length of the national State Highway network while the West Coast has less than 1% of the New Zealand permanent population[1].

The total length of roads on the West Coast is around 2,760km made up of around 1,890km local roads and around 870km of State Highways. State Highways represent a little over 30% of the network which is significantly higher than the national average of 11%[2].

Traffic volumes from NZTA for the State Highways in the region for 2015 are provided in Figure 2.2. Similar traffic volumes use the Upper Buller, Lower Buller, Maruia Valley, coastal and Reefton – Inangahua roads. Arthur's Pass carries a similar volume as the Lewis Pass, but over twice as much as the Haast Pass.



Data sourced from NZTA website: https://www.nzta.govt.nz/assets/resources/state-highway-traffic-volumes/docs/2011-2015-AADT-Booklet2.pdf

Figure 2.2: Annual Average Daily Traffic Volumes (NZTA for 2015)

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[1] Up until 2008, Transit New Zealand was responsible for operating and planning the New Zealand State Highway network. In 2008 Transit New Zealand merged with Land Transport New Zealand to form the New Zealand Transport Agency (NZTA).

[2] Tai Poutini West Coast Growth Study (2016) page 204.

The State Highway network is integral and essential to the functioning of the West Coast road system but State Highways on the West Coast were given low resilience priority in the State Highway Activity Management Plan 2015-2018. The plan assigned priority ratings from 1 to 5 to all State Highways throughout the country but all West Coast State Highways were only listed as Priority 5 except SH 73 which has a Priority 4 rating. In the more recent ONRC system, most of the State Highways are ranked as arterial, with SH 73 as Regional Collector (refer to 2.4), with several ranking layers below arterial.

2.3 District Council network

The three district councils maintain the local road network. In the main, these are all "feeder" roads off the State Highways and in most cases, are no exit roads. The main exception is the Stillwater to Jacksons Road via Moana which provides an alternative route from SH 73. There are also some interconnected roads, predominantly in Grey District, such as Nelson Creek to Rotomanu, with a few in northern Westland District which can also serve as alternative through routes.

2.4 System Importance

In terms of impact assessment, it is important to know the relative importance of the parts of a system so that both response and resilience improvement can be best targeted. An existing rating system is that created by NZTA and Local Government NZ, known as the One Network Road Classification System (ONRCS) for New Zealand. It scores roads into six main categories from "National" to "Access" on the basis of daily traffic (total and heavy), bus traffic, population linked, links to ports and airports, lifelines/resilient network and, tourist attractions. These functions reference economic and social aspects as well as purely traffic intensity. A summary description of the classification is found at www.nzta.govt.nz/assets/Road-Efficiency-Group/docs/functional-classification.pdf. We have been able to locate these classifications for the State Highways and Buller District. Lifelines aspects are not specifically built into the system and we have modified the approach for this particular study.

We have divided the road network into 26 main links. Local roads have not been included, but the links to outside the region have been extended beyond the regional boundary as these also impact directly on the regional resilience. Table 2.2 lists the main sections of the road network, along with the more important statistics with respect to usage and the ONRCS classification. Table 2.3 shows our own importance ranking. The importance attributes we have used are: ONRCS classification, role as a transport route to the regional economy, average daily traffic, heavy vehicle traffic, what services are on or accessed by the road and level of redundancy in the system (Table 2.3b). A simple 1 to 5 score is assigned for each attribute and these are summed to give an overall importance score, with a double weighting for the ONRC.

Table 2.2 Road Links and Statistics

		Road link	Length (km)	Population	AADT	%HV	ADT Heavy	ONRCS	Fibre Optic
1	SH 6	Murchison – Kawatiri	34	1110	1927	16	212	Arterial	Yes
2	SH 6	Murchison – Inangauha	52	144	954	13	124	Arterial	-
3	SH 65	Murchison – Springs Junction	71	183	991	12	119	Primary	Yes
4	SH 6	Inangahua – Westport	46	144	914	16	146	Arterial	-
5	SH 69	Inangahua – Reefton	33	324	1073	13	139	Primary	Yes
6	SH 7	Springs Junction - Hanmer	84	183	1219	17	207	Primary	-
7	SH 7	Springs Junction – Reefton	45		440	19	84	Primary	Yes
8	SH 7	Reefton – Stillwater	63	3088	1217	15	183	Primary	Yes
9	GDC	Ikamatua – Cobden	51	522					-
10	SH 67	Westport Bridge			4307	8	345	Primary	Yes
11	SH 67	Westport – Mokihinui	45	1173	894	8	72	Primary	Yes
12	BDC	Karamea Highway	52	580				Arterial	Yes
13	SH 67A	Westport – Cape Foulwind	12		2137	14	300	Primary	Yes
14	SH 6	Westport – Rapahoe	90	579	1008	10	101	Arterial	Yes
15	SH 6	Rapahoe – Cobden	11	1329	3693	8	295	Arterial	Yes
16	SH 6	Cobden bridge			4748	9	427	Arterial	Yes
17	SH 7	Stillwater – Greymouth	14	969	3051	11	336	Primary	Yes
18	GDC	Stillwater – Jacksons	54	435	434				-
19	SH 73	Kumara junction – Jacksons	46	549	1112	16	178	Regional	-
20	SH 73	Jacksons – Springfield	115	54	1396	18	251	Regional	-
21	SH 6	Greymouth – Hokitika	40	2508	4257	14	596	Arterial	Yes
22	SH 6	Hokitika – Ross	27	790	1324	13	172	Arterial	Yes
23	SH 6	Ross – Franz Joseph	107	1164	992	10	99	Arterial	Yes
24	SH 6	Franz Joseph – Haast	144	438	747	9	67	Arterial	-
25	WDC	Haast – Jackson Bay	48	240					-
26	SH 6	Haast – Lake Hawea	126	0	615	9	55	Arterial	-

Notes to Table 2.2:

1. Population is an estimate of population along that particular link, to give an indication of importance as a distribution road, as well as for through traffic.
2. AADT is annual average daily traffic, from NZTA for 2015. Links to outside the region show only traffic to the regional boundary.
3. Colours refer to the ONRCS with green traffic numbers consistent with Primary Collector routes (AADT > 1,000; Heavy vehicles > 150) and yellow for arterial routes (AADT > 3,000; Heavy vehicles > 300) in rural areas.
4. SH 6 is deemed an arterial route although traffic volumes are generally in the primary collector category; this is presumably because of its importance as connection and tourist route.
5. SH 73 is deemed a regional route, again presumably because of its strategic importance as the main east west link, rather than traffic volumes.
6. SH 67 Westport to Mokihinui is classified as Arterial by Buller DC, but Primary Collector by NZTA, and the Karamea Highway is classified as Arterial by BDC.

Table 2.3: Importance Ranking

		Road Link	ONRC	Reg Econ	Av Traff	Heavy Veh	Services	Redundancy	Score	Ranknig	ONRC
1	SH 6	Murchison – Kawatiri	4	5	4	3	5	5	30	A	A
2	SH 6	Murchison – Inangahua	2	4	3	2	2	2	17	C	P
3	SH 65	Murchison – Springs Junction	2	5	3	2	5	2	21	B	P
4	SH 6	Inangahua – Westport	4	4	3	2	2	2	21	B	A
5	SH 69	Inangahua – Reefton	2	4	3	2	4	2	19	C	P
6	SH 7	Springs Junction – Hanmer	2	5	3	3	1	2	18	C	P
7	SH 7	Springs Junction – Reefton	2	4	1	1	5	2	17	C	P
8	SH 7	Reefton – Stillwater	2	4	3	2	5	3	21	B	P
9	GDC	Ikamatua – Cobden	1	2	1	1	3	3	12	C	
10	SH 67	Westport Bridge	2	5	4	4	5	5	27	A	P
11	SH 67	Westport – Mokihinui	2	5	3	1	4	5	22	B	P
12	BDC	Karamea Highway	4	3	1	1	4	5	22	B	A
13	SH 67A	Westport – Cape Foulwind	2	2	2	3	5	2	18	C	P
14	SH 6	Westport – Rapahoe	4	3	3	2	5	2	23	B	A
15	SH 6	Rapahoe – Cobden	4	4	5	3	5	4	29	A	A
16	SH 6	Cobden bridge	4	5	5	5	5	3	31	A	A
17	SH 7	Stillwater – Greymouth	2	5	5	4	5	2	25	A	P
18	GDC	Stillwater – Jacksons	1	3	2	1	5	2	15	C	
19	SH 73	Kumara Junction – Jacksons	5	4	4	2	2	2	24	B	R
20	SH 73	Jacksons – Springfield	5	4	4	3	5	2	28	A	R
21	SH 6	Greymouth – Hokitika	4	5	4	5	5	4	31	A	A
22	SH 6	Hokitika – Ross	4	5	3	2	4	4	26	A	A
23	SH 6	Ross – Franz Joseph	4	5	3	2	4	4	26	A	A
24	SH 6	Franz Joseph – Haast	4	5	2	1	2	4	22	B	A
25	WDC	Haast – Jackson Bay	1	2	1	1	3	5	14	C	
26	SH 6	Haast – Wanaka	4	5	2	1	1	4	21	B	A

Table 2.3b: Importance Rating

Rating	Score	Description
ONRC	1	2ndry Collector
	2	Prmry Collector
	3	
	4	Arterial
	5	Regional

Rating	Score	Description
Average traffic (vehicles/d)	1	< 500
	2	500 – 800
	3	800 – 1300
	4	1300 - 2000
	5	> 2000

Rating	Score	Description
Heavy Vehicle (vehicles/d)	1	<100
	2	100 – 2100
	3	200 – 300
	4	300 – 400
	5	>400

Regional economy	1	Very little	2	3	4	5	Major

Services	1	No services in corridor or accessed by road
	2	General access to other utilities
	3	Local distribution lines/pipes in corridor
	4	Important services/ fibre optic cable along route
	5	Multiple services including trunk fibre optic cable route
Redundancy	5	Only access, no alternative
	4	Single road, no alternative but access both ends
	3	Alternative route but lesser robustness or subject to same hazard area
	2	Alternative routes separate, not impacted by same event to same degree
	1	Multiple routes

We stress that this ranking system is one of many possible. The actual scores are not important, nor is the exact position in an importance list, although it is noted that a number of different attributes and scoring have been tried and the overall order does not vary much. It should also be noted that no single ranking system will cover all aspects, and perspectives on importance will be different. For instance, the Karamea Highway is of critical importance to an individual in Karamea, as it is the only access route for goods and services and social and health needs. From the perspective of a manager in Wellington, it is of much lesser importance, serving a population of less than 500 out of the 32,000 total population in the West Coast Region.

