Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Memo

Date	7 May 2020
To	Trevor Ellis, Development Planning Manager, Waimakariri District Council Andrew Willis, Planning Matters
CC	Nick Griffiths, Hazards Team Leader, Environment Canterbury Sam Leonard, Senior Planner, Environment Canterbury
From	Helen Jack, Senior Scientist, Environment Canterbury

Using earthquake fault information in the Waimakariri District Plan review

1. Introduction

Waimakariri District Council are reviewing their District Plan. I recommend that earthquake fault information and provisions are incorporated into the District Plan to reduce the risk of damage from surface fault rupture.

Surface fault rupture is a different, and less common, earthquake hazard from earthquake shaking. It is the permanent ripping and warping of the ground surface along a fault as the ground on one side moves sideways and/or up relative to ground on the other side during an earthquake on that fault. Surface fault rupture will generally only occur when the earthquake on a fault is magnitude 7 or larger; in smaller earthquakes the movement on the fault is usually entirely underground and does not reach the ground surface.

Surface fault rupture caused damage to houses and infrastructure during the 2010 Darfield (Canterbury) earthquake and the 2016 Kaikoura-Hurunui earthquake (see Figures 1 and 2).

Figures 1 and 2: Kekerengu (above) and Papatea (right) fault ruptures during the 2016 Kaikoura-Hurunui earthquake.

The ripping and buckling of the ground from movement on a fault only affects a narrow area of land a few tens to a few hundreds of metres wide along the fault. If we know where faults are, we can avoid or manage development in those areas to reduce the likelihood of houses or infrastructure being damaged in future earthquakes on those faults.

‘Active faults’ are defined as faults that have moved within the last 125,000 years and could move again in future, causing an earthquake and possible surface fault rupture.

The strong shaking created when a fault moves (the ‘earthquake’ itself) affects a much wider area than the fault rupture. It is hard to avoid strong shaking at some point in a building's life in New Zealand. Earthquake shaking is therefore dealt with through the Building Act 2004 and the Building Code, which ensures that our buildings are constructed to be strong and flexible to withstand strong shaking.

2. District active fault mapping

Environment Canterbury commissioned GNS Science to map known and suspected active faults in Waimakariri District in 2013 as part of a regional fault mapping programme. The report *General distribution and characteristics of active faults and folds in the Waimakariri District, North Canterbury* was provided to Waimakariri District Council in November 2013 and is available on the Environment Canterbury website at https://api.ecan.govt.nz/TrimPublicAPI/documents/download/1811999.

The project compiled and reviewed existing 1:250,000 scale fault information. It did not involve new field mapping. Each fault was assigned a:

- certainty – how certain it is that the mapped feature is actually a fault: definite, likely or possible;
- surface form – how easy it is to see the fault at the ground surface: well-expressed, moderately-expressed or not expressed; and
- recurrence interval – the long-term average time between earthquakes on the fault, usually expressed as a range spanning several thousand years.

In 2019 Environment Canterbury commissioned GNS Science to review the 2013 information as part of the Waimakariri District Plan review process. The review included assessing and incorporating new information from University of Canterbury student research, as well as reassessing the information on the Starvation Hill fault at Oxford and the Rangiora monocline. This resulted in small refinements to the location of the Ellis fault near Cust and Lees Valley Fault. The Rangiora monocline was removed from the dataset after further analysis of lidar showed other, more plausible, explanations for the topographic rise. The location and characteristics of the Starvation Hill fault through Oxford remained unchanged; recent seismic reflection profiles of the fault at depth do not provide any further clarity on its position at the ground surface nor its recurrence interval. The review letter report from GNS Science was provided to Waimakariri District Council on 29 October 2019.

Most of the faults mapped in Waimakariri District are in the sparsely populated hilly areas of the Puketeraki and Mt Oxford/Mt Thomas ranges, however there are some mapped faults on the upper Canterbury Plains. Recurrence intervals of the faults range from as low as 1200 years to as much as 30,000 years. For context, fault recurrence intervals in New Zealand range from a few hundred years (e.g. Alpine Fault, Hope Fault) to many tens of thousands of years (e.g. the Greendale Fault that caused the 2010 Canterbury earthquake).

3. Fault awareness areas

The Ministry for the Environment guidelines *Planning for development of land on or close to active faults* ('the MfE guidelines') recommend mapping faults at 1:35,000 or better and delineating fault avoidance zones around these faults within which development should be managed to reduce the risk of damage from surface fault rupture.

