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CENTRAL HAWKE'S BAY DISTRICT COUNCIL

Waipukurau South Growth Cell

Desktop Assessment of Natural Hazards

23 August 2022

CONFIDENTIAL



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150 YEARS IN AOTEAROA

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Disclaimers and Limitations

This report ('**Report**') has been prepared by WSP New Zealand Limited exclusively for Central Hawke's Bay District Council ('**Client**') in relation to Waipukurau Infrastructure Acceleration Fund Support ('**Purpose**') and in accordance with the Short Form Agreement with the Client dated 19 August 2021. The findings in this Report are based on and are subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

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1 Introduction

Central Hawke's Bay District Council (CHBDC) has engaged WSP New Zealand Limited (WSP) to provide a desktop study assessing natural hazards of 67 hectares of mostly greenfield residential zoned land between Porangahau Road and Tavistock Road in Waipukurau (known as the Waipukurau South Growth Cell; the 'site', Figure 1). The site is made up of several blocks of land owned by multiple parties. CHBDC has sought funding for bulk infrastructure from the government's Infrastructure Acceleration Fund.

The primary objective of this desktop assessment is to:

- Conduct a desktop review of publicly available data to identify natural hazards that may impact residential development of the site.
- Assess implications of identified natural hazards for the development of the site.

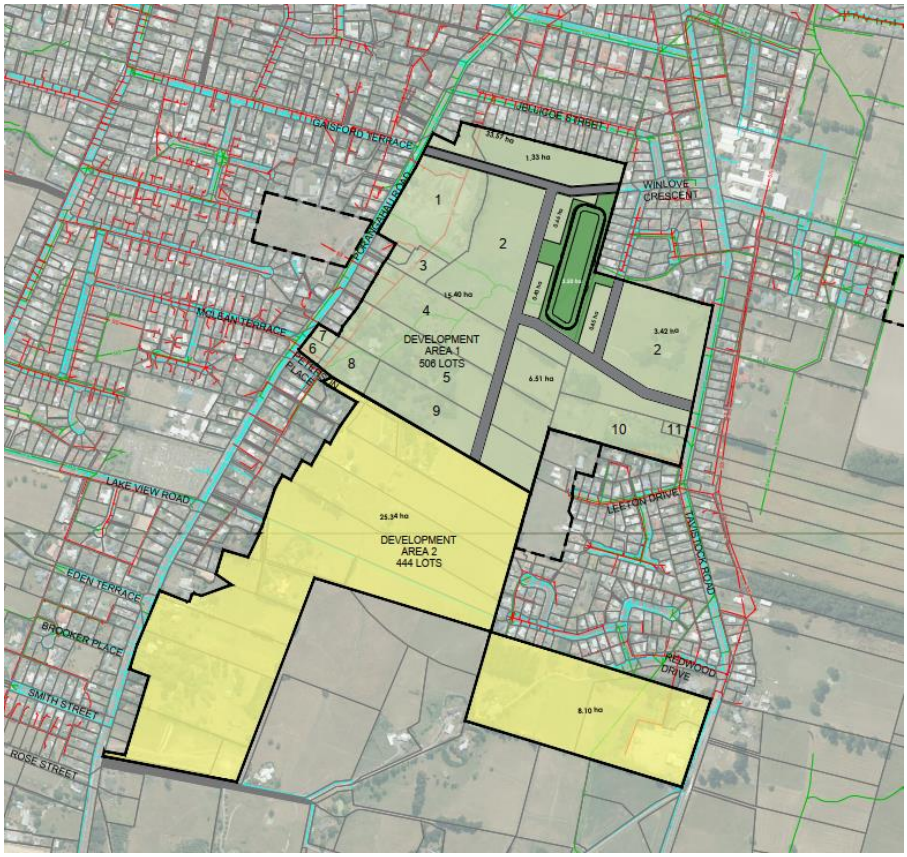


Figure 1: Overview of the proposed development areas of the Waipukurau South Growth Cell. Light green represents Development Area 1 and yellow represents Development Area 2.

2 Site Information

The desktop assessment of natural hazards considers an area of larger land parcels in Waipukurau for development into small residential land parcels. The area is located between Porangahau Road and Tavistock Road (Development Area 1 and 2 outlined in Figure 1), the Waipukurau South Growth Cell.

