Review of Dunedin City District Plan: Natural hazards

Project overview

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Summary

As part of its current review of its District Plan, the Dunedin City Council (DCC) is reviewing the way it manages the use of land, so that the effects of natural hazards (including the effects of climate change) can be avoided or adequately mitigated. The Otago Regional Council (ORC) is supporting the DCC by providing natural hazards information, knowledge and opinion through a collaborative approach, to help inform this review.

A joint DCC/ORC project to identify the characteristics and likely geographical extent of natural hazards within the Dunedin City District boundary began in 2013, using the best information currently available. This present report provides a summary of that work and identifies areas within the district where natural hazards may affect public safety, buildings and the infrastructure that supports communities.

The project coincides with a review of Otago's Regional Policy Statement (RPS). The RPS sets the framework for future planning, clarifies roles and responsibilities and focuses on reducing the current risk associated with natural hazards and avoiding additional risk. The work described in this report is an example of how the ORC works together with Otago's other local authorities (in this case the DCC) to ensure that effects of natural hazards are avoided, or adequately mitigated.

While the effects of events that occur frequently (e.g. spring tides) tend to be relatively well understood, the effects of higher-magnitude events that occur less frequently (e.g. major earthquakes) are not as well known. Often there is a public perception that the most recent or well-known 'big event' is the bench-mark for a particular type of hazard, and that there is therefore little need to consider the effects of an event larger than previously (or recently) observed. This present project describes a range of effects, including events that can occur regularly (e.g. flooding of low-lying riverside settlements), through to credible high-magnitude events that can have the most devastating effect on communities (e.g. major earthquakes and landslides).

More detailed information on natural hazards for particular areas is provided in a series of supplementary technical reports:

1.	Coastal hazards of the Dunedin City District	(ORC, 2014a)
2.	Flood hazard on the Taieri Plain and Strath Taieri	(ORC, 2014b)
3.	Flood hazard of Dunedin's urban streams	(ORC, 2014c)
4.	The hazard significance of landslides in and around Dunedin City	(GNS, 2014a)
5.	Assessment of liquefaction hazards in the Dunedin City District	(GNS, 2014b)

These reports include the results of additional investigations undertaken or commissioned by ORC, and present the best information currently available. The additional work includes an assessment of the significance of landslide hazard, an assessment of liquefaction susceptibility, and mapping the floodplain areas of the Water of Leith, Lindsay Creek and Kaikorai Stream catchments.

This report also describes the 'Principles-based' approach, which the DCC and ORC have agreed should be used to manage land-use activities, in order to avoid or mitigate natural hazards, and to take into account the effects of climate change. The principles used are consistent with those that inform the review of the natural hazards' section of the RPS and are based on the themes of 'people and communities' and 'the management of natural hazards'.

In summary, this present report, along with a series of supporting reports, has been prepared to:

- raise awareness of the characteristics of natural hazards in the Dunedin City District
- help inform the management of land use to avoid or mitigate natural hazards.

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1. Introduction

As part of its current review of its District Plan, the Dunedin City Council (DCC) is reviewing the way it manages the use of land, so that the effects of natural hazards[1] (including the effects of climate change) can be avoided or adequately mitigated. The Otago Regional Council (ORC) is supporting the DCC by collating and presenting existing information on natural hazards to help inform this review.

The review of the District Plan's approach[2] to the management of natural hazards aims to:

- introduce better rules and standards to protect people and property from the risks posed by natural hazards in certain areas
- provide better information to land owners and investors about constraints on land development as well as the most suitable land for development
- limit the exacerbation of risks from natural hazards.

A joint DCC/ORC project to identify the characteristics and likely geographical extent of natural hazards within the Dunedin City District boundary began in 2013, using the best information currently available. This report provides a summary of that work and identifies areas within the district where natural hazards may affect public safety, buildings and the infrastructure that supports communities.

This report also describes the 'Principles-based' approach, which the DCC and ORC have agreed should be used to manage land-use activities, in order to avoid or mitigate natural hazards, and to take into account the effects of climate change. These principles are consistent with the principles informing the review of the natural hazards section of the Otago Regional Policy Statement and are based around the themes of 'people and communities', and 'the management of natural hazards'.

Section 2 describes the physical and social environment of the Dunedin City District, while Section 3 describes the legislative context within which the review of the District Plan operates. Section 4 outlines the guiding principles that will help to determine the planning response to be included in the revised District Plan, and Sections 5 and 6 describe and map (at a district and community scale) the natural hazards that can affect land within Dunedin City District. More detailed information on natural hazards for particular areas is provided in a series of supplementary technical reports.

This report, along with a series of supporting documents, has been prepared to:

- raise awareness of the characteristics of natural hazard in the Dunedin City District
- help inform the management of land use to avoid or mitigate those hazards.

[1] A hazard is a source of potential harm or an event with potential to cause loss.
[2] More detail about the proposed approach and planned consultation can be found on the DCC's website at http://www.dunedin.govt.nz/whats-on/2gp.

2. Environment setting

The natural hazards experienced within the Dunedin City District are determined by its physical characteristics, along with the social or 'built' environment that may be affected by a particular event (such as an earthquake or severe storm). These characteristics are summarised below.

2.1. Geography

The Dunedin City District has a land area of 3,314 square kilometres (Figure 1). The boundary of the district extends to the Rock and Pillar Range in the west, Pleasant River in the north, the Pacific Ocean in the east and southeast, and the Waipori/Taieri River in the south. The coastline extends for approximately 200km, and includes Otago Harbour.

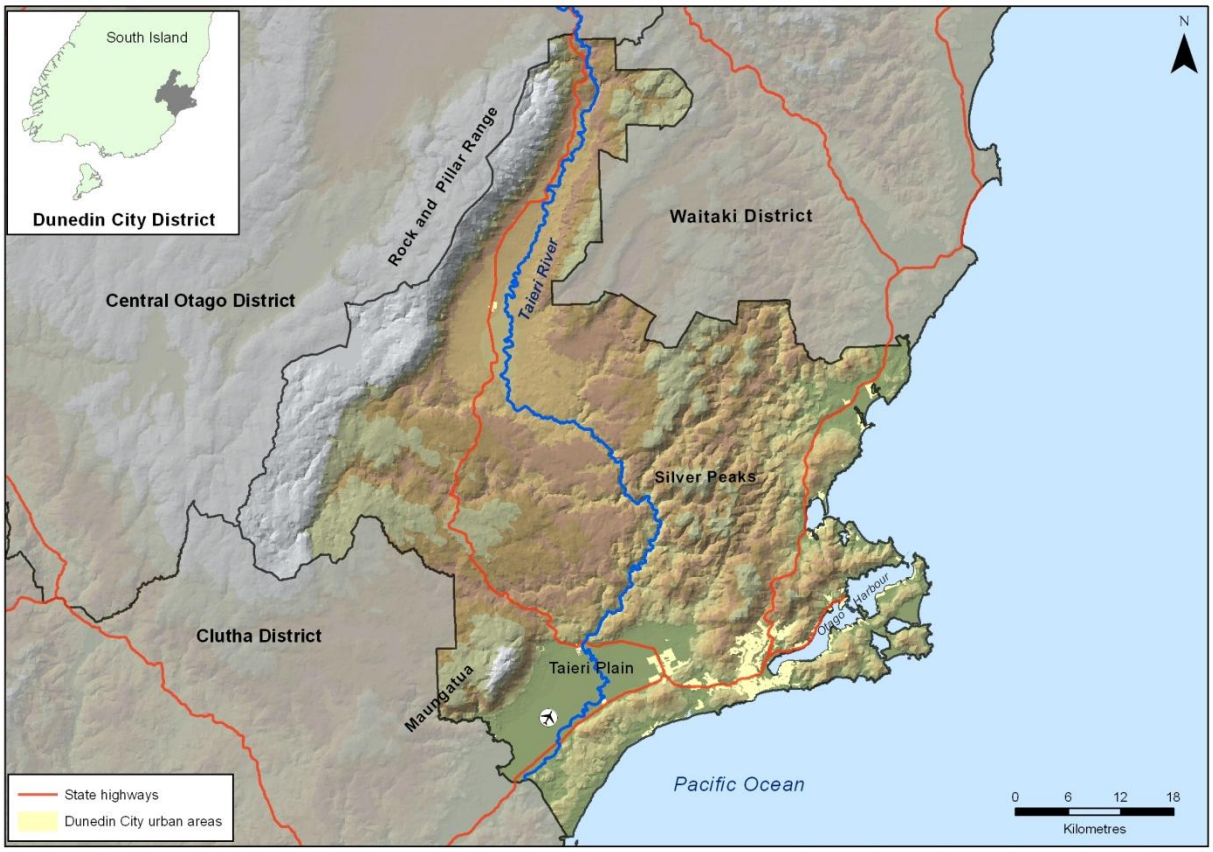

Figure 1 The boundary and main features of the Dunedin City District

2.2. Geology

The Dunedin area lies within the Pacific Plate, which is in contact with the Australian Plate across an active-plate boundary (the Alpine Fault) on the west coast of the South Island (GNS, 1996). Several smaller faults cross the district, including the Akatore Fault, which lies just off the coast, and the Titri and North Taieri faults, which straddle the Taieri Plain (Figure 2).

