West Coast Lifelines

Vulnerability and Interdependency Assessment

Executive Summary

West Coast Civil Defence Emergency Management Group

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IMPORTANT NOTES

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1 OVERVIEW

The West Coast of New Zealand is particularly vulnerable to natural disasters. Not only do its geology and topology mean there is a high risk of earthquake and storm events, but also its communities are held together physically by a far-flung network of fragile connections.

The risk – and it is a high risk – of a major earthquake resulting from rupture of the Alpine Fault is well understood. But there could be other major earthquakes such as the historic earthquakes at Murchison, Inangahua and Arthur's Pass. It is impossible to predict the extent, locality and nature of an earthquake – even an Alpine Fault event. All that can be said is that a major event will happen, and that because its nature and location are unknown beforehand, it is necessary to expect the unexpected. This is also true of storms. Major storm events are expected because of the interaction between the predominantly westerly winds and the high Southern Alps. But some storms are particularly severe either because of their immediate intensity or because they cover an unusually wide area. Again, what exactly would happen cannot be predicted. A third type of natural event – a tsunami – is rare but could be devastating to coastal areas.

Thus West Coast communities and their related economies will have to deal with severe naturally-occurring disasters whose unpredictability requires a need for resilience. Community resilience depends on a robust and resilient infrastructure. Accordingly, the prime focus of the present report is on achieving resilient infrastructure.

New Zealand's national emergency management framework divides actions related to an emergency event into four categories: reduction, readiness, response and recovery – the four R's. The first two, reduction and readiness, take place before an emergency event. Reduction includes actions to eliminate risks or reduce their impact. Readiness activities develop capabilities for dealing with the consequences of an event before it happens. The response phase relates to actions during or immediately after an event such as search and rescue, aiming to save life and property and stabilise the situation. Recovery deals with the regeneration of communities and their infrastructure and with returning them to a normal and stable functionality. In terms of post-event activities, most thinking has been directed at the response phase because of the immediate urgency of saving lives and also because this is the time when emergency services are most involved. However, a major lesson from the Christchurch earthquakes is the critical importance of dealing well with the recovery phase. Somewhat arbitrarily recovery can be taken to begin a week after the disaster event, though in practice there will be no clear break between response and recovery. The present report focusses primarily on recovery, and for this reason less emphasis is given here to problems that can be dealt with in the first week or so

following an event. However, focus on recovery necessarily involves involvement in the other three R's. Planning for recovery needs to be done before the event and thus must take place in the context of reduction and readiness, and there will be actions to facilitate recovery that must take place in the response phase immediately following the event.

The report seeks out vulnerabilities and prioritises them according to their importance (the word "vulnerability" is used in this report to mean the converse of resilience). Two bridges, for instance, might be equally vulnerable to earthquake damage, but if one leads to a single farm while damage to the other would cut off half the region, clearly the second bridge is more important. The twin ideas of *vulnerability* and *importance* underlie most of the report.

Vulnerabilities are determined by considering the West Coast and its infrastructure as a complex system, or even system of systems, and then "probing" it to see what happens. The probes in this case are major natural events: an earthquake, a storm and a tsunami. These are applied to the system to see what breaks as it were – a bridge might fail, a town might be flooded, roads might be cut or power and telecommunications might be lost. This gives vulnerabilities, both of individual elements or of parts of the networks – roading, communications and so on – that sustain the Coast.

Importance – that is, the importance of the failure of a piece of infrastructure – will be seen differently by different individuals. Closure of the road over the Karamea Bluff would be seen as vitally important to a Karamea householder, but perhaps less so to someone living in Hokitika. The approach used here is to consider importance in terms of the effect on the West Coast economy as a whole, with the addition of the effect on individual communities. A further simplification is to consider the economic effects of infrastructure failure on only the three most important economic sectors on the Coast: mining, dairying and tourism.

