REPORT

Tonkin+Taylor

Clutha Delta Qualitative Risk Assessment (Seismic)

Prepared for

Otago Regional Council

Prepared by

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1 Introduction

Otago Regional Council (ORC) engaged Tonkin & Taylor Ltd (T+T) to undertake a systematic Qualitative Risk Assessment (QRA) for seismic and co-seismic hazards within the Clutha Delta. It is understood that the purpose of this QRA study is to provide insight to guide future decision-making and to support emergency management planning. At this stage, there is no specific development plan for the QRA to inform.

This QRA follows on from the Clutha Delta Liquefaction Vulnerability Study (T+T report, June 2025) and utilises the liquefaction vulnerability and lateral spreading mapping established as part of this study. The findings from both the liquefaction vulnerability study and this QRA are anticipated to be of value to a range of stakeholders which include:

- Landowners and residents, to inform them of the potential risks posed by seismic and co-seismic hazards.
- The Clutha Delta natural hazards adaptation programme, particularly to inform assessments of seismic risks.
- The ORC Engineering team, as a high-level assessment of potential seismic and co-seismic impacts on ORC's scheme infrastructure, and the potential cascading impacts on the performance of the Lower Clutha Drainage and Flood Protection Scheme.
- The Clutha District Council (CDC), to build their awareness of the potential hazard and identify areas where this hazard may need to be considered more closely in building consent processes and infrastructure management.
- Emergency Management Otago, to build their understanding of potential event consequences for a major earthquake.

The Study Area for both the liquefaction vulnerability assessment and this QRA aligns with the boundary defined in Figure 1.1, which includes the townships of Balclutha and Kaitangata.

This report includes:

- An overview of the Proposed Regional Policy Statement (RPS) methodology for natural hazard risk assessment (Otago Regional Council, 2021) which was applied for the QRA (Section 2), including:
  - Definitions.
  - Assessment parameters.
  - Hazards.
  - Matters for consideration
- Risk analysis (Section 3), including:
  - Summary of the consequences.
  - Summary of the risk register and outputs from the assessment.
  - Discussion of cascading risks.
- Conclusions and next steps (Section 3.4).

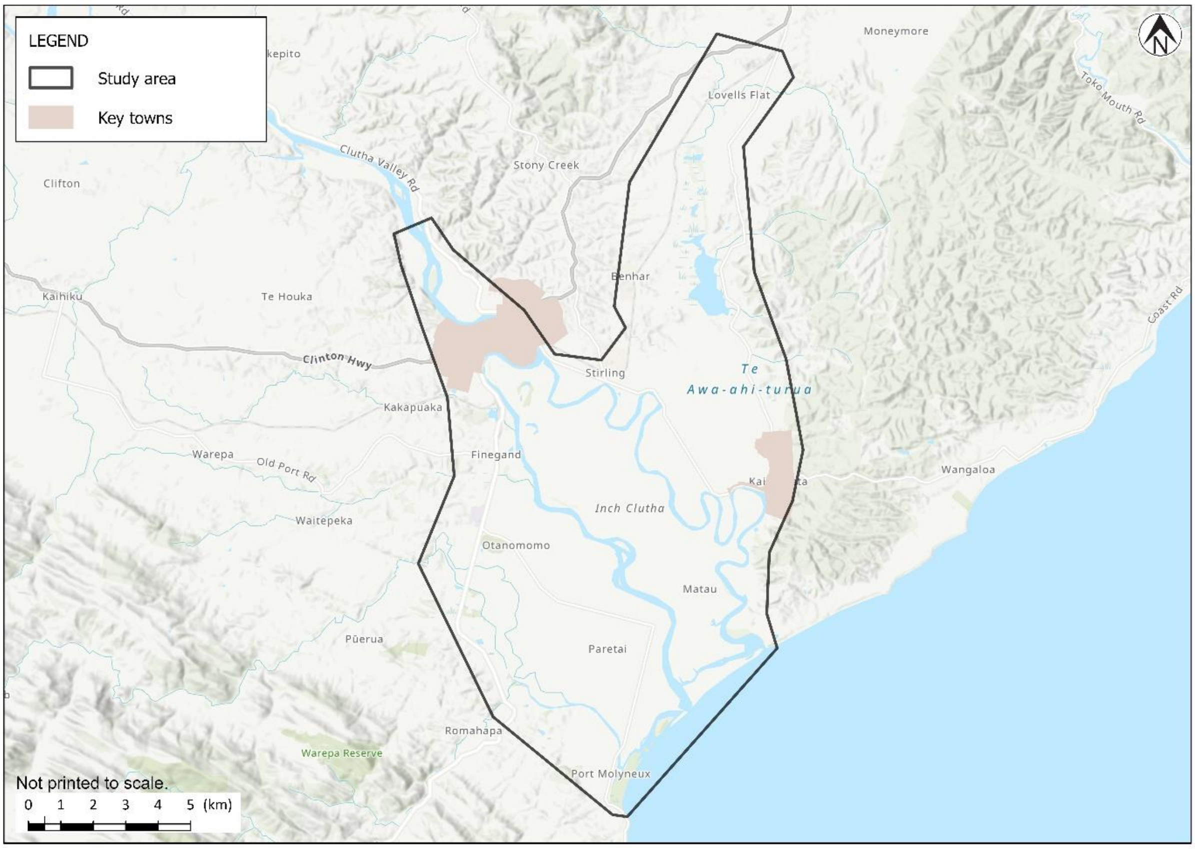

Figure 1.1: Map showing the extent of the Study Area and the townships of Balclutha and Kaitangata.

2 Methodology

The methodology is divided into three key sections:

- Proposed Regional Policy Statement (RPS) (Otago Regional Council, 2021) – natural hazard risk assessment framework.
- Seismic and co-seismic hazards – hazards for inclusion within the assessment.
- Context & supporting information – local context and other information used in the assessment.

2.1 RPS

The methodology and risk framework for this assessment is derived from the ORC RPS for natural hazard risk (Appendix 6). Risk is defined by combining hazard likelihood and consequence, in alignment with the ISO 31000:2018 approach to assessing risk (Figure 2.1).

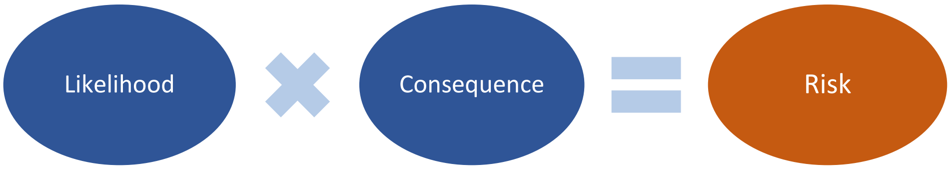

Figure 2.1: Risk equation (Otago Regional Policy Statement, 2019).

2.1.1 Likelihood

Likelihood is defined as the probability of a natural hazard event occurring and is rated on a five-point scale (Table 2.1). As per the RPS methodology, three natural hazard scenarios representing a high likelihood, median likelihood, and maximum credible event need to be considered within the assessment. This limits the likelihood ratings to a three-point scale. In consultation with ORC, the likely, possible, and rare scenarios were selected for this assessment.

Table 2.1: Likelihood definitions

Likelihood	Indicative frequency
Almost certain	Up to once every 50 years (~2% AEP)
Likely	Once every 51 - 100 years (2 -1% AEP)
Possible	Once every 101 - 1,000 years (1 - 0.11% AEP)
Unlikely	Once every 1,001 - 2,500 years (0.1 - 0.04% AEP)
Rare	2,501 years plus (<0.04% AEP)

2.1.2 Consequence

Consequence in the context of this assessment refers to the impacts on human life (health and safety), property, infrastructure, and the environment from a given natural hazard. It is rated on a five-point scale and is broken into two main categories: built environment, and health and safety (Table 2.2). The built environment requires assessment of buildings and lifelines. Health and safety requires assessment of the number of fatalities and injuries. These are discussed in the following sections.

Table 2.2: Consequence definitions (reproduced from Table 7of the RPS) (Otago Regional Council, 2021)

Severity of Impact	Built				Health & Safety
	Social/Cultural	Buildings	Critical buildings	Lifelines	
Catastrophic (V)	≥25% of buildings of social/cultural significance within hazard impact area have functionality compromised	≥50% of buildings within hazard impact area have functionality compromised	≥25% of critical facilities within hazard impact area have functionality compromised	Out of service for > 1 month (affecting ≥20% of the town/city population) OR suburbs out of service for > 6 months (affecting < 20% of the town/city population)	> 10 dead and/or > 1001 injured
Major (IV)	11-24% of buildings of social/cultural significance within hazard impact area have functionality compromised	21-49% of buildings within hazard impact area have functionality compromised	11-24% of critical facilities within hazard impact area have functionality compromised	Out of service for 1 week – 1 month (affecting ≥20% of the town/city population) OR suburbs out of service for 6 weeks to 6 months (affecting < 20% of the town/city population)	1 – 10 dead and/or 101 – 1000 injured
Moderate (III)	6-10% of buildings of social/cultural significance within hazard impact area have functionality compromised	11-20% of buildings within hazard impact area have functionality compromised	6-10% of critical facilities within hazard impact area have functionality compromised	Out of service for 1 day to 1 week (affecting ≥20% of the town/city population) OR suburbs out of service for 1 week to 6 weeks (affecting < 20% of the town/city population)	11 – 100 injured
Minor (II)	1-5% of buildings of social/cultural significance within hazard impact area have functionality compromised	2-10% of buildings within hazard impact area have functionality compromised	1-5% of critical facilities within hazard impact area have functionality compromised	Out of service for 2 hours to 1 day (affecting ≥20% of the town/city population) OR suburbs out of service for 1 day to 1 week (affecting < 20% of the town/city population	10 injured
Insignificant (I)	No buildings of social/cultural significance within hazard impact area have functionality compromised	<1% of buildings within hazard impact area have functionality compromised	No damage within hazard impact area, fully functional	Out of service for up to 2 hours (affecting ≥20% of the town/city population) OR suburbs out of service for up to 1 day (affecting < 20% of the town/city population	No dead No injured

2.1.2.1 Buildings

To assign a consequence level for damage to buildings, the number of "functionally compromised" buildings need to be assessed. The ORC RPS does not define functionally compromised, therefore we have developed criteria drawing on published information.

The Bay of Plenty Regional Council RPS defines functionally compromised as: "…*the building cannot continue to be used for its intended use immediately after the event*." The actual criteria by which functionally compromised is assessed differs depending on the hazard type. For seismic hazards a functionally compromised building is synonymous with the definition of "loss of amenity" as defined by the MBIE guidance document "repairing and rebuilding houses affected by the Canterbury earthquakes" (MBIE, 2018). One of the key performance measures in the definition of loss of amenity is the concept of "readily repairable". The MBIE guidance document defines this as "…repairable without relocation of occupants for more than four weeks…" (refer to Section 8.2.3 and Table 8.1 of the MBIE (2018) guidance document).

Based on this, the following criteria have been developed for considering the proportion of buildings that are functionally compromised:

- The building cannot continue to be used for its intended use immediately after the event; and/or
- The building is not repairable without relocation of its occupants for more than four weeks.

In consultation with ORC, critical and social/cultural buildings were assessed together under the category of "critical buildings". This is because:

- There are relatively few social/cultural buildings in the Study Area.
- Those buildings often had a dual purpose as critical and social cultural buildings.
- The consequence criteria for critical and social/cultural buildings are identical.

2.1.2.2 Lifelines

To assign a consequence level for damage to lifelines infrastructure, the outage duration, and proportion of people affected needed to be considered. The level of service and proportion of community served for each lifeline utility was not provided/available for the assessment, therefore a qualitative approach was taken. The following factors were considered when applying a consequence rating to lifeline infrastructure:

- Exposure of the asset – where the assets were located in terms of mapped liquefaction vulnerability categories, proximity to rivers, and proximity to known mapped faults.
- Vulnerability of the asset – factors that influence how severe the damage may be e.g., location of critical equipment within substations, pipe fittings being a point of failure etc.
- Availability of resources for response/restoration – the population size, location, and access to the Study Area influenced the outage time.
- Network performance/connectivity – most lifeline utilities are network based, so the connectivity between key asset types was considered in terms of outage duration.

2.1.2.3 Health and safety

The key factors for assessing consequence to health and safety were number of injuries and fatalities. This was assessed qualitatively, with the following considerations:

- Population of the Study Area – population of the key townships were taken from StatsNZ, noting that this does increase in summer months due to tourism on the Pacific Coast Highway.
- Building construction (age, material, no. of storeys etc.) – building construction type, discussed during the scoping workshop, alongside the HAZUS building fragility functions were considered when applying the consequence rating (FEMA, 2020).
- Vulnerability of the population – key vulnerability factors as discussed during the scoping workshop were considered when applying the consequence rating.

2.1.2.4 Matters for consideration

The ORC RPS also recommends the following matters be considered during the consequence assessment:

(1) the nature and scale of activities in the area,

(2) individual and community vulnerability and *resilience*,

(3) impacts on individual and community health and safety,

(4) impacts on social, cultural and economic well-being,

(5) impacts on *infrastructure* and property, including access and services,

(6) available and viable *risk* reduction and hazard mitigation measures,

(7) *lifeline utilities*, essential and emergency services, and their co-dependence,

(8) implications for civil defence agencies and emergency services,

(9) the changing *natural hazard* environment,

(10) cumulative *effects* including *multiple* and *cascading hazards,* where present, and

(11) factors that may exacerbate a *natural hazard* event including the *effects* of *climate change*.

These matters were discussed and documented during the scoping workshop with ORC and Civil Defence and Emergency Management (CDEM) staff (5 June 2025). A summary of that discussion is provided in Section 2.3 with further detail provided in the workshop minutes in Appendix A. They were then considered by T+T while undertaking the consequence assessment.

2.1.2.5 Consequence logic

Due to the inter-related nature of the co-seismic hazards, when assessing and rating consequences, the base case of seismic shaking was considered first. Liquefaction, lateral spreading, and fault rupture were then sequentially considered in that order, with each step evaluating whether the additional hazard materially altered the consequence for the asset as follows:

- If the additional hazard materially altered the consequence, the consequence level was increased.
- If the additional hazard did not materially alter the consequence, the consequence level remained the same.

2.1.3 Risk

Risk is defined by the combination of likelihood and consequence and is rated on a three-point scale: acceptable, tolerable, or significant (Table 2.3). Due to the use of three likelihood scenarios (likely, possible, and rare), only a sub-set of the risk framework is applied only to the rows outlined in blue in Table 2.3.

Table 2.3: Risk framework

	Consequence				
Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	Green	Yellow	Yellow	Red	Red
Likely	Green	Green	Yellow	Yellow	Red
Possible	Green	Green	Yellow	Yellow	Red
Unlikely	Green	Green	Green	Green	Yellow
Rare	Green	Green	Green	Green	Yellow
Green = Acceptable Risk, **Yellow** = Tolerable Risk, **Red** = Significant Risk					

2.2 Seismic hazards

The Study Area is subject to a range of natural hazards which include seismic events and their associated ground failure mechanisms due to proximity to active faults.

The four seismic and co-seismic hazards that were assessed as part of this QRA are:

- Seismic shaking.
- Liquefaction (co-seismic).
- Lateral spreading (co-seismic).
- Fault rupture.

In consultation with ORC, other co-seismic hazards such as earthquake triggered landslides and tsunami were excluded from this assessment because the exposure in the Study Area was assessed as low relative to the other hazards listed above.

Cascading hazard effects (e.g., damage to the flood protection network and subsequent impacts on flooding) are important to consider and have been discussed in Section 3.3. However, in consultation with ORC, we did not include these within the risk register (i.e., they do not have an associated risk rating). This is because of the complexity of assessing the likelihood and associated risk of cascading hazards.

2.2.1 Seismic shaking

Seismic shaking occurs as a result of an earthquake and can vary in intensity due to ground conditions and proximity to the fault rupture. Magnitude is a measure of the amount of energy released at the earthquakes' source while peak ground acceleration (PGA) is a measure of the maximum acceleration of the ground during shaking (GNS Science, 2022). Three different shaking scenarios have been established for this assessment alongside the associated magnitude and typical PGA.

The Study Area is exposed to seismic hazard from several sources. While not located on a major plate boundary, it can be affected by large earthquakes from the Alpine Fault and local faults in the Otago region, such as the Akatore and Titri faults (Barrell, 2021) (Figure 2.2). These faults can generate significant ground shaking that could impact the Study Area.