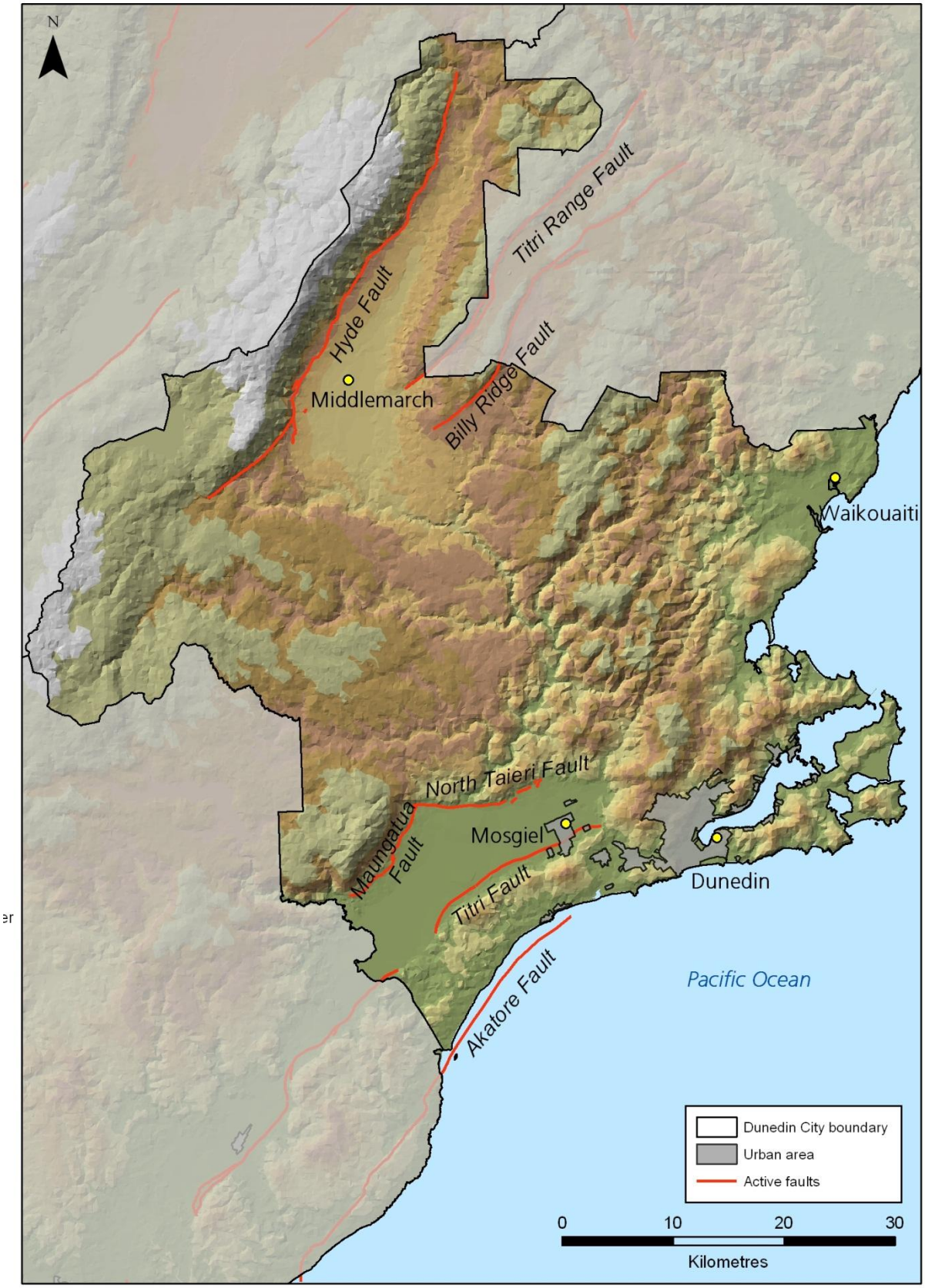

Figure 2 **Location of known active faults in the Dunedin City District**

The area has several distinct landforms:

- range-and-basin-type terrain, with flat-topped or rolling block-faulted mountain ranges, separated by broad alluvial basins in the west of the district, and on the margins of the Central Otago District
- the Taieri Plain, which lies on the northern part of the Taieri-Tokomairiro depression, and separates the elevated Central Otago plateau from the coastal ranges to the east
- a range of coastal hills, which stretch from Taieri Mouth, on the southern boundary of the city, to Green Island
- the remains of the Dunedin volcano, which includes the Otago Harbour, the Peninsula and the inner city suburbs.

2.3. Meteorological setting

The weather events that impact on Dunedin are major drivers in determining the natural hazards which affect the city, and combine to create the overall climatic picture. Fitzharris (2010) identified five distinct climatic regions within the Dunedin City District, which are determined by the area's complex topography and other controlling factors. These regions are summarised in Table 1.

Table 1 Climatic regions of Dunedin City District (sourced from Fitzharris, 2010)

Climatic region	Climate
North Otago (e.g. Waikouaiti and Karitane)	This area has a relatively low annual rainfall, ranging between 500mm to 800mm. There are generally fewer than 100 rain days, and severe droughts can occur. Prevailing winds are south-westerly and north-easterly.
Hills (e.g. Maungatuas, Flagstaff, Silver Peaks)	These areas are cooler, cloudier and wetter than further north. Rainfalls average 800mm to 1500mm annually. South-westerlies predominate, with occasional very strong north-westerly gales. Snow may lie for weeks in winter.
Transitional Central Otago (e.g. Strath Taieri)	To the west, there is a trend towards a semi-arid, semi-continental climate. Annual rainfall is below 500mm, with fewer than 80 rain days. Drought is common.
Eastern Otago (e.g. Dunedin urban area, Otago Peninsula)	Rainfall is 500mm to 900mm and is evenly distributed throughout the year, but with a slight winter minimum. Winds tend to be from the southwest, or from the northeast along the coast. The Taieri Plain is a variant climate of this region in that it is frostier and sunnier. The longest continuous rainfall record for Dunedin is located within this region, dating back to 1918 (Figure 3).
Mountains (e.g. Rock and Pillar Range)	Climate varies substantially, depending on elevation. Annual precipitation is at least 1200mm. Much of winter precipitation falls as snow and may lie on the ground for many months. Temperatures cool off with elevation.

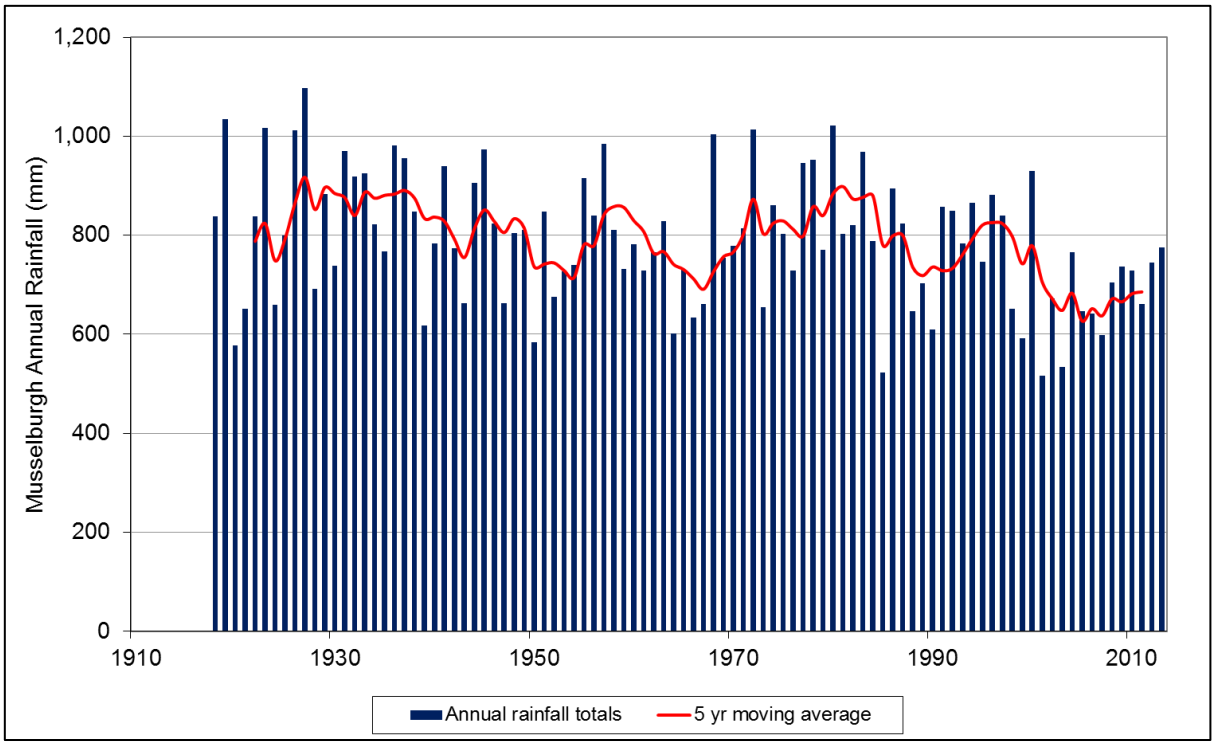

Figure 3 Annual rainfall totals at Musselburgh, 1918 to 2013

Of more importance to weather-related natural hazards (such as flooding and landslide re-activation) are the characteristics of extreme rainfall events (i.e. storms). Meteorological conditions that can drive particular climatic hazards include:

- extended periods of moderate-to-heavy rainfall from the eastern quarter, which can result in high flows in coastal catchments such as the Waikouaiti, Water of Leith, Silver Stream, and the lower reaches of the Taieri River
- a south to southwest airstream, which can also bring moderate to heavy rainfall, strong winds and occasionally heavy snow. Rainfall events associated with a southerly change are generally short lived, although they can result in high flows if catchments are already saturated from previous rainfall
- extremely heavy, but short-lived, rainfall events that can occur over the city in summer. These events may temporarily overwhelm stormwater networks, causing localised ponding and can initiate shallow landsliding on susceptible slopes
- any combination of the above. Rivers and streams rise particularly rapidly when catchments are already saturated from previous rainfall.

Very heavy rain can be experienced quite frequently within the Dunedin City District, and ORC rainfall monitoring sites on the Taieri Plain (Riccarton Road) and in the headwaters of the Silver Stream and Water of Leith catchments have recorded daily totals in excess of 160mm. A 2013 report by ORC (focusing on the Taieri Plain) found that, although there was some variability in extreme rainfall patterns, some localised areas had experienced a significant increase in the intensity and frequency of extreme rainfall events over the previous 60 years. Average temperature is predicted to increase by another 2°C by 2100. Given that a warmer atmosphere can hold more moisture, there is potential for storm events to bring heavier (or more intense) rainfall and to occur more frequently than has previously been observed (MfE, 2008b).

2.4. Hydrological setting

A number of rivers and streams traverse the Dunedin City District. The largest is the Taieri River, which rises in the Lammermoor and Lammerlaw ranges to the northwest of Dunedin and meets the Pacific Ocean at Taieri Mouth, 30km southwest of the Dunedin CBD. The Taieri River is an important feature for communities in the Strath Taieri and on the Taieri Plain (ORC, 2013).

The Silver Stream is a tributary of the Taieri River. It originates in the Silver Peaks, emerges onto the north-eastern corner of the Taieri Plains, and follows a highly modified channel to join the Taieri River downstream of Mosgiel.

The Water of Leith, Lindsay Creek and Kaikorai Stream all pass through densely populated areas of the inner city as they convey water from Dunedin's hill catchments to the coast, while the Waikouaiti and Waitati rivers further north are important features of coastal communities such as Waitati, Waikouaiti and Karitane.

2.5. Community setting

Dunedin's main urban area spreads around the upper reaches of Otago Harbour and the surrounding hills. Secondary urban centres include Mosgiel, Port Chalmers and the suburban area of Green Island – Fairfield – Waldronville. There are a number of smaller settlements scattered across the district, including:

- the coastal communities of Waikouaiti, Karitane, Warrington and Waitati to the north
- Westwood, Ocean View and Brighton along the coast to the south
- the inland communities of Allanton and Outram on the Taieri Plain, and Middlemarch on the Strath Taieri.

The city population at the time of the March 2013 Census was 120,246, an overall increase of 1.3% from 2006 (Statistics NZ, 2014). The fastest-growing areas are Mosgiel, Saddle Hill, Wingatui and East Taieri, while the population of the inner city suburbs and coastal communities has generally remained stable.

3. Legislative context

The manner and degree to which natural hazards in the Dunedin City District can be managed by the community, DCC and ORC is influenced by the obligations, powers and restrictions set out in various statutes.

The Resource Management Act 1991 (RMA) takes an 'effects-based' approach to resource management, including the management of any risk associated with natural hazards. Sections 30 and 31 of the RMA give the ORC and DCC functions to control the use of land for the avoidance and mitigation of natural hazards. Further, under RMA Section 7, in achieving the purpose of the Act, particular regard shall be given to the effects of climate change on natural hazards.

The current Otago Regional Policy Statement (RPS)[3] specifies that the DCC, through the Dunedin City District Plan, is responsible for controlling land use to avoid or mitigate the effects of natural hazards within the district. The District Plan controls what people can do on their land and how it can be developed. It applies to areas above the line of mean high water springs (MWHS) and to all users of land and the surface of water bodies in Dunedin.

