West Coast Lifelines Vulnerability and Interdependency Assessment

Executive Summary

West Coast Civil Defence Emergency Management Group

June 2017

IMPORTANT NOTES

Disclaimer

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Cover Photo: West Coast. Photo by David Elms

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1 OVERVIEW

The Christchurch and Kaikoura earthquakes had this in common: their nature and consequences were unexpected, as also were the Edgecumbe stop bank failure and the Port Hills fires. For natural disasters, the unexpected is the norm, and to be prepared for the unexpected requires resilience: community resilience and infrastructure resilience.

Thus in looking at the vulnerabilities of West Coast infrastructure, we focus on resilience. We also are particularly concerned with the recovery period after a disaster. There are two distinct phases after an emergency. The first, response, holds the line, so to speak: people are rescued, and action is taken to keep the community functioning at least at a basic level. Lifelines groups, CDEM and others have invested much thought and effort into ensuring that the immediate response will be done well. The second phase, the recovery period, is where the community and its economy are restored to normal functioning. It may take years, and one of the lessons from the Christchurch earthquakes is the importance of managing the recovery phase well. Historically, more thought has been directed at response than at recovery. We try to redress the balance here by focussing on recovery, the period starting a week or so after the initial event.

Resilience is the ability to recover from an initial impact. The smaller the damage and the quicker the recovery, the greater will be the resilience. We can think of the reverse of resilience as being *vulnerability*, particularly if by vulnerability we mean both weakness and low reparability. The report therefore explores West Coast vulnerability to natural disasters, both in detail and in terms of broader systemic or network vulnerabilities. But before being able to make recommendations for improvement, one further step is needed. If cost-effectiveness is the aim, then the cost of an improvement is obvious but effectiveness depends on the value to the community of costs saved by increased resilience. This can be thought of in terms of the *importance* of a piece or segment of infrastructure. A bridge, for instance, might be vulnerable and easily damaged, but if it is unimportant and leads to nowhere, there is no point in bothering about it. On the other hand, if loss of the bridge would be disastrous for the economy of the Coast as a whole, then even if failure would be highly unlikely, monitoring of that bridge would have to be given high priority. Thus the West Coast infrastructure must be analysed for both vulnerability and importance.

The West Coast as a whole must be seen as a system – a large, complex, mutually-interacting and dynamically-changing system of land, rivers, sea, weather, people, homes, industries, services and hopes. The first step for us was to understand it, both its infrastructure and also the nature of its community and economy.

The next step was to try to understand its vulnerabilities, particularly technical vulnerabilities where facilities might be threatened by, for example, a major tsunami. To do this, we followed a standard systems engineering approach. We took the system as a whole and probed it, so to speak, to see what would happen – what would break when pushed hard. We designed a set of hypothetical major disaster scenarios – an earthquake (two in fact), a storm event and a tsunami – and applied them to the Coast and its infrastructure. The results showed up the weaknesses. These probing disasters are not of course meant to be predictions of what would actually happen. They are simply there to find vulnerabilities. However the probing events could also give some idea of the general scale of what might happen in reality.

Lifeline vulnerabilities are not always independent. They come together at hotspots or pinchpoints. A hotspot is where a number of critical infrastructure assets converge on a single point or area, such as a road bridge or a town – Franz Joseph for instance – whose functioning depends on a number of lifelines. A pinchpoint is a significant single point of failure in a network which could have widespread effects. For example, failure of the Arahura Bridge would cut almost the whole of Westland off from the north.

As for importance, we used three ways of assessing it: economy, community and network. The economy is vitally important for recovery and the long-term survival of the West Coast communities. We chose to look at the three most important economic sectors: mining, dairying and tourism, assuming that these three would act as surrogates for the whole. To assess infrastructure importance, we considered how an infrastructure failure – of a bridge for instance – would impact on mining, dairy or tourism. To estimate the impact would first mean assessing needs. For instance, after a major event, dairy farmers would have a vital need for information at an early stage so that they could make planning decisions.

The relative importance of infrastructure segments must also take into account the needs of the local communities. For instance, in terms of the overall West Coast economy the road over the Karamea Bluff might not rate highly, but for the Karamea community it is vitally important.

The West Coast also relies on distributed networks – of roading, for instance, or power or telecommunications. Network effects must be taken into account in assessing infrastructure importance.

Finally, bringing together vulnerability and importance, we could make recommendations regarding possible actions to improve infrastructure resilience.