2 RESILIENCE

Resilience is the ability of something to recover from an impact – to bounce back. The impact of an earthquake on a bridge might impair its ability to carry traffic. The degree of resilience of the bridge would be a combination of (a) its ability to withstand and minimise damage, and (b) the length of time needed to return the bridge to full capacity. Thus there are two basic strategies for improving resilience: reducing the likely damage and speeding the recovery. The first requires design for robustness, and the second might be helped by reparability and the availability of equipment to speed recovery. A third important strategy is to provide buffering – to buy time, for instance, by having spares and fuel available. Individuals are advised to have emergency supplies of food and water on hand: this is an example of buffering.

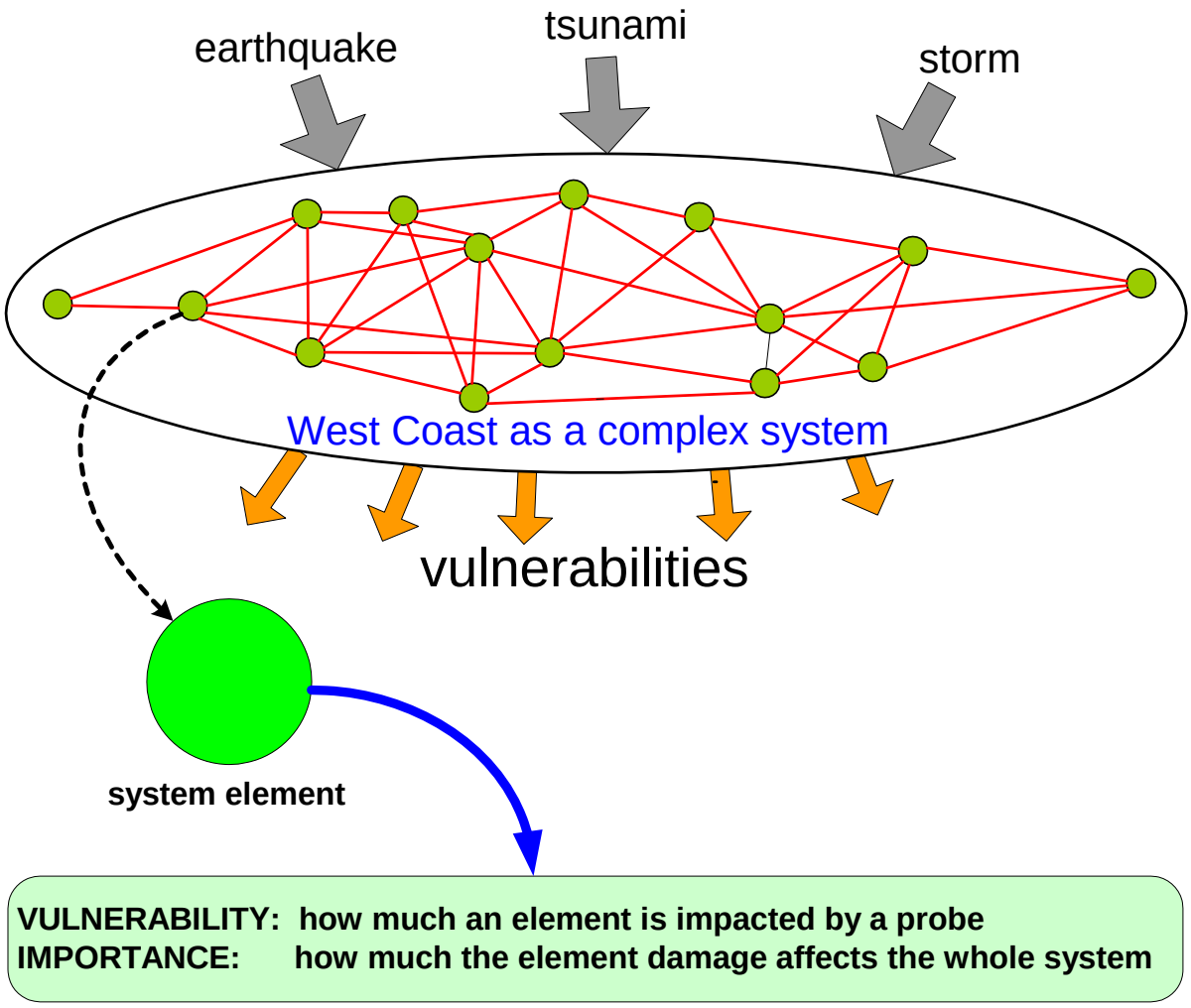
Resilience can apply to physical assets, organisations, communities and individuals.

