Tonkin+Taylor

Coastal Exposure Assessment - Stage 2 Exposure Assessment to Coastal Hazards

Prepared for
New Zealand Transport Agency
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Executive summary

Purpose

Waka Kotahi The New Zealand Transport Agency (NZTA), KiwiRail and Tonkin & Taylor Ltd (T+T) are working together to complete a first pass national coastal exposure assessment on the State Highway and Main Rail Network, to identify NZTA and KiwiRail assets that may be exposed to the effects of sea level rise.

This report provides the results of the national coastal exposure assessment of NZTA State Highway assets at national and regional levels for the following hazards:

- Four sea level rise conditions from readily available spatial mapping completed by the National Institute of Water and Atmospheric Research (NIWA), (2015/2019).
- The proximity of these assets to the coastal edge. Assets within 50 and 150 m of the coastal edge will be identified, indicating potential for exposure to erosion processes and storm effects.

Mapping units and assets exposed

Due to the national scale of this report 16 mapping units were created to allow for a more detailed exposure assessment. These mapping units are based on the Statistics New Zealand (2017) regional boundary extents.

The key assets that are assessed in this report include:

- State Highway – kilometres exposed.
- Tunnels – kilometres exposed.
- Bridges – number exposed.
- Culverts – number exposed.

Methodology

An exposure assessment solely analyses those assets that intersect a hazard extent, it does not take into consideration the severity or scale of the hazard. For this assessment two hazards were analysed independently of each other. They were then combined to understand the compounding exposure on the assets.

Two different data types were provided for this assessment which meant that two different approaches were used to understand the exposure of these assets. To analyse the road/rail and tunnel assets, the lengths were broken into 10 m segments. These segments were then overlaid on the hazard extents to gain an understanding of exposure. The segments were then aggregated back into their original state and were attributed with an exposure ratio. The ratio represents the percentage of the asset exposed to the different hazard scenarios. The output of this assessment is a length of asset exposed per region.

To analyse the bridge and culvert assets a simpler approach was undertaken. The assets were overlaid on the hazard extent and attributed with a yes or no depending on whether the asset intersected the hazard extent or not. The output of this assessment was the number of assets exposed per region.

Additional outputs presented in this report include the length of road and tunnel exposed for each different road classification type; based on the classification type in the CoreLogic dataset, the count of bridges that have an alternative route and the count of culverts for each different culvert type.

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The analysis for each hazard was done separately to allow for the combined hazard exposure assessment to be completed. Initially the assets were assessed against the coastal edge proximity extent, then the sea level rise extents. This allowed all hazard exposure attributes to be incorporated into each asset dataset for the combined asset exposure to be analysed.

Exposure

The exposure assessment is quantified in length or count of assets exposed, depending on the asset type. This is analysed at both a national and regional scale for both hazards independently and then combined. The analysis of the combined exposure outputs a hazard level for each particular asset.

Sea Level Rise

Exposure to the different sea level rise scenarios varied across the different asset types. Sea level rise exposure for the State Highway network ranged between 0.2% and 4% of the total network nationally. Notably, there were similar lengths of road exposed at current day storm surge scenarios and scenarios with sea level rise. Most of the exposed State Highway is located within the Waikato, Bay of Plenty and Canterbury regions. Tunnel exposure to the different sea level rise scenarios was comparatively lower to the State Highway network, with a maximum of 0.038km of tunnel exposed across the varying scenarios. This is equivalent to 0.3% of the national tunnel network. Sea level rise exposure for the bridge network ranged between 0.8% and 6.4% of the total network nationally. Most of the exposed assets are located within the Auckland, Bay of Plenty and Waikato regions. Culverts produced the largest range in percentage of total network exposed with 0.3% to 7.1%. The Nelson region has the highest number of culverts exposed across most scenarios, however the national total of culverts exposed in Scenario 4 is half that of bridges at the same scenario.

Coastal edge proximity

Exposure to the different coastal edge proximity extents varied across the different asset types. However, all asset types assessed had less than 6% of their total assets exposed at the two different coastal edge proximity extents.

Exposure of the State Highway to the coastal edge proximity extent ranged from 2% to 4% of the total network. The exposed assets are spread across all regions excluding the Manawatu-Wanganui region with majority located within the Bay of Plenty, Waikato, and Auckland regions. Similarly, to the sea level rise scenarios, tunnel exposure is only located within the Canterbury and Auckland regions with a maximum of 0.28km of tunnel exposed. Bridges have the highest percentage of exposure relative to the other asset types, with a maximum of 5% of the total stock exposed within 150 m of the coastal edge. The region with the most bridges exposed is the Auckland region. Culvert exposure ranges from 1.7% to 4% nationally with most exposed assets located within the Bay of Plenty, Waikato and Canterbury regions.

Combined sea level rise and coastal edge proximity

Most of the asset types were categorised as exposure level 1, with over 90% of all asset networks sitting within this category. The percentage of networks that sit within the other exposure levels varies across the different asset types. There is 2.6% of the State Highway network within exposure level 5 which is equivalent to 316km of road. Most of these assets are located in the Northland, Auckland, Waikato and Bay of Plenty regions. Exposure level 2 is the second most common category for the State Highway tunnel network. There is 4.3% of the total network exposed within exposure level 2, whilst the remaining 1.7% sits within exposure level 5. There is 2% and 1.8% of the total bridge network exposed at exposure level 5 and 3 respectively. The region with the highest number of assets within both these levels is the Auckland region. The culvert network has the highest percentage of assets within exposure level 1, with 96%. Out of the remaining assets, 1.5% is exposed at exposure level 5, with most of the assets located in the Hawke's Bay region.

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1 Introduction

1.1 Purpose

Waka Kotahi The New Zealand Transport Agency (NZTA) and KiwiRail (KR) have engaged Tonkin + Taylor (T+T) to carry out a first pass national coastal exposure assessment of the State Highway and Main Rail Network, focussing on sea level rise effects. The purpose is to identify and understand the location and quantity of NZTA and KR assets exposed to sea level rise (SLR) effects.

This assessment considered:

- The exposure of NZTA and KR assets to four SLR scenarios from available spatial mapping completed by the National Institute of Water and Atmospheric Research (NIWA), (2015/2019).
- The proximity of these assets to the coastal edge. Assets that are within 50 and 150 m of the coastal edge will be identified, indicating potential for exposure to erosion processes and storm effects.
- The combined exposure to both SLR and coastal edge proximity.

The focus of the study is limited to the assessment of the exposure of roads, rail lines, bridges, tunnels and culverts.

There have been previous studies undertaken by NIWA (2015 and 2019) as well as Local Government New Zealand (LGNZ), (2019) that highlight road exposure to SLR at a national level. However, these studies do not directly assess State Highway and rail networks at the level of detail provided for this assessment.

1.2 Stage 2 scope

The data collated in Stage 1 has been analysed at a regional scale using the Statistics New Zealand[1] regional boundaries (2017). The analysis undertaken for Stage 2 is similar to that carried out for LGNZ but also includes the quantification of inundation exposure for the four SLR scenarios, the quantification of assets within 50 m and 150 m of the coastal edge and the quantification of assets within *both* the inundation exposure and coastal edge proximity.

After the initial analysis was completed the following was discussed in a workshop that was held with representatives from NZTA and KiwiRail on 4 December 2019:

- Preliminary findings of analysis.
- Proposed report structure for Stage 2.
- The methodology for Stage 3.

1.3 Structure

This report has three main components:

- Assets and Methodology.
- Hazards.
- Exposure.

The assets and methodology sections (Section 2 and Section 3) give some context to the assets assessed and methodology that was used to complete the exposure assessment. The Hazards section in this report (Section 4) discusses the different hazard scenarios used in this exposure assessment and outlines the criteria for the combined exposure level analysis. The Exposure

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[1] Statistics New Zealand, 2017.

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component of this report outlines the results of the assessment and is reported at both a national and regional level. This section includes the quantity of assets exposed and gives references to figures that show the spatial distribution of the exposed assets.

1.4 Study limitations

Limitations and assumptions for this study include:

- A lack of high-resolution LiDAR in some regions[2] which meant, SLR exposure could not be assessed for two of the scenarios included in this study. This has meant that the coastal edge proximity hazard is the only proxy for coastal exposure in these areas.
- As a result of the lack of LiDAR and therefore SLR data for some regions, a conservative approach was taken when assigning hazard levels in the combined hazard analysis. Those areas that have no SLR data but sit within 50 m of the coastal edge have been assigned an exposure level 5 and exposure level 3 has been assigned for the assets exposed within 150 m of the coastal edge.
- This high-level national exposure assessment is to assist in identifying priority areas and areas where more refined assessments could be carried out. A regional or site-specific coastal exposure or risk assessment undertaken for a particular asset or site can take precedence over a national study. This is the case when the data used in the analysis is of a higher resolution or accuracy than that used in the national study.

Table 1.1 sets out the differences between the LGNZ 2019 report and the analysis undertaken for this report. The LGNZ assessment did not cover State Highway or Rail Network assets specifically and only analysed those assets that are owned by local councils. A more recent national coastal inundation assessment has been undertaken since the release of this report that included storm surge as well as sea level rise. This more recent data was incorporated into this study to allow for both static and dynamic inundation scenarios to be investigated as well as analysing a larger range in sea level rise conditions. This assessment also takes into consideration assets located within 50 and 150 m from the coastal edge, the LGNZ report does not cover this.

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[2] Taranaki, Marlborough, West Coast and Otago.

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Table 1.1: Differences between the LGNZ 2019 report and this study

Element	LGNZ 2019 Report	This Report
Road and rail assets assessed	· Local government owned assets, with no breakdown into State Highway or Rail Network. · No rail assets were assessed in this report.	· Core Logic Dataset (national), with breakdown into State Highway Network. · KiwiRail track centreline data.
Coastal inundation data	Bell et al., (2015) coastal inundation data, that took into consideration four scenarios: · Mean High Water Springs (MHWS) + 0.5 m SLR. · MHWS + 1.0 m SLR. · MHWS + 1.5 m SLR. · MHWS + 3.0 m SLR.	Bell et al., (2015) and Paulik et al. (2019) coastal inundation data, that took into consideration four scenarios: · MHWS + 0.5 m SLR (2015). · MHWS + 0.5 m SLR (2015). · 1% AEP + 0 m SLR (2019). · 1% AEP + 1.5 m SLR (2019). The 1% AEP SLR scenarios allows for the incorporation of current day storm surge extents and those extents with the addition of sea level rise.
Coastal edge proximity data	Coastal edge proximity not analysed.	Coastal edge proximity extents within 50 m and 150 m of the coastal edge were incorporated into this study. These were used as an indicator for those areas where coastal inundation information is not available and as a proxy for coastal erosion susceptibility.

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2 Assets exposed

2.1 Study area mapping units

To manage and report a more detailed exposure assessment, the network was split into 16 different cells as shown in Figure 2.1. These cells were based on the regional boundary extents from Statistics New Zealand (2017). This allowed there to be consistent boundaries nationally for both the NZTA and KiwRail assets.
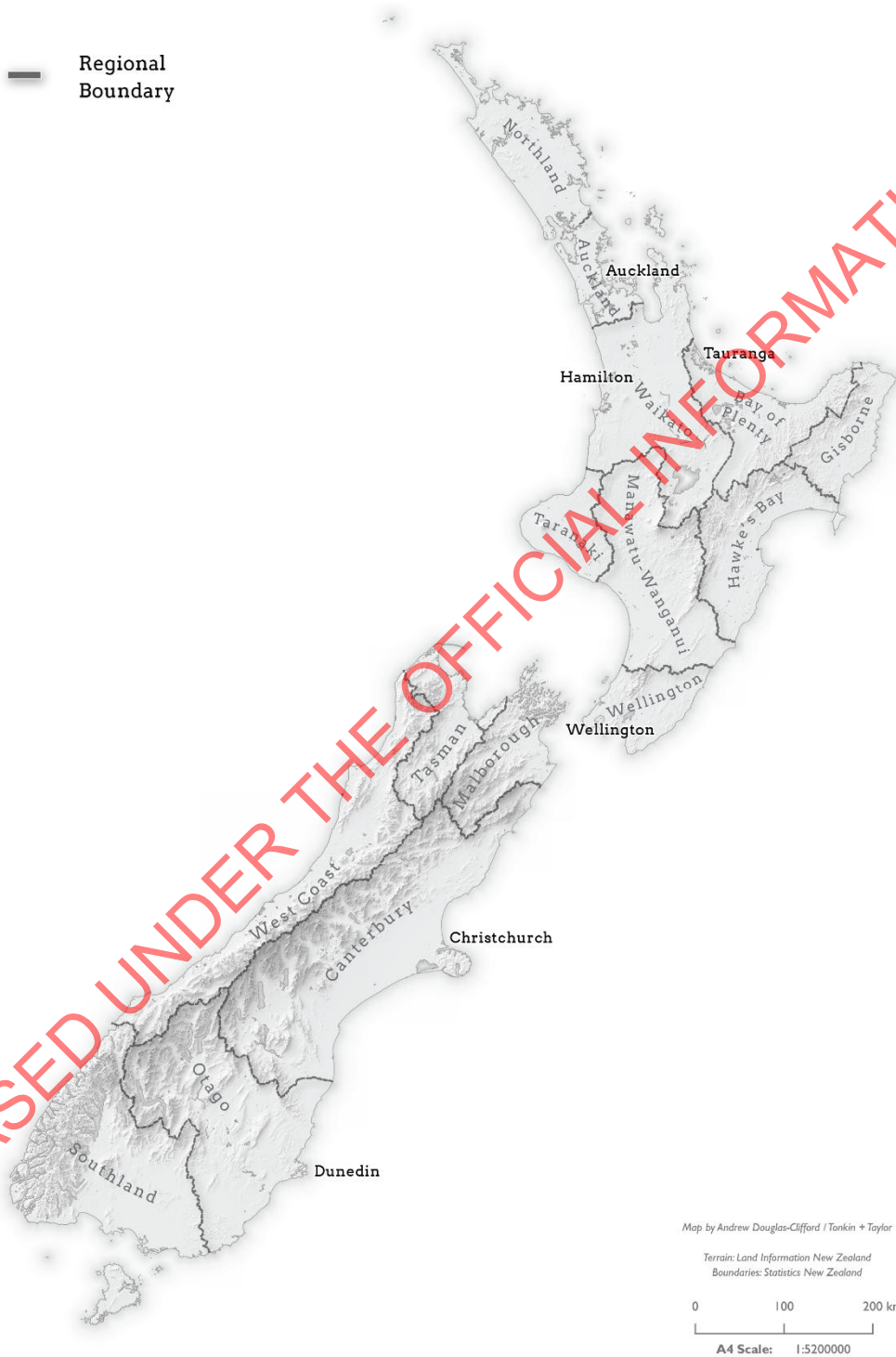
Figure 2.1: Regional boundary delineation.

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2.2 Key assets

The key assets that will be assessed that are both readily available and relevant to NZTA include:

- State Highway (SH) – kilometres exposed.
- Tunnels – kilometres exposed.
- Bridges – number exposed.
- Culverts – number exposed.

Table 2.1 shows a breakdown of the total lengths and counts of each of these assets.

Table 2.1:   Total network lengths and counts

Asset Type	Length (km)	Count
SH	11,942	
Tunnels	11.7	
Bridges		4,794
Culverts		2,008

2.2.1 Road

This assessment will only include the analysis of the NZTA SH Network. The SH Network is approximately 8% of NZTA's total road network. Table 2.2 indicates that the highest proportion of this network is located within the Waikato region, followed closely by Canterbury and Otago. However, the map shows that majority of the Waikato network is inland from the coast compared to that of Otago and Canterbury. The spatial distribution of the network and its proximity to the coast will be important in this assessment.

The NZTA SH network is broken down into different classifications in the CoreLogic dataset used [3]. The classifications that are captured in this analysis are:

- Motorway.
- Arterial rural.
- Arterial urban.
- Major rural.
- Major urban.
- Medium rural.
- Medium urban.
- Minor rural.
- Minor urban.

For the purpose of this assessment the urban and rural categories have been grouped together. Therefore, the following categories were used in this assessment:

- Motorway.
- Arterial.

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[3] It is noted that these classifications are not linked to an ONRC classification and that the current ONRC classifications are being renewed. It is advised that the classifications used in this report be reassessed when the new classifications are released.

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- Major.
- Medium.
- Minor.