There is one more thing, though, and it is important: we also make suggestions regarding the nature of resilience, how to think about it and also practical strategies for improving it. Infrastructure resilience is not just a matter of making the hardware robust. The systems involved – the broader infrastructure systems – also require the involvement of people and the broader issues of management, information, communication and economics as well as culture and attitude.

A key concept in thinking about vulnerability and importance is the idea of a virtual pipeline. We do not mean a physical pipe. Lifelines are well-discussed and understood, but now we have to look not so much at technical issues as at the economy and its nature in order to get measures of effectiveness. We can think of mining, dairy and tourism as a series of flows. Coal flows from the mines over to Lyttleton. Milk flows throughout the region to the Westland Milk Products factory in Hokitika, and milk products flow from the factory over the Alps to Canterbury. Tourists flow – travel – through the region in various ways but mainly over a loop from Canterbury to Queenstown via Haast, stopping for the night half-way and visiting attractions on the way.

We can think of these as flows through virtual pipelines. The effect of a natural disaster would be to reduce or stop the flows for a period of time, and the longer the period the more costly the result. What might compromise the flow in a pipeline?

Take tourism, for example. Tourists need roads for their vehicles – cars, buses or campervans. They need communication, especially when they are younger. They need places to stop on the way, to buy food, fuel, souvenirs and what have you, and they need accommodation as it would be difficult to complete the loop in a single day. They also need attractions of various sorts – trips to the glaciers and so forth. All these things are parts of the virtual pipeline through which they flow. Failure of any part will compromise the flow, either (and usually) directly, or at some future date due to reputational damage. If, for example, there is no accommodation at Franz Josef or Fox Glacier, then the flow must stop even though the road is open; and lack of accommodation could be because buildings are damaged but also because there is no water supply. In other words, the integrity of a virtual pipeline will involve a number of different lifelines, damage to any of which could halt the flow. The pipelines are defined terms of needs.

The virtual pipeline idea is also useful in identifying other hindrances such as those arising from regulations or organisational issues. A big lesson from the Christchurch earthquakes is that such problems can be a major impediment to recovery.

2 MINING

Of the three main economic sectors, coal mining relies on the rail system for exporting coal from the West Coast, though a small proportion is used locally as fuel. The virtual pipeline for coal simply consists of the railway. The railway is mostly self-sufficient. It can usually be brought back into action surprisingly quickly after most natural-event problems.

The rail line from Ngakawau to Lyttleton runs over much of the northern West Coast before crossing Arthur's Pass to Canterbury. It is likely that a major earthquake would affect some section of the line. Not all sections would be affected in a single event. Earthquake-generated slips and debris flows might be a problem, particularly in the Lower Buller, near Mt. Alexander and along the Taramakau as well as in the Otira Gorge and Arthur's Pass sections. A large rock avalanche in the Otira Gorge is unlikely but if it did occur there is nothing one could do beforehand. Generally, bridges on the line would be unaffected other than by slips because railway bridge design loadings are governed by train dynamics and not by earthquake loads. However, as the effects of a major earthquake would be widespread, then if a rail bridge failure did occur it might prove difficult to move a spare span from elsewhere to the West Coast. Another earthquake vulnerability would be the northern portal of the Otira Tunnel where a slip above the portal could damage access and ventilation.

As for power, apart from line damage Buller Electricity Ltd (BEL) has a number of substations such as the one at Ngakawau. We believe such facilities are already well-protected against earthquake shaking.

Regarding storms and the coal pipeline, high and prolonged precipitation would result in river flooding and slips. Flooding could scour the line in places causing washouts, it would bring down numerous slips and it could impact bridges through scour and avulsion. There is a threat of debris flow along the Lower Buller Gorge, which is important as road access is limited. There are a number of multi-span bridges up the Grey River valley which could be damaged. The spans are generally of standard lengths and spare spans are kept on hand by KiwiRail.

The main effect of a tsunami on the coal virtual pipeline would be where the line runs close to the sea between Granity and Ngakawau. As well as the rail line, roading and power would also be affected. The rail line should be back in order within two to three weeks. Power is necessary for the mine, and the most vulnerable point would be the BEL substation at Ngakawau which could be both inundated and also damaged by surge debris.

3 DAIRYING

The dairy situation on the West Coast is more complicated than mining. It affects a much wider area, its virtual pipeline is much more a network than a simple chain, it involves both road and rail, and there are two distinct components: the farms and the dairy factory.

For farms, after the immediate practical requirements of rescue and so on after a major disaster, the most important thing will be to decide what to do – whether to dry off the herd and so on – and for this, good information and communication will be vital. The other needs of power, access and supplies are important but secondary. For the dairy factory, though, the most important needs will be for power, water and access.