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3 Geological and Geomorphological Setting

The Institute of Geological and Nuclear Sciences (GNS) geological web map of New Zealand indicates that the site is underlain by Middle Pleistocene river deposits comprising undifferentiated alluvial gravel deposits (Figure 2).

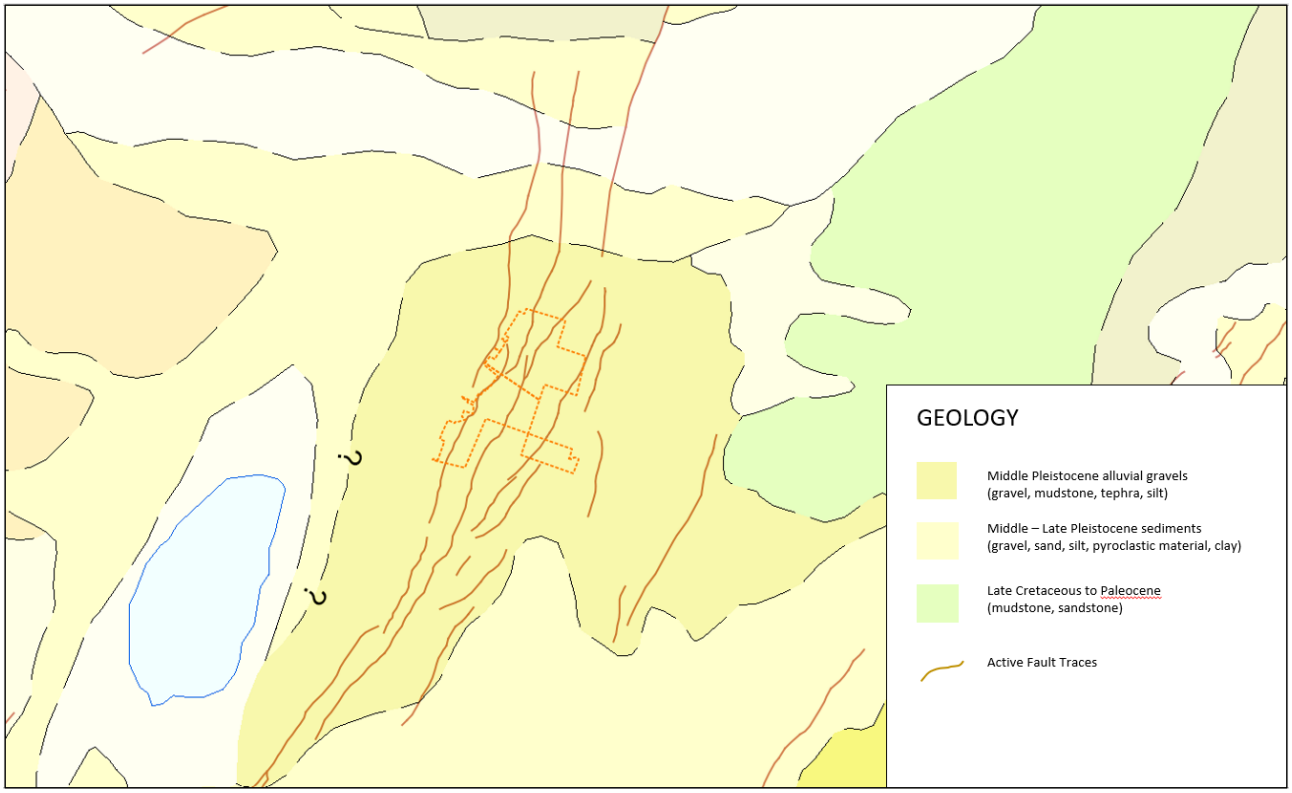


Figure 2: Geological map of the surrounding area of the proposed development. Orange-dotted polygon is indicative location of the site (annotated excerpt from GNS Science Geology Web Map).

The proposed development areas are located on relatively flat ground (155 m asl – 130 m asl) that is currently occupied by large residential and rural parcels.

Central Hawke's Bay is located within the Hikurangi accretionary margin area that is characterised by predominantly reverse fault zones (typically 1-2 km wide) which generally consist of multiple sub-parallel fault traces; this includes the Waipukurau Fault Zone (Figure *3*, GNS 2022, GNS 2014). Dominant geomorphological landforms on site are the surface expressions of the fault traces of the Waipukurau Fault Zone. Multiple fault scarps and associated folds have been identified and are visible on site crossing the area of the proposed development in NNE-SSW direction (Figure *3*).