Table 2.2:   Quantification and distribution of the NZTA SH Network nationally

Region	Roads (km)
Northland Region	855
Auckland Region	576
Waikato Region	1,936
Bay of Plenty Region	779
Gisborne Region	331
Hawke's Bay Region	526
Manawatu-Wanganui Region	995
Taranaki Region	410
Wellington Region	425
Marlborough Region	261
Nelson Region	59
Tasman Region	331
Canterbury Region	1,612
West Coast Region	883
Otago Region	1,157
Southland Region	808
Total	11,942

2.2.2   Tunnels

The tunnel network has the same classifications as the road network described above. Tunnels contribute to 0.09% of the total NZTA SH network length. Table 2.3 indicates that this is split across eight regions, with Auckland containing the largest portion of the network (around 6.5km). The figure included with the table shows the locations of the tunnels are distributed with some close to the coast. Therefore, there is potential for these assets to be exposed to coastal processes.

2.2.3   Bridges

The data format for bridges was provided by NZTA as a point location. This means that the exposure assessment will analyse the number of bridges affected and not the length exposed. Table 2.4 shows the distribution of bridges nationally and indicates that a large proportion of NZTA bridges are located in the Southland region. The Southland region has approximately double the amount of bridges that the second highest contributor (Canterbury) contains. The figure indicates a majority of these assets are located inland from the coast in Southland, therefore will be less likely to be exposed to coastal processes.

The bridge dataset gives information on whether a particular asset has an alternative route. The alternative routes that will be analysed include:

- Deviation 0 to 5km.

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- · Deviation 5 to 15km.
- · Deviation over 15km.
- · Immediately adjacent route.
- · None.
- · Other.

Table 2.3: Quantification and distribution of NZTA State Highway tunnels nationally

Region	Tunnels (km)
Northland Region	0
Auckland Region	6.46
Waikato Region	0.08
Bay of Plenty Region	0
Gisborne Region	0
Hawke's Bay Region	0
Manawatu-Wanganui Region	0.24
Taranaki Region	0.03
Wellington Region	1.44
Marlborough Region	0
Nelson Region	0
Tasman Region	0
Canterbury Region	2.16
West Coast Region	0
Otago Region	0
Southland Region	1.27
Total	11.66

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Table 2.4:   Quantification and distribution of NZTA bridges nationally

Region	Bridges (No.)
Northland Region	203
Auckland Region	407
Waikato Region	327
Bay of Plenty Region	191
Gisborne Region	399
Hawke's Bay Region	108
Manawatu-Wanganui Region	277
Taranaki Region	416
Wellington Region	220
Marlborough Region	72
Nelson Region	77
Tasman Region	99
Canterbury Region	460
West Coast Region	330
Otago Region	245
Southland Region	963
Total	4,794

2.2.4   Culverts

The data format for culverts was provided by NZTA as a point location therefore the exposure assessment considered the number of culverts affected. These structures appear to be significant structures that conduct streams, rivers or drainage channels across roads, and not the more conventional smaller diameter pipes that occur more frequently as part of the road drainage network. Table 2.5 shows the distribution of culverts nationally and indicates that most of culverts are located within the Southland region. Like bridges, the Southland region has over double the number of culverts than Canterbury, the second highest contributor. Most of these are located inland from the coast.

The NZTA culvert assets are split into different culvert types, these include:

·   Arch.

·   Multiple Pipe.

·   Pipe.

·   Box.

·   Multiple Box.

·   Triple Box.

·   Twin Box.

·   Not assigned.

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Table 2.5: Quantification and distribution of NZTA culverts nationally

Region	Culverts (No.)
Northland Region	114
Auckland Region	55
Waikato Region	182
Bay of Plenty Region	75
Gisborne Region	46
Hawke's Bay Region	70
Manawatu-Wanganui Region	143
Taranaki Region	54
Wellington Region	105
Marlborough Region	36
Nelson Region	118
Tasman Region	54
Canterbury Region	295
West Coast Region	161
Otago Region	97
Southland Region	403
Total	2,008

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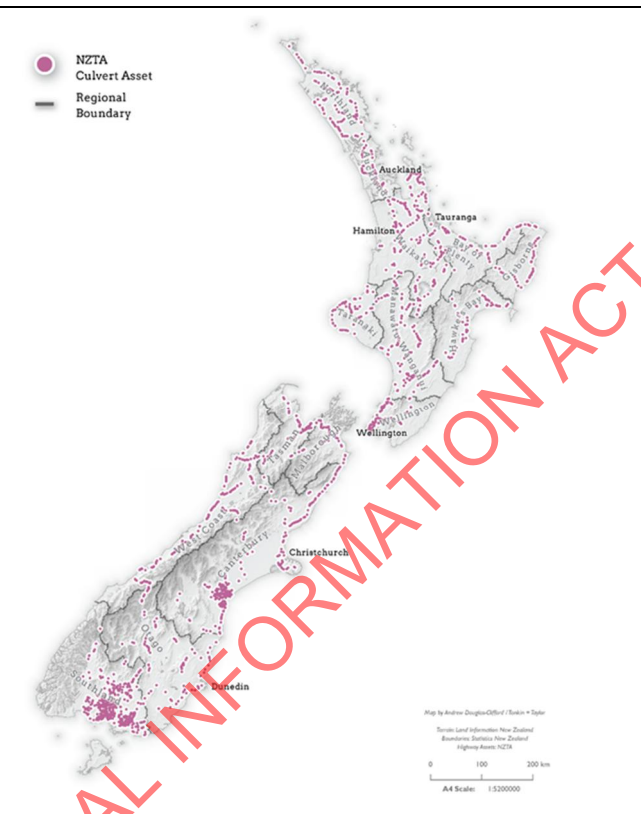
3 Methodology

An exposure assessment solely analyses those assets that intersect with a hazard extent. It does not measure the severity or scale of the hazard. For this assessment the two hazards were analysed independently of each other. They were then combined to understand the compounding exposure of the assets. The output of the combined analysis was split into five categories to understand the different levels of exposure.

T+T received the asset data as either points or lines and included:

- Road (Line).
- Tunnels (Line).
- Bridges (Point).
- Culverts (Point).

This data type variation meant two different approaches were taken to understand the exposure of these assets. Figure 3.1 represents the process undertaken to analyse the point assets. It shows that any point asset (bridge/culvert- black dot in figure) that is located within a hazard extent (blue shaded square, in figure) is defined as exposed. The result of this is a number (count) of assets exposed. However, the line assets (road/tunnels) are treated differently because they extend over larger areas. This extension of asset means that it is possible for a line segment (black line, in figure) to intersect multiple different hazard extents (blue shaded square, in figure). To ensure this information was recorded the following steps were undertaken:

- The line assets were split into 10 m segments.
- The segments were then analysed following the process outlined in Figure 3.2.
- Once initial analysis was completed the line segments were then aggregated back to their original state with a ratio attribute.
- The ratio attribute defines the proportion of road exposed to each hazard.

The final output is a length/number of each asset exposed to each of the hazards.

Figure 3.1: Geospatial methodology undertaken for the point assets.

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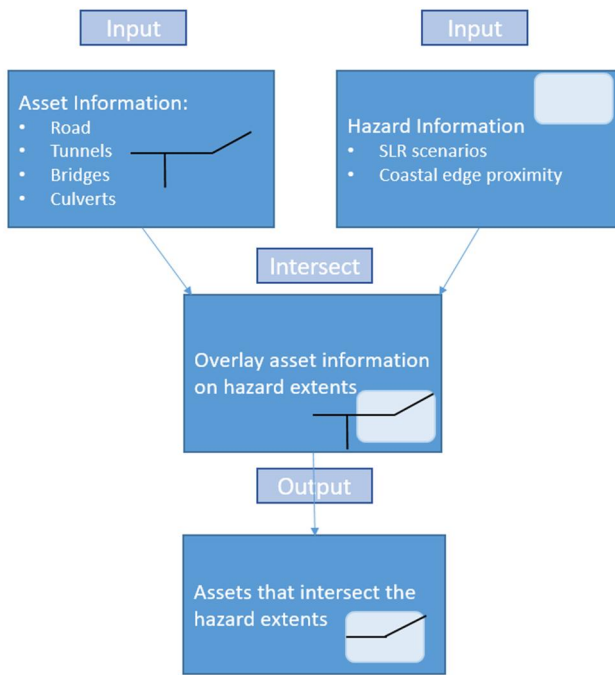
Figure 3.2: Geospatial methodology undertaken for the line assets.

The process to combine the hazards is set out in Figure 3.3. It begins with the coastal edge proximity assessment, then adds the SLR scenarios.
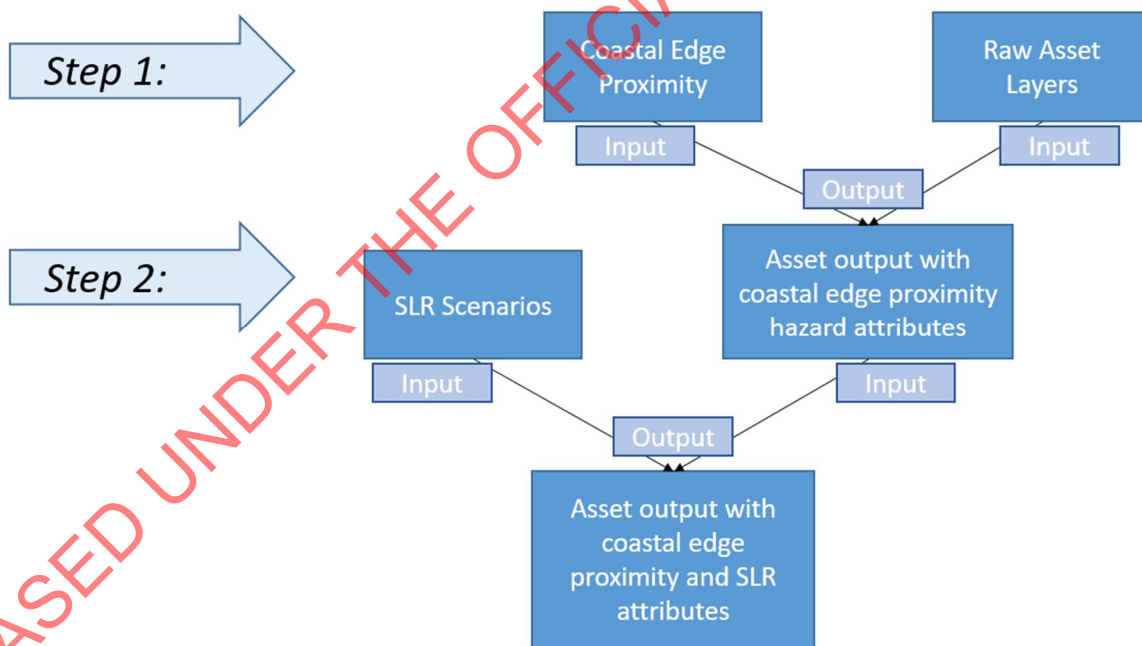
Figure 3.3: Methodology flow chart to complete the combined hazard exposure analysis.

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4 Hazards

This exposure assessment took into consideration sea level rise and the proximity to the coastal edge as a proxy for susceptibility to erosion and localised coastal processes.

4.1 Sea level rise

The SLR hazard included four scenarios from available spatial mapping completed by NIWA (2015/2019). Table 4.1 outlines the four SLR scenarios that were mutually agreed upon by NZTA, KiwiRail and T+T and that were used for this assessment. These scenarios incorporate Representative Concentration Pathways (RCP), which are pathways developed by the Intergovernmental Panel on Climate Change (IPCC) to reflect different emission scenarios and their impact. Figure 4.1 outlines the four different trajectories based on different greenhouse gas concentrations to the end of the century. Different timeframes are also considered in relation to the different RCP trajectories (X axis). RCP 8.5 represents the ongoing high baseline RCP projection and is therefore used in this assessment.
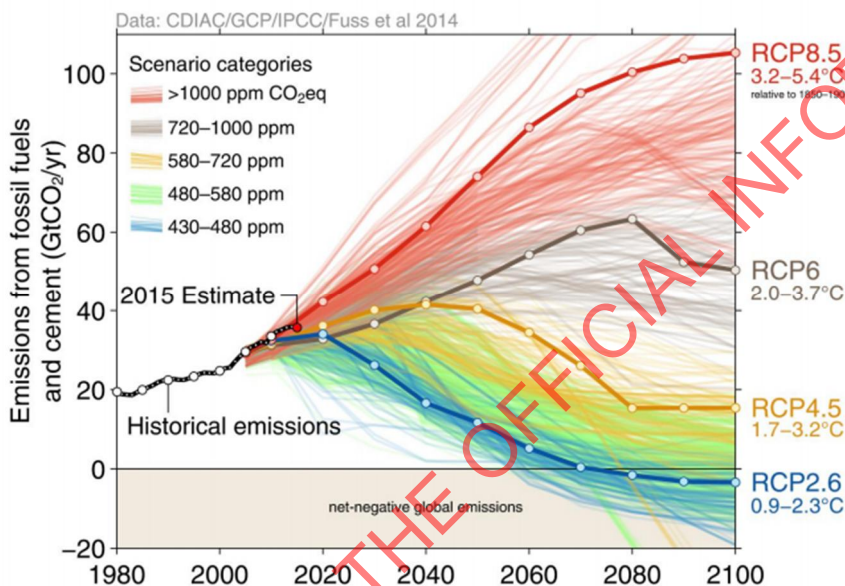
Figure 4.1: Global emissions scenarios and the four representative concentration pathway, with the historic emissions trajectory since 1980 (black), MfE 2018.

The Ministry for Environment (MfE) Coastal Hazards and Climate Change guidance (2017) gives further information on how RCP trajectories, timeframes and sea levels are connected when considering climate change (Figure 4.2). It shows the decadal increments for projections of sea level rise at four different RCP scenarios. This study used the RCP 8.5+ scenario.

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NZ SLR scenario Year	NZ RCP2.6 M (median) [m]	NZ RCP4.5 M (median) [m]	NZ RCP8.5 M (median) [m]	NZ RCP8.5 H⁺ (83rd percentile) [m]
1986–2005	0	0	0	0
2020	0.08	0.08	0.09	0.11
2030	0.13	0.13	0.15	0.18
2040	0.18	0.19	0.21	0.27
2050	0.23	0.24	0.28	0.37
2060	0.27	0.30	0.36	0.48
2070	0.32	0.36	0.45	0.61
2080	0.37	0.42	0.55	0.75
2090	0.42	0.49	0.67	0.90
2100	0.46	0.55	0.79	1.05
2110	0.51	0.61	0.93	1.20
2120	0.55	0.67	1.06	1.36
2130	0.60*	0.74*	1.18*	1.52
2140	0.65*	0.81*	1.29*	1.69
2150	0.69*	0.88*	1.41*	1.88

Figure 4.2: Decadal increments for projection of sea level rise (meters above 1986-2005 baseline) for the wider New Zealand region (for four RCP scenarios), Bell et al, 2017.

The SLR scenarios were chosen because they incorporate:

- SLR over different timeframes to incorporate different permanent inundation scenarios.
- Present day and RCP 8.5+ scenarios.
- Both MHWS and 1% AEP storm surge as baselines for SLR.
- A correlation to the Local Government New Zealand (LGNZ) study4 (Scenarios 1 and 2).

Table 4.1: SLR scenarios used for this assessment

Scenario	Water Level Condition	SLR (m)	SLR Scenario	Timeframe	Link with LGNZ	Comment
1	MHWS[3]-10	0.5	RCP 8.5+	2060[1]	Yes	Permanent inundation with 0.5 m SLR and representative of present-day typical storm.
2	MHWS-10	1.5	RCP 8.5+	2130	Yes	Permanent inundation with 1.5 m SLR[2].
3	1%AEP	0	Present day	Present day	No	Present day storm extent (excludes run-up/overtopping).
4	1%AEP	1.5	RCP 8.5+	2130	No	2130 storm surge extent (excludes run-up/overtopping).

Notes:

1. Time frame could be 2075 for RCP8.5 median projection, 2090 for RCP4.5 median projection.
2. Also represents RCP8.5 median projection after 2150.
3. MHWS-10: Mean High Water Springs (exceeded 10% of the time). AEP: Annual Exceedance Probability. RCP: Representative Concentration Pathway.

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[4] LGNZ & Tonkin and Taylor. (2019) Vulnerable: the quantum of local government infrastructure exposed to sea level rise.