Mapping faults at this level of detail is expensive. The cost of mapping all the earthquake faults in Canterbury – many of which are in sparsely populated areas – to this level of detail is difficult to justify in most places. Detailed mapping of faults has, to date, been focussed on the most active faults near developed areas, for example the Hanmer Fault at Hanmer Springs, the Hope Fault Zone at Mt Lyford Village and Kaikoura, the Ashley Fault Zone north of Rangiora and the Ostler Fault Zone at Twizel.

The regional-scale 1:250,000 fault mapping in the Waimakariri District fault report is not detailed enough to be able to apply the MfE guidelines directly using fault avoidance zones. However, the 1:250,000-scale fault information is still useful because it shows councils, developers, landowners or prospective buyers the general location of faults and it highlights locations where more detailed investigations could or should be undertaken for certain developments.

GNS Science and Environment Canterbury developed guidelines for using the 1:250,000 fault information in 2016. These recommend creating fault awareness areas, rather than fault avoidance zones, around the 1:250,000 fault information. The width of the fault awareness areas – either 125 m or 250 m either side of the fault – depends on the certainty and surface form of the fault. This 125 m or 250 m buffer accounts for the inaccuracies involved in mapping at 1:250,000 scale, and also the possibility that future fault ruptures and associated ground deformation could occur away from the mapped areas of previous fault rupture deformation, as was seen during the 2016 Hurunui-Kaikoura earthquake.

The GNS Science/Environment Canterbury guidelines are available on the Environment Canterbury website at https://api.ecan.govt.nz/TrimPublicAPI/documents/download/2147172. The guidelines can be modified to suit individual districts' requirements.

Fault awareness areas were developed for all faults in Canterbury by Environment Canterbury and this dataset was provided to Waimakariri District Council in March 2018. The fault awareness areas, which were updated in 2019 with the new information for Waimakariri District (and some new information for Kaikoura District), can be viewed on Canterbury Maps at https://mapviewer.canterburymaps.govt.nz/?webmap=f716b840dc434c009e8f74f644a271d6 and downloaded at https://opendata.canterburymaps.govt.nz/datasets/canterbury-fault-awareness-areas-2019. The Waimakariri fault awareness areas are shown in Figure 3 (the Ashley Fault Zone north of Rangiora is not included because it has been mapped in more detail – see Figure 4).

