Auckland's Exposure to Sea Level Rise: Part 1 – Regional Inventory

Nancy E Golubiewski, Kyle Balderston, Chad Hu and Jamie Boyle

March 2019 Technical Report 2019/017

RIMU Research and Evaluation Unit

Auckland Council
Te Kaunihera o Tāmaki Makaurau

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Climate Change Risk Assessment series 2019

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Climate Change Risk Assessment 2019

As communities across the world set out to plan for climate change mitigation and adaptation, they first seek to understand how climate change will affect their city, region, or country.

The Climate Change Risk Assessment (CCRA) has been produced by Auckland Council's Research and Evaluation Unit (RIMU) in support of the Auckland Climate Action Plan (ACAP), at the request of the Chief Sustainability Office. Its aim is to provide information about the risk and vulnerabilities the Auckland region may face under a changing climate regime, which is already underway. In 2018, national climate change projections were scaled-down to produce a more specific picture of their likely effects within the Auckland region. Based on this, CCRA adopted the Intergovernmental Panel on Climate Change's (IPCC) representative concentration pathway (RCP) 8.5 ("business as usual") scenario as its guiding projection, given the lack of evidence of any meaningful and sustained decreases in emissions that would shift to other projection pathways.

The eight reports in the CCRA consider various components of key risks – that is, hazard, exposure, and vulnerability – across sectors and systems of interest: people (heat vulnerability, climate change and air quality), society (social vulnerability and flooding), and natural environment (terrestrial and marine ecosystems), as well sea level rise at regional and local scales. A summary report has also been produced.

Titles in the Climate Change Risk Assessment series:

An assessment of vulnerability to climate change in Auckland
Fernandez, M. A. and N. E. Golubiewski (2019)

Development of the Auckland Heat Vulnerability Index
Joynt, J. L. R. and N. E. Golubiewski (2019)

Air quality and societal impacts from predicted climate change in Auckland
Talbot, N. (2019)

Climate change risk assessment for terrestrial species and ecosystems in the Auckland region
Bishop, C. D. and T. J. Landers (2019)

Climate change risk assessment for Auckland's marine and freshwater ecosystems
Foley, M. M. and M. Carbines (2019)

Flood risk in a changing climate: A combination of hazard, exposure and vulnerability
Golubiewski, N. E., J. L. R. Joynt and K. Balderston (2019)

Auckland's exposure to sea level rise: Part 1 – Regional inventory
Golubiewski, N. E., K. Balderston, C. Hu and J. Boyle (2019)

Auckland's exposure to sea level rise: Part 2 – Local inventory (forthcoming)
Boyle, J., N. E. Golubiewski, K. Balderston and C. Hu (2019)

Summary: *Climate change risks in Auckland*
Auckland Council (2019). Prepared by Arup for Auckland Council

Executive summary

The regional sea level rise inventory assesses Auckland's potential exposure to sea level rise and coastal inundation. To do so, it uses both land elevation bands as a proxy for a series of sea level rise (SLR) scenarios and coastal inundation models to consider extreme storm events under present and future regimes. The two approaches permit a simultaneous consideration of changing coastlines as a result of sea-level rise (an altered environment) and extreme events.

Presented as a data compendium, this report catalogues the spatial intersection of various entities of interest with the elevation band/sea level rise and coastal inundation models; potential exposure is simply defined as two-dimensional co-location. This information can be used to inform and guide work programmes and research projects that seek to address and understand more about the implications, vulnerabilities and total risk that arise from this current and ongoing component of climate change.

Key findings from the data summaries that follow include:

- Approximately 1.5%-4.5% of Auckland's land area sits in low-lying coastal areas that could be exposed to SLR ranging from 0.25 m to 3 m.
- Over the last decade population grew faster in the areas exposed to sea level rise than in the region overall; approximately 3% of Auckland's population is estimated to be in low-lying areas affected by the SLR and coastal inundation scenarios used in this report.
- Mangroves are the most exposed ecosystem type in terms of both area and proportion. Substantial proportions of coastal ecosystems are increasingly affected with projected sea level rises through the 21st century. Some indigenous coastal and scrub forests are somewhat exposed to SLR and inundation, whereas other indigenous scrub (such as kanuka and manuka) and tall forests (such as kauri and tawa) are mostly located inland and are therefore less affected by sea level rise and coastal inundation.
- In addition to the coastal ecosystems that would be exposed, the land cover category with the largest area potentially exposed to SLR is high-producing grassland. Likewise, the land use most exposed in terms of area is rural industry.
- Prime soils are the most exposed of the land use capability (LUC) classes across all sea level rise scenarios, and elite/prime soils are disproportionately exposed.
- The exposure of buildings to SLR and coastal inundation is different between the urban and rural parts of the region. Higher numbers and proportions of buildings could be exposed in rural areas than in the urban core and periphery through 1 m of SLR. However, under larger SLR scenarios and coastal inundation combined with

SLR, the number of buildings exposed is greater in the urban core and periphery than in outlying rural areas.

In contrast to the gradually changing coastline that will result from sea level rise, coastal inundation occurs as an acute event. Thus, the nature of a storm event is distinct from ongoing sea level rise. In addition, the definition of the same magnitude storm event will have decreased (becoming more common) by the end of the century when 1 m SLR is projected to occur. With this in mind, the areas exposed to coastal inundation under both current and sea level rise conditions are similar to those of 1 m and greater sea level rise scenarios. That is, inundation impacts will affect larger areas sooner than sea level rise alone.

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1.0 Introduction

1.1 Purpose

Sea level rise (SLR) is a recognised consequence of climate change. It is part of Auckland's present and future. Sea level at the Port of Auckland has risen 1.60 mm (±0.08) per year since the early 20th century (Pearce et al. 2018). Sea level rise has accelerated in recent years and is projected to continue to do so (Pearce et al. 2018).

Sea level rise will affect Auckland as changes to the coastline as well as through episodic events. Rising mean sea levels will result in new land/sea boundaries at higher elevations, progressively creeping landward. In addition, present-day high tide levels will be exceeded more frequently under sea level rise regimes (Pearce et al. 2018), and extreme storm events will inundate further inland.

Auckland Council's Research and Evaluation Unit (RIMU) has undertaken an assessment of climate change impacts and risks to understand the region's exposure to climate change and to support the development of the Auckland Climate Action Plan (Golubiewski et al. 2018). To do so, the Climate Change Risk Assessment (CCRA) programme focuses on NIWA's Auckland projections for the IPCC's Business as Usual scenario (RCP 8.5 83rd percentile) (Pearce et al. 2018) as a conservative approach. In the absence of meaningful decreases in Auckland's, New Zealand's, or global emissions (IPCC 2018), the CCRA endeavours to understand potential impacts of climate change given current trajectories.

The sea level rise inventory is one component of the CCRA programme, and it is made up of two parts. This compendium presents information about how the Auckland region as a whole may be affected by sea level rise across a range of sectors, including land and ecosystems, land use, and infrastructure. This is done by looking at the land areas and assets exposed to SLR and coastal inundation in modelled scenarios. The second part considers local scale exposure (Boyle et al. 2019).

1.2 Approach

Sea level rise was examined via two separate modelling approaches to understand both the potential consequences of changing coastlines due to SLR (a "strain event") and coastal inundation coupled with SLR scenarios ("shock events").

For the first, land elevation bands above the mean high water springs (MHWS-10) tidal water level (Bell et al. 2015) served as a proxy for sea level rise scenarios

(Figure 1). The elevation bands can be interpreted as exposed to "combinations of coastal-hazard processes and SLR" (Bell et al. 2015). Their correspondence to sea level rise increments (Bell et al. 2015) with estimated timing of occurrence under the business as usual (RCP 8.5 83rd percentile) scenario for the Auckland region are (Pearce et al. 2018):

- 0.25 m MHWS + 0.25 m SLR[1] (projected to occur by ~2045)[2]
- 0.50 m MHWS + 0.50 m SLR (projected to occur by 2060)[3]
- 1.0 m MHWS + 1.0 m SLR (projected to occur by 2100)[4]
- 2.0 m MHWS + 2.0 m SLR (projected to occur by ~2160)
- 3.0 m MHWS + 1 m SLR + 1 m storm surge + 1 m wave run up OR MHWS + 2 m SLR + 1 m storm surge

In the following tables, these scenarios are referenced as SLR_0.25m, SLR_0.50m, SLR_1m, SLR_2m, and SLR_3m, respectively.

Although sea level rise of 3.0m is not currently projected to occur this century or next, the elevation band also gives an indication of storm surges combined with SLR. Examining this elevation band also offers insight on an outer envelope of exposed areas should SLR accelerate beyond current projections, resulting in the earlier arrival of each SLR milestone (IPCC 2018). Thus, acknowledging the precautionary principle, the full range of scenarios was used. At the same time, it should be noted that this approach is used as a proxy to understand future coastal hazard exposure and, as such, is a general assessment; it should not be used for specific planning purposes or property assessments.

In order to understand changing coastal inundation dynamics, models using the combination of storm tide, wave setup and sea level rise developed specifically for Auckland were used (i.e., the 2016 update of 2013 NIWA models (Sections 1 and 2 of Stephens et al. 2016), as provided by N Carpenter and M Hernandez, Auckland Council, 11 April 2018). Stephens et al. (2016) define storm tide as the extreme water levels observed during storm events, adding storm surge (inverse barometric pressure effects and wind piling water levels up against the coast), tide and mean

[1] Equivalent to a permanent change in MHWS levels reached on a fortnightly or monthly basis (Bell et al. 2015)

[2] All dates in the list denote the year achieved for RCP 8.5 (83rd percentile) (Pearce et al. 2018). Some present-day king tides can reach 0.25 m above MHWS, thus providing an indication of future daily high tides.

[3] or MHWS + 0.5 m storm surge (Bell et al. 2015)

[4] or MHWS + 1 m storm surge/wave runup (Bell et al. 2015)

sea-level anomaly together. Wave setup is the increase in water levels occurring due to breaking waves in the surf zone.

The original NIWA 2013 models were improved by Stephens et al. (2016) with 2016 data to address two key updates: 1) small east coast estuaries values to reflect outcomes identified in the Auckland Unitary Plan hearings process, and 2) Kaipara harbour and Parakai values to reflect newer tide gauge information[5] (K. Williams, *personal communication*, January-March 2018, N. Carpenter, *personal communication*, 14 March 2018). Only the first update was incorporated into the 2016 model update, which was completed in 2018 and both made available for this project (N. Carpenter, *personal communication*, 14 March 2018 and 18 March 2019) and published to the Geomaps website as a public data set (https://geomapspublic.aucklandcouncil.govt.nz/viewer/index.html).

The ARI 100 models were used in this inventory: these are storms having a 1% probability of occurrence in any given year, known as a 1% annual exceedance probability (AEP). These are also referred to as "1 in 100-year storms" or those with a 100-year annual return interval (ARI). The three scenarios used are:

- 100 year ARI coastal inundation from a current 1% AEP event
- 100 year ARI + 1m SLR coastal inundation from a 1% AEP event under 1 m SLR regime
- 100 year ARI + 2m SLR coastal inundation from a 1% AEP event under 2 m SLR regime

In the following tables, these scenarios are referenced as ARI100, ARI100_SLR1m, and ARI100_SLR2m, respectively.

These coastal inundation scenarios do not cover the entire Auckland region (Figure 2). The coastal inundation scenarios do not include outlying islands in the Hauraki Gulf in the northeast of the Auckland region, including Great Barrier Island, so the total land area for these scenarios is less than the region as a whole, and therefore the area exposed to coastal inundation is underestimated in each scenario given the absence of these islands. For this reason, the results of the two sea level rise approaches are not directly comparable.

[5]According to Jon Clarke on behalf of Auckland Council's Engineering and Technical Services, "Point 2 is still undergoing changes due to issues in the accuracy of the LiDAR and it is also likely that a project will be underway shortly to remap all coastal inundation mapping to the more recent 2016[-18] (*sic*) LiDAR" (J. Clarke, *personal communication* (*reviewer feedback)*, 28 February 2019. See Summary (Section 7.0) for further discussion.

In contrast to the changing background environmental conditions that will result from sea level rise, coastal inundation occurs as an acute event. Thus, the nature of an extreme storm event is distinct from ongoing sea level rise. In addition, the definition of the same magnitude storm event will have decreased (becoming more common) by the end of the century when 1 m SLR is projected to occur. With this in mind, the areas exposed to coastal inundation under both current and sea level rise conditions are similar to those of 1 m and greater sea level rise scenarios. This consideration is more likely, especially when inundation events are coupled with king tides (the highest tides that occur over the year). As such, coastal inundation impacts will affect larger areas sooner than sea level rise alone.

These sea level rise scenarios were analysed at two scales for Auckland – namely the regional and local scales. Accordingly, the inventory of sea level rise in Auckland will be presented in two reports:

- Part 1 considers sea level rise exposure across the Auckland region as a whole (this report).
- Part 2 considers SLR exposure at the local scale in coastal units.

This regional sea level rise inventory is presented as a data compendium, examining the *potential exposure* (Appendix D) of a variety of sectors to sea level rise; in most cases this was defined simply as the horizontal intersection of entities of interest with the various scenarios (no vertical analysis to consider the depth of inundation against a particular entity was undertaken). In the sections that follow, components of five main sectors are examined: regional summary, terrestrial (land) systems, land use, buildings and facilities, and infrastructure. Some data were first compiled for a national study of the exposure of local government-owned assets to sea level rise (Simonson and Hall 2019), and these were further developed for this inventory in consultation with asset and data owners, including three waters infrastructure (Section 6.2), transport (Section 6.1), community facilities (Section 5.2), council greenspace (Section 4.4), and landfills (section 5.4). In this regional sea-level rise inventory, for each specific component examined, the entity assessed is described, the data used and exposure assessment are explained, and three key messages are provided, complemented by a summary section reviewing the exposure data overall. This text is followed by the data tables of the component's exposure to both the SLR and coastal inundation scenarios. Data are presented in full for the reader to peruse.

Figure 1: Exposure of Auckland to sea level rise scenarios based on elevation bands

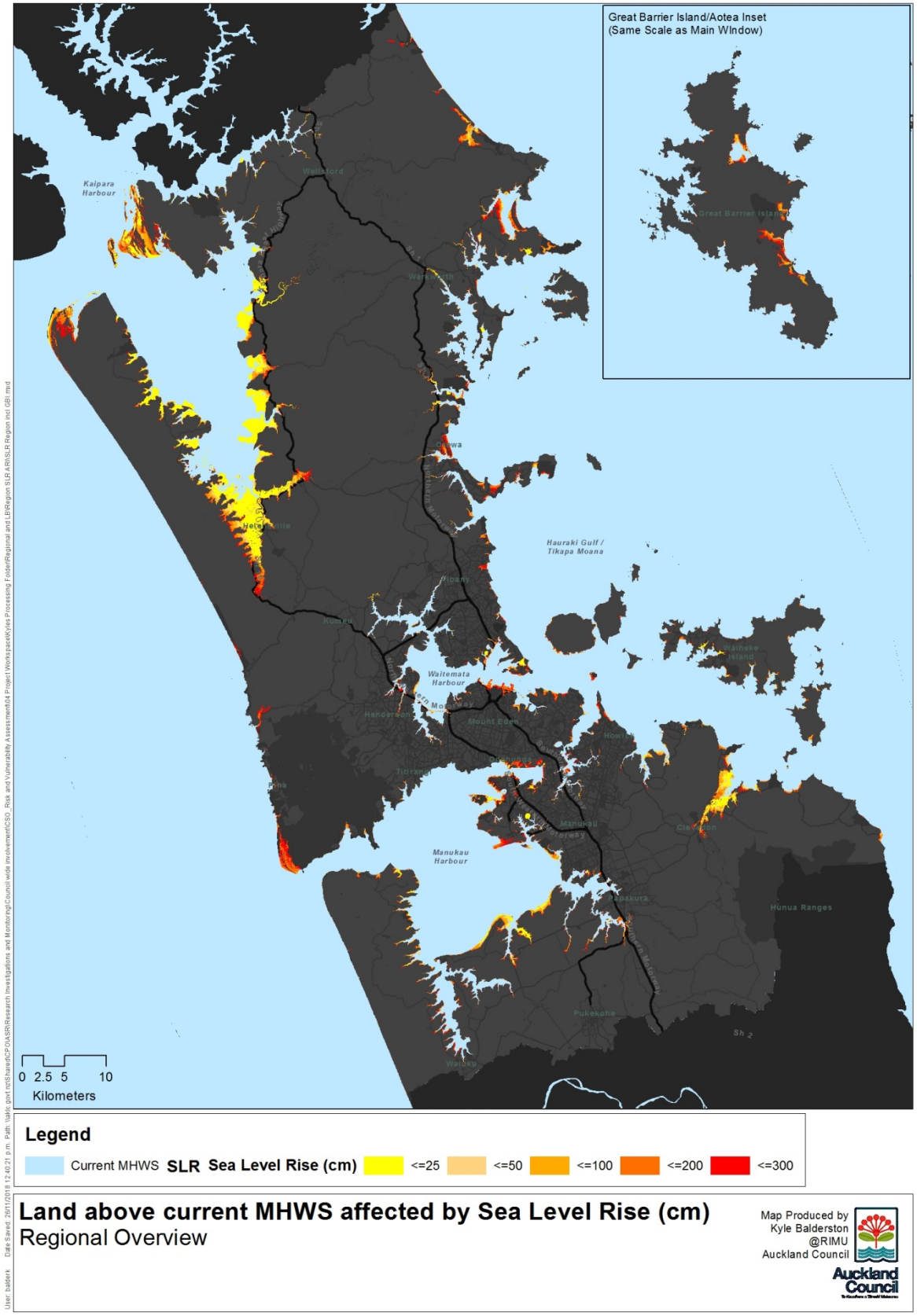
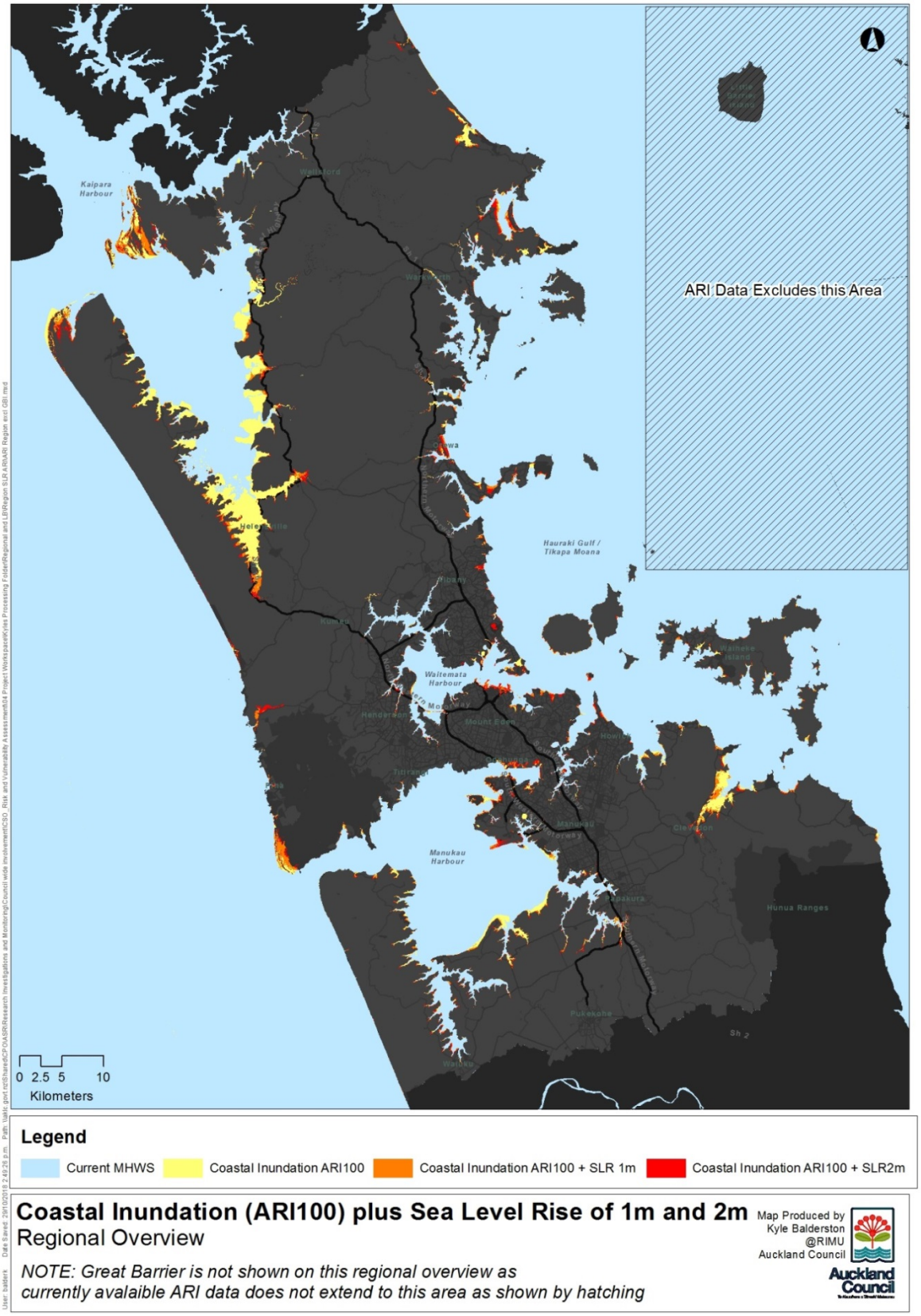


Figure 2: Exposure of Auckland to coastal inundation



2.0 Regional Exposure to Sea Level Rise

With over 3200 km of coastline, the Auckland region is well-exposed to the sea. The central city sits on an isthmus, positioned between two harbours. Constrained by both western and eastern coasts, the expanding metropolitan area extends in every landward direction from the CBD, other centres that ring the region, and outlying rural settlements.

In this section, the exposure of the Auckland region to SLR is summarised in terms of:

- Territory (land)
- Population.

2.1 Territory

What this measures:

The area of Auckland's land projected to be exposed to sea level rise is quantified. The land boundary is defined as the level of mean high water springs (MHWS-10), which would be exceeded by 10% of predicted tides in any given year. It is considered a practical measure of the current natural land-sea boundary.