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Figure 4.3 indicates the visual representation and extent of these scenarios for a test area in the Auckland region; the section of SH1 between Northcote Point and the Esmonde Road on-ramp and includes the relative sea level for each scenario at this location, with sea levels varying from 2.1 m RL to 3.9 m RL. This figure was used to help inform the SLR scenarios used in this assessment. It is noted that sea levels will vary around New Zealand due to the differing tide levels and storm surge intensities. This means that on more open coasts, storm surge levels can be higher than in the more sheltered Waitemata Harbour used in this example.
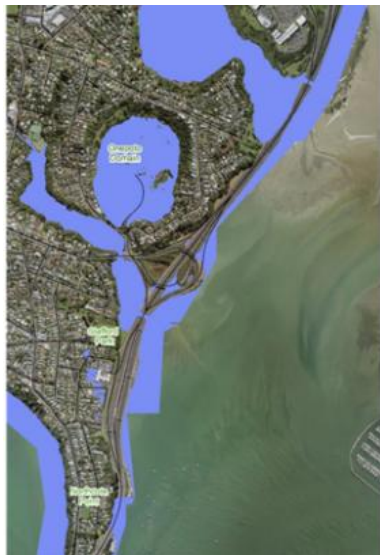
MHWS-10 plus 0.5 m SLR (2.1 m RL).

1% AEP plus 0 m SLR (2.4 m RL).

MHWS-10 plus 1.5 m SLR (3.1 m RL).

1% AEP plus 1.5 m SLR (3.9 m RL).

Figure 4.3: Visual representation of the SLR scenario extents used for this assessment on a section of SH1 in the Auckland region approaching the Harbour Bridge.

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4.2   Coastal edge proximity

The coastal edge proximity hazard extents were created using the LINZ coastal boundary. The coastal boundary was extended inland at two different distances to incorporate different levels of exposure. The two scenarios included:

·   Within 50 m of the coastal edge.
·   Within 150 m of the coastal edge.

Assets that were within 50 and 150 m of the coastal edge were identified, indicating potential for exposure to erosion processes and storm effects.

4.3   Combined sea level rise and coastal edge proximity

Assessing the combined exposure of coastal inundation and current coastal edge proximity extents will give an indication of those assets that are exposed to both coastal inundation and more localised hazards of erosion and dynamic storm/wave effects, either in the present day or as a result of sea level rise induced erosion and shoreline change. This can give an indication of those assets that have a higher exposure than others. A ranking method was used to delineate the potential exposure. Table 4.2 indicates how T+T have ranked the different likely scenarios that could occur nationally.

Table 4.2:   Combined coastal inundation and coastal edge proximity hazard levels

Exposure Level		Coastal Edge Proximity	SLR Scenarios
High	5	0 – 50 m	MHWS-10 + 0.5 m SLR and 1% AEP + 0 m SLR.
	4	0 – 50 m	MHWS-10 + 1.5 m SLR and 1% AEP + 1.5 m SLR.
Moderate	3	50 – 150 m	MHWS-10 + 0.5 m SLR and 1% AEP + 0 m SLR.
	2	50 – 150 m	MHWS-10 + 1.5 m SLR and 1% AEP + 1.5 m SLR.
Low	1	> 150 m	Greater than all SLR scenarios assessed + areas outside of the hazard extents.
1. In areas where LiDAR resolution is insufficient to apply SLR values, all assets that sit within 50 m of the coastal edge are assigned hazard level 5 and those assets that sit within 150 m of the coastal edge are assigned hazard level 3.			

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5   Exposure

The exposure assessment quantifies the length or count of NZTA assets exposed to sea level rise and coastal edge proximity. The following sections will outline each assets exposure.

5.1   Sea level rise

5.1.1   Roads

A national summary of the total exposure of SH roads to the different coastal inundation scenarios is presented in Table 5.1.

Scenario 1 shows there is 21km of particularly low-lying road assets. There is a significant increase of exposure from Scenario 1 to 2, but relatively little difference between Scenario 2 and 3. This indicates that present day storms influence a similar length of road asset as occurs with 1.5 m of sea level rise. However, the difference being that with 1.5 m SLR there will be greater extents permanently inundated. There is a tripling of road exposed from Scenario 3 to Scenario 4.

Table 5.1:   National exposure of road length to sea level rise

Scenario	Hazard Scenario	Length of Road Exposed Nationally (km)	Percentage of Total Network
1	MHWS-10 + 0.5 m SLR	21	0.2%
2	MHWS-10 + 1.5 m SLR	155	1.3%
3	1% AEP + 0 m SLR	161	1.3%
4	1% AEP + 1.5 m SLR	479	4%
Total		816	6.8%

The analysis of the NZTA SH network took into consideration the length of road exposed and the NZTA classification of roads for the four different SLR scenarios. A regional summary of the exposure analysis for the SH network to the four different SLR scenarios is summarised in Table 5.2 and Figure 5.1.

Table 5.2:   Regional breakdown of exposure of road length to sea level rise (km)

Region	MHWS-10 + 0.5 m SLR	MHWS-10 + 1.5 m SLR	1% AEP + 0 m SLR	1% AEP + 1.5 m
Northland Region	0	11.6	11.0	28.6
Auckland Region	7.4	20.7	14.4	41.0
Bay of Plenty Region	8.2	28.2	38.1	105.1
Waikato Region	0	47.4	43.6	98.1
Gisborne Region	0.1	2.9	3.3	15.1
Hawke's Bay Region	1.2	9.2	3.3	20.6
Manawatu-Wanganui Region	ND[5]	ND	7.6	11.7
Taranaki Region	ND	ND	2.7	4.5
Wellington Region	0.1	3.6	0.7	11.9

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[5] ND stands for No Data, due to no 1 m resolution LiDAR being available for the region at the time of publication.

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Region	MHWS-10 + 0.5 m SLR	MHWS-10 + 1.5 m SLR	1% AEP + 0 m SLR	1% AEP + 1.5 m
Marlborough Region	ND	ND	1.4	6.0
Nelson Region	0	1.9	0.6	18.6
Tasman Region	0.2	3.0	2.9	14.2
Canterbury Region	3.0	18.8	24.5	70.4
West Coast Region	ND	ND	ND	ND
Otago Region	0.8	7.6	3.6	20.7
Southland Region	ND	ND	3.7	12.5
Total[6]	20.98	154.96	161.34	478.81

Figure 5.1: Length of road (km) exposed regionally.

Table 5.1 and Figure *5.1* shows that the following regions have a larger length of SH exposed in comparison to others nationally:

·   Waikato.

·   Bay of Plenty.

·   Canterbury.

·   Auckland.

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[6] Total does not include those regions that have ND.

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Road exposure in the Waikato region increases from 0 to 43km between Scenario 1 and Scenario 3. This exposure more than doubles at Scenario 4 where there is close to 100km of road exposed or 0.8% of the national SH network. Scenario 4 sees 274km of road exposed collectively in the Bay of Plenty, Canterbury and Waikato regions equating to 2.3% of the total SH network. The spatial distribution of the exposed assets is shown in Figure A1.1 in Appendix A1.

Figure 5.2 indicates that the main road classifications exposed throughout all regions is Major. Nationally, there is 131km of Major SH exposed at Scenario 2 which increases to 428km at Scenario 4. In both cases this is over 1% of the total SH network. It also indicates that only two of the five categories across the network are exposed to SLR; Arterial, Medium and Minor have no exposure.
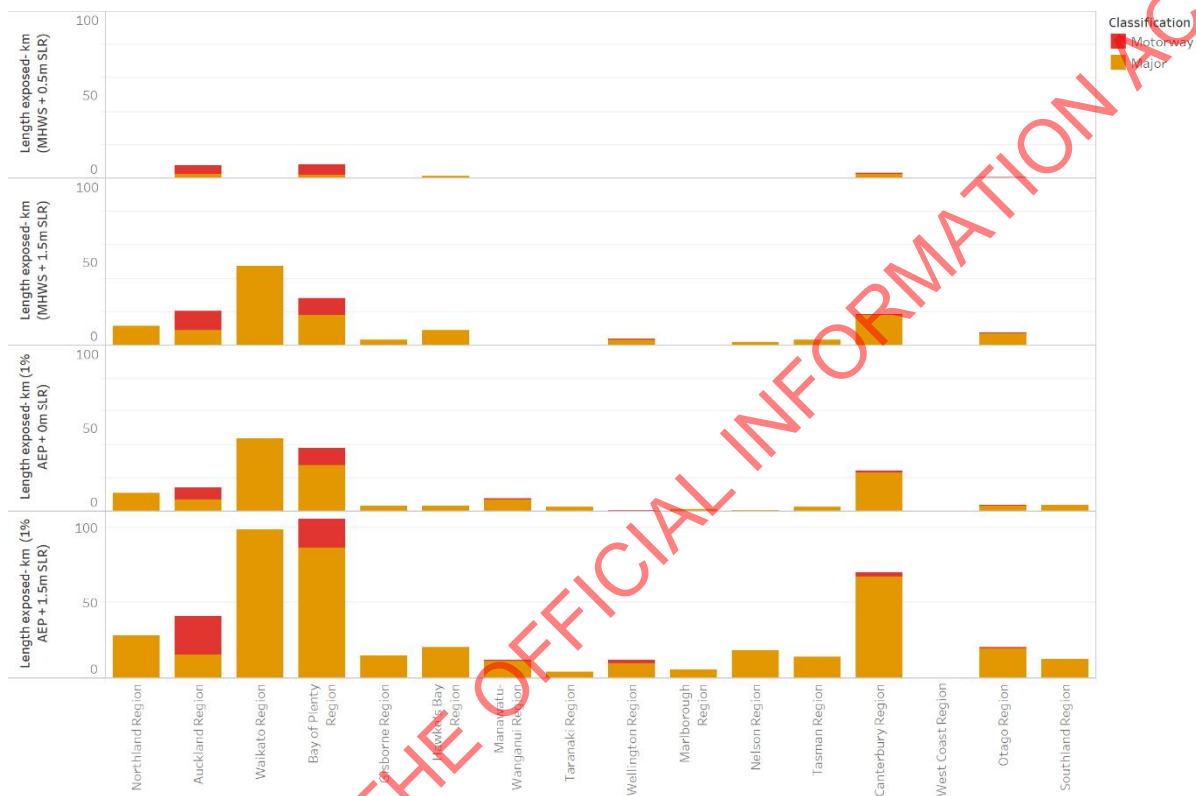
Figure 5.2: Length of road (km) exposed regionally, split into road classification.

5.1.2   Tunnels

A national summary of the total exposure of SH road tunnels to the different SLR scenarios is presented in Table 5.3. It indicates that there is less than 1% exposure of tunnel assets nationally at all SLR scenarios assessed, with no exposure in both Scenario 1 and 2.

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Table 5.3: National exposure of tunnels to sea level rise

Scenario	Hazard Scenario	Length of Tunnel Exposed Nationally (km)	Percentage of Total Network
1	MHWS-10 + 0.5 m SLR	0	0%
2	MHWS-10 + 1.5 m SLR	0	0%
3	1% AEP + 0 m SLR	0.008	0.07%
4	1% AEP + 1.5 m SLR	0.038	0.32%
Total		0.046	0.39%

The analysis of the SH tunnel network took into consideration the length of tunnel exposed and the NZTA classification of roads (including tunnels) for the four different SLR scenarios. A regional summary of the exposure analysis for the SH tunnel network to the four different SLR scenarios is summarised in Table 5.4.

Table 5.4: Regional breakdown of exposure of tunnels to sea level rise (km)

Region	MHWS-10 + 0.5 m SLR	MHWS-10 + 1.5 m SLR	1% AEP + 0 m SLR	1% AEP + 1.5 m
Northland Region	0	0	0	0
Auckland Region	0	0	0	0.03
Bay of Plenty Region	0	0	0	0
Waikato Region	0	0	0	0
Gisborne Region	0	0	0	0
Hawke's Bay Region	0	0	0	0
Manawatu-Wanganui Region	ND[7]	ND	0	0
Taranaki Region	ND	ND	0	0
Wellington Region	0	0	0	0
Marlborough Region	ND	ND	0	0
Nelson Region	0	0	0	0
Tasman Region	0	0	0	0
Canterbury Region	0	0	0.008	0.008
West Coast Region	ND	ND	ND	ND
Otago Region	0	0	0	0
Southland Region	ND	ND	0	0
Total[8]	0	0	0.008	0.038

Table 5.4 indicates only the Auckland and Canterbury regions have tunnels exposed across the different SLR scenarios that include storm surge. There is no exposure in Scenarios 1 or 2. These tunnels are located along SH1 near Peketa, Kaikoura in the Canterbury region and on the Northern SH link in Auckland Central in the Auckland region.

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[7] ND stands for No Data, due to no 1 m resolution LiDAR being available for the region at the time of publication.
[8] Total does not include those regions that have ND.

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Tunnel exposure does not differ between Scenario 3 and 4 for the Canterbury region, with 0.008km of tunnel exposed within both. This is equivalent to 0.07% of the national SH tunnel network. The Auckland region has 0.03km of tunnel exposed at Scenario 4, equivalent to 0.25% of the national SH tunnel network. To understand the spatial distribution of these assets refer to Figure A1.2 in Appendix A1.

There are two road classifications exposed for the SH tunnel network; Major and Motorway. Similar to roads, the main classification in the Auckland region is Motorway and the main classification in Canterbury is Major.

5.1.3 Bridges

A national summary of the total exposure of bridges to the different SLR scenarios is presented in Table 5.5. It indicates that there is a relatively significant increase in exposure between Scenarios 1 and 2 and that the exposure nearly doubles between Scenarios 3 and 4.

Table 5.5: National exposure of bridges to sea level rise

Scenario	Hazard Scenario	Number of Bridges Exposed Nationally	Percentage of Total Network
1	MHWS-10 + 0.5 m SLR	40	0.8%
2	MHWS-10 + 1.5 m SLR	113	2.4%
3	1% AEP + 0 m SLR	164	3.4%
4	1% AEP + 1.5 m SLR	309	6.4%
Total		626	13%

The analysis of the bridge network took into consideration the number of bridges exposed and whether a bridge asset had an alternative route. A regional summary of the exposure analysis for the NZTA bridges to the different SLR scenarios is summarised in Table 5.6 and Figure 5.3.

Table 5.6: Regional breakdown of number of bridges exposed to sea level rise

Region	MHWS-10 + 0.5 m SLR	MHWS-10 + 1.5 m SLR	1% AEP + 0 m SLR	1% AEP + 1.5 m
Northland Region	0	4	13	19
Auckland Region	27	40	32	59
Waikato Region	0	21	20	41
Bay of Plenty Region	6	24	39	65
Gisborne Region	4	12	13	23
Hawke's Bay Region	0	0	0	4
Manawatu-Wanganui Region	ND[9]	ND	3	5
Taranaki Region	ND	ND	6	20
Wellington Region	1	3	4	17
Marlborough Region	ND	ND	2	2
Nelson Region	0	3	5	9

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[9] ND stands for No Data, due to no 1 m resolution LiDAR being available for the region at the time of publication.

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Region	MHWS-10 + 0.5 m SLR	MHWS-10 + 1.5 m SLR	1% AEP + 0 m SLR	1% AEP + 1.5 m
Tasman Region	0	1	3	5
Canterbury Region	1	2	13	23
West Coast Region	ND	ND	ND	ND
Otago Region	1	3	4	10
Southland Region	ND	ND	7	7
Total[10]	40	113	164	309

Figure 5.3: Number of bridges exposed regionally.

Table 5.5 and Figure 5.3 indicate that the following regions have a larger number of bridges exposed in comparison to others nationally:

· Auckland.

· Bay of Plenty.

· Waikato.

· Gisborne.

Auckland has the largest proportion of bridges exposed at Scenario 1, with more than all other regions combined. This trend changes when considering all other Scenarios. A total of 97 assets are exposed at Scenario 2 for the aforementioned regions, equating to 2% of the national bridge

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[10] Total does not include those regions that have ND.

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network. This number slightly increases to 104 at Scenario 3. To see the spatial distribution of the exposed assets refer to Figure A1.2 in Appendix A1.