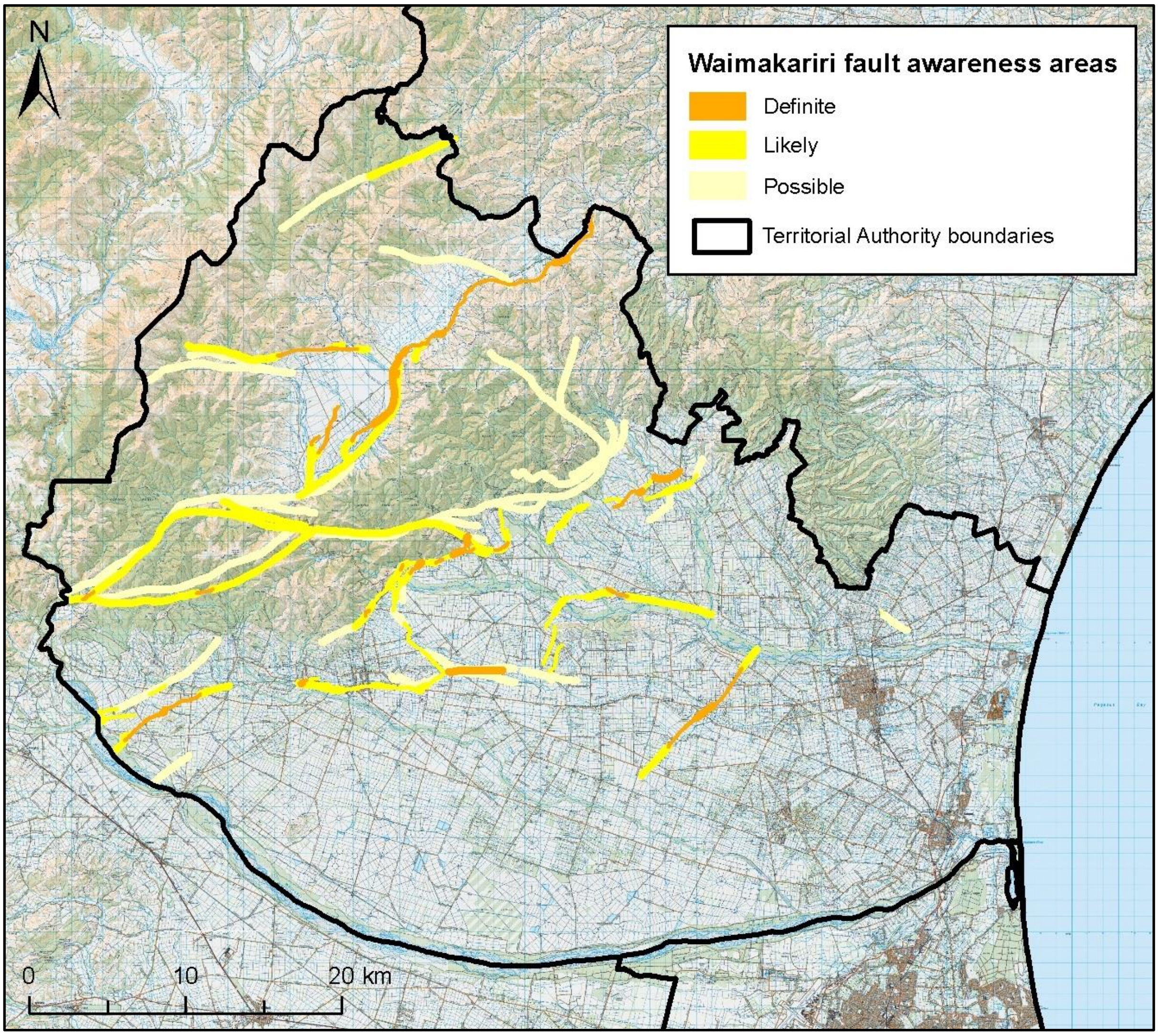

Figure 3: Fault awareness areas in Waimakariri District based on faults and folds mapped by GNS Science in 2013 and updated in 2019. (The Ashley Fault Zone north of Rangiora is not included because it has been mapped in more detail – see Figure 4.)

4. Ashley fault avoidance zone mapping

Following the 2013 Waimakariri fault report, Environment Canterbury commissioned GNS Science to undertake more detailed mapping of the Ashley Fault Zone north of Rangiora, and to develop fault avoidance zones for the fault zone. The Ashley/Loburn area had potential for further subdivision and the long-term activity of the Ashley Fault Zone was not well known, so further investigation of this 'higher risk' fault was justified.

The mapping showed several areas of well-defined and distributed fault rupture deformation varying in width from 15 metres to 120 metres. A fault avoidance zone was created by placing a 20 metre buffer around the well-defined and distributed fault rupture deformation areas, as per the MfE guidelines (see Figure 4). The fault avoidance zone also included uncertain fault rupture deformation areas, where there is evidence of tilting during past earthquakes or where the fault probably continues but cannot be seen, however a 20 metre buffer was not applied to these areas because "the precision of mapping is not sufficient to warrant defining a set-back on the ‘uncertain’ deformation areas”. The GNS Science report recommended restrictions on new development, which are discussed below.

The evidence showed that the Ashley Fault Zone has a recurrence interval of 7,000-15,000 years (possibly as short at 5,000 years), which was longer than previously thought. It was assigned a most likely recurrence interval class of IV (5,000-10,000 years), as per the MfE guidelines.

This GNS Science report was provided to Waimakariri District Council in May 2015 and is available on the Environment Canterbury website at https://api.ecan.govt.nz/TrimPublicAPI/documents/download/2147181. The fault avoidance zones, and other mapped features, can be viewed on Canterbury Maps at https://mapviewer.canterburymaps.govt.nz/?webmap=f716b840dc434c009e8f74f644a271d6 and downloaded at https://opendata.canterburymaps.govt.nz/datasets/ashley-fault-avoidance-zone-2020. This is an updated fault avoidance zone dataset (based on the original mapping) that contains the well-defined and distributed fault deformation areas with a 20 metre buffer, and the extended and uncertain fault deformation areas without a 20 metre buffer (because the precision of mapping was not sufficient to warrant a buffer, as explained above). The joins between the polygons have been manually adjusted to smooth out sharp steps in the fault avoidance zone caused by applying a 20 metre buffer on some areas and not others. I have supplied a GIS shapefile of this updated 2020 Ashley fault avoidance zone dataset with this memo.