Which data were used:

As the most recent MHWS line available in Auckland Council's GIS, the Coast Boundary MHWS-10 (MeanHighWaterSpring10m polyline feature class) (Auckland Council 2013) was used to define the region's land-sea boundary. From this, a polygon was created to represent Auckland Council's land base.

Key messages:

- In the near term, 1.5% of the Auckland region may be affected by 0.25 m sea level rise, compared to 2.5% of the region that could be affected by coastal inundation from a 1 in 100-year ARI (1% AEP).
- By the end of the century, up to 2.5% of the Auckland region may be affected by 1 m SLR, and 3.7% of the region could be exposed to coastal inundation.
- In the long term, approximately 4.5% of the region could be exposed to 3 m SLR.

Summary:

Auckland's land base comprises almost 5000 km^2: specifically, 489,581 hectares (ha) or 4896 km^2 (Table 1).

Under increasing sea level rise increments (Figure 1), 1.5% (7360 ha) to 2.5% (12,451 ha) of the region's land may be affected by sea level rise during this century[6] (Table 1). Auckland as a region is more exposed than New Zealand overall but not as exposed as Waikato, Bay of Plenty, or Canterbury (Bell et al. 2015). The widest envelope of exposure assessed, SLR_3m, indicates that up to 4.5% of the Auckland region could be affected; the corresponding national figure is 0.7% (Bell et al. 2015).

The Auckland region is already exposed to coastal inundation from storm events, and this area expands under SLR scenarios (Figure 2). More than 11,000 ha (2.5%) of the region lies in an area already exposed to coastal inundation from a storm with a 1% probability of occurrence (AEP) in any given year (Table 2). This approaches the amount of land that could be at risk from 1 m SLR alone (in the elevation band of 0-1 m) (Table 1), projected to occur by the end of the century. At that time, with SLR of 1 m, a storm of this magnitude could affect almost 17,000 ha (3.7%) of the region (Table 2).

[6] According to the RCP 8.5 (83rd percentile) projections (as throughout this report)

Table 1 Auckland region potentially exposed to sea level rise: area (ha) and proportion (%)

Total land area	SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
ha	ha	%	ha	%	ha	%	ha	%	ha	%
489,581	7,360	1.5	9,100	1.9	12,451	2.5	17,627	3.6	22,089	4.5

Table 2 Auckland region potentially exposed to coastal inundation: area[7] (ha) and proportion (%)

Total land area	ARI100		ARI100_SLR1m		ARI100_SLR2m	
ha	ha	%	ha	%	ha	%
457,809	11,668	2.5	16,921	3.7	21,009	4.6

[7] The coastal inundation scenarios do not include outlying islands in the Hauraki Gulf in the northeast of the Auckland region, including Great Barrier Island, so the total land area for these scenarios is less than the region as a whole and the area exposed to coastal inundation is underestimated in each scenario given the absence of these islands.

2.2 Population

What this measures:

This provides an estimate of the usually resident population count (population) from the last three available censuses in low-lying coastal areas potentially exposed to a combined maximum extent of SLR and coastal inundation (corresponding to the 0-3 m elevation band (SLR_3m) and the ARI 100 + 2m SLR (ARI100_2m) coastal inundation scenario). This approach was adopted as a means of dealing with the complexity of matching population to areas affected by sea level rise in order to estimate the population potentially exposed. In effect, this plotted an outer envelope of the known hazard in order to estimate a potential (maximum) exposure, from which any actual exposure to a specific increment of SLR will be less.

Which data were used:

The population in the maximum landward extent of sea level rise, defined as a combination of the SLR_3m and ARI100_2m scenarios, was estimated.

Population distributions were based on the 2013 Census data at the 2013 meshblock (2013MB) and 2013 Census Area Unit (2013CAU) geometries (which also included 2006 and 2001 census data). Meshblocks are the smallest or finest geometry at which census count data are made available. Census Area Units are the usual reporting geometry at which most census data are available without privacy related suppression, as well as the finest scale at which interpolated population estimates and future projections are produced. The usually resident population count (URPC) is a post-census re-estimate of the census night population count that reallocates people (who may be overseas, travelling or otherwise not at home) back to their usual place of residence.

A ‘maximum extent’ of SLR was developed, comprising a spatial combination of the maximum landward extent of the two SLR modelling approaches: the elevation bands (SLR_3m) and the coastal inundation zones (ARI100_2m). The area of this maximum extent within each Statistics New Zealand ‘Clipped to Coast’ geographic boundary 2013 meshblock (Statistics New Zealand 2013) was quantified, as was its proportion of the total meshblock area. This percentage meshblock area coverage was used to prorate the usually resident population count (URPC) in 2013, 2006 and 2001 for each meshblock (Equation 1), on the assumption that the population distribution within the meshblock was evenly (or randomly) distributed.

Equation 1 $$\boldsymbol{URPC\ Exposed\ in\ MB = URPC\ x\ \%\ of\ gross\ MB\ area\ in\ Max\ Extent}$$

This produces an estimate of the population exposed to potential SLR, defined as the maximum extent of the two modelled scenarios, at the meshblock scale.

This method is consistent with that outlined by Bell et al. (2015) and is subject to the same assumptions and limitations regarding over- and under-estimation, dependent on the actual population distributions within meshblocks relative to the assumed even or random distribution. Where the population is concentrated in locations in the MB farther away from the coast, this approach will result in an overestimate of population exposure to SLR. Likewise, population exposure to SLR will be underestimated where the population concentrates closer to the coast. Even so, these estimates of exposed population at the finer meshblock level supports improved population estimates at coarser scales.

Rather than simply prorating CAU population based on the proportion the CAU area exposed to SLR (Bell et al. 2015), the finer-grained meshblock land and population exposure estimates were aggregated to the CAU level in order to enable comparison with the coarser-scale SLR models. Creating a MB-weighted estimate of a CAU population's exposure allowed a finer grain understanding of the population distribution within a CAU, enabling a more accurate estimate of the proportion of each CAU's population potentially exposed to SLR. For example, if the meshblocks in a CAU area have a large area exposed but a small proportion of the CAU population, the proportion of population exposed will be weighted based on population itself, avoiding an overestimate that would occur if based only on CAU area exposed. The reverse also holds true.

Key messages:

- Estimating population in the maximum extent of SLR at the meshblock scale indicates ~43,200 (3.1%) of the usually resident population (in 2013) may be directly exposed to SLR (a combination of SLR_3m and ARI100_SLR2m).
- The total population count estimated to be exposed has increased through time from ~34,700 (2001) and ~38,700 (2006). The proportion of Auckland's population directly exposed also increased from 3.0% in 2001 and 2006 to 3.1% in 2013.
- During the 2006 to 2013 intercensal period, the population change in the coastal areas exposed to the maximum SLR extent was approximately 11.7%, which was higher than the region as a whole (8.5%). In the 2001-2006 period, the rates of coastal and regional change were similar (11.6% for exposed areas compared to 12.5% for the region as a whole).

Summary:

The maximum extent scenario covers 5.7% of Auckland's 'clipped to coast' meshblock area (~28,300 ha)[8]. Based on the assumption of an evenly distributed population in each meshblock (as described above), it was estimated that approximately 43,200 of the usually resident population count (URPC) in 2013 would be directly exposed to SLR (Table 3). This is 3.1% of the regional 2013 URPC (Table 3).

Potentially exposed population was calculated for 2001, 2006, and 2013 at meshblock and CAU levels to consider whether population changed in the maximum SLR extent through time. The total population estimated to be exposed increased from ~34,700 in 2001 to ~38,700 in 2006 and ~43,200 in 2013 (Table 3). This amounts to a 25% increase in the exposed population between 2001 and 2013 compared to a 22% increase in regional population over the same time period (Table 4). In addition, the proportion of the regional population directly exposed increased from 3.0% in 2001 and 2006 to 3.1% in 2013 (Table 3).

The growth rate of Auckland's coastal population has generally been higher than in the region overall. The regional average of the compound annual growth rate (CAGR) in population between 2001 and 2013 was 1.7%, resulting in an increase of ~255,200 URPC over the period (Table 4). The CAGR for the areas corresponding to the maximum SLR extent was 1.9%, corresponding to a population increase of ~8,600 in those areas between 2001 and 2013. The difference in these CAGRs indicates that the population growth rate in the coastal areas exposed to the maximum SLR extent was approximately 11% higher than the region as a whole over this period (Table 4).

It is important to be clear that the assumptions made here serve the purpose of estimating the URPC located within the area corresponding to projected combined SLR and coastal inundation scenarios; that is, current and past population *exposed* to future SLR scenarios. This is distinct from the population that may ultimately be *affected* by SLR, when it occurs.

[8] This figure varies from the land proportions exposed by the SLR_3m and ARI100_SLR 2m scenarios individually (Table 1 and Table 2) due to the fact that the combination of the two scenarios covers more land than either one alone as well as the differences in the seaward extent of the 'clipped to coast' Statistics New Zealand 2013 meshblock data set, relative to MHWS.

Table 3 Estimated population exposed to maximum extent of sea level rise

Population estimates	Census year		
	2001	2006	2013
Usually Residential Population Count (URPC)	1,160,040	1,304,679	1,415,256
Estimated URPC exposed to maximum extent	34,687	38,713	43,246
% of regional URPC exposed to maximum extent	3.0%	3.0%	3.1%

Table 4 Compound annual growth rate of population in Auckland and in exposed area

Growth rates and comparisons	Intercensal period		
	2001-2006	2006-2013	2001-2013
Total % increase - regional URPC	12.5%	8.5%	22.0%
Total % increase - exposed URPC	11.6%	11.7%	24.7%
Total % point difference -Exposed vs Regional	-0.9%	3.2%	6.6%
Total % proportional difference	-7%	38%	37%
CAGR increase - regional URPC	2.4%	1.2%	1.7%
CAGR increase - exposed URPC	2.2%	1.6%	1.9%
CAGR point difference- Exposed vs Regional	-0.2%	0.4%	0.2%
CAGR proportional difference	-7%	36%	11%

3.0 Terrestrial Biosphere

The terrestrial biosphere comprises the land domain: the rocks and soils of the earth itself, the vegetation forming communities and ecosystems, water bodies such as lake and rivers, and constructed features and surfaces developed by humans.

In this section, the type of land affected by sea level rise is looked at via:

- Land cover
- Ecosystems
- Soils.

3.1 Land cover

What this measures:

Land cover describes the actual surface of the earth, whether it is bare rock, vegetation, buildings, or impervious surfaces.

Which data were used:

The New Zealand Land Cover Database offers the only complete coverage of New Zealand's, and Auckland's, land cover; it is the most widely used source of land cover data in New Zealand. Four classifications have been completed to date: 1996, 2001, 2008, and 2012. The most recent 2012 version, Land Cover Database v4.1 – produced from summer 2012/13 satellite imagery and containing 33 categories (Landcare Research New Zealand Ltd 2015) – was assessed against SLR scenarios. Therefore, the statistics presented here are indicative only, as some land cover has changed in the intervening six years.

Key messages:

- Coastal ecosystems are most exposed proportionally, including mangroves and coastal wetlands.
- The land-cover category with the largest area potentially exposed to SLR is high-producing grassland.
- Some built-up (settlement) areas exist in low elevation bands and so would be exposed to SLR – potentially more than 1% of all settlement areas by the end of the century and more than 2% next century.

Summary:

The types of land cover most exposed are, not surprisingly and by definition, those that occupy low-lying areas along the coast. It is widely understood that SLR will affect beaches, as evidenced by the 10% of sand/gravel bare surfaces (largely

beaches) that could be exposed by 0.25 m SLR, increasing to almost 20% by 1 m SLR (Table 5). With 2 m SLR, almost one-third of sand/gravel area may be exposed. Inherently coastal, occupying the land/sea boundary, almost all mangroves would be exposed: more than 80% of their area could be affected in the near term, increasing throughout the century and approaching 90% under 2 m SLR (Table 5). Likewise, the majority of herbaceous saline vegetation (saltwater wetlands) could be affected from now onward. A smaller, but still substantial, proportion of freshwater wetland area (herbaceous freshwater vegetation) is also low lying and thus exposed to SLR: more than 20% under 1 m SLR (Table 5). Compounding effects of such exposure to these vulnerable ecosystems may include saline intrusion.

Other ecosystems are less affected given their usual distribution. Indigenous forests will not be as affected as deciduous forests. On the other hand, a substantial proportion (18-35%) of matagouri or grey scrub – a rare land cover type in Auckland – could be affected this century. Up to 7% of short-rotation cropland may be exposed to 1 m SLR. The land-cover category with the largest area potentially exposed to SLR is high-producing grassland, comprising almost 4% of the amount that existed in 2012 (Table 5). In terms of developed land, approximately 241 ha could be exposed to 0.25 m SLR, rising to 488 ha (1% of all settlement areas) under 1 m SLR and more than 1000 ha under 2 m SLR (2%) (Table 5).

Coastal inundation from extreme storm events mirrors larger SLR scenarios (with the caveat that the exposure estimates for those land cover types present in the Hauraki Gulf excluded from the coastal inundation scenarios will be underestimated; this is especially true for Indigenous Forest, Broadleaved Indigenous Hardwoods, and Manuka and/or Kanuka). For example, the proportion of sand/ gravel affected by a present-day ARI 100 storm (29%) (Table 6) is similar to the area projected to be exposed by 2 m SLR (32%) (Table 5). Likewise for wetlands, for which a present-day storm event is similar in area to that potentially exposed to 1 m SLR (Tables 5 and 6). The area of mangroves affected by present and future coastal inundation scenarios, 94%-97% (Table 6), exceeds that of all SLR scenarios (Table 5). More built-up area could be exposed by a present-day ARI 100 storm (412 ha) (Table 6) than by 0.25 m SLR (241 ha) or 0.50 SLR (310 ha), and would approach the amount that could be exposed to 1 m SLR (489 ha) (Table 5). The area of built environment potentially affected by a ARI100 storm combined with 1 m SLR (Table 6) approximates the amount potentially exposed to 2 m SLR scenario (Table 5).

Table 5 Land cover potentially exposed to sea level rise: area (ha) and proportion of each category (%)

	Regional land cover		SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
LCDB category	**Area (ha)**	**Proportion (%)**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
Bare surface												
Sand or gravel	3,843.4	0.7	402.4	10.5	491.8	12.8	721.2	18.8	1,245.7	32.4	1,538.9	40.0
Gravel or rock	100.7	0.02	10.2	10.2	10.9	10.9	12.1	12.0	13.9	13.8	15.3	15.2
Built/Developed land												
Built-up area (settlement)	46,124.6	9.0	241.0	0.5	309.5	0.7	488.7	1.1	1,094.3	2.4	1,823.0	4.0
Transport infrastructure	927.3	0.2	31.0	3.3	36.6	4.0	54.4	5.9	148.8	16.0	252.2	27.2
Surface mine or dump	637.4	0.1	5.7	0.9	7.0	1.1	11.6	1.8	16.3	2.6	21.7	3.4
Cropland												
Short-rotation cropland	9,255.5	1.8	309.4	3.3	379.3	4.1	615.5	6.6	820.0	8.9	979.4	10.6
Orchard, vineyard or other perennial crop	3,231.6	0.6	5.3	0.2	10.2	0.3	26.1	0.8	49.6	1.5	89.7	2.8
Grassland												
Low producing grassland	1,890.3	0.4	36.5	1.9	43.8	2.3	55.6	2.9	129.4	6.8	240.0	12.7
High producing exotic grassland	235,326.1	45.8	5,831.7	2.5	6,945.2	3.0	8,849.7	3.8	11,109.4	4.7	12,881.2	5.5
Urban parkland/open space	8,065.4	1.6	173.3	2.1	217.3	2.7	326.3	4.0	583.9	7.2	830.0	10.3
Scrub/ shrubland												
Manuka and/or kanuka	43,312.2	8.4	238.5	0.6	283.2	0.7	397.7	0.9	632.8	1.5	855.1	2.0
Matagouri or grey scrub	24.3	0.005	4.5	18.4	5.9	24.4	8.5	34.8	10.3	42.3	10.6	43.6
Mixed exotic shrubland	692.6	0.1	18.1	2.6	24.9	3.6	42.7	6.2	91.8	13.3	114.9	16.6
Gorse and/or broom	1,894.4	0.4	14.9	0.8	25.7	1.4	51.2	2.7	76.0	4.0	84.1	4.4
Forest												
Indigenous forest	63,508.2	12.4	342.6	0.5	385.1	0.6	488.0	0.8	715.5	1.1	894.5	1.4
Broadleaved indigenous hardwoods	14,911.2	2.9	144.2	1.0	162.5	1.1	203.1	1.4	278.8	1.9	339.0	2.3
Deciduous hardwoods	439.4	0.1	8.2	1.9	10.4	2.4	14.2	3.2	22.8	5.2	33.5	7.6
Exotic forest	48,187.4	9.4	87.3	0.2	104.0	0.2	143.3	0.3	225.9	0.5	307.2	0.6
Forest - harvested	4,101.2	0.8	1.4	0.03	2.0	0.05	3.3	0.1	5.2	0.1	8.5	0.2
Wetlands												
Herbaceous freshwater vegetation	1,144.5	0.2	178.1	15.6	204.5	17.9	247.5	21.6	364.3	31.8	526.0	46.0
Herbaceous saline vegetation	2,056.5	0.4	1,375.2	66.9	1,519.0	73.9	1,675.0	81.4	1,780.3	86.6	1,892.6	92.0
Flaxland	39.6	0.01	3.9	9.8	5.1	13.0	6.1	15.4	8.2	20.7	8.9	22.4
Mangrove	8,927.8	1.7	7,293.7	81.7	7,526.8	84.3	7,742.8	86.7	7,920.3	88.7	8,011.0	89.7
Waterbodies												
Lake or pond	1,227.1	0.2	37.9	3.1	58.7	4.8	78.4	6.4	98.3	8.0	115.4	9.4
River (*as mapped in LCDB; not comprehensive)	153.4	0.03	63.8	41.6	68.0	44.3	71.8	46.8	73.8	48.1	74.5	48.6
Estuarine open water	13,250.1	2.6	8,619.3	65.1	8,658.6	65.3	8,709.5	65.7	8,756.4	66.1	8,786.2	66.3

Table 6 Land cover potentially exposed to coastal inundation: area[7] (ha) and proportion of each category (%)

Land cover category	Regional land cover		ARI100		ARI100_SLR1m		ARI100_SLR2m	
	Area (ha)	Proportion	ha	%	ha	%	ha	%
Bare surface								
Sand or gravel	3,079.0	0.6	890.2	28.9	1,314.3	42.7	1,517.0	49.3
Gravel or rock	15.6	0.003	0.5	3.5	0.6	3.8	0.6	4.0
Built/Developed land								
Built-up area (settlement)	46,055.6	9.6	411.7	0.9	961.6	2.1	1,735.0	3.8
Transport Infrastructure	924.9	0.2	42.4	4.6	119.5	12.9	226.6	24.5
Surface mine or dump	636.1	0.1	14.9	2.3	20.5	3.2	25.0	3.9
Cropland								
Short-rotation cropland	9,255.5	1.9	440.3	4.8	793.2	8.6	929.4	10.0
Orchard, vineyard or other perennial crop	3,218.1	0.7	17.1	0.5	42.6	1.3	77.0	2.4
Grassland								
Low producing grassland	1,547.3	0.3	55.0	3.6	161.0	10.4	227.2	14.7
High producing exotic grassland	233,499.0	48.6	8,350.2	3.6	10,711.3	4.6	12,338.1	5.3
Urban parkland/Open space	8,043.4	1.7	270.4	3.4	526.1	6.5	776.9	9.7
Scrub/ shrubland								
Manuka and/or Kanuka	27,785.6	5.8	232.7	0.8	366.9	1.3	486.1	1.7
Matagouri or grey scrub	24.3	0.01	7.9	32.3	10.3	42.2	10.6	43.5
Mixed exotic shrubland	692.6	0.1	27.2	3.9	75.1	10.8	109.9	15.9
Gorse and/or Broom	1,884.2	0.4	56.2	3.0	76.5	4.1	84.5	4.5
Forest								
Indigenous forest	54,801.8	11.4	462.2	0.8	673.0	1.2	844.1	1.5
Broadleaved indigenous hardwoods	10,584.9	2.2	183.7	1.7	256.0	2.4	314.5	3.0
Deciduous hardwoods	439.4	0.1	13.0	3.0	23.2	5.3	48.9	11.1
Exotic forest	48,055.7	10.0	132.6	0.3	225.3	0.5	324.5	0.7
Forest – harvested	4,099.2	0.9	2.6	0.1	4.8	0.1	11.1	0.3
Wetlands								
Herbaceous freshwater vegetation	915.6	0.2	228.8	25.0	396.0	43.3	501.0	54.7
Herbaceous saline vegetation	1,901.2	0.4	1,581.0	83.2	1,704.0	89.6	1,796.7	94.5
Flaxland	39.6	0.01	6.6	16.6	8.4	21.1	9.0	22.7
Mangrove	8,799.3	1.8	8,270.2	94.0	8,467.1	96.2	8,557.2	97.2
Waterbodies								
Lake or pond	1,226.4	0.3	71.7	5.8	101.3	8.3	158.8	12.9
River (*as mapped in LCDB; not comprehensive)	143.6	0.03	138.1	96.2	139.2	97.0	139.8	97.4
Estuarine open water	13,158.4	2.7	12,951.0	98.4	13,008.7	98.9	13,039.6	99.1

3.2 Ecosystems

What this measures:

Auckland Council's "Ecosystems" data classify vegetation into community types, with a focus on those that are indigenous (native). Complementing the regional land cover categories in Section 3.1, this section, presents a more specific analysis of potential exposure for vegetative communities with biodiversity and conservation importance.

Which data were used:

Auckland Council's Current Ecosystems data (Auckland Council 2014) map indigenous and other ecosystems across the region based on the Singers et al. (2017) classification. This is the best, though still not comprehensive, detailed classification of Auckland's vegetation communities. It is, however, more current than LCDB v4.1 (which dates to 2012) insofar as it is continuously updated. So, the figures presented here are based on best-available data but do not necessarily encompass region-wide totals.