Resilience requires a specific attitude: an awareness that what will happen will be unexpected no matter how prepared one is, and a fleetness of foot, an agility, to change quickly both personally and organisationally to meet a novel and unexpected situation. Flexibility and creativity are central.

One further point: most assets and organisations that are resilient nevertheless have a limit – a tipping point – beyond which recovery will no longer be possible. It is important to ensure the tipping point is not reached if at all possible. Buffering can help here by buying time.

Supplement 1 to this report gives a more extensive discussion of resilience.

3 PROBING THE SYSTEM WITH MAJOR EVENTS



The diagram shows the West Coast as a system with many interacting elements such as the Karamea area, or Franz Josef township. The system is "probed" by applying three major natural event scenarios: an earthquake, a storm and a tsunami. They are described below. The probing scenarios are used solely for the purpose of determining vulnerabilities – weak spots in the infrastructure where improvements would be useful. They are not in any way to be taken as predictions as to what would actually happen. As noted above, whatever happens will be unexpected, which is the reason for a resilience approach.

The results of the probing are that most of the system elements show vulnerabilities. A major storm event, for example, might cause serious damage in Franz Josef, so identifying its *vulnerability* (the converse of its resilience). The *importance* of the element's damage is the effect of this on the West Coast as a whole – problems at Franz Josef, for instance, would have a serious impact on tourism. The report breaks the region into 29 elements, each of which is assessed for vulnerability and importance for each of the three probing natural event scenarios.

The earthquake scenario is based on the AF8 prediction of an event caused by rupture of the Alpine Fault, with the necessary second scenario of the 1968 Inangahua earthquake to enable vulnerability assessments in areas not greatly affected by an AF event.

Insofar as the general level of design required for the seismic design of structures in New Zealand is for a 500-year earthquake, the probing scenarios for storms and tsunamis also assume 500-year events. A 500-year storm would involve high winds and heavy rainfall, with both impacting on infrastructure in different ways, not only through primary damage and also by preventing access for restoration and repair.

Tsunamis are fortunately rare. They are damaging not only because of flooding and direct flow of water but also because of debris impact. A 500-year event would cause serious damage in coastal areas as well as in Westport, Greymouth and Hokitika.

Some vulnerabilities affecting the West Coast are actually outside the administrative boundary of the West Coast Region – for example, the vulnerability of State Highway 73 to slips at the Waimakariri Bluffs – and this report has extended some lifelines to beyond the region for this reason.

4 LIFELINES

One Merriam-Webster dictionary definition of a lifeline is "something regarded as indispensable for the maintaining or protection of life." In the context of this report, lifelines are the assets and systems that provide foundational services enabling commercial and household functioning. They are owned and operated by lifeline utilities such as the regional and district councils, telecommunications and power companies, the New Zealand Transport Authority (NZTA) and so on. They may be grouped as:

Transport – roading, rail, ports, airports
Telecommunications and broadcasting
Energy – electric power and fuel
Protection – river and coastal protection works
Water and wastewater

The report focusses on all five and their vulnerabilities, though with less emphasis on the last of the five because this has been covered in earlier work and also because, though important, water and wastewater are local rather than broader network lifelines. The first three groups are complex networks connecting the Coast to the rest of the country.

Also essential for community functioning though not directly addressed in this report are supply chains and services maintaining food supplies, medical services and supplies, building supplies, financial services, insurance, governance, emergency services and education among others. Following a disaster event, the initial priorities will include search and rescue and trying to bring lifelines to at least a temporary functionality to allow communities to survive. Permanent repairs will stretch well into the recovery period starting, as noted above, a week or so after the event. However, there must be a prioritisation. Some lifelines will be needed with more immediate urgency than others as the effectiveness of future activities will depend on them. For instance, greatest urgency will have to be given to roading (for access), to telecommunications (for management, coordination and future planning) and to safety assets such as stopbanks. For instance, although earthquake damage to a dairy farm might take months to repair (recovery phase activities), the farmer would want to know the situation as soon as possible after the event so that he could plan ahead and decide whether or not he would have to dry off his herd. The four phases (reduction, readiness, response and recovery) are not independent, with recovery, the focus of this report, depending on what is done in the other three phases.