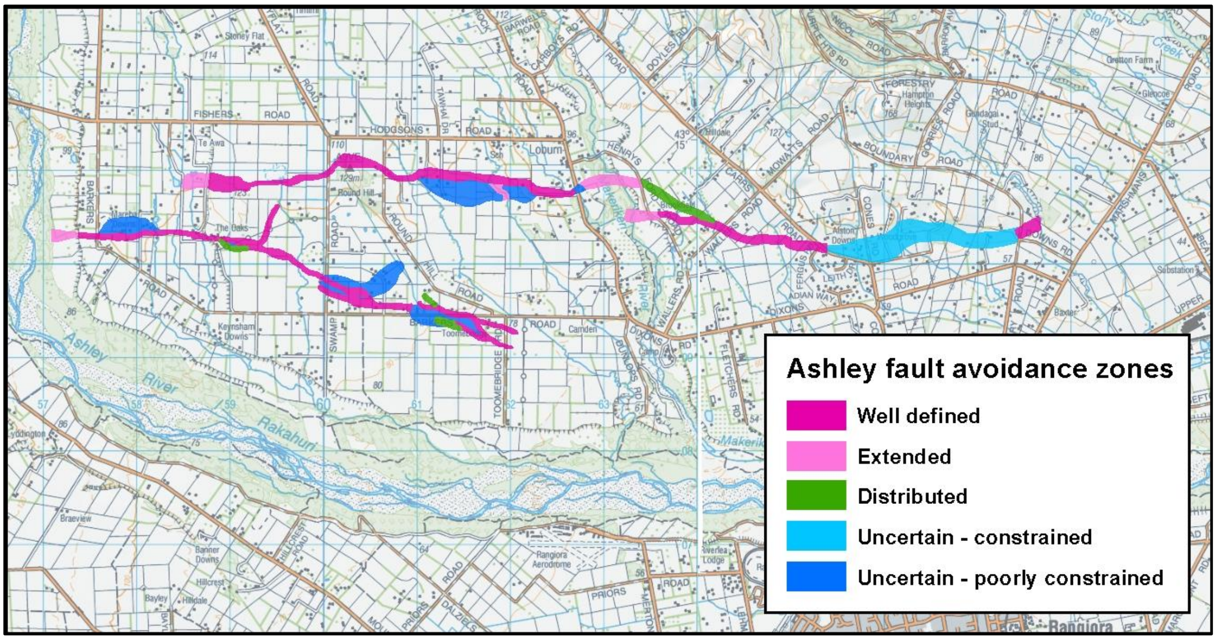

Figure 4: Fault avoidance zones for the Ashley Fault Zone, Ashley-Loburn, mapped by GNS Science in 2014. (Topomap grid lines are 1km apart.)

5. Suggested provisions within the Ashley fault avoidance zone

The MfE guidelines recommend a risk-based approach where development is managed within fault avoidance zones depending on both the activity of the fault (its recurrence interval, or long-term average time between earthquakes) and the type of proposed development (the Building Importance Level from the Building Code).

GNS Science provided recommended resource consent categories within the Ashley fault avoidance zones in 2014, which were based on recommended resource consent categories for recurrence interval class IV (5,000-10,000 years) faults in the MfE guidelines. GNS Science's recommended resource consent categories are shown in Table 1.

Building Importance Level	**1**	**2a**	**2b**	**3**	**4**
Fault complexity	**Resource consent category**				
Well-defined and distributed	Permitted	Permitted*	Permitted*	*Non-complying+*	Non-complying
Uncertain	Permitted	Permitted	Permitted	*Discretionary ++*	Non-complying
* Could be controlled or discretionary given that the fault location is well-defined. + Or Permitted or discretionary, for developed and already subdivided sites. ++ Or Permitted, for developed and already subdivided sites. *Italics* show that the activity status is more flexible. For example, where *discretionary* is indicated, controlled activity status may be considered more suitable.					

Table 1: GNS Science's recommended resource consent categories for the Ashely fault avoidance zones based on recommendations in the Ministry for the Environment's *Planning for development of land on or close to active faults*.

Building Importance Levels are as follows:

- Level 1: Structures presenting a low degree of hazard to life or property, such as walkways, outbuildings, fences and walls.
- Level 2a: Timber-framed houses.
- Level 2b: Larger structures such as car parking buildings or office buildings.
- Level 3: Structures that may contain crowds, have contents of high value to the community or pose a risk to large numbers of people in close proximity, such as conference centres, stadiums and airport terminals.
- Level 4: Buildings that must be operational immediately after an earthquake or other disastrous event, such as emergency shelters and hospital operating theatres, triage centres and other critical post-disaster infrastructure.
- Level 5 (not included in the MfE guidelines): Structures whose failure poses a catastrophic risk to a large area or a large number of people, such as dams, nuclear facilities or biological containment centres.