Key messages:

- Mangroves are the most exposed ecosystem type in terms of both area and proportion.
- Substantial proportions of coastal ecosystems are increasingly affected with projected sea level rises through the 21st century.
- Some indigenous coastal and scrub forests are somewhat exposed to SLR and inundation, whereas other indigenous scrub (such as kanuka and manuka) and tall forests (such as kauri and tawa) are mostly located inland and are therefore less affected by sea level rise and coastal inundation.

Summary:

As noted in Section 3.1, most of the current extent of Auckland's mangroves are low-lying, occupying the land-sea interface, and so are exposed to sea level rise, ranging from 84% by mid-century to 90% end of century (Table 7). And following further expectations, a substantial proportion of coastal ecosystems would be exposed, including Oioi retia sedgeland and reedland (DN5, WL10), spinifex/pingao (DN2), stonefields (SA4), Machaerina sedgeland (WL11), fernland (WL12), flaxland (WL18), and raupo reedland (WL19), as well as exotic wetlands (EW) (Table 7). The dynamics can also change as the amount of sea level rise increases, depending on the correspondence between topography and distribution of particular vegetative

communities. For example, the proportion of herbfield coastal turf exposed increases from 2.1% under 0.25 m SLR to 28% with 1 m SLR and to 90% under 2 m SLR.

As a rare ecosystem (with only 21 ha currently mapped), inland lakeshore turf is disproportionately affected, with up to three-quarters of its area exposed to sea level rise zones. Likewise for flaxland: half of the current mapped extent could be exposed to the larger SLR scenarios of 2 m and 3 m.

Some indigenous forests are somewhat exposed to SLR and inundation, including pohutakawa forests (VS1, WF4), Totara dune forests (WF5), and Kahikatea forests (WF8, MF4). Indigenous kauri and tawa forests (e.g., WF10-13) are mostly located inland and are therefore less affected by sea level rise and coastal inundation. The effects of sea level rise on Auckland's ecosystems is further discussed in the terrestrial ecosystems report of this Climate Change Risk Assessment series (Bishop and Landers 2019).

Interestingly, a high proportion of the unassigned areas in the Ecosystems data set are also in the sea level rise zones; this may indicate an urgency for data mapping completion.

Table 7 Ecosystems potentially exposed to sea level rise: area (ha) and proportion of each category (%)

Currently mapped regional occurrence			SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
Ecosystems	Code	Area (ha)	ha	%	ha	%	ha	%	ha	%	ha	%
Unassigned		13,962.7	9,084.4	65.1	9,525.9	68.2	10,012.8	71.7	10,577.2	75.8	11,009.7	78.9
Unassigned wetland		3,008.3	11.7	0.4	15.1	0.5	23.1	0.8	41.3	1.4	59.9	2.0
Pohutakawa treeland/flaxland/rockland	CL1	2,613.4	151.0	5.8	170.5	6.5	206.2	7.9	267.3	10.2	320.4	12.3
Spinifex, pingao	DN2	2,915.5	391.3	13.4	440.7	15.1	590.5	20.3	952.2	32.7	1,344.9	46.1
Oioi knobby clubrush sedgeland	DN5	469.8	41.0	8.7	45.2	9.6	57.3	12.2	240.2	51.1	370.9	79.0
Exotic forest	EF	14,146.9	33.4	0.2	41.8	0.3	62.4	0.4	96.2	0.7	132.8	0.9
Exotic grassland	EG	2,613.0	104.5	4.0	140.6	5.4	193.0	7.4	270.5	10.4	349.5	13.4
Exotic scrub	ES	1,108.1	35.6	3.2	45.4	4.1	75.6	6.8	141.8	12.8	171.2	15.4
Exotic wetland	EW	293.0	35.1	12.0	46.1	15.7	65.4	22.3	80.2	27.4	91.8	31.3
Kahikatea forest	MF4	672.3	0.6	0.1	1.4	0.2	3.6	0.5	6.4	0.9	7.5	1.1
Open water	OW	2,501.3	117.8	4.7	136.2	5.4	155.2	6.2	176.8	7.1	209.7	8.4
Planted vegetation	PL	1,201.9	25.7	2.1	43.1	3.6	85.6	7.1	142.5	11.9	183.8	15.3
Mangrove forest scrub	SA1	10,165.8	8,515.7	83.8	8,860.4	87.2	9,164.4	90.1	9,320.8	91.7	9,362.2	92.1
Shore bind weed knobby club rush gravelfield stonefield	SA4	56.2	3.4	6.0	5.1	9.1	10.2	18.2	21.0	37.3	31.7	56.4
Herbfield Coastal turf	SA5	11.8	0.2	2.1	0.5	3.9	3.3	27.5	10.8	91.1	11.3	95.2
Iceplant glasswort herbfield loamfield	SA7	59.6	0.02	0.04	0.03	0.05	0.04	0.1	0.05	0.1	0.1	0.1
Treeland	TL	1,011.7	13.8	1.4	18.3	1.8	37.0	3.7	59.0	5.8	79.1	7.8
Pohutukawa scrub forest	VS1	2,335.3	52.2	2.2	61.7	2.6	78.8	3.4	109.7	4.7	137.3	5.9
Kanuka scrub forest	VS2	35,420.4	98.6	0.3	117.5	0.3	165.8	0.5	269.2	0.8	379.4	1.1
Manuka kanuka scrub	VS3	8,472.0	25.1	0.3	32.5	0.4	63.2	0.7	97.8	1.2	117.8	1.4
Broadleaved scrub forest	VS5	5,556.5	27.6	0.5	32.5	0.6	42.6	0.8	56.0	1.0	65.6	1.2
Pohutukawa puriri broadleaved forest	WF4	4,510.4	72.4	1.6	83.2	1.8	106.4	2.4	150.9	3.3	191.5	4.2
Totara kanuka broadleaved forest dune forest	WF5	3,126.4	43.5	1.4	59.9	1.9	93.4	3.0	130.4	4.2	153.9	4.9
Puriri forest	WF7	234.5	0.03	0.01	0.04	0.02	0.1	0.03	0.2	0.1	0.4	0.2
Kahikatea pukatea forest	WF8	423.6	3.3	0.8	5.7	1.3	16.3	3.8	56.4	13.3	72.2	17.1
Taraire forest	WF9	8,366.5	2.2	0.03	2.8	0.03	4.1	0.05	6.6	0.1	9.2	0.1
Kauri forest	WF10	1,223.7	0.8	0.1	1.2	0.1	1.9	0.2	3.5	0.3	4.5	0.4
Kauri podocarp broadleaved forest	WF11	31,638.4	14.6	0.05	18.0	0.1	26.3	0.1	45.8	0.1	65.3	0.2
Kauri podocarp broadleaved beech forest	WF12	4,631.3	1.1	0.02	1.2	0.03	1.5	0.03	2.2	0.05	3.0	0.1
Tawa kohekohe rewarewa hinau podocarp forest	WF13	11,287.3	3.7	0.03	4.2	0.04	4.8	0.04	6.1	0.1	7.3	0.1
Gumland heath	WL1	104.2	1.7	1.6	1.7	1.7	1.8	1.7	1.9	1.8	2.3	2.2
Oioi restiad rushland reedland	WL10	146.6	44.9	30.6	71.6	48.8	103.4	70.6	112.4	76.7	115.1	78.5

Currently mapped regional occurrence			SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
Ecosystems	**Code**	**Area (ha)**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
Machaerina sedgeland	WL11	301.8	14.0	4.6	24.6	8.2	40.5	13.4	59.5	19.7	82.0	27.2
Manuka tangle fern scrub fernland	WL12	451.5	5.7	1.3	22.2	4.9	60.4	13.4	129.9	28.8	182.5	40.4
Inland lakeshore turf	WL15	20.6	14.9	72.3	15.0	72.8	15.2	73.6	15.4	74.7	15.6	75.8
Flaxland	WL18	54.1	1.5	2.8	2.8	5.2	8.6	16.0	25.5	47.1	30.5	56.4
Raupo reedland	WL19	1,154.3	59.8	5.2	79.9	6.9	121.4	10.5	194.4	16.8	269.4	23.3

Table 8 Ecosystems potentially exposed to coastal inundation: area[7] (ha) and proportion of each category (%)

Currently mapped regional occurrence			ARI100		ARI100_SLR1m		ARI100_SLR2m	
Ecosystems	Code	Area (ha)	ha	%	ha	%	ha	%
Unassigned		13,431.5	10,449.5	77.8	11,083.9	82.5	11,400.9	84.9
Unassigned wetland		3,008.3	23.2	0.8	41.3	1.4	59.8	2.0
Pohutakawa treeland/flaxland/rockland	CL1	1,498.6	132.6	8.8	170.7	11.4	204.7	13.7
Spinifex, pingao	DN2	2,739.8	736.8	26.9	1,095.0	40.0	1,392.4	50.8
Oioi knobby clubrush sedgeland	DN5	397.4	131.4	33.1	322.5	81.2	348.5	87.7
Exotic forest	EF	14,098.9	104.3	0.7	139.6	1.0	194.7	1.4
Exotic grassland	EG	2,497.7	179.3	7.2	260.1	10.4	330.9	13.2
Exotic scrub	ES	1,103.3	54.7	5.0	127.2	11.5	169.4	15.4
Exotic wetland	EW	287.3	55.1	19.2	75.0	26.1	99.4	34.6
Kahikatea forest	MF4	672.3	4.1	0.6	6.6	1.0	7.5	1.1
Open water	OW	2,495.5	159.1	6.4	198.9	8.0	292.7	11.7
Planted vegetation	PL	1,201.9	71.3	5.9	134.9	11.2	175.5	14.6
Mangrove forest scrub	SA1	9,861.4	9,532.2	96.7	9,695.4	98.3	9,737.2	98.7
Shore bind weed knobby club rush gravelfield stonefield	SA4	7.9	0.5	6.5	0.9	11.0	0.9	11.9
Herbfield coastal turf	SA5	8.1	6.7	83.2	7.6	93.2	7.6	93.3
Iceplant glasswort herbfield/loamfield	SA7	2.3	0.02	0.7	0.03	1.1	0.04	1.7
Treeland	TL	997.4	32.0	3.2	56.6	5.7	78.5	7.9
Pohutukawa scrub forest	VS1	2,316.8	76.9	3.3	108.4	4.7	136.1	5.9
Kanuka scrub forest	VS2	20,290.6	119.7	0.6	188.0	0.9	247.8	1.2
Manuka kanuka scrub	VS3	7,956.5	59.5	0.7	94.9	1.2	115.5	1.5
Broadleaved scrub forest	VS5	5,491.9	39.7	0.7	55.0	1.0	65.0	1.2
Pohutukawa puriri broadleaved forest	WF4	2,920.6	87.5	3.0	130.7	4.5	171.1	5.9
Totara kanuka broadleaved forest dune forest	WF5	3,126.4	60.7	1.9	116.9	3.7	145.8	4.7
Puriri forest	WF7	234.5	0.1	0.03	0.2	0.1	0.4	0.2
Kahikatea pukatea forest	WF8	423.6	11.5	2.7	44.4	10.5	72.2	17.0
Taraire forest	WF9	6,936.9	3.3	0.05	6.1	0.1	8.8	0.1
Kauri forest	WF10	710.5	1.2	0.2	2.8	0.4	4.0	0.6
Kauri podocarp broadleaved forest	WF11	24,546.7	24.3	0.1	45.1	0.2	63.5	0.3
Kauri podocarp broadleaved beech forest	WF12	4,505.0	1.3	0.03	2.0	0.04	2.8	0.1
Tawa kohekohe rewarewa hinau podocarp forest	WF13	10,225.7	4.6	0.04	5.8	0.1	7.0	0.1
Gumland heath	WL1	104.2	1.8	1.7	1.9	1.8	2.1	2.0
Oioi restiad rushland reedland	WL10	146.6	67.1	45.8	74.1	50.5	76.6	52.3
Machaerina sedgeland	WL11	298.0	35.7	12.0	73.7	24.7	82.9	27.8

Manuka tangle fern scrub fernland	WL12	118.3	15.0	12.7	29.5	25.0	34.2	28.9
Inland lakeshore turf	WL15	20.6	15.0	72.9	15.3	74.3	15.6	75.4
Flaxland	WL18	54.1	14.0	25.8	26.3	48.6	30.9	57.1
Raupo reedland	WL19	1,024.8	104.3	10.2	181.6	17.7	291.2	28.4

3.3 Soils

What this measures:

Soils provide the foundation of all terrestrial ecosystems, providing both the physical template of the land itself as well as the biochemical constituents that provide nutrients to the overlying vegetation. One way to consider their characteristics is through land use capability (LUC) class, a categorisation that indicates the type of productive use land can sustain in the long-term. In the LUC system, there are eight categories ranging from highly productive and versatile soils (LUC 1: "negligible limitations to productive use") to severe limitations to productive uses (LUC 8: "non-arable- limitations preclude productive use (conservation land)") (Lynn et al. 2009). For the purposes of the Unitary Plan, Auckland Council has deemed the LUC 1 class "elite soils" and LUC classes 2 and 3 as "prime soils" (Auckland Council 2016a). Here, the LUC class is used as a proxy for considering the multi-faceted qualities of soil and the characteristics of soils exposed to sea level rise.

Which data were used:

Land Use Capability classification of soils from Auckland Council FARM_LUC feature class covers all of the region except for developed areas that are not mapped for soils (Hicks 2016).

Key messages:

- Prime soils (LUC 2 and LUC 3) are the most exposed to sea level rise across all scenarios.
- Together, elite and prime soils (LUCs 1-3) are disproportionately affected: they are more exposed to sea level rise than non-arable soils (LUCs 5-7) in terms of both total area and proportion.
- The other major type of soils affected are LUC 8, in which limitations preclude productive use but are recommended for conservation land.

Summary:

The soils most exposed, in terms of both area and proportion, by sea level rise this century (i.e. through 1 m SLR) are those in LUC class 3, designated as prime soils in Auckland's Unitary Plan (Auckland Council 2016a) (Table 9). Almost 9% of the area in LUC class 3 could be exposed to 1 m SLR, and more than 10% to 2 m SLR. LUC class 3 is the third-most abundant LUC class in the Auckland region, after LUC classes 6 and 4, so it is noteworthy that the largest area exposed to SLR is in this class.

Proportionally, LUC class 8 is the second-most exposed LUC under 1 m SLR, becoming the most affected under 2 m and 3 m SLR scenarios (Table 9); however, it is one of the least affected in terms of total area and is the LUC class with least representation in the Auckland region.

More importantly, the so-called "highly versatile" or "high-class" soils found in LUCs 1-3, designated as elite (LUC 1) and prime (LUCs 2 and 3) in Auckland Council's Unitary Plan, are substantially exposed to sea level rise. LUC 2 is the second most-affected LUC class in terms of area across all time periods after LUC 3 (and third-most affected proportionally after LUCs 3 and 8), even though it ranks 6th of the eight LUC classes in terms of regional occurrence (Table 9). Together, then, prime soils (LUC 2 and 3) are the most exposed soils in Auckland across all sea level rise scenarios.

So-called "elite" soils (LUC 1) rank 7th in terms of LUC class area in the Auckland region, but rank 4th in terms of the proportion of LUC class area exposed to SLR. Between 1% and 2% of these highly productive soils could be exposed under this century's projected SLR, with more than 2% under 2 m SLR.

Considered together, approximately 5% of Auckland's "elite" and "prime" land (LUCs 1-3) is exposed to SLR by mid-century (under 0.25 m and 0.50 m SLR scenarios), more than 6% by end of the century (1 m SLR), and more than 8% next century (2 m SLR). This is an important consideration in the context of multiple stressors, including development pressures, on these highly fertile soils that support agricultural production.

Interestingly, the groupings are more distinct when considering coastal inundation and sea level rise scenarios (Table 10). The two main groups of affected soils are LUC 8 (recommended for conservation rather than agricultural use) and LUCs 1-3 (the best agricultural soils). The proportions shift with the omission of the outlying islands in the coastal inundation scenarios (Section 1.2), which decreases the area of LUC 7 by 30% and LUC 8 by 50%, resulting in seemingly higher proportions affected. Substantial areas and proportions of the most productive soils (LUCs 1-3) are in zones exposed to inundation, which are exacerbated by sea level rise (Table 10). This has important implications for erosion and sedimentation events in the region.

Table 9 Land Use Capability classes (soil) potentially exposed to sea level rise: area (ha) and proportion of each FARM_LUC class (%)

		Regional LUC		SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
Code	FARM_LUC Class	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
1	arable: negligible limitations to productive use	21,387.9	4.7	280.6	1.3	312.6	1.5	379.7	1.8	507.4	2.4	666.7	3.1
2	arable: slight limitations to horticulture and cropping	39,329.3	8.6	1467.1	3.7	1792.0	4.6	2280.2	5.8	3000.6	7.6	3564.5	9.1
3	arable: moderate limitations	65,003.2	14.2	3744.2	5.8	4405.7	6.8	5604.4	8.6	6745.1	10.4	7598.5	11.7
4	arable: severe limitations	80,828.2	17.6	1071.7	1.3	1226.1	1.5	1551.5	1.9	2004.5	2.5	2352.8	2.9
5	non-arable: slight limitations to grazing and forestry	53,633.0	11.7	388.8	0.7	502.7	0.9	735.2	1.4	1080.3	2.0	1344.5	2.5
6	non-arable: moderate limitations	128,609.1	28.0	1031.9	0.8	1159.9	0.9	1402.6	1.1	1789.2	1.4	2221.3	1.7
7	non-arable: severe limitations	59,845.0	13.0	573.1	1.0	701.4	1.2	905.6	1.5	1303.3	2.2	1655.8	2.8
8	non-arable: limitations preclude productive use (conservation land)	10,707.7	2.3	487.7	4.6	550.7	5.1	719.2	6.7	1147.6	10.7	1435.3	13.4

Table 10 Land Use Capability classes (soil) potentially exposed to coastal inundation: area[7] (ha) and proportion of each FARM_LUC class (%)

		Regional LUC		ARI100		ARI100_SLR1m		ARI100_SLR2m	
Code	FARM_LUC Class	ha	%	ha	%	ha	%	ha	%
1	arable: negligible limitations to productive use	21,387.9	5.0	382.6	1.8	511.7	2.4	672.2	3.1
2	arable: slight limitations to horticulture and cropping	38,652.0	9.0	2216.8	5.7	2806.2	7.3	3219.6	8.3
3	arable: moderate limitations	64,492.5	15.1	5249.7	8.1	6656.3	10.3	7466.0	11.6
4	arable: severe limitations	79,981.0	18.7	1479.8	1.9	1863.5	2.3	2157.8	2.7
5	non-arable: slight limitations to grazing and forestry	48,409.3	11.3	589.1	1.2	937.6	1.9	1222.0	2.5
6	non-arable: moderate limitations	126,423.2	29.6	1383.3	1.1	1835.4	1.5	2275.1	1.8
7	non-arable: severe limitations	42,491.9	9.9	623.2	1.5	1018.4	2.4	1275.4	3.0
8	non-arable: limitations preclude productive use (conservation land)	5,359.5	1.3	957.8	17.9	1318.5	24.6	1497.3	27.9

4.0 Land Use

Land *use*, as distinct from land *cover*, describes the *activities* that take place upon the land: how humans put it to use. It allows consideration of the function of the land – what is it for – rather than simply the surface coverage – what is there. Land use can be both dynamic and slow to alter: activities can change often, but certain areas of the city will remain residential or industrial for decades or more. It is possible to consider both how land use is planned, facilitated and provided for, as well as what actually occurs. Thus, this section considers the effects of sea level rise on planned use (unitary plan zones) as well as actual current land use from both property assessments and agricultural surveys.

In this section:

- Auckland Unitary Plan zones
- Current land use
- Primary production (agricultural) activity.

4.1 Auckland Unitary Plan zones

What this measures:

Land is zoned for different purposes by the Auckland Unitary Plan (AUP), which imposes variable levels of control on the establishment of new land uses as well as on activities on land zoned for various purposes. Zoning provides an indication of both present and future potential land uses: it recognises and protects established land-use patterns as well as manages and facilitates land-use change.

Which data were used:

Base Zones as defined in the Auckland Unitary Plan (Operative in Part) (Auckland Council 2016a) describe the current base zoning for the Auckland region. The Unitary Plan Base Zone SDE feature class (Auckland Council 2016b) representing these zones were examined for exposure to SLR and ARI scenarios above MHWS.

Data were analysed at the individual zone level (n=44), but for the purposes of conciseness the summary tables below show results at the zone group level (n=7) (i.e., the Residential zone group is made up of six residential zones facilitating low though higher density development). Individual zone level exposure data are included in Appendix B.

The “General: Hauraki Gulf Island Zone” is included but is effectively a catch-all placeholder for the wide range of zoning that is outlined by the Auckland Council Operative District Plan: Hauraki Gulf Islands Section, which will eventually be

incorporated into the Auckland Unitary Plan. Accordingly, the AUP zone group exposure figures underestimate the total for the various land use zonings included in the Gulf Islands as defined by the Hauraki Gulf Islands District Plan.

The AUP zones of "General: Coastal Marine Area" (CMA) and "General: Water[i]" have been excluded from the zoning totals as they are largely on the seaward side of the land/sea boundary (defined in this study as MHWS). For all other zones, because exposure is only measured relative to the *land above MHWS*, and the Auckland Unitary Plan is both a regional and District Plan, the plan does contain zones below MHWS (the legal boundary between regional and territorial authority jurisdiction). This means that for some zones the area exposed appears low, even when a significant portion of the zone is already 'inundated' by virtue of its location being mostly (or entirely) already in the sea or other water feature.

Zone Descriptions are available in Chapter H (Zones) of the Auckland Unitary Plan in the first numbered section of each Zone[9].