The RMA requires all operative provisions of a plan to be reviewed every ten years. The current Dunedin City District Plan was notified in 1995 and became fully operative on 3 July 2006. While some parts of the District Plan are not due to be reviewed until 2016, there are large parts that have not changed since 1995, and the DCC has decided that it is time to take an holistic look at how to improve it. The aim of the review is to produce a 'second generation' District Plan (2GP) (so called because it is the second plan prepared under the RMA).

The 2GP will be prepared under the RMA in association with the community. It identifies relevant resource management issues and develops objectives, policies and methods (including rules) to manage the effects of land-use activities on the environment. The ultimate goal of the District Plan is to manage the natural and physical resources of Dunedin sustainably to meet the needs of current and future generations, and to provide for their social, economic and cultural well-being.

3.1. Managing natural-hazard risk under the current District Plan

The current District Plan's maps do not identify the extent or location of any hazards; instead, they refer to a 'Hazards' register' that sits outside the Plan. The Hazards' register is used by DCC staff as part of issuing Land Information Memorandums (LIMs) and Project Information Memorandums (PIMs), which identify whether an activity or structure is proposed on a hazard-prone site.

The District Plan allows the DCC to require resource consent applicants to carry out a site investigation and assessment of the hazards present for activities that:

- require a consent and involve earthworks
- require a subdivision consent or resource consent where discretion is unrestricted
- require an application for building consent

[3] Regional Policy Statement for Otago, Otago Regional Council, October 1998. ISBN 0-908922-59-0.

- take place on a site located on the Hazards' register or the DCC suspects it to be hazard prone.

At present, potentially hazard-prone areas are also considered when determining zoning and developing District Plan provisions, particularly scale, location and density of development. In general, 'rural' zoning is currently used as a default zone in potentially hazard-prone areas.

3.2. Managing natural-hazard risk under the 2GP

The review of the District Plan's approach to the management of natural hazards aims to:

- introduce better rules and standards to protect people and property from the risks posed by hazards in certain areas
- provide better information to land owners and investors about constraints on land development as well as the most suitable land for development
- limit the exacerbation of risks from natural hazards.

To achieve this, the DCC is proposing to use the best available information regarding Dunedin's natural hazard risks[4] to create the following overlay zones:

- 'flood-hazard overlay zone', which includes areas at risk from the effects of flooding such as overland flow, ponding areas and alluvial fans
- 'coastal-hazard overlay zone', which includes tsunami, storm surge, erosion and sea-level rise
- 'land-based hazard overlay zone', which includes unstable areas such as landslides.

This approach was consulted on as an option during the DCC's '2GP Issues and Options Consultation Phase' from November 2012 to March 2013 and also during the 'Preferred Options Consultation Phase' in August 2013. More detail about the proposed approach and this consultation can be found on the DCC's website at http://www.dunedin.govt.nz/whats-on/2gp.

A review and overall assessment of natural hazards within the Dunedin City District has been carried out to help inform the review of the District Plan (see sections 5 and 6, and the supplementary technical reports). Based on this assessment, the 2GP preferred option will be further refined and consulted on again in mid-2014.

3.3. How this project links with the RPS review

The RPS became operative on 1 October 1998 and is currently undergoing a review, as required by the RMA. The purpose of the RPS is to achieve sustainable management of resources by providing:

- an overview of the resource management issues of the region
- policies and methods to achieve integrated management of the natural and physical resources of the whole region.

The RPS sets up the framework for future planning and assists in making decisions and creates opportunities for resource use, while protecting environmental bottom lines, providing

[4] Understanding of natural hazards within the Dunedin context has improved since the current District Plan was prepared, as has mapping technology.

an overview of resource interactions and giving effect to higher-level documents. In general, the high-level objectives of the RPS include:

- identifying the significant resource management issues for the region
- promoting prosperity (not just in the economic sense)
- ensuring a good natural environment
- enabling healthy, happy, safe and resilient communities.

The review of the RPS, with regard to managing natural hazards, will consider the following:[5]

- clarification of roles and responsibilities
- enabling more integrated management
- focusing on reducing the current risk associated with natural hazards and avoiding additional risk
- protecting people and property
- increasing awareness and understanding of natural hazards
- taking a more holistic approach to natural-hazard management (e.g. consideration of cumulative effects, residual risk).

Regional and district plans must give effect to the RPS. It is therefore important that the ORC and Territorial Local Authorities (TLA) continue to work together to ensure that the RPS and regional and district plans work effectively and efficiently to address Otago's key resource management issues. The work described in this report shows this process in action, with the ORC collating and presenting information on natural hazards to inform the review of the DCC's District Plan, so that the effects of natural hazards can be avoided or mitigated.

[5] Issues and options papers (based on a range of topics) were drafted in conjunction with TLAs, and a series of public consultation sessions was held in May 2014. A consultation draft will be prepared for public consultation in September, and ORC intends to notify the proposed RPS in December 2014.

4. Principles and planning considerations

The objectives of the RPS and the proposed approach to natural hazards are reflected in the approach this project has taken in mapping and describing natural hazards in the Dunedin City District. The planning response to be included in the revised Dunedin City District Plan will be based on a series of principles, all of which are consistent with the proposed approach to natural hazards in the RPS. The principles are based on the RMA and the functions of local government in relation to natural hazards, as outlined in the RMA.

The principles also draw from:

- Milton 2060. Flood Risk Management Strategy for Milton and the Tokomairiro Plain (ORC/CDC, 2012)
- Sustainable Development Principles (DCC, Long Term Plan 2012/13 – 2021/22, Adopted 25 June 2012, p35)
- Dunedin Towards 2050, A spatial plan for Dunedin / He mahere Wahi ki Otepoti (DCC, September 2012)
- Preparing for climate change (MFE, July 2008, p 16)
- Preparing for future flooding (MFE, May 2010, p 28)
- *New Zealand Standard 9401: 2008 Managing Flood Risk*.

The principles are grouped around two main themes (outlined below): 'People and communities' and 'The management approach for natural hazards'.

People and communities

Principle 1: Protection of people

Prevent death or injury from natural hazards, ensure public health.

Principle 2: Create liveable communities

Create communities in which people can live, work and use the land without undue stress or fear of natural hazards.

Principle 3: Create a resilient built environment

Create and maintain a built environment, including infrastructure and lifelines, which takes into account the risks from natural hazards so that it can operate effectively while still being affordable.

Management approach

Principle 4: Utilise an adaptive management approach

An adaptive risk-management approach will be required to allow for improvements in the understanding of hazards and the effects of natural climate variability. By adopting a broad-scale, adaptive approach over the longer term, the risk associated with different hazards will reduce over time. The ability to respond to changes in the nature and extent of risk, ease transitions, and provide the level of safety desired by the community is essential.

Principle 5: Take residual risk into account

It is important to address the entire risk spectrum when managing the effects of natural hazards. This principle recognises that whatever event is planned for, there will be a larger, major event. The risk from these major events also needs to be recognised and managed.

Principle 6: Some risks are intolerable

Principle 7: Avoid exacerbation of natural hazards

New development and hazard-management measures will not exacerbate the risks or effects of natural hazards elsewhere. This applies at all scales, from localised 'property to property' effects, through to the community or catchment scale.

Principle 8: Increase understanding and community awareness

Understanding the underlying natural systems and processes that operate in the Dunedin City District is crucial to managing risk and ensuring community safety. Increasing community awareness is essential to assist people in taking natural-hazard risks into account when undertaking development.

Planning considerations

The following series of planning considerations has also been developed to inform the District Plan rules, in regards to avoiding or mitigating the potential effects of natural hazards:

- Controls over the way land is used should depend on the characteristics of the hazard in that area, and its effects on people and assets.
    - The risk in each community depends on its local geography and exposure to hazard. Any planning response will depend on the nature of the hazard, and may include avoidance of new, or restrictions on existing, development or design standards to avoid or mitigate negative effects.
- The consequences of the hazard are critical, along with the likelihood of a particular event occurring.
- The disruption and economic impact at individual and community levels are important considerations.
    - The utility and amenity of land will be considered in addition to people's safety and damage to buildings.
- The cumulative effects of hazard should be considered:
    - consider the likelihood of being affected over the *longer term*
    - consider the likelihood of being affected by *any of the hazards* that may affect a particular area
    - consider the cumulative effects of *repeat events*.

5. Natural hazards in Dunedin City

A diverse range of information is available that can be used to describe natural hazards in the Dunedin City District. Observations and historical records cover the period from pre-European settlement to modern times, and include photographs, written records and early maps and sketches. More recently, technology has meant that a range of hazard scenarios have been able to be modelled, including the effects of 'extreme' events that occur infrequently (such as events that are possible, but have not been observed often, or at all, during our relatively short recorded history), and more commonly occurring events. The effects of predicted changes in climate and sea level (Fitzharris, 2010) are increasingly being integrated into these modelled scenarios.

Both types of information (observations and modelling) can be used to map certain areas which are prone to natural hazards. Another tool which helps to inform the way natural hazards are mapped is accurate topographical information (LiDAR[6]), which is now available for most of the settled part of the district. An example is shown in Figure 4.

Figure 4 **LiDAR map showing the topography of the Harwood/Otakou area on the Otago Peninsula**

In 2012, ORC launched a web-based 'Natural hazards database', which contains information on natural hazards across Otago. It is intended to improve the availability of hazard information and to help the public, local authorities and others make informed decisions

[6] LiDAR: Light Detection and Ranging is a mass of spot-height information captured over a wide area using an aircraft mounted laser. LiDAR data is held by the DCC and ORC, and typically has a vertical accuracy of +/- 0.14m.

about their exposure to natural hazards. It contains both modelled and observed information, and includes much of the information used to inform this project. It is available through the ORC website (www.orc.govt.nz).

5.1. Types of natural hazards mapped for this project

This project identifies the characteristics and likely geographical extent of the natural hazards listed in Table 2, using the best information currently available. The information has been collated and presented in a way to help inform the review of the Dunedin City District Plan. As described above, the DCC is proposing to use this information to create three hazard 'overlays' or zones – flood, coastal and land – and these are shown in Table 2.

Table 2 Natural hazards described as part of this project

Hazard	Sub-category
Flood *(DCC Flood hazard overlay zone)*	Floodwater resulting from high flows in rivers and other waterways
	Overland flow paths that drain surface runoff during heavy rainfall events
	Water ponding in low-lying areas that are natural collection points for floodwater and surface runoff
	Alluvial fans, ranging from sheet floods and channel floods carrying sediment, through to debris dominant flows
Coastal *(DCC Coastal hazard overlay zone)*	Inundation due to elevated sea level (storm surge)
	Inundation due to tsunami
	Coastal erosion
	The possible effect of additional sea-level rise on coastal hazards
Landslides *(DCC Land-based hazard overlay zone)*	Landslide features that have moved in the past
Seismic *(DCC Land-based hazard overlay zone)*	Susceptibility to lateral spreading and liquefaction
	Known active faults
	Seismic shaking

Additional information describing the hazards in Table 2 is provided in Appendix 1, including a description of how the effects of climate change and sea-level rise have been incorporated into this project.

There are other natural hazards in the Dunedin City District, for which information is held, such as drought, snow and other climatic hazards. These hazards are not addressed specifically in this project as their extent and characteristics cannot be defined with the same level of precision as those listed in Table 2. Direction to ensure these hazards are mitigated or managed is often contained outside the District Plan (e.g. New Zealand Standard 3604: 2011; Building Act, 2004). In addition, information relating to flooding associated with the failure or limited capacity of stormwater networks is not included in the reports prepared by

ORC. Information on the likelihood and effects of stormwater flooding is reported separately by DCC (2011).