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4 Natural Hazards

4.1 Earthquake Hazards

4.1.1 Context

Earthquakes directly cause two hazards: ground shaking (seismic hazard) and ground surface deformation (e.g. ground surface tilting, folding, dislocation (fault rupture), subsidence, and uplift). The ground shaking, and ground surface deformation hazards can be considered "primary earthquake hazards". The ground surface deformation hazard is typically located near to the faults that ruptured in the earthquake. The ground shaking at a location is influenced from earthquakes within hundreds of kilometres of the site.

Primary earthquake hazards give rise to secondary earthquake hazards. Secondary earthquake hazards caused by ground surface deformation include inundation (flooding) hazards and slope instability that may occur in the minutes to years following an earthquake. Secondary earthquake hazards caused by the ground shaking include liquefaction and slope instability. Both the primary and secondary earthquake hazards can cause damage to the built environment (structures and services).

The site is located within the Waipukurau Fault Zone, a major earthquake-generating fault system in the onshore part of Central Hawke's Bay. The fault has a reoccurrence interval of >3500 to ≤ 5000 years (Reoccurrence Interval Class III, GNS 2014). Because the site is located in the Waipukurau Fault Zone, areas of the site are subject to an earthquake ground surface deformation hazard. GNS (2014) has defined Fault Avoidance Zones (FAZ) based on the level of fault location accuracy and recommend that these are adopted by Central Hawke's Bay District Council.

The site is located approximately 20 km above the Hikurangi subduction interface fault, which is the main boundary between the Pacific tectonic plate to the east (beneath the interface fault), and the Australian tectonic plate to the west (on top of the interface fault). The Hikurangi subduction interface fault is capable of generating mega-thrust earthquakes with magnitudes greater than moment magnitude 8.5. The Hikurangi subduction interface fault is one of the fastest moving faults in New Zealand and in our opinion poses the highest risk from any fault in New Zealand. The Hikurangi subduction interface fault, along with other faults in the region, results in the site being subject to a very high seismic hazard.

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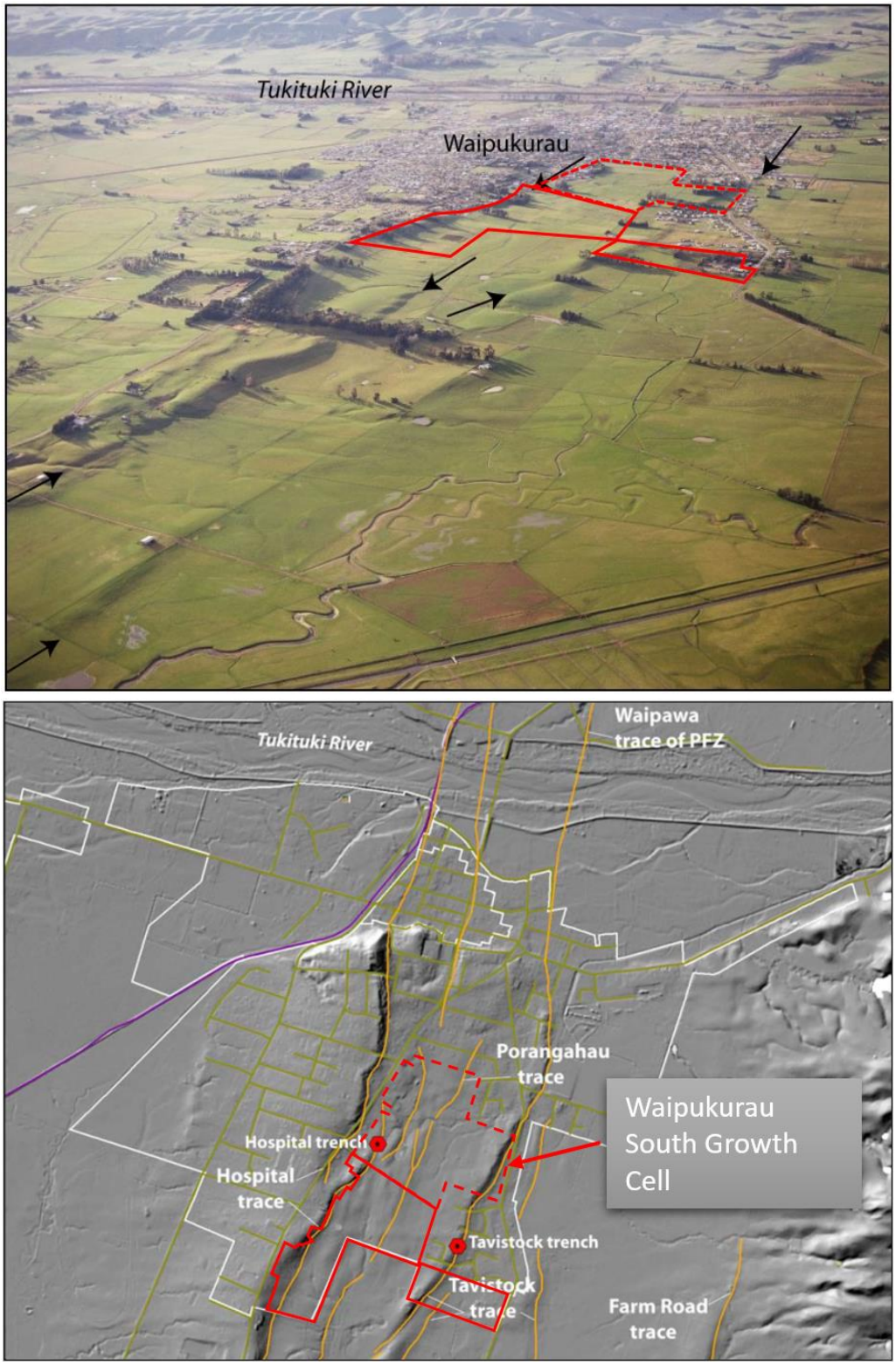