The importance may also vary according to the natural disaster event itself. The Murchison to Kawatiri section of SH 6 is one of two road links between Nelson – Marlborough and the rest of the South Island. With the 2016 Kaikoura earthquake, it has become the ONLY main road link (ignoring the very limited capacity back country roads between Hanmer and Marlborough) for an estimated period of 13 months and thus its importance became paramount during that time. Heavy traffic volumes increased nearly 3 times.

What we are attempting to do is identify a relative importance, and to do that we have grouped the importance scores into higher, medium and lower (A, B & C), to give a relative importance. This grouping is obtained simply by dividing the links into three groups of roughly equal size. In some cases, the higher scores equate with arterial status in the ONRCS system, but in other cases our ranking is considerably lower.

Insofar as our aim is to identify the significance to the West Coast economy and community of any road damage due to natural hazards, we have to combine the importance of each section with its vulnerability. The next section deals with our approach to assessing vulnerability.

2.5 System Vulnerabilities

Roads are exposed to a variety of hazards. The particular types of damage related to the various natural hazards are outlined in the respective sections on hazards (Earthquake, storm, tsunami, landslide, in *Supplements 2 – 5*), and are not repeated here.

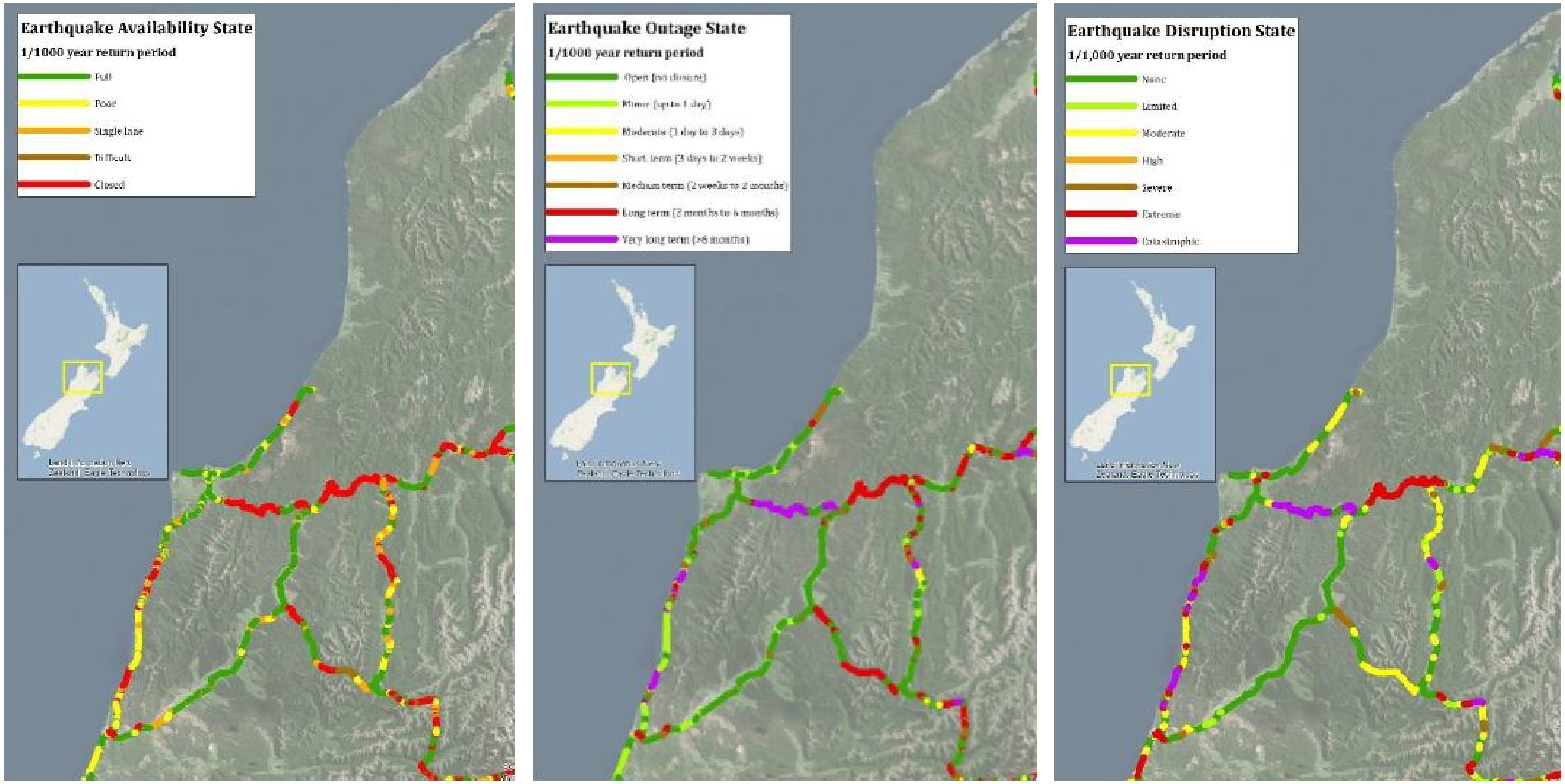
A full and detailed risk assessment of the road system has not been carried out for this study, but we are aware of a number of assessments and classifications have been done in recent years. These include:

- Resilience assessment for State Highways, developed for the NZTA and available on the NZTA website. This is a detailed assessment with a summary available in Mason & Brabhaharan 2017. It has attempted to assess the exposure of the highways on quite a detailed level and has then assigned a relative availability on a 5 step scale from full access to closed, as well as a 7 step outage scale from open to very long term closure (greater than 6 months). These are combined to give a disruption state. A sample of the output maps is shown in Figure 2.3, which covers the State Highways in Grey and Buller Districts for earthquake hazard. It must be appreciated that this is for a 1,000 year return period earthquake shaking uniformly along the roads - essentially our own approach - and thus does not reflect what might happen across the larger road network in any single specific earthquake. Similar maps show disruption for severe storms and flooding (1 in 100 year recurrence interval) and tsunami (1 in 500 year recurrence interval).

- Natural hazard exposure for roads in South Westland by researchers at the University of Canterbury. The output has a similar detailed map of SH 6 between Hokitika and Haast Pass for earthquake rupture exposure, landslide exposure, debris flow exposure and river flood exposure.

We have considered the NZTA work and have attempted to condense the information into a more compact summary form. This has inevitably involved simplification and loss of detail. To do this we have assessed the NZTA outage over each link and come to an overall outage for that section. While the NZTA study has, for instance, outage of more than six months on a road, it may be for a short length only, and our assessment is that a work-around or concentrated effort could re-open the road in a shorter time. In addition, because the NZTA study is based on a uniform hazard, it does not reflect the spatial variation that must occur with a real earthquake or storm event. The same extent of damage along the entire 100km road from Greymouth to Westport, for instance, is not realistic for most hazard scenarios impacting that road. Our assessment of the NZTA outage and our own assessment for each road link are shown in Table 2.4. In general, our suggested times to reopening are for basic four-wheel drive and truck access, with one-lane sections as necessary. The time to restore full service levels comparable to the pre-event situation might take much longer – from weeks to months, and in some instances perhaps even years.

The outage times are based on our own estimate where each of the 26 road links has been assessed for vulnerability, as shown in Table 2.5. A series of “attributes” for the physical setting and nature of each link has been used to establish a measure of vulnerability. These are terrain, hazard exposure, robustness of the link construction and reparability (Table 2.5b). Each has been given a score of 1 to 5, and then simply summed to obtain an overall vulnerability score. The vulnerability scores are then grouped into high, medium and low to give a relative vulnerability which can subsequently be combined with the relative importance, as discussed above. The vulnerability grouping is made simply by dividing the links into three groups of roughly equal size.



(a) Availability state **(b) Outage state** **(c) Disruption State**

Figure 2.3 NZTA maps of availability, outage and disruption for State Highways in Grey & Buller Districts for earthquake hazards

(from Figures 2 – 4, Mason & Brabhaharan, 2017)

Table 2.4 Road Links and Statistics

		Road Link	Length km	Terrain	Bridges			NZTA outage			This study outage		
					Total	Flood	EQ	Flood	EQ	Tsun'i	Flood	EQ	Tsun'i
1	SH 6	Murchison – Kawatiri	34	Mod		2H	2M	L	L		M	M	-
2	SH 6	Murchison - Inangauha	52	Steep	6	1M	2H	L	L		M	M	-
3	SH 65	Murchison – Springs Junction	71	Mod	3	2M	1M	L	M		M	M	
4	SH 6	Inangahua – Westport	46	Steep	13	-	1H	VL	VL		M	L	
5	SH 69	Inangahua - Reefton	33	Low	10	-		O	O		O	O	
6	SH 7	Springs Junction - Hanmer	84	Steep	7	1M	3H,1M	L	L		M	L	
7	SH 7	Springs Junction – Reefton	45	Mod	14	-	-	L	O		M	S	
8	SH 7	Reefton – Stillwater	63	Low	21	2M	1H,4M	O	O		O	O	
9	GDC	Ikamatua – Cobden	51	Low		-	-	-	-	-	M	S	
10	SH 67	Westport Bridge			1			-	-	-			
11	SH 67	Westport – Mokihinui	45	Low	15	-	1M,1H	M	M	VL	S	S	M
12	BDC	Karamea Highway	52	Steep	18		3H	-	-	-	M	M	M
13	SH 67A	Westport – Cape Foulwind	12	Low	1	-	-	O	O	VL	O	O	S
14	SH 6	Westport – Rapahoe	90	Steep	19	1M	1H,1M	VL	VL	VL	L	VL	L
15	SH 6	Rapahoe – Cobden	11	Low	6	-	-	O	S	-	VS	S	-
16	SH 6	Cobden bridge			1								
17	SH 7	Stillwater - Greymouth	14	Med	5	-	1M	L	L	-	S	S	-
18	GDC	Stillwater – Jacksons	54	Low		2M	-	-	-	-	M	M	-
19	SH 73	Kumara junction – Jacksons	46	Low	8	2M	1H,2M	O	O	-	S	S	-
20	SH 73	Jacksons – Springfield	115	Steep	11	1H,5M	5H,1M	L	VL	-	M	VL	-
21	SH 6	Greymouth – Hokitika	40	Low	13	-	2M	O	L	L	VS	S	S
22	SH 6	Hokitika – Ross	27	Low	6	-	2M	O	S	S	VS	S	S
23	SH 6	Ross – Franz Joseph	107	Steep	35	H+2m	3H,5M	m-l	L	-	M	M	-
24	SH 6	Franz Joseph – Haast	144	Steep	56	2H	5H,11M	m-l	L	VL	M	VL	M
25	WDC	Haast – Jacksons Bay	48	Low		-	-	-	-	-	M	M	L
26	SH 6	Haast – Lake Hawea	126	steep	29	2M	4H,1M	L	L	-	L	L	-

Outage:

O = open
(or closure less than 1 day)
VS = Very Short term,
1 – 3 days,
S = short term,
3 days to 2 weeks,
M = medium term,
2 weeks to 2 months,
L = Long term,
2 months to 6 months,
VL = Very long term,
greater than 6 months.