5.2. Describing the effects of natural hazards

This project describes the characteristics and effects of natural hazards in the Dunedin City District, focusing on areas of existing development, future development potential and where the effects of the hazard are significant. Rather than simply describing the effects of each hazard separately, the project considers the cumulative and long-term effects of single or multiple hazards on a community. The maps below provide an overview of the different hazard types listed in Table 2, at the scale of individual communities within the district (Figure 5 to Figure 18). More detailed information, describing and mapping the hazards that affect particular communities is provided in a series of supplementary technical reports:

1. Coastal hazards of the Dunedin City District (ORC, 2014a)
2. Flood hazard on the Taieri Plain and Strath Taieri (ORC, 2014b)
3. Flood hazard of Dunedin's urban streams (ORC, 2014c)
4. The hazard significance of landslides in and around Dunedin City (GNS, 2014a)
5. Assessment of liquefaction hazards in the Dunedin City District (GNS, 2014b)

These five reports illustrate the cumulative effects of natural hazards on particular areas, by helping to understand:

- the likelihood of an area being affected by *any* hazard (e.g. land that is susceptible to flooding may also be prone to liquefaction and lateral spread)
- the likelihood of an area being affected over the *longer term* (e.g. the chance of a coastal community being affected by a high-magnitude tsunami event in any given year may be relatively small, but the likelihood of such an event occurring at least once during the time a person may live in such an area (10 – 50+ years) is much higher)
- the cumulative effects of *repetitive events* on people and assets (e.g. where a series of flood events occur over a short space of time, affecting a particular community or area several times in quick succession)
- the adverse effects of one hazard being compounded by another hazard occurring at the same time (e.g. a coastal community at the mouth of a river, where the effects of flooding may be exacerbated by elevated sea levels).

The supplementary technical reports identify and map areas that have a similar vulnerability to natural hazards. The description of the 'hazardscape' of each community has been informed by a range of information, including previous investigations of natural hazards (e.g. ORC 2013 *Natural Hazards of the Taieri Plains,* and NIWA 2007 *Tsunami modelling study*), observations and local knowledge, historical mapping and national guidance on climate change and sea-level rise (e.g. Bell 2013, MfE 2008a,b,c). Where possible, natural hazards have been described in terms of their effect on people and assets (i.e. how they may affect public safety, buildings and other assets).

6. Community-scale overview of natural hazards

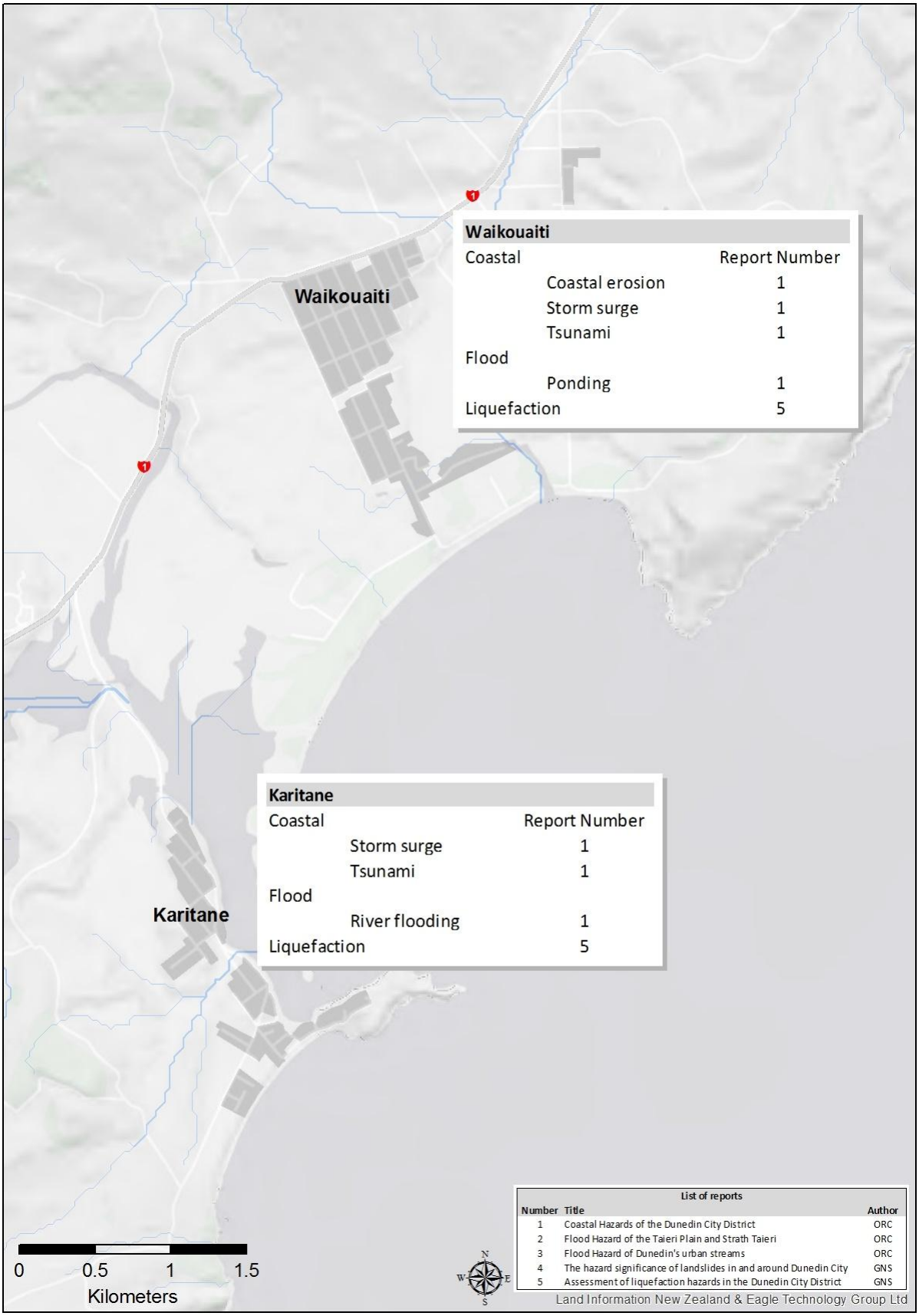

Figure 5 **Overview of the different hazard types affecting Waikouaiti and Karitane**

Figure 6 **Overview of the different hazard types affecting the coastline between Warrington and Puketeraki**