Figure 5.4 shows the exposure split by alternative route options. These alternative route options are limited to the NZTA bridge network and do not include those roads owned by local government. Therefore, there are likely to be more alternative routes then what is recorded in this analysis. Figure 5.4 shows that a large portion of the bridges exposed do not have an alternative route. This occurs particularly in Auckland, Bay of Plenty, Gisborne and Taranaki, with 54 bridges not having alternative route options. There are 29 bridges in the Waikato region that only have an alternative route of over 15km deviation.
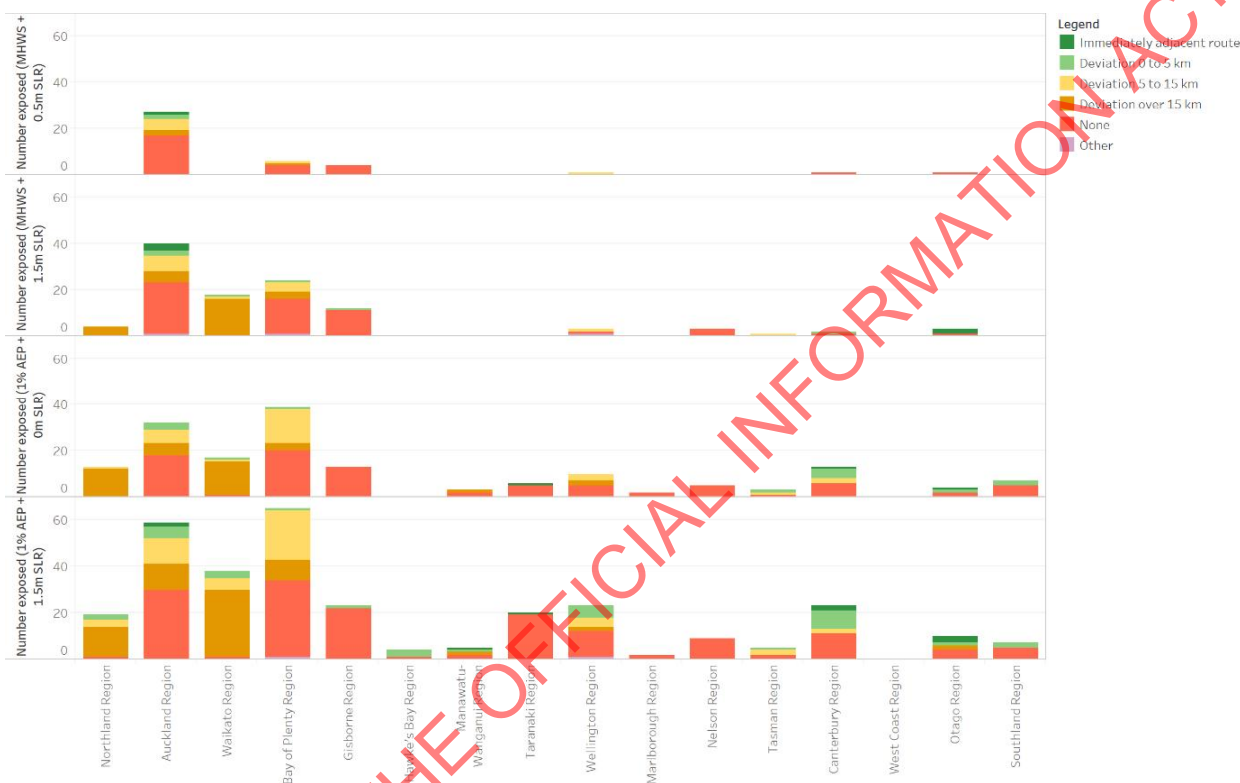
Figure 5.4: Number of bridges exposed regionally, split by alternative route options.

5.1.4   Culverts

A national summary of the total exposure of culverts to the different SLR scenarios is presented in Table 5.7. It indicates that there is a relatively significant increase in culverts exposed between Scenario 3 and 4.

Table 5.7:   National exposure of culverts to sea level rise

Hazard Scenario	Number of Culverts Exposed Nationally	Percentage of Total Network
MHWS-10 + 0.5 m SLR	6	0.3%
MHWS-10 + 1.5 m SLR	63	3.4%
1% AEP + 0 m SLR	49	2.4%
1% AEP + 1.5 m SLR	143	7.1%
Total	261	13.2%

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The analysis of the culvert network took into consideration the number of culverts exposed and the type of culvert. A regional summary of the exposure analysis for the NZTA culverts to the different SLR scenarios is summarised in Table 5.8 and Figure 5.5.

Table 5.8: Regional breakdown of number of culverts exposed to sea level rise

Region	MHWS-10 + 0.5 m SLR	MHWS-10 + 1.5 m SLR	1% AEP +0 m SLR	1% AEP + 1.5 m
Northland Region	0	2	5	11
Auckland Region	0	3	4	6
Waikato Region	0	5	3	13
Bay of Plenty Region	4	6	6	19
Gisborne Region	0	1	0	2
Hawke's Bay Region	1	4	1	8
Manawatu-Wanganui Region	ND[11]	ND	0	0
Taranaki Region	ND	0	1	2
Wellington Region	0	3	3	5
Marlborough Region	ND	0	0	0
Nelson Region	0	30	17	51
Tasman Region	0	0	0	5
Canterbury Region	1	8	8	17
West Coast Region	ND	ND	ND	ND
Otago Region	0	1	0	3
Southland Region	ND	0	1	1
Total[12]	6	63	49	143

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[11] ND stands for No Data, due to no 1 m resolution LiDAR being available for the region at the time of publication.
[12] Total does not include those regions that have ND.

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Figure 5.5: Number of culverts exposed regionally.

Scenario 2 shows that 50% of the exposed culverts are in the Nelson region, with no exposure in the Manawatu- Wanganui and Marlborough regions. Scenario 1 shows that there is only exposure in three of the sixteen regions which have a significantly lower number of assets exposed in comparison. The national total of assets exposed in Scenario 4 is half that of bridges at the same scenario. To understand the spatial distribution of these assets refer to Figure A1.3 in Appendix A1.

Figure 5.6 indicates that the main culvert type exposed across majority of the regions is a Box type culvert. Other common types exposed are Multiple Box and Not Assigned. The Nelson region has predominantly Box culverts exposed, whereas the Canterbury, Wellington and Waikato regions, have a variety of culverts types exposed.
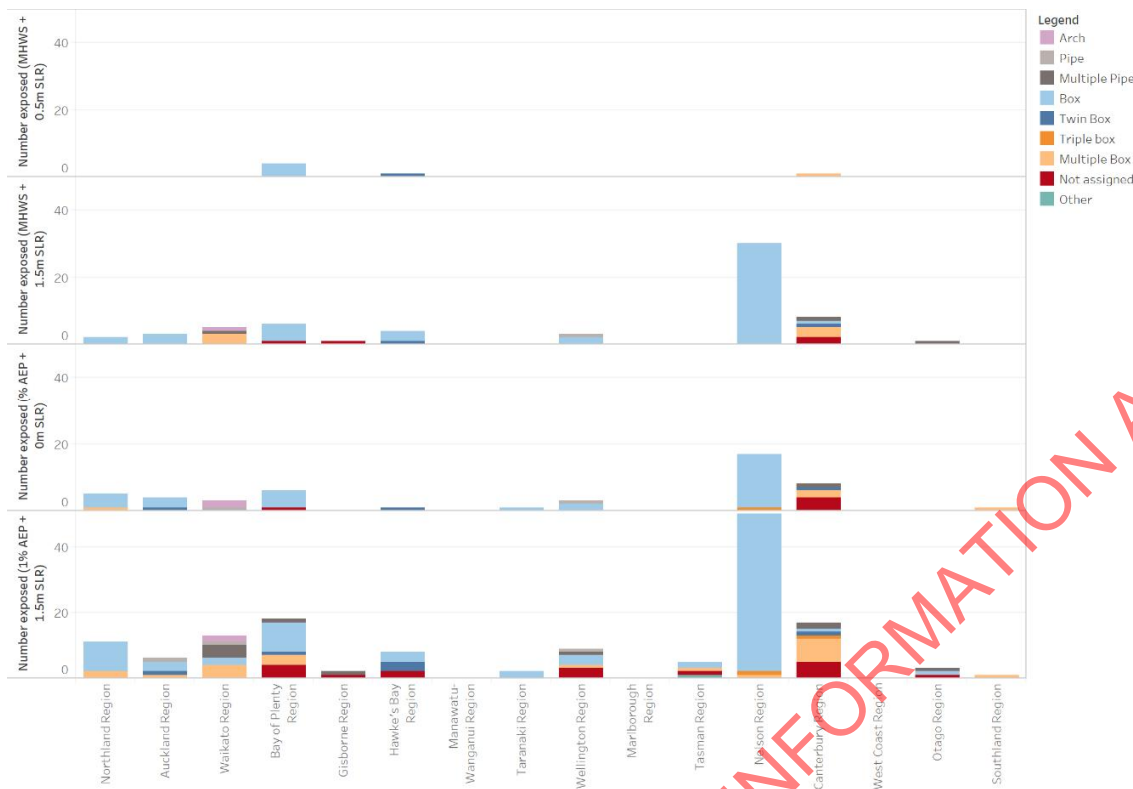
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Figure 5.6: Number of culverts exposed regionally, split into culvert type.

5.2 Coastal edge proximity

The coastal edge proximity analysis looked at two scenarios as outlined in Section 4.2. Each of the asset types were assessed against the two scenarios to gain an understanding of the length or number of assets exposed.

The following sections will outline each assets exposure at a national and regional level.

5.2.1 Roads

A national summary of the total exposure of SH roads to the different coastal edge proximity scenarios is presented in Table 5.9. It shows that there is a gradual increase in exposure as you increase the distance from the coastal edge.

Table 5.9:   National exposure of roads close to the coast

Scenario	Length of Road Exposed Nationally (km)	Percentage of Total Network
Within 50 m of the coastal edge	228	2%
Within 50-150 m of the coastal edge	224	2%
Within 150 m of the coastal edge	452	4%

A regional summary of the exposure analysis for the SH network to the coastal edge proximity scenarios is summarised in Table 5.10 and Figure 5.7.

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Table 5.10:   Regional breakdown of lengths of road close to the coast (km)

Region	Within 50 m of the Coastal Edge	Within 50-150 m of the Coastal Edge	Within 150 m of the Coastal Edge
Northland Region	22.4	15.0	37.4
Auckland Region	26.9	30.3	57.3
Waikato Region	42.5	24.3	66.8
Bay of Plenty Region	23.6	46.5	70.2
Gisborne Region	4.4	8.2	12.7
Hawke's Bay Region	1.2	13.8	15.0
Manawatu-Wanganui Region	0	0	0
Taranaki Region	0.5	3.6	4.1
Wellington Region	29.5	16.5	45.9
Marlborough Region	0.5	0.4	0.9
Nelson Region	13.9	4.0	18.0
Tasman Region	8.4	2.7	11.2
Canterbury Region	26.7	20.0	46.7
West Coast Region	8.3	27.1	35.4
Otago Region	13.9	6.3	20.2
Southland Region	5.1	5.5	10.6
Total	228	224	452

Figure 5.7: Length of road (km) exposed regionally.

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Table 5.10 and Figure 5.7 indicate that the following regions have a larger length of SH exposed in comparison to others nationally:

· Bay of Plenty.
· Waikato.
· Auckland.
· Wellington.
· Canterbury.

Each of these regions has greater than 20km of road exposed within 50 m of the coastal edge. This increases significantly for all regions when measured within the 50-150 m extent. There is 138km total length of exposure for the five main regions within 50-150 m from the coastal edge. This equates to approximately 62% of the SH network exposed and 1.2% of the entire SH network. Waikato has the longest length of road exposed within 50 m (42km) which increases to 67km exposed within 150 m of the coastal edge. The Northland, Nelson and Otago regions also have significant exposure within 50 m of the costal edge, whilst the West Coast region has higher exposure within 150 m of the coastal edge. Figure A2.1 in Appendix A2 shows the spatial distribution of these assets exposed to gain an understanding of where these assets are located.

Figure 5.8 indicates that the two main road classifications that are exposed to the coastal edge proximity hazard are; Motorway and Major. It shows 88% of the roads exposed have a Major road classification. Only two of the five road classifications are exposed, with Arterial, Medium and Minor roads having no exposure.

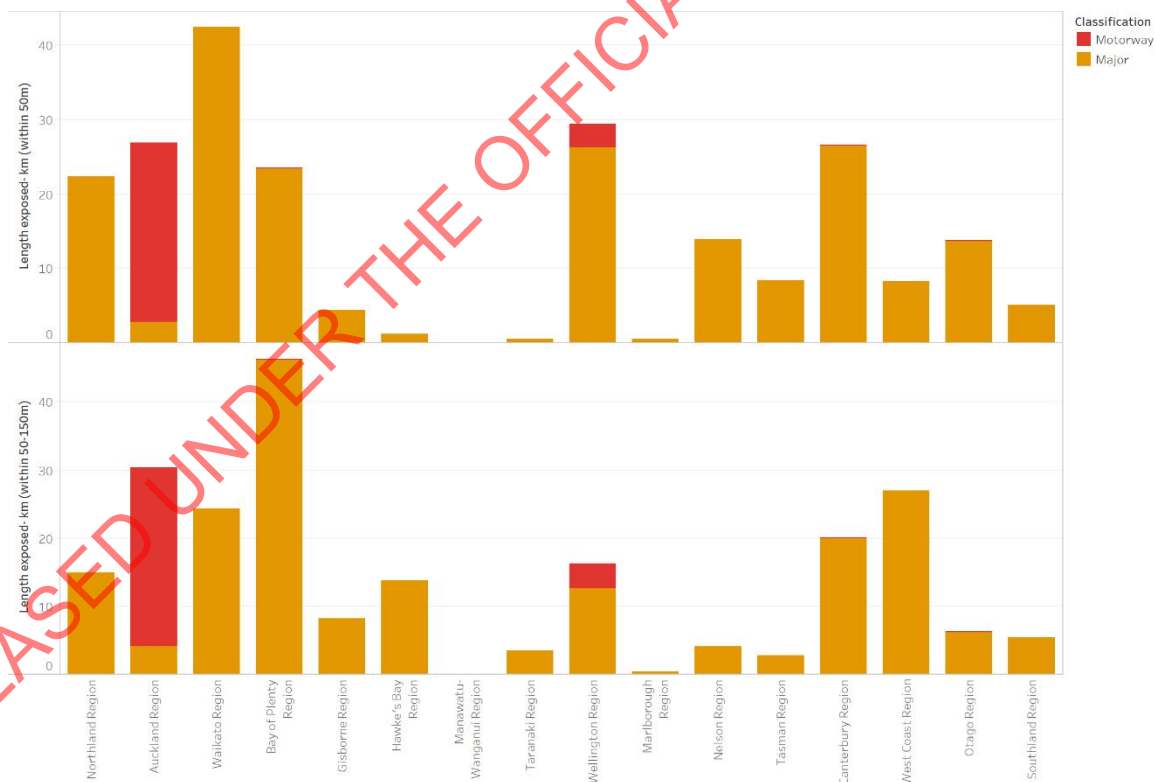*Figure 5.8: Length of road (km) exposed regionally, split into road classification.*

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5.2.2   Tunnels

A national summary of the total exposure of SH road tunnels to the different coastal edge proximity scenarios is presented in Table 5.11. It shows that a larger majority of the assets are exposed within 50 m of the coastal edge compared to within 50-150 m of the coastal edge.

Table 5.11:   National exposure of tunnels close to the coast

Hazard Scenario	Length of Tunnel Exposed Nationally (km)	Percentage of Total Network
Within 50 m of the coastal edge	0.18	1.5%
Within 50-150 m of the coastal edge	0.1	0.9%
Within 150 m of the coastal edge	0.28	2.4%

A regional summary of the exposure analysis for the SH tunnel network to the coastal edge proximity scenarios is summarised in Table 5.12.

Table 5.12:   Regional breakdown of lengths of tunnels close to the coast (km)

Region	Within 50 m of the Coastal Edge	Within 50-150 m of the Coastal Edge	Within 150 m of the Coastal Edge
Northland Region	0	0	0
Auckland Region	0	0.06	0.06
Waikato Region	0	0	0
Bay of Plenty Region	0	0	0
Gisborne Region	0	0	0
Hawke's Bay Region	0	0	0
Manawatu-Wanganui Region	0	0	0
Taranaki Region	0	0	0
Wellington Region	0	0	0
Marlborough Region	0	0	0
Nelson Region	0	0	0
Tasman Region	0	0	0
Canterbury Region	0.18	0.04	0.22
West Coast Region	0	0	0
Otago Region	0	0	0
Southland Region	0	0	0
Total	0.18	0.1	0.28

Only two regions have SH tunnels exposed; those located on SH1 near Peketa, Kaikoura in the Canterbury district and those on the Northern Motorway near Auckland Central in the Auckland region. Canterbury has an asset exposed within 50 m of the coastal edge, while the Auckland region assets become exposed within 50-150 m of the coastal edge. The location of these assets is shown in Figure A2.2 in Appendix A2.

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Similarly to SH roads, there are two road classifications exposed for the SH tunnel network; Major and Motorway. The main road classification exposed in the Auckland region is Motorway. This meaning that the road classification exposed in the Canterbury region is Major.