Lifelines are not independent of each other, and neither can they be seen as independent of other aspects of a functioning community and economy. Two useful concepts are hotspots and pinchpoints. The New Zealand Lifelines Council defines them thus:

- *Hotspots: where a number of critical infrastructure assets from different sectors converge in a single area.*
- *Pinchpoints: significant single points of failure for a network or organisation.*

Examples of hotspots are the Cobden Bridge at Greymouth which carries a major road but also carries a communication link, sewerage and water supply, and the power poles between the Mikonui River and Bold Head which carry both 11kV power and a fibre optic cable. A pinchpoint example would be the Arahura Bridge, whose failure – there is no alternative route – would cut off the whole of South Westland from the north. A pinchpoint need not be a single point – at the time of writing, road traffic from Blenheim and Nelson to the rest of the South Island must all follow SH 6 between Murchison and Kawatiri. There is no other route possible, so closure anywhere within this link would be serious.

A hotspot could also be a town. For instance major damage in Franz Josef could cut not only the road south but also the fibre optic and power links to Fox Glacier; and a major loss of the town's accommodation from building damage or failure of the water supply or wastewater systems would destroy a critical link for tourism.

5 IMPORTANCE: COMMUNITY, ECONOMY, FLOW AND "PIPELINES"

Assessing the relative importance of different vulnerabilities requires an understanding of the West Coast communities and its economy.

The region as a whole is long and narrow, stretching from Kahurangi Point in the north 400km to Jackson Bay and the Cascade River in the south. It is separated from the rest of the South Island by high mountains with only four crossings. Administratively it is broken into three districts: Buller District in the north, Westland District in the south and Grey District between them. The region is relatively sparsely populated with an overall population of about 32,500, the populations of Buller, Grey and Westland Districts being 10,500, 13,500 and 8,500 respectively. The spread-out nature of the Coast means that transportation and communication links are particularly important – and transportation includes roading, rail, air transport and fuel and also power distribution.

The system has many links, and the relative importance of the failure of any one can be estimated from the effect of its failure on the West Coast economy as well as on its individual communities. In 2016 the overall GDP of the Coast was $1,636 million in 2010 prices, with 16,615 filled jobs. The three biggest economic sectors are mining, dairying and tourism, and these three can be taken to stand for the whole. GDP and employment for 2016 in the three sectors is as follows:

	Regional GDP ($M)		Employment	
Mining	207.2	12.7%	685	4.1%
Dairy farming and manufacturing	234.5	14.3%	1528	9.2%
Tourism	111.0	6.8%	2627	15.8%

Roughly speaking, the three sectors together contribute about a third of both the region's GDP and its employment, but whereas the biggest contribution to GDP comes from dairying, tourism is the largest employer.

The relative importance of different lifeline segments depends on the effect of their failure on the regional economy, and more specifically on the effect of lifeline asset failure on the three main economic sectors of mining, dairying and tourism. This is done by introducing the concept of a *virtual pipeline*.

Each of the three economic sectors can be thought of in terms of flow. Slowing or stopping the flow harms the sector. For mining, the flow is a flow of coal (not gold, because its high value-to-volume ratio means that although it is important for the economy, it is less vulnerable to infrastructure failure). The main flow of coal is from the Stockton Mine to the Port of Lyttelton by train. The volume of coal is such that there is no viable alternative means of transport at present. The flow pattern in the dairy industry is more complex. Milk has to be collected from farms throughout the Coast and brought to Hokitika for processing, and there are often alternative routes should a road be closed. The processed product – roughly a thousand tonnes a week – is then shipped from Hokitika to Canterbury by rail. Tourism is also a flow, with tourists travelling from Canterbury down to the glaciers, possibly taking in Punakaiki on the way, and then on south through the Haast Pass to Wanaka and Queenstown.