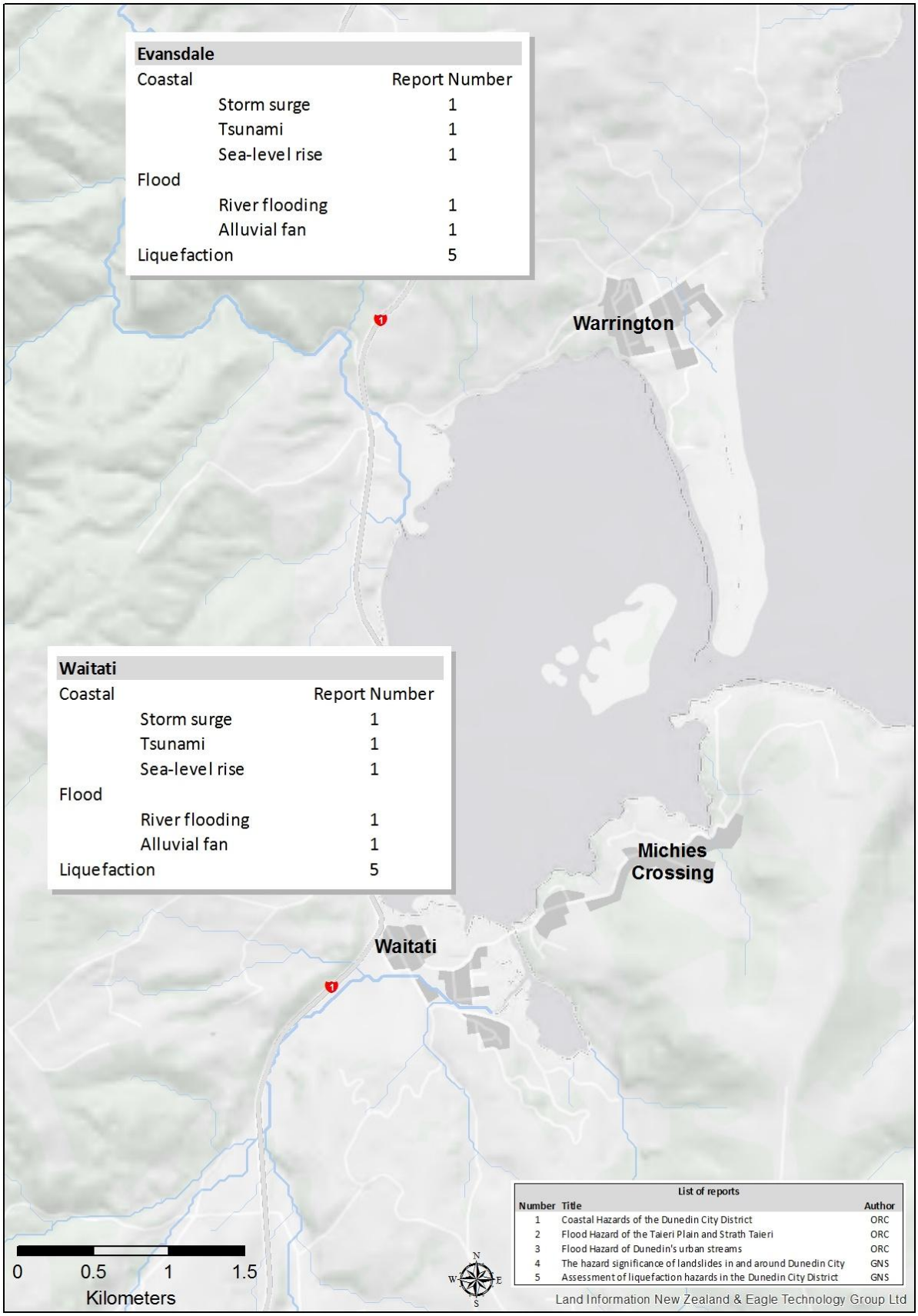

Figure 7 **Overview of the different hazard types affecting Blueskin Bay**

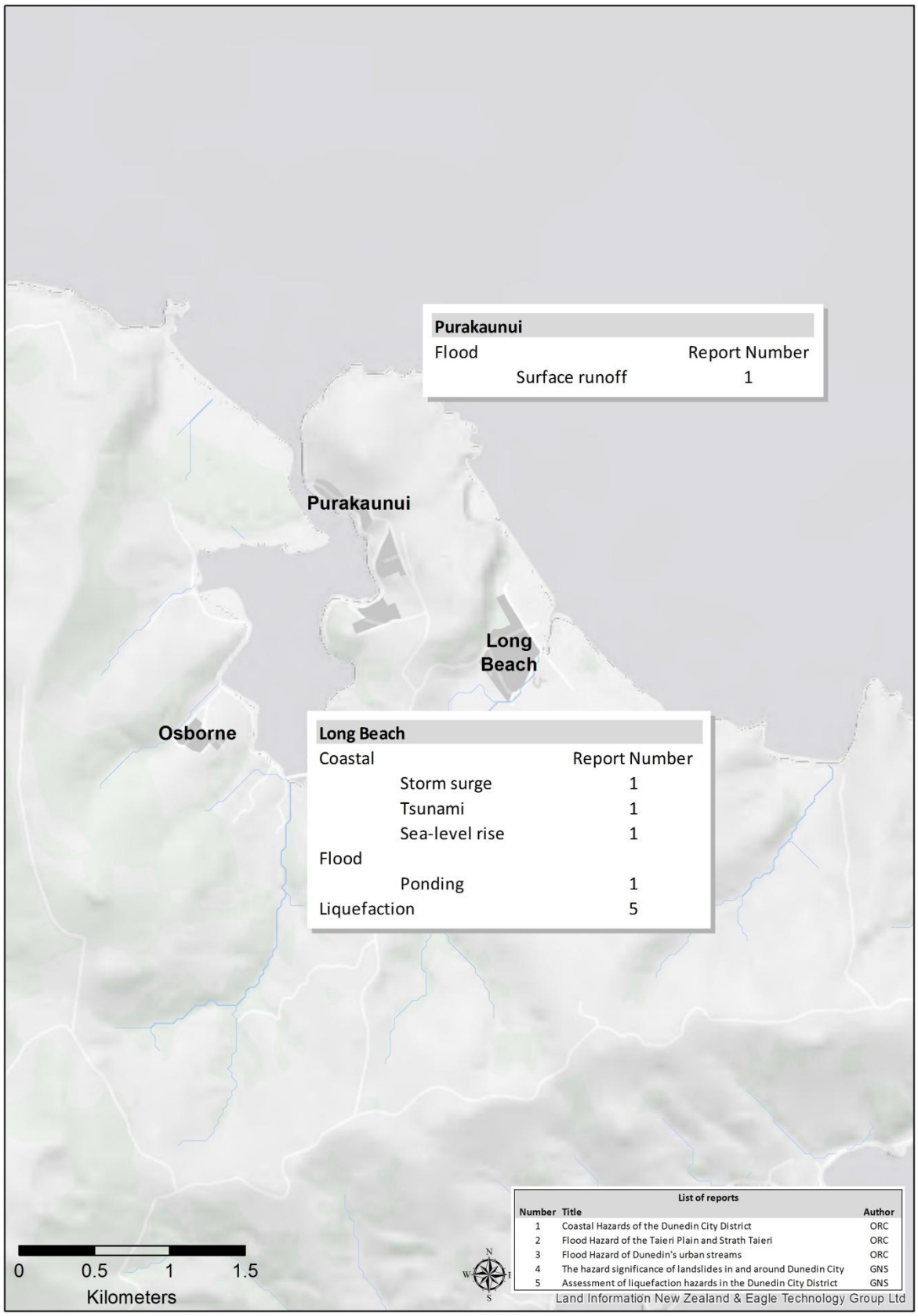

Figure 8 **Overview of the different hazard types affecting Purakanui and Long Beach**

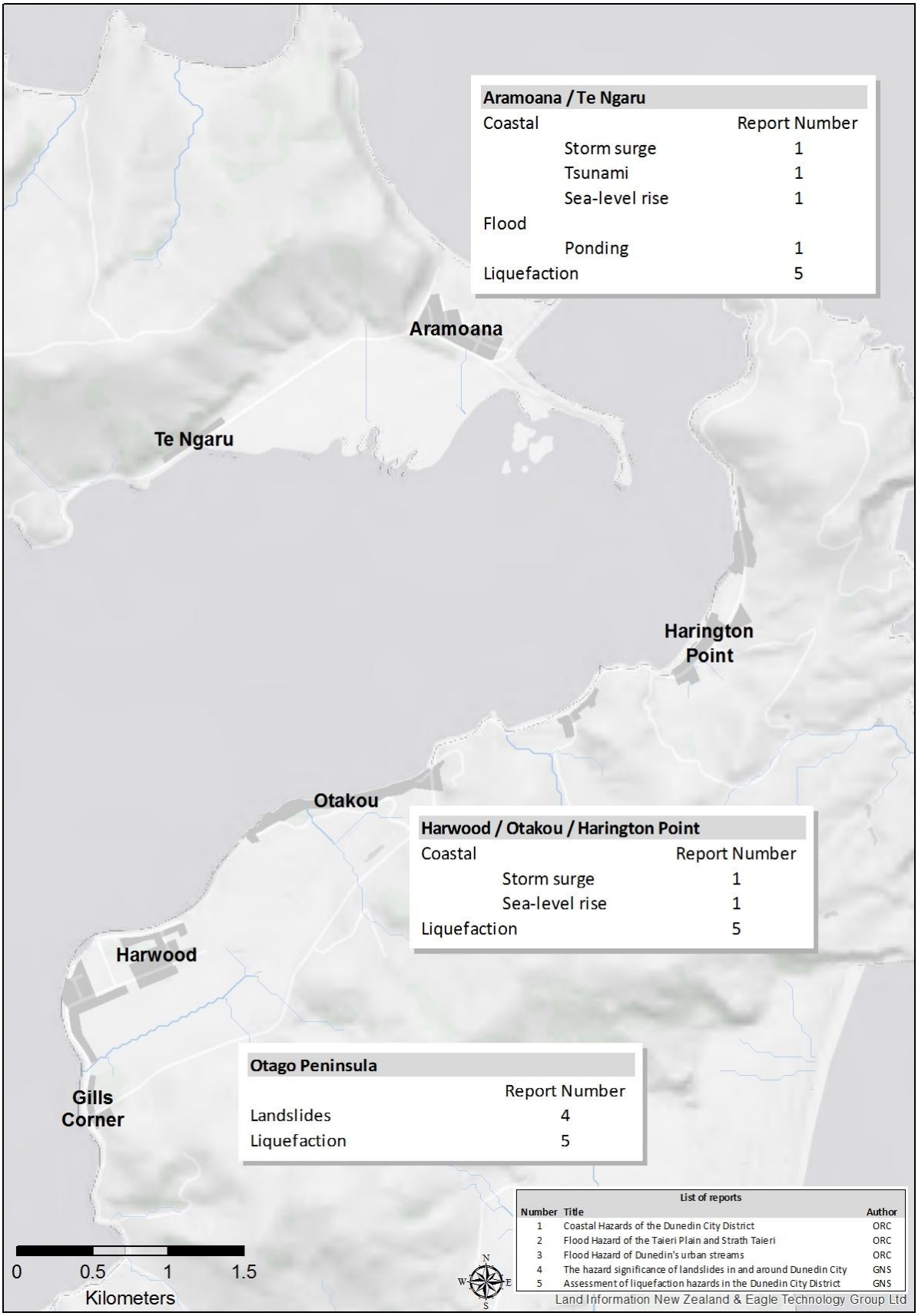

Figure 9 **Overview of the different hazard types affecting Aramoana and the northern Otago Peninsula**

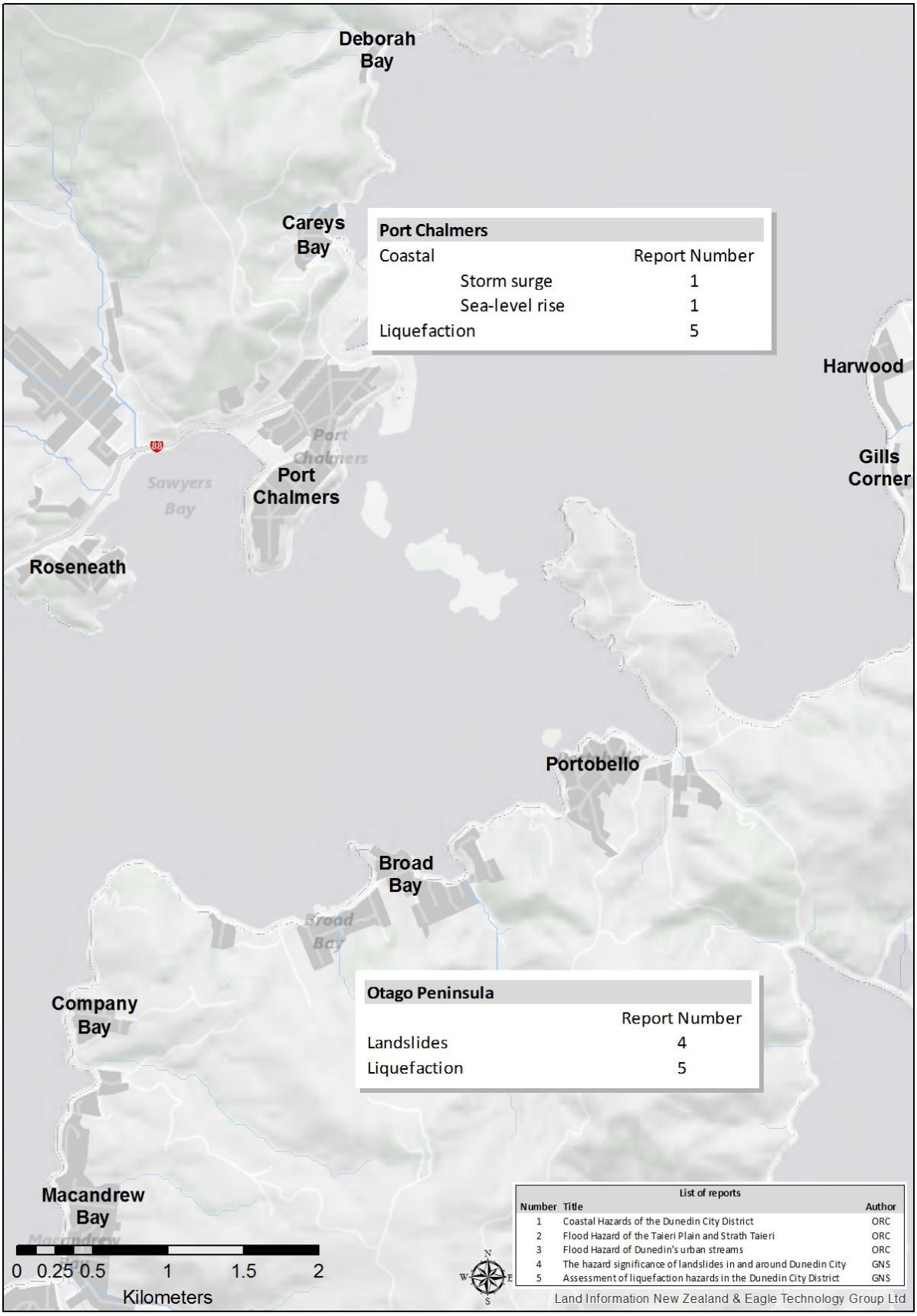

Figure 10 **Overview of the different hazard types affecting Port Chalmers and the Otago Peninsula**