5.2.3 Bridges

A national summary of the total exposure of bridges to the different coastal edge proximity scenarios is presented in Table 5.13. It shows that the exposure nearly doubles when comparing the two different scenarios.

Table 5.13:   National exposure of bridges close to the coast

Hazard Scenario	Number of Bridges Exposed Nationally	Percentage of Total Network
Within 50 m of the coastal edge	127	2.6%
Within 50-150 m of the coastal edge	114	2.4%
Within 150 m of the coastal edge	241	5%

A regional summary of the exposure analysis for the NZTA bridges to the coastal edge proximity scenarios is summarised in Table 5.14 and Figure 5.9.

Table 5.14 Regional breakdown of number of bridges close to the coast

Region	Within 50 m of the Coastal Edge	Within 50-150 m of the Coastal Edge	Within 150 m of the Coastal Edge
Northland Region	16	5	21
Auckland Region	45	36	81
Waikato Region	19	7	26
Bay of Plenty Region	10	17	27
Gisborne Region	6	6	12
Hawke's Bay Region	2	0	2
Manawatu- Wanganui Region	0	0	0
Taranaki Region	0	7	7
Wellington Region	6	15	21
Marlborough Region	4	0	4
Nelson Region	1	2	3
Tasman Region	1	1	2
Canterbury Region	8	8	16
West Coast Region	1	6	7
Otago Region	2	3	5
Southland Region	6	1	7
Total	127	114	241

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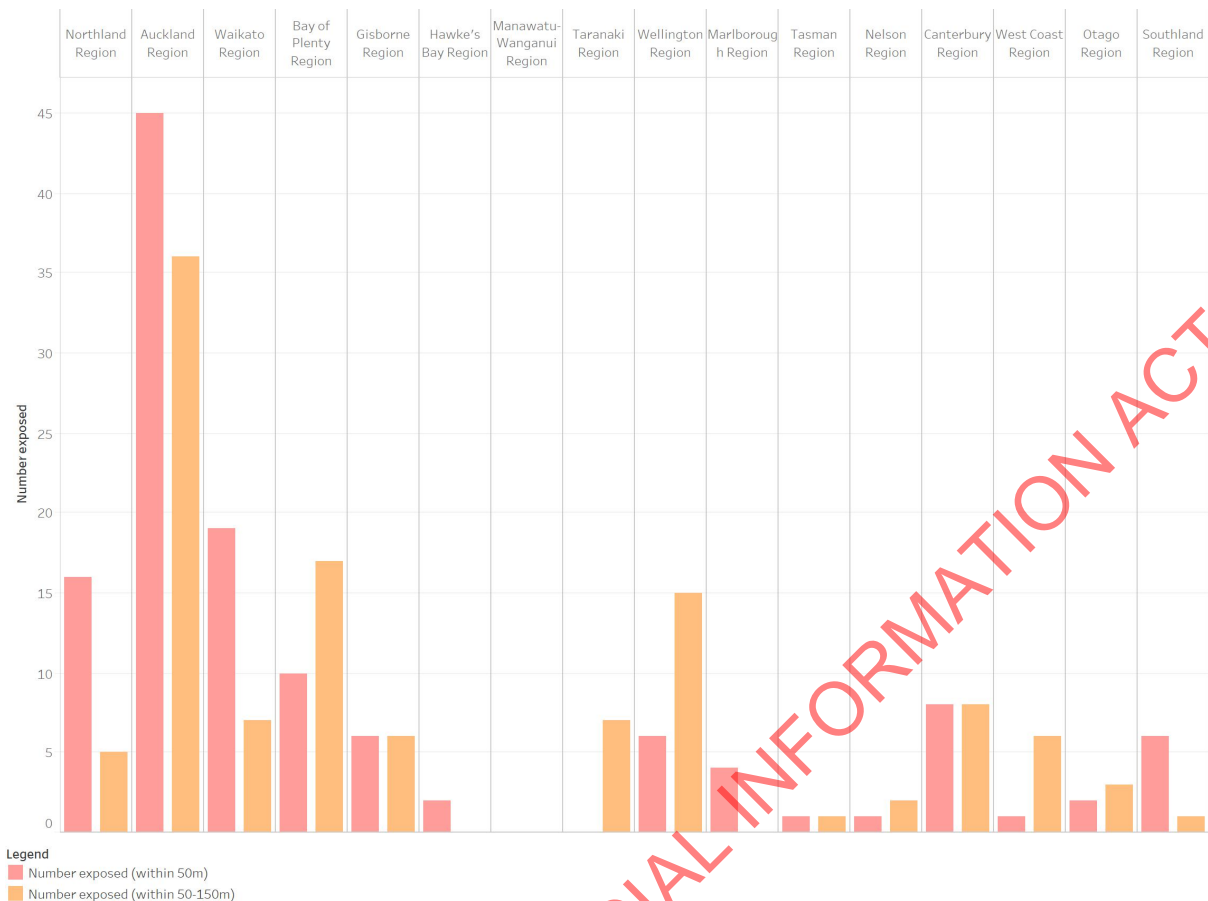April 2020
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Figure 5.9: Number of bridges exposed regionally.

Auckland has 45 bridges exposed within 50 m of the coastal edge, more than double the amount exposed in the Waikato region; the region with the second largest number of exposed bridges. Auckland's assets exposed within the 50 m extent are representative of 1% of the national bridge network. For the rest of the regions there is a common trend of more assets being exposed within 50 m of the coastal edge, compared to the assets exposed within 50-150 m of the coastal edge.

The five regions with the larger number of assets exposed are:

· Auckland.
· Waikato.
· Bay of Plenty.
· Northland.
· Wellington.

These regions combined equate to 73% of the bridges exposed within 50-150 m of the coastal edge, with a large proportion of these assets located in the Auckland, Northland and Waikato regions. Figure A2.2 in Appendix A2 show the spatial distribution of these assets nationally.

Like the SLR scenarios, Figure 5.10 indicates only those NZTA owned bridges and roads that have alternative routes and not those owned by local government. It shows that a large portion of the exposed networks nationally do not have an alternative route assigned. The main occurrence of this is in Auckland, the Bay of Plenty, Canterbury and Gisborne with 40 assets. This equates to 31% of the number of bridges exposed within the 50 m extent and 0.8% of the national bridge network. The other major alternative route exposed is "deviation of over 15km". In Northland and Waikato there

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is a combined total of 35 and 47 bridges exposed within 50 m and 150 m of the coastal edge respectively.
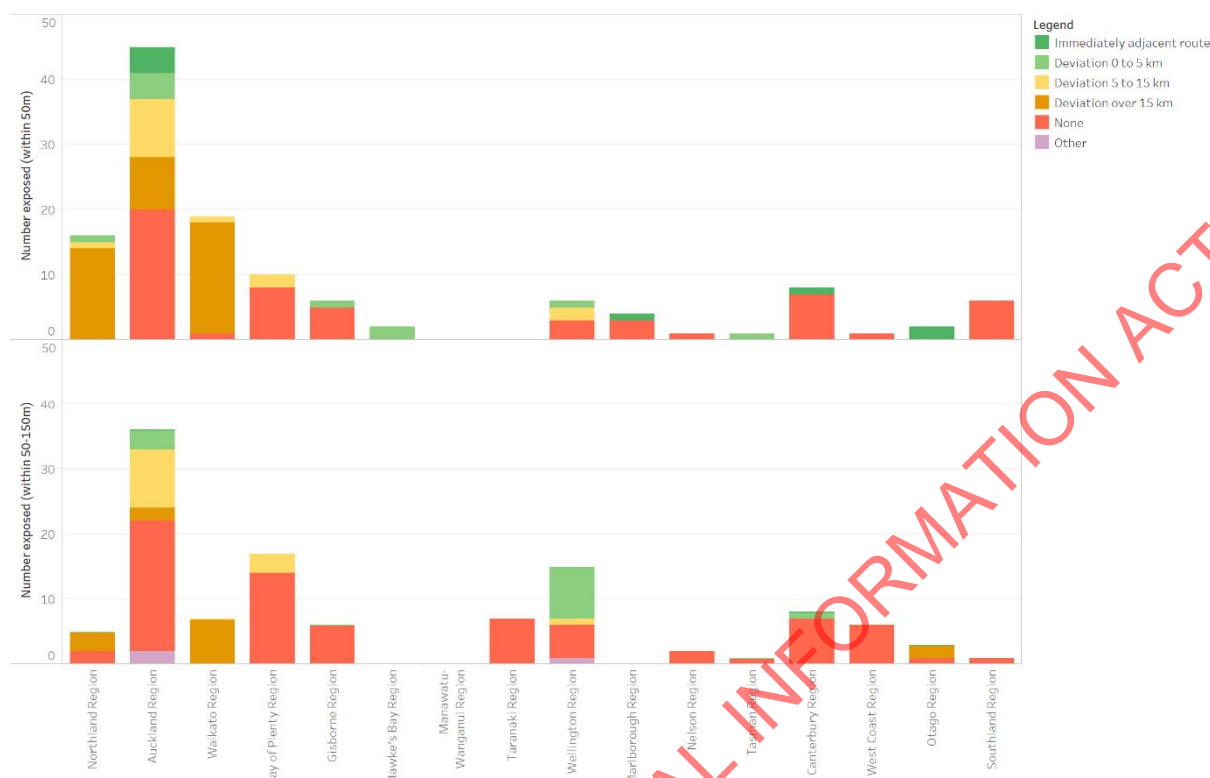

Figure 5.10: Number of bridges exposed regionally, split by alternative route options.

5.2.4 Culverts

A national summary of the total exposure of culverts to the different coastal edge proximity scenarios is presented in Table 5.15. Like bridges, the number of culverts almost doubles when comparing the two different scenarios.

Table 5.15: National exposure of culverts close to the coast

Hazard Scenario	Number of Culverts Exposed Nationally	Percentage of Total Network
Within 50 m of the coastal edge	46	2.3%
Within 50-150 m of the coastal edge	37	1.7%
Within 150 m of the coastal edge	83	4%

A regional summary of the exposure analysis for the NZTA culverts to the coastal edge proximity scenarios is summarised in Table 5.16 and Figure 5.11.

Table 5.16: Regional breakdown of number of culverts close to the coast

Region	Within 50 m of the Coastal Edge	Within 50-150 m of the Coastal Edge	Within 150 m of the Coastal Edge
Northland Region	2	4	6
Auckland Region	0	2	2

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Region	Within 50 m of the Coastal Edge	Within 50-150 m of the Coastal Edge	Within 150 m of the Coastal Edge
Waikato Region	7	7	14
Bay of Plenty Region	7	5	12
Gisborne Region	0	0	0
Hawke's Bay Region	9	0	9
Manawatu- Wanganui Region	0	0	0
Taranaki Region	0	0	0
Wellington Region	2	3	5
Marlborough Region	0	0	0
Nelson Region	5	2	7
Tasman Region	6	3	9
Canterbury Region	6	6	12
West Coast Region	2	2	4
Otago Region	0	1	1
Southland Region	0	2	2
Total	46	37	83

Figure 5.11: Number of culverts exposed regionally.

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Table 5.16 and Figure 5.11 indicates that the five regions with the largest number of assets exposed are:

- Waikato.
- Bay of Plenty.
- Canterbury.
- Hawke's Bay.
- Tasman.

Apart from Auckland, Otago and Southland, all the other regions have culverts exposed within 50 m of the coastal edge. Of those exposed within 50 m of the coastal edge the Hawke's Bay region has the most, with 9 exposed, however no additional culverts exposed within 150 m of the coastal edge. Figure A2.3 in Appendix A2 shows the spatial distribution of these assets nationally.

Figure 5.12 indicates that the main type of culvert exposed across the regions is the Box culvert. Other common types exposed are, Multiple Box and Multiple Pipe culverts. The Bay of Plenty and Waikato regions have a wide variety of culvert types exposed compared to that of the Hawke's Bay which just has one type.
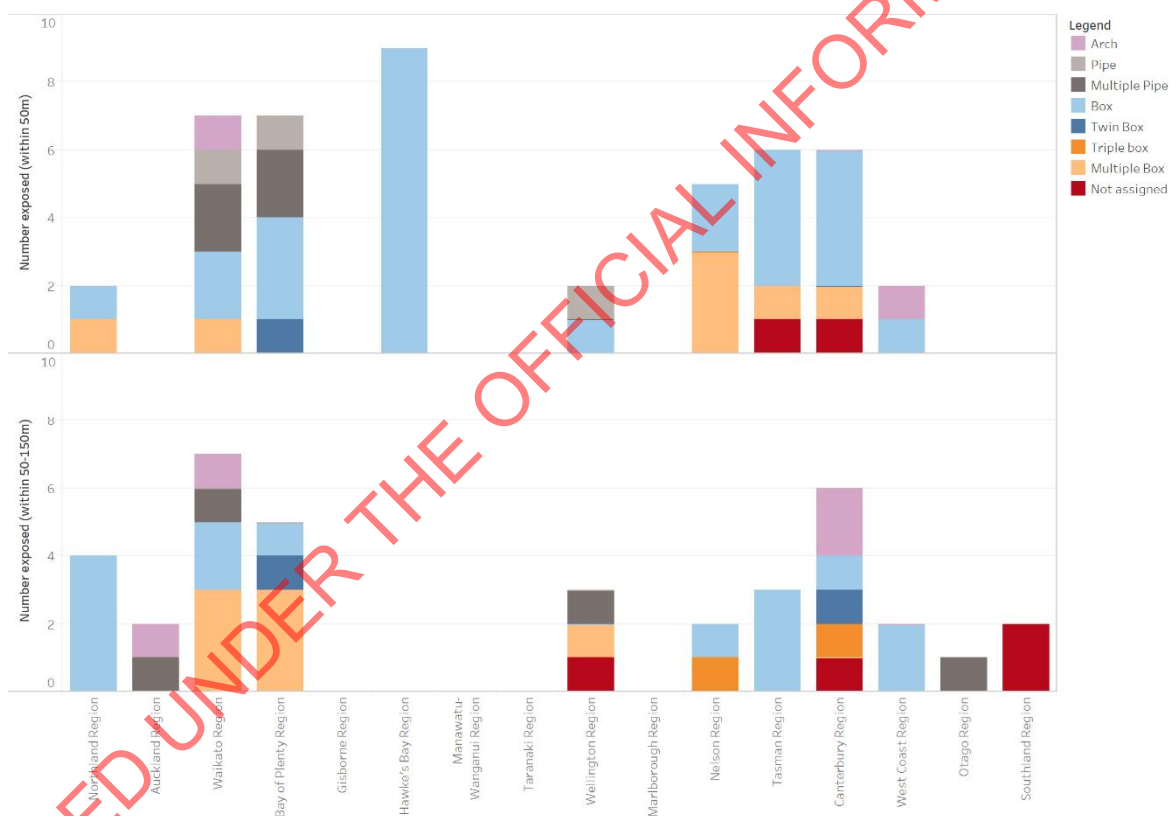
Figure 5.12: Number of culverts exposed regionally, split by type.

5.3   Combined sea level rise and coastal edge proximity

The combined analysis took into consideration the exposure of the different asset types to both coastal proximity and sea level rise. The output of the combined analysis was split into five exposure levels to understand the varying stages of exposure. The criteria for the different exposure levels is outlined in Table 4.2. The following sections will outline each assets exposure.

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5.3.1 Roads

A national summary of the total exposure SH roads to each of the different exposure levels is presented in Table 5.17. It indicates that majority of the network has low exposure, whilst 2.6% of assets have high exposure.

Table 5.17: National exposure of roads at different exposure levels

Exposure Level	Length of Road Exposed (km)	Percentage of Total Network
1 (Low)	11,279	94.5%
2	40	0.3%
3 (Medium)	188	1.6%
4	119	1.0%
5 (High)	316	2.6%
Total	11,942	100%

A regional summary of the exposure analysis for the SH network to the different exposure levels is summarised in Table 5.18 and Figure 5.13. Note that exposure level 1 has been removed from the figures, to improve clarity on the higher exposure levels.

