Gisborne District Risk Assessment

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BIBLIOGRAPHIC REFERENCE

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EXECUTIVE SUMMARY

This report presents the deliverables of a risk assessment project undertaken by GNS Science, with input from NIWA, for Gisborne District Council.

Thirteen natural hazards were confirmed to be the subject of the risk assessment: volcanic; rainfall induced landslide; tsunami (local and distance source combined); earthquake – shaking, liquefaction, landslips, and fault rupture; mud volcanoes; flooding; coastal erosion; coastal flooding (excluding tsunami); drought; and extreme temperature.

For each of the 13 hazards, descriptions of the type of hazard event expected for a specified Average Return Interval (ARI) are provided. Five ARIs were specified for each hazard: 0–50 years, 51–100 years, 101–1000 years, 1,001–2,500 years, and >2,500 years. The descriptions are based on existing research, with gaps identified where information is lacking.

Consequence descriptions, based on the hazard ARI descriptions are provided. These descriptions are based on existing research, with gaps identified where information is lacking. Two types of consequences are described: (1) health and safety, and (2) built environment and property. For built environment and property, the consequence assessments are based on asset information complied and aggregated into 11 spatial groupings, to provide spatial context to the information.

A data quality rating has been developed and is applied to both the hazard and consequence descriptions. This rating accounts for the variation in quality of information available for each of the hazards and associated consequences.

1.0 INTRODUCTION

1.1 BACKGROUND

Gisborne District Council (GDC) has identified a need for better understanding of the natural hazards that affect Gisborne District, and the level of risk associated with impacts from natural hazard events. To address this need, GDC is planning to undertake a high-level, regional risk assessment that will fulfil the purposes of both informing the review of natural hazard provisions in the Council's plans prepared under the Resource Management Act (RMA), and informing the upcoming review of the Civil Defence and Emergency Management Group Plan.

GDC identified GNS Science and NIWA as potential collaborators, based on both organisations' previous experience performing risk assessments for multiple natural hazards, as well as their joint management of the RiskScape Software, which GDC was interested in using as part of the risk assessment. RiskScape is a multi-hazard impact and risk assessment tool, developed in partnership between GNS Science and NIWA, which provides a framework to calculate impacts in terms of financial and human losses from different types of natural hazards.

1.2 SCOPE OF THIS REPORT

The hazards addressed in this report are:

1. volcanic
2. rainfall induced landslide
3. tsunami (local and distance source combined)
4. earthquake – shaking
5. earthquake – liquefaction
6. earthquake – landslips
7. earthquake – fault rupture
8. mud volcanoes
9. flooding
10. coastal erosion
11. coastal flooding (excluding tsunami)
12. drought
13. extreme temperature

A template was provided for the risk assessment, which incorporates the Director's Guidelines for CDEM Group Planning, as well as the objectives outlined in Saunders et al. (2013). The following deliverables were required:

- **Context – Built environment and property:** a text summary of the 'built environment and property' within the Gisborne Region, as well as shapefiles for use in the consequence analysis. The data was aggregated into 10–15 spatial groupings for the following assets: buildings, roads, electricity, airports, railway lines, land parcels, and land use.
- **Data quality rating:** a rating system was developed as a means of recording the variability in the quality and availability of data for each hazard.
- **Hazard sheets – description of events:** descriptions of the specified hazards based on existing research. A description for each of the Average Return Intervals (ARI) it had identified (0–50 years, 51–100 years, 101–1000 years, 1,001–2,500 years, and >2,500 years) is provided.
- **Hazard sheets – description of consequences:** description of the consequences to personal health and safety and built environment and property associated with each hazard (except for drought and extreme temperature). A description for each of the ARIs it had identified (0–50 years, 51–100 years, 101–1000 years, 1,001–2,500 years, and >2,500 years) is provided. These descriptions were based on the data collated during the 'context' task (described above).

It is noted that this is a high-level assessment, based on existing information only. As a result, the process has identified areas where current information is lacking, and some hazard and consequence descriptions are not as specific or detailed as might be ideal. These areas represent opportunities for further work.

1.3 CONTRIBUTORS

The following researchers have contributed to this report:

Context analysis:	Ryan Paulik, NIWA
Data quality rating:	Ryan Paulik, NIWA
Hazard descriptions:	Dr Natalia Deligne, GNS Science (volcanic)
	Sally Dellow, GNS Science (landslide, earthquake (shaking, landslides, liquefaction), mud volcanoes)
	Dr Robert Langridge, GNS Science (earthquake – fault rupture)
	Dr Christof Mueller, GNS Science (tsunami)
	Dr Scott Stephens, NIWA (coastal flooding)
	Michael Allis, NIWA (coastal erosion)
	Ryan Paulik, NIWA (flooding)
	Dr George Griffiths, NIWA (flooding)
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	Dr Trevor Carey-Smith (extreme temperature and drought)
Consequence descriptions:	Ryan Paulik, NIWA (for flooding and coastal hazards)
	Nick Horspool, GNS Science (geological hazards)
Project management:	Emily Grace, GNS Science

2.0 CONTEXT DESCRIPTION

Appendix 1 contains the text summarising the information on the 'built environment and property' within Gisborne District, prepared for use in the context section of GDC's risk assessment report.

This summary was prepared based on existing information; that is, no new information was generated. Existing district and national data inventories, from RiskScape and other sources, were used to create the summary, as well as GIS shape files for the assets (for use in the consequence assessments). The asset types used included buildings, roads, electricity, water, stormwater, wastewater, gas, airports, railway lines, land parcels and land use. The data sources are identified in Appendix 1.

Eleven spatial groupings, or 'areas' were identified, in consultation with GDC, as a way of organising the asset data and providing spatial context. A map showing the 11 areas is included in Appendix 1. RiskScape was used to aggregate the building data into the 11 spatial groupings. The same aggregation was applied for the other datasets (roads, electricity, airports, railway lines, land parcels, and land use) using GIS rather than RiskScape.

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3.0 DATA QUALITY RATING

There is high variability in the quality and availability of hazard, asset and consequence data for the Gisborne District. An approach was developed to convey the quality of the risk assessment for each hazard, as a result of the quality of the input data.

The quality rating criteria developed assigns separate quality descriptors (numerical rating, i.e., 1 to 5 scale) to both the hazard and consequence information, to reflect the fact that there is variance in quality in both types of information. The rating value for each information type can then be totalled to provide an overall data quality rating. The final data quality rating system used is included in Appendix 2.

Data quality descriptors and rating values are based on the availability and reliability of qualitative and quantitative hazard and consequence data. For instance, the lowest quality rating is assigned where significant judgement has been needed due to a lack of information. Conversely, assessments based on calibrated hazard exposure and asset vulnerability models are assign the highest data quality ratings.

The data quality rating was applied to each row (i.e., each ARI specified) of both the hazard and consequence descriptions.

It is important to note that the quality and detail of the information provided in the consequence descriptions is dependent on the quality and detail in the hazard descriptions. For example, if no spatial information on the extent of the impact of a hazard is available (e.g., no maps of liquefaction susceptibility currently exist), the corresponding consequence description can only describe what might happen in impacted areas, and will not be able to quantify damage or health and safety consequences. In such a situation, an understanding of the scale of the consequences is limited by the lack of information on the extent of the hazard impact.

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4.0 HAZARD DESCRIPTIONS

Appendix 3 includes the hazard descriptions for the 13 hazards specified. These descriptions are in tabular form, in accordance with the template provided.

For each hazard, a description is provided for each ARI specified by GDC (0–50 years, 51–100 years, 101–1000 years, 1,001–2,500 years, and >2,500 years), where possible. The descriptions are based on existing research and knowledge; that is, no new research was commissioned. Quantitative descriptions are provided where possible, and ‘best estimates’ or identification of gaps where quantitative information is not available. The sources of information used in the descriptions are included in Appendix 3.

Region-wide hazard event descriptions were requested by GDC, but with acknowledgement that certain types of hazard events may be limited in the area affected, and/or may differ in intensity across the region. The hazard descriptions include location-specific information where this is relevant and possible within the constraints of the information available and the high-level nature of the assessment.

For tsunami hazard, detailed tsunami inundation models were developed for GDC in 2009 by Wang et al. (2009). Through the current project, these models have been processed and developed into a RiskScape hazard module. The RiskScape hazard module contains 18 tsunami scenarios from near and distant tsunami sources. The region covered in the models is centred on Gisborne city, and extends from Muriwai in the south to just north of Wainui. The RiskScape module can be used within RiskScape by GDC to estimate tsunami impact from any of the 18 events. Impacts can include damage state of buildings, functional downtime, human displacement, human casualties, and economic loss.

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5.0 CONSEQUENCE DESCRIPTIONS

Appendix 3 includes the consequence descriptions for each of the hazards specified. These descriptions are in tabular form, in accordance with the template provided. Each consequence table follows the corresponding hazard table, as the two tables need to be read together.

Two types of consequences are assessed: health and safety, and built environment and property.

For each hazard, a consequence description is provided for each ARI specified by GDC (0–50 years, 51–100 years, 101–1000 years, 1,001–2,500 years, and >2,500 years), where possible. The descriptions are based on the corresponding hazard descriptions. They use existing research and knowledge; that is, no new research was commissioned. Quantitative descriptions are provided where possible, and 'best estimates' or identification of gaps where quantitative information is not available. Sources of information for the consequence descriptions are included in Appendix 4.

Region-wide consequence descriptions were requested, but with acknowledgement that certain types of hazard events may be limited in the area affected, and/or may differ in intensity across the region. The consequence descriptions include location-specific information where this is included in the corresponding hazard description.

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6.0 MUD VOLCANOES

The information available for mud volcano hazard and consequences is limited. It was not possible to fit the information into the templates provided by GDC. Rather, a text description is provided, referring to ARIs where possible.

The nature and behaviour of mud volcanoes is well described in Mazengarb (1997) in a report prepared by GNS Science for the Gisborne District Council. Figure 5 in Mazengarb (1997) shows the known locations of mud volcanoes and gas seeps in the Gisborne District. Guidelines for dealing with mud volcanoes in a planning context are given in Mazengarb (2002).

In a brief summary, mud volcanoes are generally static (known mud volcanoes and gas seeps do not move) localised features. They can be hazardous – explosive eruptions throwing material up to 100 metres into the air have been reported, and are often associated with flammable hydrocarbons. Anecdotal evidence after the 2007 Gisborne earthquake suggests existing (or known) features became more active and new sites were reported.

Recommendations made in Mazengarb (1997) are still valid – the key to managing and mitigating the mud volcano/gas seep hazard is having known sites accurately identified and mapped so that they can be included on District Plan maps.

Existing mud volcanoes that are continuously erupting fall into the 0–50 year ARI (likely). Experience since 1997 suggests that strong earthquake shaking (MM7 or greater – ARI 51–100 years (possible)) will increase activity at known sites and may result in the appearance of new sites.

It is recommended that after episodes of strong ground shaking a programme to identify and map new mud volcanoes and gas seeps be undertaken, with a view to adding these locations to the database of known mud volcanoes and gas seeps.

The accurate identification and mapping of mud volcanoes (at a scale that is appropriate for inclusion in District Plan maps), and following the guidelines for mitigating the hazard given in Mazengarb (2002), will enable the risk from mud volcanoes and gas seeps to be managed appropriately.

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7.0 GLOSSARY

A glossary of technical terms used in the hazard and consequence descriptions has been compiled and is presented below. The definitions come from the publicly available online GNS Science glossary[1], unless otherwise stated.

ARI: Average return interval for a hazard event.

Axial Tectonic Belt: a broad term encompassing the active faults that form the main ranges of the eastern North Island stretching from Wellington to eastern Bay of Plenty. The Axial Ranges include the Rimutaka, Tararua, Ruahine and Urewera Ranges.

Ballistics: tephra particles larger than 64 mm (including ‘blocks’ and ‘bombs’) that are ejected from a volcanic vent in any direction without being affected by wind. They rarely reach more than about 3 kilometres radius from the vent.

Holocene: a geological epoch that started approximately 11,700 years before present and continues to the present. It follows the Pleistocene and the last glacial period[2].

Earthquake: a sudden motion or trembling in the crust caused by the abrupt release of accumulated stress along a fault.

Lahar: a volcanic mudflow – a flow of water-saturated, typically dense volcanic material that resembles a flow of wet concrete. Lahars usually flow down topographical lows (i.e., valleys), however, they may overtop banks. A lahar may be caused by the rapid melting of ice/snow by an eruption or from an eruption ejecting crater lake water. In the Gisborne context, a lahar may occur anywhere ash accumulates on slopes. It may also be unaccompanied by an eruption, such as through remobilisation of volcanic material due to heavy rain. Lahars can travel well over 100 km from the source, and can be dangerous to downstream populations who are unaware of the approaching hazard. Due to the large amount of sediment carried by a lahar, water channels (and other nearby flat land) can rapidly fill with deposited sediment, causing long-term flooding issues. They are also highly erosive, and can cause a lot of damage to bridges and other infrastructure, entraining all material in their paths.

Landslide: the down-slope movement of rock and soil under the influence of gravity.

Lava Flow: magma which has reached the surface during a volcanic eruption and flows effusively away from the vent. The term is most commonly applied to the flowing rock that emits from a crater or fissure, however it also refers to cooled and solidified rock formed in this way. Lava varies in viscosity (runniness and therefore speed of movement), chemistry and temperature.

Infrastructure Land Use (as used in the context description): The following land cover type from the Land Cover Database Version 4: Transport Infrastructure.

Liquefaction: the process where a saturated soil loses strength and behaves as a liquid due to an applied stress, usually severe earthquake shaking.

Ma: millions of years ago (a point in time).

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1 http://www.gns.cri.nz/Home/Learning/Glossary#glossarytop

2 http://en.wikipedia.org/wiki/Holocene

MMI: the Modified Mercalli Intensity (MMI) scale is a measure of the intensity of shaking at the Earth's surface caused by an earthquake. The following explanation of the scale is taken from the GeoNet website[3].

The scale used in New Zealand is a twelve step ranking, with 1 representing the weakest of shaking, through to 12 representing almost complete destruction. The descriptions below are a simplified version of the New Zealand Modified Mercalli Intensity scale. We have added a generalised Intensity term, which summarises the expected effects of an earthquake at its epicentre. This is a useful way of grading the impact of an earthquake on people and the environment, and can be displayed before people have a chance to fill out felt reports and describe in more detail the actual local effects of a shake.

Intensity	Modified Mercalli Level	Description
unnoticeable	**MM 1 – imperceptible**	Barely sensed only by a very few people.
	MM 2 – scarcely felt	Felt only by a few people at rest in houses or on upper floors.
weak	**MM 3 – weak**	Felt indoors as a light vibration. Hanging objects may swing slightly.
light	**MM 4 – light**	Generally noticed indoors, but not outside, as a moderate vibration or jolt. Light sleepers may be awakened. Walls may creak, and glassware, crockery, doors or windows rattle.
moderate	**MM 5 – moderate**	Generally felt outside and by almost everyone indoors. Most sleepers are awakened and a few people alarmed. Small objects are shifted or overturned, and pictures knock against the wall. Some glassware and crockery may break, and loosely secured doors may swing open and shut.
strong	**MM 6 – strong**	Felt by all. People and animals are alarmed, and many run outside. Walking steadily is difficult. Furniture and appliances may move on smooth surfaces, and objects fall from walls and shelves. Glassware and crockery break. Slight non-structural damage to buildings may occur.
severe	**MM 7 – damaging**	General alarm. People experience difficulty standing. Furniture and appliances are shifted. Substantial damage to fragile or unsecured objects. A few weak buildings are damaged.
	MM 8 – heavily damaging	Alarm may approach panic. A few buildings are damaged and some weak buildings are destroyed.
	MM 9 – destructive	Some buildings are damaged and many weak buildings are destroyed.
	MM 10 – very destructive	Many buildings are damaged and most weak buildings are destroyed.
	MM 11 – devastating	Most buildings are damaged and many buildings are destroyed.
	MM 12 – completely devastating	All buildings are damaged and most buildings are destroyed.

3 http://info.geonet.org.nz/display/quake/Shaking+Intensity

Mud Volcano: a loose term to describe three types of features: non-explosive gas/fluid vents, mud-extrusions, and eruptive vents. There may be a continuum between the three and any one site may possess more than one feature type (Mazengarb 1997).

Natural Environment Land Use (as used in the context description)**:** The following land cover types from the Land Cover Database Version 4: all those types not included as ‘urban’, ‘infrastructure’, and ‘primary production’.

Normal Fault: a fault in which the upper, hanging wall moves down with respect to the lower, footwall.

Primary Production Land Use (as used in the context description)**:** The following land cover types from the Land Cover Database Version 4: High Producing Exotic Grassland, Low Producing Grassland, Orchard Vineyard & Other Perennial Crops, Short-rotation Cropland, Surface Mines and Dumps, Forest – Harvested, Exotic Forest.

Pyroclastic Density Current: fast-moving, lethal, hot clouds of ash, rocks and gas, caused by a volcanic eruption. They are controlled by gravity, moving laterally and usually down topographical lows at high speeds (usually between 40 to 100 km per hour). They can travel a few hundreds of metres to kilometres from the source. In large but rare caldera-forming eruptions they can travel 10’s of kilometres. They are sometimes referred to as ‘PDCs’, and types include pyroclastic flows, and pyroclastic [base] surges.

Reverse Fault: a fault in which the upper, hanging wall moves up with respect to the lower, footwall.

Tsunami: a surge of water with a long wavelength produced by the displacement of a body of water. Causes of tsunami include an earthquake causing offset (uplift or subsidence) of the sea bed, a volcanic eruption, or a large landslide (including sector collapse). The height of a tsunami is influenced by the morphology of the coastline that it travels towards. The speed of a tsunami ranges between 10–100 km/hr in shallow areas, and up to 800 km/hr when crossing deeper waters. Landslides or icefalls into lakes or fiords may also generate tsunami.

Urban Land Use (as used in the context description)**:** The following land cover types from the Land Cover Database Version 4: Built Up Area, Urban Parkland/Open Space.

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8.0 SUMMARY

GDC commissioned GNS Science to assist with a regional risk assessment it is undertaking. This assessment will contribute to upcoming reviews of plans prepared under the RMA and the Civil Defence and Emergency Management Group Plan.

GNS Science, with input from NIWA, has compiled hazard descriptions and consequence descriptions for a number of natural hazards that have the potential to impact the Gisborne Region. Hazards assessment include: volcanic; rainfall induced landslide; tsunami (local and distance source combined); earthquake – shaking, liquefaction, landslips, fault rupture; mud volcanoes; flooding; coastal erosion; coastal flooding (excluding tsunami); drought; and extreme temperature.

Hazard and consequence descriptions have been prepared based on existing information and are presented in the format required by GDC. This format required comment on hazards and consequences that may occur at a range of ARIs. Consequence assessments were limited to consequences on health and safety, and built environment and property.

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9.0 ACKNOWLEDGEMENTS

Thanks go to Dr Wendy Saunders and Dr Jim Cousins of GNS Science, and Kate Crowley of NIWA, for their review of the appendices and this report.

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APPENDICES

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APPENDIX 1: CONTEXT

A1.1 BUILT ENVIRONMENT AND PROPERTY CONTEXT SECTION FOR GISBORNE DISTRICT RISK ASSESSMENT

Gisborne District covers a land area of approximately 8,385km^2 and is divided into approximately 37,400 individual land parcels (2014). For the purpose of this description, the District has been divided into 11 areas, as identified below.

A1.1.1 Reference Areas Used for Built Environment and Property Context Section

11 Areas are identified for reference in the building environment and property context section:

East Cape	Tarndale-Rakauroa	Gisborne Urban
Ruatoria	Te Karaka	Waipaoa
Tokomaru Bay	Wharekaka	Tiniroto
Tolaga Bay	Wainui	

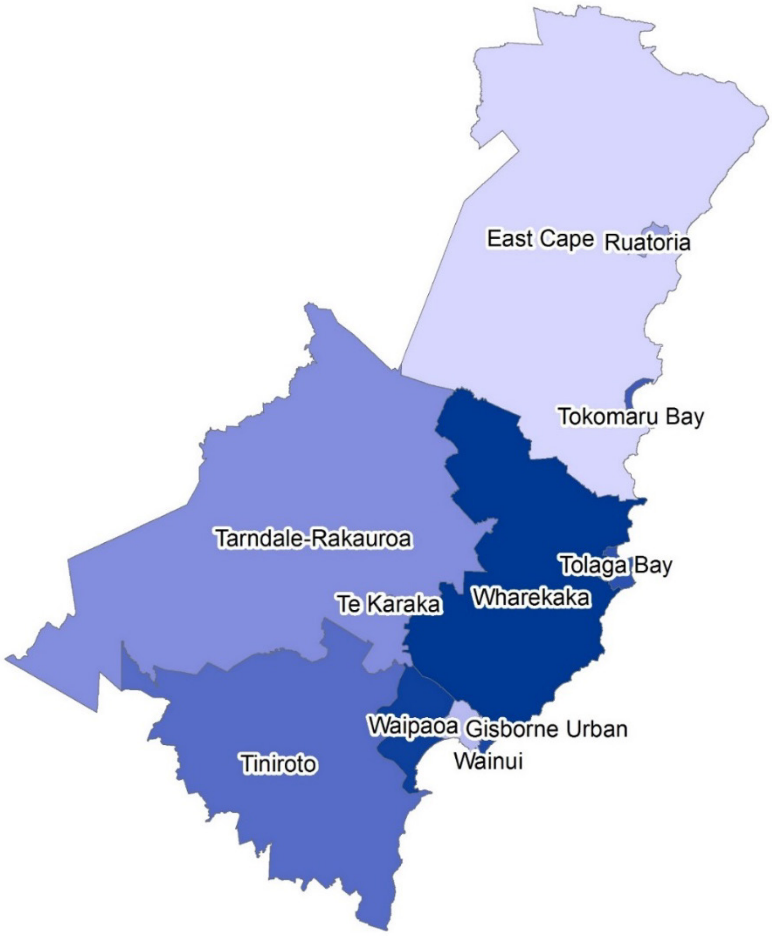

Figure A1.1 The 11 reference areas used for context section.

A1.1.2 Built Environment and Property Context Description

'Urban'[4] land use occupies 14,269 of the approximately 37,400 individual land parcels in the District, 12,065 of which are located in the Gisborne Urban area (Table 1.). Wainui, Tolaga Bay and Waipaoa account for most of the remaining urban land parcels. Although 'urban' is the most frequent land parcel use, 'primary production' is the most extensive with a parcel area coverage of 5,810km^2. 'Primary production' land is used for pastoral farming, horticultural and forestry activities. Pastoral farming land in operation covers 3,451km^2, mostly within Tarndale-Rakauroa (1,201km^2), Tiniroto (823 km^2) Wharekaka (627km^2). Horticultural land used for cropping, orchards and vineyards (117km^2) is primarily concentrated in Waipaoa (68km^2) and Wharekaka (18km^2). Forestry activities operate on 1,512km^2 of land across the district with major forestry holdings present in Tarndale-Rakauroa (594km^2), East Cape (530km^2) and Wharekaka (358km^2). The 'natural environment' consisting of non-harvestable vegetation, lakes, rivers, beaches, estuaries, wetlands and bare land is the second most extensive land parcel use. Large vegetation tracks located in the eastern areas of Tarndale-Rakauroa, Tiniroto and East Cape. All remaining land parcels are associated with infrastructure assets, with 5,028 (97km^2) designated for the districts extensive road network.

4 See the Glossary in the main body of the report for definitions of the different land uses referred to here.

Table A1.1 A summary of land parcels and their primary use in Gisborne District.

Land Parcels	East Cape	Gisborne Urban	Ruatoria	Tarndale-Rakauroa	Te Karaka	Tiniroto	Tokomaru Bay	Tolaga Bay	Wainui	Waipaoa	Wharekaka	Gisborne District
Urban No.	137	12,065	143	153	187	0	164	286	714	411	9	14,269
Urban Area (km^2)	0.14	12.6	0.15	0.18	0.24	0	0.16	0.4	0.88	0.93	0.01	15.69
Primary Production No.	2,249	747	355	1,798	185	1,408	325	378	381	2,617	1,760	12,203
Primary Production Area (km^2)	1,978.28	19.33	13.84	1,394.96	2.13	1,140.10	4.35	18.22	9.17	126.7	1,103.91	5,810.99
Natural Environment No.	2,048	683	121	1,101	6	544	190	56	117	207	700	5,773
Natural Environment Area (km^2)	794.66	6.06	7	1,229.67	0.32	235.12	5.18	9.52	3.45	15.36	154.83	2,461.17
Infrastructure No.	911	1,541	81	738	51	460	110	116	122	460	576	5,166
Infrastructure Area (km^2)	24.61	3.95	0.58	28	0.2	17.59	0.4	0.77	0.74	4.83	15.62	97.29
Total No.	5,345	15,036	700	3,790	429	2,412	789	836	1,334	3,695	3,045	37,411
Total Area (km^2)	2,797.69	41.94	21.57	2,652.81	2.89	1,392.81	10.09	28.91	14.24	147.82	1,274.37	8,385.14

Gisborne Urban area contains almost 60% of the district's 35,427 buildings (Table 2). Over half of these are residential dwellings while less than 10% are used for commercial and industrial purposes. Other urban areas such as Wainui, Tolaga Bay, Te Karaka, Ruatoria and Tokomaru Bay have similar proportions of building use. As primary production forms the district's economic base, higher proportions of 'industrial/primary production' buildings are located in rural areas than urban areas.

Timber is the dominant construction material for buildings in Gisborne District. It is estimated that 95% of all buildings are timber framed, indicating the high use of buildings for residential, primary production and 'other' (e.g., out-buildings, sheds, storage) purposes. A large proportion of masonry and steel framed buildings are located in the Gisborne Urban area, where most of the district's commercial and industrial activities are centred. Smaller townships throughout the district contain similar construction materials for commercial and industrial buildings.

Gisborne District building asset replacement value was estimated at NZD$6.63 billion in 2011, with contents replacement accounting for a further NZD$2.67 billion (Table 2). The concentration of buildings in Gisborne Urban area means over half of all building and content value occupies an area of 42km^2. Waipaoa and Wainui boarder the area and combined, contain another NZD$1 billion of building value. Average building and content replacement values are also relatively higher in Gisborne Urban and adjoining areas than in other areas. Values reduce for rural areas and remote urban centres such as Tokomaru Bay, Tolaga Bay, Te Karaka and Ruatoria.

Table A1.2 A summary of building assets (2011) in Gisborne District.

Building Attribute		East Cape	Gisborne Urban	Ruatoria	Tarndale-Rakauroa	Te Karaka	Tiniroto	Tokomaru Bay	Tolaga Bay	Wainui Beach	Waipaoa	Wharekaka	Gisborne District
Use	Residential	1,301	11,334	277	934	199	640	228	351	667	1,621	750	18,302
	Commercial	19	513	13	7	6	1	10	9	23	19	5	625
	Industrial/Primary Production	720	998	66	646	61	481	53	80	14	836	372	4,327
	Critical Facility	43	140	23	14	12	5	8	23	11	30	10	319
	Community	31	56	8	7	1	2	10	7	5	16	8	151
	Other	650	7,601	191	473	125	321	148	219	439	1,080	456	11,703
	Total Building No.	2,764	20,642	578	2,081	404	1,450	457	689	1,159	3,602	1,601	35,427
Construction Type	Timber	2,601	19,910	551	1,914	384	1,309	410	662	1,106	3,451	1,486	33,784
	Masonry	80	444	19	86	10	72	39	16	25	75	60	926
	Steel	83	288	8	81	10	69	8	11	28	76	55	717
	Other	0	0	0	0	0	0	0	0	0	0	0	0
Building Replacement Value ($NZD2011)	Average	135,761	190,924	152,242	181,086	144,213	178,045	132,409	142,215	241,012	227,012	176,435	172,850
	Total ($millions)	375.24	3,941.06	87.99	376.84	58.26	258.16	60.51	97.98	279.33	817.69	282.47	6,635.53
Content Replacement Value ($NZD2011)	Average	54,999	77,799	59,805	69,330	60,083	69,307	52,041	57,694	96,766	91,445	68,451	68,884
	Total ($millions)	152.01	1,605.93	34.56	144.27	24.27	100.49	23.78	39.75	112.15	329.38	109.59	2,676.18

Transport infrastructure in Gisborne District is heavily reliant on roads to move people and products within and outside the district. Over 3,000km of roads line the district including two state highways (SH2 and SH35) which provide links to Hawke's Bay and Bay of Plenty. Most roads are sealed or metalled (86%), though unmetalled roads are common in rural areas such as Tiniroto and Tarndale-Rakauroa (Table 3). There are 484 bridges on district roads crossing rivers and other hazardous obstacles. Gisborne District has a dense network of lower order river systems, resulting in a large number of bridges of relatively short average length in rural areas.

The Palmerston North to Gisborne railway line is the only other land transport network in Gisborne District. The line tracks from south the north through Tiniroto and Waipaoa before terminating in the Gisborne Urban area. In 2012, landslides closed the railway line between Napier and Gisborne and its operation has since ceased.

Air transport passenger services to Auckland, Wellington and other north island regional centres operate daily from Gisborne Airport located in the Gisborne Urban area. Another 107 airfields are located throughout the district, predominately in rural areas. These airfields are developed to assist with aviation training and primary production activities such as aerial spraying.