Key messages:

- The Rural Coastal Zone, a low intensity rural zone focused on coastal landscape protection, is most exposed in terms of area across all SLR scenarios, followed by the Rural Production Zone, a widespread rural zone focussing on facilitating rural land uses. As would be expected, the Coastal Zone group (including most of the marine and CMA-based activities including District and Regional Plan controls) is the most affected proportionally, though the specific zones are small in individual and total area: Coastal Defence Zone; Coastal Minor Port Zone; Coastal Ferry Terminal Zone; Coastal Transition Zone; Coastal Marina Zone; and Coastal Mooring Zone. (As noted above, the Coastal Marine Area and Water zones are excluded).
- Some residential zoned land is exposed to sea level rise: the most exposed zones are Rural and Coastal Settlement Zone (a low density residential zone for un-serviced or high landscape value rural communities) and the Single House Zone (the lowest density suburban zone, generally applied to manage hazards or amenity issues). Less than 1% of the zoned area in the Future Urban Zone (which would be a mix of zones eventually, including non-developable zonings) is exposed across the SLR scenarios.
- Changes in zonal exposure with increases in SLR vary: they can be steady across scenarios (e.g., Coastal Defence Zone), rise (e.g., residential zones), or exhibit a step change at particular thresholds (e.g., Business-City Centre Zone).

[9] See http://unitaryplan.aucklandcouncil.govt.nz/

Summary:

The Rural Coastal Zone is most exposed in terms of area across all SLR scenarios – 5783 ha (or 8% of the zone's area) under 1 m SLR – and the exposure increases with the magnitude of SLR (Appendix A). As would be expected, the other coastal zones are most exposed to sea level rise as a proportion of their total areas, although these are small in area (comprising a total of less than 1% of the Auckland region) (Table 11, Table 12). To illustrate, 77% of the Coastal - Defence Zone[10] is exposed under the three SLR scenarios up to 1 m, slightly increasing under 2 m and 3 m scenarios (Appendix A).

The Coastal Transition Zone is notable for the exposure in terms of both area and proportion, reaching more than 50% affected (728 ha) at 1 m SLR (Appendix A). However, the zone exists only because of administrative issues relating to the legacy district planning (this land was formerly unzoned) and the changing location and accuracy of the MHWS boundary over time. The zone definition states that the rules applying to any private land in a Certificate of Title will be those applying to the balance of the title.[11]

The other zones with large areas of land potentially affected are the Rural Production Zone, with exposure reaching over 2300 ha (more than 1% of the zone's area) under 1 m SLR, and the Open Space-Conservation Zone reaching 921 ha (3%) exposed at 1 m SLR (Appendix A).

Some residential land is exposed to sea level rise: 1% or less at 0.25 m or 0.50 m SLR (Table 11). The Rural and Coastal Settlement Zone is the most exposed proportionally of the residential zones, with 3% affected at 1 m SLR and increasing to 7% at 2 m SLR (Appendix A). The Rural and Coastal Settlement zone is a relatively low-density zone and applies in many existing coastal settlements, which are largely unreticulated for most water services and/or have specific landscape

10 The Coastal – Defence Zone provides for the continued operation of defence activities in the Coastal Marine Area adjacent to the Royal New Zealand Navy Devonport Naval Base and the Onetaunga Bay Wharf (Kauri Point) (Section F.7.1, Auckland Unitary Plan, Auckland Council 2016a).

11 Section F.8.1 of the Auckland Unitary Plan (Auckland Council 2016a) states, "This zone applies to land above mean high water springs that was typically un-zoned in previous district plans. The zone is administrative and has been introduced to account for improvements in the quality of information on the location of the line of mean high water springs …This zone does not presume that the land is either public or private land, rather it clarifies which zone and precinct provisions apply once the tenure of the land has been determined. The seaward boundary of the land shown on the planning maps approximates the location of the line of mean high water springs as at 2012. However, a survey may be required to confirm the exact location of the line. Where private title has mean high water springs as its seaward boundary and abuts the coastal marine area, the land will be treated under the provisions applying to the remainder of the private title in the same ownership."

qualities. The zone with the most residential land area exposed (and second-most proportionally) is the Single House Zone with exposure of 117 ha (more than 1% of the zone) under 1 m SLR and increasing to 267 ha (3%) under 2 m SLR (Appendix A). This is the lowest density 'urban' residential zone and is often applied in locations where known hazards would preclude more intensive development, including known sea level rise and coastal hazards such as coastal inundation. It is also applied in locations where other factors including heritage and amenity may limit the appropriateness of more intensive development.

Less than 1% of the Future Urban Zone (FUZ) is affected across all sea level rise scenarios; the area increases from 4 ha under 0.25 m SLR to 19 ha at 1 m SLR, doubling to 40 ha with 2 m SLR. It is worth noting the Future Urban Zone is a *placeholder* for future rezoning to an appropriate mix following extensive structure planning, and it is considered unlikely that the exposed land within the FUZ would be rezoned and developed for specifically residential or business land uses given that avoidance of known and reasonably anticipated hazards is a key consideration in this rezoning process.[12]

Notably, less than 2% of the Business–City Centre Zone is affected under the SLR scenarios projected for this century (to 1 m SLR) but jumps to 30% under the 2 m SLR scenario, projected for next century (Appendix A).

Similarly, the potential exposure statistics for coastal inundation scenarios can increase sharply when combined with sea level rise (Table 12, Table 37). For example, whereas 0.5% of the Business-City Centre Zone may be affected by coastal inundation from a storm with a 1% probability of annual occurrence (a "1 in 100 year" storm or ARI 100), exposure jumps to almost 20% when combined with 1 m SLR and almost 50% when combined with 2 m SLR. Of all business zones, the Neighbourhood Centre Zone has the highest proportional exposure.

Coastal inundation from ARI 100 storms corresponds to a minimum of 50% (half) of each small coastal zone (Appendix A, Table 37). The ARI100_1 m SLR scenario overlays at least 67% (two-thirds) of each coastal zone; this increases to 75% (three-quarters) when combined with 2 m SLR. The Rural Coastal Zone has again the largest exposure in terms of area, with a steady proportional increase through the scenarios (Appendix A, Table 37).

[12]The rezoning of FUZ land to other AUP zones is a prerequisite to its development for urban purposes. The Structure Planning process and the general land development and subdivision rules require hazards including SLR and coastal inundation to be considered when creating the future zoning and development patterns.

Residential zones are affected by coastal inundation (Table 12) in a similar manner to sea level rise (Table 11), though exacerbated with the possibility of earlier occurrence than the timing expected from sea level rise alone.

NB: All of the above, as well as other zonal exposure statistics not specified, are underestimated since the Hauraki Gulf Islands are considered as a single Unitary Plan zone (Appendix A, General Zone Group), rather than a location. There is a wide variety of rural, residential, business and other zones in these locales, outlined in the Auckland Council District Plan: Gulf Island Section that would increase the areas affected in each zone class (see *Which data were used* explanation above). Additional analysis will be required to ascertain currently operative Auckland Council District Plan: Gulf Island Section zone exposure.

Table 11 Auckland Unitary Plan zones potentially exposed to sea level rise: area (ha) and proportion of each zone (%)

Auckland Unitary Plan zones			SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
Zone group	Area (ha)	Proportion (%)	ha	%	ha	%	ha	%	ha	%	ha	%
Business	9,140.6	1.9	24.8	0.3	41.0	0.4	79.2	0.9	249.1	2.7	469.3	5.1
Coastal	2,961.9	0.6	593.4	20.0	723.0	24.4	953.1	32.2	1,200.3	40.5	1,305.8	44.1
General	75,306.4	15.5	191.1	0.3	321.4	0.4	740.5	1.0	1,619.4	2.2	2,364.6	3.1
Open space	43,904.6	9.0	542.8	1.2	816.6	1.9	1,455.9	3.3	2,776.8	6.3	3,855.5	8.8
Residential	38,507.7	7.9	66.7	0.2	106.8	0.3	213.8	0.6	540.1	1.4	921.1	2.4
Rural	308,864.5	63.5	5,600.7	1.8	6,693.0	2.2	8,511.1	2.8	10,538.7	3.4	12,243.4	4.0
Special purpose	7,441.4	1.5	38.0	0.5	57.7	0.8	113.1	1.5	272.0	3.7	468.0	6.3
Grand total	486,127.0	100.0	7,057.5	1.5	8,759.6	1.8	12,066.6	2.5	17,196.6	3.5	21,627.6	4.4

Table 12 Auckland Unitary Plan zones potentially exposed to coastal inundation: area (ha) and proportion of each zone (%)

Auckland Unitary Plan zones			ARI100		ARI100_SLR1m		ARI100_SLR2m	
Zone group	Area (ha)	Proportion (%)	ha	%	ha	%	ha	%
Business	9,140.6	1.9	59.9	0.7	194.7	2.1	433.9	4.7
Coastal	2,961.9	0.6	2,149.0	72.6	2,421.9	81.8	2,542.7	85.8
General[13]	75,306.4	15.5	470.0	0.6	913.2	1.2	1,341.8	1.8
Open space	43,904.6	9.0	1,431.5	3.3	2,884.4	6.6	3,854.7	8.8
Residential	38,507.7	7.9	163.7	0.4	487.7	1.3	876.0	2.3
Rural	308,864.5	63.5	8,081.7	2.6	10,517.6	3.4	12,199.8	3.9
Special purpose	7,441.4	1.5	89.5	1.2	226.4	3.0	416.4	5.6
Grand total	486,127.0	100.0	12,445.2	2.6	17,645.8	3.6	21,665.4	4.5

[13] Exposure Figures for the Unitary Plan 'General' Zone Group (which includes the Hauraki Gulf Islands Zone) are underreported due to lack of regional ARI modelled coverage, affecting the Great and Little Barrier Islands group.

4.2 Current land use

What this measures:

Land use denotes how humans use land for various activities. Land use is the outcome of interactions over time among physical land suitability for various activities, regulation (e.g., planning), economic decisions, and social processes. It changes over time at various rates in response to changes in these factors.

Climate change impacts will accelerate changes in all of these factors in a variety of complex and unknown ways, and land-use changes will result. The SLR and ARI scenarios (which are expected to occur in the future) are intersected with *current* land-use patterns, providing a baseline of the land uses potentially affected, but these data are not a forecast of land-use change nor necessarily reflect the land uses that may exist in the locations exposed when the scenarios modelled eventually occur.

Which data were used:

The Digital Valuation Roll (DVR) contains information collected by all councils for rating purposes. The Rating Valuations Rules 2008 outlines the codes and criteria that the DVR must contain and states, “Actual property use means the activity, or group of interdependent activities having a common purpose, performed on land or building floor space at the date of inspection” (LINZ 2010). The DVR contains a two-character field describing “Actual Property Use”: the first character indicates the ‘Primary Level Use’ and has 10 categories and the second character provides further refinement of the primary level (e.g., all codes starting with a 9 are ‘Residential’, 91 is ‘Residential: Single Unit excluding bach’ and 92 is ‘Residential: Multi-unit’). In the summary tables below, the data are summarised at the primary level for brevity, with more detailed secondary level data included in Appendix B.

To assess land uses exposed to SLR, DVR data (describing rateable units) has been combined with parcel (land) data in order to ascribe a ‘dominant use’ as the land use with the greatest summed rates assessment area on a given parcel. This avoids double counting land uses (e.g. where there are multiple rates assessments for each land parcel, such as apartments or commercial units). And land, represented by parcels, with its dominant land use (from all of the associated rates assessments) is also counted only once, including by area. For this analysis, land-use data representing ‘flattened’ rates assessments combined with parcel data as at 18 May 2018 were used.

In the process of combining rates assessments and parcel data, not all land is captured, nor can individual rates assessments and parcel data always be spatially-

or attribute-matched, particularly Roads (which are not rated). There may be data errors or missing records in either or both sets that create holes in the combined data set. Where there is no land parcel for a rates assessment to join to, data are not assessed. Where there is a land parcel but no rates assessment joined or to join, there is no land-use information and so is tagged as Unknown/No Data. The Unknown/No Data land-use category, in addition to land parcels without rates joins, covers mostly small public land parcels such as esplanade reserves and road ends or slivers, many of which tend to be coastal. Road parcels are non-rateable and are not included in the rating data or input parcels, and Hydro parcels (i.e., sea, streams, lake beds) are also excluded.

This data set was first clipped to MHWS-10 and then overlaid with the scenarios (to ensure parcels and rates assessments already below MHWS were not included). As a result, total parcel land area with land uses available for this analysis is less than the total regional parcel/rates dataset and less than the land area above MHWS intersecting with the scenarios. Thus, all figures are proportions of the land types and areas that exist in the combined and clipped data set analysed, and as land uses are constantly changing in response to a variety of drivers (including perceptions of risk), all results should be considered as a current state snapshot (as at May 2018).

Key messages:

- Rural Industry (particularly stock finishing, dairy and forestry) land uses are potentially most exposed to sea level rise in terms of area; they also have the largest regional coverage. Lifestyle blocks (i.e., non-productive rural blocks) are the second-most exposed in terms of area; they also occupy the second-largest regional coverage.
- Transport (including ports and terminals), Recreation (i.e. coastal reserves and esplanades), and Commercial/Industrial land uses have a high (>10%) proportional exposure to SLR, particularly under the larger scenarios.
- The highest *number of parcels* potentially exposed under all scenarios belong to the Residential category, followed by Recreation, Lifestyle and Rural Industry land uses. This amounts to ~1.5%-2% of residential parcels (~5600 (SLR_1m) to 8500 (ARI100_1mSLR)) exposed this century, at the same time noting that 79% of all mapped parcels (~371,000) in the region are Residential.

Summary:

Land use exposure as measured by count or area, and the relativities of these to the land-use parcel composition, is quite variable. This reflects the different spatial patterns of the primary land uses and their typical size ranges. Rural Industry covers

a large area of the region, often extending to the coastal fringe and, in some cases, into the CMA. Dominant land use at the parcel scale will also obscure within parcel land-use variation, such as coastal fringe areas on farms that may be planted or retired from grazing rather than being actively grazed or area of the site that were never farmed.

Areas subject to existing and known hazards (such as low-lying coastal flats) are often used for low intensity rural purposes, such as periodic grazing. The proportion of area exposed to SLR scenarios is in line with this distribution (Table 13, Table 14). Because rural parcels are often large, there are comparatively few and so a high proportion by count of rural industry parcels are potentially exposed, even if the total area of exposure on large rural parcels is relatively small.

Conversely, much residential land use tends not to be immediately adjacent to the coast; for example, there may be an esplanade reserve or other land use between the residential use and the coastline. However, in low lying, flatter areas a small amount of vertical rise in elevation can extend quite far inland. As such, a relatively low proportion of total residential land use area could be exposed to SLR (Table 13, Table 14). That said, the highest number of parcels exposed are in the Residential category: 5600-8500 parcels affected by the 1 m SLR and coastal inundation scenarios (Table 15, Table 16), which is approximately 1.5%-2% of the total residential parcels in the region. (Overall, the ~371,000 residential parcels in the land-use database comprise 79% of all parcels in the region.)

Land uses of public interest that are substantially exposed include Utilities (15% by count, 1% by area), Recreation (35% by count, 6% by area), Transport-excluding road parcels (24% by count, 31% by area), and Community Services (8% by count, 2% by area) (Tables 13-16). This indicates a potentially significant issue for the facilities and both soft and hard infrastructure that these land uses host, including the loss of the buffer function, as well as the recreational, amenity and coastal access points they currently provide to other land uses, particularly in urban areas.

It should be noted that the analysis is based on the intersection of SLR and ARI scenario extents with parcels, which does not necessarily directly translate to impact on the continuation or operation of the current primary land use (e.g., the inundation of a part of a residential parcel may not result in the loss of functionality or habitability of a dwelling located elsewhere on the parcel). It is also possible that the reverse may hold true; for example, a small area of exposed Transport land use could have flow-on impacts on a wide array of adjacent or non-contiguous land uses.

The data do, however, provide a first indication of *exposure*, providing a basis for prioritising further investigations of *hazard*, *vulnerability,* and *risk* (Golubiewski et al. 2018).

Table 13: Primary land use potentially exposed to sea level rise: parcel area (ha) and proportion of each category (%)

Regional land use			SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
Primary land use	Area (ha)	Proportion (%)	ha	%	ha	%	ha	%	ha	%	ha	%
Commercial	2,118.1	0.5	4.0	0.2	8.6	0.4%	15.2	0.7	51.6	2.4	93.7	4.4
Community services	5,332.5	1.1	8.8	0.2	13.5	0.3	35.8	0.7	90.6	1.7	143.3	2.7
Industrial	5,234.6	1.1	49.1	0.9	64.3	1.2	88.6	1.7	152.3	2.9	255.7	4.9
Lifestyle	112,122.4	23.9	874.4	0.8	1,123.3	1.0	1,547.9	1.4	2,142.0	1.9	2,688.8	2.4
Multi-use at primary level	5.0	0.001	-	-	-	-	-	-	-	-	-	-
Recreational	40,748.0	8.7	458.1	1.1	652.8	1.6	1,106.5	2.7	1,866.5	4.6	2,473.8	6.1
Residential	35,171.6	7.5	69.5	0.2	107.1	0.3	206.4	0.6	524.2	1.5	904.0	2.6
Rural industry	212,255.8	45.2	4,284.6	2.0	5,108.5	2.4	6,647.9	3.1	8,534.8	4.0	10,057.8	4.7
Transport	894.6	0.2	21.0	2.4	28.0	3.1	41.9	4.7	141.0	15.8	278.8	31.2
Utility services	10,184.9	2.2	53.3	0.5	60.4	0.6	80.0	0.8	102.6	1.0	122.9	1.2
Unknown/no data	41,675.0	8.9	570.0	1.4	766.8	1.8	1,130.7	2.7	1,859.5	4.5	2,480.8	6.0
Total	469,248.0	100.0	6,392.8	1.4	7,933.2	1.7	10,900.8	2.3	15,465.0	3.3	19,499.4	4.2

Table 14: Primary land use potentially exposed to coastal inundation: parcel area (ha) and proportion of each category (%)

Regional land use			ARI100		ARI100_SLR1m		ARI100_SLR2m	
Primary land use	Area (ha)	Proportion (%)	ha	%	ha	%	ha	%
Commercial	2,118.1	0.5	11.6	0.5	42.7	2.0	87.4	4.1
Community services	5,332.5	1.1	22.7	0.4	78.5	1.5	129.5	2.4
Industrial	5,234.6	1.1	83.4	1.6	135.9	2.6	232.8	4.4
Lifestyle	112,122.4	23.9	1,414.4	1.3	2,012.3	1.8	2,480.3	2.2
Multi-use at primary level	5.0	0.001	-	-	-	-	-	-
Recreational	40,748.0	8.7	904.0	2.2	1,680.1	4.1	2,298.0	5.6
Residential	35,171.6	7.5	158.6	0.5	447.0	1.3	856.8	2.4
Rural industry	212,255.8	45.2	6,301.7	3.0	8,338.0	3.9	9,731.6	4.6
Transport	894.6	0.2	36.1	4.0	99.1	11.1	232.6	26.0
Utility services	10,184.9	2.2	66.1	0.6	86.5	0.8	115.8	1.1
Unknown/no data	41,675.0	8.9	1,104.2	2.6	1,869.6	4.5	2,251.1	5.4
Total	469,248.0	100.0	10,102.6	2.2	14,789.6	3.2	18,415.8	3.9

Table 15: Primary land use potentially exposed to sea level rise: count of parcels (n) and proportion of each category (%)

Regional land use			SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
Primary land use	Count (n)	Proportion (%)	n	%	n	%	n	%	n	%	n	%
Commercial	12,174	2.6	95	0.8	115	0.9	193	1.6	548	4.5	875	7.2
Community services	6,283	1.3	179	2.8	200	3.2	245	3.9	359	5.7	478	7.6
Industrial	10,178	2.2	238	2.3	293	2.9	413	4.1	812	8.0	1,121	11.0
Lifestyle	26,873	5.7	1,371	5.1	1,507	5.6	1,713	6.4	2,073	7.7	2,436	9.1
Multi-use at primary level	4	0.001	-	-	-	-	-	-	-	-	-	-
Recreational	13,103	2.8	3,021	23.1	3,272	25.0	3,639	27.8	4,236	32.3	4,633	35.4
Residential	371,587	79.2	3,226	0.9	3,899	1.0	5,603	1.5	10,220	2.8	15,276	4.1
Rural industry	8,234	1.8	1,058	12.8	1,123	13.6	1,234	15.0	1,384	16.8	1,517	18.4
Transport	930	0.2	77	8.3	85	9.1	95	10.2	200	21.5	224	24.1
Utility services	1,881	0.4	114	6.1	136	7.2	172	9.1	235	12.5	284	15.1
Unknown/no data	18,001	3.8	1,169	6.5	1,256	7.0	1,404	7.8	1,740	9.7	2,062	11.5
Total	469,248	100.0	10,548	2.2	11,886	2.5	14,711	3.1	21,807	4.6	28,906	6.2

Table 16: Primary land use potentially exposed to coastal inundation: count (n) and proportion of each category (%)

Regional land use			ARI100		ARI100_SLR1m		ARI100_SLR2m	
Primary land use	Count (n)	Proportion (%)	n	%	n	%	n	%
Commercial	12,174	2.6	105	0.9	414	3.4	826	6.8
Community services	6,283	1.3	206	3.3	299	4.8	416	6.6
Industrial	10,178	2.2	322	3.2	671	6.6	1,013	10.0
Lifestyle	26,873	5.7	1,414	5.3	1,775	6.6	2,140	8.0
Multi-use at primary level	4	0.001	-	-	-	-	-	-
Recreational	13,103	2.8	3,190	24.3	3,909	29.8	4,335	33.1
Residential	371,587	79.2	3,972	1.1	8,518	2.3	13,825	3.7
Rural industry	8,234	1.8	1,115	13.5	1,262	15.3	1,388	16.9
Transport	930	0.2	80	8.6	178	19.1	211	22.7
Utility services	1,881	0.4	136	7.2	208	11.1	259	13.8
Unknown/no data	18,001	3.8	1,237	6.9	1,571	8.7	1,909	10.6
Total	469,248	100.0	11,777	2.5	18,805	4.0	26,322	5.6

4.3 Primary production (agricultural) activity

What this measures:

Primary production (agricultural) activities and other rural land uses in the Auckland region are assessed for their potential exposure to sea level rise.

Which data were used:

Farm Type, as recorded in the AgriBase 2016 survey (AsureQuality 2016), provides a classification of rural land use. The location-specific areas of mapped farm types were extracted against sea level rise scenarios, rather than the areas for farm enterprises (part of which may be located elsewhere).

Key messages:

- Grazing land is the farm type most exposed to SLR by area.
- A relatively large proportion (6-10%) of arable cropping land is exposed across SLR scenarios.
- Farm types not exposed to sea level rise scenarios include alpaca and llama breeding; beekeeping; and zoos.