The "virtual pipeline" comprises all those things needed for maintaining the flow. Take tourism for example. Obviously, tourists need roads to travel on. Almost all also need accommodation as the West Coast loop is too far to traverse in a single day. They also need food and drink, electric power, telecommunication links, toilet facilities, tourist attractions and shops. All these are part of the pipeline, and problems in any one aspect would impinge on the flow. For instance, even if all the roads were passable, the flow would have to stop if there were no accommodation, and it would be seriously affected if there were no tourist attractions – glacier tours and the like – available.

The report therefore considers where and how the mining, dairy and tourism pipelines would be affected by major earthquake, storm or tsunami events being used to probe the system.

6 VULNERABILITY, IMPORTANCE AND IMPROVING RESILIENCE

Prioritising action to improve resilience and reduce recovery time can be seen in terms of their importance to the West Coast economy and community. Mining, dairy and tourism are the main contributors to the economy, and the nature of each can be thought of as flow through a pipeline. The three pipelines together with community needs give a framework for understanding and prioritisation. Resilience is seen in terms of vulnerabilities to three natural hazards: earthquake, storm and tsunami.

The mining pipeline is simple: coal is won, mainly at the Stockton Mine, and is then taken by rail to the Port of Lyttelton. Rail is therefore critical. It is somewhat vulnerable to the slips and washouts caused by storm events but is generally back in operation within a week. A major tsunami would affect the line along the Granity Coast, but again it should not be closed for long. More serious is the effect of a major earthquake. Vulnerable areas are the Lower Buller Gorge and the whole length of line between Stillwater and Springfield, particularly where it runs near the Alpine Fault rupture zone from Rotomanu to Inchbonnie, in the Otira and Bealey Valleys and in the Broken River and Waimakariri Gorges. Many bridges have already been upgraded, but there is no obvious way to deal beforehand with the massive slips and general land instability to be expected in and following a major and widespread event other than to be well-prepared to tackle the problems. Preparedness might entail a review of equipment and resources stationed on the West Coast.

In contrast, the dairying pipeline is highly complex. Milk has to be collected from farms spread over 400km using a rather sparse network of roads. It is processed in Hokitika and the products are shipped out by rail. Major aspects of the pipeline are communication, power (for farms), and roads. Of these, communication and power are sufficiently flexible that they can usually be restored in some fashion fairly quickly, though consideration should be given to improving the ability of local power generation to function in the absence of grid power. Many farmers have their own generators, but reserve fuel supplies are a significant issue. The most critical issue is transportation. Rail is discussed above, but roading needs thought. It is the most important issue because of its vulnerabilities and because restoration takes longer.

The principal aspect of the tourism pipeline is the road loop from Arthur's or the Lewis Pass down the Coast and then across the Haast Pass. The pipeline is of course more than simply roading and needs accommodation and other facilities as well, but these also depend on roading for supply and repair.

Roading is vulnerable to flooding, to tsunami and to slips and landslides due either to heavy rain or to earthquakes. Some potential trouble spots are well known such as the Lake Wanaka section of SH 6, Knights Point, Kellys Creek or the Waimakariri Bluffs, but a major storm or earthquake will inevitably bring unexpected problems.