Table A1.3 A summary of transport infrastructure in Gisborne District.

Transport Infrastructure		East Cape	Gisborne Urban	Ruatoria	Tarndale-Rakauroa	Te Karaka	Tiniroto	Tokomaru Bay	Tolaga Bay	Wainui Beach	Waipaoa	Wharekaka	Gisborne District
Road	Sealed Length (km)	189	177.19	13.74	122	6.73	149.51	9.46	18.82	19.78	165.71	119.45	991.39
	Metalled Length (km)	535	5.18	7.23	590	0.89	257.71	3.65	5.26	4.33	21.63	277.54	1,708.42
	Unmetalled Length (km)	62	6.87	0	97	0	151.03	0	3.86	4.95	29.54	52.35	407.6
	Total Length (km)	786	189.24	20.97	809	7.62	558.25	13.11	27.94	29.06	216.88	449.34	3,107.41
Bridge	Bridge No.	132	23	6	129	2	92	6	3	1	19	71	484
	Average Length (km)	0.08	0.05	0.09	0.06	0.06	0.05	0.07	0.12	0.06	0.08	0.06	0.07
	Total Length (km)	11.07	1.18	0.54	7.80	0.12	4.21	0.44	0.36	0.06	1.53	3.91	2.84
Railway	Total Length (km)	0	8.25	0	0	0	26.78	0	0	0	13.88	0	48.91
Airport/ Airfield	Airport/Airfield No.	29	1	0	35	0	21	1	1	0	2	18	108
	Average Runway Length (km)	0.82	3.77	0	0.84	0	0.78	0.19	2.3	0	0.91	0.8	10.41
	Total Runway Length (km)	23.86	3.77	0	29.65	0	16.54	0.19	2.3	0	1.83	14.52	92.66

Electricity is supplied to the district via the 48km 110kV powerline connecting Tuai (Hawke's Bay) and the Gisborne Urban area. The line extends another 142km north to Tokomaru Bay where a 200km network of 50kV lines distribute electricity to East Cape and Ruatoria. Further south, 50kV lines distribute electricity from east to west significant distances across rural areas due to widespread primary production land use activities.

Table A1.4 A summary of utility infrastructure in Gisborne District.

Utility Infrastructure*		East Cape	Gisborne Urban	Ruatoria	Tarndale-Rakauroa	Te Karaka	Tiniroto	Tokomaru Bay	Tolaga Bay	Wainui Beach	Waipaoa	Wharekaka	Gisborne District
Electricity	Pylon No.	55	22	ND	ND	ND	99	3	ND	ND	106	137	422
	Powerline Length (km)	198	41	2	133	ND	163	6	8	3	90	200	844
Stormwater**	Network Point No.	345	6,674	131	79	120	ND	116	87	403	328	9	8,292
	Pipe Length (km)	2.49	166.14	2.84	0.92	2.29	ND	1.55	1.23	0.01	1.69	ND	179.17
	Drain Length (km)	ND	23.03	ND	ND	ND	ND	ND	ND	0.00	2.26	ND	25.29
Wastewater	Network Point No.	ND	3,345	ND	ND	68	ND	ND	ND	105	210	ND	3,728
	Pipe Length (km)	ND	218.00	ND	ND	5.63	ND	ND	ND	5.43	21.03	ND	250.08
Water Supply	Network Point No.	3	5,591	ND	40	53	ND	ND	ND	53	1,070	ND	6,810
	Pipe Length (km)	ND	200.08	ND	3.98	4.91	28.49	ND	ND	2.54	51.87	ND	291.86
Gas	Pipe Length (km)	ND	ND	ND	62.61	ND	ND	ND	ND	ND	9.33	8.08	80.02

* ND denotes 'No Data Available'.

** Gisborne District Council administers stormwater service networks for the following rural communities: Hicks Bay, Te Araroa, Te Puia Springs, Tikitiki (East Cape); Manutuke, Mākaraka, Patutahi (Waipaoa); Matāwai (Tarndale-Rakauroa); Muriwai (Tiniroto).

Natural gas is transported into the district from Bay of Plenty by the Kawerau-Opotiki-Gisborne pipeline administered by Vector. The pipeline runs alongside SH2 for 80km through Tarndale-Rakauroa, Waipaoa and Wharekaka (Table 4). Taranaki's Maui oil and gas field supplies natural gas to the pipeline.

Water supply, and wastewater infrastructure is provided in Gisborne, and some townships by the Gisborne District Council. Gisborne Urban area has an extensive reticulated water supply system with 200km of pipeline extending beyond its boundaries into the Western Industrial Area and Makaraka (Waipaoa) to service urban and industrial land use activities. Smaller scale water supply systems are managed by the Council to service Te Karaka and Whatatutu townships, with Manutuke being supplied by the Gisborne City supply. Wastewater reticulation, treatment and disposal systems are operated by the Council for Gisborne Urban area and Te Karaka. Water supply and wastewater for other townships and rural properties is supported by privately owned on site or local water supply and wastewater facilities. The Council provides a well-developed stormwater network of pipes and drains service the Gisborne Urban area. The Council also manages stormwater systems for all townships in rural areas (Table 4).

A1.1.3 Source Data Summary for Built Environment and Property Context Section

Table A1.5 Summary of source data for context section.

Asset Category	Asset Type	Outputs	Source	Data Type
Built Environment	Buildings	• Use Category (Residential, Commercial, Industrial/Primary Production, Critical Facility, Community, Other) • Construction Type (Timber, Masonry, Steel, Other) • Building Replacement Value (Total $NZD, $NZD Average) • Content Replacement Value (Total $NZD, $NZD Average)	RiskScape	GIS vector points
	Roads	• Road Length (km) • Road Surface Length (km) • Bridge (No.) • Bridge Length (Total (km) Average (km)).	NZTA, LINZ	GIS vector lines
	Electricity (main/national transmission lines from LINZ only)	• Powerline Length (Total (km)) • Pylon (No.)	LINZ, Gisborne District Council	GIS vector lines and points
	Water	• Network Point (No.) • Pipe Length (km).	Gisborne District Council	GIS vector lines and points
	Stormwater	• Network Point (No.) • Pipe Length (km) • Drain Length (km)	Gisborne District Council	GIS vector lines and points
	Wastewater	• Network Point (No.) • Pipe Length (km).	Gisborne District Council	GIS vector lines and points
	Gas	• Pipe Length (km).	LINZ	GIS vector lines
	Airports	• Airport/Air field (Total), • Airport/Air field Average Runway Length (km)), • Airport/Air field Total Runway Length (km).	LINZ	GIS vector lines
	Railway lines	• Railway Length (km).	LINZ	GIS vector lines
Property	Land Parcels	• Parcel (No.), • Parcel Land Use (Urban, Primary Production, Other) (No.) (km^2).	LINZ, Landcare Research	GIS vector polygons

APPENDIX 2: DATA QUALITY RATING

A2.1 DATA QUALITY RATING FOR GISBORNE DISTRICT RISK ASSESSMENT

A2.1.1 Overview

The data quality rating criteria is developed to provide basic detail on the information used to inform both hazard and consequence descriptions. In performing a high level district-wide natural hazard risk assessment, qualitative and quantitative data in various forms may be utilised. These can range from judgements or opinions on hazard exposure and corresponding assets at risk, through to well calibrated hazard exposure and asset vulnerability models which quantify asset impact and loss data. Hazard exposure and consequence data can vary in relative quality for any one location. For instance, a high resolution numerical model of tsunami hazard exposure (e.g., inundation depth and velocity) may be available for a location, though no corresponding vulnerability models for local assets may be available to quantify impacts and losses. In order to represent these situations, data quality ratings are developed for hazard and consequence descriptions, using an ordinal scale of 1 to 5, where a rating of 5 reflects descriptions based on the highest quality data available. The scale allows for a combined hazard and consequence data rating to be derived by simply adding the total of both ratings. Both hazard and consequence data ratings are provided in Tables 1 and 2 below.

Table A2.1 Hazard data quality rating.

Quality Rating	Description
1	**General knowledge of hazard** e.g., judgement made on the location, magnitude and/or frequency of hazard exposure without supporting qualitative or quantitative data.
2	**General knowledge of hazard exposure** e.g., judgement made on the location, magnitude and/or frequency of hazard exposure based on detailed knowledge of previous hazard events or an understanding of local hazardous processes.
3	**Identified hazard exposure** e.g., a qualitative model representing the location, magnitude and/or frequency of hazard exposure based on surveyed historical hazard exposure or similar detailed knowledge of previous hazard events or an understanding of local hazardous processes.
4	**Modelled hazard exposure (uncalibrated)** e.g., numerical model representing the location, magnitude and/or frequency of hazard exposure uncalibrated against surveyed historical hazard events.
5	**Modelled hazard exposure (calibrated)** e.g., numerical model representing the location, magnitude and/or frequency of hazard exposure calibrated against surveyed historical hazard events.

Table A2.2 Consequence data quality rating.

Quality Rating	Description
1	**General knowledge of assets at risk** e.g., judgement made on the location and type of assets at risk without supporting qualitative or quantitative hazard exposure data.
2	**General knowledge of assets at risk from hazard exposure** e.g., judgement made on the location and type of assets at risk based on historical experience of hazard events.
3	**Identified assets at risk** e.g., assets at risk identified from qualitative models representing the location, magnitude and/or frequency of hazard exposure based on surveyed historical hazard events or similar detailed knowledge of previous hazard events or an understanding of local hazardous processes.
4	**Modelled hazard impact and losses (uncalibrated)** e.g., asset impact and/or loss data derived from vulnerability models developed from a general understanding of impacts on assets combined with hazard exposure information derived from a numerical model representing the location, magnitude and/or frequency of hazard exposure calibrated against surveyed historical hazard events; or asset impact and loss data derived from vulnerability models developed for local conditions combined with hazard exposure information derived from numerical model representing the location, magnitude and/or frequency uncalibrated against surveyed historical hazard events.
5	**Modelled hazard exposure (calibrated)** e.g., asset impact and/or loss data derived from vulnerability models developed for local conditions combined with hazard exposure information derived from a numerical model representing the location, magnitude and/or frequency of hazard exposure calibrated against surveyed historical hazard events.

APPENDIX 3: HAZARD AND CONSEQUENCE DESCRIPTIONS

A3.1 EARTHQUAKE – INDUCED LANDSLIDES, GISBORNE DISTRICT

A3.1.1 Hazard Description: Earthquake – Induced Landslides

Earthquake-induced landslides will affect the hill country (i.e., the alluvial sediments of the river valleys will not be affected by landslides. Liquefaction, which does affect these sites, is covered separately.

Weather conditions at the time of, or in the days prior to, the earthquake will impact the extent and severity of the landslide damage, with wet conditions causing more extensive damage. Weather conditions during the days prior to the 1993 Ormond and 2007 Gisborne earthquakes were dry, making the observational damage during these earthquakes at the lower end of expectations.

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
Likely **ARI 0–50 years**	**Description:** At a 50-year return period MMI shaking will be in the range 7.0 to 7.3 throughout the Gisborne District. The maximum level of shaking expected at the 50-year return period is less than that experienced in the Ormond – Te Karaka area in 1993 and on the hills around Gisborne City in the 2007 earthquake. The damage is likely to be very minor with small rockfalls from cut slopes. **Gaps:** Two recent earthquakes, the Ormond earthquake of 1993 and the Gisborne earthquake of 2007 produced shaking at this level or greater affecting the hill country in these areas. Outside of these areas observational data is absent but is highly likely to conform to these observations based on strong earthquake shaking effects during earthquakes since 1840 throughout New Zealand.	4
Possible **ARI 51–100 years**	**Description:** A 50–100 year return period MMI shaking will be in the range 7.0 to 7.3 (50 year) to 7.4 to 7.9 (100 year) throughout the Gisborne District. The level of shaking expected at the 100-year return period is similar to that experienced in the hill country during the 2007 earthquake in Gisborne City. The damage is likely to be minor with small rockfalls from cut slopes. Some landslides may occur on vulnerable hill slopes (0–1% of slopes affected). Often present as incipient failures (i.e., ground cracking without sudden failure). Pre-existing landslides may show signs of small movement (0–100 mm).	3

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
	Gaps: Two recent earthquakes, the Ormond earthquake of 1993 and the Gisborne earthquake of 2007 produced shaking at this level affecting the hill country in these areas. Outside of these areas observational data is absent but is highly likely to conform to these observations based on strong earthquake shaking effects during earthquakes since 1840 throughout New Zealand.	
Unlikely ARI 101–1000 years	**Description:** A 100–1000 year return period MMI shaking will be in the range 7.4 to 7.9 (100 year) to 8.3 to 9.4 (1000 year) throughout the Gisborne District. Historically (since 1840) the higher levels of shaking in this range have not been observed in the Gisborne District. The highest levels of shaking for the longer return period events will occur nearest the east coast because the subduction plate interface is at its shallowest in this area, and the coast is also the closest part of the District to the known off-shore faults. The damage at the higher levels of shaking will be moderate with rockfalls from cut slopes and failure of road fills. Landslides will occur on hill slopes (1–5% of hill slopes affected). Pre-existing landslides may move up to 500 mm. **Gaps:** Two recent earthquakes, the Ormond earthquake of 1993 and the Gisborne earthquake of 2007 produced shaking at the lower return interval (100 years) and future damage at this level of shaking is likely to be similar to the damage in hill country in these areas. Outside of these areas observational data is absent but is highly likely to conform to these observations based on strong earthquake shaking effects during earthquakes since 1840 throughout New Zealand.	2
Rare ARI 1001–2500 years	**Description:** A 1000 to 2500 year return period MMI shaking will be in the range 8.3 to 9.4 (1000 year) to 8.7 to 9.8 (2500 year) throughout the Gisborne District. The highest levels of shaking for the longer return period events will occur nearest the east coast because the subduction plate interface is at its shallowest in this area, and the coast is also the closest part of the District to the known off-shore faults. The damage at the higher levels of shaking may be severe with rockfalls from cut slopes and failure of road fills. Landslides will occur on hill slopes (5–10% of hill slopes affected). Pre-existing landslides may move up to 1 m. **Gaps:** There are no historical earthquakes in the Gisborne District at these levels of shaking. Landslide damage during other large earthquakes in New Zealand provide the analogues used for descriptive purposes.	1
Very rare ARI >2500 years	**Description:** 2500 year return period or greater MMI shaking will be in the 8.7 to 9.8 (2500 year) or greater throughout the Gisborne District. The highest levels of shaking for the longer return period events will occur nearest the east coast because the subduction plate interface is at its shallowest in this area, and the coast is also the closest part of the District to the known off-shore faults. The damage at the 2500 year return period levels of shaking may be severe with rockfalls from cut slopes and failure of road. Landslides will occur on hill slopes (5–10% of hill slopes affected). Pre-existing landslides may move up to 1 m. **Gaps:** There are no historical earthquakes in the Gisborne District at these levels of shaking. Landslide damage during other large earthquakes in New Zealand provide the analogues used for descriptive purposes.	1

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A3.1.2 Consequence Description: Earthquake-Induced Landslides

A3.1.2.1 Overview

This consequence description is based on the corresponding earthquake-induced landslides hazard description, and the asset inventories created in the 'context' section of this project.

Landslides have ARI across all ranges. As the ARI increases, the number and size of landslides in any given event will increase. However, the individual consequence is the same for any given landslide. For example, a landslide has the potential to cause severe damage to the built environment and property, but over a relatively small area for each event. However, during a large earthquake event, landslides can occur over a large area. Therefore, as ARI increases, the combined consequences across the region will increase.

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
Likely **ARI 0–50 years**	**Description:** There are serious health and safety consequences due to landslides. The following consequences apply to moderate sized landslides. If struck by a landslide while outside, the chance of survival is very low. If located in a vehicle, the chance of survival increases as the vehicle provides protection and a cavity if buried, however immediate rescue is important. If there is a rockfall however large debris blocks will increase the chance of fatalities. If a person is located in a building then the fatality risk is moderate to high. The locations with the highest health and safety risk are roads adjacent to steep slopes or road cuttings or in buildings above, below or on steep slopes. **Gaps:** No spatial data exists for earthquake induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential health and safety consequences to people in the area.	1–2	**Description:** Landslides will primarily cause damage to roads where steep slopes above or below the road have slipped causing debris to cover the road (in the case of a slip from above), or undercut and destroy the road (if the slip occurs below). This will cause the road to be closed for some period of time while it is cleared and repaired. The repair time will increase with the length of road damaged and the amount of material that needs to be cleared. At the 50 year ARI, the damage is likely to be very minor with small rockfalls from cut slopes affecting some roads but unlikely to prevent use (0–2% of roads affected). Underground services (pipes, cables etc.) will be destroyed if they are located in an area that slips. To repair these services the ground will need to be stabilised which will increase down time. Nearly all structures that are located either on or in the path of a	1–2

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
			landslide will be destroyed beyond repair. Structures that are located above a landslide may have their foundations eroded or be at risk from collapsing and will generally be evacuated. Rockfalls often have a smaller damage zone than landslides. They are confined to the path that the rocks or debris fall. However, will generally cause significant damage to buildings and property in their path. During the Canterbury earthquakes, rockfalls in the Port Hills destroyed vehicles that were being driven on the road at the time, and destroyed houses. **Gaps:** No spatial data exists for earthquake induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential consequences to the built environment and property in the area.	
Possible ARI 51–100 years	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table). **Gaps:** No spatial data exists for earthquake induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential health and safety consequences to people in the area.	1-2	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table). At the 100 year ARI, the damage is likely to be minor with small rockfalls from cut slopes affecting some roads but unlikely to prevent use (0-5% of roads affected). **Gaps:** No spatial data exists for earthquake induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential consequences to the built environment and property in the area.	1-2

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
Unlikely **ARI 101–1000 years**	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table). **Gaps:** No spatial data exists for earthquake induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential health and safety consequences to people in the area.	1–2	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table). The damage at the higher levels of shaking will be moderate with rockfalls from cut slopes and failure of road fills rendering some roads unusable (5–10% of roads affected. **Gaps:** No spatial data exists for earthquake induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential consequences to the built environment and property in the area.	1–2
Rare **ARI 1001–2500 years**	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table). **Gaps:** No spatial data exists for earthquake induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential health and safety consequences to people in the area.	1–2	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table). The damage at the higher levels of shaking may be severe with rockfalls from cut slopes and failure of road fills rendering some roads unusable (10–20% of roads affected). **Gaps:** No spatial data exists for earthquake induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential consequences to the built environment and property in the area.	1–2

Likelihood	Description of Health-Safety Consequences	**Data Quality Rating** (applies to available data only)	Description of Built Environment and Property Consequences	**Data Quality Rating** (applies to available data only)
Very rare **ARI >2500 years**	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table). **Gaps:** No spatial data exists for earthquake induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential health and safety consequences to people in the area.	1–2	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table). The damage at the 2500 year return period levels of shaking may be severe with rockfalls from cut slopes and failure of road fills rendering some roads unusable (10–20% of roads affected). **Gaps:** No spatial data exists for earthquake induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential consequences to the built environment and property in the area.	1–2

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A3.2 RAINFALL – INDUCED LANDSLIDES, GISBORNE DISTRICT

A3.2.1 Hazard Description: Rainfall – Induced landslides

Rainfall-induced landslides have two important parameters:

1. the intensity of the rainfall in a given area, and
2. the extent of the area affected.

Good data exist for (1), the return periods of rainfall intensity, out to 100 years. The data on (2), extent, are poor.

Cyclone Bola in 1988 provides a good historical analogue for the 100 year return period storm, which affected most of the Gisborne District. Given the severity and extent of this storm in the Gisborne District there is little benefit in extending out to the longer return period events.

Rainfall is higher in inland areas for a given return period relative to coastal areas, and higher in northern areas relative to southern areas.

Likelihood	Description of Event	**Data Quality Rating** (applies to available data only)
Likely **ARI 0–50 years**	**Description:** At the annual level a storm affecting 100–400 km2 of the district will cause a few minor landslides and rock or soil falls. Minor landslides on slopes steeper than 300. Pre-existing landslides likely to respond as per seasonal behaviour. The 50-year return period a storm may affect 10% to 50% of the district (500–2000 km2). Hill slopes affected. Slopes greater than 300, up to 20% of slopes affected. Slopes from 20–300, up to 5% of slopes affected. Slopes less than 200, less than 1% of slopes affected. Pre-existing landslides may show movement of up to 1 m. **Gaps:** No gaps as historical records provide adequate data to assess this hazard.	5
Possible **ARI 51–100 years**	**Description:** At the one hundred year return period (the Cyclone Bola equivalent) the whole district may be affected as well as adjacent areas (Bay of Plenty and/or northern Hawke's Bay). Hill slopes affected. Slopes greater than 300, up to 50% of slopes affected. Slopes from 20–300, up to 20% of slopes affected. Slopes less than 200, less than 10% of slopes affected. Pre-existing landslides may show movement of up to 10 m. **Gaps:** No gaps as historical records provide adequate data to assess this hazard. Uncertainty around the extent of the area affected.	4

Likelihood	Description of Event	**Data Quality Rating** (applies to available data only)
Unlikely **ARI 101–1000 years**	**Description:** Worse than Cyclone Bola **Gaps:** The data to calibrate the rainfall curve for depth-duration-intensity out to these long return period events do not exist. No known historical analogues.	1
Rare **ARI 1001–2500 years**	**Description:** Worse than Cyclone Bola **Gaps:** The data to calibrate the rainfall curve for depth-duration-intensity out to these long return period events do not exist. No known historical analogues.	1
Very rare **ARI >2500 years**	**Description:** Worse than Cyclone Bola **Gaps:** The data to calibrate the rainfall curve for depth-duration-intensity out to these long return period events do not exist. No known historical analogues.	1

Caveats:

1. Sediment deposition on the flood plains is treated as a flooding hazard. Consequently the landslide hazard is only applied to hill country.

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A3.2.2 Consequence Description: Rainfall – Induced Landslides

A3.2.2.1 Overview

This consequence description is based on the corresponding rainfall induced landslides hazard description, and the asset inventories created in the 'context' section of this project.

Landslides have ARI across all ranges. As the ARI increases, the number and size of landslides in any given event will increase. However, the individual consequence is the same for any given landslide. For example, a landslide has the potential to cause severe damage to the built environment and property, but over a relatively small area for each event. However, during a large rainfall event, landslides can occur across much of the district. Therefore, as ARI increases, the combined consequences across the region will increase.

Likelihood	**Description of Health-Safety Consequences**	**Data Quality Rating** (applies to available data only)	**Description of Built Environment and Property Consequences**	**Data Quality Rating** (applies to available data only)
Likely **ARI 0–50 years**	**Description:** There are serious health and safety consequences due to landslides. The following consequences apply to moderate sized landslides. If struck by a landslide while outside, the chance of survival is very low. If located in a vehicle, the chance of survival increases as the vehicle provides protection and a cavity if buried, however immediate rescue is important. If there is a rockfall, however, large debris blocks will increase the chance of fatalities. If a person is located in a building then the fatality risk is moderate to high. The locations with the highest health and safety risk are roads adjacent to steep slopes or road cuttings or in buildings above, below, or on steep slopes. **Gaps:** No spatial data exist for rainfall induced	1–2	**Description:** Landslides from historical events in the Gisborne District (e.g., Cyclone Bola) have primarily caused damage to roads where steep slopes above or below the road have slipped causing debris to cover the road (in the case of a slip from above), or undercut and destroy the road (if the slip occurs below). This will cause the road to be closed for some period of time while it is cleared and repaired. The repair time will increase with the length of road damaged and the amount of material that needs to be cleared. At the annual level storm event, well engineered roads unlikely to be affected. 0–1% of local roads may experience partial blockage. At the 50 year storm, poorly engineered road cuts may fail causing partial blockage of main roads and blocking of many local roads (10–20% of roads affected).	1–2

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
	landslide hazard for GDC. As such, the consequence analysis can only describe the potential health and safety consequences to people in the area.		Underground services (pipes, cables etc.) will be destroyed if they are located in an area that slips. To repair these services the ground will need to be stabilised which will increase down time. Nearly all structures that are located either on or in the path of a landslide will be destroyed beyond repair. Structures that are located above a landslide may have their foundations eroded or be at risk from collapsing and will generally be evacuated. **Gaps:** No spatial data exists for rainfall induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential built environment and property consequences to people in the area.	
Possible **ARI 51–100 years**	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table). **Gaps:** No spatial data exists for rainfall induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential consequences.	1–2	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table). At the one hundred year event, poorly engineered road cuts may fail causing partial blockage of main roads and blocking of many local roads (20–50% of roads affected). **Gaps:** No spatial data exists for rainfall induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential consequences.	1–2
Unlikely **ARI 101–1000 years**	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table).	1–2	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table).	1–2

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
	Gaps: No spatial data exists for rainfall induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential consequences.		**Gaps:** No spatial data exists for rainfall induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential consequences.	
Rare **ARI 1001–2500 years**	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table). **Gaps:** No spatial data exists for rainfall induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential consequences.	1–2	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table). **Gaps:** No spatial data exists for rainfall induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential consequences.	1–2
Very rare **ARI >2500 years**	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table). **Gaps:** No spatial data exists for rainfall induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential consequences.	1–2	**Description:** As above, but the number of landslides in the region will increase which will increase the extent of damage (refer to hazard table). **Gaps:** No spatial data exists for rainfall induced landslide hazard for GDC. As such, the consequence analysis can only describe the potential consequences.	1–2

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A3.3 EARTHQUAKE – SHAKING, GISBORNE DISTRICT

A3.3.1 Hazard Description: Earthquake – Shaking

Weak rock sites are located in the hill country. Shallow soils are located in the inland reaches of the stream and river valleys, the margins of the river valleys in coastal areas, and sediments on the coastal platform. Deep soils are found in the larger river valleys near the coast, and very soft soils at least 10 m deep are the sites of present or former swamps.

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
Likely **ARI 0–50 years**	**Description:** At a 50-year return period MMI shaking will be in the range 7.0 to 7.3 throughout the Gisborne District. The maximum level of shaking expected at the 50-year return period is similar to that experienced in the Ormond – Te Karaka area in 1993 and less than that experienced on deep soft soils in the 2007 earthquake in Gisborne City, but similar to the shaking experienced on shallow soils and weak rock. **Gaps:** Two recent earthquakes, the Ormond earthquake of 1993 and the Gisborne earthquake of 2007 produced shaking at this level or greater affecting the Waipaoa River floodplain (including Te Karaka), the Gisborne urban area and Wainui. Outside of these areas observational data are absent but impacts are highly likely to conform to these observations based on strong earthquake shaking effects during earthquakes since 1840 throughout New Zealand.	5
Possible **ARI 51–100 years**	**Description:** A 50–100 year return period MMI shaking will be in the range 7.0 to 7.3 (50 year) to 7.4 to 7.9 (100 year) throughout the Gisborne District. The level of shaking expected at the 100-year return period is similar to that experienced in and near Gisborne City in the 2007 earthquake. **Gaps:** Two recent earthquakes, the Ormond earthquake of 1993 and the Gisborne earthquake of 2006 produced shaking at this level affecting the Waipaoa River floodplain (including Te Karaka), the Gisborne urban area and Wainui. Outside of these areas observational data is absent but is highly likely to conform to these observations based on strong earthquake shaking effects during earthquakes since 1840 throughout New Zealand.	4
Unlikely **ARI 101–1000 years**	**Description:** A 100–1000 year return period MMI shaking will be in the range 7.4 to 7.9 (100 year) to 8.3 to 9.4 (1000 year) throughout the Gisborne District. Historically (since 1840) the higher levels of shaking in this range have not been observed in the Gisborne District. The highest levels of shaking for the longer return period events will occur nearest the east coast because the subduction plate	3

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
	interface is at its shallowest in this area, and the coast is also the closest part of the District to the known off-shore faults. The level of shaking expected at the 1000-year return period is greater than the level of shaking experienced in and near Gisborne City during the 2007 earthquake. At these higher levels of shaking the relative damage on shallow soil sites and weak rock may be greater than the damage on deep and/or soft soil sites. **Gaps:** The highest level of shaking expected during the 100 year return period event is well constrained, with the 1966 Gisborne, 1993 Ormond, and 2007 Gisborne earthquakes providing actual records, from in and near Gisborne, of the type and extent of damage to be expected. Observational data are absent from elsewhere in Gisborne District, but are highly likely to conform to these observations based on strong earthquake shaking effects during earthquakes since 1840 throughout New Zealand. At the longer return period (1000 years) the level of damage expected in coastal areas (MM 9.4) has no historical analogue in the Gisborne area but the recent Canterbury earthquake sequence, in particular the 2011 Christchurch earthquake, provide examples of the types of shaking damage that might be expected.	
Rare **ARI 1001–2500 years**	**Description:** A 1000 to 2500 year return period MMI shaking will be in the range 8.3 to 9.4 (1000 year) to 8.7 to 9.8 (2500 year) throughout the Gisborne District. The highest levels of shaking for the longer return period events will occur nearest the east coast because the subduction plate interface is at its shallowest in this area, and the coast is also the closest part of the District to the known off-shore faults. The level of shaking expected at the 2500-year return period is greater than the level of shaking experienced during any historical earthquake in the Gisborne District. At these higher levels of shaking the relative damage on shallow soil sites and weak rock may be greater than the damage on deep and/or soft soil sites. This is because ground deformation in the deep and/or soft soils may begin to attenuate the shaking. **Gaps:** At these longer return periods (1000–2500 years) the level of damage expected in coastal areas (MM 9.8) has no historical analogue in the Gisborne area but the recent Canterbury earthquake sequence, in particular the 2011 Christchurch earthquake provide an example of the types of shaking damage that might be expected.	2
Very rare **ARI >2500 years**	**Description:** 2500 year return period or greater MMI shaking will be in the 8.7 to 9.8 (2500 year) or greater throughout the Gisborne District. Descriptions as above for 2500 year return period. **Gaps:** At this and longer return periods (2500 years) the level of damage expected in coastal areas (MM 9.8) has no historical analogue in the Gisborne area but the recent Canterbury earthquake sequence, in particular the 2011 Christchurch earthquake provide an example of the types of shaking damage that might be expected.	1

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A3.3.2 Consequence Description: Earthquake – Shaking

A3.3.2.1 Overview

This consequence description is based on the corresponding earthquake shaking hazard description, and the asset inventories created in the ‘context’ section of this project. The consequence descriptions are based on relationships between MMI shaking intensity and observed damage from earthquakes in New Zealand.