Summary:

Livestock farms, including mixed sheep and beef, beef, and dairy, occupy the most agricultural production land across Auckland (Table 17). These are also the farm types with greatest land area exposed to sea level rise scenarios, affecting 3-6% of their total areas up to 1 m SLR (Table 17), corresponding to results obtained for general land use exposure (Section 4.2).

Less than 1% of vegetable growing area is exposed to sea level rise, but up to 10% of arable cropping/seed production land could be exposed to projected 2 m SLR (Table 17).

Aquaculture comprises the farm type with highest proportion of area exposed to SLR, as would be expected given the coastal location of the enterprise, followed by those areas “non-farmed”, that is, idle or under other uses (Table 17).

Table 17 Farm type potentially exposed to sea level rise: area exposed (ha) and proportion of the category (%)

Regional agricultural activity			SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
Farm type	Area (ha)	Proportion (%)	ha	%	ha	%	ha	%	ha	%	ha	%
Alpaca and/or Llama breeding	157.6	0.04	-	-	-	-	-	-	-	-	-	-
Beekeeping and hives	43.8	0.01	-	-	-	-	-	-	-	-	-	-
Arable cropping or seed production	948.4	0.3	53.7	5.7	57.2	6.0	68.8	7.3	100.4	10.6	130.0	13.7
Beef cattle farming	75,301.4	21.4	1588.5	2.1	1923.2	2.6	2470.5	3.3	3167.9	4.2	3637.2	4.8
Dairy cattle farming	47,818.0	13.6	1948.8	4.1	2226.5	4.7	2802.3	5.9	3333.2	7.0	3831.9	8.0
Deer farming	3,728.4	1.1	23.7	0.6	30.3	0.8	40.3	1.1	91.4	2.5	121.4	3.3
Dogs	27.7	0.01	0.1	0.3	0.1	0.3	0.1	0.4	0.2	0.6	0.2	0.7
Dairy dry stock	904.7	0.3	7.5	0.8	7.8	0.9	8.5	0.9	9.6	1.1	15.3	1.7
Emu bird farming	58.0	0.02	-	-	-	-	-	-	0.01	0.01	0.6	1.0
Fish, marine fish farming, hatcheries	100.0	0.03	4.7	4.7	13.7	13.7	27.0	27.0	33.3	33.3	35.9	35.9
Flowers	619.5	0.2	5.1	0.8	11.1	1.8	32.8	5.3	43.7	7.1	50.2	8.1
Forestry	21,774.9	6.2	123.4	0.6	134.0	0.6	163.5	0.8	213.4	1.0	265.9	1.2
Fruit growing	2001.9	0.6	5.5	0.3	10.3	0.5	20.1	1.0	41.3	2.1	80.3	4.0
Goat farming	520.4	0.1	-	-	-	-	-	-	-	-	0.02	0.004
Grazing other people's stock	11,427.8	3.2	341.3	3.0	383.5	3.4	461.8	4.0	552.5	4.8	639.5	5.6
Horse farming and breeding	4675.3	1.3	99.8	2.1	153.5	3.3	242.5	5.2	289.1	6.2	312.3	6.7
Lifestyle block	41,209.4	11.7	403.7	1.0	492.5	1.2	622.1	1.5	817.1	2.0	987.6	2.4
Native bush	7,042.8	2.0	32.9	0.5	43.5	0.6	64.9	0.9	101.9	1.4	160.1	2.3
New record - unconfirmed farm type	2,179.3	0.6	65.4	3.0	71.0	3.3	77.7	3.6	83.4	3.8	97.2	4.5
Not farmed (i.e. Idle land or non-farm use)	1,413.4	0.4	344.3	24.4	353.0	25.0	363.6	25.7	418.2	29.6	522.5	37.0
Plant nurseries	422.0	0.1	0.3	0.1	0.6	0.1	3.3	0.8	7.1	1.7	10.6	2.5
Other livestock (not covered by other types)	21.5	0.01	-	-	-	-	-	-	-	-	-	-
Other planted types	279.1	0.1	-	-	-	-	0.001	0.0003	0.1	0.05	4.3	1.5
Ostrich bird farming	98.0	0.03	0.04	0.04	0.1	0.1	0.2	0.2	0.8	0.8	10.1	10.3
Enterprises not covered elsewhere	7,538.5	2.1	87.6	1.2	96.9	1.3	144.0	1.9	175.5	2.3	192.6	2.6
Pig farming	206.7	0.1	3.0	1.5	4.5	2.2	20.1	9.7	25.3	12.2	28.4	13.7
Poultry farming	1,275.4	0.4	87.8	6.9	107.2	8.4	116.3	9.1	122.0	9.6	126.0	9.9
Sheep farming	7,548.4	2.1	30.1	0.4	41.0	0.5	67.9	0.9	100.9	1.3	124.3	1.6
Mixed Sheep and beef farming	107,894.3	30.6	3086.0	2.9	3,506.0	3.2	4,201.2	3.9	5,224.6	4.8	6,049.8	5.6
Tourism (i.e. Camping ground, motel)	962.3	0.3	7.0	0.7	8.4	0.9	10.7	1.1	14.2	1.5	17.7	1.8

Regional agricultural activity			SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
Farm type	**Area (ha)**	**Proportion (%)**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
Unspecified (i.e. Farmer did not indicate)	794.3	0.2	5.3	0.7	12.6	1.6	25.7	3.2	30.6	3.8	36.4	4.6
Vegetable growing	2,717.1	0.8	16.9	0.6	18.4	0.7	20.4	0.8	23.8	0.9	29.2	1.1
Viticulture, grape growing and wine	880.1	0.2	2.8	0.3	4.4	0.5	10.1	1.1	18.1	2.1	24.4	2.8
Zoological gardens	5.6	0.002	-	-	-	-	-	-	-	-	-	-

Table 18 Farm type potentially exposed to coastal inundation: area exposed (ha) and proportion of the category (%)

Regional agricultural activity			ARI100		ARI100_SLR1m		ARI100_SLR2m	
Farm Type	Area (ha)	Proportion (%)	ha	%	ha	%	ha	%
Alpaca and/or llama breeding	157.6	0.1	-	-	-	-	-	-
Beekeeping and hives	43.8	0.01	-	-	-	-	-	-
Arable cropping or seed production	948.4	0.3	63.3	6.7	103.7	10.9	126.9	13.4
Beef cattle farming	73,259.2	23.8	2,343.6	3.2	2,946.9	4.0	3,322.9	4.5
Dairy cattle farming	47,818.0	15.5	2,524.9	5.3	3,273.7	6.8	3,766.8	7.9
Deer farming	3,728.4	1.2	43.0	1.2	99.5	2.7	118.3	3.2
Dogs	27.7	0.01	0.1	0.3	0.1	0.5	0.2	0.7
Dairy dry stock	904.7	0.3	8.4	0.9	9.3	1.0	12.2	1.4
Emu bird farming	58.0	0.02	-	-	-	-	0.6	1.1
Fish, marine fish farming, hatcheries	100.0	0.03	21.4	21.4	32.2	32.2	35.4	35.4
Flowers	615.0	0.2	17.4	2.8	42.5	6.9	46.9	7.6
Forestry	21,759.2	7.1	161.5	0.7	218.6	1.0	272.4	1.3
Fruit growing	1,997.0	0.6	16.4	0.8	35.8	1.8	68.6	3.4
Goat farming	520.4	0.2	-	-	-	-	-	-
Grazing other people's stock	11,423.5	3.7	614.6	5.4	708.6	6.2	791.7	6.9
Horse farming and breeding	4,675.3	1.5	252.4	5.4	287.5	6.1	311.8	6.7
Lifestyle block	40,816.7	13.2	592.3	1.5	799.9	2.0	973.9	2.4
Native bush	5,885.1	1.9	47.3	0.8	83.8	1.4	150.8	2.6
New record - unconfirmed farm type	2,179.3	0.7	75.8	3.5	86.4	4.0	103.4	4.7
Not farmed (i.e. Idle land or non-farm use)	1,192.3	0.4	414.0	34.7	451.4	37.9	540.7	45.3
Plant nurseries	422.0	0.1	1.0	0.2	6.4	1.5	9.5	2.2
Other livestock (not covered by other types)	21.5	0.01	-	-	-	-	-	-
Other planted types	270.0	0.1	-	-	0.002	0.001	0.01	0.003
Ostrich bird farming	98.0	0.03	0.1	0.1	0.4	0.4	5.4	5.5
Enterprises not covered by other classifications	1,824.8	0.6	83.0	4.5	121.8	6.7	130.4	7.1
Pig farming	153.7	0.05	4.5	2.9	6.9	4.5	9.0	5.8
Poultry farming	1,275.4	0.4	115.4	9.1	121.9	9.6	125.9	9.9
Sheep farming	7,415.1	2.4	51.2	0.7	91.0	1.2	114.0	1.5
Mixed sheep and beef farming	73,207.5	23.8	4,001.1	5.5	4,931.2	6.7	5,579.1	7.6
Tourism (i.e. camping ground, motel)	944.3	0.3	9.0	1.0	13.0	1.4	16.5	1.7

Regional agricultural activity			ARI100		ARI100_SLR1m		ARI100_SLR2m	
Farm Type	Area (ha)	Proportion (%)	ha	%	ha	%	ha	%
Unspecified (i.e. farmer did not give indication)	794.3	0.3	20.5	2.6	29.5	3.7	34.8	4.4
Vegetable growing	2,717.1	0.9	20.0	0.7	23.9	0.9	29.6	1.1
Viticulture, grape growing and wine	867.0	0.3	6.8	0.8	17.4	2.0	23.5	2.7
Zoological gardens	5.6	0.002	-	-	-	-	-	-

4.4 Council greenspace and sportsfields

What this section measures:

Council-owned greenspace, namely parks/reserves, sportsfields, and cemeteries, were examined for their intersection with SLR and coastal inundation scenarios.

Which data were used:

Auckland Council's spatial data sets produced by Community Facilities (CF) were used to identify greenspaces and sportsfields. Parks and reserves were identified from the Park Extent layer. From the Park Sportsfield Extent layer, sportsfields were identified as soil fields, soil field surrounds, sand carpet fields, and sand carpet field surrounds to capture active green spaces consisting of grass (lawn) and soil. Other active spaces including artificial sportsfields, cricket wickets, cricket practice area, courts, and sports tracks were also analysed. The same approach was taken for cemeteries, based on cemetery records extracted from council's SAP Maintenance Plant module. These data sets reflect all registered and verified CF sites recorded in SAP.

It should be noted the community facilities CF data are live data sets – the data are under constant update and modification, so the extents of some parks or sportsfields may have been modified since date of data extraction.

Key messages:

- The amount of council-owned greenspace that may be exposed to SLR ranges from 1% to 6%.
- Approximately 2% of sportsfield area could be exposed to 1 m SLR.
- Across 55 cemeteries (both open and closed), a total of three hectares could be exposed to 1 m SLR, with area increasing under larger SLR scenarios.

Summary:

The margins of many parks and reserves lie along shores and coastal margins. In some cases, small areas (slivers) of parks sit in low-lying elevations exposed to sea level rise; in others, larger areas could be exposed. Overall, potential exposure comprises more than 2% (1313 ha) of council greenspace under 1 m SLR and more than 4% (2326 ha) under 2 m SLR (Table 19).

Local parks are the most exposed across all SLR and ARI scenarios: 850 ha (or 10% of total local park land area) could be exposed under 1 m SLR, with a 50% increase to 1280 ha under 2 m SLR (Table 19). This is not unexpected, as large numbers of local parks are established along esplanades and coastal areas as buffer zones to mitigate impacts imposed by climate change and seal level rise. Regional parks are

the second-most exposed of council-owned greenspaces: approximately 375 ha to 872 ha under 1 m SLR and 2 m SLR (Table 19).

Sportsfields are often built on flat and low-lying locations, which means the potential exposure to sea level rise and/or storm events is higher than for other types of recreational facilities. Approximately 2% (18.6 ha) of sportsfields could be exposed to 1 m SLR and almost 7% (57.5 ha) to 2 m SLR (Table 21). The potential loss of these sportsfields to sea level rise also implies potential effects on high-value fixed assets such as surface materials, under surface drainage and irrigation systems, and power supply equipment associated with these sportsfields.

As with parks, in many cases the exposure in cemeteries consists of slivers along the land margin edge. Given the sensitivity of this land use to inundation, the extent and distribution of inundation in each location will be important to investigate. For 1 m SLR, about 1% of total cemetery land is exposed across 10 cemeteries (Table 19). The larger SLR scenarios indicate increased exposure on 12 cemetery sites, covering more land area.

Table 19 Council greenspace potentially exposed to sea level rise: area (ha) and proportion of category (%)

	Region	SLR _0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
Greenspace category	Area (ha)	ha	%	ha	%	ha	%	ha	%	ha	%
Cemetery	294.0	1.1	0.4	1.8	0.6	3.5	1.2	11.8	4.0	15.3	5.2
Other	1.4	-	-	-	-	-	-	.0001	0.01	0.1	4.2
Farm	92.9	0.3	0.3	3.1	3.4	9.2	9.9	15.8	17.0	21.2	22.9
Holiday park	35.4	0.5	1.5	1.0	2.7	3.5	9.8	4.4	12.5	5.6	15.7
Local park	8,520.0	429.9	5.0	554.5	6.5	850.4	10.0	1,280.7	15.0	1,610.1	18.9
Regional park	41,152.1	180.7	0.4	232.9	0.6	374.8	0.9	872.2	2.1	1,287.4	3.1
Sports park	1,908.8	34.6	1.8	42.8	2.2	61.3	3.2	126.8	6.6	196.1	10.3
Stormwater reserve	158.5	3.2	2.0	7.2	4.5	10.1	6.4	14.7	9.3	19.0	12.0
Undeveloped reserve	107.8	-	-	-	-	0.001	0.001	0.03	0.03	0.1	0.1
Total	52,270.9	650.4	1.2	843.3	1.6	1,312.8	2.5	2,326.4	4.5	3,154.7	6.0

Table 20 Council greenspace potentially exposed to coastal inundation: area[7] (ha) and proportion of category (%)

	Region	ARI100		ARI100_SLR1m		ARI100_SLR2m	
Greenspace category	Area (ha)	ha	%	ha	%	ha	%
Cemetery	293.3	3.4	1.1	11.6	4.1	15.1	5.1
Other	1.4	-	-	-	-	0.04	2.6
Farm	92.9	3.8	4.1	13.9	14.9	18.4	19.8
Holiday park	35.4	2.0	5.6	4.6	13.1	5.6	15.7
Local park	8,421.8	743.9	8.8	1,204.0	14.3	1,538.1	18.3
Regional park	41,069.0	569.3	1.4	1,167.1	2.8	1,460.3	3.6
Sports park	1,908.8	50.5	2.6	109.5	5.7	179.4	9.4
Stormwater reserve	158.5	9.4	5.9	14.1	8.9	18.5	11.7
Undeveloped reserve	107.8	-	-	0.03	0.03	0.1	0.1
Total	52,088.8	1,382	2.7	2,524.9	4.8	3,235.6	6.2

Table 21 Council sportsfields potentially exposed to sea level rise: area (ha) and proportion (%)

Sportsfield category	Sportsfield type	Region	SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
		Area (ha)	ha	%	ha	%	ha	%	ha	%	ha	%
Active spaces	Artificial sportsfield	15.1	-	-	-	-	-	-	0.0002	.001	0.3	1.9
	Court	38.7	0.3	0.8	0.3	0.8	0.8	2.2	2.3	6.0	3.9	10.0
	Cricket practice area	0.9	-	-	-	-	0.04	4.5	0.2	16.3	0.2	19.9
	Cricket wicket	5.0	0.0	0.7	0.1	1.5	0.1	2.4	0.6	11.5	1.0	20.6
	Sports track	3.3	-	-	-	-	-	-	0.02	0.5	0.2	4.8
Active greenspaces	Sportsfield sand	242.1	0.8	0.3	1.7	0.7	5.6	2.3	20.9	8.6	34.8	14.4
	Sportsfield soil	293.5	0.4	0.1	2.6	0.9	6.3	2.2	16.4	5.6	25.2	8.6
	Surround sand	81.8	0.3	0.3	0.5	0.6	1.5	1.8	5.7	6.9	11.9	14.5
	Surround soil	148.9	0.7	0.5	1.9	1.3	4.2	2.8	11.5	7.7	18.0	12.1
	Total	829.4	2.5	0.3	7.1	0.9	18.6	2.2	57.5	6.9	95.5	11.5

Table 22 Council sportsfield potentially exposed to coastal inundation: area (ha) and proportion (%)

Sportsfield category	Sportsfield type	Region	ARI100		ARI100_SLR1m		ARI100_SLR2m	
		Area (ha)	ha	%	ha	%	ha	%
Active spaces	Artificial sportsfield	15.1	-	-	-	-	0.1	0.4
	Court	38.7	0.5	1.4	1.7	4.4	3.7	9.7
	Cricket practice area	0.9	-	-	0.1	16.3	0.2	19.9
	Cricket wicket	5.1	0.1	2.0	0.4	7.8	0.9	17.5
	Sports track	3.3	-	-	0.0	0.1	0.1	2.2
Active greenspaces	Sportsfield sand	242.1	4.6	1.9	16.7	6.9	31.6	13.1
	Sportsfield soil	293.5	3.9	1.3	14.6	5.0	23.2	7.9
	Surround sand	81.8	1.2	1.5	3.8	4.7	9.6	11.8
	Surround soil	148.9	2.7	1.8	9.7	6.5	16.7	11.2
	Total	829.4	13.1	1.6	46.9	5.7	86.1	10.4

5.0 Buildings and Facilities

Coastal areas have long been considered attractive areas to live all over the world. As such, development has occurred in many coastal areas for a variety of purposes: to live, to work, to recreate. Thus, many structures and other objects have been built and installed in low-lying coastal environments. The degree to which those in Auckland intersect with SLR and coastal inundation scenarios is considered here.

In this section:

- Buildings
- Community facilities
- Coastal assets
- Landfills.

5.1 Buildings

What this measures:

Buildings co-located in SLR and coastal inundation scenario zones are tabulated. If part of a building outline intersected with an elevation band or an inundation model, it was counted as potentially exposed.

Which data were used:

For the urban core and its periphery, all buildings 10 m^2 and greater were assessed using the 2013 Buildings data set (Golubiewski et al. 2019). This data set was chosen since it has undergone an extensive quality assessment. It was supplemented with the LINZ building outlines for the Auckland region, most of which date to 2012 and 2015 for the northern and southern rural areas (LINZ Data Service 2018).

Key messages:

- Up to 3% of buildings in the Auckland region are located in the areas corresponding to the largest SLR and coastal inundation scenarios.
- Across the region, 1% or less of buildings could be exposed to SLR scenarios up to 1 m, but over 1.5% could be exposed in storm surge combined with 1 m SLR.
- Rural areas are disproportionately affected this century: Higher numbers and proportions of buildings are exposed to SLR in rural areas than the urban core

and periphery through 1 m SLR, but the number of buildings exposed in the urban core exceeds rural areas under larger SLR or coastal inundation combined with SLR.

Summary:

Increasing numbers of buildings are exposed to increasing levels of sea level rise and coastal inundation. Across the region, less than 1% of buildings may be exposed to sea level rise scenarios projected for this century (up to 1 m SLR) (Table 23), whereas more than 1.5% of buildings would be affected under 1 m SLR combined with storm surge (Table 24). Approximately 3% of buildings would be exposed across the region from a storm surge combined with 2 m SLR (Table 24) or under the 3 m SLR scenario (Table 23).

The exposure of buildings to SLR and coastal inundation is different between the urban and rural parts of the region. Higher numbers and proportions of buildings would be exposed in rural areas than in the urban core and periphery through 1 m of SLR (Table 23): 2891 buildings (3.9%) in rural areas compared to 475 (0.1%) in the urban core and periphery. This is similar to coastal inundation for a 1 in 100-year storm (Table 24). However, under larger SLR scenarios and storm surge combined with SLR, the number of buildings exposed is greater in the urban core and periphery than in outlying rural areas (Table 23, Table 24). A higher proportion of buildings could be exposed in rural areas than in the urban core and periphery across all scenarios. A finer scale effect of sea level rise on specific locations is further investigated at the local scale, which is undertaken in Part 2 of the SLR inventories (Boyle et al. 2019).

New construction occurred in areas exposed to sea level rise between 2010 and 2013. Change detection was conducted for the urban core and its periphery (Golubiewski et al. 2019): 10 new buildings (as of 2013) were in the 0.25 m SLR zone; 16 in the 0.50 m zone; and 36 in the 1 m SLR zone with one more under construction. For the 2 m and 3 m elevation bands, 162 and 302 buildings, respectively, were new (and two were under construction). The figures are similar for coastal inundation: 15 new buildings were recorded in the ARI 100 zone; 106 in the ARI 100+1m SLR zone; and 291 in the ARI 100+2 m SLR zone, with two buildings under construction (in 2013) in the ARI + SLR zones.

Table 23 Buildings (>10 m^2) potentially exposed to sea level rise: count (n) and proportion (%)

Building	Total	SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
	n	n	%	n	%	n	%	n	%	n	%
2013 buildings (urban core & periphery)	596,043	246	0.04	475	0.1	1,500	0.3	6,318	1.1	12,738	2.1
LINZ buildings (rural)	73,831	2,151	2.9	2,891	3.9	3,773	5.1	5,670	7.7	7,175	9.7
Regional buildings – total	669,874	2,397	0.4	3,366	0.5	5,273	0.8	11,988	1.8	19,913	3.0

Table 24 Buildings potentially to exposed coastal inundation: count (n) and proportion (%)

Buildings	Total	ARI100		ARI100_SLR1m		ARI100_SLR2m	
	n	#	%	n	%	n	%
2013 buildings (urban core & periphery)	596,043	991	0.2	5,373	0.9	12,102	2.0
LINZ buildings (rural)	71,887	3,513	4.9	5,232	7.3	6,878	9.6
Regional buildings – total	667,930	4,504	0.7	10,605	1.6	18,980	2.8

5.2 Community facilities

What this measures:

The location of buildings and other structures with specific functions, such as hospitals and schools, were assessed against the modelled SLR and coastal inundation scenarios.