Table 5.18: Regional breakdown of length of road exposed at different exposure levels (km)

Region	Exposure Level 1	Exposure Level 2	Exposure Level 3	Exposure Level 4	Exposure Level 5	Total
Northland Region	796.8	2.3	11.3	4.2	40.3	855
Auckland Region	487.4	5.6	20.3	20.5	42.7	576
Waikato Region	1,839.7	6.9	17.1	27.9	44.6	1,936
Bay of Plenty Region	663.2	14.6	29.3	24.2	47.3	779
Gisborne Region	310.6	0.4	9.4	0.5	10.0	331
Hawke's Bay Region	507.6	3.9	8.5	0.1	5.6	526
Manawatu-Wanganui Region	994.9	0	0	0	0	995
Taranaki Region	397.0	0.4	*11.5*	0	*1.0*	410
Wellington Region	376.1	2.2	9.5	8.8	28.2	425
Marlborough Region	259.3	0	*0.7*	0	*0.6*	261
Nelson Region	37.5	0.5	2.7	10.0	8.3	59
Tasman Region	314.5	0	5.0	1.8	9.4	331
Canterbury Region	1,552.4	0.9	13.9	13.2	31.6	1,612
West Coast Region	817.7	0	*38.9*	0	*25.9*	883
Otago Region	1,132.3	1.3	2.9	6.6	13.9	1,157
Southland Region	792.2	1.3	*6.7*	1.2	*6.6*	808
Total	11,279	40	188	119	316	11,942

Table 5.18 and Figure 5.13 indicate that every region has some SH's classified as high exposure except for the Manawatu-Wanganui region. More than 40km of road is exposed at exposure level 5 for the Northland, Auckland, Bay of Plenty and Waikato regions, with a combined exposure that

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equates to 1.5% of the national SH network. More than 20km of road is exposed at exposure level 3 for the Waikato, Bay of Plenty and West Coast regions, incorporating those roads on the West Coast that are exposed within the coastal edge proximity extents.

More road exposure occurs at exposure level 5 and exposure level 3 due to the incorporation of assets that are in regions that have no LIDAR (see italicised totals). Nationally exposure level 2 has the least amount of assets exposed. To see the spatial distribution of these assets refer to Figure A3.1 in Appendix A3.
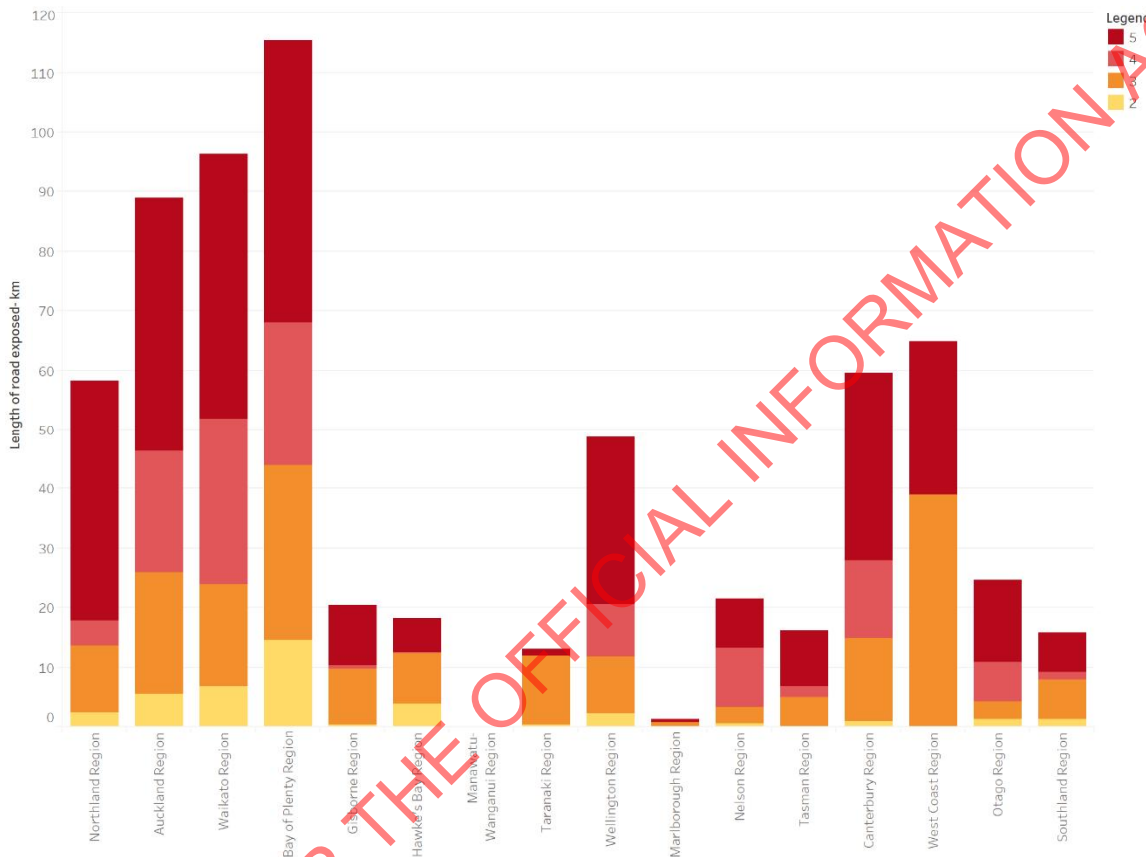
Figure 5.13: Length of road exposed to each of the different exposure levels regionally.

5.3.2   Tunnels

A national summary of the total exposure of SH road tunnels to each of the different exposure levels is presented in Table 5.19. Like roads, exposure level 1 has the most assets exposed with no exposure at exposure levels 3 and 4. The remaining 6% of asset exposure is split between exposure levels 2 and 5.

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Table 5.19: National exposure of tunnels at different exposure levels

Exposure Level	Length of Tunnel Exposed (km)	Percentage of Total Network
1	11	94%
2	0.5	4.3%
3	0	0%
4	0	0%
5	0.2	1.7%
Total	11.7	100%

A regional summary of the total exposure to the different exposure levels is presented in Table 5.20. Note that exposure level 1 has been removed from the figures, to improve clarity on the higher exposure levels.

Table 5.20: Regional breakdown of length of tunnels exposed at different exposure levels (km)

Region	Exposure Level 1	Exposure Level 2	Exposure Level 3	Exposure Level 4	Exposure Level 5	Total
Northland Region	0	0	0	0	0	0
Auckland Region	6.0	0.5	0	0	0	6.5
Waikato Region	0.1	0	0	0	0	0.1
Bay of Plenty Region	0	0	0	0	0	0
Gisborne Region	0	0	0	0	0	0
Hawke's Bay Region	0	0	0	0	0	0
Manawatu-Wanganui Region	0.2	0	0	0	0	0.2
Taranaki Region	0.03	0	0	0	0	0.03
Wellington Region	1.4	0	0	0	0	1.4
Marlborough Region	0.0	0	0	0	0	0
Nelson Region	0.0	0	0	0	0	0
Tasman Region	0	0	0	0	0	0
Canterbury Region	1.9	0	0	0	0.2	2.2
West Coast Region	0	0	0	0	0	0
Otago Region	0	0	0	0	0	0
Southland Region	1.3	0	0	0	0	1.3
Total	11.0	0.5	0	0	0.2	11.7

Table 5.20 indicates that Auckland and Canterbury are the only regions with exposure above exposure level 1. More than 0.2km of tunnel has high exposure in the Canterbury region equating to 1.7% of the national SH tunnel network. This is located along SH1 near Peketa, Kaikoura. The Auckland region has 0.45km of SH tunnel exposed at exposure level 2, equating to 4.3% of the national tunnel network. This is located on the Northern Motorway in Auckland Central. To see the spatial distribution of these exposed assets, refer to Figure A3.2 in Appendix A3.

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5.3.3   Bridges

A national summary of the total exposure of bridges to each of the different exposure levels is presented in Table 5.21. It indicates that most assets have low exposure with the second most exposed exposure level being high with 2% of the total network exposed.

Table 5.21:   National exposure of bridges at different exposure levels

Exposure Level	Number of Bridges Exposed	Percentage of Total Network
1	4,553	95%
2	28	0.6%
3	86	1.8%
4	30	0.6%
5	97	2%
Total	4,794	100%

A regional summary of the total exposure to the different exposure levels is summarised in Table 5.22 and Figure 5.14. Note that exposure level 1 has been removed from the figures, to improve clarity on the higher exposure levels.

Table 5.22:   Regional breakdown of the number of bridges exposed at different exposure levels

Region	Exposure Level 1	Exposure Level 2	Exposure Level 3	Exposure Level 4	Exposure Level 5	Total
Northland Region	180	1	4	1	17	203
Auckland Region	328	8	28	12	31	407
Waikato Region	301	3	4	8	11	327
Bay of Plenty Region	164	4	13	3	7	191
Gisborne Region	387	3	3	1	5	399
Hawke's Bay Region	106	0	0	1	1	108
Manawatu-Wanganui Region	277	0	0	0	0	277
Taranaki Region	409	3	4	0	0	416
Wellington Region	199	3	12	1	5	220
Marlborough Region	68	0	0	0	4	72
Nelson Region	74	0	2	0	1	77
Tasman Region	97	0	1	0	1	99
Canterbury Region	444	1	7	1	7	460
West Coast Region	323	0	6	0	1	330
Otago Region	240	2	1	2	0	245
Southland Region	956	0	1	0	6	963
Total	4,553	28	86	30	97	4,794

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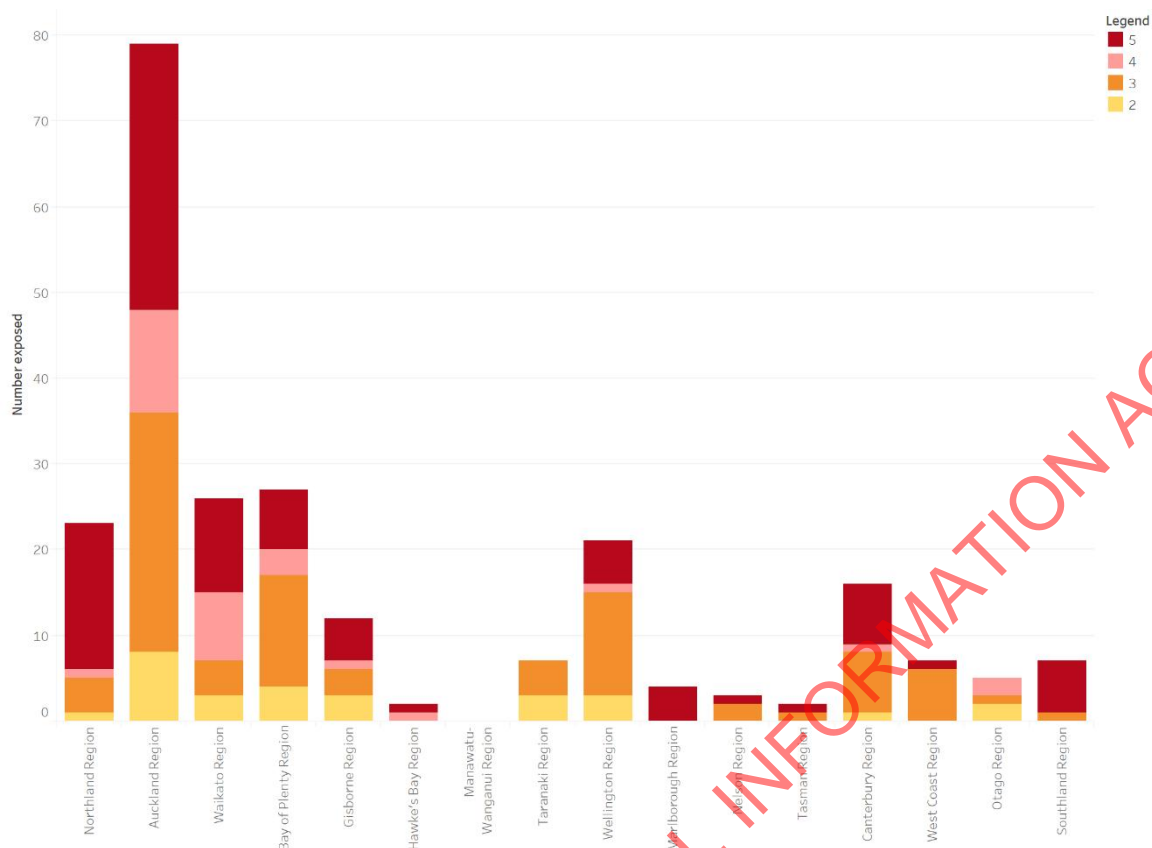April 2020
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Figure 5.14: Number of bridges exposed to each of the different exposure levels regionally.

Table 5.22 and Figure 5.14 indicate that more than 25 bridges have moderate and high exposure in the Auckland region. All other regions have less than 15 bridges exposed at these levels with the exception of Northland where 17 bridges having high exposure. Assets with high and moderate exposure in the Auckland region equate to 0.6% of the national bridge network. To understand the spatial distribution of these exposed assets, refer to Figure A3.2 in Appendix A3.

5.3.4   Culverts

A national summary of the total exposure of culverts to each of the different exposure levels is presented in Table 5.23. It indicates that majority of the network sits within exposure level 1 and that there are relatively small variations in the exposure percentage between the rest of the levels.

Table 5.23:   National exposure of culverts at different exposure levels

Exposure Level	Number of Culverts Exposed	Percentage of Total Network
1	1925	96%
2	11	0.5%
3	26	1.2%
4	16	0.8%
5	30	1.5%
Total	2008	100%

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A regional summary of the total exposure to the different exposure levels is presented in Table 5.24 and Figure 5.15. Note that exposure level 1 has been removed from the figures, to improve clarity on the higher exposure levels.

Table 5.24: Regional breakdown of the number of culverts exposed at different exposure levels

Region	Exposure Level 1	Exposure Level 2	Exposure Level 3	Exposure Level 4	Exposure Level 5	Total
Northland Region	108	2	2	1	1	114
Auckland Region	53	0	2	0	0	55
Waikato Region	168	4	3	3	4	182
Bay of Plenty Region	63	3	2	4	3	75
Gisborne Region	46	0	0	0	0	46
Hawke's Bay Region	61	0	0	0	9	70
Manawatu-Wanganui Region	143	0	0	0	0	143
Taranaki Region	54	0	0	0	0	54
Wellington Region	100	0	3	1	1	105
Marlborough Region	36	0	0	0	0	36
Nelson Region	111	0	2	3	2	118
Tasman Region	45	0	3	4	2	54
Canterbury Region	283	1	5	0	6	295
West Coast Region	157	0	2	0	2	161
Otago Region	96	1	0	0	0	97
Southland Region	401	0	2	0	0	403
Total	1,925	11	26	16	30	2,008

Table 5.24 and Figure 5.15 indicate that the Hawke's Bay region has only high asset exposure, with 9 out of the 70 culverts in the region exposed. For all other regions there are 6 or less culverts exposed in each category from exposure level 2 and higher. Nationally exposure level 2 has the least asset exposed. To see the spatial distribution of these assets refer to Figure A3.3 in Appendix A3.
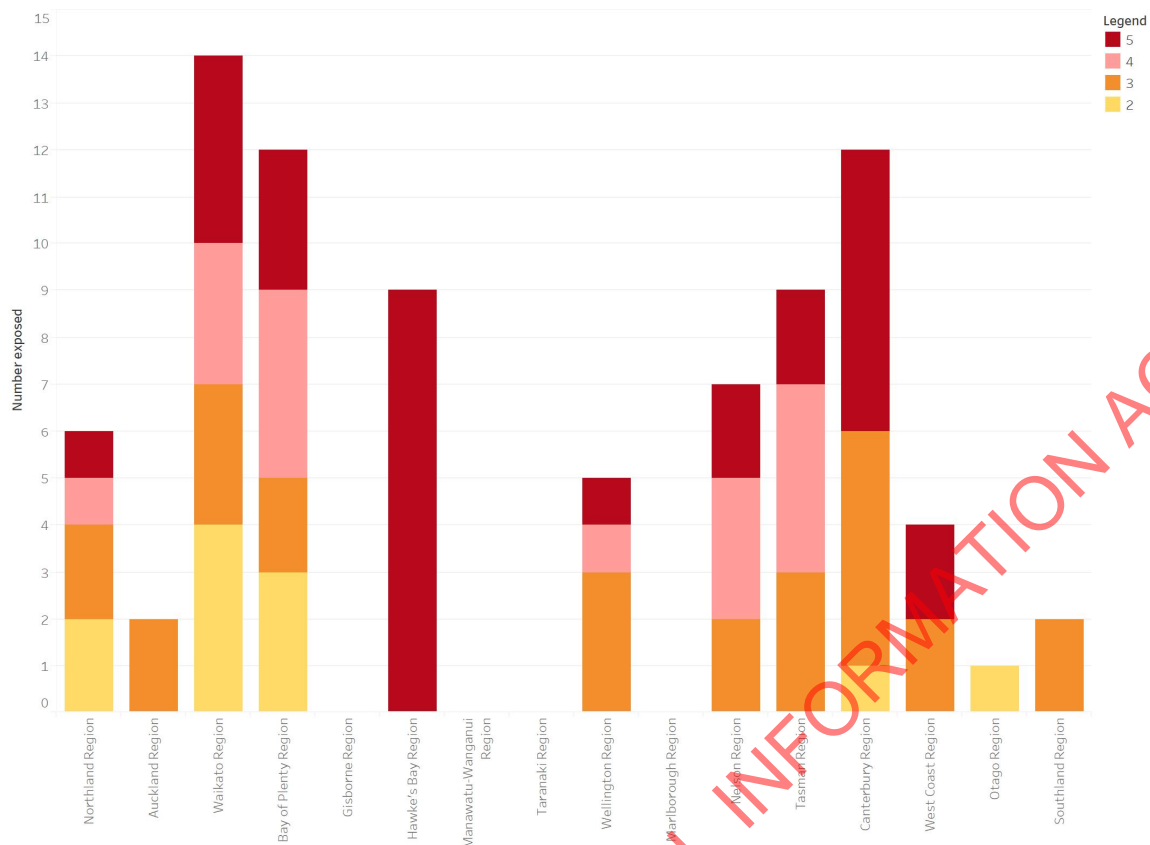
Figure 5.15: Number of culverts exposed for each of the different exposure levels regionally.