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
Likely **ARI 0–50 years**	**Description:** Please refer to description of consequences to built environment and property as this contains material relevant to this section since most health and safety consequences from ground shaking are linked to building damage. There will be a minor chance of injury and possibly death from falling chimneys (in areas outside the Gisborne city). The chance is higher if the earthquake occurs during the day and in the weekend when people are outside around their homes. Some people may be injured by falling objects or from their actions during the earthquake (i.e., trip/fall injuries). **Gaps:** These consequences are based on relationships between MMI and observed damage from earthquakes in New Zealand.	3	**Description:** Damage is likely to be confined to a small percentage (5–10%?) of unreinforced brick chimneys and poorly braced water tank stands (common on many rural properties). The most vulnerable structures will have failed in Gisborne City during the 2007 earthquake so that no collapse of buildings or failure of structural elements in buildings is expected at this level of shaking in Gisborne city. Although in areas further inland, these vulnerable elements may still be present and may collapse if shaking is MMI 6 or higher in these areas. Unrestrained contents (e.g., stock on supermarket shelves) will likely be damaged but the extent may depend on directional effects of shaking in relation to the orientation of shelving. No damage is expected to buried infrastructure. More damage is expected on deep or soft soils (especially old swamps and soils subject to a very high or high liquefaction hazard) relative to similar structures and contents on weak rock or shallow and stiff soils. For example chimney damage may be limited to deep or soft soil sites. For this level of hazard, MMI 7 is expected over the whole district.	3

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
			Gaps: These consequences are based on relationships between MMI and observed damage from earthquakes in New Zealand.	
Possible ARI 51–100 years	**Description:** As above, but there is a higher likelihood of these injuries as a higher percentage of chimneys may collapse (outside of Gisborne city). There will also likely be more injuries from falling objects. There may also be injuries or possible fatalities caused by failing masonry from masonry buildings. For example during the Gisborne 2007 earthquake, a number of masonry parapets collapsed but fortunately no one was beneath these when they failed. **Gaps:** These consequences are based on relationships between MMI and observed damage from earthquakes in New Zealand.	3	**Description:** Damage is likely to be confined to a small percentage (10%–20%?) of unreinforced brick chimneys and poorly braced water tank stands (common on many rural properties). The most vulnerable structures will have failed in Gisborne City during the 2007 and earlier earthquakes, so that no collapse of buildings or failure of structural elements in buildings is expected at this level of shaking. Although in areas further inland, these vulnerable elements may still be present and may collapse if shaking is MMI 6 or higher in these areas. There may also be some incipient failure damage such as cracking of brickwork and other minor structural damage. A building inspection process will need to be initiated to determine nature and extent of damage. Unrestrained contents (e.g., stock on supermarket shelves) will likely be damaged but the extent may depend on directional effects of shaking in relation to the orientation of shelving. Non-structural elements (e.g., ceiling tiles) may suffer some damage. More damage is expected on deep or soft soils (especially old swamps and soils subject to a very high or high liquefaction hazard) relative to similar structures and contents on weak rock or shallow and stiff soils. For example chimney damage will be greater on deep or soft soil sites in terms of both frequency (greater percentage of chimneys damaged) and magnitude (more collapse rather than just observable cracking and millimetre scale displacements).	3

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
			Some damage to buried infrastructure may occur in soft soils or soils with a very high liquefaction hazard for brittle pipe materials. Networks will need to be inspected to establish if damage has occurred and if so its extent. Inspection of structural elements of unreinforced masonry buildings required to ascertain if damage has occurred and if so the appropriate course of action. **Gaps:** These consequences are based on relationships between MMI and observed damage from earthquakes in New Zealand.	
Unlikely **ARI 101–1000 years**	**Description:** As above, but there is a higher likelihood of these injuries as a higher percentage of chimneys may collapse. There are likely to be injuries or possible fatalities caused by failing masonry from masonry buildings. Some masonry buildings may collapse at MMI 9 which will cause a life safety risk. The fatality rate from collapsed brick buildings is around 7%. Injuries and fatalities caused by falling masonry will be much higher during a day time earthquake as people are outside and near these types of buildings. If this level of shaking occurs, there is likely to be a high demand on medical services from injuries. This is likely to require assistance from outside Gisborne. **Gaps:** These consequences are based on relationships between MMI and observed damage from earthquakes in New Zealand.	3	**Description:** The level of shaking expected at the 1000-year return period is greater than the level of shaking experienced in Gisborne City during the 2007 earthquake. At these higher levels of shaking the relative damage on shallow soil sites and weak rock may be greater than the damage on deep and/or soft soil sites. At this ARI, MMI8 is likely to be experienced in East Cape, Ruatoria and Tarndale-Rakauroa. At this shaking intensity (similar to the 4 September 2010 Darfield earthquake) there will be moderate to extensive damage to vulnerable unreinforced masonry buildings. There will be a few instances of damage to buildings designed and built to recent earthquake loading standards. Most brick chimneys will suffer damage or collapse. The total replacement value of buildings and contents in the MMI 8 zone is $838M and $331M respectively. Percentage losses are expected to be 1 to 6 %. MMI 9 is likely to be experienced in the remaining regions.	3

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
			This is similar to what was experienced in the Christchurch CBD during the 22 February 2011 earthquake. Most vulnerable unreinforced masonry buildings will suffer severe damage or collapse. Most building types will suffer some damage. The total replacement value of buildings and contents in MMI 9 zone is $5,798 and $2,490 respectively. Percentage losses are expected to be 7 to 15 %. There may be some minor damage to bridges in MMI9 regions. In regions of MMI 8 and MMI 9 there will likely be some minor to moderate damage to the rail network. This is highly dependent on the soil conditions and orientation of the track in relation to the incoming seismic waves. Damage to buried infrastructure will likely occur in soft soils or soils with a very high liquefaction hazard for brittle pipe materials. Networks will need to be inspected to establish if damage has occurred and if so its extent. **Gaps:** These consequences are based on relationships between MMI and observed damage from earthquakes in New Zealand.	
Rare **ARI 1001–2500 years**	**Description:** As above **Gaps:** These consequences are based on relationships between MMI and observed damage from earthquakes in New Zealand.	3	**Description:** As above, but with potential enhancement of damage to buried services in shallow soil sites and weak rock. **Gaps:** These consequences are based on relationships between MMI and observed damage from earthquakes in New Zealand.	3

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
Very rare ARI >2500 years	**Description:** As above, plus at this level of shaking there are likely to be numerous collapsed buildings in the Gisborne CBD with many injuries and fatalities, particularly if it occurs during the day. There will likely be a large strain on the medical system and there is the possibility of increased fatalities if serious injuries are not attended to. A response from outside of Gisborne may be delayed if access to Gisborne is restricted due to landslides on the main state highways into the city. **Gaps:** These consequences are based on relationships between MMI and observed damage from earthquakes in New Zealand.	3	**Description:** MMI10 is likely to be experienced in Gisborne Urban, Wainui and Tolaga Bay. There will be extensive damage to vulnerable buildings (URM and buildings with low %NBS), and minor to extensive damage to high %NBS buildings and timber framed residential buildings. A total of $4,317M of buildings and $1,758M of contents in the MMI10 zone. Percentage losses are expected to be 16 to 30 % MMI9 is likely to be experienced in the remaining regions. This is similar to what was experienced in the Christchurch CBD during the 22 February 2011 earthquake. Most vulnerable unreinforced masonry buildings will suffer severe damage or collapse. Most building types will suffer some damage. The total replacement value of buildings and contents in MMI 9 zone is $2,034 and $920M respectively. Percentage losses are expected to be 7 to 15 %. There will likely be minor damage to bridges in MMI 9 regions and moderate damage in MMI 10 regions. Considerable damage to buried infrastructure will occur in soft soils or soils with a very high liquefaction hazard, for brittle pipe materials. Networks will need to be inspected to establish if damage has occurred and if so its extent. In regions of MMI 9 and MMI 10 there will likely be some moderate damage to the rail network. This is highly dependent on the soil conditions and orientation of the track in relation to the incoming seismic waves. **Gaps:** These consequences are based on relationships between MMI and observed damage from earthquakes in New Zealand.	3

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A3.4 EARTHQUAKE – FAULT RUPTURE, GISBORNE DISTRICT

A3.4.1 Hazard Description: Earthquake – Fault Rupture

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
Likely **ARI 0–50 years**	**Description:** There are no known faults within Gisborne District (or New Zealand) that have an ARI of <50 years for surface fault rupture*. **Gaps:** no gaps	3
Possible **ARI 51–100 years**	**Description:** There are no known faults within Gisborne District (or New Zealand) that have an ARI of 51–100 years for surface fault rupture*. As a calibration of such an event, no known surface fault rupture has occurred during the historic period (170 yr since 1840 AD) in Gisborne District **Gaps:** no gaps	3
Unlikely **ARI 101–1000 years**	**Description:** There are no known faults within Gisborne District that have an ARI of 101–1000 years for surface fault rupture*. **Gaps:** There are no likely gaps in the data. Active faults with an ARI of <1000 yr in New Zealand typically occur along the main axial tectonic belt of the country, e.g., Alpine, Hope, and Wellington Faults, and in the Taupo Volcanic Zone, e.g., Edgecumbe Fault. The axial tectonic belt and the Taupo Volcanic Zone lie to the west of Gisborne District.	3
Rare **ARI 1001–2500 years**	**Description:** There are no known faults within Gisborne District that have an ARI of 1001–2500 years for surface fault rupture*. **Gaps:** Active faults with an ARI of 1000–2500 yr in New Zealand typically occur around the main axial belt of the country, e.g., Waimana, Ohariu, Ruahine, Elliott faults. The axial belt occurs to the west of Gisborne District. Several Class IV active faults (RI 5000–10,000 yr, see next row) have basic RI data form geologic studies, while several others may be similarly active. At least 9 short faults in the district have Holocene expression and appear in the GNS Science Active faults database‡, which implies that at least one surface faulting event is possible within a 1000–2500 year period.	3

Likelihood	Description of Event	**Data Quality Rating** (applies to available data only)
Very rare **ARI >2500 years**	**Description:** There are three faults in Gisborne District that have nominal recurrence intervals of 5000–10,000 years, including the Repongaere, Pangopango and Fernside faults. Surface rupture example: fault rupture may produce an earth movement of 0.8–2.6 m along a 3–15 km length of mapped fault. Most of the mapped faults in the district have a normal or reverse sense, in which ground movements would be vertical. The 'fault damage zone', where severe ground damage could be expected, is +-120 metres either side of the fault (+-100 m to allow for locational uncertainty, and +-20 m as a 'margin of safety' buffer). **Gaps:** Several other faults with no current recurrence interval data exist within the District, including the Pakarae, Motu and Marae Beach faults. Data would be improved by new active fault (paleoseismic) studies. Other active faults may exist on land that are at present unmapped due to limited expression or a lack of research. At least 9 short faults in the district have Holocene expression and appear in the GNS Science Active faults database‡, which implies that at least two surface faulting events are possible at the 2500 year return period.	3

* rupture of faults with a longer recurrence interval is possible at any time, i.e., we do not know whether faults are close to the end of their recurrence cycle (failure)

‡ http://data.gns.cri.nz/af/

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A3.4.2 Consequence Description: Earthquake – Fault Rupture

A3.4.2.1 Overview

This consequence description is based on the corresponding earthquake – fault rupture hazard description, and the asset inventories created in the ‘context’ section of this project.

During a large shallow earthquake there is a small chance the fault will rupture the surface causing an offset at the surface. There is likely to be a damage zone ~120 m either side of the fault, within which the land will be damaged.

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
Likely **ARI 0–50 years**	**Description:** N/A **Gaps:** N/A		**Description:** N/A **Gaps:** N/A	
Possible **ARI 51–100 years**	**Description:** N/A **Gaps:** N/A		**Description:** N/A **Gaps:** N/A	
Unlikely **ARI 101–1000 years**	**Description:** N/A **Gaps:** N/A		**Description:** N/A **Gaps:** N/A	
Rare **ARI 1001–2500 years**	**Description:** N/A **Gaps:** N/A		**Description:** N/A **Gaps:** N/A	
Very rare **ARI >2500 years**	**Description:** There is a moderate to high likelihood that buildings located on the fault or within the damage zone will suffer extensive damage or collapse. The fatality risk for a collapsed residential building with timber frame construction building is ~1%. In a large fault	3	**Description:** Surface rupture of the fault will cause damage to the built environment and/or property. The movements of faults in the Gisborne Region (GR) are likely to cause vertical offsets between 0.5–2.6 m. This will likely cause significant damage to structures and localised damage to roads. Offsets such as this were observed in the Canterbury plains following	3

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
	rupture there will likely be moderate to serious injuries to those in the buildings located in the damage zone. These people will require immediate rescue and medical treatment. However, due to the low numbers (below) of people, this will likely be able to be handled by the emergency services. However, this only takes into account injuries and fatalities due to fault rupture, which will be additional to those from ground shaking from the same earthquake. There are a total of 55 people in the Tarndale-Raukauroa area who reside within buildings located in the damage zone of an active fault (Arakihi Fault). Within the Wharekaka area there are three buildings with 12 people who reside in them, that are located within the damage zones of active faults (unnamed). **Gaps:** It is not known which fault may rupture in a future event, so the descriptions described above take into account all the faults.		the 4 September 2010 Darfield Earthquake but with horizontal offset. Roads that crossed the Darfield faultline were repaired within a few days to a week by realigning the road to the new position. Note that this description only takes into account damage due to fault rupture, which will be additional to that from ground shaking from the same earthquake. *Buildings:* Within the Tarndale-Rakauroa area, \$4.9M worth of buildings are located within the damage zone of the Arakihi Fault. Within the Wharekaka area \$1.6M worth of buildings are located within the damage zone of active faults (unnamed). *Roads:* Within the Tarndale-Rakauroa region a number of roads cross active faults. These roads include; Lavenham Road and Bond Road, as well as some minor metalled roads nearby. Within the Wharekaka region, the following roads cross active faults; Tauwhareparau Road and Fernside Road, and in the East Cape region the Mata Road crosses an active fault. It is likely these roads will suffer damage if these active faults have an earthquake. The damage will be confined to a few hundred metre length of road (maximum) and will likely be vertical offset. **Gaps:** It is not known which fault may rupture in a future event, and so the descriptions above take into account all the faults.	

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A3.5 COASTAL EROSION, GISBORNE DISTRICT

A3.5.1 Hazard Description: Coastal Erosion

A3.5.1.1 Overview

Coastal erosion hazard descriptions for the Gisborne District are divided into the two predominate coastal environments, which are likely to experience storm event coastal erosion.

1. Sandy beaches and low-lying or dune-fronted coastal areas (e.g., Waipaoa, Gisborne Urban, Tologa Bay, Tokomaru Bay, Wainui, Muriwai Beach, Te Araroa beach) experience storm event driven coastal erosion in the form of instantaneous and/or temporal (days, weeks, months) shoreline fluctuations. Instantaneous erosion (e.g., wave cut of sand dune) is a component of the temporal erosion where shorelines remain in a state of retreat during the storm event(s).
2. Exposed coastal cliffs and headlands (e.g., Tiniroto coastline, various headlands and promontories of Wharekaka and East Cape regions) experience storm event coastal erosion in the form of instantaneous events as wave or subaerial processes (e.g., rainfall) trigger failure of the land (e.g., landslides, cliff collapse).

Considerations for hazard descriptions:

- The coastline records in the Gisborne District are insufficient to predict extreme coastal erosion events with average return interval > 200 years. Without taking climate change into account, it is not possible to estimate Coastal erosion return intervals greater than 100 years.
- Descriptors are in reference to a modern-day shoreline as a 20 year approximate average position.
- The coastal erosion hazards are described for single storm events only. However, a sequence of multiple smaller storms over a short timeframe is likely to emulate or exceed the hazard of a single very large storm.
- The region wide long term coastal erosion rate of the coastal sea cliffs is approximately 0.1–0.29m/year (Gibb 1994, 1995, 1998, 2002, 2004, 2008). The storm erosion event hazards described are superimposed on this long term retreat.

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
Likely **ARI 0–50 years**	**Description:** Shoreline recession from dune erosion with maximum short term dune-line fluctuations of 10m to 40m and up to 125m near river/stream mouths for Tokomaru Bay, Tologa Bay and Anaura Bay (Gibb 1998, 2008). Similarly, shoreline recession of 20m to 45m of Wainui Beach and Poverty Bay with up to 400m around of Muriwai Beach at the Waipaoa River mouth (Gibb 1995, 2002, 2004). Other east-facing embayments likely to observe similar erosion scales (Gibb 1994). Localised and persistent cliff undercutting and isolated shoreline recession of 10–30m from landslips and rockfall along some headlands and promontories e.g., Young Nicks Head, Makorori Point and Tatapouri Point (Gibb 1994, 1998, 2002, 2004). Beach/dune recovery to pre-storm state on time scale of months-years. Minor permanent morphological changes such as offshore bar migration, stream mouth migration and cliff rockfall/collapse. **Gaps:** Data for post-storm beach recovery accretion rates is separate to long-term coastal erosion trends. No detailed assessment of coastal erosion hazards in the East Cape region (Hicks Bay, Te Araroa) and smaller embayments throughout Tiniroto and Wharekaka areas.	4
Possible **ARI 51–100 years**	**Description:** Shoreline recession from dune erosion as for ARI 0–50 year events but with an additional 15m to 55m of increased erosion throughout east-facing embayments such as Tokomaru Bay, Tologa Bay, Anaura Bay, Wainui Beach and Poverty Bay (Gibb 1994, 1995, 1998, 2002, 2004, 2008) Localised cliff retreat as for ARI 0–50 years with an additional 0m to 20m, and highest where there is a relatively higher rate of historical cliff retreat, e.g., Young Nicks Head, Makorori and Tuaheni Points (Gibb 2001). Minor overtopping of eroded dunes and protection structures resulting in localised flooding of the hinterland. A significant cut in the foredunes would allow the sea to penetrate inland into the low-lying coastal plains and urban areas such as Gisborne city (Gibb, 2002). Beach recovery to pre-storm state on time scale of 1–5 years. Small scale permanent morphological changes expected e.g., stream/river mouth migration, dune erosion, offshore bar formation, cliff rockfall/collapse and erosion of low dune systems leading to isolation of headlands as islands (e.g., Orongo Beach and Young Nicks Head, Gibb 2004). **Gaps:** Data for post-storm beach recovery accretion rates is separate to long-term coastal erosion trends. No detailed assessment of coastal erosion hazards in the East Cape region (Hicks Bay, Te Araroa), and smaller embayments throughout Tiniroto and Wharekaka region.	3

Likelihood	Description of Event	**Data Quality Rating** (applies to available data only)
Unlikely **ARI 101–1000 years**	**Description:** Shoreline recession from dune erosion as for ARI 51–100 year events but with an additional 5m to 40m of increased erosion throughout east-facing embayments such as Tokomaru Bay, Tologa Bay, Anaura Bay, Wainui Beach and Poverty Bay (Gibb 1994, 1995, 1998, 2002, 2004, 2008). Localised cliff retreat as for ARI 51–100 years with an additional 0m to 20m erosion, and highest where there is a relatively higher rate of historical cliff retreat, e.g., Young Nicks Head, Makorori and Tuaheni Points (Gibb 2001). Substantial wave overtopping of eroded dunes and protection structures resulting in flooding of the hinterland. A significant cut in the foredunes would allow the sea to penetrate inland into the low-lying coastal plains and urban areas such as Gisborne city (Gibb, 2002). Permanent morphological changes expected along coastal fringe such as stream/river-mouth migration, cliff rockfall/collapse, stripping of sediments from shore platforms, erosion of low dune systems leading to isolation of headlands as islands (e.g., Orongo Beach and Young Nicks Head, Gibb 2004). Beach recovery to pre-storm state on time scales >5 years, if at all. **Gaps:** Insufficient data exists to predict this extreme coastal erosion event. Coastline records in the Gisborne District are not long enough to accurately estimate coastal erosion average return intervals between 101 years and 1000 years. Data for post-storm beach recovery accretion rates is separate to long-term coastal erosion trends. No detailed assessment of coastal erosion hazards in the East Cape region (Hicks Bay, Te Araroa) and smaller embayments throughout Tiniroto and Wharekaka region.	1
Rare **ARI 1001–2500 years**	**Description:** Shoreline recession from dune erosion as for ARI 101–1000 year events but with increased erosion throughout east-facing embayments (Gibb 1994, 1995, 1998, 2002, 2004, 2008). Localised cliff retreat as for ARI 101–1000 years with additional erosion, and highest where there is a relatively higher rate of historical cliff retreat, e.g., Makorori and Tuaheni Points (Gibb 2001). Substantial wave overtopping of eroded dunes and protection structures resulting in flooding of the hinterland and coastal urban areas such as Gisborne city (Gibb, 2002). Permanent morphological changes expected along coastal fringe such as stream/river-mouth migration, cliff rockfall/collapse, stripping of sediments from shore platforms, long term incised erosion into low-lying coastal plains (Poverty bay, Tologa Bay Tokomaru Bay), and erosion of low dune systems leading to isolation of headlands as islands (e.g., Orongo Beach and Young Nicks Head, Gibb 2004). Beach recovery to pre-storm state on time scales >5 years, if at all.	1

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
	Gaps: Insufficient data exists to predict this extreme coastal erosion event. Coastline records in the Gisborne District are not long enough to accurately estimate coastal erosion average return intervals between 1001 years and 2,500 years. Data for post-storm beach recovery accretion rates is separate to long-term coastal erosion trends. Detailed assessment of coastal erosion hazards in the East Cape region (Hicks Bay, Te Araroa) and smaller embayments throughout Tiniroto and Wharekaka region.	
Very rare ARI >2500 years	**Description:** Shoreline recession from dune erosion as for ARI 1000–2500 year events but with increased erosion throughout east-facing embayments (Gibb 1994, 1995, 1998, 2002, 2004, 2008). Localised retreat as for ARI 1000–2500 years with additional erosion, and highest where there is a relatively higher rate of historical cliff retreat e.g., Makorori and Tuaheni Points (Gibb 2001). Substantial wave overtopping of eroded dunes and protection structures resulting in flooding of the hinterland and coastal urban areas such as Gisborne city (Gibb, 2002). Permanent morphological changes expected along coastal fringe such as stream/river-mouth migration, cliff rockfall/collapse, stripping of sediments from shore platforms, long term incised erosion into low-lying coastal plains (Poverty bay, Tologa Bay Tokomaru Bay), and erosion of low dune systems leading to isolation of headlands as islands (e.g., Orongo Beach and Young Nicks Head, Gibb 2004). Beach recovery to pre-storm state on time scales >5 years, if at all. **Gaps:** Insufficient data exists to predict this extreme coastal erosion event. Coastline records in the Gisborne District are not long enough to accurately estimate coastal erosion average return intervals greater than 2,500 years. Data for post-storm beach recovery accretion rates is separate to long-term coastal erosion trends. Detailed assessment of coastal erosion hazards in the East Cape region (Hicks Bay, Te Araroa) and smaller embayments throughout Tiniroto and Wharekaka region.	1

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A3.5.2 Consequence Description: Coastal Erosion

A3.5.2.1 Overview

This consequence description is based on the corresponding coastal erosion hazard description, and the asset inventories created in the ‘context’ section of this project.

The coastal erosion descriptions are divided into two predominate coastal environments within the District, likely to experience coastal erosion.

- Sandy Coasts: Dune-fronted and low-lying coastal areas (e.g., Waipaoa (Poverty Bay), Gisborne Urban, Tologa Bay, Tokomaru Bay, Wainui, Muriwai Beach, Te Araroa beach).
- Rocky/Cliffed Coasts: Exposed coastal cliffs and headlands (e.g., Tiniroto coastline, various headlands and promontories of Wharekaka and East Cape areas).

In the hazard descriptions, coastal erosion events were defined for each coastal environment based the temporal occurrence of erosion processes. On rocky/cliffed coasts, erosion events occur instantaneously as wave or sub-aerial processes (e.g., rainfall) trigger failure of the land (e.g., landslides). On sandy coasts, erosion events can be instantaneous (e.g., wave cut of sand dune) or prolonged whereby shorelines remain in a state of retreat during successive storm events over a period of days to months.

To create the consequence descriptions, each coastal environment was identified using aerial photographs to create a GIS vector line dataset. The maximum shoreline recession distance for each ARI in the hazard descriptions, were then applied. These distances were:

- ARI 0–50 year
  - Sandy Coasts: 40m
  - Rocky/Cliffed Coasts: 30m
- ARI 50–101 year
  - Sandy Coasts: 95m
  - Rocky/Cliffed Coasts: 50m

A buffer area for each distance was created landward of the coastline, based on guidance provided in the hazard descriptions. The vector line dataset representing the coastline roughly corresponds to Mean High Water Springs (MHWS), though the horizontal accuracy relative to this datum is likely to be highly variable (offset by meters likely).