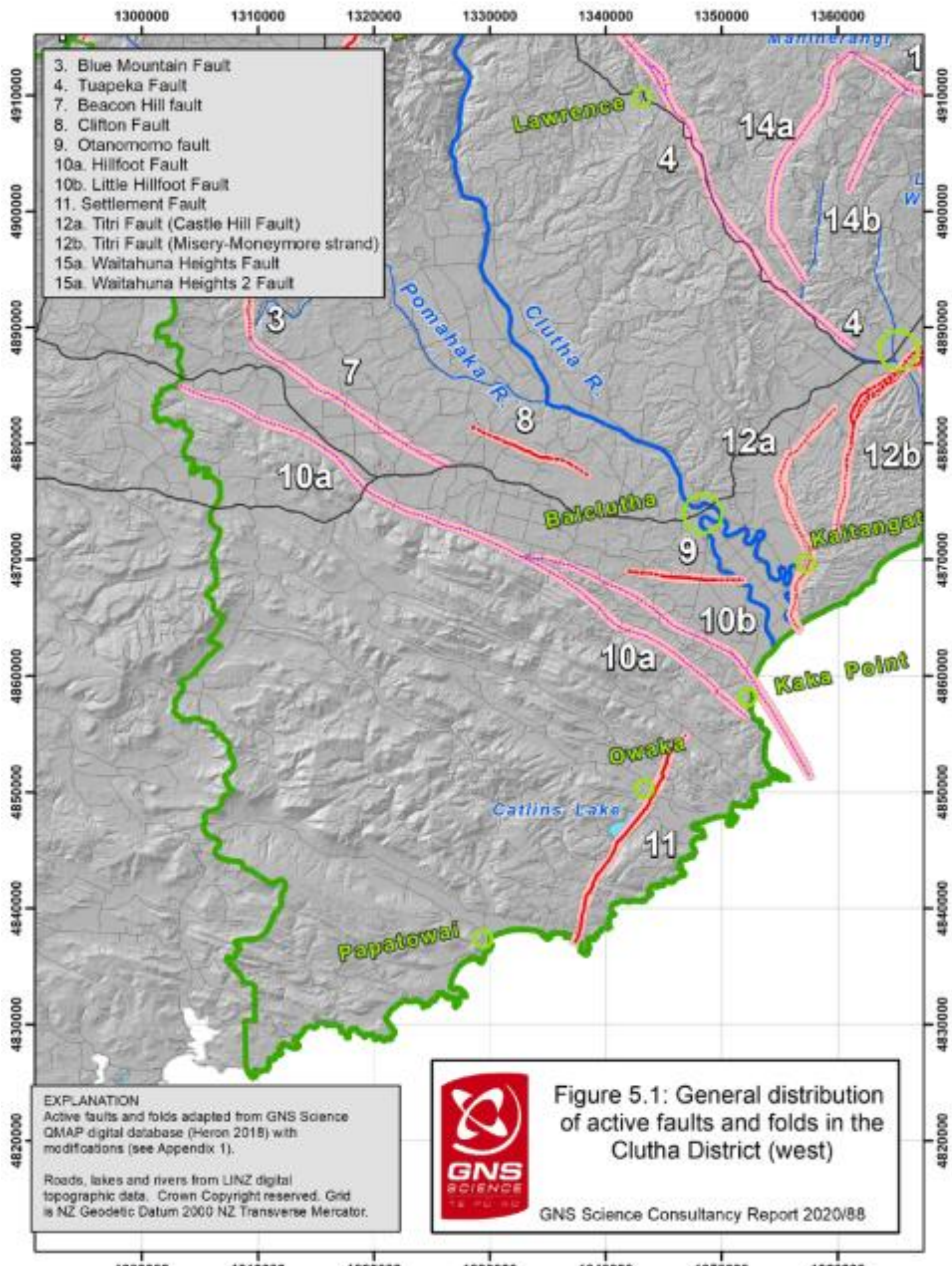

Figure 2.2: General distribution of active faults and folds in the western part of the Clutha District, Barrell 2021.

2.2.2 Liquefaction (co-seismic)

Liquefaction is a process where earthquake shaking increases the water pressure in certain types of ground conditions, resulting in temporary loss of soil strength.

The following three key elements are all required for liquefaction to occur:

- Loose non-cohesive or weakly cohesive soil (typically sands and silts, sometimes gravels, or fine-grained soils with low plasticity).
- Saturated or near-saturated soils (e.g., below the groundwater tables or in zones influenced by capillary rise).
- Sufficient ground shaking (a combination of the duration and intensity of shaking).

As outlined in the T+T report (June 2025), the elements listed above are present across significant parts of the Study Area identified as Liquefaction Damage is Possible in Figure 2.3. While there is uncertainty about where precisely liquefaction will occur in an earthquake event within the Study Area, it can be said with confidence, that in large earthquake events liquefaction will occur and that moderate-to-severe land damage is possible.

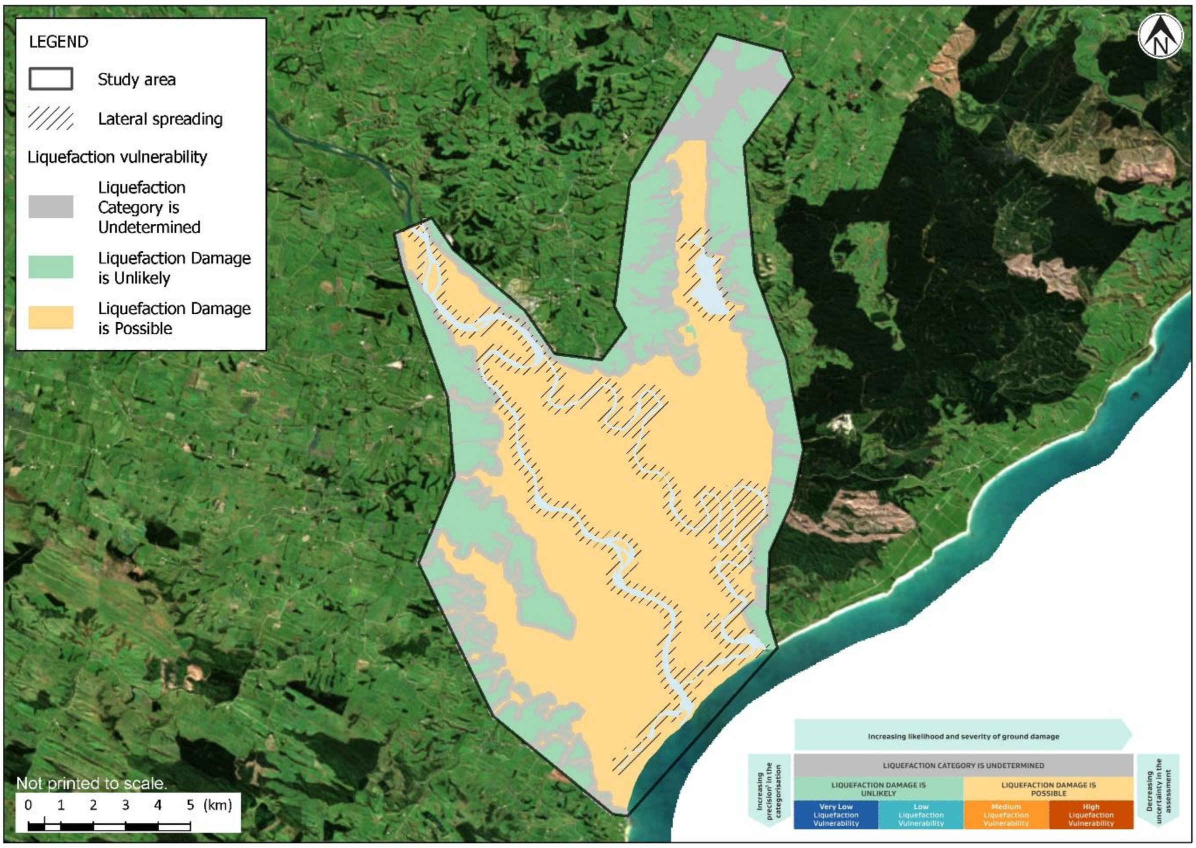

Figure 2.3: Liquefaction vulnerability classification (T+T, June 2025).

2.2.3 Lateral spreading (co-seismic)

Lateral spreading is the horizontal movement of ground towards a free-face or downslope (e.g., riverbank, channel, or road cutting), as a result of liquefaction of shallow underlying soils.

Figure 2.3 highlights areas which have the key elements required for lateral spreading to occur. Generally, the free faces associated with the larger river systems will likely result in lateral spreading which will increase in severity and extent as the seismic intensity increases. There are numerous drains across the Study Area which might also present a lateral spreading hazard but, given their smaller free-face height, the severity of damage is expected to be less extensive.

2.2.4 Surface rupture

Fault rupture refers to the displacement that occurs along a fault during an earthquake. Fault rupture may occur along a fault plane well below the ground surface or at the earth's surface (GNS Science, New Zealand's Faults, 2025). When it occurs at the earth's surface it is known as surface rupture and it is associated with visible cracks, scarps, or lateral offsets of the ground. Surface rupture was considered when assessing risks to infrastructure in this assessment.

Active faults are defined as faults that have ruptured in the past 125,000 years. If a fault has ruptured in the last 5,000 years, then it is considered a potential source of damaging earthquakes (Ministry for the Environment, 2003).

There are two active faults within the Study Area:

- Otanomomo fault.
- Titri fault (Castle Hill fault).

The Titri fault (Castle Hill fault) is located along the foot of the hills on the eastern edge of the Kaitangata township (Barrell, 2021). This fault is likely capable of generating a surface rupture; however, the likelihood of this happening is low (e.g., 10,000 to 20,000 recurrence interval). Due to the low likelihood of rupture, this has only been considered for the rare scenario.

2.2.5 Hazard scenarios

Three hazard scenarios were developed in this assessment, as per requirements under the ORC RPS:

- Likely
- Possible
- Rare

Each of the scenarios has different intensities of seismic and co-seismic hazards. These are described in detail below.

Likely – 1 in 100-year event
This scenario represents a magnitude 6.3 earthquake from a far-field source. The level of shaking is equivalent to that in an Alpine Fault 8.0 (AF8) scenario[1] for the Study Area. Light to moderate shaking is expected under this scenario, with a Modified Mercalli Intensity (MMI) of 5-6 and an average peak ground acceleration (PGA) of 0.09-0.13g. This level of shaking is generally felt both inside and outside. Most sleepers are awakened, and a few people may become alarmed. No surface rupture is generated locally, with liquefaction and lateral spreading effects limited to the most vulnerable soils or not triggered at all. No significant landsliding or tsunami generation occurs under this scenario within the Study Area.
Possible – 1 in 500-year event
This scenario represents a magnitude 6.4 earthquake, from a near-source (not directly inside the Study Area). Strong to severe shaking is expected under this scenario, with a MMI of 7-8 and an average PGA of 0.23-0.27g. This level of shaking is felt by all, and people may run outside. Walking steadily and standing can become difficult, with damage to fragile and unsecured objects. No surface rupture is generated locally; however, localised liquefaction and lateral spreading occurs (minor to moderate). No significant landsliding or tsunami generation occurs under this scenario within the Study Area.
Rare – > 1 in 2,501-year event
This scenario represents a magnitude 7.0 earthquake, due to rupture of the Titri Fault (Castle Hill Fault). Severe to extreme shaking is expected under this scenario, with a MMI of 8-9, and an average PGA of 0.39-0.43g. This level of shaking will produce general alarm, that may turn into panic. People will experience difficulty standing, and some buildings are damaged, with 'weak' buildings destroyed. Widespread ground deformation, liquefaction and lateral spreading occurs throughout the Study area. Surface rupture occurs along the Titri Fault (Castle Hill Fault) impacting directly on Kaitangata township and vertical and horizontal tectonic movement in the wider Study Area. No significant landsliding or tsunami generation occurs under this scenario within the Study Area.

2.3 Context & supporting information

Building and lifeline utility data was requested for the inclusion in this assessment. During the scoping workshop with ORC and Civil Defence and Emergency Management (CDEM) staff (5 June 2025), the following assets were confirmed for inclusion to assess the built environment:

- **Buildings**
  - All buildings within the Study Area were included within the assessment.
  - Critical and social/cultural buildings were identified spatially during the scoping workshop (5 June 2025).

[1] This scenario does not assess an Alpine Fault scenario, rather the same level of shaking that could occur based on the AF8 Scenario.

- **Lifelines**
  - Flood protection: pump stations, drains, floodbanks, and outfalls.
  - Transport: road, railway line, culverts, and bridges.
  - Three waters: pipes, treatment plant, pump station, flood gate, culvert, reservoir (water tanks), and intake locations.
  - Fuel: fuel sites.
  - Electricity: transmission towers, transmission lines, transmission, and distribution substations.
  - Telecommunications: fibre routes, critical cell sites, and cell phone towers.

Due to the importance of the flood protection scheme within the district, these assets were individually assessed within the risk assessment. The other lifeline utilities e.g., transport, three waters, electricity etc. were assessed at an amalgamated level, rather than at the individual asset level. For further detail on the spatial distribution of these assets, refer to Appendix C. During the scoping workshop (5 June 2025) with ORC and CDEM staff, the matters for consideration listed in Section 2.1.2.4 were discussed. The following is a summary of that discussion with further detail provided in the workshop minutes in Appendix A:

- **Population:** The population in the Study Area is approximately 5,000 – 6,000. Balclutha is the main town with a population of approximately 4,000. Kaitangata is a smaller residential community with a population of approximately 800. The remaining population is located on rural farms and lifestyle blocks with a low population density.
- **Economic activity:** The Clutha Delta is characterised by intensive agricultural activity and is anchored by the main town of Balclutha. The area is supported by key employers such as Silver Fern Farms (Finegand), Fonterra (Stirling dairy plant), and Danone (infant-formula plant at Clydevale). The drainage network plays a vital role in maintaining the viability of agriculture activities on the lower delta. Beyond agriculture, the region supports other significant activities including a large prison at Milburn (north of the Study Area) and steady tourism along the Pacific Coast Highway/ Catlins.
- **Buildings:** Most of the building stock are timber or masonry buildings. There are some mid-century, brick façade buildings (e.g., Library and Community Pool), however no buildings more than three storeys high. The two key community hubs of Balclutha and Kaitangata.
- **Lifelines:** Critical lifeline infrastructure such as State Highway (SH) 1, including the Clutha River bridge, and the two bridges to Inch Clutha, highlighted single points of failure. Failure at these sites could severely disrupt access to essential services, food supply to the rest of the South Island and isolate communities.
- **Health and safety:** While the general population is considered relatively resilient, three vulnerable populations were identified as elderly residents, migrant workers, and tourists. Health and safety risks are heightened by ageing buildings and limited evacuation routes. Economic and cultural impacts could arise from employment disruption and damage to key service sites.
- **Emergency response:** Emergency services face logistical challenges, including gaps in welfare-centre suitability and volunteer coverage. These challenges are exacerbated by the interconnected nature of lifelines (co-located assets and interdependencies) and cascading hazard scenarios.

This contextual information was considered when applying the consequence ratings within the risk assessment.

3 Risk analysis

A total of 120 risks were assessed as part of this assessment which are documented in detail in the associated risk register which is the main deliverable of this risk assessment and provided as a digital supplement in Appendix B. There are 120 risks because:

- The assessment considered nine subgroups of assets and Health and Safety (i.e., ten subgroups in total)
- For two of the scenarios (Likely and Possible) there are three hazards
- For one of the scenarios (Rare) there are four hazards

This section provides a summary of both the impacts (consequences) and risks associated with the seismic and co-seismic hazards assessed. It also provides discussion about the potential for cascading risks associated with this assessment.

3.1 Consequence summary

The distribution of consequence ratings across the different hazards and likelihood scenarios is presented in Figure 3.1. It highlights the higher consequences associated with the Rare scenarios, and the lower consequences associated with the Likely scenarios. It also demonstrates the compounding effects of the co-seismic hazards considered i.e., the consequences for surface rupture are highest and the consequences for seismic shaking are lowest.

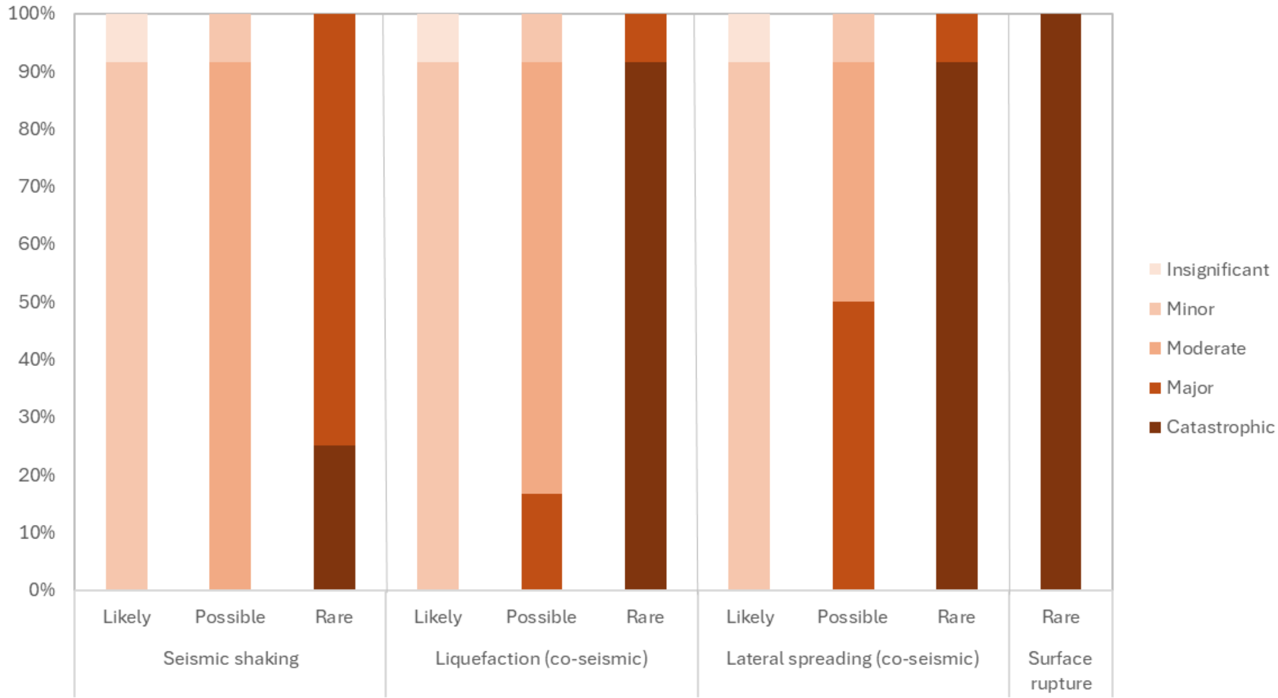

Figure 3.1: Distribution of consequence ratings across the different likelihood scenarios and hazards

Of the 120 risks assessed, 37 (31%) were rated as having a catastrophic consequence, 19 (16%) Major, 25 (21%) Moderate, 36 (30%) Minor, and 3 (2.5%) as Insignificant. Of the asset groups assessed, critical buildings and three waters had the highest number of catastrophic consequences (Figure 3.2). This reflects the conservative consequence thresholds for critical buildings, and the severity of the consequences if the three waters network were to be compromised. Flood protection and transport assets also have a high percentage of assets rated as catastrophic or major. This is largely due to the high exposure and vulnerability of these assets to liquefaction and lateral spreading (Table 3.1). Health and safety had the highest number of insignificant consequences, which is a function of the relatively small population and nature of building stock in the Study Area.