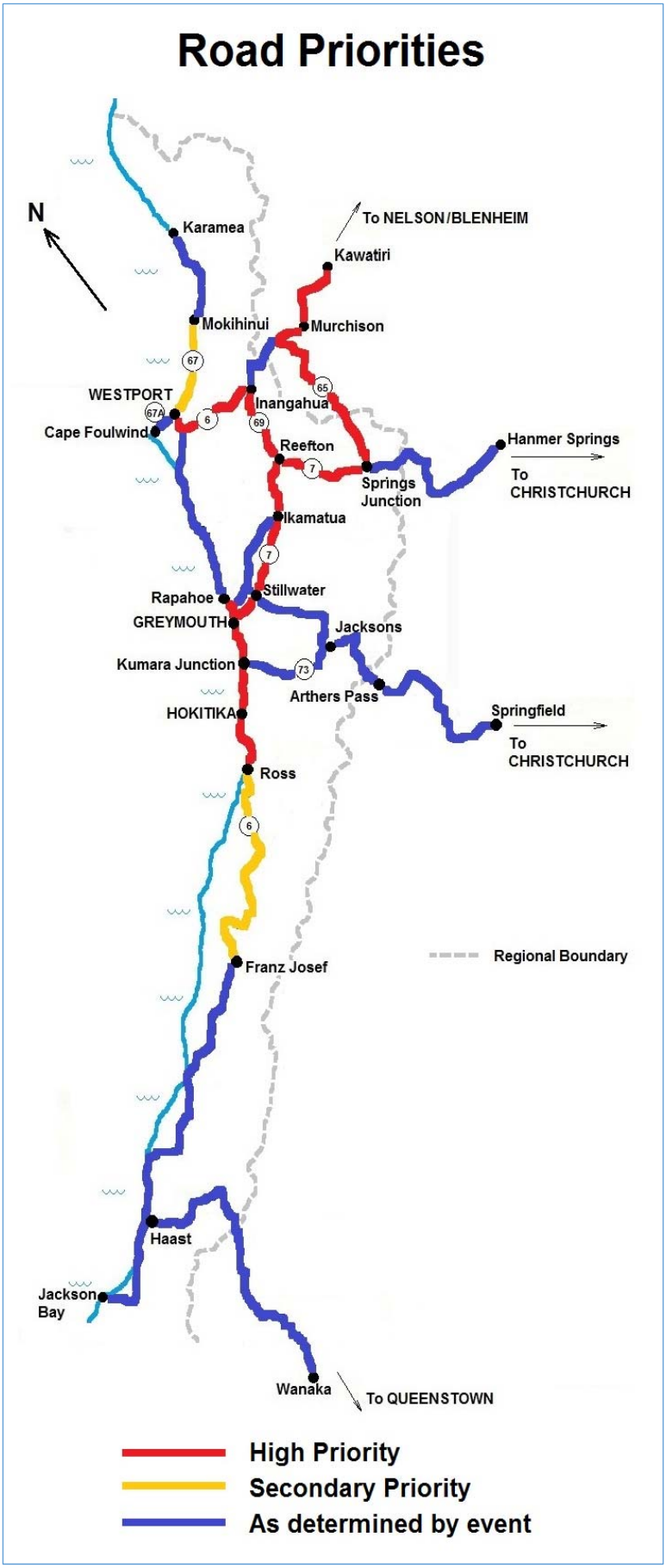
In the mid-north of the region, alternative routes are available in some places and this redundancy improves the overall roading resilience. However, the road from Westport north to Karamea is a dead-end route, and the situation is particularly bad for the Karamea area because the road over the Karamea Bluff is vulnerable to both storm and earthquake damage, with a major earthquake expected to close the road for many weeks. There is no obvious way round this problem as even if the Karamea Airport were made as robust as possible, it would not replace milk tankers[1].

South of the Arahura River, however, there is only one route through South Westland to Haast and Hawea. This is a critical route for tourism and a significant route for dairying. Beyond Ross it traverses challenging countryside and powerful rivers as well as passing near to or across sections of the Alpine Fault rupture zone. It is very vulnerable to major earthquakes and storms, both of which could produce large slips as well as bridge problems.

Essential parts of the dairying and tourist pipelines are communication and power supplies. These are more readily repaired or brought back into service than roading, but nevertheless they are particularly vulnerable in some locations. A major magnitude 8 earthquake would essentially close down dairying and tourism for many months. However, smaller events could also happen. Looking at recovery from, say, a moderate earthquake, one of the first things farmers, tourist operators and indeed almost anyone involved would need to do would be to plan ahead. They would want immediate and timely information, and this means high priority must be given to providing communication links as soon as possible after the event.

[1] There is a proposal to put a road along the route of the Wangapeka Track to connect Little Wanganui with Tapawera. This would solve the problem but would face many hurdles and could be as adversely affected by earthquake as the Karamea Highway.