Bridge
Flood & Earthquake risk:

H = high;

M = medium

Table 2.5 Vulnerability Ranking

		Road Link	Vulnerability					
			Terrain	Exposure	Robustness	Reparability	Score	Ranking
1	SH 6	Murchison – Kawatiri	3	3	3	3	12	B
2	SH 6	Murchison - Inangahua	5	3	3	4	15	B
3	SH 65	Murchison – Springs Junction	3	3	2	3	11	C
4	SH 6	Inangahua – Westport	5	3	2	2	12	B
5	SH 69	Inangahua - Reefton	1	3	2	2	8	C
6	SH 7	Springs Junction - Hanmer	5	4	4	4	17	A
7	SH 7	Springs Junction – Reefton	4	3	2	3	12	B
8	SH 7	Reefton – Stillwater	1	3	4	2	10	C
9	GDC	Ikamatua – Cobden	2	3	3	3	11	C
10	SH 67	Westport Bridge	1	4	2	3	10	C
11	SH 67	Westport – Mokihinui	2	5	3	3	13	B
12	BDC	Karamea Highway	4	5	3	5	17	A
13	SH 67A	Westport – Cape Foulwind	1	5	2	2	10	C
14	SH 6	Westport – Rapahoe	5	5	3	4	17	A
15	SH 6	Rapahoe – Cobden	2	4	3	3	12	B
16	SH 6	Cobden bridge	1	4	1	3	9	C
17	SH 7	Stillwater - Greymouth	3	3	3	3	12	B
18	GDC	Stillwater – Jacksons	3	3	3	3	12	B
19	SH 73	Kumara Junction – Jacksons	3	3	3	3	12	B
20	SH 73	Jacksons – Springfield	5	5	4	4	18	A
21	SH 6	Greymouth – Hokitika	1	5	2	2	10	C
22	SH 6	Hokitika – Ross	1	5	2	2	10	C
23	SH 6	Ross – Franz Joseph	4	5	4	4	17	A
24	SH 6	Franz Joseph – Haast	5	5	4	5	19	A
25	WDC	Haast – Jacksons Bay	2	5	4	5	16	A
26	SH 6	Haast - Wanaka	5	4	4	5	18	A

Table 2.5b Vulnerability Rating

Rating	Score	Description
Terrain	5	Steep rugged high slopes, mountain streams, large rivers
	1	Generally flat, little earthworks
Hazard exposure	5	Multiple hazard: EQ, storm, flooding, debris flow, tsunami
	1	One or two hazards of any real threat
Robustness	5	Most Structures to non-seismic design, subject to waterway problems
	3	Many structures to modern design, some less well designed
	1	Very robust, all structures to modern design
Reparability	5	Very restricted access, steep hazardous terrain, major damage
	3	Adequate access, able to work on several sites
	1	Very easy access, room for temporary work arounds

We stress that the vulnerability ranking is somewhat subjective in that it is not based on a rigorous screening, but rather on what we know of topography traversed by each section, history of problems and proximity to known fault lines for earthquake or to the shoreline for tsunami. Again, we contend that this exercise does not need a high degree of precision for our purposes. As we know that whatever natural disaster occurs, there will be surprises in terms of the scale of damage and where it occurs, a relative ranking of vulnerability is sufficient for preparedness planning. In fact, it might be argued that too detailed an analysis can be counter-productive if it drives planning into a particular expectation of damage and required response. Flexibility must remain a key element in increased resilience.

2.6 Route priority

The importance and vulnerability of the 26 road links are shown on Figure 2.4 (a) & (b). This gives some idea of these aspects, but then the question is what do they mean in terms of resilience of the network and recovery from a large natural disaster. Although the previous two sections have considered 26 individual sections of road, from the point of view of the region's resilience it is important to think of the road network as a whole. One approach would be to take the high importance routes and upgrade them to reduce their vulnerability. On paper this seems logical, but when we consider which routes are most important, we see that several of them are also very vulnerable with multiple susceptible areas on long lengths, and there are also discrete route lengths separated by lower importance roads. If some roads are taken as strategic to link the main centres, as has probably been done in making SH 6 arterial throughout its length, this also presents problems as some of the links are in the high vulnerability group, whereas there are alternative links less likely to be damaged and easier to repair. What we have done, therefore, is to consider the two maps of Figures 2.4 (a) & (b) together and select key components of the network as priority routes. These are shown in Figure 2.4 (c).

The intention with these priority routes is to provide a spine of roading that is less likely to be damaged and easier to re-open and repair, and which links the main population centres and the region with the rest of the South Island. Our suggestion is to provide a focus on SH 6 from Ross through Hokitika to Greymouth, and SH 7 from Greymouth to Reefton. At Reefton one priority route follows SH 69 to Inangahua and then SH 6 to Westport, and a second follows SH 7 to Springs Junction, SH 65 to Murchison and SH 6 to Kawatiri, with most of these last two links being outside the West Coast region.

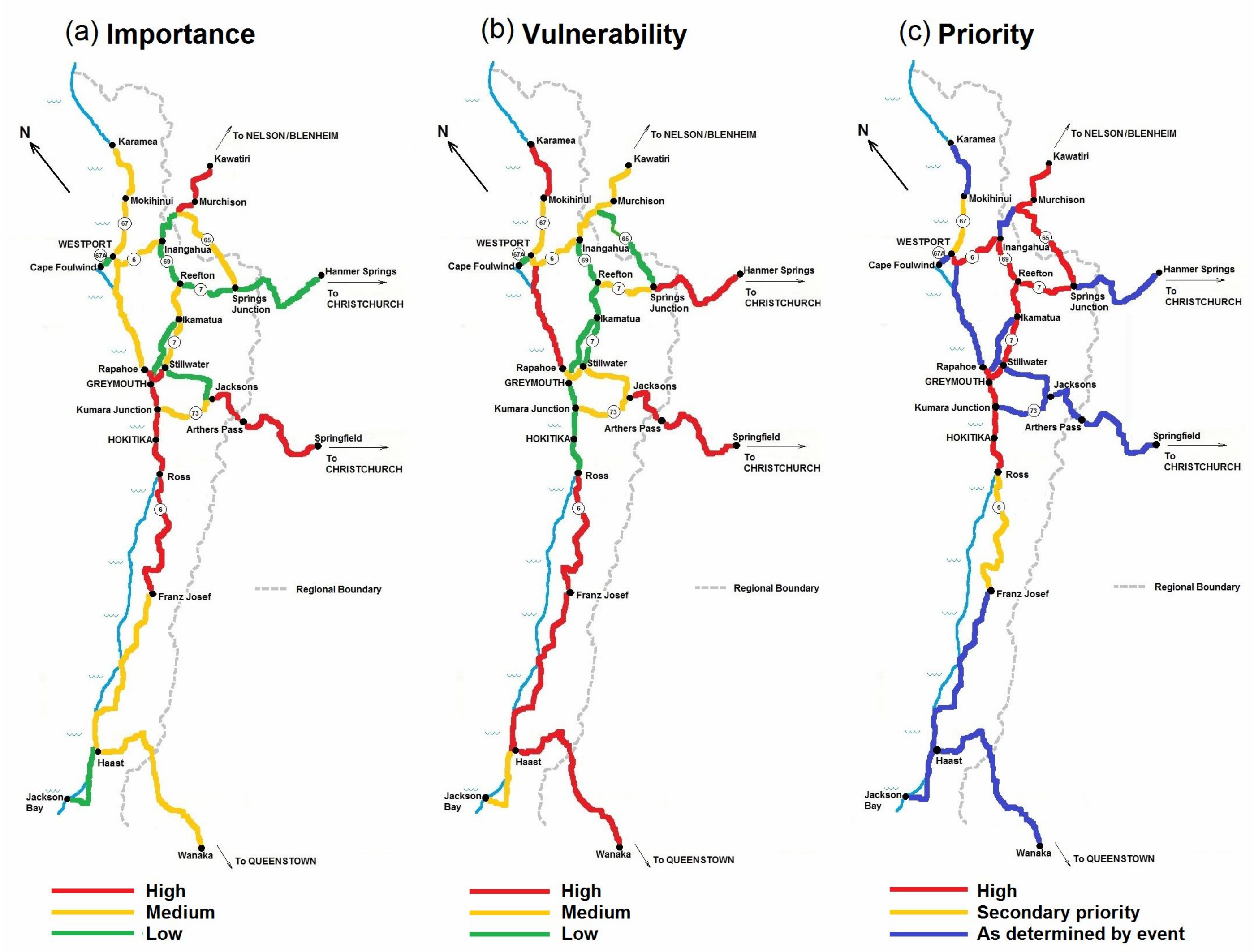


Figure 2.4 **Road Network Importance, Vulnerability & Priority**

The rationale for this choice is:

- The least vulnerable route linking the West Coast Region with the rest of the South Island is north through Murchison and Kawatiri. The other three routes all cross the Alps with high vulnerabilities. There is of course considerable redundancy in the network with these links and a large earthquake or storm event is unlikely to significantly damage all routes at one time. Rather than choosing one of the Alpine passes as a priority route and building infrastructure and planning around that, we suggest it is better to be able to respond to any actual event and use the route that is least damaged and faster to re-open. For instance, an earthquake in the Buller region, such as the 1929 Murchison earthquake, will close the SH 6 route to the north, but should have little effect on Arthur’s Pass and none at Haast. Traffic from the Coast can then be directed south and east. Conversely a large Alpine Fault earthquake is likely to have devastating effects on SH 6 in the south, serious impacts on SH 73 over Arthur’s Pass but little impact on Lewis Pass or Murchison, and Coast traffic can be directed north. This calls for a route within the West Coast able to access whichever of the outside link roads are open and suitable for traffic.
- SH 6 between Hokitika and Greymouth is of very high importance. It links the two centres with complementary services such as the hospital at Greymouth and the airport at Hokitika. It follows a route with low vulnerability, and other than for tsunami, closure times are likely to be short. South of Arahura, SH 6 is the only access to Hokitika and Westland.
- Westport is accessed from the south and east by two routes, but in our estimation the coastal route is probably more vulnerable to earthquake and landslip than the Lower Buller Gorge and is certainly vulnerable to tsunami and coastal erosion/storm surge whereas the gorge route is not exposed, although the latter is more exposed to flooding. In our assessment, it is preferable to use the Lower Buller Gorge as the priority route, in the knowledge that neither route is immune to prolonged closure.
- The main vulnerabilities in the wide valleys of the Grey and Inangahua Rivers are at river crossings, and this central route on SH 7 and SH 69 has a low vulnerability. Although the river crossings may be larger than on the alternative coastal route, they are generally on flatter gradients and with wider beds which provide better scope for work-arounds such as temporary fords or bridges than on the coastal route, as well as good access for repair. They are also not exposed to debris flows. There is also some additional redundancy with the Cobden – Ikamatua road on the west bank of the Grey River, and Browns Road at Inangahua Junction.
- SH 7 over Rahu Saddle and SH 65 down the Maruia Valley are also less exposed to landslide and offer a less vulnerable route than the Upper Buller Gorge. This route, although less direct than the Upper Buller Gorge in terms of accessing Murchison and Nelson, also links into SH 7 over Lewis Pass and thus provides additional flexibility.

The priority ranking we have arrived at looks at the overall network and is biased towards serving the greater concentrations of population. It has not placed emphasis on the many smaller population areas, often on dead-end roads. These include Karamea (note the difference between Arterial status for SH 67 north of Westport as assigned by BDC from a local perspective and Primary Collector as assigned by NZTA from a network perspective), the Gloriavale Community at Haupiri, Blackball, Kokatahi, Okarito as well as Okuru and Hannahs Clearing south of Haast. There is a tension between local need and network perspective that is not easily solved, and we do not pretend to have done so here.

Following a major natural disaster, reconnaissance and information gathering is essential. Our suggestion is that these priority routes are checked first to ascertain what damage has occurred and how soon they might be able to be re-opened. Known weaknesses on these routes, such as low strength bridges, could also be given a greater priority for upgrade or replacement to decrease the vulnerability of the routes. Consideration of bridges should not just be with regard to vulnerability but also to access and ease of repair (as noted above on SH 7 between Greymouth and Reefton).

As well as these major longer distance routes, there are also local roads which should be given a priority ranking. One would hope that these shorter links would be restored rapidly in the immediate post disaster response period, but there may be some longer-term impacts that could affect recovery. These routes include:

- Local roads accessing the airports at Westport, Greymouth and Hokitika, as the airports are essential in gathering information for damage assessment as well as for emergency supplies into the district;
- Access to hospitals and community emergency centres, firstly within each community then from outlying areas;
- Links between population areas which are close together, as there is a greater strength when combined and they often offer complimentary services. For instance, Westport and Carters Beach, Hector and Granity, Greymouth and Runanga, and Greymouth and Hokitika as mentioned previously;
- District Council link roads to smaller population centres off the State Highway network, such as Blackball, Moana, the Gloriavale Community at Haupiri, Hannah's Clearing and Karamea;
- Access to critical lifeline installations including Sewell Peak (communications), major substations and power stations (electricity), telephone exchanges (communications, although old style exchanges are being phased out), water pumping stations and reservoirs (potable water supply). We have already included communication and power lines where they run along the principal roads;
- Access to the ports of Westport and Greymouth to permit the unloading of supplies including fuel, in the event of them coming in by sea (although there are difficulties in transporting more than just

diesel in available ships, and the current condition of wharf structures and the harbour entrances makes these ports of secondary value in an emergency).

2.7 Hotspots and Pinchpoints

These terms have emerged in lifeline engineering circles to describe locations where there is a particular vulnerability. A pinchpoint is where there is a restriction/disruption along a particular infrastructure, such as the loss of a bridge on a road with no alternative access. A hotspot is where a number of lifelines go through a single location.

Pinchpoints

Much of the roading network on the West Coast presents multiple pinchpoints. For instance, damage at any point between Ross and Hawea that stops through traffic would constitute a pinchpoint. In this report, we are interested in pinchpoints that could impact on recovery after a few days following an event. These are likely to be from bridge damage sufficient to cause closure, very large landslides that either bury or destroy a section of road, or a succession of landslides that require a long time to clear successively. The vulnerability ranking above is an attempt to identify those routes most susceptible to this sort of damage, but there are also a number of key locations that warrant particular mention as potential pinchpoints.

- Upper Buller Gorge with road constructed across steep hillsides. Closure for 10 weeks in the 1968 Inangahua earthquake.
- Iron bridge on Buller River in Upper Buller Gorge. An old structure with some identified seismic weaknesses, although there was little damage in 1968.
- Lower Buller gorge with steep hillsides potentially susceptible to large landslides, and some areas potentially at risk from flooding or erosion from the river. Some very steep locations, such as Hawkes Crag, where rock fall could destroy the road and require months to re-instate.
- Buller Bridge as the only road link into Westport and the coast north.
- Karamea Bluffs; potentially vulnerable to rock fall and multiple landslides and with two seismically susceptible bridges.
- Coast road between Charleston and Rapahoe, which has multiple hazards including landslide, debris flow and sea erosion. Particular areas where loss of road by landslide could lead to long closures are the area immediately south of Meybille Bay and locations between Seventeen Mile and Rapahoe. There is a cliff collapse hazard at Punakaiki.
- The Lewis Pass traverses steep mountain terrain. A particularly difficult area is between Maruia Springs and the pass, where landslides could take a long time to clear. It is also noted that the route on the east coast follows the Hope Fault and is an area that could be impacted by earthquakes. The Arthur’s Pass route traverses more difficult terrain. A particularly large storm could produce debris flows and landslides in multiple catchments and clearance would

be sequential and therefore much longer to do. The Otira Gorge is vulnerable to rock fall, landslide and debris flow. Storm damage here in 1957 closed the road for 5 months. Exceptional flooding on the east side of the divide could impact on the road between Arthur's Pass and Cass in particular, and slope instability at Paddys Bend and the Waimakariri Bluffs could similarly take up to a few weeks or even longer to clear. Earthquakes in the eastern foothills could result in long road closures in the Porters Pass area.

- Bridges with particular importance include the Inangahua River Bridge at Reefton, the Cobden Bridge, the SH 6 Taramakau Bridge, and the Arahura Bridge. The Inangahua Bridge is a key link between Buller and Greymouth, although there may be an alternative through Globe Mine roads. The Arahura Bridge is of recent construction and should be resilient to both earthquake and flooding, but it is the only bridge across this river and carries both road and rail on the one set of caissons and pile caps. The combined road-rail Taramakau Bridge is to revert to rail only with a new road bridge currently under construction alongside it, but again is a key component on the road system. The SH 6 Hokitika Bridge is also a key structure but there is a second crossing of this river upstream at Kaniere to provide some redundancy.
- In south Westland, the road to Franz Josef has a number of particularly susceptible locations. These include the bridges across the Wanganui, Paeroa, Whataroa and Waitangitaona Rivers, and landslide susceptibility on Mt Hercules between Harihari and Whataroa in particular. The Wanganui River Bridge is very close to the Alpine Fault and has been identified as having vulnerabilities both seismically and to flooding.
- South of Franz Josef, particular locations are the Waiho River crossing with the particularly changeable river and bed levels with a potential to avulse to the south, the Cook Saddle area with steep terrain very close to the Alpine Fault and a history of slips, the three suspension bridges across the Fox, Cook and Karangarua Rivers, various smaller river crossings subject to debris flows, Bruce Bay with coastal erosion and tsunami damage potential, and Knights Point where complete loss of the road by landslip is conceivable.
- The Haast Pass road has a history of closures with landslides and debris flows. This extends on the east side of the Pass through to Lake Hawea.

Hotspots

The obvious hotspots on the roading system are the Buller Bridge at Westport and the Cobden Bridge at Greymouth. Both bridges carry regional fibre optic cable, sewer pipes, water pipes and power cables. The bridges themselves are of relatively modern design and construction and do not have any particular weakness, but the ancillary services are dependent on the bridge integrity. The most vulnerable aspect is likely to be damage at the bridge abutments where slumping and settlement of the approaches could result in acute deformation and severance of the service pipes and cables. The rail bridge just upstream from the Cobden Bridge could be used as an emergency alternative for some of the services if some catastrophe occurred to the Cobden Bridge, but there is no alternative to the Buller Bridge.

Road corridors also carry aerial power lines on some lengths as well as regional fibre optic cables, both buried and suspended. These do not really constitute hotspots, but the fibre optic cables carried on many road bridges could add to delays in repair because of the need to co-ordinate work and protect the cables.

2.8 Bridges

Bridges are obviously key elements in the road network, and many can be regarded as pinchpoints. They are exposed to flooding, river scour, erosion and or aggradation in ways that most of the road length is not, some are at risk from debris flows, and they are also subject to structural shaking in earthquakes. NZTA has carried out screening for seismic risk and also scour and waterway risk of all the bridges on the State Highway system. A summary of the more at-risk structures is contained in Appendix A. The District Councils have also had, or are in the process of having, seismic screening of their bridges.