Figure 3: Top: Annotated oblique aerial image of Waipukurau showing multiple key fault traces of the Waipukurau Fault Zone and the indicative position of the Waipukurau South Growth Cell (source: GNS 2006). Bottom: Waipukurau Fault Zone – Main fault traces (annotated image, GNS 2006).

The following subsections review the primary and secondary earthquake hazards at the site. Implications arising from the recognised earthquake hazards for the proposed development are discussed in Section 5.

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4.1.2 *Earthquake ground surface deformation*

Ground surface deformation including fault surface-rupture during a large earthquake event is likely to occur in a zone along existing fault scarps. GNS science has developed fault avoidance zones (FAZ) that are assigned to each mapped active fault trace to manage development in the area where future ground surface deformation is expected (GNS 2014, refer Figure 4 image on right). The width of the FAZ depends on the fault mechanism and uncertainty associated with the location of the fault; a margin of safety (or setback) buffer is included to accommodate the uncertainty (refer to GNS 2014, Table 4.2) and for distributed deformation (e.g. tilting, Figure 4) which is concentrated near the fault trace.

The Waipukurau Fault Zone has a reverse faulting mechanism (Figure 4) and its known fault traces are well defined and visible in the area of the proposed development (Figure 3). Based on specialist interpretation of the local landscape features and historical fault ruptures with a reverse faulting mechanism it is likely that ground deformation is mostly concentrated on the uplifted side (or hangingwall side) of the fault trace. This is why the buffer areas in Figure 4 are not uniform in width on either side of the fault traces.

The distribution of the FAZ across the area of the proposed Waipukurau South Growth Cell is presented in Figure 4. The width of the FAZ ranges from 70 m for the "well-defined" fault trace to 115 m for the "distributed" area along the fault trace (GNS 2014, Table 4.2).