More examples of structures within each level are given in Clause A3 of the Building Code (http://www.legislation.govt.nz/regulation/public/1992/0150/latest/DLM162576.html#DLM4417717)

GNS Science also provided recommended resource consent categories for recurrence interval class III (3,500-5,000 years), given the uncertainty around the recurrence interval of the Ashley Fault Zone. The only difference from Table 1 above is that Building Importance Level 2b buildings also become *Non-complying+* and *Discretionary++* for well-defined/distributed and uncertain fault avoidance zones respectively.

Subdivision and residential buildings

GNS Science recommended (based on the MfE guidelines) that individual habitable buildings can be permitted within the Ashley fault avoidance zones, but they could be controlled or discretionary within the well-defined and distributed fault avoidance zones given that the location of the fault is well constrained in those zones.

Given these recommendations, one approach could be to permit individual habitable buildings in the uncertain fault avoidance zones but make the construction of new individual habitable buildings in the well-defined and distributed fault avoidance zones a discretionary activity.

Another, less onerous, approach could be to permit individual habitable buildings in the fault avoidance zones in areas that have already been subdivided and there is an expectation to be able to build, but have controls in place for any new subdivision within the fault avoidance zones to require:

- lots with building platforms that are outside the well-defined and distributed fault avoidance zones.
- more detailed mapping within the uncertain and extended fault avoidance zones to better determine the fault rupture hazard and to either apply set backs for building platforms or require engineering solutions (e.g. Technical Category 2 equivalent foundations to mitigate the effects of minor ground deformation in the uncertain-poorly constrained areas where there is past evidence of 'slight tilting') based on the results of that investigation.

Important or critical infrastructure or facilities

GNS Science recommended, based on the MfE guidelines, that proposed BIL 3 and 4 (and 5) structures are non-complying, discretionary, or in some cases permitted within the Ashley fault avoidance zone, depending on the BIL, the fault complexity and whether the activity is occurring in a Greenfield or already subdivided area.

The resource consent categories recommended in the MfE guidelines are complex and were developed primarily with urban areas in mind. Because the Ashley-Loburn area is a lightly-populated rural residential area, land parcels are generally big enough that faults can be avoided, and major infrastructure or other developments are unlikely, I suggest a simplified approach to BIL 3, 4 and 5 structures: that all proposed BIL 3, 4 and 5 structures within the Ashley fault avoidance zone be treated as either all discretionary *or* all non-complying activities, regardless of fault complexity or whether the site is Greenfield or already developed. If discretionary, BIL 3, 4 and 5 structures could be allowed if it can be shown that the fault rupture hazard can be mitigated through engineering measures.

6. Suggested provisions within fault awareness areas

Based on the 2016 GNS Science/Environment Canterbury fault guidelines, I recommend that provisions are included in the proposed Waimakariri District Plan to manage future subdivision and the development of important or critical infrastructure and facilities within the fault awareness areas.

Subdivision

The 2016 GNS Science/Environment Canterbury fault guidelines recommend that if a new subdivision consent application is received proposing development within a fault awareness area of a definite (well-expressed or moderately-expressed) or likely (well-expressed or moderately-expressed) fault, that the applicant is required to map the zone of deformation associated with fault rupture at a scale of 1:35,000 or better (preferably 1:10,000 or better) to create fault avoidance zones as per the Ministry for the Environment fault guidelines, i.e. the zone of fault deformation plus a 20 metre buffer. Any building sites should be set back from the fault avoidance zone. This can be achieved through methods such as the land parcels being set back from the fault avoidance zone or, if the land parcels do include part of the fault avoidance zone, a consent notice that ensures the building setback is enforced when the subdivision is completed.