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
Likely **ARI 0–50 years**	**Description: Sandy Coasts** *Health and safety:* It is estimated that up to 159 building occupants could be exposed to erosion hazards if present in buildings at time of impact. Residential buildings account for 125 people, with 118 located in Wainui. All remaining people potentially occupy buildings used for industrial/primary production purposes. On sandy coasts there are few if any cases in Gisborne District or New Zealand where occupants have remained in buildings at the time of failure from erosion. Subsequently, risk to life or injury from erosion is deemed 'low' however, there is potential for occupants to sustain physical injuries or psychological illness during the clean-up and recovery process. **Description: Rocky/Cliffed Coasts** *Health and safety:* Approximately 8 people in the East Cape area could be affected by erosion hazards if present in buildings at time of exposure. On rocky/cliffed coasts there are few cases in Gisborne District or New Zealand where occupants have remained in buildings at the time of failure from erosion (most evacuate pre-erosion event). However, risk to life or injury from erosion is deemed 'High', particularly when the erosion event is instantaneous and exposes the entire building or property to hazardous processes e.g., landslide. There is potential for occupants to sustain physical injuries or psychological illness during the clean-up and recovery process.	3 3	**Description: Sandy Coasts** *Property:* Approximately 493 land parcels are identified as potentially exposed to erosion. Almost all urban land parcels are located in Wainui (145 out of 146). Parcels used for primary production (176) are most commonly exposed to erosion while those occupied by natural environments (111) in East Cape and Wharekaka also account for a considerable number of properties potentially exposed to erosion. These areas also account for the greatest a number of road land parcels in the district potentially exposed to erosion. *Buildings:* Seventy three buildings are identified as exposed to erosion. Most buildings are located in Wainui (59) with 47 of these used for residential purposes and 58 constructed of timber. Wainui also accounts for most the building and content replacement value in the district with NZD$18.1m and NZD$7.4m respectively. Outside of Wainui, almost all other buildings exposed to erosion are located in East Cape coastal settlements. *Transport:* Localised erosion could potentially occur along road segments that comprise 63km of the district road network. East Cape, Wharekaka, Wainui, Waipaoa and Tolaga Bay coastal roads are most likely to be affected. One bridge each in East Cape and Wharekaka located in areas are potentially exposed to erosion. *Services:* Segments (<290m) of stormwater and wastewater pipelines are potentially exposed to erosion in East Cape, Gisborne Urban and Wainui areas. Other services in these areas and all other areas are unlikely to be exposed to erosion.	3

Likelihood	Description of Health-Safety Consequences	**Data Quality Rating** (applies to available data only)	Description of Built Environment and Property Consequences	**Data Quality Rating** (applies to available data only)
	Gaps: The exact number of people occupying buildings at the time of erosion hazard exposure is unknown due to the absence of a high resolution building occupancy database for areas where erosion hazards are identified. The likelihood of people in open spaces (e.g., beaches, reserves, private property) coming into contact with erosion hazards is also uncertain.		**Description: Rocky/Cliffed Coasts** *Property:* 527 land parcels are identified as exposed to erosion. Parcels comprising natural environments (225) and those used for primary production (207) are most commonly exposed to erosion hazards. The majority of these parcels are located in East Cape, Tiniroto and Wharekaka. Approximately 86 infrastructure land parcels for roads boarding rock coasts are potentially exposed to erosion hazards. Half of these occur in the East Cape. Urban property land parcels are the least exposed (9). *Buildings:* Ten buildings are identified as exposed to erosion with two of these 'residential' use. The remaining buildings are uninhabited, used for 'industrial/primary production' and 'other' activities. Combined, these buildings have replacement and content replacement values of NZD$834,284 and NZD$343,885 respectively. *Transport:* Localised erosion could potentially occur along road segments that comprise 96km of the district road network. East Cape and Wharekaka coastal roads are most likely to be affected. Three bridges in each of these areas are also located in areas potentially exposed to erosion along with one airfield in East Cape. *Services:* Short segments (<150m) of stormwater, wastewater and potable water pipelines are potentially exposed to erosion in Gisborne Urban and East Cape areas. In Wharekaka, electricity pylons and attached powerline segments located close to rock coastline are likely to be exposed to erosion. These segments form part of a 51km powerline network across Wharekaka. Services in all other areas are unlikely to be exposed to erosion.	3

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
			Gaps: No detailed hazard assessment of sandy and rocky coast erosion hazards in the East Cape area (Hicks Bay, Te Araroa) and smaller embayments throughout Tiniroto and Wharekaka means 'general' estimates of erosion hazard exposure are inferred from similar geomorphological settings in Gisborne District.	
Possible **ARI 51–100 years**	**Description: Sandy Coasts** *Health and safety:* Around 560 building occupants could be exposed to erosion hazards if present in buildings at time of impact. Residential buildings account for approximately 520 people, who are located in Wainui (340), East Cape (50), Wharekaka (30) and Gisborne Urban areas (75). All remaining people potentially occupy buildings used for industrial/primary production purposes. On sandy coasts there are few, if any, cases in Gisborne District or New Zealand where occupants have remained in buildings at the time of failure from erosion. Subsequently, risk to life or injury from erosion is deemed 'low' however, there is potential for occupants to sustain physical injuries or psychological illness during the clean-up and recovery process. **Description: Rocky/Cliffed Coasts** *Health and safety:* Approximately 73 people in Wharekaka (43), East Cape (28) and Gisborne Urban (3) area could be affected by erosion hazards if present in buildings at time of exposure. The majority of people would be located in residential buildings (58) with the remaining occupants in those used for industrial/primary production. On rocky/cliffed coasts there are few cases	3 3	**Description: Sandy Coasts** *Property:* 794 land parcels are identified as exposed to erosion. Urban (269) and primary production (268) land parcels are most commonly exposed. Most urban parcels are located in Wainui (209) with the remaining parcels in Gisborne Urban (47) and East Cape (13). Parcels occupied by natural environments (123) and infrastructure (134) are approximately half of urban and primary production exposure respectively. East Cape and Wainui are most likely to experience infrastructure land parcel exposure to erosion due to the close proximity of some road segments to sandy coasts. *Buildings:* 371 buildings are identified as exposed to erosion. Most buildings are located in Wainui (232) with over half of these residential and most constructed of timber (225). Wainui accounts NZD$52.1m and NZD$20.8m building and content replacement value respectively. Outside of Wainui, most other buildings exposed to erosion are located in the Gisborne Urban (46) area and East Cape (43) and Wharekaka (28) coastal settlements. Combined, building and content replacement values exposed to erosion in the district are NZD$85.8m and NZD$34.3m respectively.	3

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
	in Gisborne District or New Zealand where occupants have remained in buildings at the time of failure from erosion (most evacuate pre-erosion event). However, risk to life or injury from erosion is deemed 'High', particularly when the erosion event is instantaneous and exposes the entire building or property to hazardous processes e.g., landslide. There is potential for occupants to sustain physical injuries or psychological illness during the clean-up and recovery process. **Gaps:** Information gaps are similar to ARI 0–50 year event description.		*Transport:* Localised erosion could potentially occur along road segments that comprise 90km of the district road network. East Cape, Wharekaka and Wainui coastal roads are most likely to be affected. Three bridges in East Cape and one bridge in Wharekaka are located in areas potentially exposed to erosion. *Services:* Stormwater pipelines are potentially exposed to erosion in East Cape, Gisborne Urban, Wainui and Tokomaru Bay. Approximately 1.25km of pipeline is exposed in Wainui with segments between 0.07km and 0.37km exposed in the other areas. In Gisborne Urban area 0.8km and 0.29km of wastewater and water supply pipleline are located on land potentially exposed to erosion. Other services in these areas and all other areas are unlikely to be exposed to erosion. **Description: Rocky/Cliffed Coasts** *Property:* 613 land parcels are identified as exposed to erosion. Urban land parcels are the least exposed with 16 affected, mainly in the Gisborne Urban area (11). Parcels comprising natural environments (283) and those used for primary production (219) are most commonly exposed to erosion hazards. Approximately 95 infrastructure land parcels for roads boarding rock coasts are potentially exposed to erosion hazards. *Buildings:* Fifty seven buildings are identified as exposed to erosion with 26 being of 'residential' use. Wharakaka (17) and East Cape (8) are most likely to have residential buildings exposed to erosion. The remaining buildings are used for 'industrial/primary production' (12) and 'other' (18) activities. The majority of buildings exposed are timber	3

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
			construction. Combined replacement and content replacement values for all exposed buildings are NZD$6.4m and NZD$2.6m respectively. *Transport:* Road segments along approximately 97km of the district road network could be exposed to erosion, most likely in East Cape and Wharekaka. Four and three bridges respectively in these areas are located in areas potentially exposed to erosion along with one airfield in East Cape. *Services:* Consequences similar to ARI 0–50 year event description. **Gaps:** No detailed hazard assessment of sandy and rocky coast erosion hazards in the East Cape area (Hicks Bay, Te Araroa) and smaller embayments throughout Tiniroto and Wharekaka means ‘general’ estimates of erosion hazard exposure are inferred from similar geomorphological settings in Gisborne District.	
Unlikely ARI 101–1000 years	**Description:** Sandy and rocky/cliff coast erosion consequences are similar to ARI 51–100 year event description. **Gaps:** Available erosion records in Gisborne District are not long enough to accurately estimate coastal erosion exposure for average return interval events between 101 years and 1000 years. Sandy and rocky /cliffed coast erosion consequence descriptions provided for average return interval events of 51–100 years should be used until the erosion hazard is further refined. The exact number of people occupying buildings at the time of erosion hazard exposure is unknown due to the absence of a high resolution building occupancy	1	**Description:** Sandy and rocky/cliff coast erosion consequences are similar to ARI 51–100 year event description. **Gaps:** Available erosion records in Gisborne District are not long enough to accurately estimate coastal erosion exposure for average return interval events between 101 years and 1000 years. Sandy and rocky/cliffed coast erosion consequence descriptions provided for average return interval events of 51–100 years should be used until the erosion hazard is further refined.	1

Likelihood	**Description of Health-Safety Consequences**	**Data Quality Rating** (applies to available data only)	**Description of Built Environment and Property Consequences**	**Data Quality Rating** (applies to available data only)
	database for areas where erosion hazards are identified. The likelihood of people in open spaces (e.g., beaches, reserves, private property) coming into contact with erosion hazards is also uncertain.			
Rare **ARI 1001–2500 years**	**Description:** Sandy and rocky/cliff coast erosion consequences are similar to ARI 51–100 year event description. **Gaps:** Information gaps are similar to ARI 101–1000 year event description.	1	**Description:** Sandy and rocky/cliff coast erosion consequences are similar to ARI 51–100 year event description. **Gaps:** Information gaps are similar to ARI 101–1000 year event description.	1
Very rare **ARI >2500 years**	**Description:** Sandy and rocky/cliff coast erosion consequences are similar to ARI 51–100 year event description. **Gaps:** Information gaps are similar to ARI 101–1000 year event description.	1	**Description:** Sandy and rocky/cliff coast erosion consequences are similar to ARI 51–100 year event description. **Gaps:** Information gaps are similar to ARI 101–1000 year event description.	1

A3.6 COASTAL FLOODING, GISBORNE DISTRICT

A3.6.1 Hazard Description: Coastal Flooding

A3.6.1.1 Overview

Estimates of sea-level elevations from storm-tide plus wave set-up and run-up are provided for various average recurrence intervals (ARI).

Storm-tide is a combination of mean sea level (MSL) plus tide plus storm-surge; storm surge results from low barometric pressure and wind pushing water onshore (see Figure 1 below). Wave set-up describes an average raised elevation of sea level at the coast when breaking waves are present. Wave run-up is the maximum vertical extent of wave “up-rush” on a beach or structure above the instantaneous still-water or storm-tide level (that would occur without waves), and thus constitutes only a short-term fluctuation in water level relative to wave set-up, tidal and storm-surge time scales. Wave run-up includes the wave set-up component.

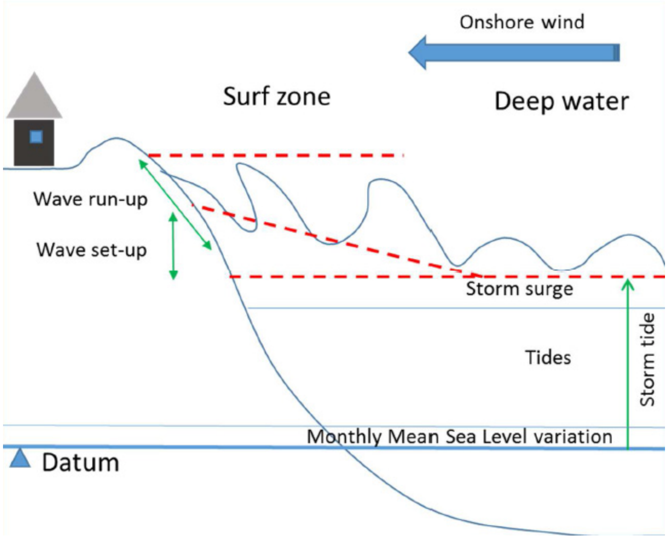

Figure A3.1 Schematic illustrating the various processes that contribute to coastal inundation. Source: Stephens et al. (2014).

Elevations below the storm-tide plus wave set-up elevation could experience extensive flooding, provided that they are connected to the sea at those elevations. If a coastal barrier is present then areal extent of storm-tide and wave induced flooding depends on the local geomorphology, and the duration that sea-level remains at the reported elevations. This requires localised mapping that is beyond the scope of this project. Beach-front property at elevations below the storm-tide plus wave run-up elevation may experience flooding, wave splash or wave impact.

Data sources

Storm-tide plus wave set-up and run-up were calculated using the Gisborne Coastal Calculator described in Stephens et al. (2014).

The wave set-up and run-up were calculated using the Stockdon et al. (2006) formulae that were developed from empirical measurements made on 10 sandy beaches on USA and Netherlands coastline with different morphologies; they are expected to be appropriate for sandy beaches along the Gisborne District coastline. The Stockdon et al. (2006) formula estimates wave set-up using the offshore significant wave height[5] and wavelength and the slope of the upper beach face. Depending on the nature of the coastline at each location, it may be more appropriate to use empirical formulae designed for offshore reef, gravel beaches, rock revetments or sea walls (e.g., EurOtop, 2007; HR Wallingford; Van Rijn, 2010)[6], but this has not been undertaken as part of this study.

The storm-tide plus wave run-up estimates have been checked against field evidence for storm wave run-up elevations (SWRU) reported by Coastal Management Consultancy Limited for Tokomaru Bay (Gibb, 2008), Tologa and Anaura Bay (Gibb, 1998), Wainui Beach (Gibb, 2001), northern Poverty Bay and Wainui Beach (Gibb, 1995), and southern Poverty Bay (Gibb, 2004).

Uncertainties

Wave set-up is highly sensitive to the beach profile shape (Stephens et al., 2011) and likewise, calculations made using the empirical wave set-up are also sensitive to the beach slope parameter. Thus there is considerable uncertainty around the use of empirical wave set-up calculations, because beach profiles are in a constant state of evolution, and it is often difficult to pick a representative beach slope from a profile. Wave run-up is similarly highly sensitive to the beach profile shape.

The wave conditions simulated by Stephens et al. (2014) were for open-coast conditions and included a wave sheltering algorithm to block waves from directions sheltered by headlands. However, local effects such as shoaling over offshore reefs or the seabed inside the bay were not accounted for, and the resulting wave set-up and run-up values are likely to be conservatively high.

To reiterate: the areal extent of storm-tide and wave induced flooding depends on the local geomorphology, and the duration that sea-level remains at the reported elevations. This requires localised mapping that is beyond the scope of this project.

The tables below contain sea-level elevation estimates for rare events, events that we expect to be equalled or exceeded only once, on average, every 100-years (for 100-year ARI) or more, for example. Sea-level rise and climate change over the next 100 years and beyond may cause changes in the drivers of tides and storms that could change the present-day frequency–magnitude distributions of storm-tides and waves that are reported here.

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[5] The average wave height of the highest 33% of waves.

[6] http://www.overtopping-manual.com/calculation_tool.html

Summary of methods used in developing coastal flooding hazard descriptions for Gisborne District

- ARI 0–50 years: Sea-level elevations were estimated using the GDC Coastal Calculator for a 5% AEP event using the Stockdon et al. (2006) formulae with a steep beach slope of 0.1.
- ARI 51–100 years: Sea-level elevations were estimated using the GDC Coastal Calculator for a 1% AEP event using the Stockdon et al. (2006) formulae with a very steep beach slope of 0.15.
- ARI 101–1000 years: Sea-level elevations were estimated using the GDC Coastal Calculator for a 0.5% AEP event using the Stockdon et al. (2006) formulae with a very steep beach slope of 0.15.
- ARI 1001–2500 years: Elevations were derived using the maximum storm-tide elevation added to the maximum wave set-up and run-up elevations predicted by the GDC Coastal Calculator using the Stockdon et al. (2006) formulae with a very steep beach slope of 0.15.
- ARI >2500 years: Elevations were derived using the maximum storm-tide elevation added to the maximum wave set-up and run-up elevations predicted by the GDC Coastal Calculator using the Stockdon et al. (2006) formulae with a very steep beach slope of 0.15. Tides and storm systems that drive waves and surge are physically limited by ocean and atmospheric physics. No increase is proposed above the maximum elevations already applied to the 1001–2500 year ARI scenario.

<table>
<tr><th>Likelihood</th><th>Description of Event</th><th>Data Quality Rating
(applies to available data only)</th></tr>
<tr><td>Likely
ARI 0–50 years</td><td>Description: Storm-tide plus wave set-up elevation is estimated between 2.1m and 2.8m above GVD-26 (Gisborne Vertical Datum). Storm-tide plus wave run-up elevation up to 6m above GVD-26. Note that wave set-up is an integral component of wave run-up. Elevations below the storm-tide plus wave set-up elevation are likely to experience flooding, subject to gaps described below. Beach-front property at elevations below the storm-tide plus wave run-up elevation may experience flooding, wave splash or wave impact. Elevations were estimated using the GDC Coastal Calculator (Stephens et al., 2014) for a 5% AEP event using the (Stockdon et al., 2006) formulae with a beach slope of 0.1.

<table>
<tr><th>Location</th><th>Storm-tide plus wave set-up elevation (m)</th><th>Storm-tide plus wave run-up elevation (m)</th></tr>
<tr><td>East Cape</td><td>2.8</td><td>6.0</td></tr>
<tr><td>Tokomaru Bay</td><td>2.7</td><td>5.8</td></tr>
<tr><td>Tologa Bay</td><td>2.6</td><td>5.5</td></tr>
<tr><td>Wainui (Wainui Beach)</td><td>2.4</td><td>5.0</td></tr>
<tr><td>Gisborne Urban</td><td>2.1</td><td>4.2</td></tr>
<tr><td>Waipaoa (Poverty Bay)</td><td>2.2</td><td>4.5</td></tr>
<tr><td>Tiniroto (Southern Poverty Bay)</td><td>2.4</td><td>5.0</td></tr>
</table>

Gaps: The extent of flooding depends on the local geomorphology, and the duration that sea-level remains at the reported elevations. This requires a local mapping study.</td><td>4</td></tr>
</table>

<table>
<tr><th>Likelihood</th><th>Description of Event</th><th>Data Quality Rating
(applies to available data only)</th></tr>
<tr><td>Possible
ARI 51–100 years</td><td>Description: Storm-tide plus wave set-up elevation is estimated between 3m and 3.5m above GVD-26. Storm-tide plus wave run-up elevation up to 8m above GVD-26. Elevations below the storm-tide plus wave set-up elevation are likely to experience flooding, subject to gaps described below. Beach-front property at elevations below the storm-tide plus wave run-up elevation may experience flooding, wave splash or wave impact. Elevations were estimated using the GDC Coastal Calculator (Stephens et al., 2014) for a 1% AEP event using the (Stockdon et al., 2006) formulae with a steep beach slope of 0.15, and supported by empirical evidence from Gibb (1998).

<table>
<tr><th>Location</th><th>Storm-tide plus wave set-up elevation (m)</th><th>Storm-tide plus wave run-up elevation (m)</th></tr>
<tr><td>East Cape</td><td>3.0</td><td>7.0</td></tr>
<tr><td>Tokomaru Bay</td><td>3.0</td><td>6.5</td></tr>
<tr><td>Tologa Bay</td><td>3.0</td><td>6.5</td></tr>
<tr><td>Wainui (Wainui Beach)</td><td>3.5</td><td>8.0</td></tr>
<tr><td>Gisborne Urban</td><td>3.0</td><td>6.5</td></tr>
<tr><td>Waipaoa (Poverty Bay)</td><td>3.3</td><td>7.0</td></tr>
<tr><td>Tiniroto (Southern Poverty Bay)</td><td>3.5</td><td>8.0</td></tr>
</table>

Gaps: Information gaps are similar to ARI 0–50 year event description.</td><td>4</td></tr>
</table>

<table>
<tr><th>Likelihood</th><th>Description of Event</th><th>Data Quality Rating
(applies to available data only)</th></tr>
<tr><td>Unlikely
ARI 101–1000 years</td><td>Description: Storm-tide plus wave set-up elevation is estimated between 3.5m and 4.5m above GVD-26. Storm-tide plus wave run-up elevation up to 10m above GVD-26. Elevations below the storm-tide plus wave set-up elevation are likely to experience flooding, subject to gaps described below. Beach-front property at elevations below the storm-tide plus wave run-up elevation may experience flooding, wave splash or wave impact. Elevations were estimated using the GDC Coastal Calculator (Stephens et al., 2014) for a 0.5% AEP event using the (Stockdon et al., 2006) formulae with a steep beach slope of 0.15, and supported by empirical evidence from Gibb (1998).

<table>
<tr><th>Location</th><th>Storm-tide plus wave set-up elevation (m)</th><th>Storm-tide plus wave run-up elevation (m)</th></tr>
<tr><td>East Cape</td><td>4.5</td><td>10.0</td></tr>
<tr><td>Tokomaru Bay</td><td>4.0</td><td>8.5</td></tr>
<tr><td>Tologa Bay</td><td>4.0</td><td>9.0</td></tr>
<tr><td>Wainui (Wainui Beach)</td><td>4.0</td><td>8.5</td></tr>
<tr><td>Gisborne Urban</td><td>3.5</td><td>7.0</td></tr>
<tr><td>Waipaoa (Poverty Bay)</td><td>3.5</td><td>7.5</td></tr>
<tr><td>Tiniroto (Southern Poverty Bay)</td><td>4.0</td><td>8.5</td></tr>
</table>

Gaps: Information gaps are similar to ARI 0–50 year event description.</td><td>3</td></tr>
</table>

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
Rare **ARI 1001–2500 years**	**Description:** Storm-tide plus wave set-up elevation is estimated between 4m and 6m above GVD-26. Storm-tide plus wave run-up elevation up to 11m above GVD-26. Elevations below the storm-tide plus wave set-up elevation are likely to experience flooding, subject to gaps described below. Beach-front property at elevations below the storm-tide plus wave run-up elevation may experience flooding, wave splash or wave impact. Elevations were derived using the maximum storm-tide elevation added to the maximum wave set-up and run-up elevations predicted by the GDC Coastal Calculator (Stephens et al., 2014) using the (Stockdon et al., 2006) formulae with a steep beach slope of 0.15.	2

Location	Storm-tide plus wave set-up elevation (m)	Storm-tide plus wave run-up elevation (m)
East Cape	6.0	11.0
Tokomaru Bay	6.0	11.0
Tologa Bay	6.0	11.0
Wainui (Wainui Beach)	5.0	10.5
Gisborne Urban	4.0	8.0
Waipaoa (Poverty Bay)	4.3	8.5
Tiniroto (Southern Poverty Bay)	5.0	10.5

Gaps: Information gaps are similar to ARI 0–50 year event description.

<table>
<tr><th>Likelihood</th><th>Description of Event</th><th>Data Quality Rating (applies to available data only)</th></tr>
<tr><td>Very rare
ARI >2500 years</td><td>Description: Storm-tide plus wave set-up elevation is estimated between 4m and 6m above GVD-26. Storm-tide plus wave run-up elevation up to 11m above GVD-26. Elevations below the storm-tide plus wave set-up elevation are likely to experience flooding, subject to gaps described below. Beach-front property at elevations below the storm-tide plus wave run-up elevation may experience flooding, wave splash or wave impact. Elevations were derived using the maximum storm-tide elevation added to the maximum wave set-up and run-up elevations predicted by the GDC Coastal Calculator (Stephens et al., 2014) using the (Stockdon et al., 2006) formulae with a steep beach slope of 0.15.
<table>
<tr><th>Location</th><th>Storm-tide plus wave set-up elevation (m)</th><th>Storm-tide plus wave run-up elevation (m)</th></tr>
<tr><td>East Cape</td><td>6.0</td><td>11.0</td></tr>
<tr><td>Tokomaru Bay</td><td>6.0</td><td>11.0</td></tr>
<tr><td>Tologa Bay</td><td>6.0</td><td>11.0</td></tr>
<tr><td>Wainui (Wainui Beach)</td><td>5.0</td><td>10.5</td></tr>
<tr><td>Gisborne Urban</td><td>4.0</td><td>8.0</td></tr>
<tr><td>Waipaoa (Poverty Bay)</td><td>4.3</td><td>8.5</td></tr>
<tr><td>Tiniroto (Southern Poverty Bay)</td><td>5.0</td><td>10.5</td></tr>
</table>
Gaps: Information gaps are similar to ARI 0–50 year event description.</td><td>1</td></tr>
</table>

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A3.6.2 Consequence Description: Coastal Flooding

A3.6.2.1 Overview

This consequence description is based on the corresponding coastal flooding hazard description, including the storm-tide and wave setup elevation estimates, and the asset inventories created in the ‘context’ section of this project.

Coastal flood inundation (e.g., depth and velocity) models are not currently (November 2014) available for either storm-tide plus wave setup or storm-tide plus wave setup plus wave runup elevations estimate identified along the Gisborne coastline by Stephens e al. (2014). In the absence of these models a surrogate inundation model was used to identify land along the Gisborne District coastline potentially susceptible to coastal flood inundation for events up to a 100 year average return interval. An elevation model developed by Bell and Wadwha (2014) that identifies land 3m above mean high water springs (MHWS) was deemed to provide a reasonable estimate of maximum exposure for these events. Overestimation of inundation exposure is likely for event magnitudes less than ARI 100 years, particularly as the GIS vector polygon dataset representing land 3m above Mean High Water Springs (MHWS) in the District does not take into account geomorphology at local scales, which can limit or exacerbate inundation. Furthermore, the horizontal accuracy relative to this datum may be variable (offset by meters likely) and could further lead to over or underestimates of the inundation extent.

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
Likely **ARI 0–50 years**	**Description:** *Health and Safety:* It is estimated that up to 2,000 building occupants could be exposed to coastal flood inundation hazards if present in buildings at time of impact. Residential buildings account for 1,220 people, with 1,140 located in the Gisborne Urban Area. A further 630 people could be in buildings used for industrial/primary production purposes. Outside of the Gisborne Urban area, approximately 140 could be exposed to inundation hazards in Tologa Bay (90), Waipaoa (67) and Wainui (25) coastal settlements. There are few, if any, cases in Gisborne District or New Zealand where occupants have remained in buildings at the time of coastal flood inundation. Subsequently, risk to life or injury is deemed 'low' as it is highly likely building occupants will evacuated prior to inundation. If people cannot evacuate inundated buildings then the potential for fatalities or injuries increases considerably. Regardless of their presence in buildings, there is a high likelihood that occupants may sustain physical injuries or psychological illness during the clean-up and recovery process. **Gaps:** The extent of storm-tide and wave induced flooding depends on the local geomorphology, and the duration that sea-level remains at the reported elevations for Gisborne District. This requires a local flood inundation mapping study which in turn improves the ability to identify human exposure to hazards. Two-	2	**Description:** *Property:* 1,560 land parcels are identified as exposed to coastal flood inundation. Urban (726) land parcels are most common with the majority located in Gisborne Urban (588) area and Wainui (98). Parcels used for primary production (411) are possibly exposed to inundation in all coastal areas with more than 40 each in Waipaoa, East Cape, Tologa Bay and Wharekaka. A similar number of parcels occupied by natural environments (212) and infrastructure (211) are exposed to inundation. The majority of these parcels are located in East Cape and the Gisborne Urban areas account. *Buildings:* 961 buildings are identified as exposed to inundation. The majority of buildings are located in Gisborne Urban (849) area with over half of these residential (430) and most are constructed of timber (673). A considerable number of buildings used for industrial/primary production (238) activities are also exposed to inundation hazards. All exposed buildings in the Gisborne Urban are accounts for NZD$264m and NZD$117m in building and content replacement value respectively. Outside of this area, most other buildings exposed to inundation are located in the Waipaoa (46) and Tologa Bay (43) coastal settlements. Combined, building and content replacement values exposed to inundation in the district total NZD$299.9m and NZD$131.6m respectively. *Transport:* Localised inundation could occur along road segments comprising 105km of the district road network. Roads in the Gisborne Urban area, Wharekaka and Waipaoa are most extensively exposed with short segments exposed in	2

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
	dimensional flood inundation models allow for quantitative human losses to be estimated through the use of storm surge casualty models. The exact number of people occupying buildings at the time of coastal flood hazard exposure is unknown due to the absence of a high resolution building occupancy database for areas where inundation hazards are identified. The likelihood of people in open spaces (e.g., beaches, reserves, private property) coming into contact with inundation hazards is also uncertain.		East Cape, Tokomaru Bay, Tolaga Bay and Wainui. Six bridges are located in areas potentially exposed to inundation, three are in the Gisborne Urban area. Gisborne Airport and Tologa Bay airfield are also situated on land potentially exposed to inundation. Wharf structures and reclaimed land at Gisborne Port could be overtopped or damaged by waves due to water levels being temporary elevated by storm-tide and wave set-up processes. *Services:* Kilometres of stormwater (13.6km), wastewater (29.8km) and potable water pipelines (15.9km) are potentially exposed to inundation in the Gisborne Urban area. In Waipaoa, approximately 12km and 4km of wastewater and potable water pipelines respectively are exposed. Although most pipelines are below ground, elevated water levels along the coast and estuaries are likely to cause backflows preventing these systems to operate efficiently. Shorter segments (<0.11km) of stormwater pipelines are located in areas of Tokomaru Bay, Tolaga Bay and Wainui exposed to inundation. In the Gisborne Urban area, electricity pylons and attached powerlines (3.6km) are located within areas exposed to inundation though powerlines will be suspended above water levels. **Gaps:** The extent of storm-tide and wave induced flooding depends on the local geomorphology, and the duration that sea-level remains at the reported elevations for Gisborne District. This requires a local flood inundation mapping study which in turn improves the ability to identify built and property	

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
			asset exposure to hazards. Two-dimensional flood inundation models allow for quantitative asset impacts and losses to be estimated from vulnerability models.	
Possible ARI 51–100 years	**Description:** Coastal flooding consequences are similar to ARI 0–50 year event description. **Gaps:** Information gaps similar to ARI 0–50 year event description.	3	**Description:** Coastal flooding consequences are similar to ARI 0–50 year event description. **Gaps:** Information gaps are similar to ARI 0–50 year event description.	3
Unlikely ARI 101–1000 years	**Description:** Coastal flooding consequences are similar to ARI 0–50 year event description. **Gaps:** Information gaps are similar to ARI 0–50 year event description.	2	**Description:** Coastal flooding consequences are similar to ARI 0–50 year event description. **Gaps:** Information gaps are similar to ARI 0–50 year event description.	2
Rare ARI 1001–2500 years	**Description:** Coastal flooding consequences are similar to ARI 0–50 year event description. **Gaps:** Information gaps are similar to ARI 0–50 year event description.	1	**Description:** Coastal flooding consequences are similar to ARI 0–50 year event description. **Gaps:** Information gaps are similar to ARI 0–50 year event description.	1
Very rare ARI >2500 years	**Description:** Coastal flooding consequences are similar to ARI 0–50 year event description. **Gaps:** Information gaps are similar to ARI 0–50 year event description.	1	**Description:** Coastal flooding consequences are similar to ARI 0–50 year event description. **Gaps:** Information gaps are similar to ARI 0–50 year event description.	1

References

Bell, R.G.; Wadwha, S. 2014. National coastal susceptibility: Vulnerable areas and demographics. Report Prepared for Centre for Research Evaluation and Social Assessment (CRESA). *NIWA Client Report* No: HAM2014-071.

Stephens, S.A.; Robinson, B.; Gorman, R.M. 2014. Extreme sea-level elevations from storm-tides and waves along the Gisborne District coastline. *NIWA Client Report* No: HAM2014-052 for the Gisborne District Council (June 2014). p103.