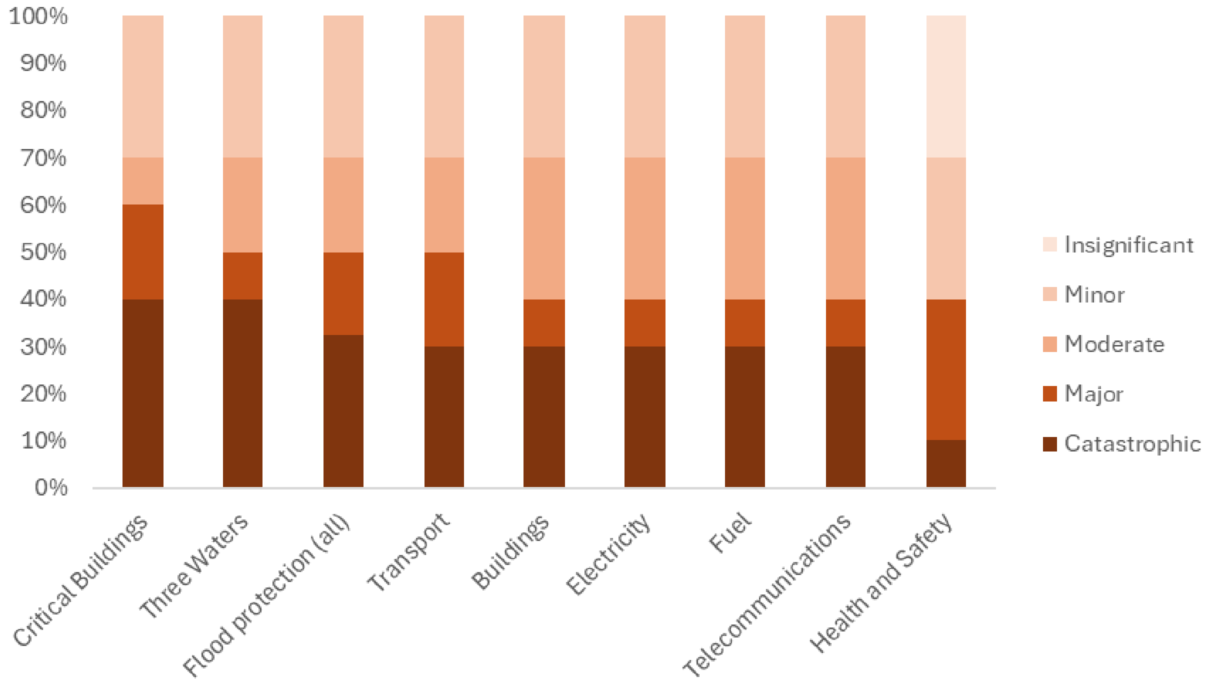

Figure 3.2: Consequence summary, grouped by asset grouping.

Particular factors that have influenced the consequence rating for each asset grouping are described in Table 3.1 below.

Table 3.1: Factors influencing the consequence rating

Asset group	Consequence discussion
Critical buildings	The lower thresholds associated with the percentage of buildings functionally compromised, results in a higher number of risks having higher consequence ratings.
Three waters	The exposure, and vulnerability to liquefaction and lateral spreading and the network performance of these assets, results in higher consequence ratings for this asset grouping.
Flood protection (all)	The exposure, and vulnerability to liquefaction and lateral spreading and the network performance of these assets, results in higher consequence ratings for this asset grouping.
Transport	The interdependent nature of these assets, alongside the percentage of population affected if disruptions were to occur, has resulted in higher number of major and catastrophic consequences.
Buildings	Given both the nature of the building stock within the Study Area, and the percentage thresholds, the consequence ratings are distributed relatively evenly across the scenarios.
Electricity	The consequence ratings are distributed relatively evenly across the scenarios, largely due to the prioritisation that is given to the electricity network post disaster (lowering the outage duration).
Fuel	The consequence ratings are distributed relatively evenly across the scenarios, given the reduced number of sites within the Study Area and the isolated nature of these assets.
Telecommunications	The consequence ratings are distributed relatively evenly across the scenarios, largely due to the prioritisation that is given to the electricity network post disaster (lowering the outage duration).
Health and Safety	The consequences ratings for health and safety are influenced by the small population within the Study Area, and the building stock i.e., no high-rise buildings. This limits the number of injuries and fatalities, and therefore higher consequence thresholds are not met.

Damage will also vary depending on the scenario and the asset type. A summary table of the likely damage and consequences for each hazard under each scenario is presented in Table 3.2.

Table 3.2: Summary of damage descriptions for each hazard and likelihood scenario

Hazard	Likely	Possible	Rare
Seismic shaking	• Hairline cracks in buildings and infrastructure • Minor displacements of fittings and joints in pipes, culverts, bridges and mechanical systems • Electrical and telecommunications equipment may require reset/ inspection • Temporary service outages (generally up to 1 day).	• Structural cracking and misalignment of components (pipes, cables, bridges, tanks) • Mechanical failure in pump stations and treatment plants • Temporary loss of sealing capacity e.g., flood gates and intake structures • Service disruption generally up to 1-week.	• Structural failure, and potential collapse of buildings, bridges and tanks • Rupture of pipes, and displacement of culverts • Widespread disruption to electricity, telecommunications and transport corridors • Service disruption likely to exceed 1-month in most cases.
Liquefaction	• Minor ground deformation, with limited structural impact • Slight settlement possible • Service disruption is limited to inspections and minor repairs.	• Localised liquefaction causing differential settlement and misalignment of assets e.g., pipes, culverts, drains, flood gates etc. • Ejected material may block culverts, drains, and outfalls, reducing flow capacity • Service disruption is likely up to 1-week.	• Widespread liquefaction causing severe ground deformation and structural failure • Rupture or uplift of buried infrastructure • Service disruption is likely to exceed 1-month.
Lateral spreading	• Limited horizontal movement near river margins • Minor displacement of foundations and buried infrastructure • Service disruption is limited to inspections and minor repairs.	• Localised lateral spreading may result in localised deformation • Misalignment and cracking of structures • Damage to embankments, bridges and pipe networks • Service disruption of up to 1-week.	• Extensive lateral spreading causing structural failure of bridges, and buildings • Severance of buried infrastructure, and potential collapse of containment systems • Service disruption is likely to exceed 1-month.
Surface rupture	-	-	• Surface rupture intersecting asset footprints can cause complete structural failure • Severance of buried infrastructure, transport corridors and flood protection assets • Total loss of function of schemes from ground deformation • Service disruption likely to exceed 1-month.

3.2 Risk summary

A total of 120 risks were assessed across a range of seismic and co-seismic hazards and likelihood scenarios. Of the 120 risks assessed, 70 (58%) were rated as Tolerable, 50 (42%) were rated as Acceptable, and no risks were rated as Significant – this is a function of the nature of the risk framework and the relatively low probability of high intensity seismic events in the area (i.e., high consequence events are typically rare).

Of the hazards assessed, liquefaction and lateral spreading had the most Tolerable risks (22 each), highlighting that these hazards pose the greatest potential risk for disruption across multiple asset types (Figure 3.3). All risks were rated as Tolerable for fault rupture, reflecting the rare but severe nature of this hazard. Seismic shaking had the highest number of acceptable risks, highlighting the high likelihood but generally lower consequence of this hazard independent of liquefaction and lateral spreading.

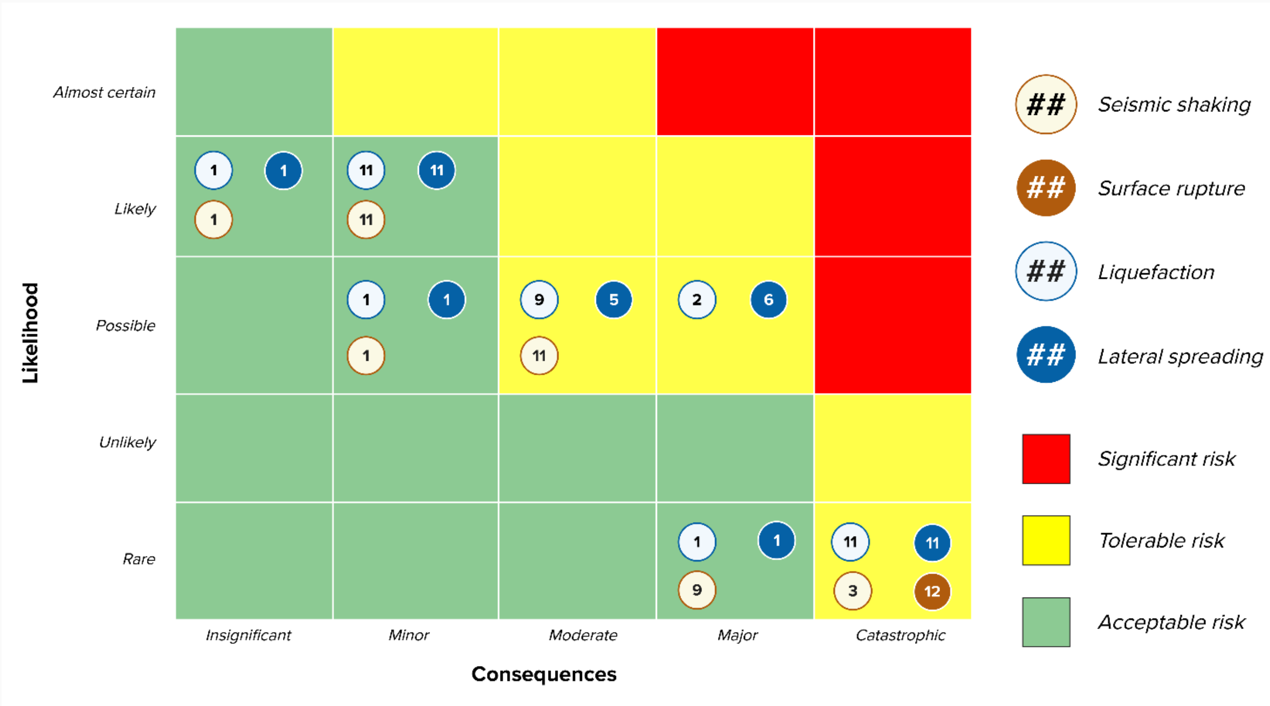

Figure 3.3: Risk summary matrix.

Of the assets assessed, critical buildings and floodbanks had more tolerable risks, highlighting the critical nature of these assets and the severity of the consequences if they were to be damaged or functionally compromised (Figure 3.4). Health and safety risks are generally rated as Acceptable, even under rare scenarios. This is a function of the relatively small population and nature of building stock in the Study Area (i.e., very few multi-storey buildings). However, the risk rating does increase to Tolerable when considering fault rupture, with the estimated number of fatalities driving this consequences rating. All other asset groups have 60% of risks rated Tolerable and 40% rated Acceptable.

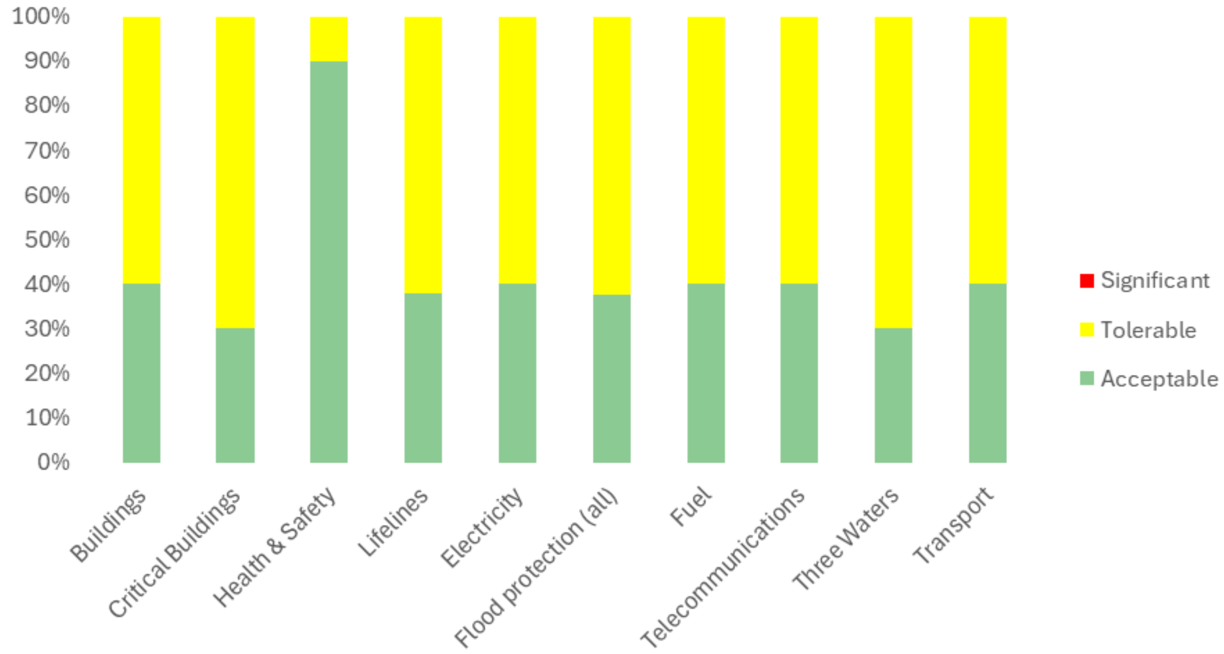

Figure 3.4: Risk summary, grouped by asset.

3.3 Cascading risks

Seismic and co-seismic events can result in widespread damage across critical infrastructure systems. Due to the interdependent nature of these systems, damage in one system can propagate through others, exacerbating the overall impact. Failure in some key infrastructure systems such as flood protection can also result in increased exposure to other hazards e.g., flooding. Figure 3.5 presents a summary of interconnections and potential cascading risks from seismic and co-seismic hazards.

Key observations from this cascade analysis include:

- The electricity network has many interdependent relationships, and failure of this network can result in disruption to:
  - Wastewater systems (treatment plant mechanisms).
  - Flood protection assets (mechanical components e.g., pump stations).
  - Telecommunications.
  - Fuel (payment mechanisms and petrol stations).
  - Transport (signal disruption).

  Failure in these systems can then result in impacts to public health and safety and can hinder emergency services, delaying response times.
- Damage and leakage of contaminants from wastewater and fuel systems can increase public health and safety and environmental risks. These impacts can be long lasting and can cascade into other networks e.g., the stormwater network may transport contaminated water into other receiving environments, and the water supply network can be compromised, resulting in potable water becoming unsafe for consumption.
- Fuel and electrical systems can increase the likelihood of fire. Damage to electrical infrastructure such as short circuits, arcing or equipment failure during or after a seismic event can ignite fires, particularly if flammable materials are present. Similarly, ruptured fuel lines and damaged storage tanks can release flammable liquids or gases, which may be ignited by electrical sparks or other ignition sources. The lifelines fuel site is located within close proximity to a residential area, so has potential to spread rapidly if ignited.
- Damage to both the flood protection and stormwater networks, can result in an increased flood risk post seismic event. Ejected material because of liquefaction, and ground deformation associated with lateral spreading and surface rupture may also exacerbate flood risk within the Study Area (as was seen following the Canterbury Earthquake Sequence).

  In a rare (>2,501 year ARI) scenario, impacts to the functioning of the flood protection and drainage scheme are expected to be widespread and extensive, with significant long-term repair and construction required. These impacts include:
  - Widespread deformation and cracking of floodbanks increasing the likelihood of failure
  - Drain blockage from sediment collapse and redirection of flowpaths
  - Structural damages to pump stations and outfall structures or rendered inoperable due to power supply disruption (as described above).

  As highlighted by the consequence descriptions in the risk register and summaries provided above, the potential damage to the flood protection and stormwater is extensive and would take a long time to repair and restore to previous levels of service. While this repair is underway, the exposure and associated risk of flooding in the study area would be significantly elevated. As the owner and operator of the flood protection network, this cascading risk is of particular relevance to ORC.

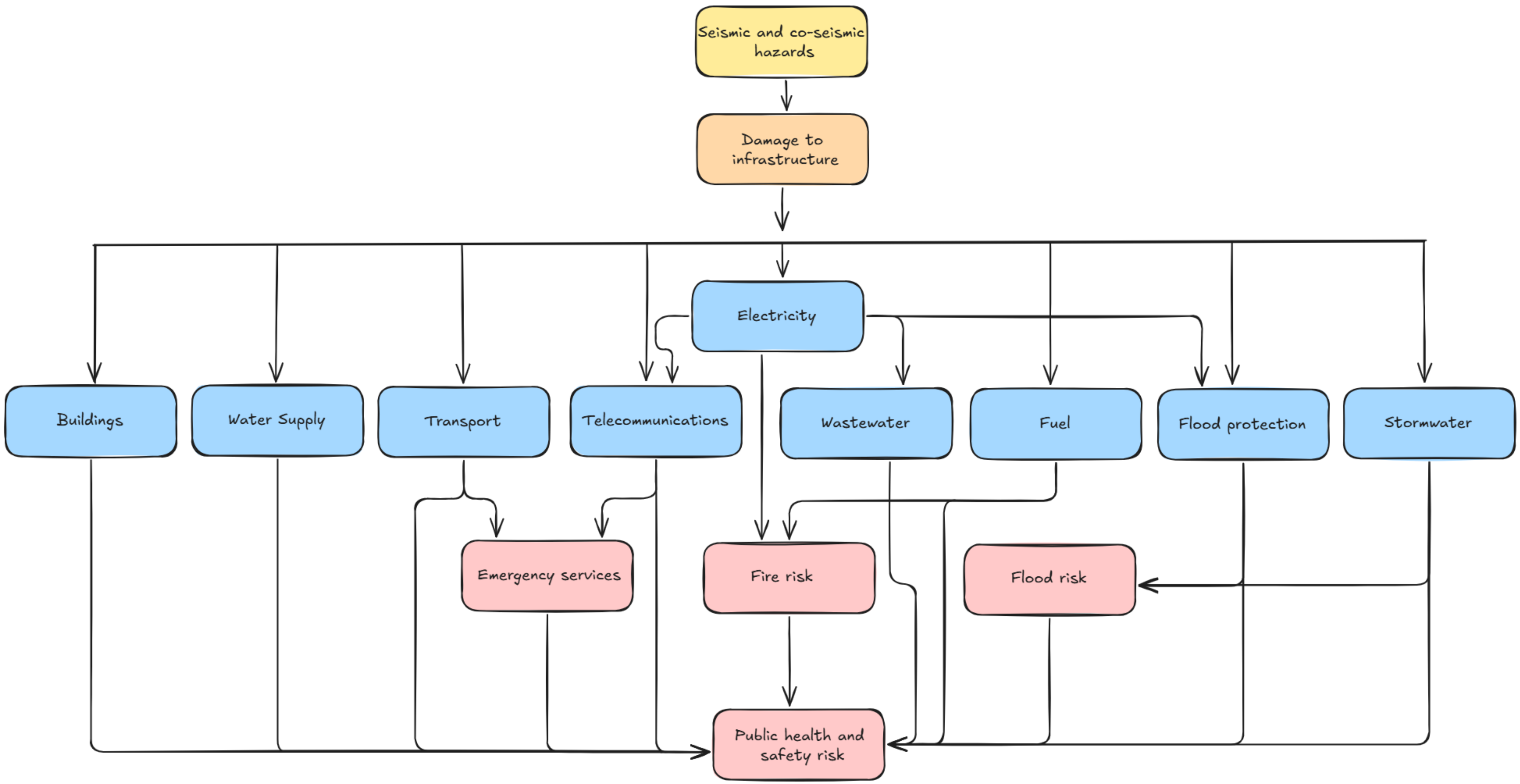

Figure 3.5: Cascading risks from seismic and co-seismic hazards.