I suggest that this approach is adopted and that the requirement to map any fault deformation also applies to some small lengths of definite (not expressed) and likely (not expressed) fault awareness area where they link two definite (well-expressed or moderately-expressed) or likely (well-expressed or moderately-expressed) fault awareness areas on the following faults:

- Springbank monocline
- Starvation Hill fault (western end)
- Ashley Fault (west)
- View Hill Fault Zone
- Knowles Top fault zone
- Mt Lawry fault zone
- Lees Valley Fault

I suggest these fault awareness areas are included because while they are classified as 'not-expressed' the fault is definitely present but may, for example, have been eroded by a stream or covered in landslide debris since the last movement, and the fault rupture hazard should still be considered as part of a subdivision consent. I suggest these small lengths of definite (not expressed) and likely (not expressed) fault awareness area have their width reduced to be the same as the definite (well-expressed or moderately-expressed) and likely (well-expressed or moderately-expressed) fault awareness areas on either side (total width 250 metres) as it is unlikely that the actual location of the fault trace deviates from the adjacent definite (well-expressed or moderately-expressed) and likely (well-expressed or moderately-expressed) fault awareness areas.

This overlay could be called the fault hazard (subdivision) overlay, or similar, and is shown in Figure 5. I have supplied a GIS shapefile of this suggested overlay with this memo. The attribute fields of the shapefile have been simplified to only include the fault name, certainty and surface form and recurrence interval information. Other, more technical fault attributes, such as fault dip, can be found in the 2019 Canterbury Fault Awareness Area dataset that this shapefile was extracted from.

The GNS Science/Environment Canterbury guidelines state that there can be some discretion in this provision around the size or nature of the proposed subdivision, i.e. it may only apply to subdivisions over a certain size or involving a certain number of lots. Also, detailed fault mapping should not be required for areas of the proposed subdivision that are not within the fault hazard (subdivision) overlay.