The bridges with the highest likelihood of damage are the major bridges on SH 73 through Arthur's Pass. Between Ross and Franz Josef, nine bridges are susceptible to strong seismic shaking, and they are all long multi-span structures. South of Franz Josef, there are thirteen bridges which will be shaken sufficiently to cause serious damage requiring closure (fourteen if the Waiho Bridge is included). Of these, four are likely to collapse with an Alpine Fault rupture through the area (but obviously not affected by an earthquake in the north of the region). Earthquake damage can be time consuming to repair and in the extreme, the bridge could need full replacement. One of the SH 6 suspension bridges in South Westland suffered damage from the high winds in Cyclone Ita in 2014 (see *Supplement 3: Storm Scenario)*, and these bridges appear to have some vulnerability to extreme winds

There are 12 State Highway bridges in the region which NZTA have scored a more than 50% risk rating from scour or waterway issues. Three of these are between Greymouth and Lewis Pass, three between Kumara and Arthur's Pass and the remaining six on SH 6 south of Ross. It is unusual for waterway and abutment erosion damage to close a bridge for more than a few days, although if a pier is scoured, it can take a long time to fully reinstate. Temporary repair can often be done with the installation of a Bailey bridge across the affected spans allowing the route to be re-opened within a few days.

2.9 Upgrades and Improvements

Improvements to the physical infrastructure of the roading network will always be constrained by financial considerations. The West Coast is particularly difficult in this respect because of the low population and low traffic volumes over much of the network. Upgrading and bridge replacement are scheduled into the asset management plans of the district councils and NZTA. Our recommendation is to review those plans in light of the priority routes discussed previously and perhaps move the time frame of any planned upgrades on these routes closer to the "top of the queue".

While key roads in the region can be identified prior to the disaster event, as discussed previously, the order of priority for reinstating access along them will be subject to the actual damage sustained. A clear protocol for reconnaissance in the first instance is necessary, and then during recovery, a clear decision-making process for the order of re-opening and repair.

The priority is also closely linked to the State Highway network, and the NZTA and District Councils must work closely together in co-ordinating road recovery. While this will be forced on both parties through the emergency management regime that will be imposed after the disaster, liaison between the parties prior to any emergency could greatly enhance the speed and ease of recovery. An example of this is the Cobden Bridge at Greymouth. Although NZTA seismic assessment of the bridges suggests that it would survive most earthquakes with little damage, their ranking includes a ranking of importance within the NZTA system. This ranking may be quite different to the importance the Grey District may have for the bridge, as not only is it a vital link to Cobden and the communities to the north, but it also carries the main Greymouth water supply, electricity and communication cables. Damage to this bridge or its immediate approaches could have severe repercussions on the ability of the district to respond quickly after the earthquake, and some additional mitigation work on the bridge and its approaches may be warranted from the district's perspective. A similar situation exists for the Buller Bridge at Westport. In other words, the acceptable level of risk may be quite different for Councils and the NZTA, and this would be best to be openly discussed and for management procedures to be reviewed before a major natural disaster. There are several bridges like this:

- The Buller River Bridge at Westport, which is critical in providing the only road access to Westport and the North Buller coastal communities and also carries services including water supply to Carters Beach, power from the Westport substation to the BEL southern distribution, sewer pipe lines and fibre optic cable connecting the Buller District to the rest of New Zealand,
- Cobden Bridge, which while there is alternative bridging at Stillwater, carries the water main to Greymouth, sewer, power cables and fibre-optic communication cables and is an integral link within Greymouth,
- The Taramakau Bridge: although there are two other crossings of the river, they involve very long detours,
- The Arahura Bridge: a new structure for road and rail but which is the only bridge across this river and is the only link south to Hokitika, and South Westland,
- The Wanganui River Bridge, across a difficult river and the only access from the north to Harihari and beyond.

For several bridges, such as those listed above, the designs are modern and no physical improvements may be necessary or practical, but adequacy should not become a given assumption, and a regular review is recommended to not only ensure that the structure continues to be sound, the abutments remain secure against scour and there has been no loss of armouring, but also that any new information on either the expected hazard or design weaknesses that might arise from research or performance on other bridges is brought into the assessment.

3 RAILWAY

3.1 General Description

The New Zealand railway network is owned and operated by the state-owned enterprise KiwiRail Holdings Ltd trading as KiwiRail. The West Coast is linked to the national rail network via the Midland Line from Rolleston (Christchurch) and shown in Figure 3.1. At Stillwater it splits to a north line to Reefton, Inangahua, Westport and Ngakawau, while a south line leads to Greymouth, Rapahoe and Hokitika. The line is single tracked with numerous passing loops and it varies considerably in age and condition. The major traffic on the line is coal transport from Ngakawau (Stockton Mine). Westland Milk Products also rails most of its products from the Hokitika factory. The future of the railways is closely linked to these two industries, although the TranzAlpine passenger train is of some importance for tourism. The Rapahoe branch line is currently not in use following closure of the Spring Creek coal mine. If the Hokitika dairy factory were to use alternative transport, the Greymouth – Hokitika branch line would probably close as well. The Midland Line is heavily dependent on coal traffic from Stockton, and if production were to drop significantly, the economic viability of the whole rail network west of Canterbury would be questionable.

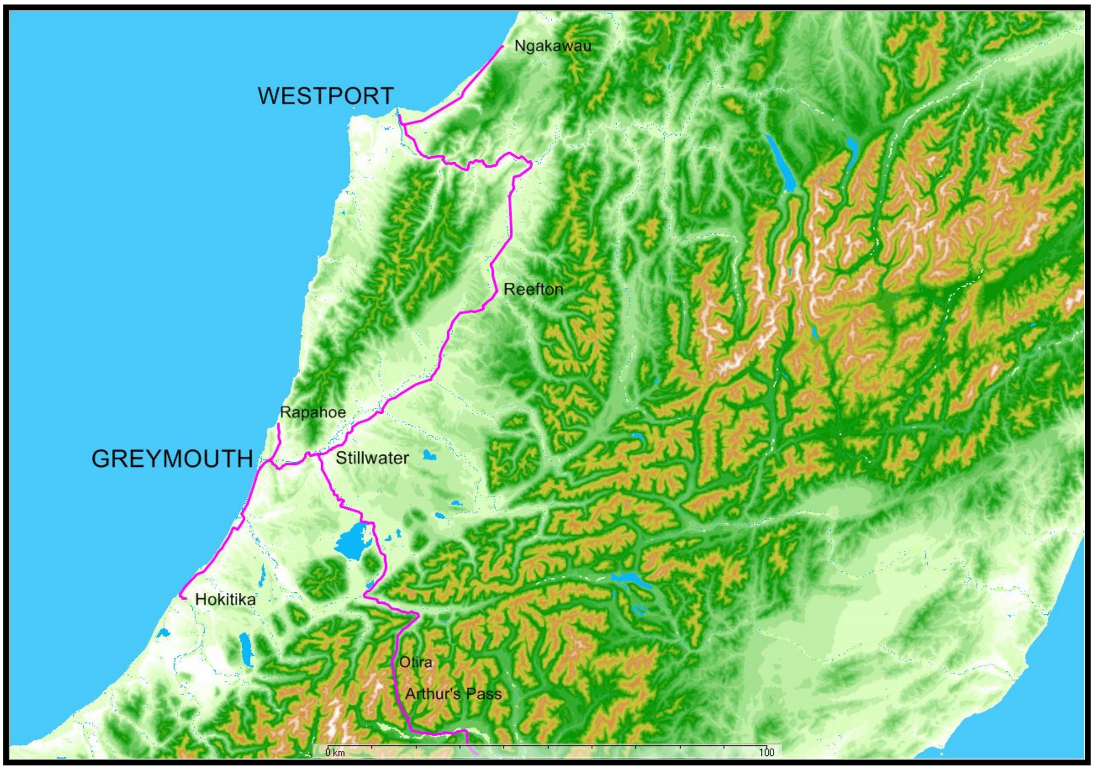


Figure 3.1: West Coast Rail Network Map provided courtesy of KiwiRail

Significant investments were made in replacing bridges, upgrading track and extending crossing loops to cater for increasing coal traffic until a fall in world coal prices resulted in a major reduction in coal production, closure of the Spring Creek Mine and the eventual sale of Solid Energy assets.

3.2 Significant Asset Risks.

The railway network within the West Coast Region and the link to Canterbury passes through mountainous and in places unstable country. This means that even with the best intent, it is not practicably possible to safeguard the railway against unexpected land slips and bridge damage. With railways, alignment and gradients are much more critical than for roads, and therefore temporary bypasses are much harder to implement and sometimes impractical. However, provided the track work is not physically removed by the hazard event, it can be reinstated and packed to level relatively quickly to allow train passage, even if at a low speed.

3.3 Earthquake

The railway crosses the Alpine Fault near Lake Poerua. An Alpine Fault earthquake can occur with a number of rupture lengths and locations. The more likely rupture is to the south of the Hope Fault junction at the Taramakau River, and this would not cut the railway, but it is also quite possible that the rupture could extend across the railway and parallel to the line to beyond Rotomanu. The rupture damage would be localised and the main vulnerability from any earthquake that produces strong shaking in the area of the rail line is from landslides, with shaking damage and some embankment damage as lesser risks. A study of the railway vulnerability to an Alpine Fault earthquake (Elms et al,

2011) found that while first impressions might assume more significant damage, the railway actually has very modest earthworks associated with it. The Midland Line essentially follows wide flat-bottomed valleys right through the mountains from Avoca to Rotomanu. The formation was built by nineteenth century technology by constructing low embankments (generally less than 2m high) along one side of the valleys, thus avoiding excavation into the steep mountain sides. Usually the line is tens of metres from the toe of the mountains, and thus only large landslips are likely to impact directly on to the line, although there is risk from flood damage on the other side. However extensive slip damage must be expected between Jacksons and Staircase (in Canterbury) as well as in the Taramakau, Otira and Bealey Valleys. Embankments will be damaged by slumping and the rail track thrown out of alignment. Debris flows and river aggradation are likely to have a serious impact on the railway east of Moana.