3.4 Discussion

While no risks were identified as Significant in accordance with the RPS, a large proportion (53%) of the Tolerable risks were associated with Rare scenarios and Catastrophic consequences. These types of risks are commonly referred to as low probability, high consequence (LPHC) risks. LPHC risks create a governance challenge: how to manage risks that are infrequent yet catastrophic, especially under the conditions of deep uncertainty associated with seismic hazards.

Risk mitigation concepts that can be useful under these circumstances include:

- **Risk tolerance and the ALARP Principle**: The Natural Hazards Commission's Risk Tolerance Methodology (Toka Tū Ake EQC, 2023) offers a nationally aligned framework differentiating acceptable, tolerable and intolerable risk levels. For those risks deemed tolerable, the "as low as reasonably practicable" (ALARP) principle may guide proportional decision-making. The principle pursues risk reduction until further measures would be disproportionate to the expected benefit. Documenting where further mitigation is deemed proportionate, helps to support transparency and public confidence in decision-making.
- **Preparation for Emergency Response:** For LPHC risks, especially those with cascading hazards, preparedness for emergency response is critical. Stock piling of materials (e.g., suitable fill material, sheet piles and pumps), pre-arranged contracts, clear access plans, and prioritisation protocols could all be effective means to reduce recovery time and the consequences of such events. Consideration of alternative risk transfer mechanisms such as parametric insurance products to fund emergency response efforts could also be of use.
- **Dynamic Adaptive Policy Pathways (DAPP):** The DAPP framework was specifically developed to support planning under deep uncertainty and ORC has signalled its intent to use DAPP for adaptation planning in its Clutha Delta programme (van Woerden, Conroy, & Payan, 2023). This approach results in mapping of short-term no-regrets measures (e.g., enhancing redundancy and cross-training staff), medium to long term adaptation pathways, and associated decision triggers (e.g., updated hazard information and infrastructure performance degradation).

In summary, approaches to managing LPHC are not about elimination of risk, they target proportionate risk reduction (where practical), preparation for response, and remaining adaptable over time. Further consideration of these risk reduction methodologies, and other relevant examples, constitute useful next steps.

4 Conclusions and next steps

This QRA has identified and evaluated seismic and co-seismic hazards across the Clutha Delta, focusing on impacts to three main asset groups: buildings, lifelines infrastructure, and health and safety. The risk assessment highlighted that seismic shaking is the most likely hazard, with liquefaction, and lateral spreading triggered under a higher intensity of shaking, and surface rupture occurring under a rare scenario only.

Liquefaction, lateral spreading, and surface rupture pose more severe risks, particularly under rare event scenarios. This is due to the additional damage they cause in relation to seismic shaking. Critical buildings, three waters, and flood protection assets were identified as having the highest number of catastrophic and major consequences. With the same asset groupings having the highest number of risks identified at Tolerable.

While no risks were classified as Significant, a large proportion of those rated Tolerable are low probability, high consequence (LPHC) risks. These risks have the potential to cause catastrophic impacts to critical assets and generate cascading consequences across interconnected infrastructure systems.

Seismic and co-seismic events pose a significant cascading hazard risk due to the high interdependencies between infrastructure systems. Damage to lifelines such as electricity, wastewater, fuel, and transport can quickly propagate into wider service failures. For example, power outages can disable pump stations, disrupt telecommunications, and hinder emergency response, while damage to flood protection assets can heighten flood risk during recovery.

The flood protection and drainage networks are of particular relevance to ORC because it owns and operates them. Ensuring the resilience and preparedness of these assets is therefore a core responsibility for ORC.

Possible next steps for ORC based on this assessment:

- Share findings with key asset managers, and validate the assumptions made within this assessment.
- Complete a quantitative and/or site-specific risk assessment for key asset groups such as flood protection assets, critical buildings, and three waters. This can provide further granularity in the assessment and support prioritisation of risk mitigation efforts. The approach should remain adaptive, with regular updates and reviews as new hazard information becomes available.
- Complete a detailed assessment of cascading risks, focusing on how damage to flood protection assets from seismic hazards could increase the likelihood and severity of subsequent flooding (e.g., breach modelling).
- Consider different risk mitigation and management approaches that are suitable for LPHC risks. Examples introduced in this assessment include exploration of risk tolerance using the ALARP principle, and Dynamic Adaptive Policy Pathways (DAPP).
- Use the risk assessment as the basis of a review of emergency management plans, focusing on welfare centre locations, and evacuation routes in relation to the risks identified within this assessment.
- Share findings with asset owners e.g., New Zealand Transport Agency, so they can consider the need for develop of mitigation strategies for high-consequence assets, e.g., floodbanks, critical buildings, and single point of failure infrastructure (SH1 bridge).

5 References

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6 Applicability

This report has been prepared for the exclusive use of our client Otago Regional Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

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Authorised for Tonkin & Taylor Ltd by:

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Project Director

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Appendix A Workshop Minutes

Minutes

Meeting:	Clutha Delta QRA | Context & Pre-screening Workshop		
Venue:	Online	**Date:**	5 June 2025
Job No:	1093960	**Time:**	1:30 pm
Present:	Tim van Woerden (ORC), Pete Weir (ORC), Jason Michie (Otago CDEM), Paula Cathie (Otago CDEM), James Russell (T+T), Morgan Waugh (T+T), Matt Ogden (T+T)		
Apologies:	None		

Agenda	
	Agenda Item
1	Introductions
2	Confirmation of study extent
3	Confirmation of hazards
4	Risk framework overview (including matters for consideration)
5	Built environment assets
6	Health and safety considerations
7	Agreeing outputs
8	Summary and close

Actions				
Action Item		**Responsible**	**Due Date**	**Status**
1	Compile workshop outcomes and circulate summary for confirmation.	Matt O	13/06/2025	In progress
2	Finalise critical-asset map and issue for validation.	Matt O	13/06/2025	In progress
3	Provide Lifeline Vulnerability Report.	Tim vW	N/A	Completed
4	ORC to screen for additional historic-cultural sites within boundary.	Jason M/ Paula C	13/06/2025	In progress

1 Workshop objectives

The aim of the workshop was to:

- Confirm the geographic extent of the Clutha Delta Qualitative Risk Assessment (QRA).
- Agree the list of seismic and co-seismic hazards to be considered.
- Validate the qualitative risk-assessment framework—particularly hazard-likelihood scenarios—against the Otago Regional Policy Statement (RPS).
- Develop the inventory for the built-environment, lifeline, and community assets (including identifying vulnerable populations).
- Outline deliverables (Excel-based risk register and report).

2 Key discussion points

The key topics that were discussed with their outcomes are summarised in Table 2.1.

Table 2.1: Key discussion points from workshop

Topic	Outcome from workshop
Assessment approach	The team endorsed a qualitative risk matrix (3-point likelihood × 5-point consequence). Annual-recurrence-interval (ARI) numbers (1 in 100, 1 in 500, 1 in 2,500) are mapped to the qualitative likelihood categories ("likely", "possible", "rare"). **Quantitative loss modelling is out of scope.**
Study extent	Analyse the whole Clutha Delta as one unit; spatial variation of the hazard will be considered.
Hazards in scope	Ground shaking, liquefaction (free-field & lateral spreading), fault rupture. ORC raised that work is being undertaken towards improving the fault mapping database. We will integrate the findings of this research should it become available ahead of delivery of the QRA. Commentary for landslide risk will be included but excluded from the risk assessment due to minimal exposure across the study area.
Asset categories & critical facilities	Assets discussed included – key lifelines (State Highway 1 and rail bridges, pump stations, drainage network, 33 kV sub-station, transmission lines, water intakes/outfalls), supermarkets as essential-goods supply, social-critical buildings (hospital, community hub, schools, Clutha District Council, welfare centres). Schools should be classified "critical" for their role in emergency-management.
Vulnerable populations	Prisoners (Milton/Milburn – discussed but outside of study area), transient agricultural workers, assisted-living and retirement facilities, Samoan communities on the coast, residents now living in the historic hospital premise, and tourists to the region.
Risk-register design	Deliverable will include excel workbook which includes: 1 Risk framework tab (definitions, qualitative scales, colour scheme) 2 Risk register tab (one row per asset class × hazard) 3 Filtered risks (inspection of risk register by various groupings) 4 Risk totals – summary (count of risks by hazard)

	A report will accompany the risk register outlining the implementation of the risk framework and commentary about hazards not included within the risk register, as stated above.

3 Matters for consideration

Matters for consideration are presented in the ORC RPS (advice note 2) which were discussed in the workshop as an important component of developing the context.

3.1 Nature and scale of activities in the area

- **Primary land uses** – Balclutha is a small service town at the centre of an intensively farmed flood-plain; dairying and cropping dominate the rural delta.
- **Key industries/employers** – Silver Fern Farms meat-works at Finegand, Fonterra's dairy plant at Stirling, and the Danone infant-formula plant at Clydevale are major regional employers.
- **Other activities** – A large prison at Milburn (just north of the study area), small-scale coal mining near Kaitangata and year-round tourism on the Pacific Coast Highway / Catlins coast.

3.2 Individual and community vulnerability and resilience

- **Inherent rural resilience noted** – Farm communities have equipment, skills and a "can-do" culture that speeds self-help recovery.
- **Vulnerable groups identified**:
  - Balclutha rest home (~60 beds) and an adjacent hospital wing.
  - Retirement housing complexes on Charlotte St.
  - Disability centre ("PACT House") on the flood plain.
  - Ethnically diverse migrant worker communities on the coast and dairy farms.
  - Former hospital site (Hospital Road) now used for transient accommodation (raised as potential concern).
  - Tourists to the region.

3.3 Impacts on individual and community health and safety

- **Bridge failure** could cut access to food, fuel and medical care for the wider Southland region.
- **Only two bridges to Inch Clutha** – failure would isolate farms and residents.
- **Earthquake-prone or older buildings** – mid-century brick-facade buildings, the library and community pool noted as potential higher risk. Note that we will not use the term "earthquake-prone" unless an official notice exists. Buildings should be described by age and construction type instead.
- **Aftershock sequences** could delay recovery and prolong unsafe conditions.

3.4 Impacts on social, cultural and economic well-being

- **Employment disruption** at meat-works, dairy factories and mine if utilities or bridges fail.
- **Tourism losses** along the Catlins scenic route if Southern Scenic Route or coastal campsites are cut off.
- **Cultural values & sites** – Māori coastal urupā (burial grounds) outside but near the study area noted as sensitive.

3.5 Impacts on infrastructure and property (incl. access & services)

- **Critical bridges** – State Highway 1 and rail bridges at Balclutha, Clydevale bridge, new Beaumont bridge; all carry heavy freight, utilities and fibre backhaul.
- **Drainage & stop-bank network** – essential for keeping the low-lying delta farmable; pump-stations not designed for major flood pumping.
- **Substation north of Balclutha** and co-located utilities depend on bridge corridors (raised verbally).

3.6 Available and viable risk-reduction / hazard-mitigation measures

- **Existing measures** – flood banks, day-to-day groundwater pump-stations and engineered drainage network.
- **Proposed analysis** – qualitative risk register, asset-grouping approach and updated fault-awareness mapping (another project which is in progress).
- **Design standards** – bridges (e.g. new Beaumont bridge) built to higher seismic ratings, providing redundancy.

3.7 Lifeline utilities, essential & emergency services, and their co-dependence

- All three waters, power and fibre share the two bridge corridors – single points of failure.
- Police station and St John ambulance hub lie inside the flood-plain and have already been relocated once because of rising groundwater.
- Six lifeline categories will be assessed (roads, rail, power, telecoms, three waters, flood protection) as separate asset rows in the risk register.

3.8 Implications for civil defence agencies and emergency services

- **Welfare-centre network** – Cross Rec Centre (in flood hazard), Milton Library, new Kaitangata church, Lawrence Centennial Park and Clinton community centre identified; suitability of some venues questioned.
- **Alternate ECC / HQ** – Rosebank Lodge and South Otago High School named as backup if Council HQ or police out of action.
- **Volunteer fire service coverage gaps** on holiday weekends noted; misinterpretation of sirens by migrant groups highlighted as a communication risk.

3.9 Changing natural hazard environment

- **Sea-level rise raising groundwater** can result in higher liquefaction potential.
- **Ground-subsidence feedback loop** – liquefaction-induced settlement thins the non-liquefying crust, increasing future vulnerability.
- **Altered rainfall patterns** could change pump demand and groundwater balance, adding uncertainty.

3.10 Cumulative effects incl. multiple and cascading hazards

- **Aftershocks** – repeated liquefaction events (Christchurch analogue) extend damage and delay recovery.
- **Cross-contamination risks** – simultaneous sewer damage and potable-water pipe failure identified as a cascade to public-health impacts.
- **Drainage & stop-bank network failure** – contributing to increased flooding risk.

3.11 Factors that may exacerbate a natural-hazard event (incl. climate change)

- **Climate-driven groundwater rise** (sea-level rise and rainfall) exacerbates liquefaction likelihood and severity.
- **Shallow groundwater** (≤4 m) means even small rises materially increase risk.

Appendix B Risk Register

Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
1	Lifelines	Flood protection- Pump station	Seismic shaking	Likely	Minor	Damage to pump stations is likely to be minimal (cosmetic). However, power outages may result in loss of electric and back-up power leading to service disruption of up to 2 hours.	Acceptable
2	Lifelines	Flood protection- Pump station	Seismic shaking	Possible	Moderate	Damage to pump stations is likely to be moderate. Some structural damage may occur, with power outages causing service disruptions of up to 1-week.	Tolerable
3	Lifelines	Flood protection- Pump station	Seismic shaking	Rare	Major	Damage to pump stations is likely to be extensive. Structural damage can occur, with pumps being damaged beyond repair. Power outages may result in service disruption of up to 1 month.	Acceptable
4	Lifelines	Flood protection- Pump station	Liquefaction (co-seismic)	Likely	Minor	Liquefaction is unlikely to be triggered under this scenario, however minor ground deformation may occur. Pump station likely to have service disruption based on seismic shaking.	Acceptable
5	Lifelines	Flood protection- Pump station	Liquefaction (co-seismic)	Possible	Moderate	Localised liquefaction is likely, causing minor to moderate damage to pump stations. This could result in settlement of ground surface (up to 100 mm in height) which could result in misalignment and loss of service up to 1-week.	Tolerable
6	Lifelines	Flood protection- Pump station	Liquefaction (co-seismic)	Rare	Catastrophic	Widespread liquefaction is likely, resulting in significant ground deformation (>100 mm). Pump stations may experience foundation failure and structural damage, with service disruption more than 1 month. All flood protection pump stations within the study area are located in zones mapped as "liquefaction is possible".	Tolerable
7	Lifelines	Flood protection- Pump station	Lateral spreading (co-seismic)	Likely	Minor	Lateral spreading is likely to be limited and concentrated near river margins if it is triggered. Pump station foundations may incur damage leading to misalignment of equipment. Service disruption of up to 1-day is likely.	Acceptable
8	Lifelines	Flood protection- Pump station	Lateral spreading (co-seismic)	Possible	Major	Localised lateral spreading may result in major damage to pump station structures and pipelines. Service disruption of up to 2 weeks is likely, with potential for cascading impacts on the drainage network. Three (60%) of the pump stations within the study area are located within mapped lateral spreading zones. Increased flood risk is likely due to service disruption.	Tolerable
9	Lifelines	Flood protection- Pump station	Lateral spreading (co-seismic)	Rare	Catastrophic	Extensive lateral spreading is expected, particularly in areas with shallow groundwater and soft soils. Pump stations may experience structural failure and complete loss of function. Service disruption exceeding 1 month is likely, with significant implications for flood management across the delta.	Tolerable
10	Lifelines	Flood protection- Pump station	Surface rupture	Rare	Catastrophic	Surface rupture intersecting pump station footprint may result in complete structural failure. Deformation associated with surface rupture could significantly impact how the scheme functions, with service disruption exceeding 1 month. The Rutherford and Kaitangata pump stations are located within close proximity to the Titri fault, therefore are more susceptible to surface rupture than the other pump stations within the scheme.	Tolerable
11	Lifelines	Flood protection- Floodbank	Seismic shaking	Likely	Minor	Minor cracking and potential slumping of floodbanks is likely. No breach expected, but inspection and minor repairs may be required (up to 1-day).	Acceptable
12	Lifelines	Flood protection- Floodbank	Seismic shaking	Possible	Moderate	Moderate deformation of floodbanks may occur, including cracking and settlement. Temporary reduction in flood protection capacity is expected (up to 1 week).	Tolerable

Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
13	Lifelines	Flood protection- Floodbank	Seismic shaking	Rare	Catastrophic	Extensive deformation and cracking likely, leading to potential breach of floodbanks. Loss of flood protection function may occur, requiring significant repair. Property and infrastructure located within Inch Clutha will likely have increased flood risk.	Tolerable
14	Lifelines	Flood protection- Floodbank	Liquefaction (co-seismic)	Likely	Minor	Minor ground settlement may occur beneath floodbanks. No significant impact on structural integrity is expected.	Acceptable
15	Lifelines	Flood protection- Floodbank	Liquefaction (co-seismic)	Possible	Moderate	Localised liquefaction may result in moderate settlement and cracking of floodbanks. Temporary reduction in effectiveness is likely. Loss of service of up to 1-week is likely. Ejecta within the river corridor may also reduce the capacity of the floodbanks and increase the flood risk of the surrounding area.	Tolerable
16	Lifelines	Flood protection- Floodbank	Liquefaction (co-seismic)	Rare	Catastrophic	Widespread liquefaction is likely, resulting in significant deformation or breach of floodbanks. This may compromise the integrity of the flood protection system, particularly in low-lying areas of the delta. Restoration could take several weeks-months, with full reconstruction required for some parts of the network.	Tolerable
17	Lifelines	Flood protection- Floodbank	Lateral spreading (co-seismic)	Likely	Minor	Lateral spreading is likely to be limited and concentrated near river margins if it is triggered. Floodbanks by nature are located within close proximity to river margins, therefore are more susceptible to lateral spreading. Floodbank is likely to have service disruption based on seismic shaking rather than lateral spreading in this scenario.	Acceptable
18	Lifelines	Flood protection- Floodbank	Lateral spreading (co-seismic)	Possible	Major	Localised lateral spreading may result in major damage and displacement of floodbanks, with potential for overtopping or breach. Emergency repairs are likely to be required, with a loss of service of up to 1-month. Increased flood risk post event is likely, particularly for Inch Clutha.	Tolerable
19	Lifelines	Flood protection- Floodbank	Lateral spreading (co-seismic)	Rare	Catastrophic	Extensive lateral spreading is expected, causing widespread displacement and failure of floodbanks. This may lead to uncontrolled flooding of rural land and isolation of communities, with long-term recovery required.	Tolerable
20	Lifelines	Flood protection- Floodbank	Surface rupture	Rare	Catastrophic	Surface rupture intersecting floodbanks may cause complete structural failure and uncontrolled water flow. Deformation associated with surface rupture could significantly impact how the scheme functions. Full reconstruction and potential realignment of damaged areas likely required (disruption exceeding 1 month). Floodbanks along the Clutha River/ Matau Branch are more susceptible to damage from surface rupture due to their proximity to the Titri Fault.	Tolerable
21	Lifelines	Flood protection- Drain	Seismic shaking	Likely	Minor	Seismic shaking may cause minor slumping of open drains and displacement of sediment within channels. Flow paths remain largely uninterrupted without blockages. Minor repairs/ reshaping and removal of material may be needed. Temporary reduction in drainage may occur in low-lying paddocks, particularly following a rainfall event.	Acceptable

Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
22	Lifelines	Flood protection- Drain	Seismic shaking	Possible	Moderate	Seismic shaking may result in slumping, bank cracking, and partial blockage from sediment collapse. Repairs/reshaping and removal of excess sediment is likely, with up to 1-week of disruption. Reduced flow capacity may result in increased surface ponding and drainage issues.	Tolerable
23	Lifelines	Flood protection- Drain	Seismic shaking	Rare	Major	Widespread bank collapse, blockage from sediment collapse and redirection of flowpaths is likely to occur under this level of shaking. Significant repair and reconstruction will be needed, with up to 1 month disruption. Prolonged disruption may result in waterlogging of farmland, and increased flood risk, where drains are the primary outlet.	Acceptable
24	Lifelines	Flood protection- Drain	Liquefaction (co-seismic)	Likely	Minor	Liquefaction is unlikely to be triggered under this scenario, however minor ground deformation may occur. Drain function will remain intact, and largely unaffected.	Acceptable
25	Lifelines	Flood protection- Drain	Liquefaction (co-seismic)	Possible	Moderate	Localised liquefaction may result in settlement of drain banks and infilling of channels with ejected material. Removal of excess sediment from drains will be needed, with service disruption of up to 1 week.	Tolerable
26	Lifelines	Flood protection- Drain	Liquefaction (co-seismic)	Rare	Catastrophic	Widespread liquefaction is likely, resulting in significant deformation and potential collapse of banks. Infilling of channels from ejected material will occur which can redirect and impact flowpaths. 141 km (98%) of drains are located within "Liquefaction is Possible" extents. Extensive repair and reconstruction is likely with outage of more than 1 month expected. Prolonged disruption may result in waterlogging of farmland, and increased flood risk, where drains are the primary outlet.	Tolerable
27	Lifelines	Flood protection- Drain	Lateral spreading (co-seismic)	Likely	Minor	Lateral spreading is likely to be limited and concentrated near river margins if it is triggered. Lateral ground movement may cause minor displacement of drain banks, however damage is likely to be limited to minor reshaping.	Acceptable
28	Lifelines	Flood protection- Drain	Lateral spreading (co-seismic)	Possible	Major	Localised lateral spreading may result in bank slumping, channel misalignment and partial blockage. Drains are more susceptible to lateral spreading due to inherently being free faces. Reduced flow capacity may result in increased surface ponding and drainage issues.	Tolerable
29	Lifelines	Flood protection- Drain	Lateral spreading (co-seismic)	Rare	Catastrophic	Extensive lateral spreading is expected, causing widespread displacement and slumping of drain banks, redirecting flows. 6 km (4%) of drains are located within mapped lateral spreading zones. Extensive repair and reconstruction is likely with outage of more than 1 month expected. Prolonged disruption may result in waterlogging of farmland, and increased flood risk, where drains are the primary outlet.	Tolerable
30	Lifelines	Flood protection- Drain	Surface rupture	Rare	Catastrophic	Surface rupture intersecting the drain network may result in the partial collapse or offset of channels, resulting in permanent redirection and blockage. Deformation associated with surface rupture could significantly impact how the scheme functions, with full re-establishment of the impacted drains likely, with outage of more than 1 month. While rare, rupture near Kaitangata from the Titri fault is possible, and could intersect drains within close proximity.	Tolerable

Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
31	Lifelines	Flood protection- Outfall	Seismic shaking	Likely	Minor	Seismic shaking may result in minor displacement or loosening of outfall components, including fittings and any gate structures. Cosmetic damage is likely, with functionality remaining intact. Outage time is limited to inspection and minor adjustments.	Acceptable
32	Lifelines	Flood protection- Outfall	Seismic shaking	Possible	Moderate	Seismic shaking may result in cracking, misalignment of fittings, and may damage mechanical components (if any). Some outfalls may be blocked and temporarily inoperable. Repair to damaged components needed, with disruption of up to 1 week likely.	Tolerable
33	Lifelines	Flood protection- Outfall	Seismic shaking	Rare	Major	Seismic shaking may result in structural damage to outfalls including cracking or slumping leading to the disruption of flows. This may increase flood risk and ponding upstream of the structure due to reduced capacity. Repair to damaged components needed, with disruption of up to 1 month likely.	Acceptable
34	Lifelines	Flood protection- Outfall	Liquefaction (co-seismic)	Likely	Minor	Liquefaction is unlikely to be triggered under this scenario, however minor ground deformation may occur. Outfall function will remain intact, and largely unaffected.	Acceptable
35	Lifelines	Flood protection- Outfall	Liquefaction (co-seismic)	Possible	Moderate	Localised liquefaction may result in settlement of outfall structures, misalignment of fittings and gates (if any). Outfalls may become blocked with ejected material, limiting the flow capacity. Clearance of sediment and realignment may be required, resulting in service disruption of up to 1 week.	Tolerable
36	Lifelines	Flood protection- Outfall	Liquefaction (co-seismic)	Rare	Catastrophic	Widespread liquefaction is likely, resulting in severe settlement and tilting of outfall structures. Gate mechanisms may be inoperable (if any) and outfalls may become blocked with ejected material, limiting flow capacity. All outfall structures are located within "Liquefaction is Likely" extents. Extensive repair and reconstruction is likely, with outage of more than 1 month expected. Prolonged disruption may result in ponding, and uncontrolled water levels disrupting adjacent farms.	Tolerable
37	Lifelines	Flood protection- Outfall	Lateral spreading (co-seismic)	Likely	Minor	Lateral spreading is likely to be limited and concentrated near river margins if it is triggered. Lateral ground movement may cause minor displacement of outfall structures, with damage limited to realignment and inspection.	Acceptable
38	Lifelines	Flood protection- Outfall	Lateral spreading (co-seismic)	Possible	Major	Localised lateral spreading may result in misalignment of gates, slumping of surrounding ground and potential partial or full loss of operability. This can lead to reduced control of water discharge and service disruption of up to 1 week.	Tolerable
39	Lifelines	Flood protection- Outfall	Lateral spreading (co-seismic)	Rare	Catastrophic	Extensive lateral spreading is expected, causing structural failure of outfalls and gate collapse (if any). All outfalls within the study area are located within mapped lateral spreading zones. Flow control may be lost, and full reconstruction may be necessary. Outage or more than 1 month likely. Prolonged disruption may result in ponding, and uncontrolled water levels disrupting adjacent farms.	Tolerable

Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
40	Lifelines	Flood protection- Outfall	Surface rupture	Rare	Catastrophic	Surface rupture intersecting outfall structures, may result in complete structural failure and may sever gate mechanisms (if any). Permanent redirection and blockage of flow is likely. Deformation associated with surface rupture could also significantly impact how the scheme functions. Service disruption is likely more than 1 month, with some reconstruction needed to impacted outfalls. The Kaitangata and Rutherford Locks are more susceptible to fault rupture due to their proximity to the Titri Fault.	Tolerable
41	Lifelines	Transport	Seismic shaking	Likely	Minor	Seismic shaking may result in minor cracking and surface deformation on roads and rail lines. Culverts may shift slightly, and bridges may experience minor joint movement or bearing displacement. Service disruption is likely to be limited to short-term lane or track closures for inspection and minor repairs (from 2 hours to 1 day). Minor disruption may occur on critical routes such as SH1 and the rail bridges at Balclutha.	Acceptable
42	Lifelines	Transport	Seismic shaking	Possible	Moderate	Moderate structural damage may occur to bridges and culverts, including cracking of abutments and misalignment of spans. Road and rail surfaces may experience differential settlement. Service disruption of up to 1-week is likely due to damage and closures (road and rail). Prioritisation will be given to critical roads such as SH1 to ensure connectivity to the lower Southland area. Some local roads may have disrupted access isolating communities and restricting access to key lifelines e.g., healthcare, food and fuel.	Tolerable
43	Lifelines	Transport	Seismic shaking	Rare	Major	Extensive structural damage is likely for bridges and culverts, including potential span failure or pier cracking. Road and rail corridors may be impassable due settlement/ deformation. Service disruption could range from 1-week to 1-month, with impacts to regional transport and supply chains (e.g., fast moving consumer goods). Damage/ failure of key structures such as the Clydevale or Balclutha bridges would isolate parts of the delta, and disconnect Southland from the rest of the country. These structures are co-located with other key utilities such as three waters, electricity and telecommunications. Cascading impacts are likely from the failure of these lifeline utilities.	Acceptable
44	Lifelines	Transport	Liquefaction (co-seismic)	Likely	Minor	Minor ground settlement may occur beneath roads/rail lines, with limited impact on structural components. Culverts and bridges remain functional. Service disruptions are likely to be brief, with a focus on inspections. No significant outage likely (up to 2 hours). Liquefaction is unlikely to be triggered in most areas under this scenario, however in low-lying areas with shallow ground water may have minor impacts.	Acceptable

Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
45	Lifelines	Transport	Liquefaction (co-seismic)	Possible	Major	Localised liquefaction may result in settlement and deformation of road and rail surfaces, misalignment of culverts, and damage to bridge approaches. Bridge abutments may be deformed, damaging bridge foundations and superstructure. 42 km (22%) of rail, 116 km (25%) of road , 22(100%) bridges and 8 (57%) culverts are located within "Liquefaction is Possible" zones. Service disruption could range from 1-week to 1 month, with road/rail closures for remediation. Prioritisation will be given to critical roads such as SH1 to ensure connectivity to the lower Southland area. Some local roads may have disrupted access isolating communities and restricting access to key lifelines e.g., healthcare, food and fuel.	Tolerable
46	Lifelines	Transport	Liquefaction (co-seismic)	Rare	Catastrophic	Widespread liquefaction is likely, resulting in severe settlement and loss of bearing capacity beneath roads, rail, and bridge abutments. Culverts may be uplifted or blocked. 42 km (22%) of rail, 116 km (25%) of road , 22(100%) bridges and 8 (57%) culverts are located within "Liquefaction is Possible" zones. Service disruption is likely to be greater than one month, with major detours in place and loss of critical structures. Damage/ failure of key structures such as the Clydevale or Balclutha bridges would isolate parts of the delta, and disconnect Southland from the rest of the country. These structures are co-located with other key utilities such as three waters, electricity and telecommunications. Cascading impacts are likely from the failure of these lifeline utilities.	Tolerable
47	Lifelines	Transport	Lateral spreading (co-seismic)	Likely	Minor	Lateral spreading is likely to be limited and concentrated near river margins if it is triggered. Minor displacement of road and rail surfaces may occur, with culverts experiencing slight joint movement and bridges showing minor abutment displacement. Service disruption is limited to short-term lane or track closures for inspection and minor repair (up to 1-day). These disruptions on critical routes such as SH1 could have minor impacts on the flow of goods and services.	Acceptable
48	Lifelines	Transport	Lateral spreading (co-seismic)	Possible	Moderate	Localised lateral spreading may result in slumping and cracking of road and rail embankments, misalignment of culverts and displacement of bridge abutments. 19 km (25%) of rail and 42 km (22%) of road, 7 (32%) bridges and 4 (29%) culverts are located within mapped lateral spreading zones. Service disruption of up to one-week is likely due to partial closures and repair works. Disruption to key routes such as SH1 and the rail corridor may restrict access to lifelines (e.g., healthcare, food and fuel), and isolate those communities particularly in Inch Clutha.	Tolerable

Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
49	Lifelines	Transport	Lateral spreading (co-seismic)	Rare	Catastrophic	Extensive lateral spreading is expected, particularly along riverbanks. Severe displacement may result in structural failure of bridges, collapse of culverts and impassable roads and rail corridors. 19 km (25%) of rail and 42 km (22%) of road, 7 (32%) bridges and 4 (29%) culverts are located within mapped lateral spreading zones. Service disruption will exceed one month, with major detour routes in place and long-term loss of critical structures. Damage/ failure of key structures such as the Clydevale or Balclutha bridges would isolate parts of the delta, and disconnect Southland from the rest of the country. These structures are co-located with other key utilities such as three waters, electricity and telecommunications. Cascading impacts are likely from the failure of these lifeline utilities.	Tolerable
50	Lifelines	Transport	Surface rupture	Rare	Catastrophic	Surface rupture intersecting transport corridors may result in complete structural failure of bridges, collapse or off-set of culverts, and severe offset of road and rail alignments. Deformation associated with surface rupture could significantly impact how the network functions. Service disruption will exceed one month, with full reconstruction or a new alignment required for damaged infrastructure. It is unlikely that SH1 will be directly impacted by surface rupture in this scenario, however key roads in and out of Kaitangata may be impacted, resulting in isolation of this community from critical lifelines (e.g., healthcare, food and fuel).	Tolerable
51	Lifelines	Three Waters	Seismic shaking	Likely	Minor	Seismic shaking may result in minor cracking (hairline) of buried pipes, displacement of fittings and cosmetic damage to reservoirs (water tanks) and pump stations. Flood gates and water intake structures may experience joint movement. Service disruption is likely to be limited to short-term outages (up to 1 day) for inspection and minor repairs. Electrical equipment at treatment plants and pump stations may be disrupted, resulting in short term service outages.	Acceptable
52	Lifelines	Three Waters	Seismic shaking	Possible	Moderate	Seismic shaking may result in cracking and misalignment of pipes and joints, alongside reservoirs (water tanks) that are concrete. Mechanical components at pump stations and treatment plants are likely to be damaged, with loss of sealing capacity at flood gates. Service disruption of up to 1 week is likely, with prioritisation likely focused on water supply and wastewater infrastructure.	Tolerable
53	Lifelines	Three Waters	Seismic shaking	Rare	Catastrophic	Seismic shaking may result in structural damage to treatment plants, collapse of reservoirs (water tanks) and failure of pump station components. Pipes may rupture, and culverts may be displaced or blocked. Service disruption of more than 1 month is likely with wider cascading impacts to other parts of the water supply, wastewater and stormwater system. Co-located assets i.e., bridges carrying pipes, may isolate parts of the network and delay recovery further. Prioritisation is likely to be focused on water supply and wastewater infrastructure.	Tolerable
54	Lifelines	Three Waters	Liquefaction (co-seismic)	Likely	Minor	Liquefaction is unlikely to be triggered under this scenario, however minor ground deformation may occur. Pipes and reservoirs (water tanks) may experience slight settlement, however functionality remains intact. Service disruption is limited to checks and minor repairs (up to 1-day).	Acceptable

Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
55	Lifelines	Three Waters	Liquefaction (co-seismic)	Possible	Moderate	Localised liquefaction may result in differential settlement, tilting of reservoirs (water tanks), and pump stations and misalignment of buried pipes. Ejected material may partially block culverts and intake structures leading to service disruption of up to 1 week, to allow for repair and clearance of material. 209 km (58%) of pipes, 5 (83%) treatment plants, 14 (74%) pump stations, 3 (100%) intake locations and 35 (90%) flood gates are all located within extents mapped as "Liquefaction is Possible".	Tolerable
56	Lifelines	Three Waters	Liquefaction (co-seismic)	Rare	Catastrophic	Widespread liquefaction is expected, resulting in severe ground deformation, loss of bearing capacity and structural failure of reservoirs (water tanks), pump stations and intake structures. Pipes may rupture, and/ or uplift and ejected material is likely to block culverts and intake structures. 209 km (58%) of pipes, 5 (83%) treatment plants, 14 (74%) pump stations, 3 (100%) intake locations and 35 (90%) flood gates are all located within extents mapped as "Liquefaction is Possible". Service disruption is likely to exceed one month, with major reconstruction required. Failure of some of these key assets may result in loss of potable water, uncontrolled wastewater discharge, and increased flood risk.	Tolerable
57	Lifelines	Three Waters	Lateral spreading (co-seismic)	Likely	Minor	Lateral spreading is likely to be limited and concentrated near river margins if it is triggered. Minor displacement of buried pipes and fittings may occur, with pump stations and, treatment plants, intake locations and reservoirs (water tanks) experiencing slight misalignment. Service disruption is limited to inspection and minor repairs (up to 1-day).	Acceptable
58	Lifelines	Three Waters	Lateral spreading (co-seismic)	Possible	Major	Localised lateral spreading may shear pipe joints, displace reservoirs (water tanks), and misalign pump station foundations. Culverts and intake locations may be partially blocked or deformed, with flood gates becoming potentially inoperable. 62 km (17%) of pipes, 4 (67%) treatment plants, 11 (58%) pump stations, 3 (100%) intake locations, and 29 (74%) flood gates are located within mapped lateral spreading zones. Service disruption of up to 1-week is likely, with reduce service capacity in impacted areas.	Tolerable
59	Lifelines	Three Waters	Lateral spreading (co-seismic)	Rare	Catastrophic	Extensive lateral spreading is expected, causing rupture of pipes, collapse of reservoirs (water tanks) and structural failure of pump stations and intake locations. 62 km (17%) of pipes, 4 (67%) treatment plants, 11 (58%) pump stations, 3 (100%) intake locations, and 29 (74%) flood gates are located within mapped lateral spreading zones. Service disruption is likely to exceed 1 month, with widespread loss of service and cascading impacts to public health and flood management.	Tolerable
60	Lifelines	Three Waters	Surface rupture	Rare	Catastrophic	Surface rupture intersecting three waters infrastructure may result in partial or complete structural failure of reservoirs (water tanks), pump stations, treatment plants, and intake structures. Pipes may be severed or offset and culverts may collapse. Deformation associated with surface rupture could also significantly impact how the three waters network functions. Service disruption is likely to exceed 1 month, with isolated areas of service disruption. Three waters infrastructure located in and around Kaitangata is likely to be more susceptible to damage, due to its proximity to the Titri Fault.	Tolerable

Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
61	Lifelines	Fuel	Seismic shaking	Likely	Minor	Seismic shaking may result in minor displacement of above-ground tanks, loosening of pipe connections, and cosmetic damage to dispensing equipment. Service disruption is likely to be limited to short-term inspection and minor repairs (up to 1 day). Fuel sites located near transport corridors may experience minor disruption to supply logistics.	Acceptable
62	Lifelines	Fuel	Seismic shaking	Possible	Moderate	Seismic shaking may result in cracking of tank foundations, misalignment of underground piping and damage to mechanical fittings. Service disruption of up to 1 week is expected, with temporary closure of affected sites for inspection and repair. This may result in impacts to fuel availability within the study area for emergency services and agricultural operations.	Tolerable
63	Lifelines	Fuel	Seismic shaking	Rare	Major	Seismic shaking may result in structural damage to tanks, rupture of underground pipes, and structural failure of containment structures. Service disruptions of up to 1 month likely, with potential environmental and public health impacts from fuel leakage. Failure/ damage of this infrastructure may exacerbate impacts to the transport and emergency response efforts post event, particularly for isolated areas.	Acceptable
64	Lifelines	Fuel	Liquefaction (co-seismic)	Likely	Minor	Liquefaction is unlikely to be triggered under this scenario, though minor ground deformation may occur. Tanks and underground infrastructure remain functional, other than damage as a result of seismic shaking. Service disruption of up to 1-day is possible for inspections.	Acceptable
65	Lifelines	Fuel	Liquefaction (co-seismic)	Possible	Moderate	Localised liquefaction may result in settlement of tank foundations, misalignment of underground pipes, and damage to containment structures. Service disruption of up to 1 week is expected, with temporary closure of affected sites for inspection and repair. This may result in impacts to fuel availability within the study area for emergency services and agricultural operations.	Tolerable
66	Lifelines	Fuel	Liquefaction (co-seismic)	Rare	Catastrophic	Widespread liquefaction is likely, resulting in severe settlement and loss of bearing capacity beneath tanks and underground infrastructure. Rupture of pipes and failure of containment systems may occur. There are various petrol stations within the study area, alongside one fuel site (lifelines). 89% (8) petrol stations and the lifelines fuel site are located within "Liquefaction is Possible" extents. Service disruption is likely to exceed 1 month, with environmental remediation required. Fuel site failure may result in hazardous spills, increased fire risk, public health concerns and prolonged disruption to regional fuel supply.	Tolerable
67	Lifelines	Fuel	Lateral spreading (co-seismic)	Likely	Minor	Lateral spreading is likely to be limited and concentrated near river margins if it is triggered. It may cause minor displacement of tank foundations and underground piping. Service disruption is limited to inspection and minor repairs (up to 1-day).	Acceptable

Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
68	Lifelines	Fuel	Lateral spreading (co-seismic)	Possible	Moderate	Localised lateral spreading may shear underground pipes, misalign tanks, and damage containment systems. Service disruption of up to 1 week is likely, with partial loss of operability. This may result in impacts to fuel availability within the study area for emergency services and agricultural operations.	Tolerable
69	Lifelines	Fuel	Lateral spreading (co-seismic)	Rare	Catastrophic	Extensive lateral spreading is expected, causing rupture of underground pipes, collapse of containment systems and structural damage to tanks. 44% (4) petrol stations and the lifelines fuel site are located within mapped lateral spreading zones. Service disruption is likely to exceed 1 month, with environmental remediation required. Fuel site failure may result in hazardous spills, increased fire risk, public health concerns and prolonged disruption to regional fuel supply.	Tolerable
70	Lifelines	Fuel	Surface rupture	Rare	Catastrophic	Surface rupture intersecting fuel sites may result in complete structural failure of tanks, severing of underground pipes, and loss of containment. Service disruption is likely to exceed 1 month, with environmental and public health and safety risks requiring full remediation. The two petrol stations located near Kaitangata are more susceptible to damage due to their proximity to the Titri Fault. The lifelines fuel site is located in Balclutha so is less susceptible to damage from fault rupture.	Tolerable
71	Lifelines	Electricity	Seismic shaking	Likely	Minor	Seismic shaking may result in minor displacement of equipment, loosening of fittings, and cosmetic damage to substation components. Transmission towers may sway but remain structurally sound. Service disruption is limited to inspections and minor repairs (up to 1 day).	Acceptable
72	Lifelines	Electricity	Seismic shaking	Possible	Moderate	Seismic shaking may result in cracking of substation foundations, misalignment of switchgear and damage (cracking) to transmission tower footings. Transmission towers may sway, but remain structurally sound. Equipment within substations can become dislodged, or short-circuit resulting in disruption to services. Service disruption is up to 1 week, for inspection and repair. Temporary outages likely, with electricity disrupted immediately post event. Service disruption will have a cascading impacts on other lifeline utilities e.g., telecommunications, water and emergency services.	Tolerable
73	Lifelines	Electricity	Seismic shaking	Rare	Major	Seismic shaking may result in structural damage to substations, tilting of transmission towers and potential failure of high-voltage components. Shaking may also cause tall, or slim structures to oscillate causing damage to lines and co-located assets such as transformers. Equipment within substations can become dislodged, or short circuit, leading to power outages. Service disruption could range from 1-week to 1-month, with cascading impacts on other lifeline utilities e.g., telecommunications, water and emergency services.	Acceptable
74	Lifelines	Electricity	Liquefaction (co-seismic)	Likely	Minor	Liquefaction is unlikely to be triggered under this scenario, though minor ground deformation may occur around substation pads and tower footings. Equipment remains functional, with no structural damage expected. Service disruption is limited to inspections and minor repair (up to 1-day).	Acceptable

Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
75	Lifelines	Electricity	Liquefaction (co-seismic)	Possible	Moderate	Localised liquefaction may result in settlement of substation pads, minor tilting of transmission towers, and misalignment of buried cables. Electrical components and co-located assets such as transformers may be stressed, or dislodged. Service disruption of up to 1-week is expected with temporary outages likely. Re-routing is likely to be required. Service disruption will have cascading impacts on other lifeline utilities e.g., telecommunications, water and emergency services.	Tolerable
76	Lifelines	Electricity	Liquefaction (co-seismic)	Rare	Catastrophic	Widespread liquefaction is likely, resulting in severe settlement and loss of bearing capacity beneath substations and towers. Structural failure of footings and rupture of underground cables may occur. There is one transmission tower located within the study area and it is located within a "Liquefaction is Possible" extent. Service disruption is likely to exceed 1 month with some infrastructure needing complete reconstruction, while others needing repair. Service disruption will have cascading impacts on other lifeline utilities e.g., telecommunications, water and emergency services.	Tolerable
77	Lifelines	Electricity	Lateral spreading (co-seismic)	Likely	Minor	Lateral spreading may cause minor displacement of tower footings and substation foundations, particularly near river margins or free faces. Service disruption is limited to inspection and minor repairs (up to 1-day).	Acceptable
78	Lifelines	Electricity	Lateral spreading (co-seismic)	Possible	Moderate	Localised lateral spreading may shear buried cables, misalign components, and damage substation foundations and components. Co-located assets such as transformers can be stressed or short-circuited. Service disruption of up to 1-week is expected with temporary outages likely. Re-routing is likely to be required. Service disruption will have cascading impacts on other lifeline utilities e.g., telecommunications, water and emergency services.	Tolerable
79	Lifelines	Electricity	Lateral spreading (co-seismic)	Rare	Catastrophic	Extensive lateral spreading is expected, leading to shearing of cables, misalignment of components and damage to substation foundation and components. Tilting of transmission towers is possible, and stress of co-located assets is likely to occur. The one transmission tower within the study area is located within a mapped lateral spreading zone. Service disruption is likely to exceed 1 month, with widespread outages and cascading impacts on other lifeline utilities e.g., telecommunications, water and emergency services.	Tolerable
80	Lifelines	Electricity	Surface rupture	Rare	Catastrophic	Surface rupture intersecting electricity infrastructure may result in complete structural failure of towers, substations, severing both transmission and distribution lines. Service disruption would exceed 1 month, with widespread outages not only locally but within the region. There are no major electricity assets located within the Kaitangata township which is located within close proximity to the Titri Fault.	Tolerable
81	Lifelines	Telecommunications	Seismic shaking	Likely	Minor	Seismic shaking may result in minor displacement of cell tower components and minor deformation of fibre cable supports. Antennae may sway but remain structurally sound. Service disruption is limited to inspections and minor repairs (up to 1-day). Fibre routes co-located with bridges or road corridors may require inspection, but functionality is expected to stay intact.	Acceptable

Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
82	Lifelines	Telecommunications	Seismic shaking	Possible	Moderate	Seismic shaking may result in displacement of cell tower components, damage to antennae mounts and stress on fibre cables. Equipment cabinets may shift or short-circuit. Service disruption of up to 1-week is likely for inspections and minor repairs. Service disruption is also dependant on impacts / outages within the electricity network. Reduced signal strength and data capacity may result from this level of shaking. Disruption may affect emergency services communications and internet access, particularly in rural and coastal areas, with limited redundancy.	Tolerable
83	Lifelines	Telecommunications	Seismic shaking	Rare	Major	Seismic shaking may result in structural damage to cell towers, collapse of antennae, and severance of fibre cables. Equipment cabinets may be dislodged or damaged. Service disruption of up to 1 month is likely, with cascading impacts on emergency coordination, public communication and digital services. Failure of fibre backhaul may isolate communities digitally, particularly where co-located infrastructure is also damaged (e.g., SH1).	Acceptable
84	Lifelines	Telecommunications	Liquefaction (co-seismic)	Likely	Minor	Liquefaction is unlikely to be triggered under this scenario, though minor deformation may occur. Fibre cables and cell tower infrastructure is likely to remain functional. Service disruption is limited to inspections and any minor repairs (up to 1-day).	Acceptable
85	Lifelines	Telecommunications	Liquefaction (co-seismic)	Possible	Moderate	Localised liquefaction may result in settlement of cell tower and cell site foundations, misalignment of antennae and deformation of fibre cables. Service disruption is likely up to 1 week, with reduced signal strength, and data capacity. Service disruption is also dependant on impacts/ outages within the electricity network. Disruption may affect emergency services communications, and internet access, particularly in rural and coastal areas, with limited redundancy.	Tolerable
86	Lifelines	Telecommunications	Liquefaction (co-seismic)	Rare	Catastrophic	Widespread liquefaction is likely, causing severe settlement and potential structural failure of cell towers and cell sites. Fibre cables are likely to be severed/ ruptured, disconnecting communications locally. Service disruption is likely to exceed 1 month, with reconstruction of some infrastructure likely. Of the 4 cell sites/ towers within the study area, 3 are located within "Liquefaction is Possible" extents. 62 km (30%) of fibre cable is also located within "Liquefaction is Possible" extents.	Tolerable
87	Lifelines	Telecommunications	Lateral spreading (co-seismic)	Likely	Minor	Lateral spreading may cause minor displacement of cell tower footings, cell site foundations and fibre cables, particularly near river margins and free faces. Service disruption is limited to inspection and minor repairs (up to 1-day).	Acceptable
88	Lifelines	Telecommunications	Lateral spreading (co-seismic)	Possible	Moderate	Localised lateral spreading may result in the shearing of fibre cables, and damage of cabinet equipment. Service disruption of up to 1 week is expected, with reduced signal strength and data capacity likely. Service disruption is also dependent on impacts/outages within the electricity network. Disruption may affect emergency services communications, and internet access, particularly in rural and coastal areas, with limited redundancy.	Tolerable

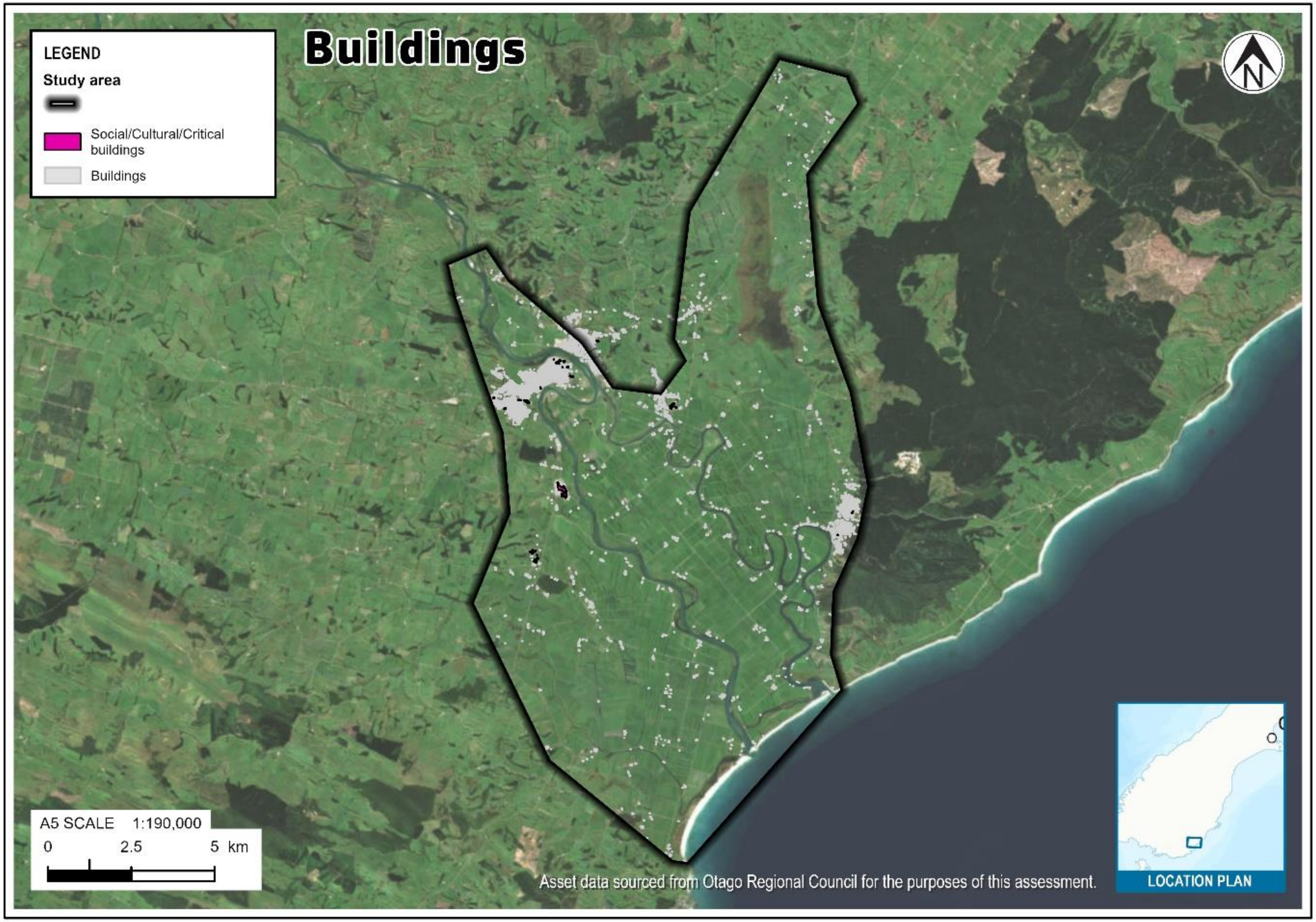
Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
89	Lifelines	Telecommunications	Lateral spreading (co-seismic)	Rare	Catastrophic	Extensive lateral spreading is expected, causing tilting of cell towers, structural damage to cell sites and severance of fibre cables. Equipment cabinets may be displaced or completely destroyed. Service disruption is likely to exceed 1 month, with full reconstruction needed for some damaged infrastructure. Failure of fibre backhaul may isolate communities digitally, particularly where co-located infrastructure is also damaged (e.g., SH1). One of the cell sites is located within mapped lateral spreading zones, alongside 22 km (11%) of fibre cable.	Tolerable
90	Lifelines	Telecommunications	Surface rupture	Rare	Catastrophic	Surface rupture intersecting telecommunications infrastructure may result in the collapse of cell towers, loss of structural integrity for cell sites and severing of fibre cables. Equipment cabinets may be displaced or destroyed. Service disruption is likely to exceed 1 month with full reconstruction required for damaged infrastructure. Failure of fibre backhaul may isolate communities digitally, particularly where co-located infrastructure is also damaged (e.g., SH1). One of the cell sites is located north of the Kaitangata township, so may be more susceptible to damage from fault rupture.	Tolerable
91	Buildings	Buildings	Seismic shaking	Likely	Minor	Seismic shaking may result in cosmetic to moderate damage of buildings. Small unstable fittings and objects may be displaced with some glassware and crockery broken. Some windows may also crack. Older unreinforced buildings are more susceptible to damage and some may be functionally compromised under this level of shaking.	Acceptable
92	Buildings	Buildings	Seismic shaking	Possible	Moderate	Seismic shaking may result in cracking and structural/non-structural damage. Unreinforced stone and brick walls can crack, with roof tiles being dislodged. Domestic chimneys may be damaged, alongside suspended ceilings. Unrestrained water cylinders may move or leak and windows are likely to crack.	Tolerable
93	Buildings	Buildings	Seismic shaking	Rare	Major	Seismic shaking may result in structural damage or collapse of unreinforced and poorly constructed buildings. Some monuments and elevated tanks and factory stacks are twisted or brought down. Some infill masonry panels damaged, with a few brick veneers damaged. Houses not secured to foundations may move.	Acceptable
94	Buildings	Buildings	Liquefaction (co-seismic)	Likely	Minor	Liquefaction is unlikely to be triggered under this scenario, however minor ground deformation may occur. Buildings may experience slight tilting or hairline foundation cracks. Inspections may be required (up to 1-day).	Acceptable
95	Buildings	Buildings	Liquefaction (co-seismic)	Possible	Moderate	Localised liquefaction may result in differential settlement of buildings, particularly those on susceptible soils. Foundations may tilt and crack, with minor structural damage occurring. Residents may need to temporarily evacuate for inspection and repairs.	Tolerable

Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
96	Buildings	Buildings	Liquefaction (co-seismic)	Rare	Catastrophic	Liquefaction is expected to be widespread, particularly in areas with shallow groundwater and susceptible soils (33% (1,902) of buildings located within "Liquefaction is Possible" zones). Buildings may experience severe foundation damage, tilting and partial collapse. Functionality is likely to be compromised, with long term or permanent displacement likely for affected residents.	Tolerable
97	Buildings	Buildings	Lateral spreading (co-seismic)	Likely	Minor	Lateral ground movement may cause minor displacement of building foundations (hairline cracks) particularly those located near riverbanks/ free faces. Misalignment of doors/windows may occur as a result of displacement. Buildings will likely remain functional, and may need minor repairs.	Acceptable
98	Buildings	Buildings	Lateral spreading (co-seismic)	Possible	Moderate	Localised lateral spreading may result in foundation displacement and cracking, influencing the structural integrity of the building. Buildings may be temporarily uninhabitable while repairs are undertaken. Utility connections may also be displaced, causing disruption and health and safety concerns.	Tolerable
99	Buildings	Buildings	Lateral spreading (co-seismic)	Rare	Catastrophic	Extensive lateral spreading is expected, causing severe foundation displacement and structural damage. Buildings may undergo partial or full collapse resulting in long term and potentially permanent relocation for residents. 13% (765) of buildings are located within mapped lateral spreading zones.	Tolerable
100	Buildings	Buildings	Surface rupture	Rare	Catastrophic	Buildings located on or near the fault rupture zone may experience complete structural failure due to ground offset. Foundations may be split, or displaced leading to partial or full collapse. Total loss of building function is expected, with reconstruction required. Buildings located in Kaitangata are more susceptible to damage due to their proximity to the Titri Fault.	Tolerable
101	Buildings	Critical Buildings	Seismic shaking	Likely	Minor	Seismic shaking may result in cosmetic to moderate damage of buildings. Small unstable fittings and objects may be displaced with some glassware and crockery broken. Some windows may also crack. Older or unreinforced buildings are more susceptible to damage and may be functionally compromised under this level of shaking (e.g., Library and Community Pool).	Acceptable
102	Buildings	Critical Buildings	Seismic shaking	Possible	Moderate	Seismic shaking may result in cracking and structural/non-structural damage. Unreinforced stone and brick walls can crack, with roof tiles being dislodged. Domestic chimneys are likely to be damaged, alongside suspended ceilings. Unrestrained water cylinders may move or leak and windows are likely to crack.	Tolerable
103	Buildings	Critical Buildings	Seismic shaking	Rare	Catastrophic	Seismic shaking may result in structural damage or collapse of unreinforced and poorly constructed buildings. Some monuments and elevated tanks and factory stacks are twisted or brought down. Some infill masonry panels damaged, with a few brick veneers damaged. Houses not secured to foundations may move.	Tolerable
104	Buildings	Critical Buildings	Liquefaction (co-seismic)	Likely	Minor	Liquefaction is unlikely to be triggered under this scenario, however minor ground deformation may occur. Buildings may experience slight tilting or hairline foundation cracks. Inspections may be required, however functionality remains intact.	Acceptable

Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
105	Buildings	Critical Buildings	Liquefaction (co-seismic)	Possible	Major	Localised liquefaction may result in differential settlement of buildings, particularly those on susceptible soils. Foundations may tilt and crack, with minor structural damage occurring. Occupants may need to temporarily evacuate for inspection and repairs.	Tolerable
106	Buildings	Critical Buildings	Liquefaction (co-seismic)	Rare	Catastrophic	Liquefaction is expected to be widespread, particularly in areas with shallow groundwater and susceptible soils (17% (10) of critical buildings are located within "Liquefaction is Possible" zones). Buildings may experience severe foundation damage, tilting and partial collapse. Functionality is likely to be compromised, with long term or permanent displacement likely for affected residents.	Tolerable
107	Buildings	Critical Buildings	Lateral spreading (co-seismic)	Likely	Minor	Lateral ground movement may cause minor displacement of building foundations (hairline cracks) particularly those located near riverbanks/ free faces. Misalignment of doors/windows may occur as a result of displacement. Buildings will likely remain functional, and may need minor repairs.	Acceptable
108	Buildings	Critical Buildings	Lateral spreading (co-seismic)	Possible	Major	Localised lateral spreading may result in foundation displacement and cracking, influencing the structural integrity of the building. Buildings may be temporarily uninhabitable while repairs are undertaken. Utility connections may also be displaced, causing disruption and health and safety concerns.	Tolerable
109	Buildings	Critical Buildings	Lateral spreading (co-seismic)	Rare	Catastrophic	Extensive lateral spreading is expected, causing severe foundation displacement and structural damage. Buildings may undergo partial or full collapse resulting in long term and potentially permanent relocation for residents. 10% (6) of critical buildings are located within mapped lateral spreading zones.	Tolerable
110	Buildings	Critical Buildings	Surface rupture	Rare	Catastrophic	Buildings located on or near the fault rupture zone may experience complete structural failure due to ground offset. Foundations may be split, or displaced leading to partial or full collapse. Total loss of building function is expected, with reconstruction required. Buildings located in Kaitangata are more susceptible to damage due to their proximity to the Titri Fault.	Tolerable
111	Health & Safety	Health and Safety	Seismic shaking	Likely	Insignificant	Seismic shaking is expected to result in no injuries or fatalities. Most buildings will remain structurally sound, with only minor internal hazards e.g., falling objects.	Acceptable
112	Health & Safety	Health and Safety	Seismic shaking	Possible	Minor	Seismic shaking may result in minor injuries that are likely to require medical attention, particularly from falling debris or internal hazards in older buildings. No fatalities are expected. Estimating the number of fatalities and injured is dependant on many factors including building construction (age, construction and no. of storeys), time of day and the vulnerability of the population.	Acceptable
113	Health & Safety	Health and Safety	Seismic shaking	Rare	Major	Seismic shaking may result in multiple injuries (more than 100) and potentially up to 10 fatalities, particularly in unreinforced masonry buildings. Vulnerable populations within Balclutha, including the aged residents (Balclutha rest home, PACT House, and retirement housing on Charlotte Street), alongside migrant/ seasonal workers are likely at greater risk due to mobility limitations, building fragility and uncertainty around these types of events.	Acceptable
114	Health & Safety	Health and Safety	Liquefaction (co-seismic)	Likely	Insignificant	Liquefaction is unlikely to cause direct injury. Minor ground deformation may pose low risk to personal safety, no injuries or fatalities are likely.	Acceptable

Risk ID	Asset Grouping	Asset Subgroup	Hazard	Likelihood	Consequence	Consequence description	Risk Score
115	Health & Safety	Health and Safety	Liquefaction (co-seismic)	Possible	Minor	Localised liquefaction may result in minor injuries due to ground instability or secondary hazards e.g., falling structures, tripping. Some injuries may require medical attention, particularly for vulnerable populations such as aged residents.	Acceptable
116	Health & Safety	Health and Safety	Liquefaction (co-seismic)	Rare	Major	Widespread liquefaction may lead to structural damage, with some partial collapse of buildings. This can result in injuries and potential fatalities. Vulnerable populations within Balclutha, including the aged residents (Balclutha rest home, PACT House, and retirement housing on Charlotte Street), alongside migrant/ seasonal workers are likely at greater risk due to mobility limitations, building fragility and uncertainty around these types of events.	Acceptable
117	Health & Safety	Health and Safety	Lateral spreading (co-seismic)	Likely	Insignificant	Lateral spreading is expected to be limited and not pose a significant risk to personal safety. No injuries or fatalities are expected.	Acceptable
118	Health & Safety	Health and Safety	Lateral spreading (co-seismic)	Possible	Minor	Localised lateral spreading may cause minor injuries as a result of ground displacement or structural movement. Some injuries may require medical attention, particularly for vulnerable populations such as aged residents.	Acceptable
119	Health & Safety	Health and Safety	Lateral spreading (co-seismic)	Rare	Major	Extensive lateral spreading may result in structural failure and potential collapse, particularly for buildings located near river margins. Both PACT House and Holmdede Home For The Aged are located within mapped lateral spreading zones so may be more susceptible to damage, and therefore health and safety risk for residents. Multiple injuries and potential fatalities are likely, particularly in unreinforced or poorly constructed buildings. Emergency response may be severely impacted as well, exacerbating health and safety risks.	Acceptable
120	Health & Safety	Health and Safety	Surface rupture	Rare	Catastrophic	Surface rupture may result in the collapse of buildings that it intersects. Multiple fatalities and injuries are likely, particularly in unreinforced or poorly constructed buildings. Emergency response may also be severely impacted.	Tolerable