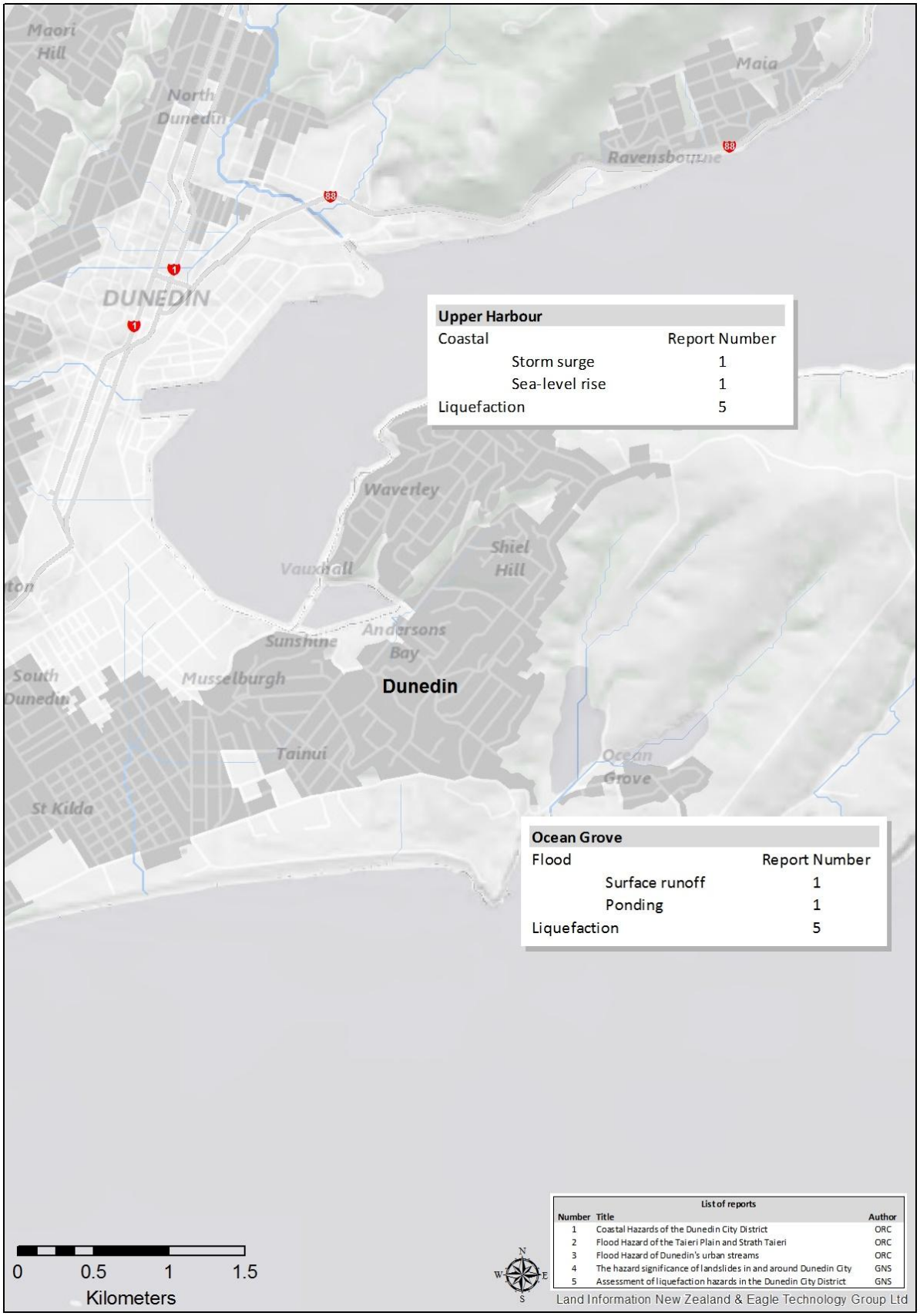

Figure 11 **Overview of the different hazard types affecting the Upper Otago Harbour and Ocean Grove**

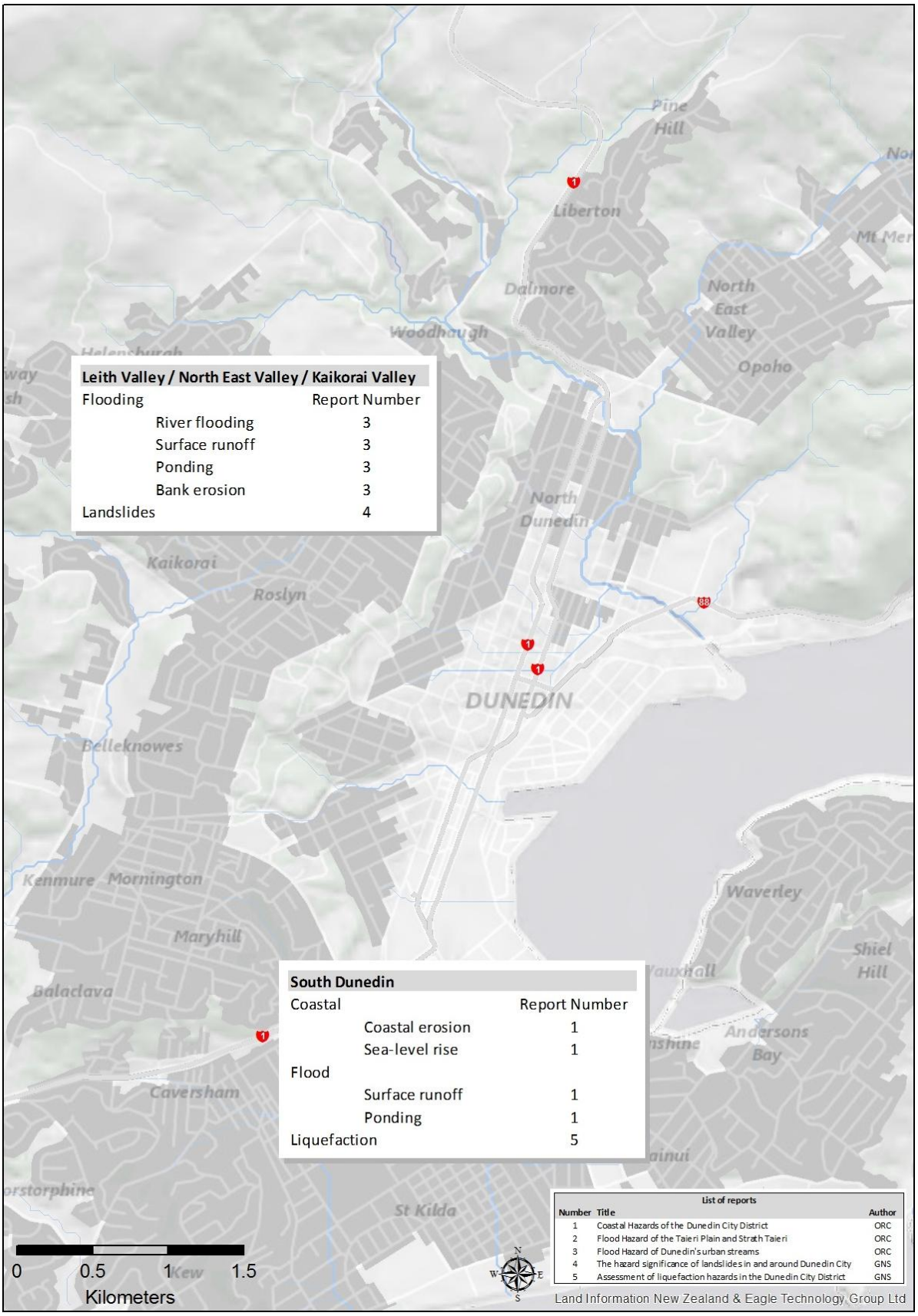

Figure 12 **Overview of the different hazard types affecting South Dunedin and Dunedin's urban streams**

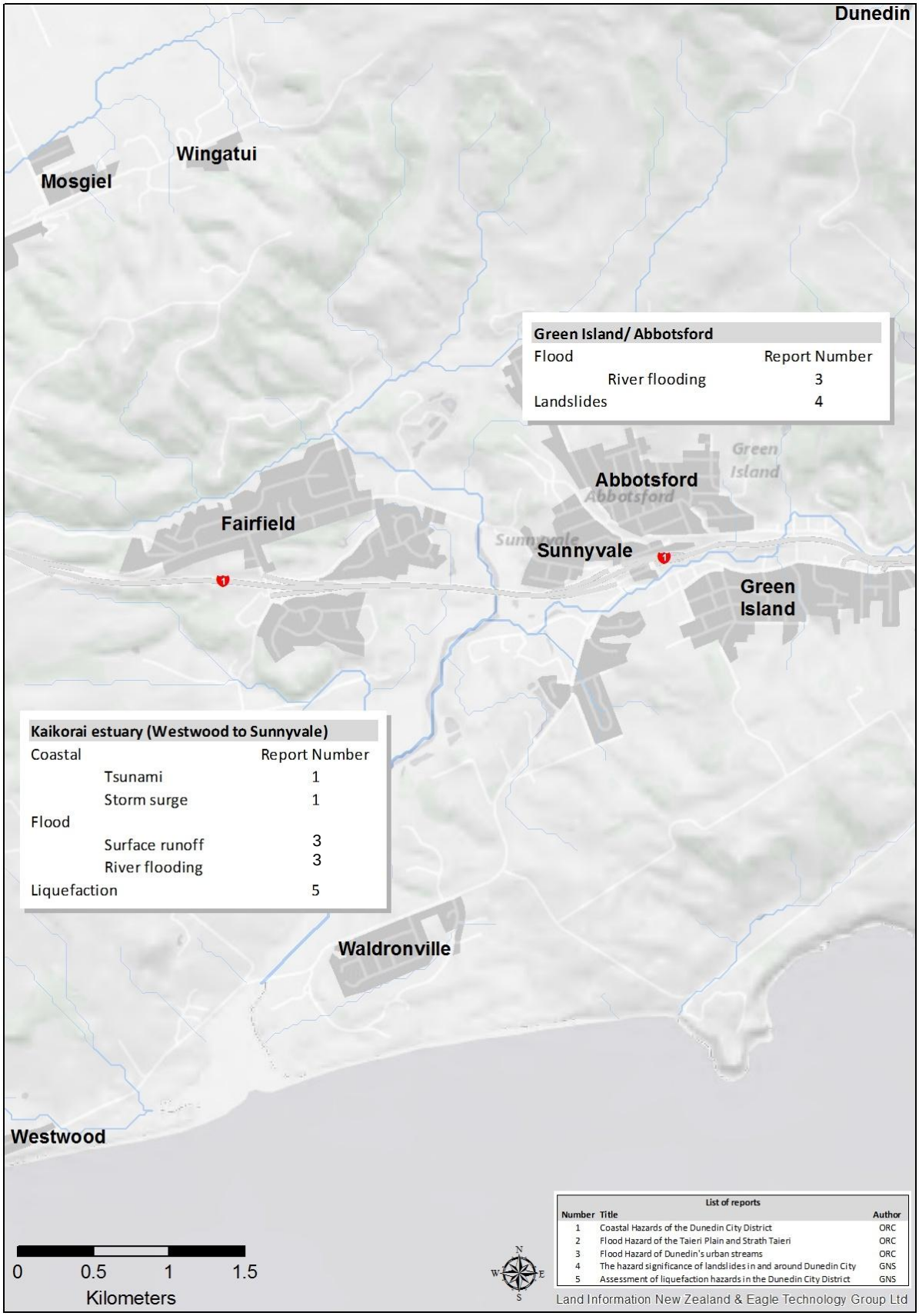

Figure 13 **Overview of the different hazard types affecting the lower reaches of the Kaikorai Stream catchment (Green Island to Westwood)**