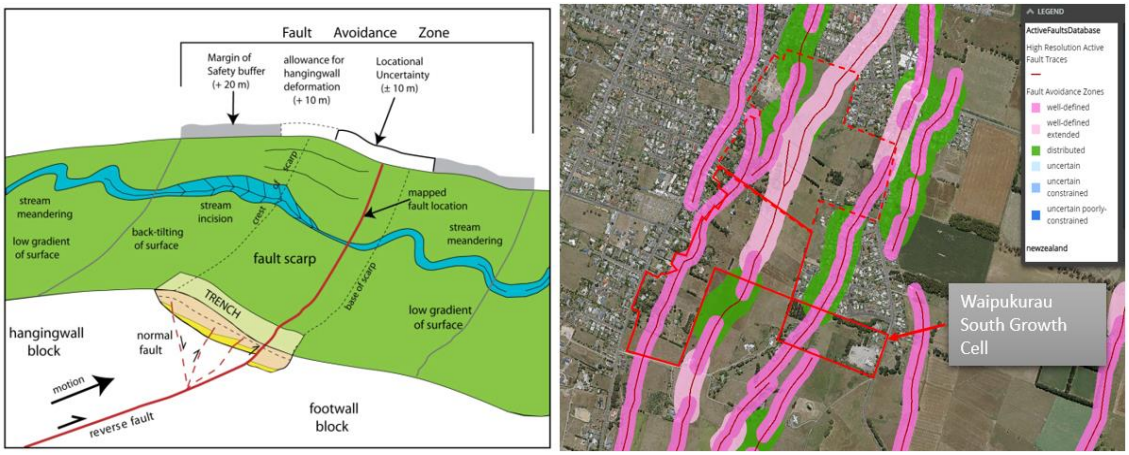


Figure 4: Left: Schematic diagram of a reverse fault and typically associated geomorphologic features (Source: GNS 2014). Right: Distribution of Fault Avoidance Zones across the area of the proposed Waipukurau South Growth Cell.

4.1.3 *Seismic hazard (ground shaking)*

The seismic hazard at the site is classed as high as accounted for in design standards such as New Zealand Standard (NZS) 1170.5 that are used for the design of most residential dwellings in New Zealand. The understanding of seismic hazard in NZS 1170.5 is based on a national-scale Probabilistic Seismic Hazard Analysis (PSHA) undertaken in the late 1990's by GNS Science. There have been large developments in the ability to estimate seismic hazard in New Zealand since the late 1990's and consequently the New Zealand National Seismic Hazard Model is currently being revised with results expected to be released publicly in late 2022. This national-scale re-assessment of seismic hazard may result in a new understanding of the seismic hazard at the site.

MBIE 2021 - Module 1 provides guidance on design parameters that relate specifically to geotechnical hazards associated with earthquakes. Table 1 presents the current recommended seismic design parameters for Waipukurau, until an updated national seismic hazard model is published.

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Table 1: WAIPUKURAU - Peak Ground Acceleration (a_{max}) and Earthquake Magnitude (M) values recommended for Geotechnical Assessment, for Site Classes A, B, C, D and E, for level ground conditions (MBIE 2021).

Return Period			
25 - Year		500 - Year	
a_{max} (g)	M_w	a_{max} (g)	M_w
0.12	6.4	0.58	7.1

4.1.3.1 Amplification of ground shaking

The intensity of seismic hazard can be affected locally by site-effects that amplify or dampen earthquake ground motions.

GNS (1998) evaluated the ground shaking amplification potential caused by near-surface (tens of meters) soils for the Hawke's Bay Regional Council at a regional scale. Four site classes were defined to characterise the relative earthquake amplification potential:

Table 2: GNS 1998 - Site Classification for Hawkes Bay Region.

Site Response Class	Geological Description	Relative Earthquake Amplification
4	Unconsolidated swamp, estuarine and lagoonal deposits and reclaimed land	High ↑
3	Alluvial sand, silt and gravel – Soft soil, soft clay with soil profile	
2	Compact alluvial sand, silt, and gravel (incl. firm to stiff clayey sand and gravels) – Stiff soil	
1	Bedrock, soft rock and soil overlying rock - Very dense soil	Low

The site lies within an area that has been evaluated by GNS (2006) to represent Site Response Class 2 – Compact alluvial sand, silt, and gravel (incl. firm to stiff clayey sand and gravels). This site response class is likely to have relatively low amplification potential for earthquake ground motions.

Localised topographic effects on top of elevated fault traces (hanging wall) might cause amplification of ground motions during large earthquake events.

4.1.3.2 Liquefaction

No liquefaction has been reported in Waipukurau during historical earthquake events (GNS 2017).

MBIE 2017 provides guidance for a risk-based process to manage liquefaction-related risk in land use planning and development decision making. A regional-scale (level A) assessment of liquefaction susceptibility (according to MBIE 2017) has been undertaken by GNS (2017). Based on this limited assessment a liquefaction hazard requiring mitigation is unlikely to be present at the site. However, due to possible variation of subsurface ground conditions across the large area of the proposed development, site-specific liquefaction vulnerability should be assessed during future geotechnical investigations at the site.

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4.2 Geotechnical Hazards

The local geological deposits may differ significantly because the site includes the Waipukurau Fault Zone. When the Waipukurau Fault Zone ruptures it likely offsets drainage channels and causes localised high and low points. This can result in the accumulation of localised deposits such as wetlands that result in the accumulation of fine-grained soils, or ponds that may result in the localised deposits of fine-grained soils (clay, silt, sand and mixtures thereof).