A3.7 DROUGHT, GISBORNE DISTRICT

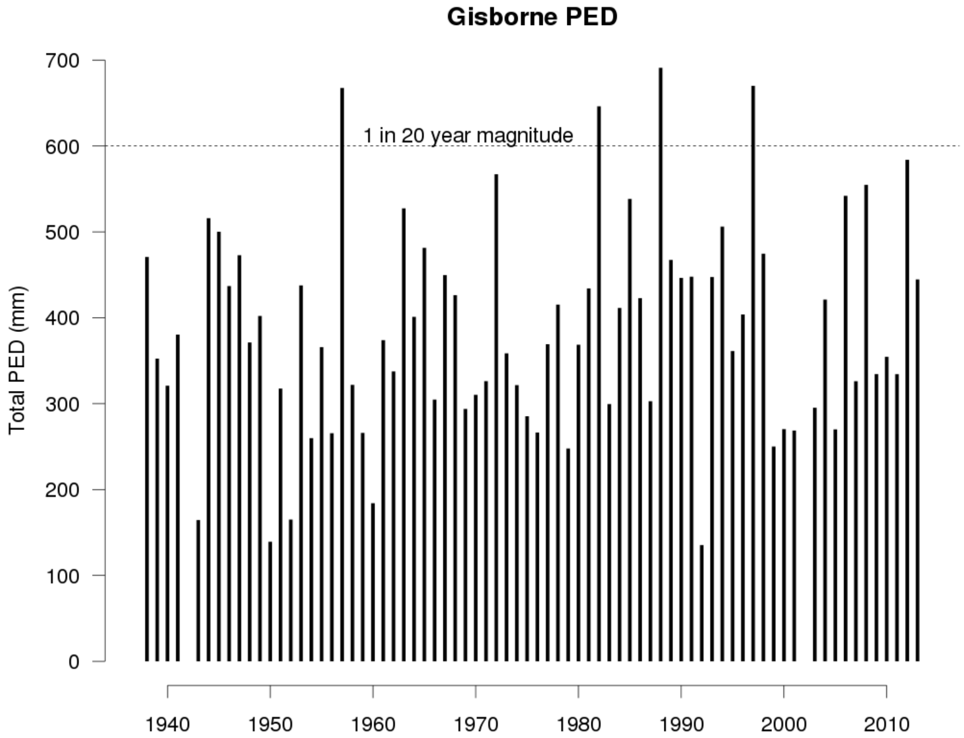
A3.7.1 Hazard Description: Drought

A3.7.1.1 Overview

To quantitatively assess the extent and severity of a drought it is necessary to use a drought index. Here we have used the potential evapotranspiration deficit (PED), following Tait (2006) and Porteous and Mullan (2013). PED can be thought of as the amount of water needed to be added as irrigation, or replenished by rainfall, in order to keep pastures growing at levels that are not constrained by a shortage of water. Annual totals of PED (used in the table below) need to include the full growing season, so are accumulated from July through June.

Records of PED long enough for drought analysis are available for four climate stations in the Gisborne District. These are Gisborne Airport, Waihirere (Waipaoa), Waingake (Tiniroto) and Tologa Bay. Estimates for other locations have been made using a gridded observation dataset. This dataset, the virtual climate station network (VCSN), has a 5km spatial resolution and is created by fitting a smooth surface through all available climate observations (Tait 2008). This provides the best estimate for a particular environmental variable at locations that do not have observing sites. The VCSN data set is 40 years long.

<table>
<tr><th>Likelihood</th><th>Description of Event</th><th>Data Quality Rating
(applies to available data only)</th></tr>
<tr><td>Likely
ARI 0–50 years</td><td>Description: The 20-year return period of annual totals of PED is a useful working definition of drought. This was estimated for four climate stations in the Gisborne District: three within the Gisborne Urban area (Gisborne Airport, Waiherere and Waingake), and one at Tologa Bay. These values are shown below (standard errors in brackets) and are consistent with those given by Tait (2006).
<table>
<tr><th></th><th>10 years</th><th>20 years</th><th>50 years</th><th>Record length</th></tr>
<tr><td>Gisborne Airport</td><td>549 (22) mm</td><td>600 (26) mm</td><td>656 (34) mm</td><td>78 years</td></tr>
<tr><td>Waihirere</td><td>542 (24) mm</td><td>583 (27) mm</td><td>626 (33) mm</td><td>39 years</td></tr>
<tr><td>Waingake</td><td>437 (23) mm</td><td>482 (28) mm</td><td>531 (37) mm</td><td>49 years</td></tr>
<tr><td>Tologa Bay</td><td>514 (39) mm</td><td>591 (54) mm</td><td>688 (79) mm</td><td>48 years</td></tr>
</table>
</td><td>4</td></tr>
</table>

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
	These sites are producing current estimates of PED (as are stations at Motu and Hicks Bay although these records are too short for estimating return periods). The figure below shows that there have been numerous droughts with less than a 20 year return period in recent times. The 2012/13 drought had an annual total PED of 584mm and a return period just less than 20 years (it was the 5th largest drought event).  The table below provides estimates (standard errors in brackets) of the 20 year average return interval total annual PED for areas other than Gisborne Urban and Tologa Bay, estimated using the VCSN (see 'overview' above for explanation of VCSN). For regions covering a larger area, a range of values has been given.	

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
	(table below)	

Location	Based on	10 years	20 years	50 years
Wainui	1 VCSN point	635 (36) mm	700 (46) mm	775 (63) mm
Te Karaka	1 VCSN point	585 (28) mm	635 (33) mm	688 (41) mm
Tokomaru Bay	1 VCSN point	540 (29) mm	591 (35) mm	648 (45) mm
Tarndale-Rakauroa	113 VCSN points	82–609 (34) mm	125–657 (55) mm	212–709 (92) mm
Ruatoria	1 VCSN point	520 (30) mm	574 (36) mm	633 (47) mm
East Cape	114 VCSN points	101–593 (29) mm	146–654 (37) mm	224–726 (53) mm
Tiniroto	Waingake climate station	437 (23) mm	482 (28) mm	531 (37) mm
	56 VCSN points	242–634 (30) mm	295–685 (38) mm	364–739 (51) mm
Wharekaka	50 VCSN points	322–607 (31) mm	401–674 (38) mm	495–751 (50) mm
Waipaoa	Waihirere climate station	542 (24) mm	583 (27) mm	626 (33) mm
	7 VCSN points	632–655 (31) mm	686–718 (37) mm	738–794 (48) mm

Gaps: Outside of Gisborne Urban area and Tologa Bay, climate records are not long enough to estimate PED average return intervals greater than 10 years. For these locations, average return intervals have been estimated from gridded VCSN data. Values derived directly from the VCSN should be used with care.

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
Possible ARI 51–100 years	**Description:** The table below shows the total annual PED for average return intervals of 75 and 100 years for the Gisborne Urban area (standard error in brackets):	2

	75 years	100 years	Record length
Gisborne Urban (based on Gisborne Airport)	678 (39) mm	693 (42) mm	78 years

<table>
<tr><th>Likelihood</th><th>Description of Event</th><th>Data Quality Rating
(applies to available data only)</th></tr>
<tr><td></td><td>The table below provides estimates (standard errors in brackets) of the 75 and 100 year average return interval total annual PED for regions other than Gisborne Urban. The record length at the Tologa Bay climate station is not long enough to estimate return periods longer than 50 years. Therefore, the 50 year ARI derived from the climate station record has been used as an estimate of the 75 and 100 year event magnitude. For areas without climate stations, the gridded observational data set (VCSN) has been used to estimate PED. However, the gridded observational data set is also not long enough to estimate drought events for average return intervals greater than 50 years. The spatial pattern of PED for longer return periods is likely to be similar to that for the 50 year period. As a best guess for the 75 and 100 year event magnitudes, the 50 year ARI event is used.
<table>
<tr><th>Location</th><th>Based on</th><th>75 years</th><th>100 years</th></tr>
<tr><td>Wainui</td><td>50 Year ARI</td><td>775 mm</td><td>775 mm</td></tr>
<tr><td>Te Karaka</td><td>50 Year ARI</td><td>688 mm</td><td>688 mm</td></tr>
<tr><td>Tologa Bay</td><td>Climate station 50 Year ARI</td><td>688 mm</td><td>688 mm</td></tr>
<tr><td>Tokomaru Bay</td><td>50 Year ARI</td><td>648 mm</td><td>648 mm</td></tr>
<tr><td>Tarndale-Rakauroa</td><td>50 Year ARI</td><td>212–709 mm</td><td>212–709 mm</td></tr>
<tr><td>Ruatoria</td><td>50 Year ARI</td><td>633 mm</td><td>633 mm</td></tr>
<tr><td>East Cape</td><td>50 Year ARI</td><td>224–726 mm</td><td>224–726 mm</td></tr>
<tr><td>Tiniroto</td><td>50 Year ARI</td><td>364–739 mm</td><td>364–739 mm</td></tr>
<tr><td>Wharekaka</td><td>50 Year ARI</td><td>495–751 mm</td><td>495–751 mm</td></tr>
<tr><td>Waipaoa</td><td>50 Year ARI</td><td>738–794 mm</td><td>738–794 mm</td></tr>
</table>

The figure in the row above showing variations in the PED in Gisborne over time, shows there have been four events larger than the 20-year magnitude event in the past 80 years, the most recent being the 1997/98 El Nino.
Gaps: Outside of Gisborne Urban area, climate records are not long enough to estimate PED average return intervals greater than 50 years.</td><td></td></tr>
</table>

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
Unlikely **ARI 101–1000 years**	**Description:** Drought hazards are similar to ARI 51–100 year event description. **Gaps:** Climate records in Gisborne District are not long enough to accurately estimate PED average return intervals between 100–1000 years. Without taking climate change into account (via the use of numerical climate models for example) it is not possible to estimate PED return intervals greater than 100 years.	1
Rare **ARI 1001–2500 years**	**Description:** Drought hazards are similar to ARI 51–100 year event description. **Gaps:** Information gaps are similar to ARI 101–1000 year event description.	1
Very rare **ARI >2500 years**	**Description:** Drought hazards are similar to ARI 51–100 year event description. **Gaps:** Information gaps are similar to ARI 101–1000 year event description	1

References

Clark, A.; Mullan, B.; Porteous, A. 2011. Scenarios of regional drought under climate change. *Client Report WLG2010-32 for Ministry of Agriculture and Forestry* (June 2011). p135.

Porteous, A.; Mullan, B. 2013. The 2012–13 drought an assessment and historical perspective. *Client Report WLG2013-27 for Ministry for Primary Industries* (June 2013). p57.

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Tait, A. 2008. Future projections of growing degree days and frost in New Zealand and some implications for grape growing. Weather and Climate. 28. 17–36.

A3.8 EXTREME TEMPERATURE, GISBORNE DISTRICT

A3.8.1 Hazard Description: Extreme Temperature

A3.8.1.1 Overview

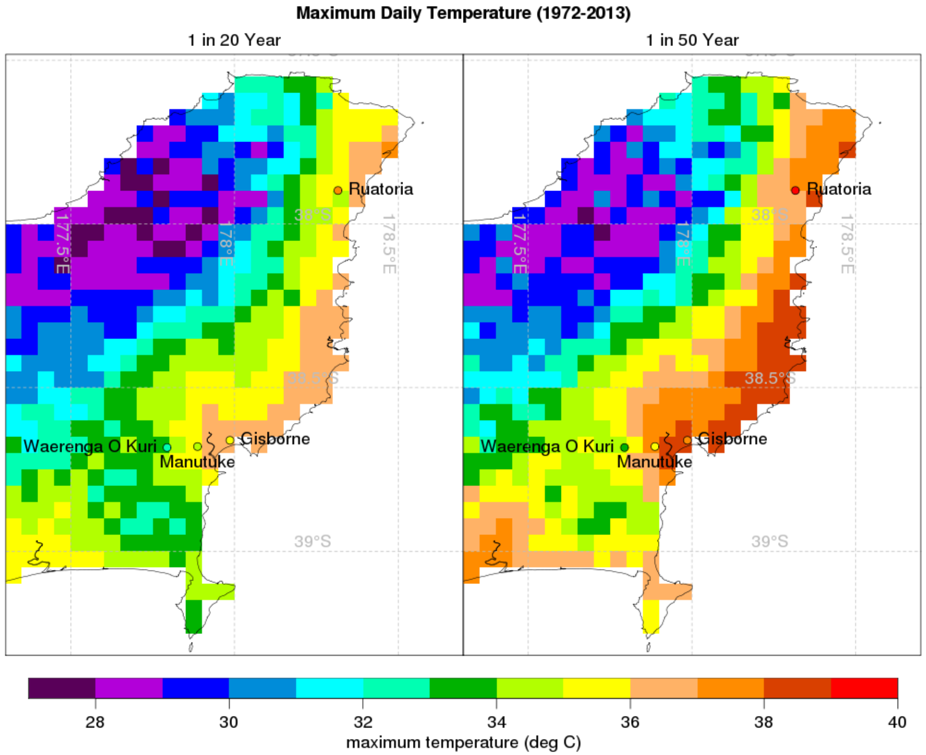
Maximum temperature event magnitudes for various average return intervals have been estimated using both climate station records and, for locations without long-term records, a gridded observation dataset (VCSN). For both types of records, event magnitudes were estimated by fitting a generalised extreme value distribution (GEV) to an annual maxima series of daily maximum temperatures. The GEV distributions were fitted using the methodology of Alliot et al. (2011) which also provides a standard error estimate.

The VCSN (virtual climate station network) is a gridded data set at 5km spatial resolution that is created by fitting a smooth surface through all available climate observations (Tait 2008). This provides the best estimate for a particular environmental variable at locations that do not have observing sites. For temperature, elevation is taken into account using the lapse rate, the rate at which the temperature decreases with altitude (approximately 6.5°C per km).

Likelihood	**Description of Event**	**Data Quality Rating** (applies to available data only)
Likely **ARI 0–50 years**	**Description:** The table below shows the daily maximum temperature for average return intervals (ARI) of 10, 20 and 50 years at selected climate stations (standard error in brackets). Of these stations, only Gisborne Airport is still operating:	4

Station	ARI 10 years	ARI 20 years	ARI 50 years	Record length
Gisborne (Gisborne Urban and Wainui areas)	35.4 (0.4) °C	36.5 (0.6) °C	37.8 (0.9) °C	79 years
Manutuke (Waipaoa area)	34.4 (0.5) °C	35.5 (0.7) °C	36.7 (1.0) °C	46 years
Waerenga O Kuri	32.2 (0.6) °C	33.0 (0.7) °C	33.9 (0.9) °C	27 years
Ruatoria (Ruatoria area)	36.2 (1.2) °C	38.0 (1.7) °C	40.5 (2.8) °C	27 years

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
	Other climate stations in operation, but with records too short for estimating return periods are Tolaga Bay, Motu, Mahia and Hicks Bay. For comparison, some recent extreme maximum temperatures at Gisborne include 36.3°C on Feb 2, 2011 (see http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=10706290 although the claim that this was the warmest day on record is inaccurate) and 36.8°C on Jan 7, 1999. The maximum temperature recorded in Gisborne since 1905 was 38.1°C on Jan 11, 1979. Maximum temperature values vary considerably across the Gisborne District. The spatial variability of the 20 and 50 year average return intervals magnitudes can be estimated from a 40 year gridded observational dataset (VCSN) – see figure below.	



<table>
<tr><th>Likelihood</th><th>Description of Event</th><th>Data Quality Rating (applies to available data only)</th></tr>
<tr><td></td><td>Estimates of average return interval event magnitudes for maximum daily temperature for areas other than Ruatoria, Wainui, Waipaoa and Gisborne Urban areas have been estimated using the VCSN – see table below. For regions covering a larger area, a range of values have been given.

<table>
<tr><th>Location</th><th>Based on</th><th>ARI 10 years</th><th>ARI 20 years</th><th>ARI 50 years</th></tr>
<tr><td>Te Karaka</td><td>1 VCSN point</td><td>33.9 (0.6) °C</td><td>35.1 (0.9) °C</td><td>36.6 (1.3) °C</td></tr>
<tr><td>Tolaga Bay</td><td>1 VCSN point</td><td>35.3 (0.9) °C</td><td>36.8 (1.2) °C</td><td>38.8 (1.8) °C</td></tr>
<tr><td>Tokomaru Bay</td><td>1 VCSN point</td><td>34.6 (0.9) °C</td><td>36.2 (1.2) °C</td><td>38.2 (1.7) °C</td></tr>
<tr><td>Tarndale-Rakauroa</td><td>113 VCSN points</td><td>27.3–34.3 (0.4) °C</td><td>27.6–35.4 (0.5) °C</td><td>28.0–36.9 (0.6) °C</td></tr>
<tr><td>East Cape</td><td>114 VCSN points</td><td>27.6–35.7 (0.7) °C</td><td>27.9–37.1 (0.8) °C</td><td>28.3–38.6 (1.1) °C</td></tr>
<tr><td>Tiniroto</td><td>56 VCSN points</td><td>31.6–34.7 (0.5) °C</td><td>32.4–35.9 (0.7) °C</td><td>33.5–37.9 (1.0) °C</td></tr>
<tr><td>Wharekaka</td><td>50 VCSN points</td><td>30.5–35.4 (0.8) °C</td><td>31.3–36.9 (1.1) °C</td><td>32.2–38.8 (1.6) °C</td></tr>
</table>

Gaps: Outside of Ruatoria, Waipaoa, Wainui and Gisborne Urban area, climate records are not long enough to estimate maximum daily temperatures with average return intervals greater than 10 years. For other locations, average return intervals have been estimated from the gridded VCSN data.</td><td></td></tr>
<tr><td>Possible
ARI 51–100 years</td><td>Description: The daily maximum temperature for average return intervals (ARI) of 75 and 100 years at selected climate stations (standard error in brackets):

<table>
<tr><th>Location</th><th>ARI 75 years</th><th>ARI 100 years</th><th>Record length</th></tr>
<tr><td>Gisborne (Gisborne Urban and Wainui areas)</td><td>38.4 (1.0) °C</td><td>38.8 (1.1) °C</td><td>79 years</td></tr>
<tr><td>Manutuke (Waipaoa area)</td><td>37.2 (1.2) °C</td><td>37.5 (1.3) °C</td><td>46 years</td></tr>
</table>

For comparison, the maximum temperature recorded in Gisborne since 1905 was 38.1°C on Jan 11, 1979. This day was also the hottest for Manutuke where the temperature reached 37.0°C.</td><td>2</td></tr>
</table>

Likelihood	Description of Event	**Data Quality Rating** (applies to available data only)
	The gridded observational data set is not long enough to estimate average return intervals greater than 50 years. However, the spatial pattern for return intervals longer than 50 years is expected to be similar to that for 50 years. The table below shows estimates for areas other than Gisborne Urban and Waipaoa areas.	

Location	Based on	ARI 75 years	ARI 51–100 years
Wainui	50 Year ARI		37.8 °C
Te Karaka	50 Year ARI		36.6 °C
Tolaga Bay	50 Year ARI		38.8 °C
Tokomaru Bay	50 Year ARI		38.2 °C
Tarndale-Rakauroa	50 Year ARI		28.0–36.9 °C
Ruatoria	50 Year ARI		40.5 °C
East Cape	50 Year ARI		28.3–38.6 °C
Tiniroto	50 Year ARI		33.5–37.9 °C
Wharekaka	50 Year ARI		32.2–38.8 °C

Gaps: Outside of Waipaoa and Gisborne Urban areas, climate records are not long enough to estimate maximum daily temperature average return intervals greater than 50 years. For other locations, average return intervals have been estimated from the gridded VCSN data.

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
Unlikely **ARI 101–1000 years**	**Description:** Extreme temperatures are similar to ARI 51–100 year event description. **Gaps:** Climate records in Gisborne District are not long enough to accurately estimate maximum daily temperature average return intervals between 101–1000 years. Without taking climate change into account (via the use of numerical climate models for example) it is not possible to estimate return intervals greater than 100 years.	1
Rare **ARI 1001–2500 years**	**Description:** Extreme temperatures are similar to ARI 51–100 year event description. **Gaps:** Information gaps are similar to ARI 101–1000 year event description	1
Very rare **ARI >2500 years**	**Description:** Extreme temperatures are similar to ARI 51–100 year event description. **Gaps:** Information gaps are similar to ARI 101–1000 year event description	1

References

Alliot, P.; Thompson, C.; Thomson, P. 2011. Mixed methods for fitting the GEV distribution, Water Resources Research. 47. doi:10.1029/2010WR009417.

Tait, A. 2008. Future projections of growing degree days and frost in New Zealand and some implications for grape growing. Weather and Climate. 28. 17–36.

National Climate Database (http://cliflo.niwa.co.nz).

A3.9 FLOODING, GISBORNE DISTRICT

A3.9.1 Hazard Description: Flooding

A3.9.1.1 Overview

A number of important studies regarding flooding have been carried out in the Gisborne District. In particular, hydraulic modelling has been undertaken to a high standard to assess the performance of stopbank systems in, for example, the Waipaoa, Taruheru and Waikanae catchments. These exercises provide useful information for estimating damage to the protection schemes and in judging the location and magnitude of potential outflows. Flood hazard exposure mapping has been performed for overflows from the lower Hikuwai River affecting Mangatuna, Wharekaka and Waipurapura, from the Waipaoa affecting Poverty Bay Flats and for the Waimata and Taruheru Rivers in Gisborne City. These maps indicate areas where flood inundation is likely with some information on water depths and velocities. Finally, reports have been prepared describing the general effects of specific flood events, notably Cyclone Bola (1988).

Previous flood hazard work provides useful background and some specific information in places. However, at district level only a qualitative overview is possible based on these reports and other information obtained from flood events elsewhere in New Zealand. To assist a district-wide qualitative overview of flood hazards in Gisborne District, a table of flood hazard descriptors is set out below to provide guidance on the level of flood hazard exposure for each of the 11 specified areas for each average return interval range.

Flood Hazard Exposure	Possible Flood Hazard Exposure Experienced
Low	Flood hazards mainly confined to river channels.
Minor	Flood hazards mainly confined to river channels with small areas of inundation on floodplain close to river bank breaches.
Moderate	Large areas of inundation on floodplain close to river bank breaches, flood depths and velocities on land are generally wadeable or driveable with all-terrain vehicles depending on local topography. Inundation duration of a few days.
High	Inundation across most of the floodplain, flood depths and velocities on land not wadeable or driveable in any vehicle. Inundation duration lasting a week in some areas.
Extreme	Floodplain wide inundation, flood depths and velocities on land not wadeable or driveable in any vehicle even in the early stages of flooding. Inundation duration likely to last for weeks in some areas.

Likelihood	Description of Event	**Data Quality Rating** (applies to available data only)
Likely **ARI 0–50 years**	**Description:** There are few reports of flood hazard exposure from historic or modelled events in the 0–50 year average return interval event range. Location specific flood hazard exposure is reported for the following locations: *Gisborne Urban:* Minor channel outflows expected in the Gisborne City area from the Waimata and Taruheru Rivers. Waikanae Creek is expected to experience channel outflows in a 50 year ARI flood event particularly when coinciding with high tides. In most cases, flood waters may inundate up to 0.5km2 of land with depths ranging between 0.25m and 1m across much of this area. *Tokomaru Bay:* Flood waters mostly confined within channel banks, some outflows expected to inundate approximately 0.07km2 of land along the lower Managhauini River. *Tologa Bay:* Flood waters are mostly confined within the Uawa River channel. *Waipaoa:* Stopbank systems in Waipaoa should generally maintain their integrity and hold water within the channel and designed floodway. Along the Waipaoa River up to 15.4km2 of land within the stopbanks could be inundated. *Wainui:* Extensive ponding and surface flooding is likely in urban areas due to overloading of stormwater infrastructure combined with channel outflows along Wainui Stream similar to those experienced in the June 1977 flood event. Most of the *Wainui* Stream floodplain (0.8km2) will potentially be inundated. *Wharekaka:* The lower Hikuawi River is expected to overflow its banks, inundating land in and around Mangatuna, Wharekaka and Wapurapura. In February 1938, a significant flood occurred with flood water depths in Mangatuna reaching 1.5m in parts of the settlement. A further qualitative overview of flood hazard exposure in Gisborne District based on the previous flood hazard exposure descriptions and general knowledge of flood hazard process is provided in the table below.	3 (Reports)

<table>
<tr><th>Likelihood</th><th>Description of Event</th><th>Data Quality Rating
(applies to available data only)</th></tr>
<tr><td></td><td>
<table>
<tr><th>Location</th><th>Flood Hazard Exposure</th><th>Predominant Floodplain Land Use Exposed to Flood Inundation</th></tr>
<tr><td>Gisborne Urban</td><td>Minor</td><td>Urban</td></tr>
<tr><td>Wainui</td><td>Moderate</td><td>Urban, Primary Production</td></tr>
<tr><td>Te Karaka</td><td>Minor</td><td>Urban, Primary Production</td></tr>
<tr><td>Tolaga Bay</td><td>Minor</td><td>Urban, Primary Production</td></tr>
<tr><td>Tokomaru Bay</td><td>Minor</td><td>Urban, Primary Production</td></tr>
<tr><td>Tarndale-Rakauroa</td><td>Minor</td><td>Primary Production, Natural Environment</td></tr>
<tr><td>Ruatoria</td><td>Minor</td><td>Primary Production,</td></tr>
<tr><td>East Cape</td><td>Minor</td><td>Primary Production, Natural Environment</td></tr>
<tr><td>Tiniroto</td><td>Minor</td><td>Primary Production</td></tr>
<tr><td>Wharekaka</td><td>Minor</td><td>Primary Production</td></tr>
<tr><td>Waipaoa</td><td>Minor</td><td>Urban, Primary Production</td></tr>
</table>

Gaps: Although land previously or potentially exposed to flood inundation is identified for some floodplains in Waipaoa, Wainui, Wharekaka, Tologa Bay, Tokomaru Bay and Gisborne Urban areas, these provide limited details about local flood hazards (e.g., flood depth, velocity and duration). Two dimensional hydraulic flood inundation modelling for settled or economically productive floodplains (e.g., Hikuawi River Catchment) will help to improve information on flood hazard exposure in the district. The accuracy of such models may be limited by the availability of high resolution topographical data (e.g., LiDAR) and hydrological flow and rainfall records longer than 50 years.
</td><td>2 (Table)</td></tr>
</table>

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
Possible **ARI 51–100 years**	**Description:** Similar to the 0–50 year average return interval event range there are only few reports of flood hazard exposure from historic or modelled events. A summary of location specific flood hazards is reported for the following locations: *Gisborne Urban:* Major channel outflows expected in the Gisborne City area from the Waimata and Taruheru Rivers. Overflows from the Taruheru River entering Waikanae Creek will exacerbate flood hazard exposure in this catchment. Up to 32.7km2 of land could be inundated in a 100 year ARI event. *Tokomaru Bay:* Flood hazard exposure is similar to ARI 0–50 year event description. *Tologa Bay*: Flood waters in the lower Hikuwai and Uawa Rivers are likely to breach channels flooding adjacent rural land south of the river channel and parts of the Tologa Bay urban settlement. *Waipaoa:* Moderate to major overflows will be experienced along the Waipaoa River stopbank systems if structural integrity is diminished in places. ‘Cyclone Bola’ (1988) is often cited as the 100 year ARI event for this area. If stopbank design capacity is exceeded in a similar event, flood hazard exposure on the Poverty Bay flats will be exacerbated by the mixing of flood waters overflowing from the Taruheru River, Te Arai and Whakaahu Streams. In total a land area of approximately 92km2 could be inundated in Waipaoa. Within this area 2.7km2 is identified as ‘high’ hazard (e.g., depth x velocity ≥1) potential and 11km2 susceptible to ponding with inundation depths exceeding at least 1m and 2m in some locations (Peacock and Attapatu, 1996). The remaining areas are likely to experience flood inundation depths up to 1m or greater in some topographical depressions. High sediment loads transported in the Waipaoa River system means silt deposition is expected on all inundated land, particularly areas where ponding occurs. *Wainui:* Flood hazard exposure is similar to ARI 0–50 year event description. *Wharekaka:* Major overflows along the lower Hikuwai and Uawa Rivers will occur, inundating land in and around Mangatuna, Wharekaka and Wapurapura. Approximately 30.4km2 of land could be inundated with depths between 0.3m to 1m expected across much of the floodplain. Depths may increase to 1.7m to 2m in some topographical depressions (Attapatu, 1991). Adjacent the lower Hikuwai and upper Uawa Rivers, 2 km2 is identified as ‘high’ hazard (e.g., depth x velocity ≥1). High sediment loads transported in these river systems means silt deposition is expected on all inundated land, particularly areas where ponding occurs. Observations following Cyclone Bola (1988) noted that silt deposition up to 0.6m occurred in parts of the floodplain with most inundated land covered by 0.25m to 0.5m.	3 (Reports)

<table>
<tr><th>Likelihood</th><th>Description of Event</th><th>Data Quality Rating
(applies to available data only)</th></tr>
<tr><td></td><td>
<table>
<tr><th>Location</th><th>Flood Hazard Exposure</th><th>Floodplain Land Use Exposed to Flood Hazards</th></tr>
<tr><td>Gisborne Urban</td><td>High</td><td>Urban</td></tr>
<tr><td>Wainui</td><td>Moderate</td><td>Urban, Primary Production</td></tr>
<tr><td>Te Karaka</td><td>Extreme</td><td>Urban, Primary Production</td></tr>
<tr><td>Tolaga Bay</td><td>High</td><td>Urban, Primary Production</td></tr>
<tr><td>Tokomaru Bay</td><td>Moderate</td><td>Urban, Primary Production</td></tr>
<tr><td>Tarndale-Rakauroa</td><td>Moderate</td><td>Primary Production, Natural Environment</td></tr>
<tr><td>Ruatoria</td><td>High</td><td>Primary Production,</td></tr>
<tr><td>East Cape</td><td>High</td><td>Primary Production, Natural Environment</td></tr>
<tr><td>Tiniroto</td><td>High</td><td>Primary Production</td></tr>
<tr><td>Wharekaka</td><td>High to Extreme</td><td>Primary Production</td></tr>
<tr><td>Waipaoa</td><td>High to Extreme</td><td>Urban, Primary Production</td></tr>
</table>

Gaps: Gaps are similar to ARI 0–50 year event description</td><td>2 (Table)</td></tr>
<tr><td>Unlikely
ARI 101–1000 years</td><td>Description: Expect extensive overtopping for all flood control schemes with major incursion of flood waters in low-lying settlements board. In general, flood hazard exposure in all areas will be more severe than Cyclone Bola (1988) which is often cited as a 100 year ARI event.</td><td>1</td></tr>
</table>

<table>
<tr><th>Likelihood</th><th>Description of Event</th><th>Data Quality Rating (applies to available data only)</th></tr>
<tr><td></td><td>
<table>
<tr><th>Location</th><th>Flood Hazard Exposure</th><th>Floodplain Land Use Exposed to Flood Hazards</th></tr>
<tr><td>Gisborne Urban</td><td>Extreme</td><td>Urban</td></tr>
<tr><td>Wainui</td><td>High</td><td>Urban, Primary Production</td></tr>
<tr><td>Te Karaka</td><td>Extreme</td><td>Urban, Primary Production</td></tr>
<tr><td>Tolaga Bay</td><td>Extreme</td><td>Urban, Primary Production</td></tr>
<tr><td>Tokomaru Bay</td><td>High</td><td>Urban, Primary Production</td></tr>
<tr><td>Tarndale-Rakauroa</td><td>High</td><td>Primary Production, Natural Environment</td></tr>
<tr><td>Ruatoria</td><td>Extreme</td><td>Primary Production,</td></tr>
<tr><td>East Cape</td><td>High</td><td>Primary Production, Natural Environment</td></tr>
<tr><td>Tiniroto</td><td>High</td><td>Primary Production</td></tr>
<tr><td>Wharekaka</td><td>Extreme</td><td>Primary Production</td></tr>
<tr><td>Waipaoa</td><td>Extreme</td><td>Urban, Primary Production</td></tr>
</table>

Gaps: No historic or modelled information is currently available for average return period events greater than 100 years in Gisborne District floodplains. Two dimensional hydraulic flood inundation modelling for important floodplains (e.g., Waipaoa River) will help to improve information on flood hazard exposure in the district however, the accuracy of such models may be limited by the availability of high resolution topographical data (e.g., LiDAR) and hydrological flow and rainfall records longer than 100 years.
</td><td></td></tr>
</table>

Likelihood	**Description of Event**	**Data Quality Rating** (applies to available data only)
Rare **ARI 1001–2500 years**	**Description:** Flood hazard exposure is similar to ARI 100–1001 year event description. **Gaps:** Gaps are similar to ARI 100–1001 year event description	1
Very rare **ARI >2500 years**	Description: Flood hazard exposure is similar to ARI 100–1001 year event description. **Gaps:** Gaps are similar to ARI 100–1001 year event description	1

References

Attapatu, D. 1991. Tolaga Bay Flood Hazard Mapping. *Technical Report (A385735)*. p9.