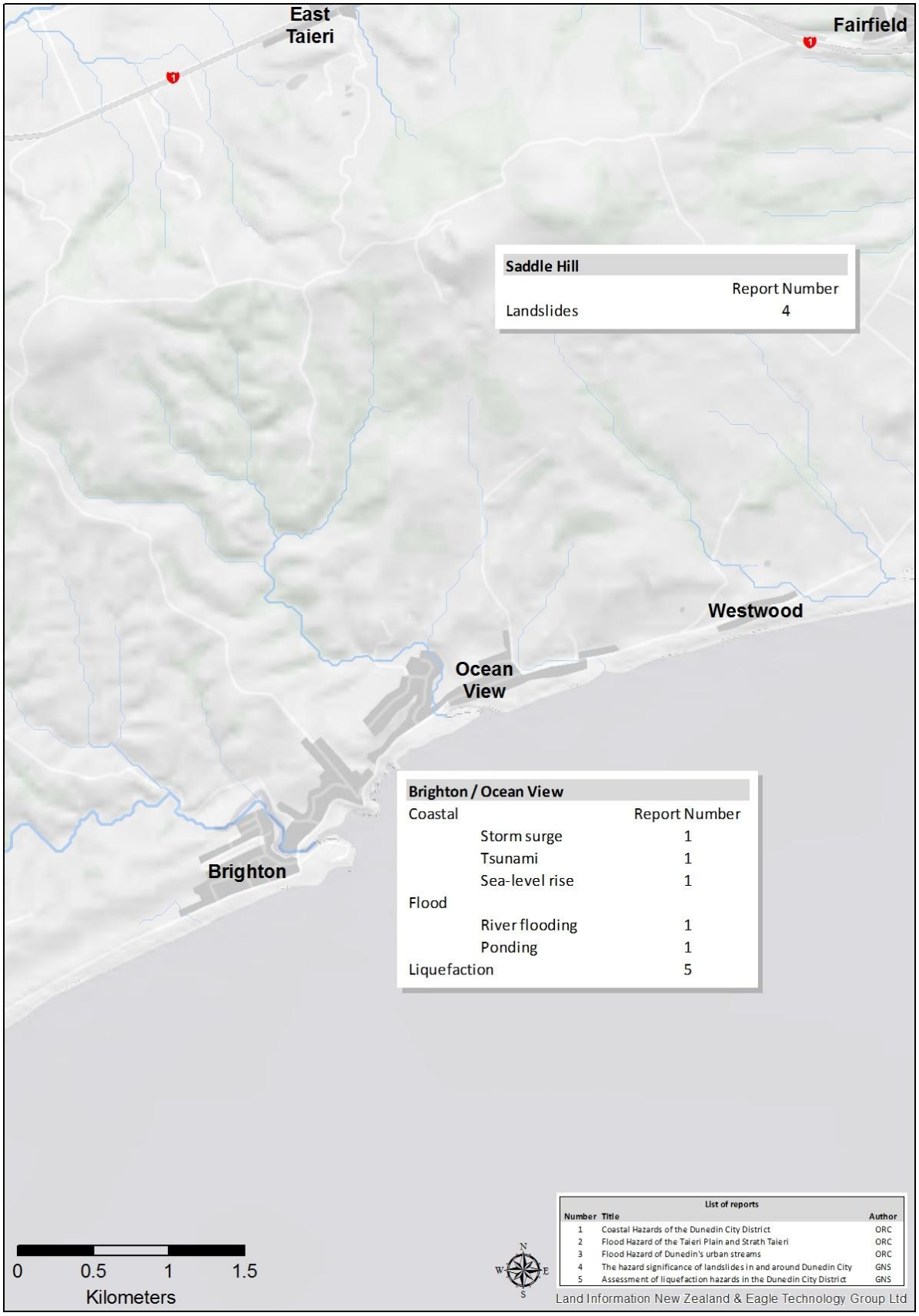

Figure 14 **Overview of the different hazard types affecting Brighton, Ocean View and Saddle Hill**

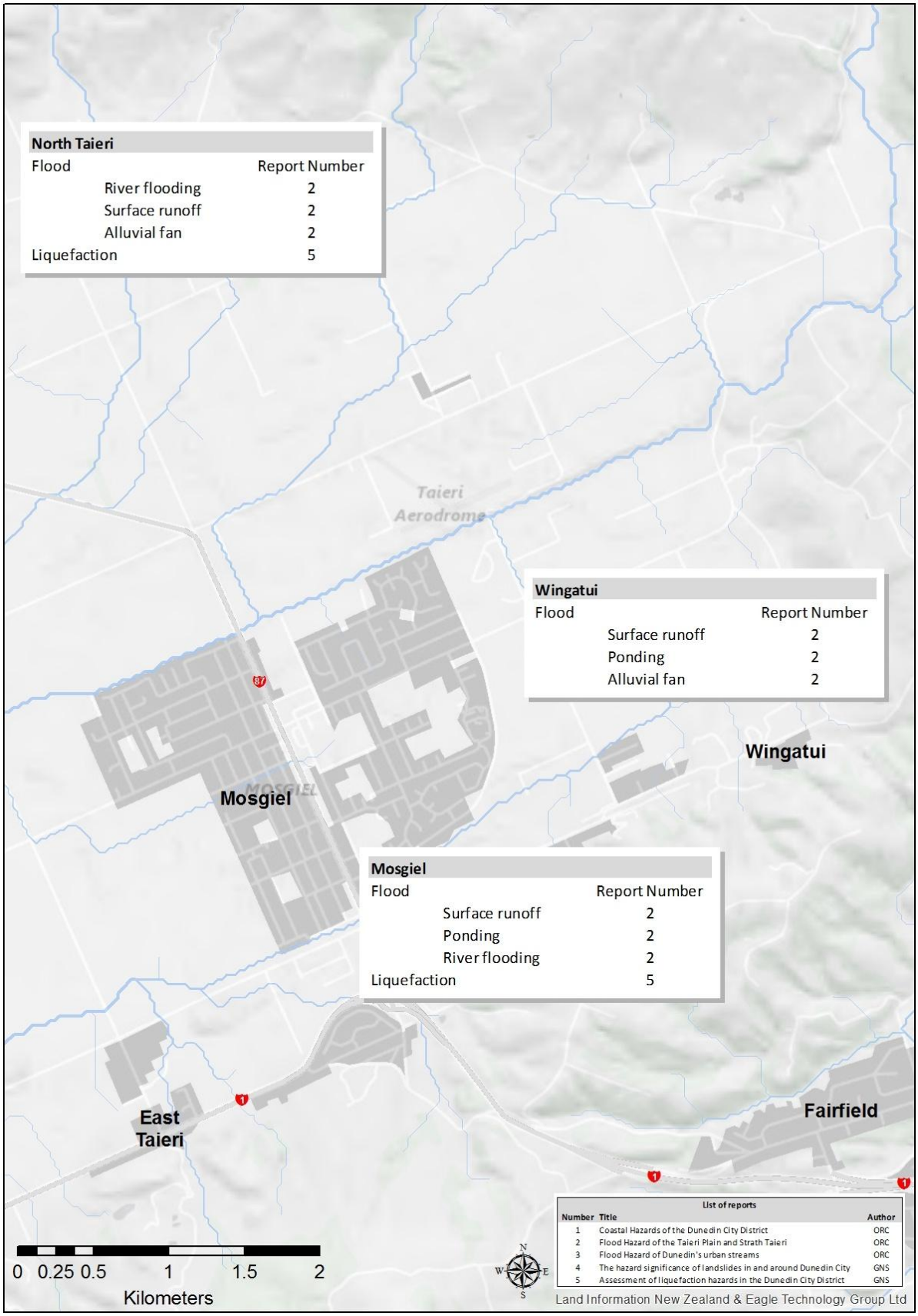

Figure 15 **Overview of the different hazard types affecting North Taieri, Wingatui and Mosgiel**

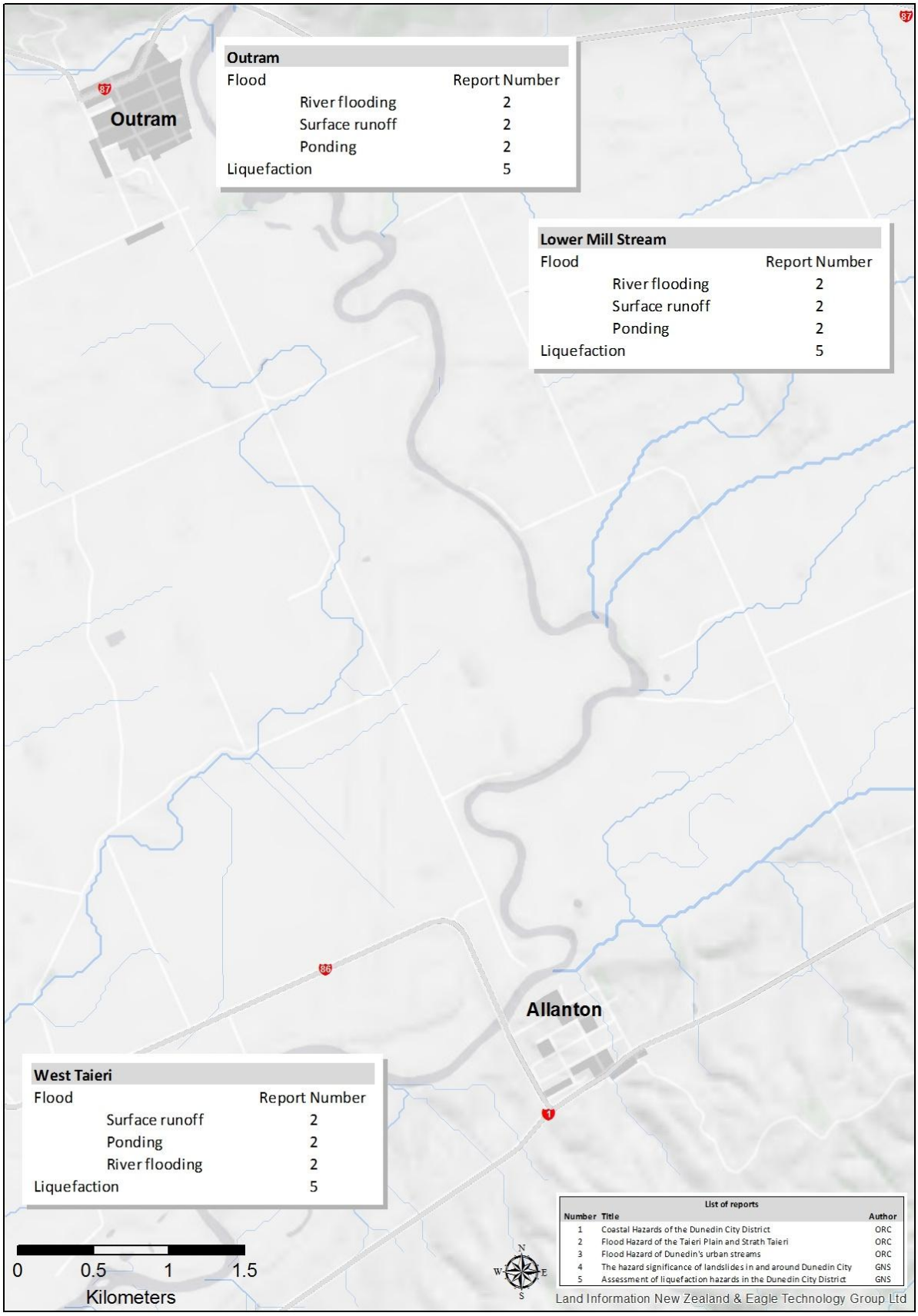

Figure 16 **Overview of the different hazard types affecting Outram, Mill Stream and the West Taieri Plain**