Which data were used:

Various spatial and non-spatial data sets were used to intersect with SLR scenarios to identify exposed community facilities. Auckland Council Community Facilities' (CF) Park Building layer and building records extracted from CF's SAP Maintenance Plant and Real Estate modules were used to identify council owned and maintained facilities. Due to the complex nature of building use, the facility data are grouped into seven main categories; detailed building category data are included in Appendix C.

The DVR data and the 2013 Buildings data set were used to assess the number of district health board related facilities and council-owned housing units that could be exposed to sea level rise and coastal inundation.

It should be noted that CF's building data are under constant updates and modifications. The number of buildings identified in this report was a snapshot of the data set. Furthermore, CF's Park Building layer only captures facilities that are maintained by council's Chief Operations Office (COO) Operations Division; it does not necessarily capture all facilities maintained and owned by other council-controlled organisations, namely Auckland Transport (AT), Auckland Tourism, Events and Economic Development (ATEED), Panuku Development Auckland (Panuku), and Regional Facilities Auckland (RFA).

Key messages:

- Less than 5% of council-maintained facilities are exposed to sea level rise of up to 1 m; there is a marked increase in facility types and numbers exposed at 2 m SLR and above.
- Combined with storm surge events, the number of exposed public amenities and service buildings doubles under 1 m SLR.
- Significant facility types exposed include mixed use facilities, public amenities, and service buildings.

Summary:

Overall, few facilities are exposed to sea level rise and coastal inundation scenarios (Table 25, Table 26), especially through 1 m SLR. There is a marked increase in the

number and types of exposed structures between sea level rise of 1 m and 2 m (Table 25, Table 26).

Proportionally, facilities and assets located on the coast and beaches are more highly exposed, such as public amenities buildings (toilets and changing rooms) and service buildings (e.g. storage sheds and utility structures) located on esplanades and coastal parks/reserves. Combined with storm surge events, the number of exposed public amenities and service buildings more than doubles under 1 m SLR, which jumps from 86 to 206 (Table 25, Table 26).

Some facility types of significance to community welfare and emergency management are exposed under the larger sea level rise scenarios, including evacuation centres, libraries, and community facilities. Four leisure buildings are exposed to SLR scenarios above 1 m and four libraries are exposed to 2 m SLR and greater.

In addition to council-owned community facilities, council-owned housing units were also examined. Auckland Council owns two types of housing portfolios (not including dwelling units owned and managed by Panuku), namely Housing for the Older People and Own-Your-Own units. Of these units, one building could be exposed to 2 m SLR, whereas 15 buildings could be exposed to coastal inundation from a ARI 100 storm in combination with 2 m SLR (Table 27, Table 28).

Table 25 Facilities potentially exposed to sea level rise: count (n) and proportion of facility type (%)

CF maintained facilities	Regional count (n)	SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
		n	%	n	%	n	%	n	%	n	%
Commercial	111	1	0.9	1	0.9	2	1.8	8	7.2	12	10.8
Community	515	2	0.4	4	0.8	6	1.2	38	7.4	46	8.9
Corporate	24	-	-	-	-	-	-	2	8.3	5	20.8
Leisure	66	1	1.5	2	3.0	4	6.1	5	7.6	6	9.1
Mixed use	197	3	1.5	6	3.0	7	3.6	33	16.8	37	18.8
Public amenities	750	7	0.9	10	1.3	45	6.0	178	23.7	197	26.3
Service	582	2	0.3	4	0.7	41	7.0	115	19.8	135	23.2
Total	**2245**	**16**	**0.7**	**27**	**1.2**	**105**	**4.7**	**379**	**16.9**	**438**	**19.5**

Table 26 Facilities potentially exposed to coastal inundation: count[14] (n) and proportion of facility type (%)

CF maintained facilities	Regional count (n)	ARI100		ARI100_SLR1m		ARI100_SLR2m	
		n	%	n	%	n	%
Commercial	111	-	-	8	7.2	9	8.1
Community	515	4	0.8	26	5.0	43	8.3
Corporate	24	-	-	-	-	2	8.3
Leisure	66	4	6.1	4	6.1	6	9.1
Mixed use	195	5	2.6	19	9.7	34	17.4
Public amenities	742	24	3.2	114	15.4	176	23.7
Service	564	24	4.3	92	16.3	122	21.6
Total	2217	61	2.8	263	11.9	392	17.7

[14] The coastal inundation scenarios do not include outlying islands in the Hauraki Gulf in the northeast of the Auckland region, including Great Barrier Island, so the total counts for these scenarios is less than the region as a whole and the number exposed to coastal inundation is underestimated in each scenario given the absence of these islands.

Table 27 Council housing[15] potentially exposed to sea level rise: count (n) and proportion of total (%)

Housing portfolio	Region count	SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
		n	%	n	%	n	%	n	%	n	%
Housing for older people	527	-	-	-	-	-	-	1	0.2	19	3.6
Own-your-own units	71	-	-	-	-	-	-	-	-	-	-
Total	598	-	-	-	-	-	-	1	0.2	19	3.2

Table 28 Council housing[14] potentially exposed to coastal inundation: count (n) and proportion of total (%)

Portfolio types	Region count	ARI100		ARI100_SLR 1m		ARI100_SLR 2m	
		n	%	n	%	n	%
Housing for older people	527	-	-	-	-	15	2.8
Own-your-own units	71	-	-	-	-	-	-
Total	598	-	-	-	-	15	2.5

[15] Council housing counts are derived from the 2013 Building footprint (building area greater than 10 m^2) dataset. The majority of council-owned houses are attached flats, with each building structure comprised of multiple dwelling units. While it is possible to identify how many building structures are exposed to sea level rise and coastal inundation, the actual number of dwelling units exposed cannot be examined due to lack of internal partition information.

5.3 Coastal assets

What this measures:

The location of a variety of coastal assets with specific functions, such as boat ramps, jetties, sea walls and wharves as well as boardwalks, stairs, footpaths and carparks, were assessed against the modelled SLR and coastal inundation scenarios.

Which data were used:

Four Community Facilities' (CF) spatial datasets were used, namely, Park Asset Route layer, Park Garden Turf Route layer, Park Structure Hard Surface layer, and Park Water Beach Extent layer. Asset records extracted from CF's SAP Maintenance Plant module were used to identify and validate council-owned assets that intersect with the SLR and coastal inundation models. For the purpose of this inventory, the detailed asset groups are also grouped into four main coastal asset groups.

As mentioned in previous sections, CF's spatial datasets are under constant updates and modifications. The number of assets identified in this report was a snapshot of the full data list. Asset records extracted from CF's SAP Maintenance Plant were incorporated in this analysis to provide better clarity on CF's asset data structure, as well as to remove all redundant and/or temporary data entries that are captured in the spatial layers.

Key messages:

- As structures located at the land/sea boundary, coastal assets are exposed to changes in environmental conditions (sea level rise) as well as extreme events (coastal inundation).
- Beaches and accompanying coastal structures are more exposed to all coastal inundation scenarios than SLR alone.
- A majority of boat ramps and wharves (and all jetties), would be exposed under all scenarios; land-based access assets are less exposed.

Summary:

Inherently, structures and assets located in coastal areas are largely exposed to SLR and coastal inundation (Table 29, Table 30). Whereas boardwalks and bridges would be highly exposed to SLR (Table 29), the proportions of other access assets for people and vehicles exposed are potentially low at 0.25 m and 0.50 m SLR, increasing markedly at 1 m SLR and greater. Walls and barriers are more exposed,

proportionally, than fences and retaining walls (Table 29). A majority of boat ramps and wharves (and all jetties), would be exposed under all scenarios, as would be expected given their position and function. Likewise beaches themselves are largely exposed to SLR and coastal inundation – almost by definition (here, those maintained by Auckland Council are tabulated).

Table 29 Coastal assets[16] potentially exposed to sea level rise

Data source name	Asset group	Asset category	Region	SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
			Length (m)	Length (m)	%	Length (m)	%	Length (m)	%	Length (m)	%	Length (m)	%
Asset Route	Fences and walls	Barrier	1,764.4	226.7	12.8	272.6	15.5	411.6	23.3	604.4	34.3	650.9	36.9
		Handrail[17]	28,612.0	2,539.1	8.9	2,916.5	10.2	3,754.9	13.1	5,405.2	18.9	6,792.1	23.7
Garden Turf Route		Fence	831,890.2	6,821.4	0.8	12,260.5	1.5	34,457.4	4.1	78,627.0	9.5	110,508.6	13.3
		Retaining wall	572.4	-	-	-	-	-	-	-	-	10.3	1.8
		Wall	138,663.2	34,659.4	25.0	43,040.8	31.0	56,621.2	40.8	68,218.8	49.2	72,666.3	52.4
		Grand total	1,001,502.3	44,246.5	4.4	58,490.4	5.8	95,245.0	9.5	152,855.3	15.3	190,628.3	19.0
			Area (m^2)	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%
Structure hard surface	Access (people and vehicles)	Access way	463,033.7	2,864.2	0.6	6,862.7	1.5	22,142.3	4.8	53,306.2	11.5	73,067.8	15.8
		Boardwalk	49,145.3	10,056.6	20.5	11,945.8	24.3	14,882.6	30.3	18,817.3	38.3	22,229.5	45.2
		Bridge	46,906.7	5,002.8	10.7	5,830.1	12.4	7,438.4	15.9	9,860.6	21.0	11,470.7	24.5
		Carpark	1,702,062.1	10,164.2	0.6	25,108.5	1.5	77,415.7	4.5	210,798.8	12.4	296,471.4	17.4
		Cycleway	148,645.0	2.2	0.0	980.7	0.7	3,274.2	2.2	8,670.4	5.8	13,437.8	9.0
		Helipad	23,178.1	12.2	0.1	148.9	0.6	797.7	3.4	5,619.2	24.2	9,450.3	40.8
		Park road	1,039,510.0	7,727.1	0.7	16,027.0	1.5	48,326.1	4.6	115,721.1	11.1	168,746.7	16.2
		Park structure	31,311.2	98.0	0.3	303.0	1.0	455.5	1.5	2,834.5	9.1	8,840.1	28.2
		Path	2,021,544.1	20,664.8	1.0	35,498.3	1.8	88,687.8	4.4	205,395.1	10.2	290,670.3	14.4
		Platform	9,682.8	264.1	2.7	338.9	3.5	523.4	5.4	911.3	9.4	1,145.5	11.8
		Steps stairs	36,712.0	870.1	2.4	1,072.9	2.9	1,622.0	4.4	2,863.3	7.8	3,750.4	10.2
	Boat ramps, jetties and wharves[18]	Boat ramp	43,718.0	26,613.1	60.9	29,354.6	67.1	33,966.4	77.7	36,856.0	84.3	37,749.5	86.3
		Jetty	100.3	100.3	100.0	100.3	100.0	100.3	100.0	100.3	100.0	100.3	100.0
		Wharf	17,704.4	10,696.9	60.4	10,969.7	62.0	12,094.2	68.3	12,741.8	72.0	12,854.6	72.6
		Grand total	5,633,253.7	95,136.6	1.7	144,541.4	2.6	311,726.9	5.5	684,495.7	12.2	949,984.9	16.9

[16] Categories are as captured in SAP database.

[17] Some multi-function fences and walls are captured as handrails. Council SAP records do capture the level of details to differentiate various components; however, such information is deeply embedded in the system which the assessment team cannot assess.

[18] The regional inventory aims to examine the two dimensional spatial dispersion and expansion of coastal inundation and sea level rise. Boat ramps, jetties and wharves, though designed for the dynamic coastal environment, are included in this report to help readers better understand the impacts and implications of climate change and sea level rise to the existing coastal recreation areas.

Data source name	Asset group	Asset Category	Region	SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
			Area (m^2)	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%
Water beach extent	Coastal structure (large)	Beach extent[19]	324,134.4	201,951.9	62.3	237,914.7	73.4	272,889.8	84.2	292,600.7	90.3	296,146.6	91.4
		Coastal structure	31,332.1	26,978.9	86.1	27,727.3	88.5	28,135.6	89.8	28,224.6	90.1	28,225.0	90.1
		Grand total	355,466.4	228,930.8	64.4	265,642.1	74.7	301,025.4	84.7	320,825.3	90.3	324,371.6	91.3

[19] The beach extent asset category identifies potentially exposed premium beach areas that require regular maintenance work such as beach grooming and sand shifting. It is included in this report to help readers better understand the impacts and implication of climate change and sea level rise to the existing coastal recreation areas.

Table 30 Coastal assets[20] potentially exposed to coastal inundation scenarios

Data source name	Asset group	Asset Category	Region	ARI100		ARI100_SLR 1m		ARI100_SLR 2m	
			Length (m)	Length (m)	%	Length (m)	%	Length (m)	%
Asset route	Fences and walls	Barrier	1,764.4	456.9	25.9	594.6	33.7	629.2	35.7
		Handrail	28,612.0	3,448.1	12.1	5,255.3	18.4	6,823.8	23.8
Garden turf route		Fence	831,890.2	27,599.3	3.3	73,052.6	8.8	105,327.0	12.7
		Retaining wall	572.4	-	-	-	-	7.0	1.2
		Wall	138,663.2	51,752.7	37.3	67,433.3	48.6	71,968.6	51.9
		Grand total	1,001,502.3	83,257.1	8.3	146,335.8	14.6	184,755.6	18.4
			Area (m^2)	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%
Hard surface structure	Access (people and vehicles)	Access way	463,033.7	15,305.1	3.3	48,078.2	10.4	72,289.5	15.6
		Boardwalk	49,145.3	13,459.9	27.4	18,335.1	37.3	22,146.5	45.1
		Bridge	46,906.7	6,780.9	14.5	9,449.8	20.1	11,818.2	25.2
		Carpark	1,702,062.1	55,025.7	3.2	188,232.3	11.1	290,919.3	17.1
		Cycleway	148,645.0	1,379.8	0.9	7,860.4	5.3	11,828.7	8.0
		Helipad	23,178.1	593.7	2.6	993.8	4.3	993.8	4.3
		Park road	1,039,510.0	37,451.5	3.6	107,524.0	10.3	158,255.8	15.2
		Park structure	31,399.1	500.5	1.6	3,065.6	9.8	8,414.2	26.8
		Path	2,021,544.1	56,037.9	2.8	177,953.9	8.8	269,570.8	13.3
		Platform	9,682.8	511.2	5.3	806.0	8.3	1,105.4	11.4
		Steps stairs	36,712.0	1,241.0	3.4	2,469.5	6.7	3,452.8	9.4
	Boat ramps, jetties and wharves[18]	Boat ramp	43,718.0	37,255.4	85.2	41,832.2	95.7	42,791.5	97.9
		Jetty	100.3	100.3	100.0	100.3	100.0	100.3	100.0
		Wharf	17,704.4	15,147.9	85.6	16,723.9	94.5	16,772.1	94.7
		Grand total	5,633,341.6	240,790.9	4.3	623,424.8	11.1	910,459.0	16.2
			Area (m^2)	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%
Water beach extent	Coastal structures (large)	Beach extent	324,134.4	288,257.7	88.9	314,002.0	96.9	319,983.1	98.7
		Coastal structure	31,332.1	30,326.8	96.8	30,779.8	98.2	30,924.6	98.7
		Grand total	355,466.4	318,584.5	89.6	344,781.8	97.0	350,907.8	98.7

[20] Categories are as captured in SAP database.

5.4 Landfills

What this measures:

The co-location of active and closed landfills, as well as transfer stations, with low-elevation bands/sea level rise scenarios and coastal inundation models were investigated.

Which data were used:

Auckland Council's landfill spatial data set (Bauzon 2013) were intersected with the scenarios.

Key messages:

- Almost half of closed landfills in the Auckland region could be exposed to sea level rise or coastal inundation.
- One of Auckland's two active landfills could be exposed under a 3 m SLR scenario.
- Auckland has one transfer station, which is not exposed.

Summary:

The Auckland region does not have high exposure to SLR in terms of active landfills and transfer stations (Table 31). In large part, this is due to few locations – two landfills and one transfer station; much of the waste is transported to locations outside the region. The active landfill that is exposed to SLR of 2 m and 3 m is located on Great Barrier Island; it is not accounted for in the coastal inundation scenarios (Table 32) since this is part of the excluded area in those models (Section 1.2).

In contrast, many closed landfills remain across the region, and many are small sites and/or coastal. They are historical legacies, and many have been repurposed into reserves, parks, and other open space land uses. Almost half of these closed landfills could be exposed to increasing levels of sea level rise (Table 31) and coastal inundation (Table 32).

Table 31 Landfills potentially exposed to sea level rise: count (n) and proportion (%) of total

Regional waste sites		SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
Type	Count (n)	n	%	n	%	n	%	n	%	n	%
Active landfills	2	-		-		-		1	50.0	1	50.0
Closed landfills	198	86	43.4	89	44.9	90	45.5	97	49.0	99	49.3
Transfer station	1	-		-		-		-		-	

Table 32 Landfills potentially exposed to coastal inundation: count (n) and proportion (%) of total

Regional waste sites		ARI100		ARI100_SLR1m		ARI100_SLR2m	
Type	Count (n)	n	%	n	%	n	%
Active landfills	1	-		-		-	
Closed landfills	198	86	43.4	94	47.5	97	49.0
Transfer station	1	-		-		-	

6.0 Infrastructure

Cities are often built around infrastructure, and populations rely on it for many aspects of daily life. Due to both how cities develop and the requirements of certain infrastructure services, many infrastructure assets are often found on the coast. The co-location of some of Auckland's council infrastructure assets with potential sea level rise zones are considered here.

In this section:

- Transport
- Three Waters.

6.1 Transport

What this section measures:

The exposure of transport assets route, land, and marine categories were considered.

Which data were used:

Auckland Transport provided asset data for roads, bridges, and jetties/wharves. Auckland Council geospatial data sets were used to tabulate airports, boat ramps, and marinas.

Key messages:

- The regional proportion of exposed road is just over 1% under 1 m SLR, although there are known hotspots of affected roads.
- Some areas of Auckland International Airport are affected at every sea level rise scenario.
- Marine facilities are usually affected by sea level rise, given their coastal position.

Summary:

All transport asset categories are exposed to sea level rise scenarios to some degree. Many transportation assets are located along the coast for both historical and functional reasons.

Just over 1% of the region's roads are exposed to sea level rise of 1 m, which can increase to 5% at 3 m SLR (Table 33). Although a relatively low portion at the

regional scale, known local hotspots exist, including Tāmaki Drive and Onehunga Town Centre (Pearce et al. 2018).

Auckland Airport is situated along the Manukau Harbour and, as such, the airport's land and facilities are exposed to sea level rise and coastal inundation.

All marine facilities will, by definition, be affected. All jetties and wharves were considered by Auckland Transport to be exposed across scenarios, and an increasing number of boat ramps would be exposed with increasing sea levels (Table 33). Some portion of the six council-owned marinas could be affected across scenarios, given their location across the land/sea margin: in some cases slivers along land margins; in others, larger areas (Table 33).

Table 33 Transportation assets potentially exposed to sea level rise: quantity and proportion of each asset type in region (%)[21]

			SLR_0.25m		SLR_0.5m		SLR_1m		SLR_2m		SLR_3m	
Asset type	**Unit**	**Council total**	**quantity**	**%**	**quantity**	**%**	**quantity**	**%**	**quantity**	**%**	**quantity**	**%**
Routes												
Roads – all	km	7,391			41.5	0.6	93.4	1.3			367	5.0
Bridges	No.	1,260										
Facilities – land												
Bus terminals	No.	not available										
Airports	No.	1			1	100	1	100			1	100
Facilities – marine												
Marinas[22]	No.	6			6	100	6	100			6	100
Jetties/Wharves	No.	28										
Boat ramps	No.	221			142	64	152	69			161	73

[21] Data for all SLR scenarios were not available from Auckland Transport at time of publication. No data were provided for the coastal inundation (ARI100, ARI100_1m and ARI100_2m) scenarios. Bridge and bus terminal data were not provided by time of publication.

[22] Here, only council-owned marinas were tabulated.

6.2 Three waters

What this measures:

Three waters infrastructure comprises wastewater, water supply, and stormwater. Assets in each of these categories were tabulated for their intersections with modelled SLR and coastal inundation scenarios.

Which data were used:

Wastewater and water supply data were provided by Watercare. Stormwater data were provided by Auckland Council's Healthy Waters department.

Key messages:

- One wastewater treatment plant is potentially exposed under all SLR scenarios; two wastewater treatment plants would be potentially exposed to storm surge combined with SLR.
- In the water supply system, pump stations and pipes are exposed, as are reservoirs in the largest scenarios.
- Pipes and manholes in the stormwater system are exposed at every SLR scenario (as would be expected).

Summary:

Stormwater pipes and manholes would be exposed under all SLR and coastal inundation events, as would be expected given their function (Table 34, Table 35). It is usual to have stormwater outfalls that extend into the sea at current levels. As noted by Andrew Chin, Auckland's Waters Portfolio manager, "The issue is not whether the assets become submerged more frequently with sea level rise, it is the reduced capacity of the pipes due to a lower hydraulic gradient: in steep catchments there are unlikely to be issues, but in flat catchments there will be problems" (*personal communication*, 29 November 2018). This simple overlay analysis does not specify the short-term and long-term implications of further submersion or inundation, neither for the infrastructure itself nor the conveyance of stormwater, which is the subject of more detailed analyses and operational efforts. The function of the overlay analysis is to provide a regional overview (this volume) for potential exposure (Appendix D).

One of Auckland's wastewater treatment plants could be exposed to SLR of any magnitude (Table 34, Box 1). Coastal inundation occurring as a result of a ARI 100 storm combined with SLR of 1-2 m could affect two treatment plants (Table 35). One

water supply treatment plant and one water supply well/bore could also be exposed at the 3 m SLR scenario (Table 34).

Relatively low proportions of other wastewater asset categories are exposed to SLR and coastal inundation (Table 34, Table 35).

A relatively low proportion of total pipe length could be exposed; and, between one and three water supply pump stations could be exposed under increasing SLR regimes, with or without storm surge (Table 34, Table 35). Reservoirs in Auckland's water supply system could be exposed in the 3 m elevation band or to an ARI 100 storm combined with 2 m SLR.