Looking beyond immediate issues of economic and social recovery, one of the first things required after a major event would be road connection both within the West Coast and between the Coast and the rest of New Zealand. A strategic recommendation is thus to establish a robust central spine of roads either immediately useable after an event or easily and quickly reparable. The red roads in the accompanying diagram represent such a spine. It runs northwards from Ross to Greymouth and then up the Grey Valley to Reefton where it divides, with one arm going to Inangahua then down the Lower Buller Gorge to Westport while the other crosses to Springs Junction before turning north and following the Maruia River to the Buller and up to Murchison and Kawatiri. This road system connects main centres of population (Greymouth, Westport, Hokitika and Reefton) while working towards possible connections to Nelson, Blenheim and Canterbury. The roads marked in red are key and should be made as robust as possible. Next in priority are those shown in yellow, extending the spine south to Franz Josef and north to Karamea. Priority for restoring those other roads shown in blue would be determined by the nature of the event and where restoration would be easiest: down through the Haast Pass, through Arthur's Pass or over the Lewis Pass as seemed most appropriate at the time.



Beyond mining, dairying and tourism which are the main economic contributors, there must also be a focus on the resilience of the community, particularly the larger urban communities of Greymouth, Westport and Hokitika and, in the context of this report, with emphasis on lifeline infrastructure and its performance in the recovery phase. The effects of earthquakes are now becoming more widely understood, but it is of particular concern that the three main centres are likely to have serious flooding resulting from either a major (500-year) storm or a major far-source tsunami. Some centres – Greymouth for instance – are well-protected against normal severe floods, but could still succumb to an even higher flood level. Apart from damage to individual dwellings and businesses, there would be a serious impact on infrastructure such as water supply, sewerage, power and telecommunications. The impact could either be direct, with facilities or capacities overwhelmed, or it could be as a secondary effect resulting from damage to event management capabilities such as communications or records. The general lesson here, of course, is to make sure equipment and records are well-protected, with a Plan B in place and tested.

7 RECOMMENDATIONS

Recommendations are made in three levels. Those in the first set are general with broad application, such as the recommendation about a central roading spine given in the previous section.

In the second level the recommendations are more specific. They are derived from a step-by-step survey of vulnerability and importance across the region, and briefly beyond it where infrastructure failure would directly affect the Coast. The second-level recommendations relate to those West Coast elements where both vulnerability and importance were judged to be very high. The report gives details of the survey.

At the third level the recommendations are local and detailed. They are not given in this executive summary but are confined to the report's supplements, particularly Supplements 10 to 12 which deal with the infrastructure assets of the three West Coast districts, and Supplements 6 to 9 which address other lifelines. Section 8 below lists and describes all Supplements.

Level 1 recommendations are as follows:

1. When considering resilience, three points should be remembered. The first is to expect the unexpected. The second is that quick, flexible and creative response is required – a need to be fleet of foot. The third is to use and enhance buffering wherever possible, to buy time. All three are helped by practice.
2. Consider what can be done to improve the resilience (robustness and reparability) of a central spine of roading, as identified in the previous section.
3. Consider how power from local electricity generation (including diesel) can best be made available and distributed following a disaster which has taken out grid power.

4. Review the adequacy and availability of fuel supplies for recovery, in particular for road repairs and emergency generators.
5. Immediately following a disaster ensure the speedy availability of communication and information to help future planning through the recovery period.
6. Emphasise restoration of the economy, including the three virtual pipelines: mining, dairy and tourism.
7. Consider improving fibre-optic redundancy by installing a cable from Inangahua to Westport.
8. Check infrastructure resilience to flooding in Westport, Greymouth and Hokitika.

Level 2 recommendations are given in Table 1 below.