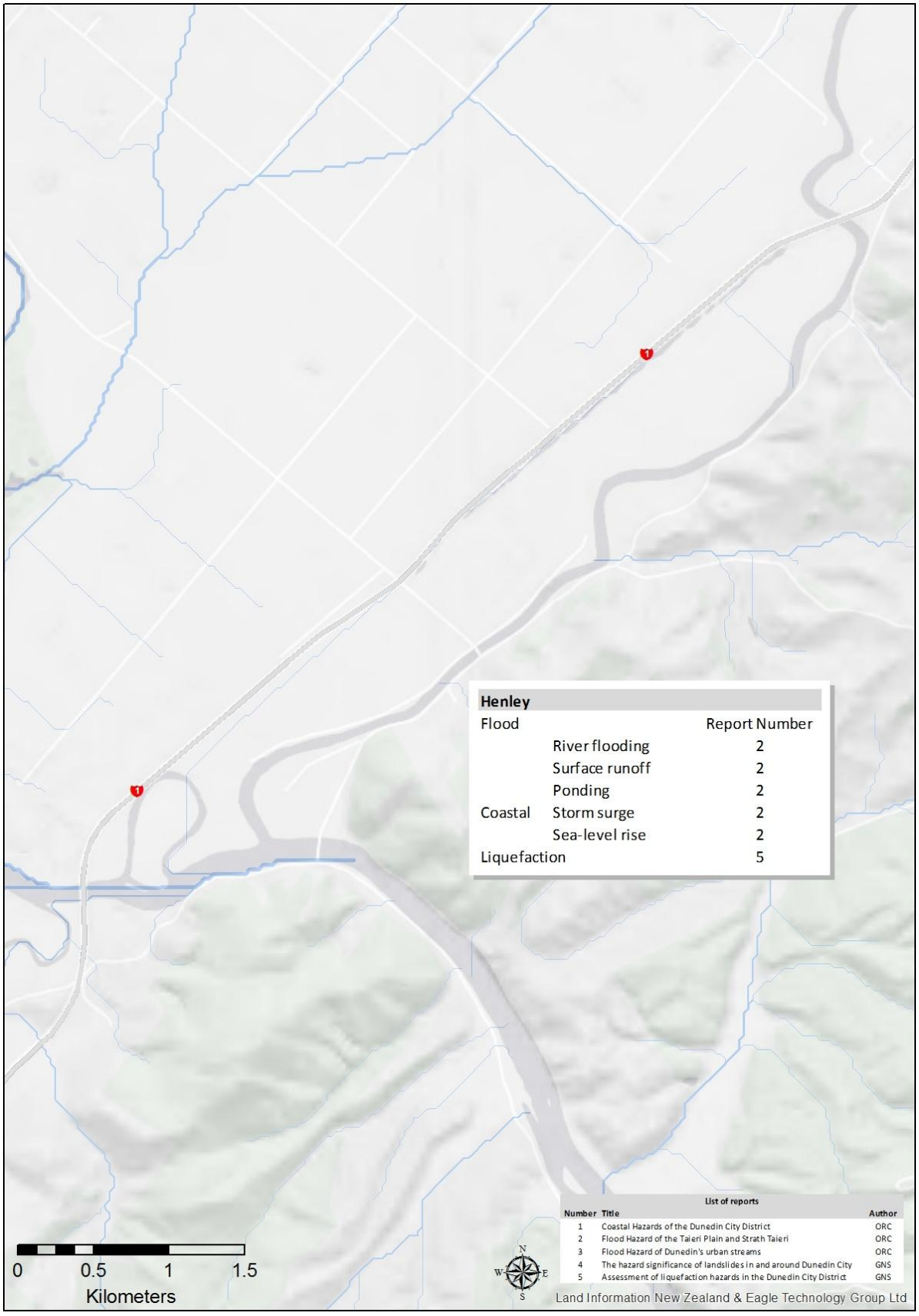

Figure 17 Overview of the different hazard types affecting Henley

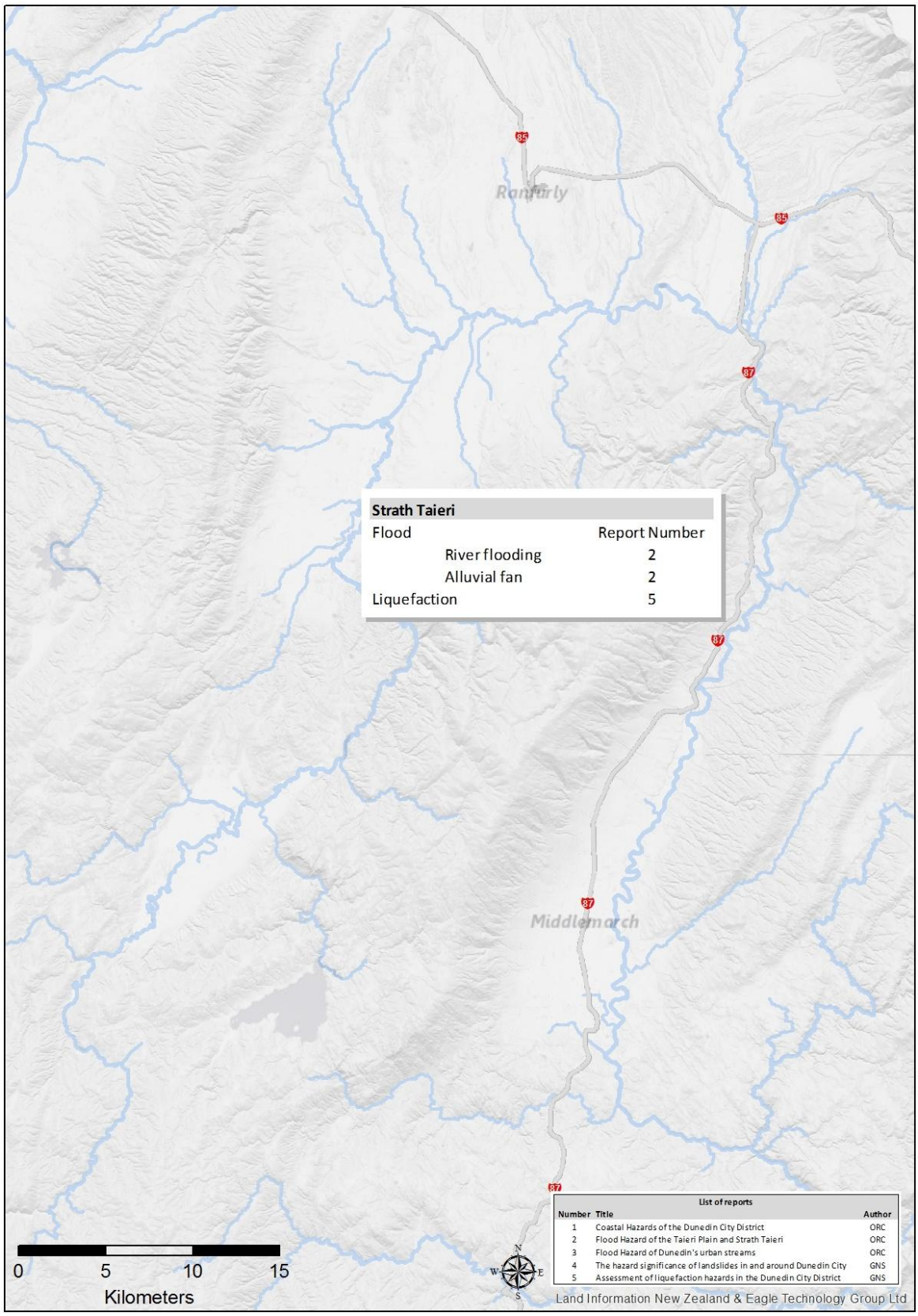

Figure 18 Overview of the different hazard types affecting the Strath Taieri

Appendix 1. Additional information on natural hazards

Flooding

The flood areas mapped for this project show land that is at risk of inundation due to flood events in rivers and estuaries, as well as surface ponding and ephemeral features such as overland flows paths and alluvial fans (see below). It does not include flooding due to overloading of the urban stormwater network. In addition, flood extents are only shown for areas where this hazard has been documented and investigated. Mapped flood areas do not cover sections of some rivers and estuaries where ORC does not hold sufficient information to assess flood hazard accurately.

The effects of flooding (and other climatic hazards) may be exacerbated in the future by changes in climate, with heavier and/or more frequent extreme rainfalls expected over New Zealand (MfE, 2008b). Where possible, the effects of climate change have been considered when mapping flood areas. This has been done by incorporating knowledge about high-magnitude historical events for which there is limited information available, and by identifying areas on the margins of mapped flood areas that could be affected by events larger than those observed in recent times.

Alluvial fans

An alluvial fan is an accumulation of river or stream (alluvial) sediments that form a sloping landform, and shaped like an open fan or a segment of a cone. They typically occur near the boundary between hillslopes and valleys. They owe their origins to changes in the slope of natural drainage systems (e.g. where a steep gully merges onto a flatter valley floor).

The alluvial fans identified in the Dunedin District vary in size, age and level of activity, and many of the fans only become active during high rainfall events. Mapped alluvial fans are derived from work undertaken by Opus (2009) at a regional 1:50,000 scale. Additional work has been undertaken to determine the significance of alluvial fans on the east Taieri (GNS, 2014c).

Coastal hazards: storm surge and tsunami

NIWA (2007 and 2008) mapped the height and likely extent of water associated with a limited range of credible storm-surge and tsunami scenarios. This work assumed no erosion of the coastline and did not include the potential effects of debris, vegetation or structures. The effect of sea-level rise of up to 0.5m was included in this work.

This information has been used to identify communities that are vulnerable to coastal hazards and to help create mapped coastal hazard areas in the report ‘Coastal hazards of the Dunedin City District’ (ORC, 2014a). The latest recommendations on likely rates of sea-level rise over the coming century were used to help assess coastal hazards. A more recent assessment of all sources of tsunami that could potentially affect the New Zealand coast is also referred to in this report (GNS, 2013).

Landslides

The term ‘landslide’ describes a variety of processes that result in the downward and outward movement of slope-forming materials, including rock, soil, artificial fill or a combination of these. The materials may move by falling, toppling, sliding, spreading or flowing. Landslides can vary in size from a single boulder in a rock fall to tens of millions of cubic metres of material in a debris avalanche.

Landslides (along with other landscape-forming processes) have helped to shape the Dunedin area over many thousands of years. Landslides which have been mapped within the Dunedin City District include areas that have moved relatively recently and locations where distinct landforms have been used to map historical landslide features. The likelihood of further movement and the significance of any hazard that may be associated with that movement have also been investigated as part of this project (GNS, 2014a).

Only known landslides are shown. Areas that may be prone to landslides (due to slope, substrate or other characteristics of the land) are not shown. Some areas within the Dunedin City District have not been investigated with respect to landslides.

Liquefaction

Liquefaction occurs when saturated fine-grained sediments (such as sand and silt) are subjected to high-intensity shaking and lose their ability to stay cohesive. As sediments are shaken, they act like a fluid or shaken jelly, causing deformation, settlement and sometimes lateral spread towards rivers or lakes. Areas with unconsolidated sediments, soils and high groundwater tables have a high-risk exposure to liquefaction and lateral spreading of soils. Locations close to active faults have a higher-risk exposure to liquefaction due to more intense ground shaking. These characteristics were used to identify the susceptibility of land to liquefaction and lateral spread during an earthquake. Additional work by GNS (2014b) was undertaken to help this assessment.

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