Box 1 Watercare's approach to climate change risk

"The Mangere Wastewater Treatment Plant (WWTP) is Watercare's largest asset and treats the wastewater of more than one million Aucklanders. It is situated on the shore of the Manukau Harbour, which is projected to be impacted by sea level rise of approximately one metre by 2100. Watercare has recognised the significant consequences climate change will have and has reviewed the vulnerability of our assets to these potential impacts. A range of long-term planning responses are being considered, including capital interventions, operational optimisation, land use and environmental policy engagement and, in the worst-case scenario, asset abandonment.

For the Mangere WWTP, due to the degree of sunk investment in the treatment plant and all the accompanying wastewater conveyance network, the total replacement of the plant is the least preferred option. It is likely that the Mangere WWTP will be protected by both capital interventions (e.g. the construction of protective bund walls) and operational optimisation (e.g. backup energy supply) to ensure it remains resilient to climate change."

Chris Thurston, Head of Sustainability, Watercare

Table 34 Water infrastructure potentially exposed to sea level rise[23]: quantity and proportion of each asset type in region (%)

		Regional	SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
Asset type	**Unit**	**Total**	**Quantity**	**%**	**Quantity**	**%**	**Quantity**	**%**	**Quantity**	**%**	**Quantity**	**%**
Wastewater												
Treatment plants	No.	18			1	5.6	1	5.6			1	5.6
Pump stations[24]	No.	550			6	1.1	17	3.1			42	7.6
Manholes[25]	No.	160,000			68	0.04	118	0.1			466	0.3
Pipes <300mm[25, 26]	km	7,900			2.2	0.5	3.2	0.6			9	1.3
Pipes >300mm[25, 26]	km				35		45				93	
Water supply (potable)												
Treatment plants	No.	15			0		0				1	7
Water supply wells / bores	No.	18			0		0				1	7
Pump stations	No.	93			0		1	1.1			3	6
Pipes <300mm[25, 26]	km	9,000			2	0.1	4.4	0.2			8.1	0.4
Pipes >300mm[25, 26]	km				8.1		13.4				30.5	
Reservoirs	No.	9			0		0				1	11.1
Stormwater												
Manholes	No.	154,327	169	0.1	304	0.2	715	0.5	2,904	1.9	5,594	3.6
Pipes	km	6,395.1	49.0	0.8	63.6	1.0	99.7	1.6	230.4	3.6	360.0	5.6

[23] Data for the 0.25 m and 2 m SLR scenarios were not available from Watercare at time of publication.

[24] With delivery of data, Watercare noted: “Number of pump stations will also be over-estimated. This is because their associated lots are identified when intersected by the various shape files, not just the actual physical asset itself.”

[25] With delivery of data, Watercare noted: “In relation to the number of manholes, and the lengths of pipe that are anticipated to be “exposed” to the various SLR/coastal inundation scenarios, does not infer that replacement of these assets would be required. Currently, as most water and wastewater pipes are constructed at sub-surface, SLR and associated coastal inundation events would not adversely affected their operation. Manholes can also be sealed to prevent water inflow.”

[26] With delivery of data, Watercare noted: “the pipe lengths data (in km) will all be an over-approximation. This is because the pipe length has been measured from node to node, so will include additional lengths that go beyond the intersection with the various SLR/coastal inundation scenarios shape file intersections.”

Table 35 Water infrastructure potentially exposed to coastal inundation: quantity and proportion of each asset type in region (%)

		Regional	ARI100		ARI100_SLR1m		ARI100_SLR2m	
Asset type	**Unit**	**Total**	**Quantity**	**%**	**Quantity**	**%**	**Quantity**	**%**
Wastewater								
Treatment plants	No.	18	0		2	11.1	2	11.1
Pump stations[24]	No.	550	10	1.8	17	3.1	36	6.5
Manholes[25]	No.	160,000	88	0.1	118	0.1	428	0.3
Pipes <300mm[25,26]	km	7,900	3.1	0.5	7.1	0.9	8.9	1.2
Pipes >300mm[25,26]	km		39.6		66.3		89.1	
Water supply (potable)								
Treatment plants	No.	15	0		0		0	
Water supply wells / bores	No.	18	0		0		0	
Pump stations[24]	No.	93	1	1.1	1	1.1	3	3.2
Pipes <300mm[25,26]	km	9,000	3.5	0.2	5.5	0.3	7.3	0.4
Pipes >300mm[25,26]	km		12		17.4		30.2	
Reservoirs	No.	9	0		0		1	11.1
Stormwater								
Manholes	No.	154,327	498	0.3	2,471	1.6	5,195	3.4
Pipes	km	6,395.1	75	1.2	197	3.1	333	5.2

7.0 Summary

This first comprehensive inventory of exposure to sea level rise for the Auckland region provides estimates of the magnitude of land and objects that may be affected across sectors by various amounts of sea level rise. The timing ascribed to the SLR and coastal inundation amounts selected were taken from the upper end of the likely range for the business as usual scenario (RCP 8.5, 83rd percentile), covering the possibility of polar ice sheet instabilities (Pearce et al. 2018), which would lead to an acceleration of sea level rise. Thus, a precautionary, conservative approach has been adopted in order to understand the range of potential exposure for the Auckland region.

This exposure study is a snapshot in time – dependent on both available data and current understanding of the processes and effects of climate change. As such, the inventory can be updated as and when new data and knowledge become available. This could include, but would not be limited to:

- Updated understanding and models of sea level rise (e.g. due to acceleration should ice sheets collapse or other drivers occur).
- Corrected and/or improved coastal inundation mapping may be undertaken based on a recently collected LiDAR data set (2016-2018), which will correct previous errors and provide new information about the region's terrain.
- Data from the 2018 Census are expected to be made available at the required subnational scales from mid-2019 onwards.
- Updates and improvements to any of the spatial land or asset data sets.

Improvements to key data sets and advancements in knowledge about SLR processes and/or the region's terrain will lead to better understanding about the *hazard* posed by this climate change impact. New data and updated data sets of mapped entities (land, population, and objects) will provide greater insight to what may be *exposed* to SLR and coastal inundation. Thus, begins an ongoing process of inventorying exposure to SLR.

Moreover, the exposure data as put forward here offers the foundation upon which to pursue further research about the climate change impact of sea level rise. In any sector, and across sectors, many questions arise about the intricacies of the impacts of exposure and vulnerabilities to them. So, not only will exposure itself require ongoing investigation, but perhaps more importantly the complexity of hazard, exposure, and vulnerability will require more attention and resource in order to ascertain Auckland's risk from sea level rise.

8.0 Acknowledgements

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Appendix A Auckland Unitary Plan zone (detail)

Table 36 Auckland Unitary Plan zones potentially exposed to sea level rise: area (ha) and proportion of each zone (%)

Unitary Plan zones: regional area (ha) and proportion (%)			SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
Unitary Plan zone	**Area (ha)**	**Proportion**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
Business - City Centre Zone	258.1	0.05	2.0	0.8	2.6	1.0	5.0	1.9	76.6	29.7	125.1	48.5
Business - General Business Zone	353.9	0.07	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.6	0.2
Business - Heavy Industry Zone	1,868.8	0.38	4.5	0.2	5.6	0.3	10.3	0.5	39.8	2.1	116.2	6.2
Business - Light Industry Zone	4,477.6	0.92	15.6	0.3	27.2	0.6	48.3	1.1	85.7	1.9	131.7	2.9
Business - Local Centre Zone	243.4	0.05	0.1	0.0	0.1	0.0	0.4	0.2	2.7	1.1	7.7	3.2
Business - Metropolitan Centre Zone	381.4	0.08	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.6	0.2
Business - Mixed Use Zone	976.5	0.20	0.7	0.1	1.3	0.1	7.3	0.7	27.9	2.9	54.5	5.6
Business - Neighbourhood Centre Zone	135.2	0.03	1.8	1.3	4.0	3.0	6.8	5.0	9.9	7.4	11.2	8.3
Business - Town Centre Zone	445.7	0.09	0.1	0.0	0.1	0.0	0.9	0.2	5.9	1.3	21.9	4.9
Coastal - Coastal Transition Zone	1,430.0	0.29	375.4	26.2	503.4	35.2	727.7	50.9	945.7	66.1	1,040.0	72.7
Coastal - Defence Zone	16.6	0.00	12.9	77.6	12.9	77.7	12.9	77.8	13.1	78.6	13.3	79.9
Coastal - Ferry Terminal Zone	7.8	0.00	3.2	40.6	3.2	41.7	3.8	48.4	4.7	60.0	4.8	62.1
Coastal - Marina Zone	242.9	0.05	59.0	24.3	60.3	24.8	64.6	26.6	88.6	36.5	99.3	40.9
Coastal - Minor Port Zone	17.2	0.00	7.4	43.1	7.5	43.6	8.3	48.3	12.5	72.6	12.6	73.3
Coastal - Mooring Zone	1,247.3	0.26	135.6	10.9	135.7	10.9	135.7	10.9	135.7	10.9	135.7	10.9
Future Urban Zone	10,520.2	2.16	3.9	0.0	7.7	0.1	18.8	0.2	40.4	0.4	70.8	0.7
Hauraki Gulf Islands	47,153.2	9.70	76.0	0.2	162.0	0.3	480.8	1.0	1,121.3	2.4	1,622.2	3.4
Open Space - Community Zone	90.9	0.02	0.1	0.1	0.5	0.5	0.9	1.0	2.1	2.3	4.7	5.2
Open Space - Conservation Zone	32,320.9	6.65	375.3	1.2	543.0	1.7	920.9	2.8	1,773.7	5.5	2,470.6	7.6
Open Space - Informal Recreation Zone	8,415.0	1.73	99.1	1.2	178.7	2.1	384.5	4.6	735.4	8.7	1,011.1	12.0
Open Space - Sport and Active Recreation Zone	3,077.8	0.63	68.4	2.2	94.4	3.1	149.6	4.9	265.7	8.6	369.0	12.0
Residential - Large Lot Zone	2,910.7	0.60	2.6	0.1	4.7	0.2	8.1	0.3	15.3	0.5	22.5	0.8
Residential - Mixed Housing Suburban Zone	15,070.2	3.10	4.7	0.0	8.9	0.1	24.8	0.2	96.8	0.6	197.3	1.3
Residential - Mixed Housing Urban Zone	7,594.8	1.56	0.7	0.0	1.3	0.0	4.2	0.1	28.3	0.4	88.9	1.2
Residential - Rural and Coastal Settlement Zone	1,852.3	0.38	8.6	0.5	18.1	1.0	57.6	3.1	126.3	6.8	151.8	8.2
Residential - Single House Zone	8,575.6	1.76	49.8	0.6	73.3	0.9	117.0	1.4	266.8	3.1	435.2	5.1
Residential - Terrace Housing and Apartment Building Zone	2,504.1	0.52	0.3	0.0	0.4	0.0	2.0	0.1	6.8	0.3	25.4	1.0
Road	17,633.0	3.63	111.2	0.6	151.7	0.9	240.8	1.4	457.8	2.6	671.5	3.8

Unitary Plan zones: regional area (ha) and proportion (%)			SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
Unitary Plan zone	**Area (ha)**	**Proportion**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
Rural - Countryside Living Zone	22,521.4	4.63	53.7	0.2	89.6	0.4	153.7	0.7	254.3	1.1	342.4	1.5
Rural - Mixed Rural Zone	39,080.8	8.04	103.9	0.3	125.1	0.3	174.1	0.4	282.0	0.7	459.1	1.2
Rural - Rural Coastal Zone	73,286.5	15.08	3,863.0	5.3	4,563.5	6.2	5,783.4	7.9	6,958.3	9.5	7,860.5	10.7
Rural - Rural Conservation Zone	3,088.8	0.64	10.7	0.3	16.8	0.5	33.0	1.1	55.2	1.8	72.0	2.3
Rural - Rural Production Zone	167,746.2	34.51	1,569.1	0.9	1,897.2	1.1	2,362.4	1.4	2,965.6	1.8	3,449.5	2.1
Rural - Waitakere Ranges Zone	3,140.8	0.65	0.2	0.0	0.8	0.0	4.4	0.1	23.4	0.7	59.9	1.9
Special Purpose - Airports and Airfields Zone	1,541.8	0.32	7.9	0.5	14.5	0.9	30.4	2.0	96.0	6.2	205.5	13.3
Special Purpose - Cemetery Zone	290.2	0.06	0.1	0.0	0.2	0.1	1.2	0.4	7.2	2.5	9.6	3.3
Special Purpose - Healthcare Facility and Hospital Zone	164.4	0.03	0.1	0.0	0.1	0.1	0.2	0.1	0.7	0.4	1.6	1.0
Special Purpose - Māori Purpose Zone	87.1	0.02	0.3	0.3	0.5	0.6	1.6	1.9	5.5	6.3	8.5	9.8
Special Purpose - Major Recreation Facility Zone	454.0	0.09	0.1	0.0	0.1	0.0	0.2	0.0	0.8	0.2	1.6	0.3
Special Purpose - Quarry Zone	1,666.7	0.34	7.9	0.5	8.7	0.5	11.4	0.7	17.2	1.0	24.7	1.5
Special Purpose - School Zone	668.4	0.14	0.1	0.0	0.2	0.0	0.4	0.1	1.2	0.2	3.2	0.5
Strategic Transport Corridor Zone	2,568.7	0.53	21.5	0.8	33.4	1.3	67.6	2.6	143.4	5.6	213.4	8.3

Table 37 Auckland Unitary Plan zones potentially exposed to coastal inundation: area[2] (ha) and proportion of each zone (%)

Unitary Plan zones: regional area[2] (ha) and proportion (%)			ARI100		ARI100_SLR1m		ARI100_SLR2m	
Unitary Plan zone	Area (ha)	Proportion	ha	%	ha	%	ha	%
Business - City Centre Zone	258.1	0.1	1.4	0.5	48.2	18.7	122.0	47.3
Business - General Business Zone	353.9	0.1	0.1	0.0	0.2	0.1	0.5	0.1
Business - Heavy Industry Zone	1,868.8	0.4	7.1	0.4	29.6	1.6	96.1	5.1
Business - Light Industry Zone	4,477.6	1.0	41.6	0.9	76.9	1.7	126.2	2.8
Business - Local Centre Zone	243.4	0.1	0.2	0.1	2.7	1.1	7.5	3.1
Business - Metropolitan Centre Zone	381.4	0.1	0.1	0.0	0.2	0.1	0.5	0.1
Business - Mixed Use Zone	976.5	0.2	3.2	0.3	21.9	2.2	47.9	4.9
Business - Neighbourhood Centre Zone	135.2	0.03	5.5	4.1	9.1	6.7	10.8	8.0
Business - Town Centre Zone	445.7	0.1	0.7	0.2	5.8	1.3	22.5	5.0
Coastal - Coastal Transition Zone	1,430.0	0.3	720.8	50.4	962.3	67.3	1070.6	74.9
Coastal - Defence Zone	16.6	0.0	16.3	98.0	16.4	98.5	16.6	100.0
Coastal - Ferry Terminal Zone	7.4	0.0	4.6	62.2	5.7	77.5	6.0	80.9
Coastal - Marina Zone	242.9	0.1	200.3	82.5	225.8	93.0	237.6	97.8
Coastal - Minor Port Zone	17.2	0.0	12.4	71.7	16.9	98.2	17.2	99.7
Coastal - Mooring Zone	1,194.8	0.3	1194.6	100.0	1194.7	100.0	1194.7	100.0
Future Urban Zone	10,520.2	2.3	26.9	0.3	47.8	0.5	79.0	0.8
Hauraki Gulf Islands	15,378.4	3.4	219.4	1.4	429.0	2.8	599.1	3.9
Open Space - Community Zone	90.9	0.02	1.0	1.1	2.0	2.2	4.5	5.0
Open Space - Conservation Zone	32,320.9	7.1	969.9	3.0	1939.0	6.0	2509.4	7.8
Open Space - Informal Recreation Zone	8,415.0	1.9	348.3	4.1	720.3	8.6	999.5	11.9
Open Space - Sport and Active Recreation Zone	3,077.8	0.7	112.4	3.7	223.1	7.2	341.3	11.1
Residential - Large Lot Zone	2,910.7	0.6	6.0	0.2	13.2	0.5	20.5	0.7
Residential - Mixed Housing Suburban Zone	15,070.2	3.3	24.1	0.2	89.4	0.6	178.0	1.2
Residential - Mixed Housing Urban Zone	7,594.8	1.7	3.2	0.0	23.3	0.3	87.3	1.1
Residential - Rural and Coastal Settlement Zone	1,852.3	0.4	32.7	1.8	118.7	6.4	149.8	8.1
Residential - Single House Zone	8,575.6	1.9	96.6	1.1	235.9	2.8	415.0	4.8
Residential - Terrace Housing and Apartment Building Zone	2,504.1	0.6	1.0	0.0	7.2	0.3	25.3	1.0
Road	17,633.0	3.9	223.7	1.3	436.5	2.5	663.7	3.8
Rural - Countryside Living Zone	22,521.4	5.0	119.1	0.5	228.3	1.0	313.2	1.4
Rural - Mixed Rural Zone	39,080.8	8.6	155.3	0.4	259.9	0.7	409.5	1.0

Unitary Plan zones: regional area[2] (ha) and proportion (%)			ARI100		ARI100_SLR1m		ARI100_SLR2m	
Unitary Plan zone	Area (ha)	Proportion	ha	%	ha	%	ha	%
Rural - Rural Coastal Zone	73,286.5	16.1	5363.4	7.3	6881.9	9.4	7797.3	10.6
Rural - Rural Conservation Zone	3,088.8	0.7	26.4	0.9	51.8	1.7	70.5	2.3
Rural - Rural Production Zone	167,746.2	36.9	2413.4	1.4	3054.5	1.8	3499.3	2.1
Rural - Waitakere Ranges Zone	3,140.8	0.7	4.1	0.1	41.2	1.3	110.1	3.5
Special Purpose - Airports and Airfields Zone	1,541.8	0.3	22.6	1.5	70.0	4.5	167.7	10.9
Special Purpose - Cemetery Zone	290.2	0.1	1.2	0.4	7.4	2.5	9.7	3.3
Special Purpose - Healthcare Facility and Hospital Zone	164.4	0.04	0.2	0.1	0.4	0.3	1.1	0.7
Special Purpose - Māori Purpose Zone	87.1	0.02	0.1	0.2	0.6	0.6	1.4	1.6
Special Purpose - Major Recreation Facility Zone	454.0	0.1	0.8	0.2	5.1	1.1	8.3	1.8
Special Purpose - Quarry Zone	1,666.7	0.4	5.1	0.3	12.7	0.8	20.1	1.2
Special Purpose - School Zone	668.4	0.2	0.4	0.1	1.1	0.2	3.1	0.5
Strategic Transport Corridor Zone	2,568.7	0.6	59.1	2.3	129.1	5.0	205.1	8.0

Appendix B Land use – secondary DVR category

Table 38 Land use (secondary DVR category) affected by sea level rise: area (ha) and proportion of each category (%)

Regional Land Use: area (ha) and proportion (%)				SLR_0.25m		SLR_0.50m		SLR_1m		SLR_2m		SLR_3m	
Primary Level Land Use	Secondary level land use	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Unknown/no data		41675.0	8.9	570.0	1.4	766.8	1.8	1130.7	2.7	1859.5	4.5	2480.8	6.0
Commercial	Car parking - commercial	49.1	0.0	0.1	0.2	0.3	0.5	1.1	2.2	4.0	8.1	5.7	11.6
Commercial	Multi-use within commercial	510.5	0.1	0.2	0.0	1.2	0.2	2.8	0.5	12.8	2.5	23.8	4.7
Commercial	Offices	311.5	0.1	0.4	0.1	0.5	0.1	0.7	0.2	9.1	2.9	18.4	5.9
Commercial	Retail	895.0	0.2	2.0	0.2	4.5	0.5	8.0	0.9	17.5	2.0	32.9	3.7
Commercial	Services	97.4	0.0	0.2	0.2	0.2	0.2	0.3	0.3	0.8	0.8	1.8	1.8
Commercial	Vacant - commercial	202.0	0.0	1.3	0.6	1.9	1.0	2.3	1.1	7.3	3.6	10.3	5.1
Commercial	Wholesale	52.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.8	1.6
Community Services	Cemeteries & crematoria	411.9	0.1	0.6	0.1	1.1	0.3	3.4	0.8	10.9	2.6	15.0	3.6
Community Services	Defence	1131.4	0.2	0.7	0.1	2.2	0.2	11.0	1.0	21.6	1.9	25.3	2.2
Community Services	Educational	1884.4	0.4	3.1	0.2	3.7	0.2	5.8	0.3	14.5	0.8	29.2	1.6
Community Services	Halls	243.1	0.1	1.7	0.7	2.8	1.2	6.7	2.8	17.1	7.0	29.3	12.1
Community Services	Medical hospital clinic	147.9	0.0	0.3	0.2	0.4	0.3	0.7	0.4	1.7	1.1	3.5	2.4
Community Services	Multi-use within community services	974.6	0.2	0.9	0.1	1.6	0.2	5.0	0.5	16.2	1.7	26.3	2.7
Community Services	Personal & property	223.1	0.0	0.2	0.1	0.3	0.1	0.5	0.2	1.2	0.6	3.5	1.6
Community Services	Religious	261.8	0.1	1.1	0.4	1.3	0.5	2.1	0.8	4.6	1.8	6.6	2.5
Community Services	Vacant community services	54.3	0.0	0.1	0.1	0.1	0.2	0.6	1.2	2.7	5.0	4.5	8.3
Industrial	Building materials other than timber	240.4	0.1	0.0	0.0	0.3	0.1	1.2	0.5	3.9	1.6	6.1	2.5
Industrial	Chemicals, plastics, rubber and paper	234.8	0.1	0.0	0.0	0.0	0.0	0.5	0.2	4.0	1.7	11.7	5.0
Industrial	Depots & yards	222.9	0.0	2.5	1.1	4.8	2.1	10.0	4.5	16.6	7.4	23.3	10.5
Industrial	Engineering, metalwork, appliances and machinery	796.8	0.2	18.2	2.3	23.9	3.0	29.5	3.7	42.8	5.4	60.0	7.5
Industrial	Food, drink & tobacco	413.8	0.1	0.1	0.0	0.3	0.1	1.4	0.3	3.8	0.9	9.6	2.3
Industrial	Multi-use within industrial	986.0	0.2	4.3	0.4	5.4	0.5	7.7	0.8	23.7	2.4	55.2	5.6
Industrial	Other industries, including storage	1242.7	0.3	2.8	0.2	5.0	0.4	9.0	0.7	16.7	1.3	29.5	2.4
Industrial	Textiles, leather & fur	126.5	0.0	0.0	0.0	0.1	0.1	0.5	0.4	3.5	2.7	7.1	5.6