It is not practicable to assess geotechnical hazards with currently available information. A geotechnical investigation comprising, boreholes, cone penetration tests and possibly geophysical investigations would be required to characterise the nature and distribution of materials underlying the site. With the results of a geotechnical investigation geotechnical hazards could be assessed such as settlement caused by new structures (earth and buildings) and liquefaction susceptibility of the local soils. Currently no geotechnical investigations are available in or around the site on the New Zealand Geotechnical Database (NZGD).

4.3 Hydrological Hazards

The developments are subject to flooding due to stormwater as outlined in the detailed hydraulic assessment of Waipukurau by GHD and the Initial Infrastructure Assessment by WSP (2021).

The interim flood hazard mapping presented through the Hawke's Bay Hazard Portal indicates, while most of the proposed development is not part of the study area, that parts of Development Area 2 are within an area that is at risk of being flooded. The flood extents shown are at regional scale and limited to a scale of 1:20,000.

Strands of the Waipukurau Fault Zone may influence the depth to ground water across the site. The depth to ground water can influence the water storage capacity of near-surface soils and the selection and design of stormwater infrastructure. The depth to groundwater should be assessed as part of geotechnical site investigations.

The flood risk to the proposed development area could be evaluated using the hydraulic model being developed by WSP for other purposes.

4.4 Environmental Hazards

The site has no records within the Hazardous Activities and Industries List (HAIL) that identifies historic activities which have the potential to have caused contamination from hazardous substance use, storage or disposal (source: Hawke's Bay Hazard Portal).

However, hazardous substances may be encountered during future intrusive site works and may require immediate adequate management.

4.5 Slope Instability

The topography at the site is relatively flat; therefore, not considered to be subject to slope instability. Limited risk of localised small-scale slope instability is expected along the elevated topography of the fault scarps. When the Waipukurau fault ruptures, it is likely that there would be a period of heightened slope instability along fault scarps due to tilting of land.

4.6 Coastal Hazards

Due to the site's topographic location, it is not considered to be subject to coastal hazards such as tsunami inundation or flooding caused by raised sea water elevation, high tides, or storm surges.

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5 Implications

The two major considerations are how to manage the high seismic hazard (shaking) and the ground deformation hazard in the fault zone.

No specific assessment is required to consider the high seismic hazard, other than using the latest available guidance and codes, and if possible, adopting the results of the revised national seismic hazard model when designing services, and earth- and building-structures.

However, development of the proposed area will require careful consideration of the tectonic ground deformation hazard in the active Waipukurau Fault Zone. The following section is intended to provide additional information for the consideration of this hazard.

The framework for managing natural hazards like these is complex and is variously covered by the RMA, District Plan, NZ Building Code and guidance from the Ministry for the Environment (MfE). There is also international best practice that can be considered if required. While a review of applicable standards and requirements is beyond the scope of this report, we have undertaken a cursory review of the District Plan and provide some commentary on this, and MfE guidance below.

With respect to ***subdivision***, Section 106 of the RMA enables the Council to refuse subdivision applications, or to grant subdivision consent subject to conditions, where the Council considers that there is a significant risk from natural hazards (considering likelihood of the natural hazard occurring, the material damage that would result, and any likely subsequent use of the land that would accelerate, worsen, or result in material damage). The RMA states that the Council must not grant a subdivision consent unless those adverse effects can be avoided, remedied, or mitigated.

The District Plan contains various objectives, policies and rules around subdivision and natural hazards, including the objective '*to ensure that land being subdivided, including any potential structure on that land, is not subject to significant risk of material damage by the effects of natural hazards, including flooding, inundation, erosion, subsidence or slippage and earthquake faults*'. There are also specific rules governing activity status for subdivisions or structures within identified fault hazard zones.

The Ministry for the Environment (2003) guidance "Planning for development of land on or close to active faults" provides a risk-based planning approach:

"Building away from areas of fault rupture can avoid, or certainly mitigate, the fault hazard risk. For example, a new subdivision can be required to avoid building in an area of fault rupture (a fault avoidance zone in the district plan). This is the safest and most satisfactory long-term solution for current and later landowners and for the territorial authority. It can be achieved for little or no extra cost (although we recognise that loss of development opportunities are a cost to the developer)." – ***Principle 2: Plan to avoid fault rupture hazard before development and subdivision***.