The nature of the pipeline flow is obvious enough. Milk is brought from the farms by tanker to the Westland Milk Products factory in Hokitika where it is transformed into milk products which are shipped out by rail to Canterbury and beyond. The overall pipeline requires other lifelines beyond road and rail to be in place to allow the flow to happen. We could say that in general the dominant lifeline will be the road network but the most immediately important one will be communications.

4 TOURISM

Most tourists travel in buses, campervans or cars in a loop from Christchurch over the Lewis Pass or Arthur's Pass and then down the Coast either directly through Greymouth or via Punakaiki, to the glaciers and hence to Queenstown via Haast. They might travel in either direction. Many take a longer loop through Murchison to the Nelson – Marlborough region, and a few – a small fraction – might venture further north to Karamea and the Oparara Arches. Because of the length of the route, they need to spend at least one night on the way, generally at Franz Josef or Fox Glacier. The major tourist needs, therefore, are:

- Roads
- Fuel
- Accommodation, which in turn requires:
- Attractions, which are enhanced with things such as:
- Communication

All these are necessary, and if any were missing, the flow of tourists would stop. There might be workarounds for some of the needs on a temporary basis, if for example a sewerage scheme were out of action, but in the long run all would have to be provided.

There will be some points on the pipeline – hotspots – where a number of different services converge. Examples would be the villages of Franz Josef and Fox Glacier.

5 ROADING

For both dairy and tourism, the road network is the dominant lifeline; not so much because it is more necessary than the others as because repairs are more difficult and take longer. In addition, road access facilitates the repair and recovery of other lifelines. We broke the West Coast road system into 26 segments and produced a priority rating for each, based on assessments of vulnerability and importance, with the results shown in the following diagram.

red high priority yellow secondary priority blue as determined by event

Roading priorities

The red-marked roads are those we think should be given highest priority in recovery because they form a central spine, because they are generally less vulnerable and fastest to repair so that they can be used while reconstruction is going on elsewhere and also because they are important for the economy. The yellow segments, from Westport to Mokihinui and from Ross to Franz Josef are given secondary priority, while the blue segments would have to be assessed following a disaster event as to what should be done. The prioritisation takes into account all three probing disasters – earthquake, storm and tsunami.

It would be inappropriate to be more specific than this system-wide characterisation of the road network. People on the ground would know the detailed problems far better than we. For much of the area, alternative routes are possible which helps reduce the vulnerability of the system as a whole. The exceptions are the dead-end road going north from Westport to Kohaihai, and the long road from Hokitika to Hawea.

6 TELECOMMUNICATIONS AND POWER

Telecommunications and power are region-wide lifelines as opposed, for instance, to sewerage or river control whose importance is local. The two lifelines are interconnected in various ways. In some locations, fibre-optic cable and power lines share common poles. This is an instance of a "hotspot", though we find the name misleading – several kilometres of shared poles are hardly a spot. Some telecommunications equipment – cell phone towers for instance – requires an external electrical power supply. Though buffering is in place by way of standby generators or battery backup these arrangements can only supply power for a limited time, unless the generators can be refuelled.

Generally, telecommunication and power service can be restored more quickly than roading damage. On the other hand, the requirement for communication after a disaster is urgent and immediate. While acknowledging the very real needs of others, nevertheless we are primarily concerned with the needs of dairy farmers and tourists. Farmers have to plan what to do following a disaster event and so do tourists, though they also want to let friends and relatives know their situation.

Considering telecommunications first, there is considerable flexibility in the overall system. There is also an ability to make temporary repairs rapidly, with permanent repairs to come later. At the time of the Kaikoura earthquake, normally-competing mobile phone companies were able to work together to get a service up and running, while temporary fibre cable could be laid over the surface of the land by helicopter.

The fibre-optic network is in the form of a star, centred on Greymouth. Four fibre cables run from Greymouth: northwards to Karamea and beyond via the coast road through Westport; southwards to Fox Glacier; to the northeast via Reefton, Springs Junction and Murchison; and to the southeast via the Arnold Valley, Moana, Inchbonnie and Arthur's Pass. Cellphone towers are connected to the fibre network and rely on it for connection beyond the West Coast.

For a major earthquake, there will probably be many breaks in the cable network. Quite apart from damage due to slips and ground movement, the route from Greymouth to Christchurch has 33 bridges and that from Greymouth to Nelson 37 bridges within the West Coast Region. For most earthquakes it is unlikely that both routes are equally damaged, so recovery would initially involve repairing the least damaged route. Repair could take up to a week, depending as ever on the size and location of the earthquake.