Appendix C Asset Figures


Buildings
LEGEND
Study area
Social/Cultural/Critical buildings
Buildings
A5 SCALE 1:190,000
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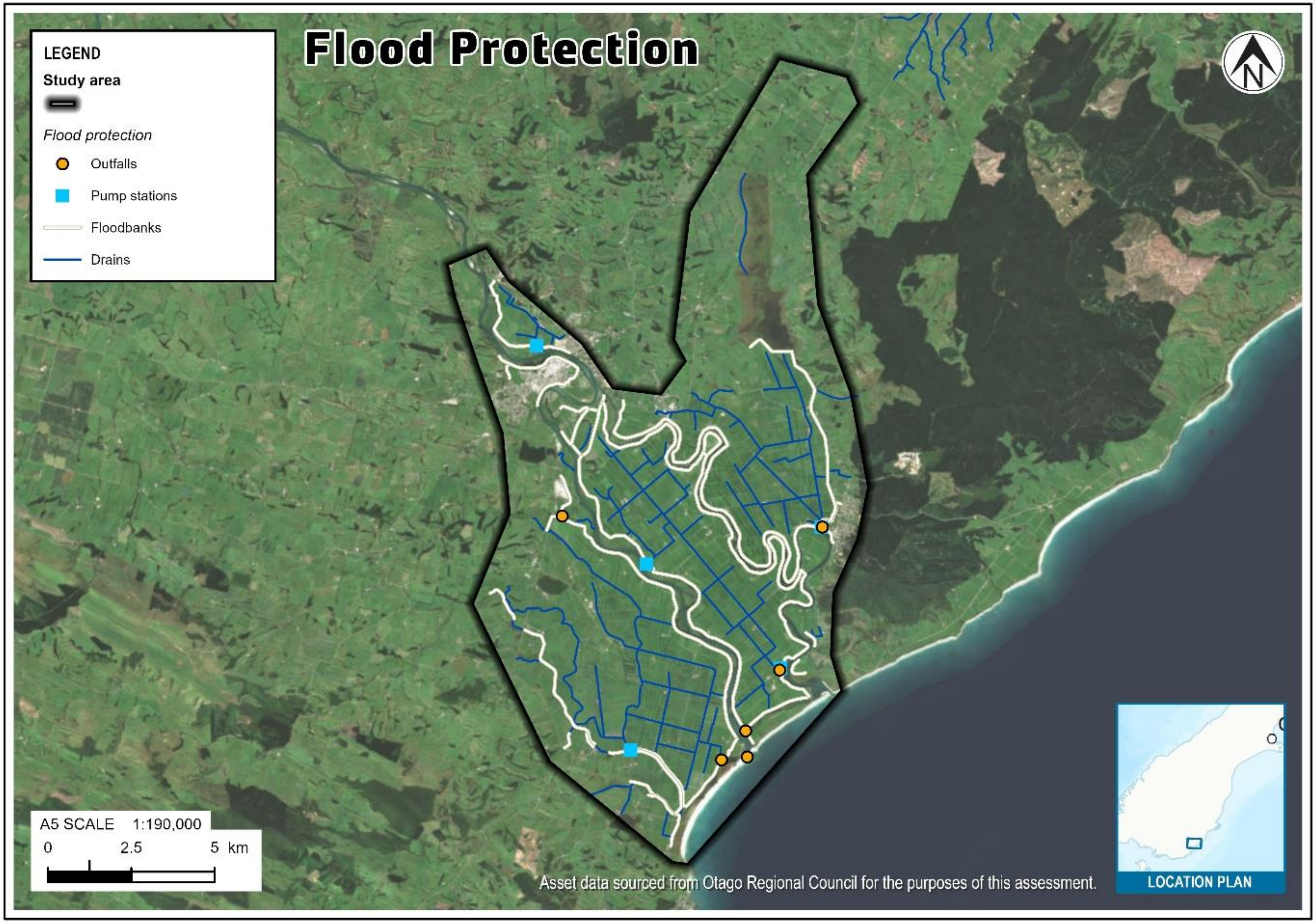
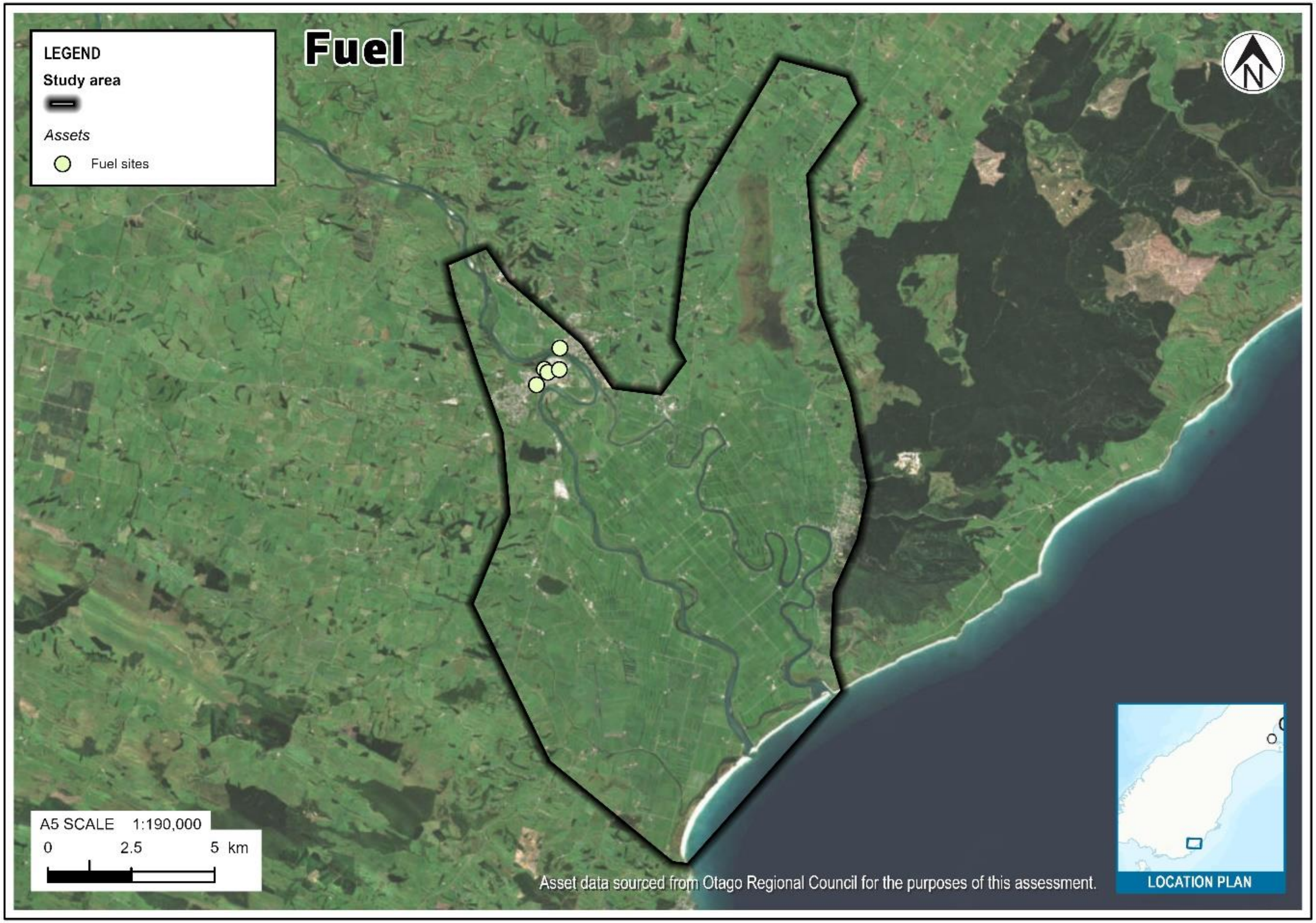
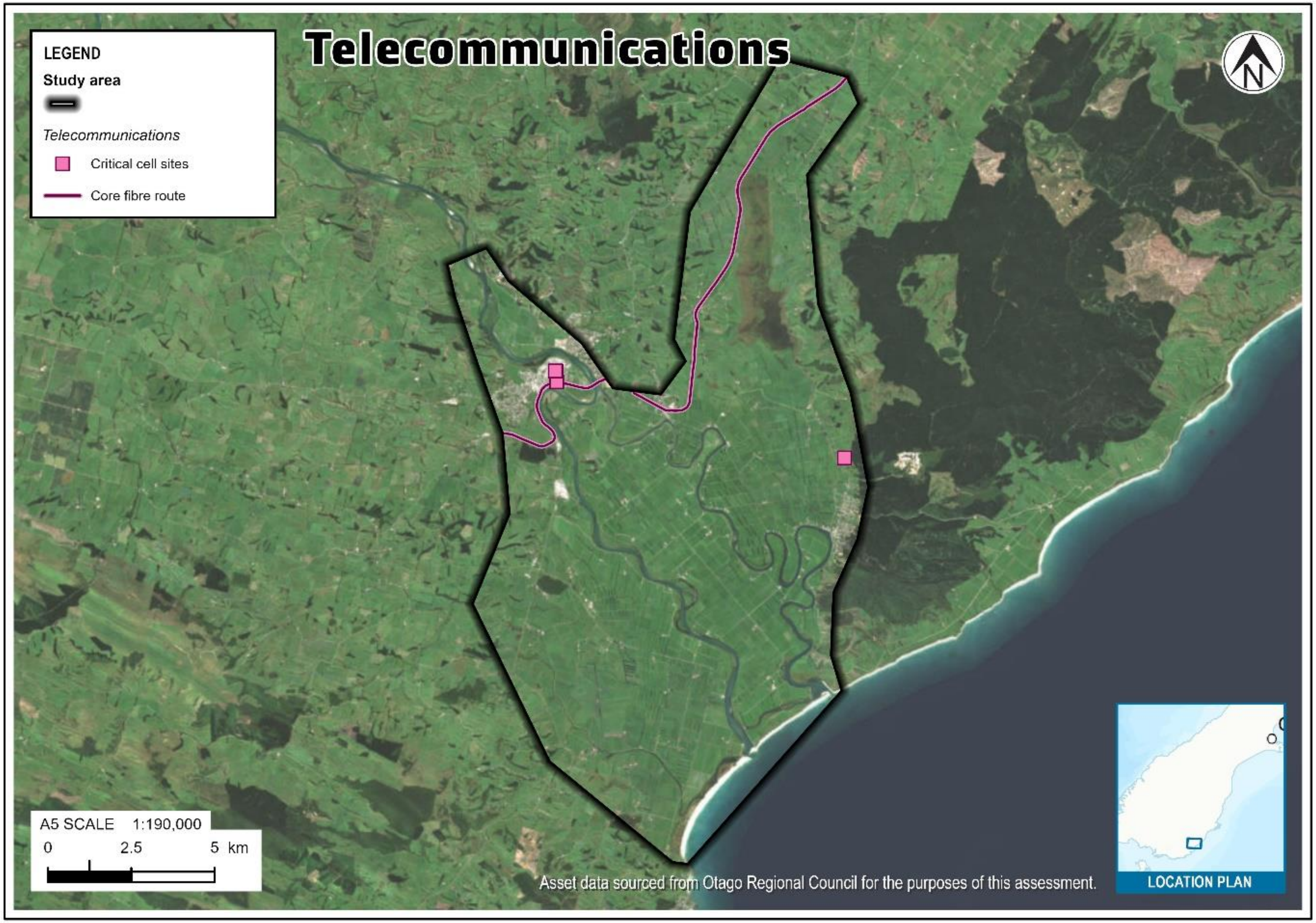
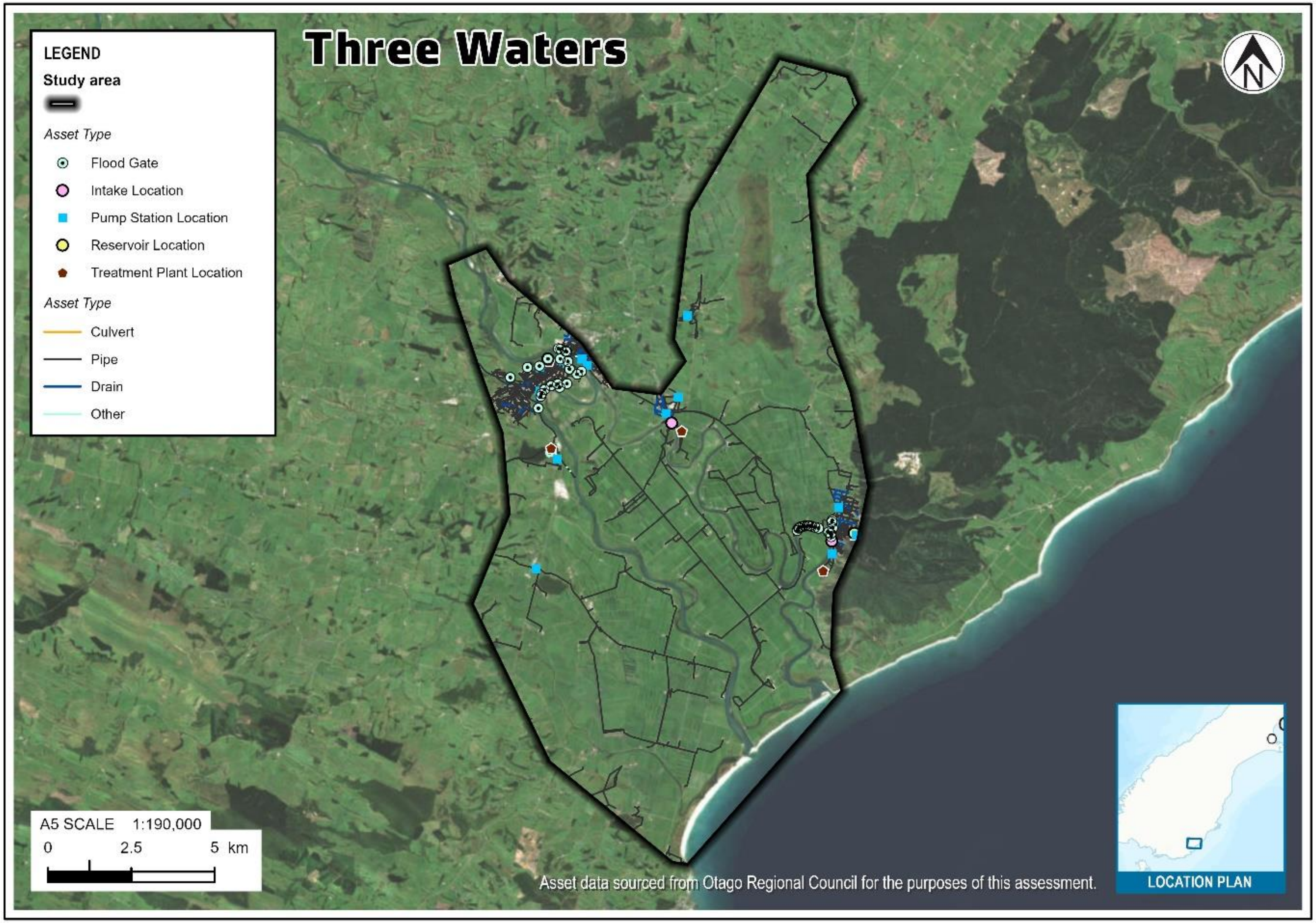
2.5
5 km
Asset data sourced from Otago Regional Council for the purposes of this assessment.
LOCATION PLAN
N

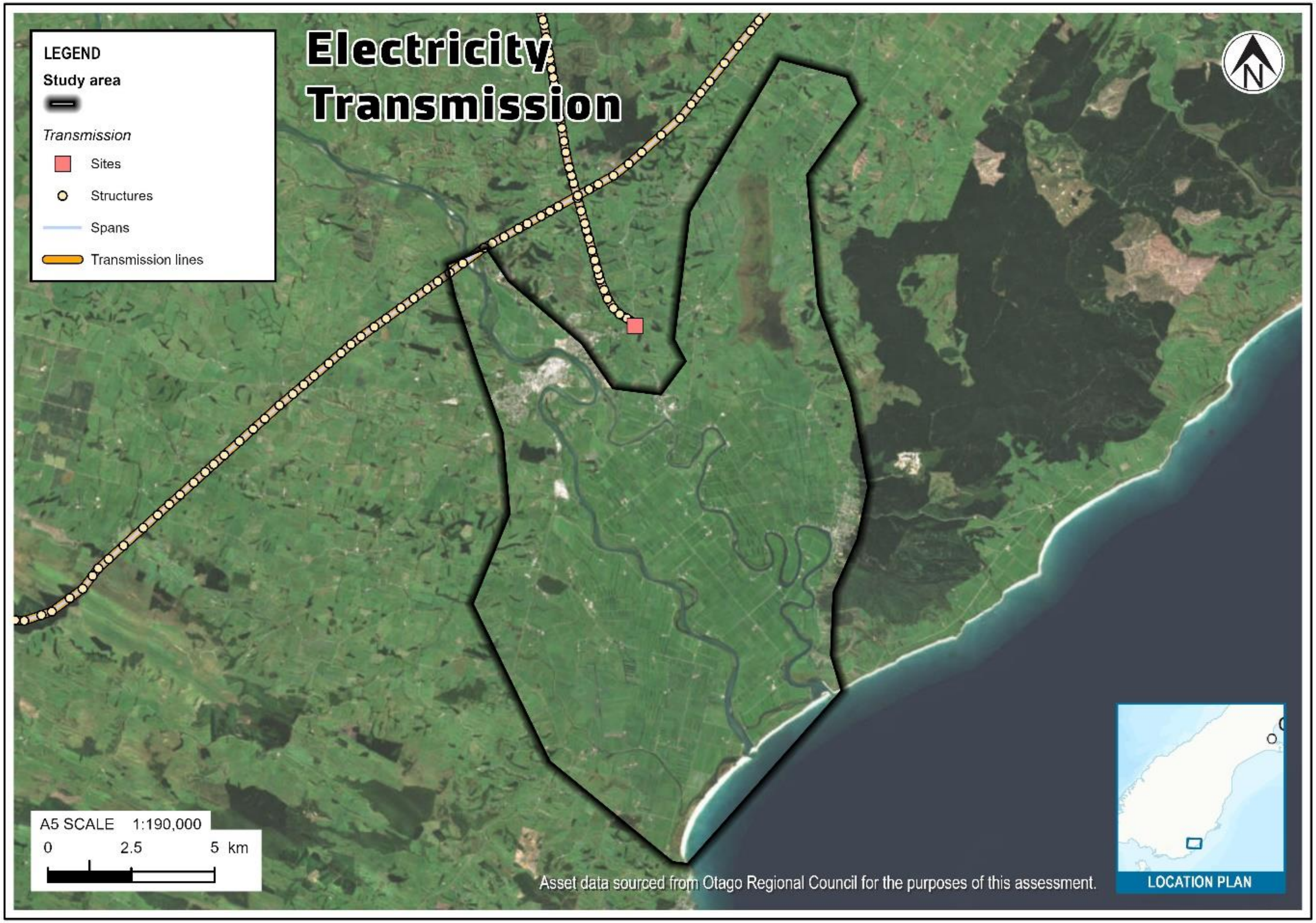

Flood Protection
LEGEND
Study area
Flood protection
Outfalls
Pump stations
Floodbanks
Drains
A5 SCALE 1:190,000
0
2.5
5 km
Asset data sourced from Otago Regional Council for the purposes of this assessment.
LOCATION PLAN
N

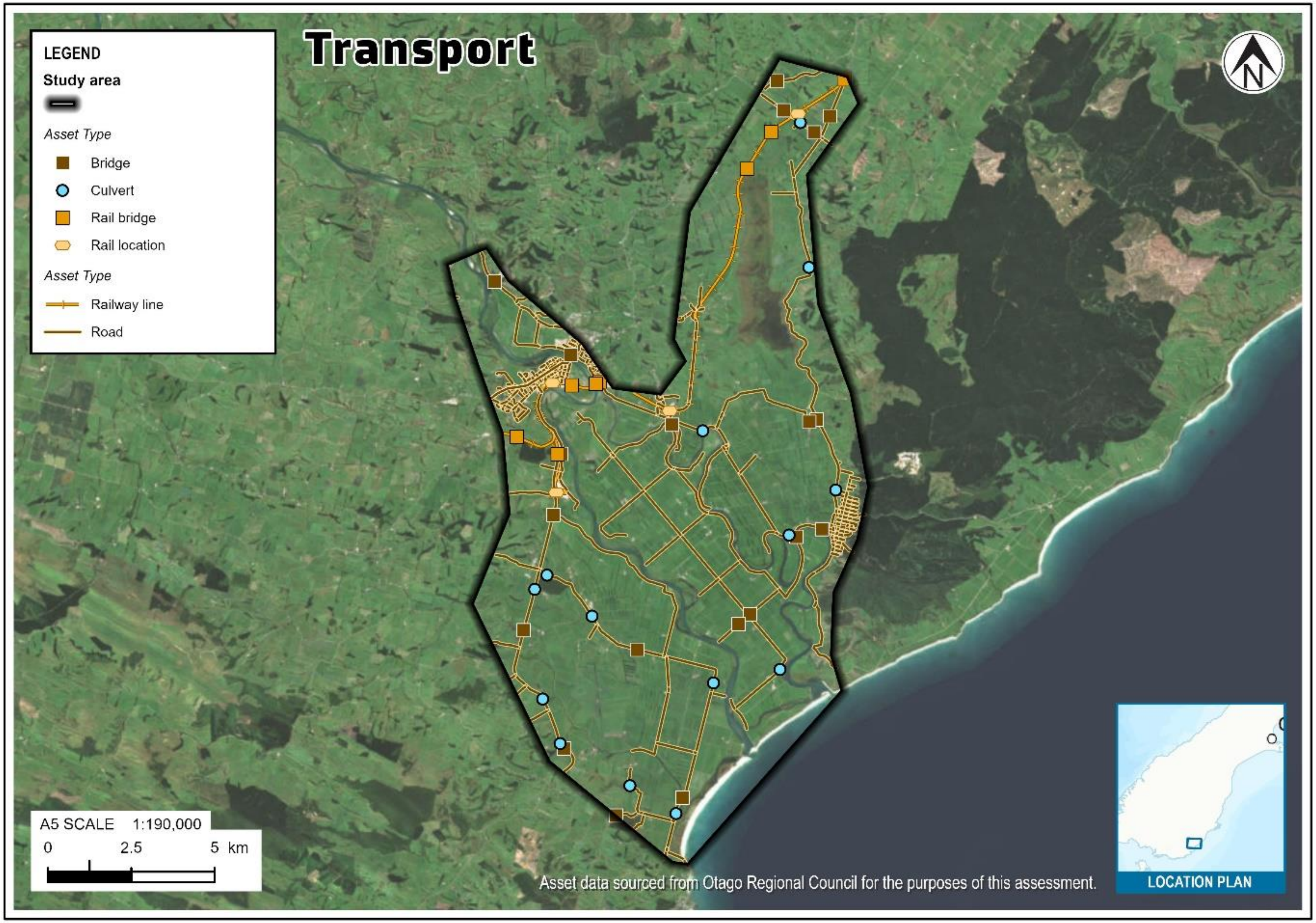

Fuel
LEGEND
Study area
Assets
Fuel sites
A5 SCALE 1:190,000
0
2.5
5 km
Asset data sourced from Otago Regional Council for the purposes of this assessment.
LOCATION PLAN
N



Telecommunications
LEGEND
Study area
Telecommunications
Critical cell sites
Core fibre route
A5 SCALE 1:190,000
0 2.5 5 km
N
Asset data sourced from Otago Regional Council for the purposes of this assessment.
LOCATION PLAN


Three Waters
LEGEND
Study area
Asset Type
Flood Gate
Intake Location
Pump Station Location
Reservoir Location
Treatment Plant Location
Asset Type
Culvert
Pipe
Drain
Other
A5 SCALE 1:190,000
0 2.5 5 km
Asset data sourced from Otago Regional Council for the purposes of this assessment.
LOCATION PLAN
N


Electricity Transmission
LEGEND
Study area
Transmission
Sites
Structures
Spans
Transmission lines
A5 SCALE 1:190,000
0 2.5 5 km
Asset data sourced from Otago Regional Council for the purposes of this assessment.
LOCATION PLAN


Transport
LEGEND
Study area
Asset Type
Bridge
Culvert
Rail bridge
Rail location
Asset Type
Railway line
Road
A5 SCALE 1:190,000
0 2.5 5 km
N
Asset data sourced from Otago Regional Council for the purposes of this assessment.
LOCATION PLAN