Hawkes Bay Regional Council. 2009. Waikanae Creek Analysis – 2 Dimensional Modelling. *Technical Report (LRI/196010)* December 2009. p8.

Peacock, D.H. 2011. *Wainui Stream Catchment Study Technical Report*. Report Prepared by Peacock DH Ltd, August 2011. p30.

Peacock, D.H.; Attapatu, D. 1996. Poverty Bay Flood Hazard Mapping. *Technical Report (EWTR96_04)* September 1996. p28.

A3.9.2 Consequence Description: Flooding, Gisborne District

A3.9.2.1 Overview

This flood consequence description is based on the corresponding flooding hazard description, including the available flood inundation extent maps, and the asset inventories created in the ‘context’ section of this project.

The available flood inundation extent maps were derived from the following reports:

- Attapatu, D. (1991). Tolaga Bay Flood Hazard Mapping. Technical Report (A385735). p9.
- Hawkes Bay Regional Council (2009). Waikanae Creek Analysis – 2 Dimensional Modelling. Technical Report (LRI/196010) December 2009. p8.
- Peacock, D. H. (2011). Wainui Stream Catchment Study Technical Report. Report Prepared by Peacock DH Ltd, August 2011. p30.
- Peacock, D. H., Attapatu, D. (1996). Poverty Bay Flood Hazard Mapping. Technical Report (EWTR96_04) September 1996. p28.

Two dimensional flood inundation exposure models did not accompany the maps provided by these reports (with the exception of Waikanae Creek). This meant quantitative impact and loss modelling for assets located within areas exposed to flood inundation could not be undertaken. Available flood inundation extents were used to provide an envelope of potential flood exposure for 0-50 and 51- 100 average return interval events.

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
Likely **ARI 0–50 years**	**Description:** *Health and Safety*: It is estimated that around 330 building occupants could be exposed to flood hazards if present in buildings at time of impact. Residential buildings account for 156 people, with 77 located in the Gisborne Urban Area and 68 in Wainui. A further 159 people in the Gisborne Urban Area could be in buildings used for industrial/primary production purposes. There are few recorded cases in Gisborne District or New Zealand where occupants have remained in buildings experiencing significant flood hazard exposure (e.g. depth x velocity ≥1) and experienced injuries or fatalities. The Kōpuawhara flood of 1938 is the exception where 22 people were killed when flood depths inundated buildings up to 5m. In Gisborne district risk to life or injury is deemed ‘low’ as in most cases it is possible building occupants will evacuate prior to significant flood hazard exposure. If people cannot evacuate inundated buildings then the potential for injuries or fatalities increases considerably. Regardless of their presence in buildings, there is a high likelihood that occupants may sustain physical injuries or illness, or psychological illness during the clean-up and recovery process. **Gaps:** Although land previously or potentially exposed to flood inundation is identified for some floodplains in Wainui, Wharekaka, Tologa Bay, Tokomaru Bay and Gisborne Urban areas, these provide limited details	3	**Description:** *Property*: Around 2,195 land parcels are identified as exposed to flood inundation. Parcels used for primary production (735) are most commonly affected with the majority located in Waipaoa (312) and Wharekaka (188). Pastoral land (5.83km^2) is more likely to be inundated than horticultural land (2.18km^2) on floodplains. Slightly fewer Urban (675) land parcels are located within inundation areas. The greatest numbers of these properties are located in the Gisborne Urban area (539) and Wainui (131). Parcels occupied by natural environments (516) and infrastructure (259) within the ARI 0-50 year floodplains most frequently occupy the Waipaoa, Wharekaka and the Gisborne Urban areas. *Buildings:* Approximately 157 buildings are identified as exposed to inundation. The majority of buildings are located in the Gisborne Urban (106) area with most are constructed of timber (105) and over half used for industry/primary production (60). Residential use accounts for 62 buildings. These are predominately located in the Gisborne Urban area (29) and Wainui (27). Combined, all building and content replacement values exposed to inundation in the district total NZD$71.4m and NZD$30.3m respectively while Gisborne Urban area maintains NZD$57.1m and NZD$24.6m of these values. *Transport*: Localised inundation could occur along road segments comprising 121km of the district road network. Roads in the Gisborne Urban area, Wharekaka and Waipaoa are most extensively exposed with short segments also exposed in Tokomaru Bay, Tolaga Bay and Wainui. Forty five bridges	3

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
	about local flood hazards (e.g. flood depth, velocity and duration). Two dimensional hydraulic flood inundation modelling for settled floodplains will help to improve information on people's exposure to flood hazards in the district. The exact number of people occupying buildings at the time of flood hazard exposure is unknown due to the absence of a high resolution building occupancy database for areas where inundation hazards are identified. The likelihood of people in open spaces (e.g. roads, reserves, private property) coming into contact with inundation hazards is also uncertain.		located in these areas potentially exposed to inundation. Waipaoa and the Gisborne Urban area have 15 bridges each and Wharekaka has 12. Approximately 19km of the Napier-Gisborne Railway has sections crossing land exposed to flood hazards in Waipaoa and the Gisborne Urban area. *Services*: Kilometers of stormwater (9.5), wastewater (11.4) and potable water pipelines (6.3) are potentially exposed to inundation in the Gisborne Urban area. In Waipaoa, approximately 6.8km of water pipelines are also located within areas exposed to inundation. Although most pipelines are below ground, elevated water levels in rivers, streams and drains are likely to cause backflows preventing these systems to operate efficiently. Shorter segments (<3km) of stormwater pipelines are located in areas of Tokomaru Bay and Wainui potentially exposed to inundation. In Waipaoa, Wharekaka and the Gisborne Urban area, electricity pylons and attached powerlines are located within inundation areas though powerlines will be suspended above water levels. Sections of the Kawerau-Opotiki-Gisborne gas pipeline are further exposed to flood inundation along an 8.4km section in Waipaoa. **Gaps:** Although land previously or potentially exposed to flood inundation is identified for some floodplains in Waipaoa, Wainui, Wharekaka, Tologa Bay, Tokomaru Bay and Gisborne Urban areas, these provide limited details about local flood hazards (e.g. flood depth, velocity and duration). Two dimensional hydraulic flood inundation modelling for settled or economically productive floodplains (e.g. Hikuawi River Catchment) will help	

Likelihood	**Description of Health-Safety Consequences**	**Data Quality Rating** (applies to available data only)	**Description of Built Environment and Property Consequences**	**Data Quality Rating** (applies to available data only)
			to improve the ability to derive information about asset exposure and consequences in the district. The accuracy of such models may be limited by the availability of high resolution topographical data (e.g. LiDAR) and hydrological flow and rainfall records longer than 50 years.	
Possible **ARI 51–100 years**	**Description:** *Health and Safety*: Approximately 10,900 people could be exposed to flood hazards in the identified ARI 100 year floodplains. The majority of people who may come into contact with flood hazards might be located in or around residential buildings (9,292). Residential buildings in the Gisborne Urban Area account for 7,340 people. A further 1,703 people are located in Waipaoa (872), Te Karaka (463) and Wharekaka (369). Around 1,450 workers in buildings used for industrial/primary production could also be potentially exposed to flood hazards. The highest exposure occurs in Waipaoa where up to 600 people may be present in these buildings at the time of flood exposure. Te Karaka (135), Wharekaka (176) and Gisborne Urban (437) areas similarly have large numbers of workers within areas possibly exposed to flood hazards. There are few recorded cases in Gisborne District or New Zealand where occupants have remained in buildings experiencing significant flood hazard exposure (e.g. depth x velocity ≥1) and experienced injuries or fatalities. The 1938 Kōpuawhara flood (Hawkes Bay) is the exception where 22 people were killed when flood	3	**Description:** *Property*: Approximately 9,495 land parcels are identified as potentially exposed to inundation in the ARI 51-100 year floodplain. Urban (4,237) land parcels are most common with the majority located in Gisborne Urban area (3,815) and Wainui (131). Parcels used for primary production (735) are most commonly exposed within Waipaoa (1,636) and Wharekaka (526). In Waipaoa it is estimated that 19.3km^2 of pastoral land could be inundated along with 52.9km^2 of horticultural land. Large tracts of land used for these economic activities are also exposed in Wharekaka with 13.8km^2 of pastoral land and 19.5km^2 of horticultural land potentially exposed. Parcels occupied by natural environments (833) and infrastructure (1,219) in the ARI 51–100 year floodplains most frequently occupy the Waipaoa, Wharekaka and the Gisborne Urban areas. *Buildings:* 7,130 buildings have been identified within the districts ARI 51-100 year floodplains. The majority of buildings are located in Gisborne Urban (4,982) area with over half of these residential (2,771) and most constructed of timber (4,883). Hundreds of residential buildings in Te Karaka (192), Waipaoa (498) and Wharekaka (155) are also located on land that could be inundated. A considerable number of buildings used for industrial/primary	3

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
	depths inundated buildings up to 5m. In Gisborne district risk to life or injury is deemed 'low' as in most cases it is possible building occupants will evacuate prior to significant flood hazard exposure. If people cannot evacuate inundated buildings then the potential for injuries or fatalities increases considerably. Regardless of their presence in buildings, there is a high likelihood that occupants may sustain physical injuries or illness, or psychological illness during the clean-up and recovery process. People located in open spaces (e.g. roads, farms) are often more vulnerable to flood hazards. During Cyclone Bola (1988), three people were killed in Gisborne District when their car was swept away by flood waters. The potential for similar fatalities is high possible in flood events of ARI 51–100 years. **Gaps:** Information gaps similar to ARI 0–50 year event description.		production (687) activities are also exposed to inundation hazards. Waipaoa (340) has over half of these buildings while Gisborne Urban area also has many (165). About 50 critical facilities (e.g. buildings occupied by emergency services or used for emergency management) are potentially exposed with 30 located in Gisborne Urban area. Another 2,500 buildings used for 'other' purposes such as garages and outbuildings are identified in ARI 51-100 year floodplains. Again, the majority of these are located in the Gisborne Urban (1,950) area and Waipaoa (323). Combined, building and content replacement values for all buildings identified as potentially exposed to inundation in the districts ARI 51-100 year floodplains totals NZD$1.1b and NZD$473.6m respectively. All exposed buildings in the Gisborne Urban are account NZD$748.2m and NZD$306m of these building and content replacement value respectively. *Transport*: Localised inundation could occur along road segments comprising 450km of the district road network. Roads in the Gisborne Urban area, Tiniroto Wharekaka and Waipaoa are most extensively exposed with short segments also exposed in Tokomaru Bay, Tolaga Bay and Wainui. Fifty seven road and railway bridges combined are located in areas potentially exposed to inundation. Waipaoa and the Gisborne Urban area have 17 bridges each and Wharekaka has 15. Four airfields, two each in Tiniroto and Waipaoa are situated on land potentially exposed to inundation. Approximately 48km of the Napier-Gisborne Railway has sections crossing land exposed to flood hazards in Tiniroto, Waipaoa and the Gisborne Urban area.	

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
			Services: Many kilometers of stormwater (61.2), wastewater (70.6) and potable water pipelines (59.4) are potentially exposed to inundation in the Gisborne Urban area. In Waipaoa, approximately 14km and 30km of wastewater and potable water pipelines are located in area exposed to inundation. Although most pipelines are below ground, elevated water levels in rivers, streams and drains are likely to cause backflows preventing these systems to operate efficiently. Shorter segments (<3km) of stormwater pipelines are located in areas of Tokomaru Bay and Wainui potentially exposed to inundation. In Waipaoa, Wharekaka and the Gisborne Urban area, electricity pylons and attached powerlines are located within inundation areas though powerlines will be suspended above water levels. Sections of the Kawerau-Opotiki-Gisborne gas pipeline are further exposed to flood inundation along an 8.4km section in Waipaoa. **Gaps:** Information gaps are similar to ARI 0–50 year event description.	
Unlikely ARI 101–1000 years	**Description:** Flood consequences are similar to ARI 51-100 year event description. **Gaps:** Two dimensional hydraulic flood inundation modelling for settled or economically productive floodplains (e.g. Hikuawi River Catchment) has not been performed in Gisborne District for events with average return intervals greater than 100 years. Future modelling of these flood events will help to improve the ability to derive information about human exposure and consequences in the district.	1	**Description:** Flood consequences are similar to ARI 51–100 year event description. **Gaps:** Two dimensional hydraulic flood inundation modelling for settled or economically productive floodplains (e.g. Hikuawi River Catchment) has not been performed in Gisborne District for events with average return intervals greater than 100 years. Future modelling of these flood events will help to improve the ability to derive information about asset exposure and consequences in the district.	1

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
Rare **ARI 1001-2500 years**	**Description:** Flood consequences are similar to ARI 51-100 year event description. **Gaps:** Information gaps are similar to ARI 101-1000 year event description.	1	**Description:** Flood consequences are similar to ARI 51-100 year event description. **Gaps:** Information gaps are similar to ARI 101-1000 year event description.	1
Very rare **ARI >2500 years**	**Description:** Flood consequences are similar to ARI 51-100 year event description. **Gaps:** Information gaps are similar to ARI 101-1000 year event description.	1	**Description:** Flood consequences are similar to ARI 51-100 year event description. **Gaps:** Information gaps are similar to ARI 101-1000 year event description.	1

References

Attapatu, D. 1991. Tolaga Bay Flood Hazard Mapping. *Technical Report (A385735).* p9.

Hawkes Bay Regional Council, 2009. Waikanae Creek Analysis – 2 Dimensional Modelling. *Technical Report (LRI/196010)* December 2009. p8.

NZ Historic Weather Events Catalog, 2014. *March 1988 North Island Ex-tropical Cyclone Bola (1988-03-06)*. [Online]. Available: http://hwe.niwa.co.nz/event/March_1988_North_Island_Ex-tropical_Cyclone_Bola. (November 10 2014).

Peacock, D.H. 2011. *Wainui Stream Catchment Study Technical Report*. Report Prepared by Peacock DH Ltd, August 2011. p30.

Peacock, D.H.; Attapatu, D. 1996. Poverty Bay Flood Hazard Mapping. *Technical Report (EWTR96_04)* September 1996. p28.

A3.10 LIQUEFACTION, GISBORNE DISTRICT

A3.10.1 Hazard Description: Earthquake – Liquefaction

A3.10.1.1 Overview

Conservatively, liquefaction occurring during strong earthquake shaking will be confined to alluvial and estuarine sedimentary deposits less than 2 million years old. Liquefaction, where the extent and severity will cause disruptive damage, will be limited to fine-grained (average particle size less than 2 mm) alluvial and estuarine deposits less than 10,000 years old. This limits liquefaction hazards to modern river flood plains and the estuaries at their mouths. The extent of the area affected will be limited to part of the district only.

This hazard description uses four classes of liquefaction susceptibility: very high, high, moderate, and low. Liquefaction susceptibility maps for the Gisborne District were produced in 1997 (Mazengarb et al., 1997). These maps use the classes high, moderate and low. In the following table, 'very high' equates to the 'high' class on the 1997 maps, 'high' equates to the 'moderate' class, and 'moderate' equates to the 'low' class. The 'low' susceptibility class used in the following table is not shown on the 1997 maps.

The liquefaction susceptibility class can be combined with the MMI shaking intensity for each of the ARIs to determine the 'liquefaction damage rating' – a description of the expected ground damage for that ARI – see table below (the liquefaction damage ratings are the numbers in the body of the table):

Table A3.1 Liquefaction susceptibility classes and liquefaction damage ratings assigned at different Modified Mercalli shaking intensities (after Dellow, et al., 2003).

Liquefaction Susceptibility Class	MM Intensity				
	MM6	MM7	MM8	MM9	MM10
Very high	0	1	2	3	4
High	0	0	1	2	3
Moderate	0	0	0	1	2
Low	0	0	0	0	1
None	0	0	0	0	0

The liquefaction damage ratings are explained in the table below:

Table A3.2 Descriptions of expected liquefaction induced ground damage for liquefaction damage ratings (after Dellow, et al., 2003).

Liquefaction Damage Rating	Description of expected liquefaction induced ground damage
0	No liquefaction damage is seen.
1	A few sand boils and minor fissures. Estimate up to 10% of total area affected.
2	Sand boils and moderate fissuring – more extensive near basin edges and in waterlogged areas: banks of rivers broken up, and embankments slumped. Settlements of up to 0.2 m. Estimate 10–20% of total area affected.
3	Lateral spreading common, with many fissures in alluvium (some large), slumping and fissuring of stop-banks, common sand boils. Settlements of up to 0.5 m. Estimate 20–50% of total area affected.
4	Lateral spreading widespread, with extensive fissures and horizontal (and some vertical) displacements of up to 10 m common especially near channel edges. Settlement of uncontrolled fills by up to 1.0m. Estimate >50% of total area affected.

The above process has been used to create the hazard descriptions presented in the table below.

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
Likely **ARI 0–50 years**	**Description:** At a 50-year return period MMI shaking will be in the range 7.0 to 7.3 throughout the Gisborne District. Two recent earthquakes, the Ormond earthquake of 1993 and the Gisborne earthquake of 2007 produced shaking at this level affecting the Waipaoa River floodplain. In both cases isolated sand boils were reported. **Very high liquefaction susceptibility areas:** Sand boils with few fissures. Horizontal displacements less than 0.2 m. Vertical displacements less than 50 mm. Deformation (fissures) extend no more than 20 m from free face (river bank). Estimate 0% (1 year ARI) to 5% (50 year ARI) of very high liquefaction susceptibility area affected. **Gaps:** Good observational data exists for the Waipaoa floodplain (including Te Karaka), the Gisborne urban area and Wainui at this level of shaking. Outside of these areas observational data are absent but are highly likely to conform to these observations based on liquefaction during strong earthquake shaking during earthquakes since 1840 throughout New Zealand.	4
Possible **ARI 51–100 years**	**Description:** A 50–100 year return period MMI shaking will be in the range 7.0 to 7.3 (50 year) to 7.4 to 7.9 (100 year) throughout the Gisborne District. **Very high liquefaction susceptibility areas:** MM7: sand boils common, minor fissures. Horizontal displacements less than 0.5 m. Vertical displacements less than 100 mm. Deformation (fissures) extend no more than 50 m from free face (river bank). Estimate up to 5% (50 year ARI) to 10% (100 year ARI) of very high liquefaction susceptibility area affected. **High liquefaction susceptibility areas:** MM7: Sand boils with few fissures. Horizontal displacements less than 0.2 m. Vertical displacements less than 50 mm. Deformation (fissures) extend no more than 20 m from free face (river bank). Estimate 0% (50 year ARI) to 5% (100 year ARI) of high susceptibility area affected. **Moderate and low liquefaction susceptibility areas:** no liquefaction damage expected. **Gaps:** Good observational data exists for the Waipaoa floodplain (including Te Karaka), the Gisborne urban area and Wainui at this level of shaking. Outside of these areas observational data are absent but are highly likely to conform to these observations based on liquefaction during strong earthquake shaking during earthquakes since 1840 throughout New Zealand. However, this assessment is not constrained by geotechnical data such as cone penetrometer tests.	4
Unlikely **ARI 101–1000 years**	**Description:** A 100–1000 year return period MMI shaking will be in the range 7.4 to 7.9 (100 year) to 8.3 to 9.4 (1000 year) throughout the Gisborne District. Historically (since 1840) the higher levels of shaking in this range have not been observed in the Gisborne District. The highest levels of shaking for the longer return period events will occur nearest the east coast because the subduction plate interface is	2

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
	at its shallowest in this area, and the coast is also the closest part of the District to the known off-shore faults. The sediments with the highest relative susceptibility to liquefaction are those closest to the coast. **Very high susceptibility areas:** MM8: Moderate fissuring – Horizontal displacements less than 2 m. Vertical displacements less than 200 mm. Deformation (fissures) extend no more than 100 m from free face (riverbank). Estimate 10–20% of total area affected. MM9: Lateral spreading common – Horizontal displacements less than 5 m. Vertical displacements less than 500 mm. Deformation (fissures) extend no more than 500 m from free face (riverbank). Estimate 20–50% of total area affected. **High susceptibility areas:** MM8: sand boil commons, minor fissures. Horizontal displacements less than 0.5 m. Vertical displacements less than 100 mm. Deformation (fissures) extend no more than 50 m from free face (river bank). Estimate 5% to 10% of total high liquefaction susceptibility area affected. MM9: Moderate fissuring – Horizontal displacements less than 2 m. Vertical displacements less than 200 mm. Deformation (fissures) extend no more than 100 m from free face (river bank). Estimate 10–20% of total area affected. **Moderate susceptibility areas:** MM8: Sand boils with few fissures. Horizontal displacements less than 0.2 m. Vertical displacements less than 50 mm. Deformation (fissures) extend no more than 20 m from free face (river bank). Estimate 0% (50 year ARI) to 5% (100 year ARI) of high susceptibility area affected. MM9: sand boils common, minor fissures. Horizontal displacements less than 0.5 m. Vertical displacements less than 100 mm. Deformation (fissures) extend no more than 50 m from free face (river bank). Estimate up to 5% (100 year ARI) to 10% (1000 year ARI) of moderate liquefaction susceptibility area affected. **Low liquefaction susceptibility areas:** no damage. **Gaps:** Limited observational data at the lower end of this ARI (100 years). No observational data from Gisborne District at the higher ARI (1000 years).	
Rare **ARI 1001–2500 years**	**Description:** A 1000 to 2500 year return period MMI shaking will be in the range 8.3 to 9.4 (1000 year) to 8.7 to 9.8 (2500 year) throughout the Gisborne District. These MMI ranges are similar to those expected for ‘unlikely’ events (ARI 101–1000) described above. The ground damage descriptions for this ‘rare’ category are the same as those described in the row above. **Gaps:** No observational or geotechnical data available to support this assessment	2

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
Very rare ARI >2500 years	**Description:** 2500 year return period or greater MMI shaking will be in the 8.7 to 9.8 (2500 year)or greater throughout the Gisborne District. The highest levels of shaking for the longer return period events will occur nearest the east coast because the subduction plate interface is at its shallowest in this area, and the coast is also the closest part of the District to the known off-shore faults. The sediments with the highest relative susceptibility to liquefaction are those closest to the coast. **Very high susceptibility areas:** MM8: Moderate fissuring – Horizontal displacements less than 2 m. Vertical displacements less than 200 mm. Deformation (fissures) extend no more than 100 m from free face (river bank). Estimate 10–20% of total area affected. MM9: Lateral spreading common – Horizontal displacements less than 5 m. Vertical displacements less than 500 mm. Deformation (fissures) extend no more than 500 m from free face (river bank). Estimate 20–50% of total area affected. MM10: Lateral spreading widespread – Horizontal displacements greater than 5 m. Vertical displacements greater than 500 mm. Deformation (fissures) extend more than 500 m from free face (river bank). Estimate >50% of total area affected. **High susceptibility areas:** MM8: sand boils common, minor fissures. Horizontal displacements less than 0.5 m. Vertical displacements less than 100 mm. Deformation (fissures) extend no more than 50 m from free face (river bank). Estimate 0% to 10% of total area affected. MM9: Moderate fissuring – Horizontal displacements less than 2 m. Vertical displacements less than 200 mm. Deformation (fissures) extend no more than 100 m from free face (river bank). Estimate 10–20% of total area affected. MM10: Lateral spreading common – Horizontal displacements less than 5 m. Vertical displacements less than 500 mm. Deformation (fissures) extend no more than 500 m from free face (river bank). Estimate 20%–50% of total area affected. **Moderate susceptibility areas:** MM8: Sand boils with few fissures. Horizontal displacements less than 0.2 m. Vertical displacements less than 50 mm. Deformation (fissures) extend no more than 20 m from free face (river bank). Estimate 20%–50% of total area affected. MM9: sand boils common, minor fissures. Horizontal displacements less than 0.5 m. Vertical displacements less than 100 mm. Deformation (fissures) extend no more than 50 m from free face (river bank). Estimate up to 10% to 20% of total area affected. MM10: Moderate fissuring – Horizontal displacements less than 2 m. Vertical displacements less than 200 mm. Deformation (fissures) extend no more than 100 m from free face (river bank). Estimate 0%–10% of total area affected **Low susceptibility areas:** MM10: Sand boils with few fissures. Horizontal displacements less than 0.2 m. Vertical displacements less than 50 mm. Deformation (fissures) extend no more than 20 m from free face (river bank). Estimate 0%–10% of total area affected. **Gaps:** No observational or geotechnical data available to support this assessment.	1

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A3.10.2 Consequence Description: Liquefaction

A3.10.2.1 Overview

This consequence description is based on the corresponding liquefaction hazard description and the asset inventories created in the ‘context’ section of this project.

Damage to the built environment and property from liquefaction can occur due to three main phenomena; vertical settlement, lateral spreading (horizontal movement) and sand boils. These phenomena are considered in the descriptions of the built environment and property consequences.