3.3.1 Bridges

In discussion with KiwiRail engineers we found that normally, earthquake loadings do not govern the design of bridges as the most severe loads come from the static and dynamic loads imposed by trains. It has been assumed that damage to bridge structures would not be severe given the general robustness of rail bridge design. The most likely source of trouble would be damage to foundations, abutments and approaches.

Most of the bridges are simple pier and beam construction of modest height and length and could be readily repaired even if partial collapse occurred.

Bridges can also be vulnerable to scour or aggradation of the river bed. Most bridges appear to be well founded to below likely scour depths, but occasionally such events have occurred. Debris flows in very steep catchments have also caused issues with either loss of waterway or on occasion, complete burial of the bridge.

KiwiRail has a good track record on rapid temporary bridge repair followed later by permanent work. It also has a supply of spare bridge spans, mostly held in Wellington but with some at the Middleton Yard in Christchurch. Most rail bridges on the line are low, with simply supported spans of standard length, the exception being some higher reinforced concrete bridges in the Buller Gorge and the four high viaducts in Canterbury. The risk of an extensive outage due to bridge failure is low.

3.3.2 Tunnels

There are 25 tunnels on the Midland route to Lyttelton, including the 8.56km long Otira tunnel, a short tunnel near Arnold, the 370m long Reefton Saddle tunnel and four tunnels up to 260m long in the Buller Gorge. The tunnels are lined but some of the lining is of poor quality material.

Generally, tunnels are robust structures, and experience in earthquakes is that overall there is little damage, as most damage to engineering structures occurs due to surface waves which have no effect other than near the surface. However a fault shearing movement across a tunnel would be a significant problem. The tunnel portal area tends to be a focus of damage as the surface waves interact with the structure and there is the additional risk of landslides. Tunnel 1 on the Stillwater – Westport line is brick lined and passes through weak rock below the Reefton Saddle. A large slip caused problems with the line in 2010 and there is a small chance that pressures from the ground could initiate deformation of the lining to the degree where action would be needed. Movement is likely to be slow and remedial work could be undertaken in a planned fashion with only short interruptions to rail traffic.

3.3.3 Recovery Time

The Elms et al 2011 report considered in some detail what could be involved in reopening the Midland Line following an Alpine Fault earthquake. A time of 3 to 6 weeks was arrived at. This was based on a great many assumptions in terms of what damage occurred and availability of resources, and is likely to be optimistic. The Westport line was re-opened after 3 weeks in 1968 after the Inangahua earthquake, but the Christchurch to Picton line is likely to have been closed for 9 – 10 months after the 2016 Kaikoura earthquake. It is noted that the railway along the Kaikoura Coast hugs the toe of steep hillsides of poor quality rock mass in a way that the Midland line does not, but clearly this example suggests that a six week recovery time is probably optimistic.

3.4 Severe storm and floods.

The line passes through the mountains by following river valleys. This results in long lengths of line parallel to and close to major rivers and frequent bridges across the tributaries as well as over the main rivers themselves. In addition, the West Coast side of the Alps is an area of high rainfall and frequent floods. The line has a long history of damage and interruptions from floods scouring out the railway formation, but line closures have rarely exceeded more than a few days and it is hard to conceive of any flood event which would impact on the line to such an extent that it would remain closed for more than one to two weeks, especially with the modern availability of large earthmoving equipment. The other potential impact of floods is aggradation of the rivers following a large earthquake. This possibility is discussed further in *Supplement 2* of this study.

Taramakau River Avulsion

One particular flood scenario that could have greater implications is the potential for the Taramakau River to change its course at Inchbonnie (refer to *Supplement 9* of this study). Should the Taramakau change course it could have a significant impact on the railway because of increased river and flood levels in the Arnold and lower Grey Rivers. The railway bridge across the Arnold River would have insufficient waterway clearance, several kilometres of track would be inundated with large floods, and the track formation would probably be affected by higher ground water levels. It is most probable that the community response would be to return the Taramakau to its existing course as soon as possible and the effect on the railway should be no more than the loss of the Arnold River bridge (a low 3 span structure which could easily be repaired temporarily) and some scour of formation. Restoration of services would be expected within one or two weeks.

Storm related Landslips

Associated with extreme rainfall causing floods is the potential for widespread landslip, as frequently occurred in the past, but the railway has rarely been closed for more than a few days. A very large event can be expected to generate more slips, and a comparison could be made with the 1975 Cyclone Alison along the Kaikoura Coast and which closed the railway for two weeks. On the Midland Line, the terrain is exposed to frequent heavy rain and is less likely to generate slips on such an extensive basis without an additional trigger such as earthquake damage. The more common major interruption is from debris flow, as occurred several times at Rocky Creek prior to 2005, and at Deception Bluffs in 2017 (see *Supplement 5).*

Meteorological

Severe weather can disrupt traffic on the line. Extreme rainfall results in floods, as discussed above. High wind could conceivably derail a train, and lightning could interfere with communication and signalling, but the most significant weather related outage after floods would be snowfall. This has closed the railway in the past, but never for more than a day or two.

3.5 Tsunami

The railway is exposed to very large tsunami where it is close to the coastline at Granity – Ngakawau, Greymouth and Hokitika. In these locations, the track bed is expected to be damaged from scour of ballast and embankment, and the line blocked by debris from buildings etc. between the rail and the shore. A few bridges south of Greymouth may be vulnerable to a large tsunami from erosion of the abutment fill, impact damage on the structure and possible scour of abutments and piles.

3.6 Large Landslide

Large landslides usually have some precipitating trigger such as a prolonged much wetter than normal weather pattern which increases groundwater levels, or an earthquake. There are no known large landslide areas on the railway route, with the exception of the slow moving earthflow at Omoto slip just east of Greymouth on the railway to Stillwater. The most likely cause of a new large landslide would be strong earthquake shaking.

White Cliffs is an area on the railway just west of the Buller River Bridge, where the railway passes close below a limestone cliff. There are large blocks of rock above the line which could conceivably fall on to the line. The difficulty here is the size of debris which could obstruct the line and the restricted access to the site, with little room to form a deviation around the obstruction. It is not unknown for rock failures to occur without any obvious trigger, but such an event should be able to be dealt with within two weeks or so. It is noted that these cliffs are close to the epicentre of the 1968 Inangahua earthquake and survived, so the likelihood of failure is probably not great.

3.7 Fire

A large wildfire could interrupt traffic, but is unlikely to cause any significant damage. West of Arthurs Pass, the climate is such that wildfire is extremely rare. East of the divide, vegetation is generally sparse, but a fire in early 2017 resulted in severe damage to timber piers to a bridge in Canterbury causing a 5 week outage of the line while the piers were rebuilt. Fire damage to cabling and timber work on ancillary structures should be relatively easy to repair and with reinstatement taking no more than a couple of days. Timber bridges are being replaced with structures made of non-flammable materials. KiwiRail operates firefighting equipment in Canterbury and controls fires close to the railway.

4 AIRPORTS

4.1 Description

There are seven aerodromes listed with the Civil Aviation Authority on the West Coast:

- Karamea
- Westport (part certified 139)
- Greymouth
- Hokitika
- Franz Josef
- Fox (Helipad)
- Haast

Karamea Aerodrome is a non-certified facility 2km north of Karamea. It has a grass runway 945m by 60m with a sealed runway within it 945m by 8m width. There is a second grass runway 655m long. There are no lights or facilities. It is operated by Karamea Airport (Inc)

The Westport Airport (owned by BDC and the Ministry of Transport) is managed by the Buller District Council who operate the airport on a day to day basis. The airport is used by regular commercial flights to Wellington (Sounds Air) as well as charter and industry users. This is the only airport on the West Coast certified under part 139 of the Civil Aviation Authority rules for operation of an aerodrome, allowing regular air transport with aircraft of seating capacity of more than 30 passengers. It has a single sealed runway 1,280m by 30m with two grass taxiways to associated buildings. The runway has a retro reflector system for use in emergencies with pilot activated strobe lights indicating an extended runway centre line. There are standby power and fuel facilities.

The airport at Greymouth is owned and operated by GDC. It consists of a single 1,091m by 32m paved runway that is normally used for light aircraft and helicopters, but is capable of handling larger aircraft – an Air Force C130 Hercules has landed here. There are no scheduled flights using the airport. An important use is the ferrying of patients to and from the adjacent Greymouth Hospital and St John’s Ambulance centre using an air ambulance, but it is also the base for Air Search & Rescue and Land

Search & Rescue. The airport is located near the coast and is in an area that is likely to be liquefiable and its low elevation means it is at risk of inundated by flooding and tsunami.

The Greymouth airport is an unmanned facility with only a part time flight control officer present on an as required basis. The airport has a basic ground to air radio facility with a battery powered hand held transmitter/receiver held at the Grey District offices. Approaching planes can activate the airport runway lighting prior to landing. An emergency generator backs up emergency lighting. There is a fuel facility. Emergency procedures at the airport are very limited with reliance on the CAA and the Fire Service.

Hokitika airport is owned by the Westland District Council through a subsidiary holdings company. It is the busiest airport on the West Coast, serving both Hokitika and Greymouth with up to five commercial flights a day to Christchurch, as well as by helicopter and charter flights. It has two sealed runways, one being 1,314m by 30m and the second 1,176m by 18m. Only the first runway and taxiway have lighting and there is a standby generator for runway lights and communications only. There are fuel facilities and a passenger terminal.

Franz Josef aerodrome consists of a single 800m by 9m sealed runway 5km SW of the township. There is no lighting but it does have a fuel facility. It is operated by Air Safaris and Services, based in Lake Tekapo. Helicopter operations are based at the Franz Josef Heliport adjacent to the township. This is operated by Westland District Council holding company and has fuel on site.

Fox Heliport is operated by Glacier Southern Lakes Helicopters Ltd and is 1.5km west of the township. There is no lighting or facilities, and it is limited to 15m long helicopters. There is a grass airstrip about 700m long 0.5km north of the township.

Haast aerodrome is a 700m by 60m grass runway facility operated by Heliventures Ltd, 0.5km south of the Haast Hotel and Department of Conservation centre. It has no lighting but it does have a fuel facility.