The best form of mitigation against natural hazards is avoidance. There are several spatial scales that avoidance could be considered at and ultimately this should be a risk-based decision:

- Broadest Scale: Development of the whole Waipukurau South Growth Cell which is near an active fault. Not developing this area could be considered avoidance of the earthquake ground surface deformation hazard.
- Intermediate scale: Adopt the current FAZ and optimise the layout of the development to have non-critical elements located along the GNS mapped FAZ. E.g. build houses and align services away from the FAZ, build parks and roads along the FAZ. This approach requires acceptance of natural hazard risk and would also likely result in fewer residential lots.

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- Smallest Scale: Refine FAZ and avoid them. Undertake additional studies to more narrowly constrain FAZ. Additional studies could be based on detailed assessment of landscape features, geophysical and intrusive geotechnical investigations, trenching across known fault traces can expose the extend of historic ground deformation of subsurface soils of past fault movements. The width of the FAZ can be refined and building development in zones of past ground deformation can be avoided. More detailed assessment of the recurrence interval of movement on the faults and the time since the last movement may allow a more detailed consideration of the likelihood of fault rupture (e.g. conditional probability).

With respect to ***buildings*** within a FAZ and particularly buildings across active faults, the recurrence interval of fault rupture can be related to acceptable levels of risk in the current Building Code. The Ministry of Environment (2003) provides guidance for planners depending on the Recurrence Interval Class of the fault, the Building Importance Category, and the Fault Complexity Type. Note that buildings within a FAZ or across a fault are highly likely to be damaged during a seismic event.

MfE applicable resource consent categories for the buildings in a fault zone are presented and highlighted in Table 3. Importance Level (IL) 2a buildings (residential single-story timber frame) are 'permitted', however IL 2b (residential buildings greater than 300 square metres, or of two storeys, or outside NZS3604 or multi-occupancy buildings) require resource consent. We note that the provisions below appear to have been generally adopted in the District Plan.

Table 3: Ministry for the Environment Guidance of Resource Consent Categories for Greenfield sites along Recurrence Interval Class III Faults, i.e. Waipukurau Fault Zone.

Greenfield Sites - Resource Consent Categories for: Recurrence Interval Class III (> 3500 years to ≤ 5000 years) i.e. Waipukurau Fault Zone					
Building Importance Category (BIC)	1	2a	2b	3	4
Fault Complexity	Resource Consent Category				
A - Well Defined	Permitted	Permitted*	*Non-Complying*	*Non-Complying*	Non-Complying
B - Distributed	Permitted	Permitted	*Discretionary*	*Discretionary*	Non-Complying
C - Uncertain - constrained	Permitted	Permitted	*Discretionary*	*Discretionary*	Non-Complying

Notes:
* Indicates that the Resource Consent Category is permitted but could be Controlled or Discretionary given that the fault location is well defined.

Italics: The use of italics indicates that the Resource Consent Category – activity status of these categories is more flexible. For example, where 'Discretionary' is indicated, 'Controlled' may be considered more suitable by Council, or vice versa.

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To further understand and assess these hazards, and inform a mitigation approach, the following assessments could be undertaken:

- A further detailed assessment of the fault rupture hazard to inform risk-based approach to the proposed development area. This could include:
    - Geotechnical investigations and geophysical investigations to constrain the amount and extent of past off-fault distributed deformation to refine the extent of the avoidance zones. This involves trenching across the faults and mapping the FAZ. It is possible that the extent of the FAZ would be reduced following this investigation.
    - Paleoseismic studies to determine the recurrence interval of the fault zone and the elapsed-time since the last surface-rupturing event. This would allow the conditional probability of fault-rupture to inform the risk-based approach. Paleoseismic investigations involve trenching across fault traces to see the evidence of past fault movements and constraining the age of that evidence using techniques like radiocarbon dating. It is unlikely that this would result in a longer recurrence interval, however.
- Additional geotechnical investigations to assess if there are settlement prone, or liquefaction susceptible materials in the proposed development area. The geotechnical investigations could also assess the depth to groundwater. Note that geotechnical investigations on the site will need to be more extensive than would normally be undertaken for a subdivision because fault movement may have caused greater variability in ground conditions.

6 References

The desktop study to assess the natural hazards that may impact the site was undertaken using the following publicly available information:

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7 Closure

We trust this meets your requirements. If you require further information or have any questions, please do not hesitate to contact WSP.

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