Likelihood	**Description of Health-Safety Consequences**	**Data Quality Rating** (applies to available data only)	**Description of Built Environment and Property Consequences**	**Data Quality Rating** (applies to available data only)
Likely **ARI 0–50 years**	**Description:** There are unlikely to be any direct health and safety consequences for this level of liquefaction hazard but there may be some minor secondary impacts. In areas of very high liquefaction susceptibility there may be some minor damage to water and waste water pipes. If the service is interrupted it will likely require boiling of drinking water and use of portable toilets. This increases the risk of water-borne infections and contamination during the period of no pipe services. **Gaps:** No digital spatial data exist for liquefaction hazard for GDC. As such, the consequence analysis can only describe the potential health and safety consequences to people in the area.	2	**Description:** For this level of hazard, in areas of low, moderate and high liquefaction susceptibility, there is unlikely to be any damage. **Very high susceptibility areas:** In areas of very high liquefaction susceptibility there may be some minor damage associated with vertical settlement near areas that have liquefied and where lateral spreading has occurred. In these areas, minor cracking (few mm’s to few cm’s wide) of roads and concrete surfaces will occur due to vertical or horizontal movement. Some minor damage may occur to bridge abutments in areas where lateral spreading is present. Any minor damage to structures will primarily include damage to foundations, especially those with “concrete slab on grade” foundations. Vertical settlement can increase the flood hazard in areas and may make property more susceptible to flooding. However, at this level of settlement (<0.2 m) this is likely to be insignificant. Sand boils may occur that may cause minor damage to property and will require clean up. Following two recent earthquakes, the Ormond earthquake of 1993 and the Gisborne earthquake of 2007, isolated sand boils	2

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
			were reported, with the worst damage being to 200 metres of stop-bank which was lowered by lateral spreading of the foundations by up to 0.5 m. **Gaps:** No digital spatial data exists for liquefaction hazard for GDC. As such, the consequence analysis can only describe the potential consequences.	
Possible **ARI 51–100 years**	**Description:** Same as above **Gaps:** Same as above	2	**Description:** Same as above, but minor damage as described above will start occurring in areas of high liquefaction susceptibility (as well as in very high areas) – instances of liquefaction will be more widespread but still relatively isolated. The severity of damage in very high liquefaction susceptibility areas will increase slightly. Some settlement of bridge abutment embankments might be observed but is unlikely to damage the bridge structures. **Gaps:** No digital spatial data exists for liquefaction hazard for GDC. As such, the consequence analysis can only describe the potential consequences.	2
Unlikely **ARI 101–1000 years**	**Description:** Same as above **Gaps:** Same as above	2	**Description:** At this level of hazard, areas of liquefaction damage are likely to be isolated to patches (refer to hazard table for description of percent area affected). Vertical settlement can increase the flood hazard in areas and may make property more susceptible to flooding. **Very high susceptibility areas:** Moderate to major damage will occur to structures and lifelines at this level of hazard. Damage due to lateral spreading will be confined to areas near slope faces (e.g., near the coast, river/stream channels and banks) will be in the form of large (up to 10's of cm) fissures (cracks) forming across roads and open ground and will likely cause damage to	2

Likelihood	Description of Health-Safety Consequences	**Data Quality Rating** (applies to available data only)	Description of Built Environment and Property Consequences	**Data Quality Rating** (applies to available data only)
			bridge abutments. Liquefaction will cause damage to underground infrastructure. Buried tanks (petroleum, water) may be pushed upwards and break the surface. It is likely there will be significant damage to buried pipes that could cause complete interruption to the services, especially to sewers, and need urgent repair. Liquefaction will cause moderate to major damage to structures, mainly in the form of damage to the foundations. Structures with shallow foundations or concrete slab on grade will likely suffer more damage than those with deep pile foundations. This will include buildings and critical infrastructure such as substations. The damage will become more severe and extensive with increasing MMI. **High susceptibility areas:** In areas of high liquefaction susceptibility there is likely to be some minor damage associated with vertical settlement near areas that have liquefied and where lateral spreading has occurred. In these areas, minor cracking (few mm's to few cm's wide) of roads and concrete surfaces will occur due to vertical or horizontal movement. Some minor damage may occur to bridge abutments in areas where lateral spreading is present. Any minor damage to structures will primarily include damage to foundations, especially those with "concrete slab on grade" foundations. The damage will become more severe and extensive with increasing MMI. **Moderate susceptibility areas:** In areas of moderate liquefaction susceptibility there may be some minor damage associated with vertical settlement near areas that have liquefied and where lateral spreading has occurred. In these areas, minor cracking (few mm's to few cm's wide) of roads and concrete surfaces will occur due to vertical or horizontal movement. Some minor damage may occur	

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
			to bridge abutments in areas where lateral spreading is present. Any minor damage to structures will primarily include damage to foundations, especially those with "concrete slab on grade" foundations. Vertical settlement can increase the flood hazard in areas and may make property more susceptible to flooding. However, at this level of settlement (<0.2 m) this is likely to be insignificant. The damage will become more severe and extensive with increasing MMI. **Gaps:** No digital spatial data exists for liquefaction hazard for GDC. As such, the consequence analysis can only describe the potential consequences.	
Rare **ARI 1001–2500 years**	**Description:** Same as above **Gaps:** Same as above	2	**Description:** As above **Gaps:** As above	2
Very rare **ARI >2500 years**	**Description:** Same as above **Gaps:** Same as above	2	**Description:** At this level of hazard, areas of liquefaction damage are likely to be isolated to patches (refer to hazard table for description of percent area affected). Vertical settlement can increase the flood hazard in areas and may make property more susceptible to flooding. **Very high susceptibility areas:** Major to extensive damage will occur to structures and lifelines at this level of hazard. Damage due to lateral spreading will be confined to areas near slope faces (e.g., near the coast, river/stream channels and banks) will be in the form of large (up to 10's of cm) fissures (cracks) forming across roads and open ground and will likely cause damage to bridge abutments. Liquefaction will cause severe damage to underground infrastructure. Buried tanks (petroleum, water) may be pushed upwards and break the surface. There will be	2

Likelihood	Description of Health-Safety Consequences	**Data Quality Rating** (applies to available data only)	Description of Built Environment and Property Consequences	**Data Quality Rating** (applies to available data only)
			significant damage to buried pipes that are likely to cause complete and lengthy interruption to the services, particularly to sewers. Liquefaction will cause major damage to structures, mainly in the form of damage to the foundations. Structures with shallow foundations or concrete slab on grade will likely suffer more damage than those with deep pile foundations. This will include buildings and critical infrastructure such as substations. The damage will become more severe and extensive with increasing MMI. **High susceptibility areas:** In areas of high liquefaction susceptibility there is likely to be some minor damage associated with vertical settlement near areas that have liquefied and where lateral spreading has occurred. In these areas, minor cracking (few mm's to few cm's wide) of roads and other concrete surfaces will occur due to vertical or horizontal movement. Some minor damage may occur to bridge abutments in areas where lateral spreading is present. Any minor damage to structures will primarily include damage to foundations, especially those with "concrete slab on grade" foundations. The damage will become more severe and extensive with increasing MMI. **Moderate susceptibility areas:** In areas of moderate liquefaction susceptibility there may be some minor damage associated with vertical settlement near areas that have liquefied and where lateral spreading has occurred. In these areas, minor cracking (few mm's to few cm's wide) of roads and other concrete surfaces will occur due to vertical or horizontal movement. Some minor damage may occur to bridge abutments in areas where lateral spreading is present. Any minor damage to structures will primarily include damage to foundations, especially those with "concrete slab on	

Likelihood	**Description of Health-Safety Consequences**	**Data Quality Rating** (applies to available data only)	**Description of Built Environment and Property Consequences**	**Data Quality Rating** (applies to available data only)
			grade" foundations. Vertical settlement can increase the flood hazard in areas and may make property more susceptible to flooding. However, at this level of settlement (<0.2 m) this is likely to be insignificant. The damage will become more severe and extensive with increasing MMI. **Low susceptibility areas:** There may be some minor damage associated with vertical settlement near areas that have liquefied and where lateral spreading has occurred. In these areas, minor cracking (few mm's to few cm's wide) of roads and other concrete surfaces will occur due to vertical or horizontal movement. Some minor damage may occur to bridge abutments in areas where lateral spreading is present. Any minor damage to structures will primarily include damage to foundations, especially those with "concrete slab on grade" foundations. Vertical settlement can increase the flood hazard in areas and may make property more susceptible to flooding. However, at this level of settlement (<0.2 m) this is likely to be insignificant. **Gaps:** No digital spatial data exists for liquefaction hazard for GDC. As such, the consequence analysis can only describe the potential consequences.	

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A3.11 VOLCANIC ERUPTIONS, GISBORNE DISTRICT

A3.11.1 Hazard Description: Volcanic Eruptions

A3.11.1.1 Overview

This assessment focuses on the following volcanic hazards: ash fall, gas, lahars and mass movement, and proximal volcanic phenomena (ballistics, lava flows, pyroclastic density currents, lahars).

It is unlikely that there will be any ash fall in the Gisborne District from eruptions in New Zealand smaller than 0.01 km^3. Eruptions larger than 0.01 km^3 happen every 20 to 50 years in New Zealand. Small eruptions will only deposit ash in the Gisborne District with favourable wind conditions. The prevalent wind directions are from the west and south, so the Gisborne District is often downwind of volcanic centres (Ruapehu, Okataina, Taupo, Taranaki). Due to these prevalent wind directions, White Island infrequently impacts the Gisborne District. Medium to large eruptions (between 1 and 10 km^3) from Taupo and Okataina will almost always impact the Gisborne District (return period 2500 – 5000 years) (Scott, 1997).

Likelihood	Description of Event	**Data Quality Rating** (applies to available data only)
Likely	**Description:**	
ARI 0–50 years	**Ash fall:** Trace amounts to 1 mm ash covering Gisborne District, 1–3 such events in 50 year time period.	3
	Gas: Smell of sulphur (H2S), which might happen a few times over an eruptive period occurring in the central North Island, 3–10 such events in 50 year time period.	2
	No proximal volcanic phenomena (ballistics, lava flows, pyroclastic density currents, lahars).	3
	Gaps: There will likely be variability in the areas that get trace to 1 mm ash fall across Gisborne District, with areas further away from the main wind direction unlikely to get any. Presence/absence highly dependent on wind direction at the time of the eruption.	
	Frequency of gas smell events unknown.	
	Duration of gas smell events unknown; strongly dependent on wind at the time of eruption in the central North Island over the course of the eruption.	
	Concentration of gas unknown, likely very low.	
	Increase in PM2.5 particulates likely to occur with ash fall and/or gas smells, but unknown what severity of increase will be (likely not severe).	

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
Possible **ARI 51–100 years**	**Description:** **Ash fall:** 1–5 mm ash covering Gisborne District, on top of several discrete trace to 1 mm ash events. **Gas:** Smell of sulphur (H2S) which might happen a few times over an eruptive period occurring in the central North Island, 3–10 such events in 100 year time period. Other more harmful gases such as SO2 may be present in small concentrations. No proximal volcanic phenomena (ballistics, lava flows, pyroclastic density currents, lahars). **Gaps:** There will likely be variability in ash thickness across Gisborne District, with areas further away from the main wind direction receiving less ash. Highly dependent on duration of ash-producing eruption phase and wind direction at the time. Frequency of gas smell events unknown. Duration of gas smell events unknown; strongly dependent on wind at the time of eruption in the central North Island over the course of the eruption. Concentration of gas unknown. Increase in PM2.5 particulates likely to occur with ash fall and/or gas smells, but unknown what severity of increase will be (will be more severe for the larger deposition events).	 3 2 3
Unlikely **ARI 101–1000 years**	**Description:** **Ash fall:** 5–10 mm ash covering Gisborne District, on top of several < 5 mm events and numerous trace to 1 mm ash events. **Gas:** Smell of sulphur (H2S). Other more harmful gases such as SO2 may be present in small concentrations. Acid rain may an issue. No proximal volcanic phenomena (ballistics, lava flows, pyroclastic density currents, lahars) **Gaps:** There will likely be variability in ash thickness across Gisborne District, with areas further away from the main wind direction receiving less ash. Highly dependent on duration of ash-producing eruption phase and wind direction at the time Frequency of gas smell events unknown. Duration of gas smell events unknown; strongly dependent on wind at the time of eruption in the central North Island over the course of the eruption. Duration of acid rain unknown. Also requires rain, so time of year may be important. Concentration of gas unknown, likely low. Increase in PM2.5 particulates likely to occur with ash fall and/or gas smells, but unknown what severity of increase will be.	 3 2 3

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
Rare **ARI 1001–2500 years**	**Description:** **Ash fall:** 10–100 mm ash covering Gisborne District, on top of numerous < 10, < 5 mm, <1 ash events. **Gas:** Smell and effects of sulphur (H2S). Other more harmful gases such as SO2 may be present. Acid rain likely to result. **Lahar / mass movement:** lahars soon after eruption, mass movement on steeper slopes until ash mostly removed. Can last several years after the eruption. No proximal volcanic phenomena (ballistics, lava flows, pyroclastic density currents, lahars). **Gaps:** There will likely be variability in ash thickness across Gisborne District, with areas further away from the main wind direction receiving less ash. Highly dependent on duration of ash-producing eruption phase and wind direction at the time Frequency of gas smell events unknown. Duration of gas smell event unknown; strongly dependent on wind at the time of eruption in the central North Island over the course of the eruption. Duration of acid rain unknown. Also requires rain, so time of year may be important. Concentration of gas unknown. Increase in PM2.5 particulates likely to occur with ash fall and/or gas smells, but unknown what severity of increase will be.	 3 2 2 3
Very rare **ARI >2500 years**	**Description**: **Ash fall:** 100–1000 mm ash (thickest ash bed in region is 3 m, from 1 Ma). Fairly uniform across the region, with thickness decreasing further from volcanic centre. **Gas:** Acid rain likely prevalent. **Lahars / mass movement:** Will occur for years to decades after event. **Proximal volcanic phenomena** (ballistics, lava flows, pyroclastic density currents, lahars): for the very largest events might get pyroclastic density currents. Most of the central North Island will be significantly impacted in this situation. **Gaps:** There will likely be variability in ash thickness across Gisborne District, with areas further away from the main wind direction receiving less ash and areas further away getting less ash. Highly dependent on duration of ash-producing eruption phase and wind direction at the time. Duration of time with lahars and mass movements unknown. Frequency of gas smell events unknown.	 3 2 2 3

Likelihood	Description of Event	**Data Quality Rating** (applies to available data only)
	Duration of gas smell event unknown; strongly dependent on wind at the time of eruption in the central North Island over the course of the eruption. Duration of acid rain unknown. Also requires rain, so time of year may be important. Concentration of gas unknown. Increase in PM2.5 particulates likely to occur with ash fall and/or gas smells, but unknown what severity of increase will be.	

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A3.11.2 Consequence Description: Volcanic Eruptions

A3.11.2.1 Overview

This consequence description is based on the corresponding volcanic eruption hazard description and the asset inventories created in the 'context' section of this project.

Ash can reduce permeability, particularly at greater thicknesses. This can increase surface runoff and peak flood discharge, and decrease flood duration. Ash can be remobilized by wind, particularly if there has been no recent rain or conditions are very dry. Large ash deposits can result in increased mass movement on steep slopes (Manville, 2004).

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
Likely **ARI 0–50 years**	**Description:** **Ash fall:** Volcanic ash can cause very minor respiratory and eye irritations at this level. Symptoms will be short lived and generally not require medical attention. Asthmatics and children are more likely to be affected. There is a small chance of contamination of drinking supplies, particularly roof-fed supplies. **Gas:** H_2S is unlikely to cause any health and safety impacts besides people being irritated by the smell of rotten eggs. **Gaps:** The amount of people impacted is unknown as this is dependent on the hazard footprint which is unknown.	3 2	**Description:** **Ash fall:** Possible minor damage to houses, vehicles and equipment caused by fine abrasive ash. **Gas:** There are not likely to be consequences to the built environment or property. **Gaps:** Due to lack of spatial information on the hazard extent, the areas impacted and number/value of structures and property is not known.	3 2
Possible **ARI 51–100 years**	**Description:** **Ash fall:** Volcanic ash can cause minor respiratory and eye irritations at this level. Symptoms will be short lived and some may require medical attention. Asthmatics and children are more likely to be affected. There is a likely	3	**Description:** **Ash:** Minor damage to houses will occur if fine ash enters buildings, soiling interiors, blocking air-conditioning filters, etc. Electricity may be cut; ash shorting occurs at substations if the ash is wet and therefore conductive. Low	3

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
	chance of contamination of drinking supplies, particularly roof-fed supplies. **Gas:** H_2S is unlikely to cause any health and safety impacts besides people being irritated by the smell of rotten eggs. **Gaps:** The amount of people impacted is unknown as this is dependent on the hazard footprint which is unknown.	2	voltage systems are more vulnerable than high voltage. Roads may need to be cleared to reduce the dust nuisance and prevent storm-water systems from becoming blocked. Sewage systems may be blocked by ash, or disrupted by loss of electrical supplies. Damage to electrical equipment and machinery may occur. **Gas:** There are not likely to be consequences to the built environment or property **Gaps:** Due to lack of spatial information on the hazard extent, the areas impacted and number/value of structures and property is not known.	2
Unlikely **ARI 101–1000 years**	**Description:** **Ash fall:** Volcanic ash can cause respiratory and eye irritations. At this level of ash fall, there will be widespread respiratory health impacts. Many people, especially those with pre-existing respiratory illness will require medical attention. These health impacts will be long lasting (days to weeks) as ash will settle and then be subsequently remobilised by the wind. There will be contamination of drinking supplies, particularly roof-fed supplies. **Gas:** Sulphur dioxide (oxidised form of H_2S) is irritating to the eyes, throat and respiratory system and can cause symptoms such as coughing, burning eyes, and difficulty breathing. Symptoms occur at 1-5ppm of $S0_2$ in healthy people and as low as 0.3–0.8 ppm in people with asthma. Due to the unknown concentrations of gas for Gisborne region, only a range of possible consequences can be noted.	3 2	**Description:** **Ash fall:** Major ash removal operations will be required in urban areas. Most buildings will support the ash load but weaker roof structures may collapse, particularly if the ash is wet. Road transport may be halted due to the build-up of ash on roads. Cars still working may soon stop due to clogging of air-filters. Rail transport may be forced to stop due to signal failure bought on by short circuiting if ash becomes wet. Electricity will likely be cut; ash shorting occurs at substations if the ash is wet and therefore conductive. Low voltage systems are more vulnerable than high voltage. Removal of 5–10 mm of ash from farmland will be impracticable. Impacts on animals will be serious, and consequent loss of production/income will be severe (20–30%). Recovery could take 1 to 5 years. **Gas:** There are not likely to be consequences to the built	3 2

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
	Gaps: The amount of people impacted is unknown as this is dependent on the hazard footprint which is unknown. Because gas concentration of SO_2 is not known, the severity of health & safety consequences are not known and only possible outcomes are highlighted. However the exact number of people affected and severity of symptoms will depend on where the gas is located and the concentrations.		environment or property. **Gaps:** Due to lack of spatial information on the hazard extent, the areas impacted and number/value of structures and property is not known.	
Rare **ARI 1001–2500 years**	**Description:** **Ash fall:** Volcanic ash can cause respiratory and eye irritations. At this level of ash fall (10-100 mm covering Gisborne region), there will be widespread respiratory health impacts. Many people, especially those with pre-existing respiratory illness will require medical attention. These health impacts will be long lasting (weeks to months) as ash will settle and then be subsequently remobilised by the wind. There will be contamination of drinking supplies, particularly roof-fed supplies. **Gas/Acid Rain:** Sulphur dioxide (oxidised form of H_2S) is irritating to the eyes, throat and respiratory system and can cause symptoms such as coughing, burning eyes, and difficulty breathing. Symptoms occur at 1-5ppm of $S0_2$ in healthy people and as low as 0.3–0.8 ppm in people with asthma. Due to the unknown concentrations of gas for GDC, only a range of possible consequences can be noted.	3 2	**Description:** **Ash fall:** Major ash removal operations in urban areas. Most buildings will support the ash load but weaker roof structures may collapse at 100 mm ash thickness, particularly if the ash is wet. Road transport may be halted due to the build up of ash on roads. Cars still working may soon stop due to clogging of air-filters. Rail transport may be forced to stop due to signal failure bought on by short circuiting if ash becomes wet. Electricity will likely be cut; ash shorting occurs at substations if the ash is wet and therefore conductive. Low voltage systems are more vulnerable than high voltage. Removal of 10–100 mm of ash from farmland will be impossible. Impacts on animals will be very serious, and consequent loss of production/income will be severe to total (30% to 100%). Recovery could take 5 to 200 years. Removal of 10–100 mm of ash from urban areas will be an interesting task.	3 2

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
	Lahars/mass movement: Lahars and mass movement of slopes have the potential to injure and kill people if the depth of flowing material is large enough to overcome a standing person. The flow of a lahar will be similar to that of a flash flood except it will contain large amounts of debris. In small lahars people will have difficulty standing if the flow reaches just below waist height and may get knocked over by debris. Once a person is not standing they will likely suffer severe injuries or death. For large lahars, people will suffer severe crush injuries or be killed by drowning or debris impacts. **Gaps:** The amount of people impacted is unknown as this is dependent on the hazard footprint which is unknown. Because gas concentration of SO_2 is not known, the severity of health & safety consequences are not known and only possible outcomes are highlighted. However the exact number of people affected and severity of symptoms will depend on where the gas is located and the concentrations.	2	**Gas:** Acid rain will likely cause an increase in corrosion rate of metal and stone products such as building materials and vehicles. **Lahars/mass movement:** Large lahars will likely cause severe damage to buildings and property. They may cause increased erosion along the flow path. **Gaps:** Due to no spatial information on the hazard extent, the areas impacted and number/value of structures and property is not known.	2
Very rare ARI >2500 years	**Description:** **Proximal volcanic phenomena** (ballistics, lava flows, pyroclastic density currents, lahars): These volcanic phenomena have severe consequences to life safety. If caught in a pyroclastic density current the chance of survival is extremely low. **Ash fall:** Volcanic ash can cause respiratory and eye irritations. Asthmatics and children are more likely to be affected. At this level of ash fall (100 - 1000 mm, fairly	2 3	**Description:** **Proximal volcanic phenomena** (ballistics, lava flows, pyroclastic density currents, lahars): Pyroclastic density currents will destroy anything in their path. **Ash fall:** Buildings that are not cleared of ash will run the risk of roof collapse, especially large flat roofed structures and if ash becomes wet. Loading and possible breakage of power and telephone lines. Roads unusable until cleared. Cars still working may soon stop due to clogging of air-	2 3

Likelihood	Description of Health-Safety Consequences	Data Quality Rating (applies to available data only)	Description of Built Environment and Property Consequences	Data Quality Rating (applies to available data only)
	uniform across the region), there will be widespread respiratory health impacts. Many people, especially those with pre-existing respiratory illness will require medical attention. These health impacts will be long lasting (months to years) as ash will settle and then be subsequently remobilised by the wind. From long term (years) exposure to volcanic ash, there is a small chance of developing serious lung diseases. There will be contamination of drinking supplies, particularly roof-fed supplies. **Gas**: Sulphur dioxide (oxidised form of H_2S) is irritating to the eyes, throat and respiratory system and can cause symptoms such as coughing, burning eyes, and difficulty breathing. Symptoms occur at 1-5ppm of $S0_2$ in healthy people and as low as 0.3–0.8 ppm in people with asthma. Due to the unknown concentrations of gas for GDC, only a range of possible consequences can be noted. **Lahars/mass movement:** Lahars and mass movement of slopes have the potential to injure and kill people if the depth of flowing material is large enough to overcome a standing person. The flow of a lahar will be similar to that of a flash flood except it will contain large amounts of debris. In small lahars people will have difficulty standing if the flow reaches just below waist height and may get knocked over by debris. Once a person is not standing they will likely suffer severe injuries or death. For large lahars, people will suffer severe crush injuries or be killed by drowning or debris impacts	2 2	filters. Rail transport may be forced to stop due to signal failure bought on by short circuiting if ash becomes wet. In reality, 100mm or more of ash over the Gisborne Region will make the region uninhabitable. Removal from urban areas will be nigh-on impossible. All farm production will be lost, and recovery is likely to take 20 to 200 years (Smith et al., 2007). **Gas:** Acid rain will likely cause an increase in corrosion rate of metal and stone products such as building materials and vehicles. **Lahars/mass movement:** Large lahars will likely cause severe damage to buildings and property. They may cause increased erosion along the flow path. **Gaps:** Due to no spatial information on the hazard extent, the areas impacted and number/value of structures and property is not known.	2 2

Likelihood	**Description of Health-Safety Consequences**	**Data Quality Rating** (applies to available data only)	**Description of Built Environment and Property Consequences**	**Data Quality Rating** (applies to available data only)
	Gaps: The amount of people impacted is unknown as this is dependent on the hazard footprint which is unknown. Because gas concentration of SO_2 is not known, the severity of health & safety consequences are not known and only possible outcomes are highlighted. However the exact number of people affected and severity of symptoms will depend on where the gas is located and the concentrations.			

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A3.12 TSUNAMI, GISBORNE DISTRICT

A3.12.1 Hazard Description: Tsunami

A3.12.1.1 Overview

This tsunami hazard description uses the Tsunami Intensity Scale (TIS), defined and published by Papadopoulos and Imamura (2001), as assessed by expert opinion in Wang et al. (2009). This TIS provides a measure of the impact of the tsunami hazard, so combines some damage (consequence) information with the hazard descriptions. The TIS has 12 levels, with a description provided for the impact expected at each level. The TIS, including impact descriptions, is set out at the end of this table. Rather than repeat the descriptions in the table, the table records the level for the particular section of coast, and the reader is asked to refer to the scale at the end of the table for the full description.

'HT' included with the TIS number indicates that the tsunami is assumed to occur at 'High Tide'. Otherwise, Mean Sea Level is the datum used. The TIS numbers are stated for the particular area of coast (e.g., 'Gisborne: TIS 5 (TIS 6 HT)' means that the intensity scale for Gisborne is 5 at Mean Seal Level, and 6 at High Tide).

We are interpreting the **ARI** as the **return period** of any given tsunami event. The return period is distinguished from the **recurrence interval**, which states how often an individual tsunami source on average will trigger. Many different sources can cause comparable events (tsunami experienced at a target location). The return period gives the averaged assumed time span in which a particular type of event will return to the target region (e.g., comparable extent of inundation or offshore wave height). The return period is often much smaller than the recurrence interval of any given source causing such an event. As an example: If two sources affecting the same area and causing the same impact have the same recurrence interval than the combined return period is half the recurrence interval.

Different scenarios concentrate their impacts on different parts of the coast, hence a variety of events are presented. No one single event typifies the range of possibilities.

We have also listed the main contributing sources representing given return periods, with their magnitudes and maximum offshore tsunami heights for reference, from the Review of the Tsunami Hazard in New Zealand (2013 update). This review divides the coast of New Zealand into 268, 20 km long sections, and reports tsunami information for each 20 km stretch of coast. This hazard description lists the tsunami impacts for each 20 km coastal section in the Gisborne District. During a tsunami, the peak water levels will vary considerably even across a 20 km section of the coast. Here we give the amplitude as the highest offshore water elevation to be found in any one coastal section. The median tsunami height within each section may be significantly lower.

Please note that the magnitudes quoted below for the earthquake sources in the 'Review of Tsunami Hazard in New Zealand (2013 update)' are 'effective magnitudes' as defined in that report (Power, 2013, page 128.). In some cases these may be significantly higher than the conventional moment magnitude (MW) of the source earthquake.