5.4 Summary

The exposure assessment quantified the length or count of NZTA assets exposed to inundation and proximity to the coast scenarios and then looked at the combined exposure.

Sea level rise exposure varied between regions and across the different asset types, however all asset types assessed had less than 10% of their total networks exposed to SLR. Of those assets exposed most were located within the Waikato, Bay of Plenty and Canterbury regions. Tunnel exposure only occurred in Canterbury and Auckland, with a maximum of 0.038km exposed across the various SLR scenarios. This is equivalent to 0.3% of the national tunnel network. SLR exposure to the bridge network ranged between 0.8% and 6.4% with most assets located in the Auckland, Waikato and Bay of Plenty regions. The maximum network percentage of culverts exposed was 7.1%, with the Nelson region having the highest number of culverts exposed.

Exposure to the different coastal edge proximity extents was like the SLR scenarios. There were variations in total network percentages exposed across the different asset types, however like the SLR scenarios they were all less than 10%. Exposure of the SH network to the coastal edge proximity extents ranged from 2% to 4% of the total network, with greater lengths of the assets exposed located in the Bay of Plenty, Waikato and Auckland regions. The Auckland and Canterbury regions are the only regions with tunnel exposure with a maximum of 0.28km of tunnel exposed within 150 m of the coastal edge. Auckland has the most bridges exposed within 150 m of the coastal edge, equivalent to 1.7% of the national bridge network. Culvert exposure ranged from 1.7% to 4% of total network exposed across the different scenarios. Regions with the highest levels of exposed assets are in the Bay of Plenty, Waikato and Canterbury regions.

Nationally, most assets sat within low exposure areas with over 90% of all asset networks falling into this category. The percentage of networks that sit within the other exposure levels varied across the

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different asset types. The SH network has 2.6% of its assets within high exposure areas, which decreases to 0.3% at exposure level 2. Exposure level 2 is the second most exposed category for the SH tunnel network with 4.3% of the network in this exposure level. The remaining 1.7% has high exposure. The bridge network has 0.6% exposure at both exposure levels 2 and 4 which increases to 1.8% and 2% at exposure levels 3 and 5 respectively. The Auckland region has the highest number of bridges exposed at exposure level 5, equating to 0.6% of the 2% exposed. The culvert network has the highest percentage of assets with low exposure, with 96%. Out of the remaining assets, 1.5% have high exposure, with most of the assets located in the Hawke's Bay.

National trends arise when looking at exposure for all asset networks. The Bay of Plenty, Waikato, Auckland and Canterbury regions all have high asset exposure and in similar locations across the various asset types. For a spatial overview of all asset exposure refer to Figure A3.4 in Appendix A3.

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6 References

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7 Applicability

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

Tonkin & Taylor Ltd

Report prepared by: Authorised for Tonkin & Taylor Ltd by:

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Morgan Lindsay   Chris Perks

Richard Reinen-Hamill   Project Director

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Appendix A: Asset exposure figures

A1 Sea level rise exposure:

- Figure A1.1 Exposure of state highway network to sea level rise.
- Figure A1.2 Exposure of the tunnel and bridge network to sea level rise.
- Figure A1.3 Exposure of culvert network to sea level rise.

A2 Coastal edge proximity exposure:

- Figure A2.1 Exposure of state highway network to coastal edge proximity.
- Figure A2.2 Exposure of the tunnel and bridge network to coastal edge proximity.
- Figure A2.3 Exposure of the culvert network to coastal edge proximity.

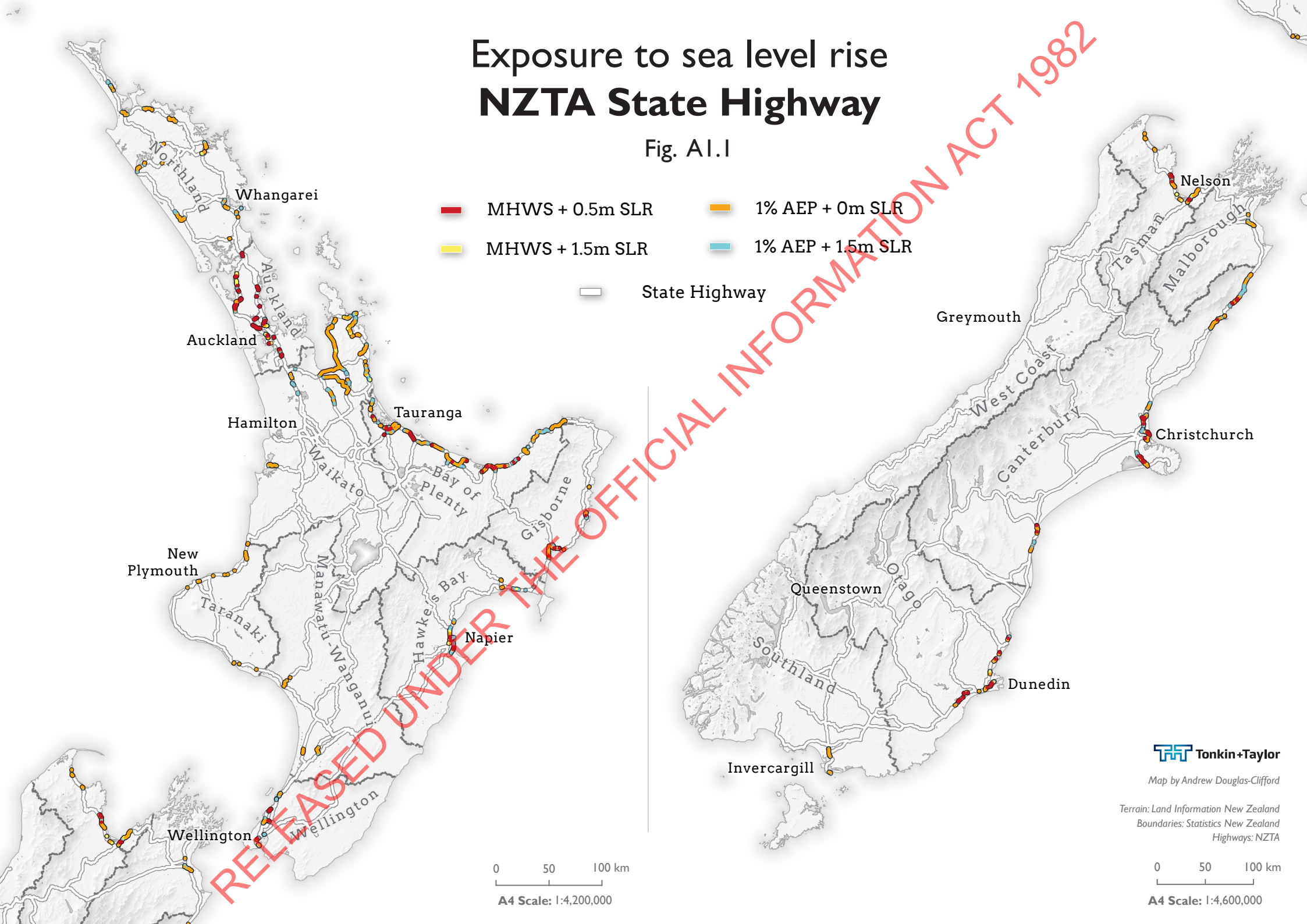## A3 Combined sea level rise and coastal edge proximity exposure:

- Figure A3.1 Exposure of state highway network to different exposure levels.
- Figure A3.2 Exposure of the tunnel and bridge network to different exposure levels.
- Figure A3.3 Exposure of the culvert network to different exposure levels.
- Figure A3.4 Exposure of all asset networks to different exposure levels.

Exposure to sea level rise
NZTA State Highway

Fig. A1.1

MHWS + 0.5m SLR

MHWS + 1.5m SLR

1% AEP + 0m SLR

1% AEP + 1.5m SLR

State Highway

Northland

Whangarei

Auckland

Auckland

Hamilton

Tauranga

Bay of Plenty

Waikato

Gisborne

New Plymouth

Taranaki

Manawatu-Wanganui

Hawke's Bay

Napier

Wellington

Wellington

Nelson

Tasman

Malborough

Greymouth

West Coast

Canterbury

Christchurch

Queenstown

Otago

Southland

Dunedin

Invercargill

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Map by Andrew Douglas-Clifford

Terrain: Land Information New Zealand
Boundaries: Statistics New Zealand
Highways: NZTA

0   50   100 km

A4 Scale: 1:4,200,000

0   50   100 km

A4 Scale: 1:4,600,000

Exposure to sea level rise
NZTA Tunnels & Bridges
Fig. A1.2

Legend:
- MHWS + 0.5m SLR (dark red)
- MHWS + 1.5m SLR (yellow)
- 1% AEP + 0m SLR (orange)
- 1% AEP + 1.5m SLR (cyan)
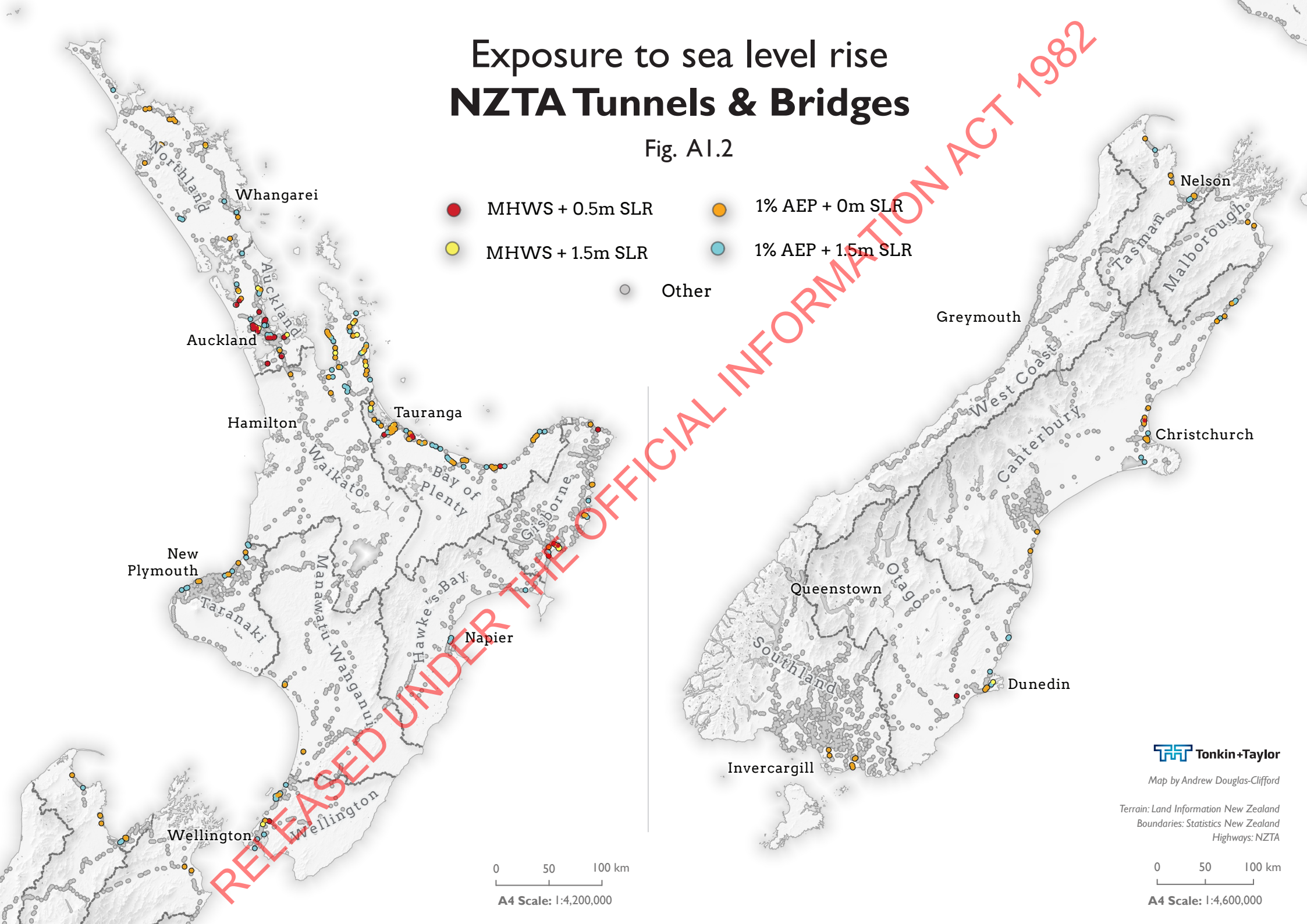- Other (grey)

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Map by Andrew Douglas-Clifford

Terrain: Land Information New Zealand
Boundaries: Statistics New Zealand
Highways: NZTA

0   50   100 km
A4 Scale: 1:4,200,000

0   50   100 km
A4 Scale: 1:4,600,000

Exposure to sea level rise
NZTA Culverts

Fig. A1.3

Legend:
- ● MHWS + 0.5m SLR
- ● MHWS + 1.5m SLR
- ● 1% AEP + 0m SLR
- ● 1% AEP + 1.5m SLR
- ● Other Culverts

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Terrain: Land Information New Zealand
Boundaries: Statistics New Zealand
Highways: NZTA