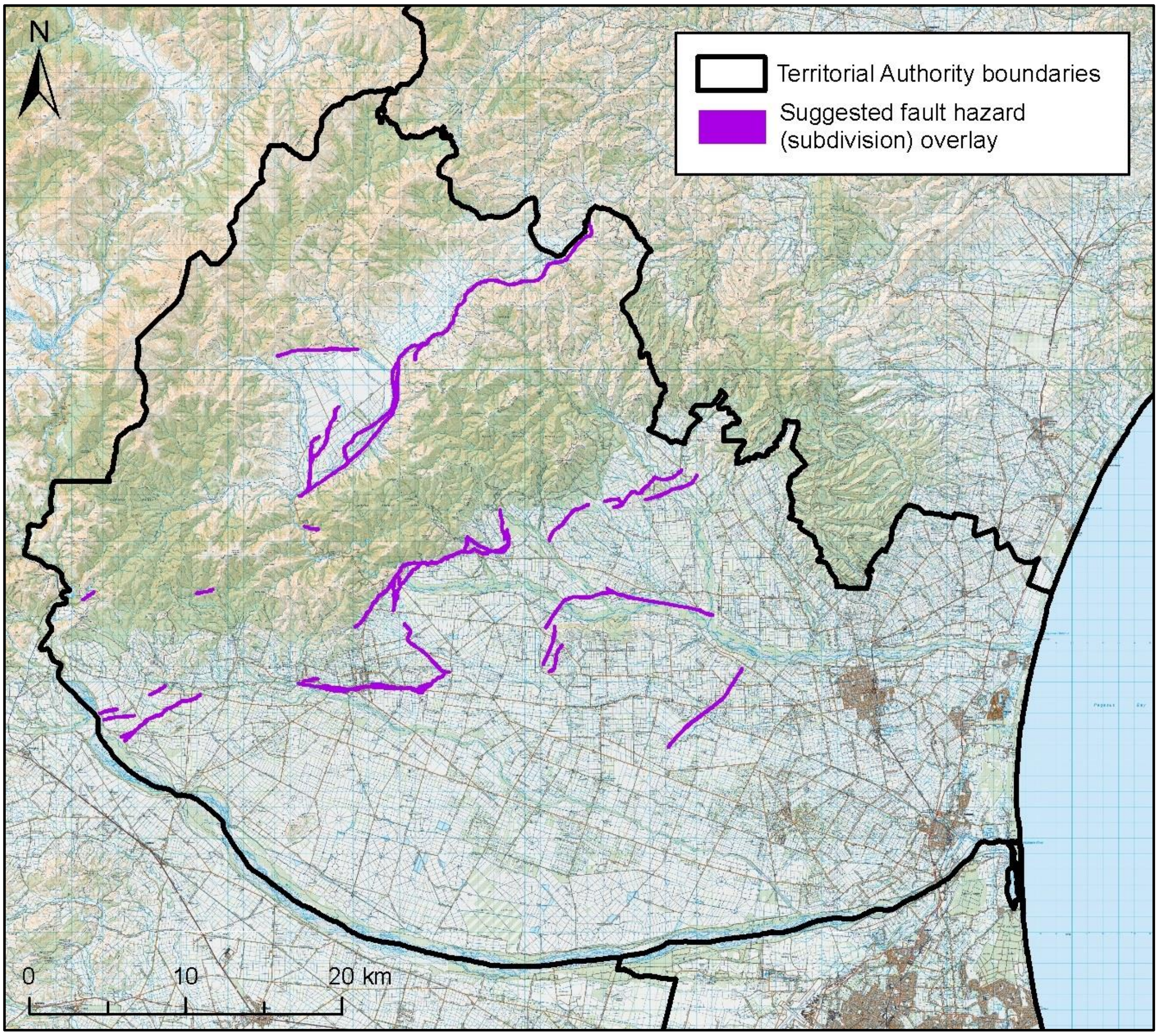

Figure 5: Suggested fault hazard (subdivision) overlay for Waimakariri District, based mainly on definite and likely, moderately- and well-expressed fault awareness areas.

Important or critical infrastructure or facilities

Important or critical infrastructure or facilities usually require a resource consent for other reasons. I suggest that one of the matters of assessment or discretion, if the proposed activity falls within any fault awareness area (including those where the fault is considered 'possible' and/or is not well expressed at the ground surface), should be whether the surface fault rupture hazard has been adequately assessed and, where required, steps have been taken to mitigate it if practicable.

Depending on the scope of the proposed important or critical infrastructure or facility, there may be a need to do sub-surface investigations to confirm the presence (or not) of the fault. I suggest that, depending on the results of the site-specific investigation, that where practicable the infrastructure or facility is sited at least 20 metres away from the zone of deformation associated with the fault, or the potential effects of surface fault rupture are mitigated through engineering design.

‘Important or critical infrastructure or facilities’ needs to be defined in the District Plan. Following the MfE fault guidelines, important or critical infrastructure or facilities refers to Building Importance Level 3, 4 and 5 structures, which are given in section 5 above. Selwyn District Council is using the definitions given for Building Importance Levels 3, 4 and 5 for the fault provisions in their proposed District Plan. Alternatively, Waimakariri District Council may already have a definition that could be used, or the definition of critical infrastructure in the Canterbury Regional Policy Statement could be used:

> Infrastructure necessary to provide services which, if interrupted, would have a serious effect on the communities within the Region or a wider population, and which would require immediate reinstatement. This includes any structures that support, protect or form part of critical infrastructure. Critical infrastructure includes:
>
> - regionally significant airports
> - regionally significant ports
> - gas storage and distribution facilities
> - electricity substations, networks, and distribution installations, including the electricity distribution network
> - supply and treatment of water for public supply
> - storm water and sewage disposal systems
> - telecommunications installations and networks
> - strategic road and rail networks (as defined in the Regional Land Transport Strategy)
> - petroleum storage and supply facilities
> - public healthcare institutions including hospitals and medical centres
> - fire stations, police stations, ambulance stations, emergency coordination facilities.

However, the Canterbury Regional Policy Statement definition does not cover all the structures within the Building Code Building Importance Levels 3, 4 and 5.

The District Plan provision for important or critical infrastructure or facilities should be written so there is flexibility around the scale of investigation required depending on the nature and size of the development. The investigations and mitigation that might be needed for telecommunications infrastructure are obviously different to what would be needed for the likes of a major dam, so there should be some discretion in the level of investigation and mitigation required. The important thing is that the known or possible presence of a surface fault rupture hazard is recognised and addressed during the project development and steps are taken to mitigate the risk if necessary and practicable.

This overlay could be called the fault hazard (important infrastructure or facilities) overlay, or similar, and is shown in Figure 6. This includes all known and suspected faults within the district. I have supplied a GIS shapefile of this suggested overlay is with this memo. The attribute fields of the shapefile have been simplified to only include the fault name and recurrence interval information. All other faults attributes can be found in the 2019 Canterbury Fault Awareness Area dataset that this shapefile was extracted from.