<table>
<tr><th>Likelihood</th><th>Description of Event</th><th>Data Quality Rating (applies to available data only)</th></tr>
<tr><td>Likely
ARI 0–50 years</td><td>Description: Existing tsunami information is based on an ARI of 100 years or less. Therefore, this information is recorded in the 51–100 year ARI row (see below).</td><td></td></tr>
<tr><td>Possible
ARI 51–100 years</td><td>Description (represent ARI < 100 years):
Local sources
Source: Tsunami earthquakes, similar to March & May 1947 tsunami
Description: At the 100 year return time the inundations from the March and May 1947 events can provide a rough guide to the extent of inundation. These scenarios were not modelled, but the historical impacts are well known and provide the best available guide (Wang et al., 2009). The 1947 events did not cause fatalities, but generated run-up heights of up to 10 m and affected 120 km of coastline north of Hawke's Bay. Current research suggests that there may be ~4–6 seamounts at various stages in the process of being subducted off the coast of the Napier/Gisborne region, though it is not known how many of these are currently at a depth where they may cause tsunami-generating earthquakes. One of these is assumed to be the trigger of the tsunami earthquake that caused the March 1947 events, and another is believed to be the cause of the May 1947 tsunami earthquake (Bell et al., 2010; Bell et al., 2014). A possible predecessor of the 1947 tsunami earthquakes occurred in 1880. Hence we assume the return period for similar events to be smaller than 100 years. In the case of such an event the effects on the coast are likely to be similar to those experienced in 1947. A similar length of coast is likely to be affected.
Distant sources
Source: Peru & Central America earthquake MW ≤9.1
Other Pacific Rim earthquake MW ≤9.4
Description:
Gisborne: TIS 4 (TIS 4-5 HT)
Muriwai: TIS 6 (TIS 6 HT)
Wainui: TIS 4 (TIS 4-5 HT)
Gaps: Not simulated for Tolaga Bay, Hicks Bay or Tokomaru Bay</td><td>2

4</td></tr>
</table>

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
Unlikely **ARI 101–1000 years**	**Description** (101–500 years): **Local sources** **Source:** Earthquakes on subduction-zone splay faults (Lachlan, Ariel Bank, Gable End) possibly with slip on the deeper plate interface. Plate interface earthquakes (Raukumara & Hawke's Bay region) MW ≤8.1 **Description:** Ariel Bank Fault: Gisborne: TIS 2-3, Muriwai: TIS 4, Wainui: TIS 2-3 Gable End Fault: Gisborne: TIS 2-3, Muriwai: TIS 3, Wainui: TIS 3 Lachlan Fault: Gisborne: TIS 3, Muriwai: TIS 4, Wainui: TIS 2-3 Lachlan w/Deep Rupture: Gisborne: TIS 5, Muriwai: TIS 6, Wainui: TIS 4 Lachlan w/Deep Rup. (HT): Gisborne: TIS 6, Muriwai: TIS 7, Wainui: TIS 5 Gisborne Segment MW: Gisborne: TIS 4-5, Muriwai: TIS 6, Wainui: TIS 3 GPS Coupling MW: Gisborne: TIS 3, Muriwai: TIS 5, Wainui: TIS 4 (Wang et al., 2009, all of the above)	4
	Distant sources **Source:** Peru earthquake MW ≤9.4 Other Pacific Rim earthquake MW ≤9.5 (no data) **Description:** **Gisborne:** TIS 6 (TIS 6-7 HT) **Muriwai:** TIS 7 (TIS 8 HT) **Wainui:** TIS 5 (TIS 6 HT) At fourteen hours following the earthquake in Peru, waves reach the Eastern Part of the Northern Island. Large inundation is caused in both Tolaga Bay and Hicks Bay from this scenario. Inundation for Tokomaru Bay is much more limited due to protection by high cliffs. (Barberopoulou et al., 2012) Based on the simulations, the first waves cause inundation that is fairly constrained within the East/North East facing beach area and around Uawa and Mangaheia rivers in addition to streams of Uawa River. Within 15 –20 minutes a second wave or train of waves causes extensive flooding that inundates most of the low-lying areas. Simulations appear to suggest approximately six distinct	4

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
	flooding "events" with the fourth being by far the greatest at approximately one hour after the first, followed by two more events. Reflections and refractions due to local bathymetric features and orientation of the source attribute to the characteristics of the flooding in Tolaga Bay. (Barberopoulou et al., 2012) Similar but less prominent flooding events can be identified for Tokomaru Bay although the inundation extent is clearly much smaller than for Tolaga Bay because of the sharp elevation changes with distance from the coast. (Barberopoulou et al., 2012) Flooding in Hicks Bay and Te Araroa also occurs over several "events", with the largest inundation happening during what appears to be the arrival of the third train of waves. Inundation appears to occur approximately to Te Araroa Rd to the south and about 700m inland from the coast to the north and around Wharekahika river. Although variation between the simulation and the actual tsunami event will occur due to variations in source and other factors, it is important to note the duration of the tsunami event during a South America ~Mw 9.0 type of event. Distant tsunami events last generally longer than local and regional events and flooding can happen many times with the largest inundation often occurring after the first wave arrivals. Emergency personnel have to take that into consideration when making evacuation plans. (Barberopoulou et al., 2012) **Review of the Tsunami Hazard in New Zealand (2013 update)** Maximum offshore tsunami heights and magnitude of main local and distance contributing sources, for 500 year return period: Te Araroa: ~ 7.5 m high wave offshore (50th percentile), Peru 9.3, Kmdec 8.95 East Cape: ~ 8.5 m high wave offshore (50th percentile), Peru 9.24, Kmdec 9.01 Port Awanui: ~ 8.2 m high wave offshore (50th percentile), Peru 9.33, Kmdec 8.96 Waipiro Bay: ~ 8.0 m high wave offshore (50th percentile), Peru 9.31, Kmdec 8.97 Tokomaru Bay: ~ 8.85 m high wave offshore (50th percentile), Peru 9.29, Kmdec 9.035 Tolaga Bay: ~ 9.28 m high wave offshore (50th percentile), Peru 9.33,Kmdec 9.02 Waihau Bay: ~ 7.59 m high wave offshore (50th percentile), Peru 9.35, Chile 9.58, Hikur 8.86 Pariokonohi Point: ~ 7.33 m high wave offshore (50th percentile), Peru 9.35, Chile 9.53, Hikur 8.87 Gisborne: ~ 7.53 m high wave offshore (50th percentile), Peru 9.38, Chile 9.52, Hikur 8.76, Hawkes Bay Outer Rise 8.29 Waiparapara: ~ 5.73 m high wave offshore (50th percentile), Peru 9.4, Hikur 8.83, Chile 9.57, Hawkes Bay Outer Rise 8.16 Mahanga Beach: ~ 6.69 m high wave offshore (50th percentile), Peru 9.39, Hikur 8.83, Chile 9.56 (Power 2013) **Gaps:** Tsunami earthquakes larger than March 1947.	4

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
Rare **ARI 1001–2500 years**	**Description** (501 years–2500 years): **Local sources** **Source:** Whole Margin earthquake MW 8.8 **Description:** Gisborne: TIS 6, Muriwai: TIS 7, Wainui: TIS 5 (Wang et al., 2009) **Source:** Whole Margin earthquake MW 9.0 **Description:** Gisborne: TIS 9, Muriwai: TIS 9, Wainui: TIS 8 (Wang et al., 2009) **Source:** Whole Margin earthquake MW 9.0 (HT) **Description:** Gisborne: TIS 9, Muriwai: TIS 10, Wainui: TIS 8 (Wang et al., 2009) The proximity of the Hikurangi source does not allow much time for warnings other than natural-warnings (15–20mins). Flooding of Tolaga Bay happens with the first arrivals, but the tsunami event continues for at least two hours with different levels of flooding from later arrivals due to refractions and reflections from bathymetric features offshore. Flow depths from the Hikurangi source in Tokomaru Bay are quite large and reach 10m. Flooded areas are constrained by high elevation areas and large flow depths are found around the Mangahauini River. Flooding in Hicks Bay and Te Araroa occurs with a larger delay than for Tokomaru and Tolaga Bays. Although the largest inundation occurs with the arrival of the first waves, similar to the other areas, inundation continues to occur for more than 2 hours after the earthquake (Barberopoulou et al., 2012).	4
	Source: Raukumara Outer Rise earthquake MW 8.0 **Description:** Gisborne: TIS 3, Muriwai: TIS 5, Wainui: TIS 8 (Wang et al., 2009) Two Raukumara Outer Rise (Outer Rise and Outer Rise 2) events were considered, because the locations of the outer rise faults are uncertain. One was from a 2009 GDC study (Wang et al., 2009) and the other a modified scenario where the source was placed further north and east of the original one. Tolaga Bay appears to have the largest difference in inundation extent occurring as a result of the change in the source location. Larger inundation occurs from the original source with larger flow depths (4–10m) when compared to the modified Outer Rise. This is probably expected since the modified source is placed further north and away from the coast. Inundation from the two sources is similar for both Tokomaru Bay and Hicks Bay but flow depths are subtly greater for the modified source. In contrast to the distant scenario, Tolaga Bay is flooded with the arrival of the first waves from the source which arrive at about 30 minutes following the rupture. The most striking difference is during the Outer Rise 2 scenario, when flooding occurs not with the arrival of the first waves but with the second train of waves that arrive at about 45 minutes following the first	4

<table>
<tr><th>Likelihood</th><th>Description of Event</th><th>Data Quality Rating (applies to available data only)</th></tr>
<tr><td></td><td>arrivals. Tokomaru and Hicks Bays are located to the north of Tolaga Bay and closer to the Outer Rise 2 source – which is also parallel to the coastline –and that may explain the larger flow depths predicted for those locations. Tokomaru Bay gets small extent of inundation due to local topography with flow depths and inundation distribution probably due to the shape of the bay (i.e., focusing) and reflections within the Bay. The narrow strip of land at low elevation probably explains the large flow depths near the coastline predicted during the Outer Rise scenarios (i.e., constructive interference of waves). Inundation extent is larger for the modified Outer Rise scenario for Hicks Bay. However, flow depths are similar and no larger than about 4m (Barberopoulou et al., 2012).

Regional Sources
Source: Kermadec trench MW 9.1 (no data)
Description: Inundation extent and flow depths for Tolaga Bay from this scenario are considerably smaller than the other scenarios. This is not surprising as most of the energy is directed towards the open Pacific, the South Fiji basin and New Caledonia. The same is also true for the other coastal communities where maximum flow depths are 3–5m and inundation is confined to a smaller area along the coast. For Tokomaru Bay in particular, inundation is fairly limited to a thin strip of land parallel to the coastline (Barberopoulou et al., 2012).

Distant sources
Source: Peru MW ≤9.5 (no data)</td><td>4</td></tr>
<tr><td></td><td>Review of the Tsunami Hazard in New Zealand (2013 update)
Maximum offshore tsunami heights and magnitude of main local and distance contributing sources, for 2,500 year return period:
Te Araroa: ~ 11 m high wave offshore (50th percentile), Peru 9.44, Kmdec 9.3
East Cape: ~ 13.24 m high wave offshore (50th percentile), 9.38, Kmdec 9.23
Port Awanui: ~ 12.24 m high wave offshore (50th percentile), Peru 9.45, Kmdec 9.14
Waipiro Bay: ~ 12.16 m high wave offshore (50th percentile), Peru 9.45, Kmdec 9.12
Tokomaru Bay: ~ 13.28 m high wave offshore (50th percentile), Peru 9.42, Kmdec 9.19
Tolaga Bay: ~ 13.80 m high wave offshore (50th percentile), Peru 9.47, Kmdec 9.28, Hikur 9.04
Waihau Bay: ~ 11.32 m high wave offshore (50th percentile), Peru 9.5, Hikur 9.03, Kmdec 9.42
Pariokonohi Point: ~ 10.92 m high wave offshore (50th percentile), Peru 9.49, Hikur 9.03, Chile 9.66
Gisborne: ~ 11.05 m high wave offshore (50th percentile), Peru 9.51, Hikur 8.94, Chile 9.66</td><td>4</td></tr>
</table>

Likelihood	Description of Event	Data Quality Rating (applies to available data only)
	Waiparapara: ~ 8.56 m high wave offshore (50th percentile), Peru 9.56, Hikur 8.98, Chile 9.71 Mahanga Beach): ~ 9.77 m high wave offshore (50th percentile), Peru 9.54, Hikur 8.98, Hawkes Bay Outer Rise 8.38 (Power 2013) **Gaps:** Landslide sources, Plate interface earthquakes (Raukumara & Hawke's Bay region) MW ≤8.5, Whole margin ruptures MW ≤9.0 (Wang et al., 2009)	
Very rare **ARI >2500 years**	**Description:** The Ruatoria Debris Avalanche is dated at 170 ± 40 thousand years before present (Collot et al., 2001). The volume of this submarine avalanche is estimated at 3150 ± 630 km^3. The tsunami consequences of such an event would probably be totally devastating for all Gisborne coastal communities. The ARI of similar events is likely to be very large, measured in 100s of thousands of years. **Gaps:** The likelihood and consequences of tsunami caused by smaller landslides such as the Paritu Debris Avalanche (7.6 ± 0.6 thousand years BP, ~30 km^3; Mountjoy and Micallef, 2012) are not well known.	1

Tsunami Intensity Scale

The tsunami intensity scale proposed by Papadopoulos and Imamura (2001) incorporates twelve divisions (PI scale 1~12), consistent with the twelve-grade seismic intensity scales. The scale is arranged according to (a) the effects on humans, (b) the effects on objects, including vessels of variable size, and on nature, and (c) damage to buildings.

1. Not felt
   - Not felt even under the most favourable circumstances.
   - No effect on objects
   - No damage to buildings
2. Scarcely felt
   - Felt by few people on board small vessels. Not observed on the coast.
   - No effect on objects
   - No damage to buildings
3. Weak
   - Felt by most people onboard small vessels. Observed by few people on the coast.
   - No effect on objects
   - No damage to buildings
4. Largely observed
   - Felt by all onboard small vessels and by a few people onboard large vessels. Observed by most people on the coast.
   - A few small vessels move slightly onshore.
   - No damage to buildings
5. Strong
   - Felt by all onboard large vessels and observed by all on the coast. A few people are frightened and run to higher ground.
   - Many small vessels move strongly onshore, a few of them crash each other or overturn. Traces of sand layer are left behind on ground with favourable conditions. Limited flooding of cultivated land.
   - Limited flooding of outdoors facilities (e.g., gardens) of near-shore structures.
6. Slightly damaging
   - Many people are frightened and run to higher ground.
   - Most small vessels move violently onshore, or crash strongly into each other, or overturn.
   - Damage and flooding in a few wooden structures. Most masonry buildings withstand.
7. Damaging
   - Most people are frightened and try to run to higher ground.

- Many small vessels damaged. A few large vessels oscillate violently. Objects of variable size and stability overturn and drift. Sand layers and accumulations of pebbles are left behind. A few aquaculture rafts washed away.
- Many wooden structures damaged, a few are demolished or washed away. Damage of grade 1 and flooding in a few masonry buildings.

8. Heavily damaging
   - Nearly all people escape to higher ground, a few people are washed away.
   - Most small vessels are damaged, many are washed away. A few large vessels are moved ashore or crash into each other. Big objects are drifted away. Erosion and littering in the beach. Extensive flooding. Slight damage in tsunami control forest and stop drifts. Many aquaculture rafts washed away, a few are partially damaged.
   - Most wooden structures are washed away or demolished. Damage of grade 2 in a few masonry buildings. Most RC buildings sustain damage, in a few damage of grade 1 and flooding is observed.
9. Destructive
   - Many people are washed away.
   - Most small vessels are destroyed or washed away. Many large vessels are moved violently ashore, a few are destructed. Extensive erosion and littering of the beach. Local ground subsidence. Partial destruction in tsunami control forest and stop drifts. Most aquaculture rafts washed away, many partially damaged.
   - Damage of grade 3 in many masonry buildings, a few RC buildings suffer from damage grade 2.
10. Very destructive
    - General panic. Most people are washed away.
    - Most large vessels are moved violently ashore, many are destroyed or collide with buildings. Small boulders from the sea bottom are moved inland. Cars overturned and drifted. Oil spills occur, fires start. Extensive ground erosion.
    - Damage of grade 4 in many masonry buildings, a few RC buildings suffer from damage grade 3. Artificial embankments collapse, port breakwaters damaged.
11. Devastating
    - Lifelines interrupted. Extensive fires. Water backwash drifts cars and other objects in the sea. Big boulders from the sea bottom are moved inland.
    - Damage of grade 5 in many masonry buildings. A few RC buildings suffer from damage grade 4, many suffer from damage grade 3.
12. Completely devastating
    - Practically all masonry buildings demolished. Most RC buildings suffer from at least damage grade 3.

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A3.12.2 Consequence Description: Tsunami

A3.12.2.1 Overview

This consequence description is based on the corresponding tsunami hazard description, and the asset inventories created in the ‘context’ section of this project.

Detailed tsunami inundation models were developed for GDC in 2009 by Wang et al. (2009). Through the current project, these models have been processed and developed into a RiskScape hazard module. The RiskScape hazard module contains 18 tsunami scenarios from near and distant tsunami sources. The region covered in the models is centred on Gisborne city, and extends from Muriwai in the south to just north of Wainui. These modules have contributed to the consequence descriptions in the following table.

<table>
<tr><th>Likelihood</th><th>Description of Health-Safety Consequences</th><th>Data Quality Rating (applies to available data only)</th><th>Description of Built Environment and Property Consequences</th><th>Data Quality Rating (applies to available data only)</th></tr>
<tr><td>Likely
ARI 0–50 years</td><td>Existing tsunami information is based on an ARI of 100 years or less. Therefore, tsunami consequence information is recorded in the 51–100 year ARI row (see below).</td><td></td><td>Existing tsunami information is based on an ARI of 100 years or less. Therefore, tsunami consequence information is recorded in the 51–100 year ARI row (see below).</td><td></td></tr>
<tr><td>Possible
ARI 51–100 years</td><td>Description:
Local Tsunami: The two 1947 tsunami generated by local earthquakes provide direct experience of a tsunami at this ARI. See description beside for details of the tsunami event.
March 1947 Health-Safety consequences:
Five people in the cottage survived the tsunami, three trapped within the one room that remained intact, and two by running inland when the first wave was observed.
The human consequences from the 1947 events were minor compared to what could happen today with many more people living, working and undertaking activities near the coast. The fatality rate (% of people that will die if caught in the tsunami) for tsunami inundation depths observed during the 1947 Gisborne tsunamis is 10–30%. With a time of approximately 30 minutes between the earthquake and the first tsunami wave, the amount of casualties will be highly dependent on the proportion of people who immediately start evacuating.
Distant Tsunami: A distant tsunami has the potential to cause loss of life at this ARI. However, the time between the earthquake and tsunami would be on the order of 20+ hours. The following table shows casualty consequences from a M9.1 from Peru at high tide.
<table>
<tr><th>Suburb</th><th>Light</th><th>Moderate</th><th>Serious</th><th>Critical</th><th>Dead</th></tr>
<tr><td>Wainui</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Gisborne City</td><td>1–10</td><td>10–100</td><td>1–10</td><td>1–10</td><td>10–100</td></tr>
<tr><td>Tiniroto</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Lower Waipaoa</td><td>0</td><td>1–10</td><td>1–10</td><td>0</td><td>0</td></tr>
</table>
Gaps: There is no modelling for the local 1947 tsunami so the consequences based on the current population cannot be determined.
The modelling for the consequences for all tsunami assumes no evacuation and a night-time population (i.e., the population is in their place of residence).
The tsunami hazard modelling has only been undertaken for the region between Muriwai and Wainui. The only hazard information outside this area is from the review of tsunami hazard in New Zealand update (2013). This information is wave heights at the coast and as such no consequence modelling can be undertaken. However, a large proportion of the coastal population are within the modelled area.</td><td>2</td><td>Description:
Local Tsunami: The two 1947 tsunami generated by local earthquakes provide direct experience of a tsunami at this ARI.
The MW 7.0–7.1 earthquake that occurred offshore Poverty Bay on 26 March 1947, 8:32 am (NZST) was identified as a "tsunami earthquake" and generated one of the largest tsunami in New Zealand's historical record.
Although the earthquake itself caused no damage, the tsunami caused damage to beachside cottages and buildings, bridges, fences and roads. The tsunami was observed along 115km of coastline from Mahia Peninsula to Tokomaru Bay, probably at Waitangi, and possibly at Tuapeka, in the Chatham Islands.
The tsunami occurred less than half an hour before high tide (at Gisborne), which was about the level of mean high water spring tide, and hence its effects were at their maximum.
At Tatapouri Point, Pouawa and the south side of Turihaua Point, where the tsunami was most pronounced, large breaking waves said to be 10–13m high were observed offshore. At the northern end of Pouawa Beach, where seaweed was found 12m above sea-level in telegraph wires well inland from the beach, and the decking and superstructure of a 16m span wooden bridge across the Pouawa River was swept about 800m inland, indicate a water height at the maximum inundation limit of about 10m. At the southern end of the beach, where the water height at the maximum inundation limit was possibly 6–8m, three rooms of a 4-roomed cottage were demolished and the building swept from its foundation.
Another tsunami occurred in 1947, caused by the 17 May 1947 M_w 6.9–7.1 offshore Tolaga Bay earthquake. The tsunami was not well observed, as it occurred on a stormy winter night about half an hour after the earthquake, which was at 7:06 pm (about 1.5 hours before low tide). Nevertheless, its effects (damage, debris and inland water penetration) were noticeable the next day from Wainui Beach, near Gisborne, to at least Tolaga Bay, and possibly as far as Tokomaru Bay, spanning 50–80km of coastline.
The greatest damage and height reached above sea level at the time (~6m) was at Waihau Beach, where logs piled ready to repair the bridge damaged in the tsunami two months previously were washed away. Here, the sea penetrated 400m inland up a creek, further inland and to a higher level than in the March tsunami. Water swept 50m inland at Tolaga Bay and the water height was estimated to be 1.8–2.4m higher than in the 26 March event. Taking the tide level into account suggests the waves may have reached 4–5m above sea level at the time.</td><td>2</td></tr>
</table>

<table>
<tr><th>Likelihood</th><th>Description of Health-Safety Consequences</th><th>Data Quality Rating
(applies to available data only)</th><th>Description of Built Environment and Property Consequences</th><th>Data Quality Rating
(applies to available data only)</th></tr>
<tr><td></td><td></td><td></td><td>
Distant Tsunami:
The following table shows costs associated with a M9.1 from Peru at high tide.
<table>
<tr><th>Suburb</th><th>Asset Repair Cost($)</th><th>Contents Repair Cost($)</th><th>Cleanup Cost($)</th></tr>
<tr><td>Wainui</td><td>$0</td><td>$0</td><td>$0</td></tr>
<tr><td>Gisborne City</td><td>$19,100,000</td><td>$9,100,000</td><td>$1,500,000</td></tr>
<tr><td>Tiniroto</td><td>$0</td><td>$0</td><td>$0</td></tr>
<tr><td>Lower Waipaoa</td><td>$200,000</td><td>$200,000</td><td>$0</td></tr>
<tr><td>Total</td><td>$19,300,000</td><td>$9,300,000</td><td>$1,600,000</td></tr>
</table>
Gaps: There is no modelling for the local 1947 tsunami so the consequences based on the current built environment cannot be determined.
The modelling for the consequences for all tsunami assumes no evacuation and a night-time population (i.e., the population is in their place of residence).
The tsunami hazard modelling has only been undertaken for the region between Muriwai and Wainui. The only hazard information outside this area is from the review of tsunami hazard in New Zealand update (2013). This information is wave heights at the coast and as such no consequence modelling can be undertaken. However, a large proportion of the coastal population are within the modelled area.
</td><td></td></tr>
<tr><td>Unlikely
ARI 101–1000 years</td><td>
Description:
Local Tsunami: The following table shows casualties from a local source on the Lachlan Fault at high tide.
<table>
<tr><th>Suburb</th><th>Light</th><th>Moderate</th><th>Serious</th><th>Critical</th><th>Dead</th></tr>
<tr><td>Wainui</td><td>0</td><td>1–10</td><td>1–10</td><td>0</td><td>0</td></tr>
<tr><td>Gisborne City</td><td>1–10</td><td>100–1000</td><td>10–100</td><td>10–100</td><td>10–100</td></tr>
<tr><td>Tiniroto</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Lower Waipaoa</td><td>0</td><td>10–100</td><td>0</td><td>0</td><td>1–10</td></tr>
</table>
Distant Tsunami:
The following table shows casualties for a M9.4 from Peru at high tide.
<table>
<tr><th>Suburb</th><th>Light</th><th>Moderate</th><th>Serious</th><th>Critical</th><th>Dead</th></tr>
<tr><td>Wainui</td><td>0</td><td>1–10</td><td>0</td><td>0</td><td>1–10</td></tr>
<tr><td>Gisborne City</td><td>1–10</td><td>100–1000</td><td>10–100</td><td>10–100</td><td>10–100</td></tr>
<tr><td>Tiniroto</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Lower Waipaoa</td><td>1–10</td><td>1–10</td><td>1–10</td><td>1–10</td><td>1–10</td></tr>
</table>
</td><td>4</td><td>
Description:
Local Tsunami: The following table shows associated costs from a local source on the Lachlan Fault at high tide.
<table>
<tr><th>Suburb</th><th>Asset Repair Cost($)</th><th>Contents Repair Cost($)</th><th>Cleanup Cost($)</th></tr>
<tr><td>Wainui</td><td>$200,000</td><td>$200,000</td><td>$0</td></tr>
<tr><td>Gisborne City</td><td>$101,500,000</td><td>$66,600,000</td><td>$4,600,000</td></tr>
<tr><td>Tiniroto</td><td>$0</td><td>$0</td><td>$0</td></tr>
<tr><td>Lower Waipaoa</td><td>$2,900,000</td><td>$600,000</td><td>$200,000</td></tr>
<tr><td>Total</td><td>$104,600,000</td><td>$67,400,000</td><td>$4,800,000</td></tr>
</table>
Distant Tsunami: The following table shows associated costs for a M9.4 from Peru at high tide.
<table>
<tr><th>Suburb</th><th>Asset Repair Cost($)</th><th>Contents Repair Cost($)</th><th>Cleanup Cost($)</th></tr>
<tr><td>Wainui</td><td>$1,300,000</td><td>$200,000</td><td>$200,000</td></tr>
<tr><td>Gisborne City</td><td>$292,900,000</td><td>$187,000,000</td><td>$12,000,000</td></tr>
<tr><td>Tiniroto</td><td>$0</td><td>$0</td><td>$0</td></tr>
<tr><td>Lower Waipaoa</td><td>$25,100,000</td><td>$15,300,000</td><td>$1,200,000</td></tr>
<tr><td>Total</td><td>$319,300,000</td><td>$202,500,000</td><td>$13,400,000</td></tr>
</table>
</td><td>4</td></tr>
</table>

<table>
<tr><th>Likelihood</th><th>Description of Health-Safety Consequences</th><th>Data Quality Rating (applies to available data only)</th><th>Description of Built Environment and Property Consequences</th><th>Data Quality Rating (applies to available data only)</th></tr>
<tr><td></td><td>Gaps: The modelling for the consequences for all tsunami assumes no evacuation and a night-time population (i.e., the population is in their place of residence).
The tsunami hazard modelling has only been undertaken for the region between Muriwai and Wainui. The only hazard information outside this area is from the review of tsunami hazard in New Zealand update (2013). This information is wave heights at the coast and as such no consequence modelling can be undertaken.</td><td></td><td>Gaps: The modelling for the consequences for all tsunami assumes no evacuation and a night-time population (i.e., the population is in their place of residence).
The tsunami hazard modelling has only been undertaken for the region between Muriwai and Wainui. The only hazard information outside this area is from the review of tsunami hazard in New Zealand update (2013). This information is wave heights at the coast and as such no consequence modelling can be undertaken. However, a large proportion of the coastal population are within the modelled area.</td><td></td></tr>
<tr><td>Rare
ARI 1001–2500 years</td><td>Description:
Local Tsunami: The following table shows casualties for a M9.0 along the Hikurangi margin at high tide.
<table>
<tr><th>Suburb</th><th>Light</th><th>Moderate</th><th>Serious</th><th>Critical</th><th>Dead</th></tr>
<tr><td>Wainui</td><td>1–10</td><td>100–1000</td><td>1–10</td><td>1–10</td><td>100–1000</td></tr>
<tr><td>Gisborne City</td><td>1–10</td><td>1000–10000</td><td>10–100</td><td>10–100</td><td>100–1000</td></tr>
<tr><td>Tiniroto</td><td>1–10</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Lower Waipaoa</td><td>1–10</td><td>1–10</td><td>1–10</td><td>1–10</td><td>1–10</td></tr>
</table>
Distant Tsunami: The consequences from distant source tsunami at this ARI will be similar to above.
Gaps: The modelling for the consequences for all tsunami assumes no evacuation and a night-time population (i.e., the population is in their place of residence).
The tsunami hazard modelling has only been undertaken for the region between Muriwai and Wainui. The only hazard information outside this area is from the review of tsunami hazard in New Zealand update (2013). This information is wave heights at the coast and as such no consequence modelling can be undertaken. However, a large proportion of the coastal population are within the modelled area.</td><td>4</td><td>Description:
Local Tsunami: The following table shows associated costs for a M9.0 along the Hikurangi margin at high tide.
<table>
<tr><th>Suburb</th><th>Asset Repair Cost($)</th><th>Contents Repair Cost($)</th><th>Cleanup Cost($)</th></tr>
<tr><td>Wainui</td><td>$40,300,000</td><td>$13,000,000</td><td>$2,300,000</td></tr>
<tr><td>Gisborne City</td><td>$371,300,000</td><td>$298,700,000</td><td>$14,200,000</td></tr>
<tr><td>Tiniroto</td><td>$0</td><td>$0</td><td>$0</td></tr>
<tr><td>Lower Waipaoa</td><td>$25,500,000</td><td>$21,200,000</td><td>$1,100,000</td></tr>
<tr><td>Total</td><td>$437,100,000</td><td>$332,900,000</td><td>$17,600,000</td></tr>
</table>
Distant Tsunami: The consequences from distant source tsunami at this ARI will be similar to above.
Gaps: The modelling for the consequences for all tsunami assumes no evacuation and a night-time population (i.e., the population is in their place of residence).
The tsunami hazard modelling has only been undertaken for the region between Muriwai and Wainui. The only hazard information outside this area is from the review of tsunami hazard in New Zealand update (2013). This information is wave heights at the coast and as such no consequence modelling can be undertaken. However, a large proportion of the coastal population are within the modelled area.</td><td>4</td></tr>
<tr><td>Very rare
ARI >2500 years</td><td>Description:
Local Tsunami: The tsunami consequences of such an event would probably be totally devastating for all Gisborne coastal communities. There would mass fatalities for all coastal communities.
Distant Tsunami: The consequences from distant source tsunami at this ARI will be similar to above.
Gaps: There is no modelling of such a local event and therefore the consequences are not well constrained. Although, due to the potential size of such an event, there will be near total destruction.</td><td>1

4</td><td>Description:
Local Tsunami: The tsunami consequences of such an event would probably be totally devastating for all Gisborne coastal communities. There would mass fatalities for all coastal communities.
Distant Tsunami: The tsunami consequences of such an event would probably be totally devastating for all Gisborne coastal communities. There would be wide spread destruction of most coastal communities.
Gaps: There is no modelling of such a local event and therefore the consequences are not well constrained. Although, due to the potential size of such an event, there will be near total destruction.</td><td>1

4</td></tr>
</table>

References

http://info.geonet.org.nz/display/tsunami/Gisborne+tsunami,+25+March+and+17+May+1947

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