Table 1: Recommendations – Second Level

No	Description	Lifeline assets	Comments	Recommendations
1	Karamea Bluffs and Mokihinui	Road, power, fibre	Only surface link to Karamea area. Major earthquake would give long outage due to ongoing slips and also debris flow down streams.	Review hardening possibilities in detail, including rerouting, benching, providing passage for stream debris.
2	Westport	Road, rail, power, fibre, water supply, sewage, asset management	Level of destruction from a 500-year storm-related flood would have significant impact on mining, community (local and regional) and to a lesser extent tourism and dairy.	Work to improve flood protection, bearing in mind that though it might deal with most flooding, there would always be the possibility that a 500-year storm might overwhelm the defences. Review infrastructure resilience including management capability.
3	Greymouth	Road, rail, power, fibre, water supply, sewage, asset management	Flood due to 500-year storm would have severe impact on local and regional community and on a number of engineering and support services including hospital. Local infrastructure would suffer and so might telecommunications. Asset management capability could be compromised.	Review infrastructure resilience including management capability on the assumption that some day, the floodwalls would be overtopped.
4	Stillwater to Jackson's	Road, rail, fibre, stopbank	Earthquake damage: shaking, ground rupture, slips, bridges; potentially severe impact on mining, dairy, tourism. Stopbank shearing at Inchbonnie could result in diversion of Taramakau through L. Brunner	Resources available for speedy restoration. Consider doubling width of Inchbonnie stopbank to avoid complete shear rupture.

5	Jackson's to Springfield	Road, rail, fibre, power	Widespread earthquake damage, potentially severe impact on mining, dairy and tourism.	Ensure resources available for speedy restoration. Consider rerouting vulnerable (and awkward) section of SH 73 at Paddy's Bend/Waimakariri Bluffs to follow rail route.
6	Westland Milk Products factory	Earthquake shaking damage	Severe impact on West Coast dairy industry	Earthquake is likely to cause structural damage to the factory buildings and to damage the integrity of the processing and storage facilities. Suggest careful checking of all.
7	Ross to Fox Glacier	Road, power, fibre	Earthquake and storm damage would have great impact on tourism and some impact on dairy. Earthquake would give shaking damage, ground rupture, landslides and bridge damage. Major storm would produce flooding, slips, bridge scour and wind-related damage. Restoration would suffer from access problems.	Resources available for speedy restoration, including availability of temporary bridging. Capability required for rapid damage assessment.
8	Franz Josef and Fox Glacier townships	Road, power, fibre, water supply, sewerage, accommodation	Franz Josef particularly is very vulnerable to earthquake and storm (flood) damage. The two townships are critical points for West Coast tourism.	Every effort should be made to decrease the vulnerability of Franz Josef in particular and to ensure resources are in place to repair damage and restore functionality as quickly as possible.
9	Fox Glacier to Hawea	Road	A major earthquake in this region would produce major damage to infrastructure through shaking ground rupture, landslides and bridge damage. The area is vulnerable to storm damage through flooding, slips and debris flows as well as to wind damage. The road is a critical link for tourism.	Resources available for speedy restoration, including availability of temporary bridging. Capability required for rapid damage assessment. Consider possible means of decreasing road vulnerability at Knights Point.

8 THE REPORT AND ITS SUPPLEMENTS

The report as a whole deals with West Coast lifeline vulnerabilities and how the Coast might respond to a major natural disaster. It is split into the report itself, covering the broad issues, and a series of supplements which go into more detail. The 12 supplements are stand-alone documents in their own right, designed to be read independently according to the reader's particular interests.

The supplements are summarised as follows:

Supplement No.	
1	A short piece on the nature of resilience and on strategies for improving it. For many people, a focus on resilience requires a shift in stance, a change of attitude with an emphasis (the report explains) on black swans. It is background information, and recommended reading for all ages.
2, 3 and 4	Outlines of the three major disaster scenarios used for probing the system and discovering vulnerabilities arising from earthquake, storm and tsunami respectively. Earthquakes are well-trodden ground for most engineers, but the other two may be less familiar in their details.
5	A general discussion on landslides, slips and debris flows, clarifying the distinction between them.
6	A discussion of transportation: road, rail, air and sea together with the relevant infrastructure.
7	This supplement deals with telecommunications – landlines, cell phones and radio communications of different sorts, focussing again on infrastructure as well as functionality.
8	Energy on the West Coast: electric power and its distribution as well as fuel issues.
9	A consideration of regional flood protection infrastructure.
10, 11, 12	Reviews of Buller, Grey and Westland District Council assets respectively.