Along the coast to the north and south, in most places the fibre cable is supported on power poles. We see the most vulnerable section as the cable following the coast road from Greymouth to Westport. It is vulnerable to all three hazards: earthquake, storm and tsunami. The road is also vulnerable so access would be a problem. Further north, both fibre and power are vulnerable over the Karamea Bluff to earthquake or storm-related damage, and on the low-lying coast from Granity to Mokihinui and Little Wanganui to Karamea it is vulnerable to damage from storm or tsunami.

To the south there are multiple threats to the fibre cable from earthquake and flood as it crosses steep country and big rivers. There is also a threat from tsunami where fibre and power are close to the coast between Ross and Bold Head.

Like telecommunications, a number of players are involved in providing power on the West Coast. Transpower has a target of 5 days to get power back to the Coast following a major earthquake, presumably with a shorter time for storm-related outage.

To the north, BEL provides electricity from Meybille Bay to Karamea and beyond. There is virtually no redundancy in the network, but a buffering strategy exists in a standby generator in Karamea and a trailer-mounted diesel generator. The two substations at Ngakawau and Kongahu are both vulnerable to inundation from tsunami and possibly storm surge, with the former also involving a greater risk of physical damage from debris. Physical access to the line following a major storm might be a significant problem, particularly over the Karamea Bluff.

The Westpower network delivers power to most of the rest of the Coast apart from in the far south where NZ Electricity Ltd operates an independent network, and in the east where Network Tasman supplies power up the Maruia Valley to Springs Junction. There is widespread vulnerability to major events, but no single vulnerability setting itself apart with the exception perhaps being the section of line between Ross and Bold Head which appears vulnerable to tsunami.

There are a number of small hydro stations on the West Coast. Normally, except in Haast, they feed into the grid. However, most cannot operate independently of the grid or at least of another supply as they require them for synchronisation. Thus the integrity of those that can provide synchronisation is important.

7 COMMUNITY

To this point we have focussed on the needs of mining, dairying and tourism, currently the three main industries on the West Coast. This has meant an emphasis on the network lifelines of transport (road and rail), telecommunications and power. But the Coast is not made up of these three industries alone. To get a balanced view of vulnerabilities and resilience we must also consider individuals and communities, particularly the latter.

A local community has needs other than those we have already taken into account. Consider any Coast community. Take Moana for example, and the smaller communities around it such as Rotomanu. Families living there will need basic services of water, sewerage and so on, and they will require road access for many reasons such as daily school attendance by their children. Their needs should be significant drivers of any proposals for action to increase lifeline resilience.

There are locations on the Coast that are particularly vulnerable to being isolated for weeks or even more than a month; Karamea due to earthquake, storm damage to the Karamea Bluff road or tsunami damage to SH 67 between Westport and Ngakawau. South of Ross there is potential for communities to be divided up into a series of “islands” by major damage from earthquake, storm or tsunami events to infrastructure particularly the state highway.

We will not pursue this line of thinking further at this point. Among other things we do not think it would add to what we explored in earlier reports. However, this should be taken to mean we do not think local communities are important. Far from it. One of the major lessons from the Christchurch earthquakes was the importance of strong community organisation and morale in a disaster. Strong groups such as Lyttelton survived well despite extensive damage, but loose-knit communities found recovery harder going by far.

8 FUEL

Response and recovery will require many resources. However one of the most important resources will be fuel; fuel to power generators, to operate machinery to clear roads and undertake other repairs, and for cooking and heating. Consideration should be given to strategically locating buffer fuel storage in areas more vulnerable to being isolated. The buffers could operate as self-serve fuel stations during peace time but with large fuel storage.

9 THE REPORT

The full report on West Coast lifeline vulnerabilities is very large, reflecting the complexity of the Coast and the many different aspects of its nature and how it might respond to a major natural disaster. No one, or at least, very few, would want to read all of it. Accordingly it has been split into 13 separate volumes to reflect different interests.