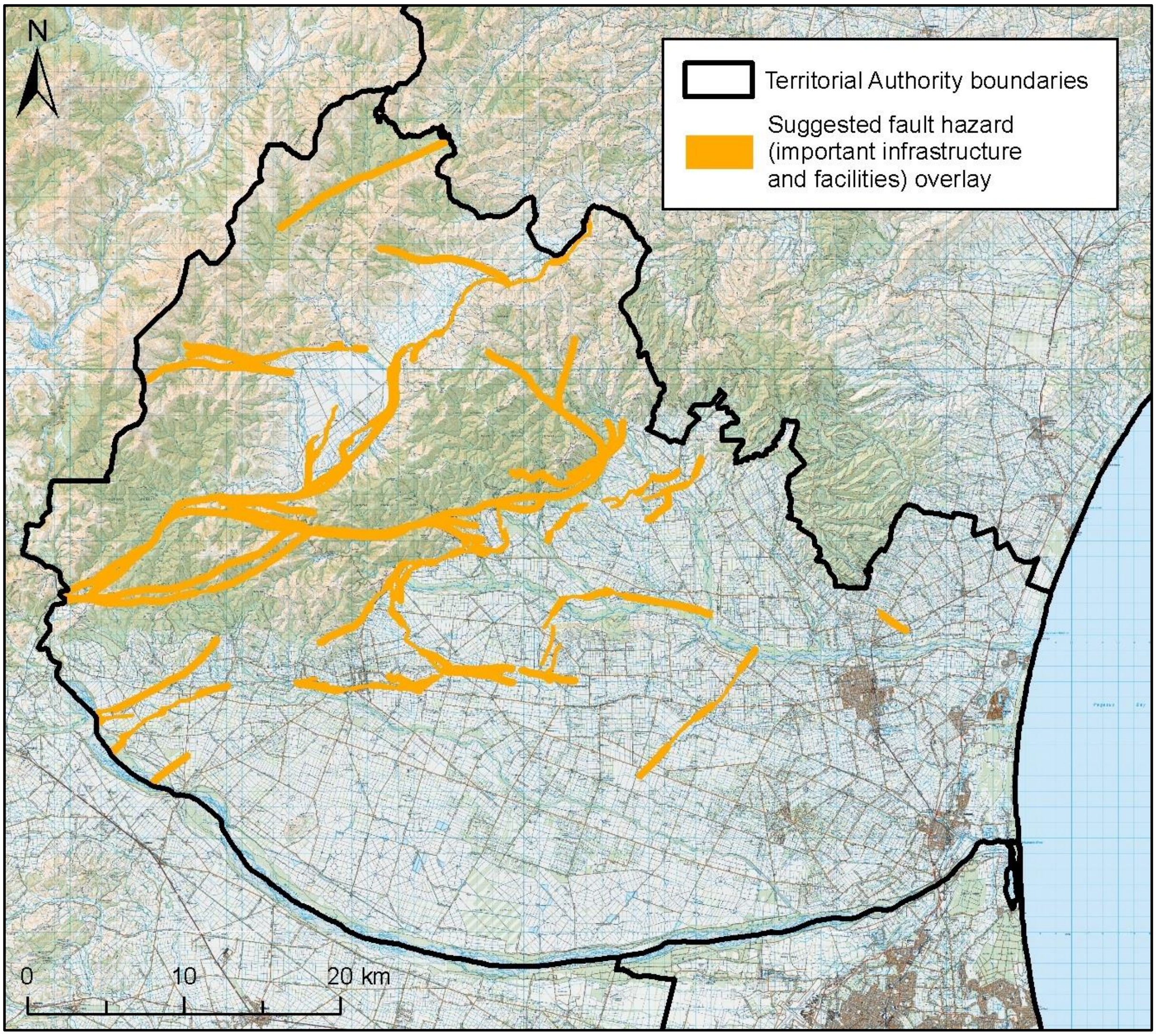

Figure 6: Suggested fault hazard (important infrastructure and facilities) overlay for Waimakariri District, based on all fault awareness areas.

Plan Changes

For proposed plan changes within a fault awareness area, whether classed as definite, likely or possible, that enable intensification of land use, or where development could be damaged by surface fault rupture, Policy 11.3.3 of the Canterbury Regional Policy Statement applies. This requires a site-specific investigation including detailed mapping of the fault at 1:35,000 or better and assessment of its recurrence interval (if not already well constrained) be undertaken to a level sufficient to apply the MfE guidelines.

Residential and farm buildings (outside new subdivisions)

I do not recommend that there are restrictions on new individual timber-framed residential buildings or farm buildings (Building Importance Level 1 and 2 structures) outside new subdivisions within fault awareness areas. This is because the zones of deformation associated with fault rupture have not been mapped in enough detail and requiring these to be mapped for such activities would be too onerous for the applicant.

I recommend that fault awareness areas be included in the District Plan and on Land Information Memoranda for information so that people can make their own decisions about where to locate new buildings.