Industrial	Timber products and furniture	206.9	0.0	0.1	0.0	0.3	0.2	0.7	0.4	2.2	1.1	7.7	3.7
Industrial	Vacant - industrial	763.8	0.2	21.2	2.8	24.3	3.2	28.2	3.7	35.1	4.6	45.5	6.0
Lifestyle	Multi-unit - lifestyle	11436.5	2.5	56.3	0.5	77.8	0.7	112.6	1.0	176.1	1.5	241.0	2.1
Lifestyle	Multi-use within lifestyle	2598.4	0.6	3.8	0.1	9.1	0.3	27.3	1.1	47.1	1.8	68.0	2.6
Lifestyle	Single unit - lifestyle	71531.0	15.4	546.6	0.8	671.9	0.9	888.7	1.2	1234.2	1.7	1542.1	2.2
Lifestyle	Vacant - lifestyle	26556.5	5.7	267.7	1.0	364.5	1.4	519.3	2.0	684.6	2.6	837.7	3.2
Multi-Use at Primary Level	Commercial - multi	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Multi-Use at Primary Level	Lifestyle - multi	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Multi-Use at Primary Level	Residential - multi	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Recreational	Active indoor	238.9	0.1	1.1	0.5	2.7	1.1	7.9	3.3	17.3	7.3	38.4	16.1
Recreational	Active outdoor	5719.2	1.2	26.4	0.5	42.4	0.7	95.7	1.7	202.4	3.5	296.2	5.2
Recreational	Entertainment	174.4	0.0	0.8	0.5	1.2	0.7	1.6	0.9	3.0	1.7	3.8	2.2
Recreational	Multi-use within recreation	3712.0	0.8	48.4	1.3	71.2	1.9	137.0	3.7	227.1	6.1	308.1	8.3
Recreational	Passive indoor	146.5	0.0	0.1	0.1	0.2	0.1	0.7	0.5	1.7	1.2	2.9	2.0
Recreational	Passive outdoor	19359.4	4.2	248.8	1.3	338.3	1.7	520.9	2.7	828.8	4.3	1072.6	5.5
Recreational	Vacant - recreational	11397.7	2.4	132.4	1.2	196.8	1.7	342.7	3.0	586.2	5.1	751.7	6.6
Residential	Bach	425.9	0.1	2.3	0.5	4.6	1.1	11.3	2.7	26.1	6.1	34.7	8.2
Residential	Car parking - residential	13.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	3.6	0.7	5.1
Residential	Communal residence dependent on other use	13.1	0.0	0.0	0.1	0.0	0.2	0.3	1.9	0.7	5.2	0.8	6.1
Residential	Multi-unit	4487.1	1.0	4.7	0.1	9.3	0.2	20.4	0.5	62.2	1.4	126.8	2.8
Residential	Multi-use within residential	495.7	0.1	0.3	0.1	0.9	0.2	4.6	0.9	15.7	3.2	25.2	5.1
Residential	Public communal - licenced	157.7	0.0	0.2	0.1	0.3	0.2	0.7	0.4	3.4	2.2	5.1	3.2
Residential	Public communal - unlicenced	117.8	0.0	1.6	1.3	4.3	3.7	10.5	8.9	16.2	13.8	17.8	15.1
Residential	Single unit excluding bach	26833.9	5.8	51.8	0.2	72.1	0.3	121.4	0.5	300.8	1.1	549.8	2.0
Residential	Special accommodation	364.7	0.1	0.6	0.2	0.9	0.2	1.4	0.4	4.4	1.2	9.1	2.5
Residential	Vacant - residential	2262.5	0.5	8.1	0.4	14.8	0.7	35.7	1.6	94.2	4.2	134.1	5.9
Rural Industry	Dairying	43004.4	9.2	2379.8	5.5	2708.7	6.3	3297.6	7.7	3863.4	9.0	4345.3	10.1
Rural Industry	Forestry	39993.4	8.6	33.7	0.1	66.5	0.2	164.1	0.4	447.1	1.1	730.5	1.8
Rural Industry	Market gardens & orchards	7412.6	1.6	30.4	0.4	45.5	0.6	66.4	0.9	149.7	2.0	227.0	3.1
Rural Industry	Mineral extraction	799.3	0.2	1.7	0.2	1.9	0.2	2.3	0.3	3.4	0.4	8.1	1.0
Rural Industry	Multi-use within rural	5618.7	1.2	85.7	1.5	110.4	2.0	169.9	3.0	236.9	4.2	278.7	5.0

Rural Industry	Specialist livestock	4477.3	1.0	54.0	1.2	85.2	1.9	136.2	3.0	173.5	3.9	210.0	4.7
Rural Industry	Stock finishing	85752.0	18.4	1634.4	1.9	1993.5	2.3	2645.0	3.1	3404.2	4.0	3931.3	4.6
Rural Industry	Store livestock	22873.0	4.9	26.1	0.1	46.0	0.2	103.2	0.5	180.7	0.8	234.3	1.0
Rural Industry	Vacant - rural	2325.1	0.5	38.8	1.7	50.7	2.2	63.4	2.7	75.9	3.3	92.7	4.0
Transport	Air transport	636.3	0.1	17.3	2.7	23.2	3.6	33.8	5.3	75.1	11.8	177.1	27.8
Transport	Multi-use within transport	93.2	0.0	2.2	2.3	2.5	2.6	3.6	3.9	47.3	50.7	72.3	77.5
Transport	Parking	42.2	0.0	0.1	0.2	0.2	0.5	0.8	1.8	7.9	18.8	13.7	32.5
Transport	Rail transport	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transport	Road transport	52.6	0.0	0.7	1.4	0.9	1.8	1.5	2.9	5.5	10.4	7.8	14.9
Transport	Vacant - transport	59.5	0.0	0.5	0.8	0.8	1.3	1.1	1.9	2.3	3.8	3.5	5.9
Transport	Water transport	8.8	0.0	0.2	2.7	0.5	5.5	1.1	11.9	3.0	34.2	4.3	48.6
Utility Services	Communications	358.9	0.1	0.0	0.0	0.0	0.0	0.2	0.1	0.7	0.2	2.4	0.7
Utility Services	Electricity	203.6	0.0	40.4	19.8	41.5	20.4	43.0	21.1	45.7	22.5	47.4	23.3
Utility Services	Gas	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Utility Services	Multi-use within utility services	165.7	0.0	0.1	0.1	0.2	0.1	0.5	0.3	5.5	3.3	9.5	5.7
Utility Services	Other utility services	89.4	0.0	0.9	1.0	1.3	1.4	2.2	2.5	4.2	4.7	7.4	8.3
Utility Services	Sanitation	458.6	0.1	8.0	1.7	11.9	2.6	25.9	5.6	33.0	7.2	37.3	8.1
Utility Services	Vacant - utility	137.0	0.0	3.6	2.6	4.6	3.4	5.3	3.9	7.3	5.3	10.3	7.5
Utility Services	Water	8768.9	1.9	0.3	0.0	1.0	0.0	2.8	0.0	6.1	0.1	8.7	0.1

Table 39 Land Use (secondary DVR category) affected by coastal inundation: area[2] (ha) and proportion of each category (%)

Regional Land Use: area (ha) and proportion (%)				ARI100		ARI100_SLR1m		ARI100_SLR2m	
Primary Level Land Use	Secondary level land use	ha	%	ha	%	ha	%	ha	%
UNKNOWN/NO DATA		41675.0	8.9	1104.2	2.6	1869.6	4.5	2251.1	5.4
Commercial	Car parking - commercial	49.1	0.0	0.6	1.1	3.5	7.1	5.4	10.9
Commercial	Multi-use within commercial	510.5	0.1	2.3	0.5	10.8	2.1	22.0	4.3
Commercial	Offices	311.5	0.1	0.1	0.0	6.1	2.0	15.8	5.1
Commercial	Retail	895.0	0.2	6.4	0.7	15.4	1.7	31.5	3.5
Commercial	Services	97.4	0.0	0.3	0.3	0.7	0.7	1.7	1.7
Commercial	Vacant - commercial	202.0	0.0	1.9	0.9	6.1	3.0	10.2	5.1
Commercial	Wholesale	52.6	0.0	0.0	0.0	0.1	0.2	0.8	1.5
Community Services	Cemeteries & crematoria	411.9	0.1	3.3	0.8	11.1	2.7	15.2	3.7
Community Services	Defence	1131.4	0.2	4.9	0.4	20.9	1.9	24.3	2.1
Community Services	Educational	1884.4	0.4	4.8	0.3	12.2	0.6	26.0	1.4
Community Services	Halls	243.1	0.1	3.3	1.3	12.7	5.2	24.5	10.1
Community Services	Medical hospital clinic	147.9	0.0	0.5	0.4	1.4	0.9	3.1	2.1
Community Services	Multi-use within community services	974.6	0.2	3.7	0.4	12.4	1.3	23.6	2.4
Community Services	Personal & property	223.1	0.0	0.5	0.2	1.2	0.5	2.9	1.3
Community Services	Religious	261.8	0.1	1.5	0.6	4.4	1.7	6.3	2.4
Community Services	Vacant community services	54.3	0.0	0.2	0.4	2.0	3.8	3.6	6.6
Industrial	Building materials other than timber	240.4	0.1	0.9	0.4	3.1	1.3	6.0	2.5
Industrial	Chemicals, plastics, rubber and paper	234.8	0.1	0.2	0.1	2.5	1.1	11.4	4.9
Industrial	Depots & yards	222.9	0.0	10.7	4.8	15.6	7.0	22.7	10.2
Industrial	Engineering, metalwork, appliances and machinery	796.8	0.2	28.8	3.6	40.7	5.1	58.4	7.3
Industrial	Food, drink & tobacco	413.8	0.1	1.1	0.3	3.3	0.8	8.2	2.0
Industrial	Multi-use within industrial	986.0	0.2	6.4	0.6	19.2	2.0	42.0	4.3
Industrial	Other industries, including storage	1242.7	0.3	8.5	0.7	14.4	1.2	27.0	2.2
Industrial	Textiles, leather & fur	126.5	0.0	0.4	0.3	3.1	2.4	6.8	5.4
Industrial	Timber products and furniture	206.9	0.0	0.4	0.2	1.7	0.8	7.0	3.4

Regional Land Use: area (ha) and proportion (%)				ARI100		ARI100_SLR1m		ARI100_SLR2m	
Primary Level Land Use	Secondary level land use	ha	%	ha	%	ha	%	ha	%
Industrial	Vacant - industrial	763.8	0.2	26.1	3.4	32.2	4.2	43.2	5.7
Lifestyle	Multi-unit - lifestyle	11436.5	2.5	107.6	0.9	182.9	1.6	227.8	2.0
Lifestyle	Multi-use within lifestyle	2598.4	0.6	16.0	0.6	42.6	1.6	57.3	2.2
Lifestyle	Single unit - lifestyle	71531.0	15.4	851.9	1.2	1202.3	1.7	1495.6	2.1
Lifestyle	Vacant - lifestyle	26556.5	5.7	438.9	1.7	584.5	2.2	699.7	2.6
Multi-Use at Primary Level	Commercial - multi	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Multi-Use at Primary Level	Lifestyle - multi	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Multi-Use at Primary Level	Residential - multi	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Recreational	Active indoor	238.9	0.1	6.8	2.8	15.8	6.6	34.6	14.5
Recreational	Active outdoor	5719.2	1.2	77.3	1.4	182.4	3.2	265.0	4.6
Recreational	Entertainment	174.4	0.0	1.6	0.9	2.8	1.6	3.5	2.0
Recreational	Multi-use within recreation	3712.0	0.8	113.5	3.1	185.1	5.0	255.9	6.9
Recreational	Passive indoor	146.5	0.0	0.5	0.3	1.6	1.1	2.8	1.9
Recreational	Passive outdoor	19359.4	4.2	464.0	2.4	799.8	4.1	1053.0	5.4
Recreational	Vacant - recreational	11397.7	2.4	240.4	2.1	492.8	4.3	683.2	6.0
Residential	Bach	425.9	0.1	8.4	2.0	24.0	5.6	34.0	8.0
Residential	Car parking - residential	13.2	0.0	0.0	0.0	0.4	2.6	0.6	4.8
Residential	Communal residence dependent on other use	13.1	0.0	0.0	0.3	0.7	4.9	0.8	6.0
Residential	Multi-unit	4487.1	1.0	16.7	0.4	56.8	1.3	122.3	2.7
Residential	Multi-use within residential	495.7	0.1	5.1	1.0	10.4	2.1	14.0	2.8
Residential	Public communal - licenced	157.7	0.0	0.7	0.4	3.2	2.1	5.1	3.2
Residential	Public communal - unlicenced	117.8	0.0	6.8	5.8	16.0	13.6	17.5	14.9
Residential	Single unit excluding bach	26833.9	5.8	95.2	0.4	256.6	1.0	527.5	2.0
Residential	Special accommodation	364.7	0.1	1.1	0.3	3.8	1.0	8.9	2.4
Residential	Vacant - residential	2262.5	0.5	24.6	1.1	75.2	3.3	126.1	5.6
Rural Industry	Dairying	43004.4	9.2	3055.9	7.1	3803.9	8.8	4284.7	10.0
Rural Industry	Forestry	39993.4	8.6	213.9	0.5	473.1	1.2	738.6	1.8
Rural Industry	Market gardens & orchards	7412.6	1.6	67.9	0.9	155.0	2.1	215.0	2.9

Regional Land Use: area (ha) and proportion (%)				ARI100		ARI100_SLR1m		ARI100_SLR2m	
Primary Level Land Use	Secondary level land use	ha	%	ha	%	ha	%	ha	%
Rural Industry	Mineral extraction	799.3	0.2	7.7	1.0	9.0	1.1	11.5	1.4
Rural Industry	Multi-use within rural	5618.7	1.2	159.3	2.8	229.8	4.1	267.3	4.8
Rural Industry	Specialist livestock	4477.3	1.0	127.9	2.9	165.6	3.7	198.4	4.4
Rural Industry	Stock finishing	85752.0	18.4	2528.7	2.9	3290.0	3.8	3734.1	4.4
Rural Industry	Store livestock	22873.0	4.9	83.3	0.4	145.7	0.6	190.8	0.8
Rural Industry	Vacant - rural	2325.1	0.5	57.0	2.5	65.9	2.8	91.0	3.9
Transport	Air transport	636.3	0.1	30.3	4.8	49.7	7.8	130.9	20.6
Transport	Multi-use within transport	93.2	0.0	1.0	1.1	31.4	33.7	72.3	77.6
Transport	Parking	42.2	0.0	1.3	3.0	8.5	20.2	13.9	32.9
Transport	Rail transport	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transport	Road transport	52.6	0.0	1.7	3.3	5.3	10.1	8.3	15.7
Transport	Vacant - transport	59.5	0.0	1.1	1.8	1.8	3.0	3.2	5.3
Transport	Water transport	8.8	0.0	0.8	9.0	2.4	27.3	4.1	46.0
Utility Services	Communications	358.9	0.1	0.3	0.1	1.2	0.3	3.7	1.0
Utility Services	Electricity	203.6	0.0	42.5	20.9	44.2	21.7	46.8	23.0
Utility Services	Gas	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Utility Services	Multi-use within utility services	165.7	0.0	0.3	0.2	4.4	2.6	9.2	5.5
Utility Services	Other utility services	89.4	0.0	2.0	2.2	3.6	4.0	6.0	6.7
Utility Services	Sanitation	458.6	0.1	13.2	2.9	19.9	4.3	32.9	7.2
Utility Services	Vacant - utility	137.0	0.0	5.1	3.7	7.1	5.2	8.7	6.3
Utility Services	Water	8768.9	1.9	2.8	0.0	6.2	0.1	8.6	0.1

Appendix C Community facilities – detail

Table 40 Number of community facilities potentially exposed to sea level rise

Community Facilities Category	Asset group	Region count	SLR_0.25m	SLR_0.50m	SLR_1m	SLR_2m	SLR_3m
Commercial	Office accommodation	1	0	0	0	1	1
	Other buildings	4	1	1	1	3	4
	Regional Park buildings	4	0	0	1	4	4
	Not supplied	102	0	0	0	0	3
Community	Art	2	0	0	0	1	2
	Building on Community Lease	8	0	1	2	6	8
	Community centre	2	0	0	0	2	2
	Library	4	0	0	0	4	4
	Local and Sports Park buildings	4	0	1	1	4	4
	Other buildings	8	1	1	1	6	8
	Regional Park buildings	3	0	0	0	3	3
	Venue for Hire	12	1	1	2	12	12
	Not supplied	472	0	0	0	0	3
Corporate	Customer service centre	1	0	0	0	1	1
	Other buildings	1	0	0	0	1	1
	Not supplied	22	0	0	0	0	3
Leisure	Pools and Leisure	6	1	2	4	5	6
	Not supplied	60	0	0	0	0	0
Mixed Use	Unknown	1	0	1	1	1	1
	Art	1	0	0	0	1	1
	Building on Community Lease	2	0	0	0	2	2
	Community centre	1	0	0	0	1	1
	Holiday park buildings	8	0	1	2	6	8
	Local and Sports Park buildings	3	0	1	1	3	3
	Other buildings	2	0	0	0	2	2
	Pools and Leisure	2	0	0	0	2	2
	Regional Park buildings	2	0	0	0	2	2

Community Facilities Category	Asset group	Region count	SLR_0.25m	SLR_0.50m	SLR_1m	SLR_2m	SLR_3m
	Toilet	8	2	2	2	8	8
	Toilet changing room	2	1	1	1	2	2
	Venue for Hire	2				2	2
	Not supplied	163				1	3
Public Amenities	Building on Community Lease	1				1	1
	Building on Ground Lease	2				1	2
	Other buildings	1				1	1
	Toilet	131	7	10	30	122	128
	Toilet changing room	41			11	37	40
	Not supplied	574			4	16	25
Service	Unknown	3			1	3	3
	Animal management	10			2	10	10
	Rural fire station	1				1	1
	Holiday park buildings	24			13	19	24
	Local and Sports Park buildings	7		2	5	7	7
	Other buildings	8			1	7	7
	Regional Park buildings	69	1	1	18	65	69
	Not supplied	460	1	1	1	3	14
Grand total		2245	16	27	105	379	438

Table 41 Number of community facilities potentially exposed to coastal inundation

Community facilities category	Asset group	Region count	ARI100	ARI100_SLR1m	ARI100_SLR 2m
	Office Accommodation	1			1
	Other Buildings	4		4	4
	Regional Park buildings	4		4	4
Commercial	Not supplied	102			
	Art	2		1	2
	Building on Community Lease	8	1	3	8
	Community Centre	2		1	2
	Library	4		1	4
	Local and Sports Park buildings	4	1	2	4
	Other Buildings	8	1	5	8
	Regional Park buildings	3		3	3
	Venue for Hire	12	1	10	12
Community	Not supplied	472			
	Customer Service Centre	1			1
	Other Buildings	1			1
Corporate	Not supplied	22			
	Pools and Leisure	6	4	4	6
Leisure	Not supplied	60			
	Unknown	1	1	1	1
	Art	1		1	1
	Building on Community Lease	2		2	2
	Community Centre	1			1
	Holiday Park Buildings	8	1	4	8
	Local and Sports Park buildings	3		2	3
	Other Buildings	2		1	2
	Pools and Leisure	2			2
	Regional Park buildings	2		2	2
	Toilet	8	2	3	8
Mixed Use	Toilet Changing Room	2	1	2	2

Community facilities category	Asset group	Region count	ARI100	ARI100_SLR1m	ARI100_SLR 2m
	Venue for Hire	2		1	2
	Not supplied	163			
	Building on Community Lease	1		1	1
	Building on Ground Lease	2			2
	Other Buildings	1		1	1
	Toilet	131	20	84	131
	Toilet Changing Room	41	4	28	41
Public Amenities	Not supplied	574			
	Unknown	3		2	3
	Animal management	10	1	9	10
	Rural fire station	1		1	1
	Holiday Park Buildings	24	2	15	24
	Local and Sports Park buildings	7	4	5	7
	Other Buildings	8		1	8
	Regional Park buildings	69	17	59	69
Service	Not supplied	460			
Grand total		2245	61	263	392

Appendix D Glossary

Coastal inundation	Flooding along the coastal margin as a result of the combination of storm, tide, wave setup and sea level rise.
Exposure	Refers to the [potential] exposure of entities of interest to the projected sea level rise and coastal inundation models. The entities of interest are spatially intersected with the models to identify what is co-located.
Mean sea level (MSL)	The average sea level usually taken over rolling 19-year blocks, measuring the average of all high and low tides. Also serves as a vertical datum from which heights such as elevations are measured.
Risk	The CCRA project considers risk to be a combination of hazard, exposure, and vulnerability, following the IPCC, each of which are considered as distinct components. More traditionally, risk has been assessed by combining the probability of an impact occurring (or its 'likelihood') with the 'consequence' of the impacts. The CCRA more methodically considers risk as emerging from consequences related to the exposure to hazard and vulnerability of assets, people, or ecosystems.
Sea level rise (SLR)	The long-term increase in mean sea level.
Storm surge	Inverse barometric pressure effects and wind piling water levels up against the coast. A storm surge is most severe when it occurs in conjunction with a high tide.
Storm tide	The extreme water levels observed during storm events, adding storm surge, tide and mean sea-level anomalies together.
Vulnerability	Defined as the predisposition of human or biological systems to be adversely affected. It incorporates the concepts of sensitivity to harm and adaptive capacity of these systems to effectively cope with, or adapt to, the impacts of climate change.
Wave setup	Wave setup is the increase in water levels occurring due to breaking waves in the surf zone.

Find out more: phone 09 301 0101, email rimu@aucklandcouncil.govt.nz or visit aucklandcouncil.govt.nz **and knowledgeauckland.org.nz**

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