- Volume 1 is the main report and covers all the issues, sometimes summarising results and leaving details to other volumes.
- Volume 2 is 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.
- Volumes 3, 4 and 5 outline the major disaster scenarios used for probing the system and discovering vulnerabilities. They deal with earthquake, storm and tsunami respectively. Earthquakes are well-trodden ground for most engineers, but perhaps the other two are less familiar in their details.
- Volume 6 is a general discussion on landslides, slips and debris flows and clarifies the distinction between them.
- Volume 7 discusses transportation: road, rail, air and sea, and the relevant infrastructure.
- Volume 8 deals with telecommunications – landlines, cell phones and radio communications of different sorts, focussing again on infrastructure as well as functionality.
- Volume 9 addresses energy: electric power and its distribution as well as fuel issues.
- Volume 10 considers regional flood protection infrastructure.
- Volumes 11, 12 and 13 review Buller, Grey and Westland District Council assets respectively.

10 RECOMMENDATIONS

Here are some of our main recommendations. Others are more detailed and will be found in various volumes of the report, particularly in Volume 1.

- Work could be done above the north portal of the Otira rail tunnel to reduce the likelihood of damaging slips that could block the tunnel and impact on the ventilation fan facilities.
- Consideration should be given to keeping a spare rail bridge span permanently at some location on the Coast.
- We recommend that, if it has not already been done, that the railway line along the Lower Buller Gorge and the country above it be checked for the likelihood of debris flows.
- KiwiRail could permanently station at least one hi-rail digger on the Coast.
- We recommend the roading sector resilience be prioritised, as discussed above, with effort being directed at what is in effect a prioritised central spine.
- The case should be investigated for a fibre-optic cable link from Inangahua to Westport.
- Consideration should be given as to how much fuel should be kept on site for the Karamea standby generator.
- The two BEL substations at Ngakawau and Kongahu appear vulnerable to inundation and debris damage from tsunami. We recommend that these vulnerabilities be investigated and if necessary addressed. Surrounding the substation with a stout block wall or bund could give protection in such a situation and could be a worthwhile investment.
- The need for external synchronisation of many of the West Coast hydro power stations is a vulnerability. If more stations can be converted to operate without external synchronisation and if vulnerabilities to earthquake and storm damage of those plants that are already able to operate alone are reduced, the overall vulnerability of the power system is reduced.
- Consideration should be given to strategically locating buffer fuel storage in areas more vulnerable to being isolated.

Some general principles should also be considered:

- Dependency on single supply lines is often a given reality, but where possible, the more redundancy that exists in a system, that is, the more alternative supply channels there are, then the more resilient is the system and the shorter is the time needed for recovery. Economics might suggest a single water source to a water supply system, for instance, but alternative sources can provide a greater security of supply. Both the Hokitika and Westport water supplies have had alternative sources added in the last ten years primarily to meet demand, but they also provide resilience for other natural disasters.
- Infrastructure should be constructed robustly so that it is less vulnerable to damage. Some of this can be done at little cost, such as looping cable at bridge abutments so that if there is movement between fill and bridge, there is capacity in the cable to accommodate the displacement. Other cases may be more expensive such as raising the deck level of a new

bridge to allow for river aggradation. But always it is a useful exercise to ask the question "what if?" throughout the design process from concept to completion.

- Thought should be given to low-cost high-benefit ways of improving resilience. Two examples would be to install stay cables on the Karangahua suspension bridge to prevent wind motion, and to double the width of the Inchbonnie stop bank so that shearing due to Alpine Fault rupture would be unlikely to lead to a complete break of the stop bank.
- Reparability is important. Damage will happen in a natural disaster, and in terms of recovery, if the damage can be easily repaired then the consequences will be reduced. Following a major disaster, normal supply chains and access to specialist workers will be greatly disrupted. It is clear from our disaster "probing" that some parts of the West Coast region can expect to be semi-isolated for quite long periods of time after a large natural disaster. Thus if damage can be repaired by whatever skills, material and plant are available locally, the recovery will be enhanced. Initial design must take this into account. For instance, an oxidation pond is essentially a simple structure that can be repaired with some machines and suitable soils if breached, whereas a sophisticated and complex package sewage treatment plant may need replacement components and skills that have to be sourced from outside the region.
- Insofar as we do not know the precise nature and extent of a natural disaster beforehand and whatever happens will always differ from expectations, resilient infrastructure should be resilient against any untoward happening. It should not focus on a specific event. It is a matter of expecting the unexpected. Two things follow from this. Firstly, there is a requirement of *awareness* – awareness of what is actually happening. In practice this might, for example, lead to a regular inspection of infrastructure elements, or to using data-gathering techniques to monitor vulnerabilities. Secondly, resilience requires speed – *fleetness of foot* – to be able to deal with the situation, whatever it may be, with speed and versatility. For example, recovery times might be shortened by having spares available locally. Generally, speed at the time means being prepared beforehand.