There are numerous smaller private grassed airstrips on the West Coast able to be used by light aircraft that are not on the civil aviation register. These include the following as shown on 1:50,000 maps, from north to south:

- Cape Foulwind
- Reefton, 3km and 8km north of the town
- Maruia, Creighton Rd, 10km north of school
- Ruatapu, Falls Creek Rd, 6km south
- Kowhitirangi, Stopbank Rd, 4km south
- Inangahua Landing
- Nelson Creek Farm Settlement
- Coal Creek Farm Settlement
- Milltown (upper Arahura valley)
- Kokatahi, Whites Rd, 2km north
- Larrys Creek
- Ahaura
- Nelson Creek
- Okarito
- Okuru

- Tatare, 2km north of Franz Josef township
- Fox Glacier, 6km west of township
- Neils Beach
- Kaniere 2.5km to South East near Taminelli Creek
- Karangarua, 1.5km west of the bridge

4.2 Airport Vulnerability

The airport vulnerabilities are summarised in Table 4.1.

Table 4.1 Airport Vulnerabilities

Airport	Description	Earthquake	Storm	Tsunami
Karamea	Slightly raised alluvial surface	Liquefaction unlikely; little damage	Unlikely	Inundated; some damage
Westport	Beach ridge; probably gravel,	Liquefaction unlikely; little damage	Unlikely	Inundated, some damage to runway; all electrical and buildings badly damaged
Greymouth	Beach ridge at south end, reclaimed land at north	Liquefaction likely in parts of northern end	Probable inundation if Grey Floodwall is breached, with flooding & debris	Inundated; damage to runway and all electrical and buildings badly damaged
Hokitika	On raised outwash terrace	Some minor ground deformation possible; limited damage	Not affected	Not affected
Franz Josef	On Waiho floodplain	Some minor ground deformation possible; limited damage	Vulnerable to flooding from Waiho –scour and deposition of debris	Not affected
Fox	On alluvial surface	Some minor ground deformation possible; limited damage	Possible local flooding	Not affected
Haast	On alluvial gravels	Some minor ground deformation possible; limited damage	Possible flooding if stopbank breached; then scour and debris deposition; otherwise local flooding	Not affected

4.2.1 Earthquake

Of the listed aerodromes, Greymouth is almost certainly on liquefiable soils for part of its length towards the north end. Westport appears to be on old storm beach deposits which are probably gravel and non-liquefiable. Hokitika is on a high terrace of consolidated outwash gravel. The others are on alluvial surfaces that have a low probability of liquefaction damage.

The possible damage at the airports is very dependent on where an earthquake occurs. A large earthquake in the Buller area may possibly produce some limited liquefaction damage at Karamea and Westport, whereas an Alpine Fault earthquake, being centred much further away is unlikely to result in any damage to these two airports, and they could be made operational immediately.

For most Alpine Fault earthquake scenarios, Greymouth is likely to suffer some liquefaction damage to the northern part of the runway. This is likely to limit use to helicopters and small aircraft able to use a short runway. It should be possible to reinstate the runway for larger aircraft within one to three days, depending on the damage sustained and the priority given to making it operational.

Hokitika airport is likely to sustain very little damage to the runway and aircraft areas, but the shaking would cause significant damage to the terminal building contents. This airport should be able to be functional within a short time following the earthquake. The lack of backup power should be checked, and standby power arranged if necessary.

Franz Josef aerodrome could play a crucial role in evacuating people from the area. It is about 4.5km from the fault line and would be subjected to very strong shaking. The runway is likely to remain useable, although some distortion to the surface and damage to seal is possible. A major risk to the utility of this aerodrome is its location on the south side of the Waiho River. The fault rupture would cut the road in two places and the bridge could well be damaged or destroyed, thus making access from the township difficult. Its location is also vulnerable to avulsion from the Waiho River anywhere in the 5km of river between it and the road bridge, particularly as the river bed is higher than the adjacent land upstream of Canavans Knob.

Fox Glacier heliport is about 1km from the fault line. Damage to the hanger and fuel facility is probable. It should be possible to land small aircraft at one or both of the two airstrips at Fox.

The Haast aerodrome should remain functional after even a major earthquake on the Alpine Fault, given its location on gravels, although there is a possibility of some ground deformation.

4.2.2 Severe storm

Severe weather, including wind, would be likely to interrupt airport operations during an event, and there might be flooding on some airfields for a period after an event. Karamea airport is outside the Karamea River flood zone, as is Westport, but in both instances flooding would be likely to cut road access. Greymouth airfield would be likely to be flooded if the Grey flood bank were breached. Hokitika airport is elevated and thus relatively immune from storm other than local ponding.

4.2.3 Tsunami

Karamea, Westport and Greymouth airports are all located close to the shore and are all vulnerable to inundation in a large tsunami. The underlying ground is gravel and sand and some scour of the edge of the runway pavement is possible. Debris, gravel and sand would be likely to obstruct the runways. The small airport buildings would be damaged or even destroyed and all equipment, runway lighting etc. flooded, damaged or even destroyed. Hokitika airport is located well above tsunami level and would not be affected. The Haast aerodrome is 2km inland from the shore at an elevation of 6 – 7m. It is unlikely that a 500 year return period tsunami would reach the facility, although an extreme event could.

5 PORTS

5.1 Westport Harbour

The Westport Harbour assets are fully owned by the Buller District Council. BDC manages the port through Buller Holdings a 100% subsidiary of BDC. Buller Holdings has a portfolio of three enterprises one of which is the Buller Port Authority which manages the day to day operations of the port. Servicing fishing boats is the main function of the port, but infrastructure remains in place for bulk ships and barges. The assets of the harbour include a dredge, pilot vessel/tug (although with no regular larger vessels using the port, these may not be kept long term), all wharves, jetties and navigation aids, harbour office and assorted buildings, and an engineering workshop. The tug is 14m long with a 3 ton bollard pull. The dredge is 55m long, 915 tonne gross with a hopper capacity of 635 m^3. The port maintains one electric travelling crane on the wharf, which has a 12 tonne capacity. There is flat storage area of 20,000m^2 and a merchandise shed of approximately 3,500m^3. The fishing harbour includes unloading and refuelling facilities.

Since Holcim Cement closed down its operation and withdrew from the Buller District the harbour has not been dredged as large ships no longer come to the port. Dredging is not required for fishing boats. The dredge is currently working at other harbours around New Zealand.

The harbour is limited by the river bar entrance which can cause problems with river currents setting up very steep short breaking waves and dangerous cross sets across the entrance. The harbour was effectively closed to large vessels for two months in 2005 because of low river flows allowing the bar to build up and limit the available draft depth.

5.2 Greymouth Harbour

Figure 5.1: Port of Greymouth
Photo of the Port of Greymouth looking towards the mouth of the Grey River.

The Port of Greymouth is a relatively small facility near the mouth of the Grey River. Breakwaters have been formed on both sides of the river mouth and a half tide wall on the north side to maintain the depth of the water over the sand bar at the river's confluence with the open sea.

The port is predominately used as a base for coastal fishing boats. Vessels of up to 5m draft can enter the port. However bar sounding to confirm depth must be undertaken before the vessel can enter. The closest bar sounding equipment is at Westport.

Two ship-loading cranes are still at the wharf but have been decommissioned. The wharf is in poor condition and only really able to support pedestrian traffic. There is only very limited access at the wharf for mobile crane facilities for ship to shore good transfer. The fishing vessel berthage and slipway is outside the main river in the Blaketown Lagoon (Erua Moana). This area needs dredging to maintain draft depths.

5.3 Jackson Bay Wharf

The Jackson Bay wharf is operated and maintained by the Westland District Council. The wharf is about 65m long, with a 145m long trestle approach from the shore. It is a timber structure built in 1937-38. The water depth at the wharf and the wharf load capacity are not known, but it would be adequate for the size of vessel able to use Greymouth port. Jackson Bay is currently used as a base for fishing boats.

The wharf's seismic capacity is not known. It should survive an Alpine Fault earthquake with rupture north of Paringa with little damage, but could be significantly damaged if the fault rupture extended to or south of the Arawhata River (AF8). It is recommended that its seismic strength is checked.

While currently of limited use and probably of marginal economics to keep functional, this wharf could be of great importance post-earthquake when all road access to the Haast area is expected to be cut for a significant period. While the permanent Haast population is less than 300 people, from late August to mid-November the whitebaiting season swells the population to over 1,000 and numbers stay high through the summer from tourism. The wharf's importance may increase with the recent consenting for water exports by pipeline from Neils Beach to a mooring buoy offshore.

REFERENCES

Brabhaharan, P. 2006, *Recent Advances in Improving Resilience of Road Networks*. Remembering Napier 1931 – Building on 75 Years of Earthquake Engineering in New Zealand. Annual Conference of the New Zealand Society for Earthquake Engineering. Napier, 10 – 12 March 2006.

Davies,A.J. et al, 2017. *Transport Infrastructure Performance and Management in the South Island of New Zealand, during the first 100 days following the 2016 M_w 7.8 "Kaikoura" Earthquake*. Bulletin of the New Zealand Society for Earthquake engineering, Vol 50, No.2, June 2017

Elms,D., Dewhirst, R., McCahon, I., 2007; *Alpine Fault Earthquake Midland Line Vulnerability Report*, report for Solid Energy NZ Ltd.

Elms,D., Dewhirst, R., McCahon, I., 2011; *Midland Railway Line Natural Hazard Vulnerability Report*, report for Solid Energy NZ Ltd.

Evans, S., Westergard, F., 2009; *Bridge Scour and Waterway Risk Screening Region 12 – West Coast State Highway Network*, report for NZ Transport Agency, by Opus Consultants.

Kirkaldie, D.K.; 1999, *Seismic Screening of State Highway Bridges Region 12 West Coast*, Report for Transit NZ by Opus Consultants.

Mason, D., Brabharan, P., 2017 *Resilience Assessment of State Highways in New Zealand*. Annual Conference of the New Zealand Society for Earthquake Engineering. Wellington, 27-28 April 2017.

McCahon, I., Elms, D., & Dewhirst, R.; 2006, *West Coast Engineering Lifelines Study*, Alpine Fault Earthquake Scenario.

State Highway Resilience Study NZTAR https://nzta.maps.arcgis.com/apps/MapSeries/index.html?appid=5a6163ead34e4fdab638e4a0d6282bd2.

APPENDIX A
BRIDGES ON THE ROAD NETWORK

Bridges are obviously key elements in the road network. They are exposed to flooding, river scour, erosion and or aggradation in ways that most of the road length is not, and they are also subject to structural shaking in earthquakes. NZTA has carried out screening for both seismic risk and scour and waterway risk of all the bridges on the State Highway system.

A.1 Seismic Screening

The seismic screening report on Region 12 – West Coast (Kirkaldie, 1999) identified the following bridges in the region as at risk of serious damage or collapse, requiring closure, from strong earthquake shaking. The level of shaking needed to cause serious damage requires an earthquake centred close to the bridge, and thus not all these bridges would suffer damage in any single earthquake. Other bridges are at risk of damage, but have not been included in Table A.1. The Table has been updated from the 2006 report[3] with status as of early 2016 supplied from NZTA. Ten bridges have been removed from the table as strengthening work has been completed or the bridge replaced since 2006.

Notes to Table A.1 (following pages)

(1) Probable peak ground acceleration (PGA) at the bridge location from the Alpine Fault earthquake AF8 scenario, for south Westland only. Other earthquake sources, or different rupture lengths on the Alpine Fault will produce different PGA

(2) Minimum PGA to cause significant damage to bridge

(3) Extent of damage to bridge

1 – insignificant; superficial damage, no disruption to traffic

3 – moderate; significant damage in a number of locations requiring closure

5 – Catastrophic; damage requiring replacement of more than one span

(4) likelihood of risk event

A – very likely B – likely C – moderate D – unlikely

E – very unlikely

*** Strengthening of these three suspension bridges is planned to allow the removal of current weight restrictions. Seismic resistance may be improved as part of this work.

[3] McCahon, Elms & Dewhirst, 2006, West Coast Engineering Lifelines Study, Alpine Fault Earthquake Scenario

Table A.1: SH Bridges with Significant Seismic Risk – NZTA Study

State Highway	Bridge		Min. PGA (2)	Damage (3)	Likelihood (4)	Comments
6	***Upper Buller***					
	Iron Bridge		0.5	5	D	Poor truss bracing – possible collapse
	(Buller R)		0.5	5	D	Abutment rock slide – possible collapse
	Inangahua R		0.5	3	D	
6	***Lower Buller***					
	Fern Arch		0.5	5	C	Collapse from rock failure
69	***Inangahua – Reefton*** (no bridge classified at risk)					
65	***Murchison – Springs Junction***					
	Maruia		0.5	3	C	
7	***Reefton – Greymouth***					
	Inangahua		0.5	3	C	
	Nelson Ck		0.5	3	C	
	Kiwi O/B		0.5	3	C	
67	***Westport – Seddonville***					
	Big Ditch		0.4	3	C	Liquefaction
	Waimangaroa O/B		0.4	3	C	Liquefaction settlement, slumping of fills
	Mohikinui		0.5	3	D	Shear failure, settlement
6	***Westport – Greymouth***					
	Mountain Ck		0.5	5	C	Probable collapse from pier failure
	Nile		0.4	3	C	
	Canoe Ck		0.4	3	C	Liquefaction abutment + pier movement
	Camp O/B		0.5	3	D	
	Coal Ck O/B		0.5	3	C	
6	***Greymouth – Hokitika***					
	South beach O/B		0.4	3	C	Settlement, distortion from liquefaction
	Saltwater		0.5	3	C	Probable collapse from pier failure
	New river		0.5	3	D	
	Taramakau		0.5	3	D	Bridge being replaced

Table A.1: SH Bridges with Significant Seismic Risk – NZTA Study (continued)

State Highway	Bridge	PGA AF8 EQ (1)	Min. PGA (2)	Damage (3)	Likelihood (4)	Comments
73	***Arthur's Pass - Kumara***					
	Yorkeys Point		0.5	3	B	Bearing failure, settlement deck damage
	Otira		0.5	3	B	
	Taipo		0.4	5	B	Possible collapse from pier failure
	Big Wainihinihi		0.5	3	B	
	Turiwhate		0.4	3	B	
6	***Hokitika – Franz Josef***					
	Donnelly Ck	0.7	0.5	3	C	
	Kakapotahi	0.8	0.5	3	C	Damage, settlement from pier failure
	Wanganui	0.8+	0.5	3	B	Damage, settlement from pier failure
	Poerua	0.8+	0.5	3	B	Damage, settlement from pier failure
	Whataroa	0.8+	0.5	3	C	Bridge settlement from pier failure
	Waitangitaona	0.8+	0.5	5	C	Probable collapse
	Tatare	0.8+	0.5	3	C	Damage, settlement from pile cap failure
6	***Franz Josef – Haast***					
	Waiho	Temporary, not analysed				Very close to fault – damage very likely
	Kiwi Jacks	0.8+	0.5	5	C	Rock fall onto bridge - possible collapse
	Waikukupa	0.8+	0.5	3	C	damage, settlement from pile cap failure
	Fox River ***	0.8+	0.5	5	C	Probable collapse from tower buckling
	Cook River ***	0.8+	0.5	5	C	Probable collapse from tower buckling
	Ohinetamatea	0.8+	0.5	3	C	
	Karangarua ***	0.8+	0.5	5	C	Probable collapse from tower buckling
	Manakaiaua	0.8+	0.5	3	C	
	Jacobs River	0.8+	0.45	3	C	
	Papakeri	0.8+	0.5	3	C	

Table A.1: SH Bridges with Significant Seismic Risk – NZTA Study (continued)

State Highway	Bridge	PGA AF8 EQ (1)	Min. PGA (2)	Damage (3)	Likelihood (4)	Comments
	Mahitahi	0.8+	0.5	3	C	Damage, settlement from pile cap failure
	Windbag	0.8+	0.5	3	C	
	Moeraki	0.8+	0.6	3	C	Pile failure – settlement
	Whakapohai	0.8+	0.4	3	C	Damage, settlement from pile cap failure
	Ship Creek	0.8+	0.6	3	C	Pile failure – settlement
	Waita	0.8+	0.6	3	C	Pile failure – settlement
	Haast River	0.8+	0.5	3	C	Linkage damage to joints and abutment
			0.5	5	C	Pier failure, assessment/design in process
6	***Haast – Haast Pass***					
	Pivot Creek	0.8+	0.6	3	C	

It should be recognised that these bridges have been identified from a preliminary screening study, and detailed analysis may reduce (or increase) the relative risk. For instance, the Iron Bridge over the Buller River has been subject to MM IX shaking in 1929 and MM X in 1968, and survived with relatively minor damage, whereas the screening suggests that significant damage might have been expected.

This study is for earthquake hazard throughout the region and from any earthquake source. However the Alpine Fault earthquake presents a particular challenge for the roads in South Westland. Comparison of the PGA expected with the Alpine Fault and the minimum PGA needed to initiate the serious damage indicated in the damage column indicates that all the listed bridges in South Westland south of Ross are susceptible to damage. Between Ross and Franz Josef, nine bridges will be closed of which three would suffer collapse (a fourth – the Wanganui Bridge at Harihari should be added given its proximity to the fault). All of these bridges are long multi-span structures. South of Franz Josef, there are thirteen bridges which would be shaken sufficiently to cause serious damage requiring closure (14 if the Waiho Bridge is included). Of these, four are likely to collapse.

A.2 Scour and Waterway Screening

The West Coast State Highway bridges have also been screened for bridge scour and waterway risk (Opus, 2009). The 20 most at risk bridges are listed in Table A.2. Some of these bridges are at risk of aggradation, rather than scour. Scour can result in the loss of support to abutments or piers; aggradation can result in loss of waterway with subsequent reduction in waterway capacity to convey flood flows, and may result in the burying of the bridge. Remedial work was planned in 2009 for Wanganui Bridge; this may have been carried out. The table includes the bridges assessed as most at risk at that time. Kellys Creek on SH 73 near Otira scored 36% in 2009, but subsequently has been subject to aggradation that has blocked the road. This underscores the limitations of a screening process, as it is not possible to predict with certainty where an extreme event or significant damage may occur. At Kellys Creek, the primary cause was landsliding in the catchment, remote from the road and the bridge, and it was the subsequent aggradation of the river bed carrying a large sediment supply that resulted in the problem.

Table A.2: SH Bridges with Significant Scour Risk – NZTA Study

Notes:

Y indicates a significant risk
Risk rating provides a relative probability of damage. The derivation of this rating is not given in the report

State Highway		Bridge	Scour	Aggradation	Risk Rating
7	***Reefton - Lewis***	Rough Creek		Y	52%
7	***Reefton – Greymouth***	Inangahua	Y		48
		Devils Creek		Y	52%
		Ongionui Creek	Y		52%
67	***Westport – Seddonville***	Edges Creek		Y	48%
		Waimangaroa		Y	44%
6	***Westport – Greymouth***	Mountain Creek		Y	36
		Fox		Y	48
6	***Greymouth – Hokitika***	Houhou Creek	Y		40
73	***Arthur's Pass - Kumara***	Candys Creek		Y	52% (aggradation)
		Otira	Y		68% (degradation)
		Rocky Creek		Y	52%
6	***Hokitika – Franz Josef***	Mikonui	Y		52%
		Wanganui	Y		72%
		Harold Creek		Y	52%
6	***Franz Josef – Haast***	Waiho		Y	72%
		Boulder Creek	Y		72%
		Bullock Creek		Y	64%
		Paringa	Y		48%
		Haast River	Y		38

A.3 District Council Bridges

Information on District Council bridges that has been sighted in the Asset Management Plans is not so detailed. A *Buller District Council Bridge Criticality and Route Security Assessment* (Aurecon 2009) is reported as listing the following 5 bridges in the top category for route security and failure likelihood (p93 BDC RAMP 2015)

- Little Wanganui Bridge, Karamea Highway (Bridge no. 130)
- Granite Creek Bridge, Karamea Highway (Bridge no. 132)
- Tidal Creek Bridge No 2, Karamea Highway (Bridge no. 128)
- Oparara Bridge, Karamea Kohaihai Road (Bridge no 5)
- Rough River Bridge, Atarau Road (in conjunction with Grey DC)

Details of the vulnerabilities (seismic or scour) are not known.