A4 Scale: 1:4,200,000

A4 Scale: 1:4,600,000

Exposure to coastal edge proximity
NZTA State Highway

Fig. A2.1

Road within 50m of Coastal Edge

Road within 150m of Coastal Edge

State Highway
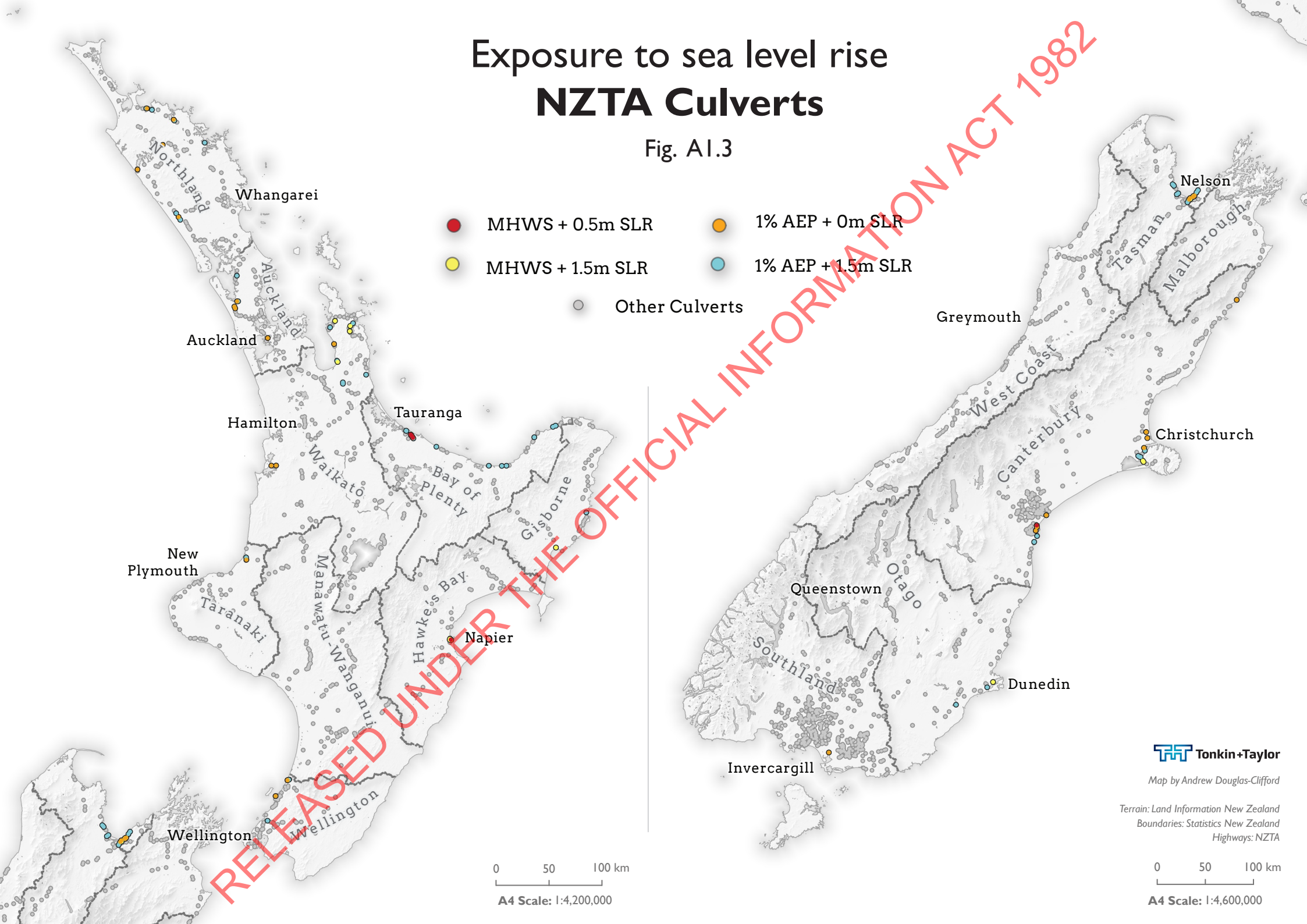

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Map by Andrew Douglas-Clifford

Terrain: Land Information New Zealand
Boundaries: Statistics New Zealand
Highways: NZTA

0   50   100 km

A4 Scale: 1:4,200,000

0   50   100 km

A4 Scale: 1:4,600,000

Exposure to coastal edge proximity
NZTA bridges & tunnels
Fig. A2.2

- 🔴 Asset within 50m of Coastal Edge
- 🟡 Asset within 150m of Coastal Edge
- ⚪ Other

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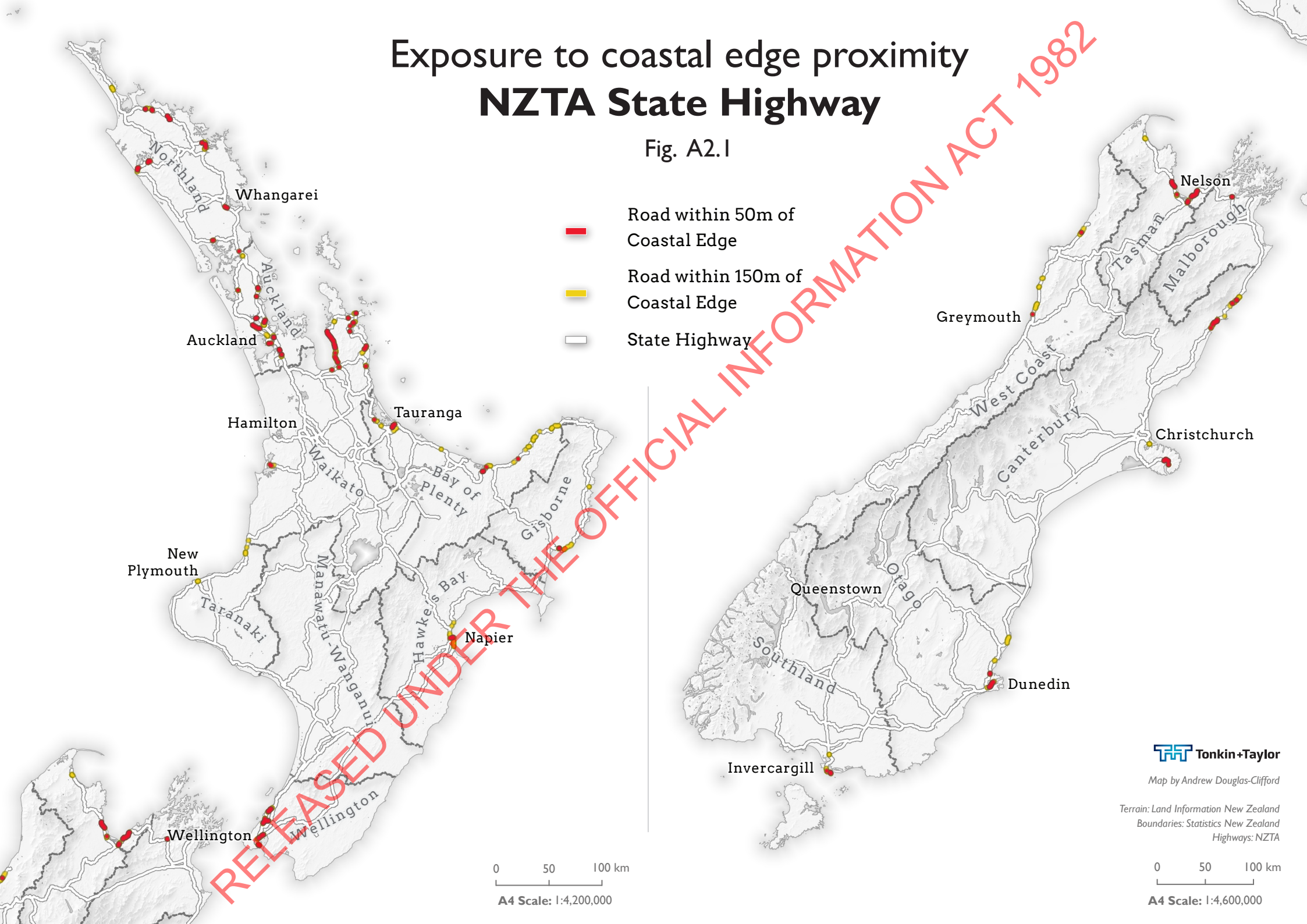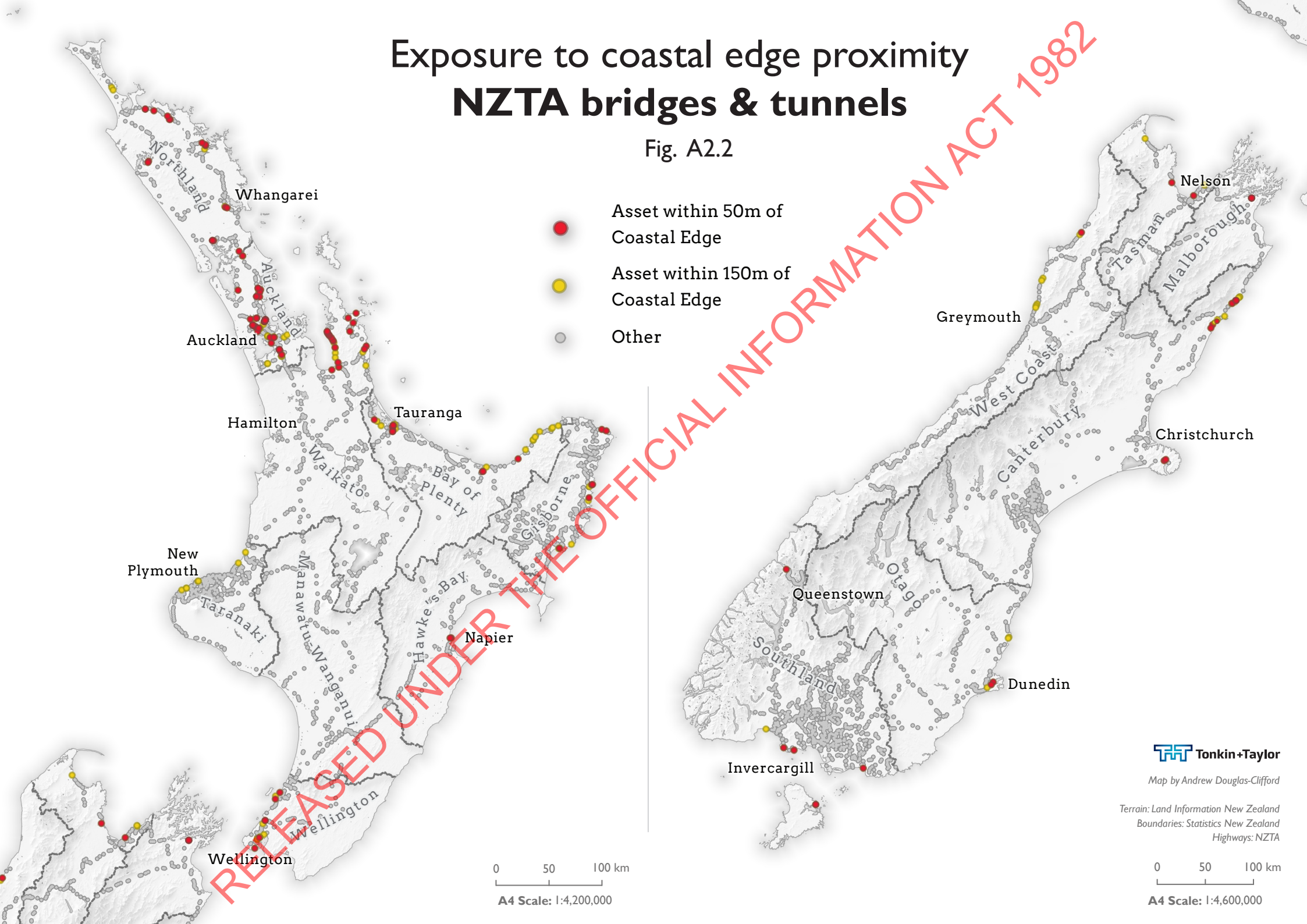
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Terrain: Land Information New Zealand
Boundaries: Statistics New Zealand
Highways: NZTA

0 50 100 km

A4 Scale: 1:4,200,000

0 50 100 km

A4 Scale: 1:4,600,000

Exposure to coastal edge proximity
NZTA Culverts

Fig. A2.3

Legend:
- Culvert within 50m of Coastal Edge (red)
- Culvert within 150m of Coastal Edge (yellow)
- SH Culverts (grey)
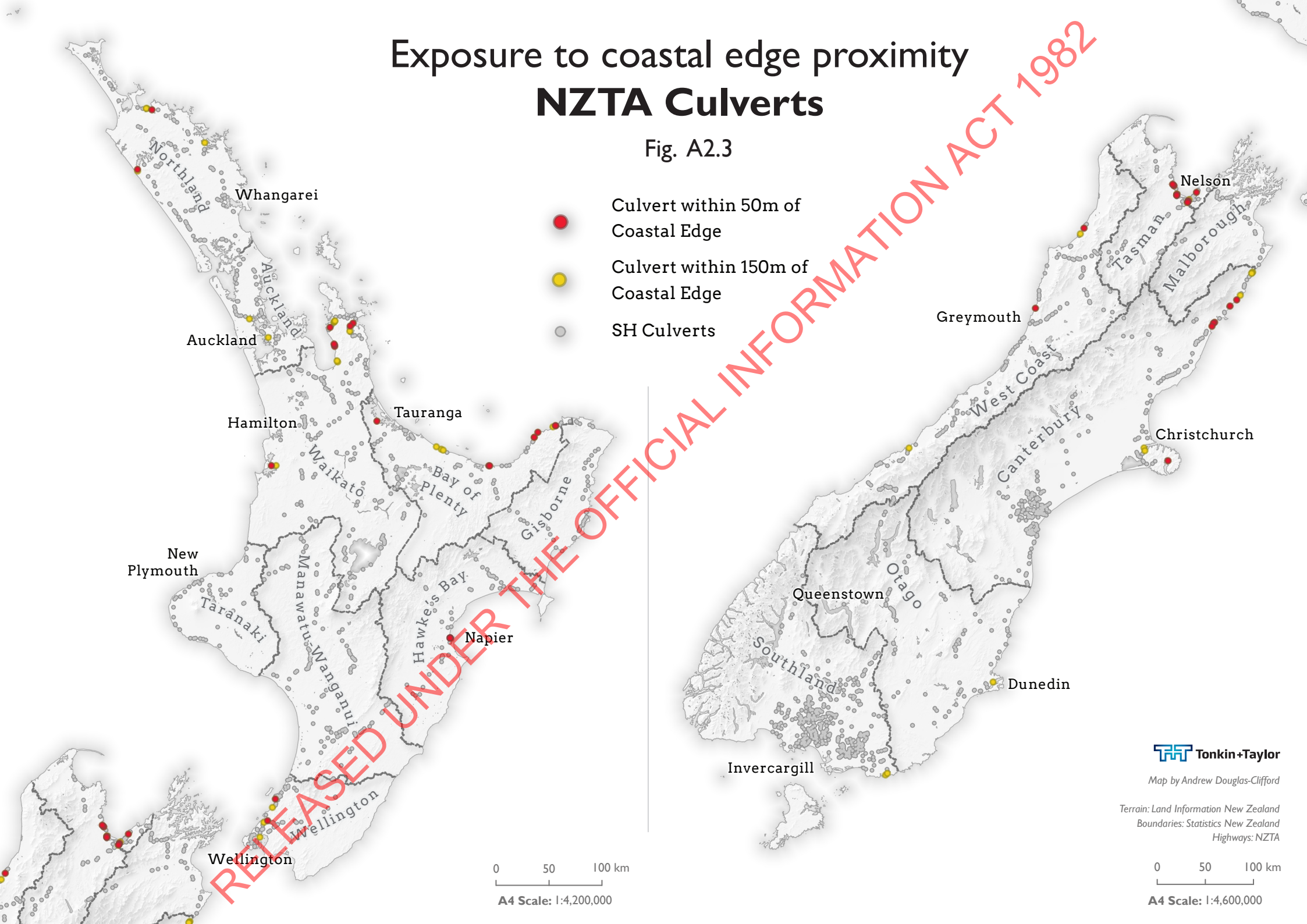
North Island labels: Northland, Whangarei, Auckland, Hamilton, Tauranga, New Plymouth, Taranaki, Waikato, Bay of Plenty, Gisborne, Manawatu-Wanganui, Hawke's Bay, Napier, Wellington

South Island labels: Nelson, Tasman, Marlborough, Greymouth, West Coast, Canterbury, Christchurch, Queenstown, Otago, Southland, Dunedin, Invercargill

Map by Andrew Douglas-Clifford

Terrain: Land Information New Zealand
Boundaries: Statistics New Zealand
Highways: NZTA

A4 Scale: 1:4,200,000
A4 Scale: 1:4,600,000

0 50 100 km

Combined exposure level
NZTA State Highway

Fig. A3.1

Exposed at Level:

5
4
3
2
1

Northland
Whangarei
Auckland
Auckland
Hamilton
Waikato
Tauranga
Bay of Plenty
Gisborne
New Plymouth
Taranaki
Manawatu-Wanganui
Hawke's Bay
Napier
Wellington
Wellington

Nelson
Tasman
Marlborough
Greymouth
West Coast
Canterbury
Christchurch
Queenstown
Otago
Southland
Dunedin
Invercargill

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Map by Andrew Douglas-Clifford

Terrain: Land Information New Zealand
Boundaries: Statistics New Zealand
Highways: NZTA

0   50   100 km

A4 Scale: 1:4,200,000

0   50   100 km

A4 Scale: 1:4,600,000

Combined exposure level
NZTA Tunnels & Bridges
Fig. A3.2

Exposed at
Level:

■	5
■	4
■	3
■	2
□	1

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Northland

Whangarei

Auckland

Auckland

Waikato

Hamilton

Tauranga

Bay of
Plenty

Gisborne

New
Plymouth

Taranaki

Manawatu-Wanganui

Hawke's Bay

Napier

Wellington

Wellington

Nelson

Tasman

Malborough

Greymouth

West Coast

Canterbury

Christchurch

Queenstown

Otago

Southland

Dunedin

Invercargill

T╦T **Tonkin+Taylor**

Map by Andrew Douglas-Clifford

Terrain: Land Information New Zealand
Boundaries: Statistics New Zealand
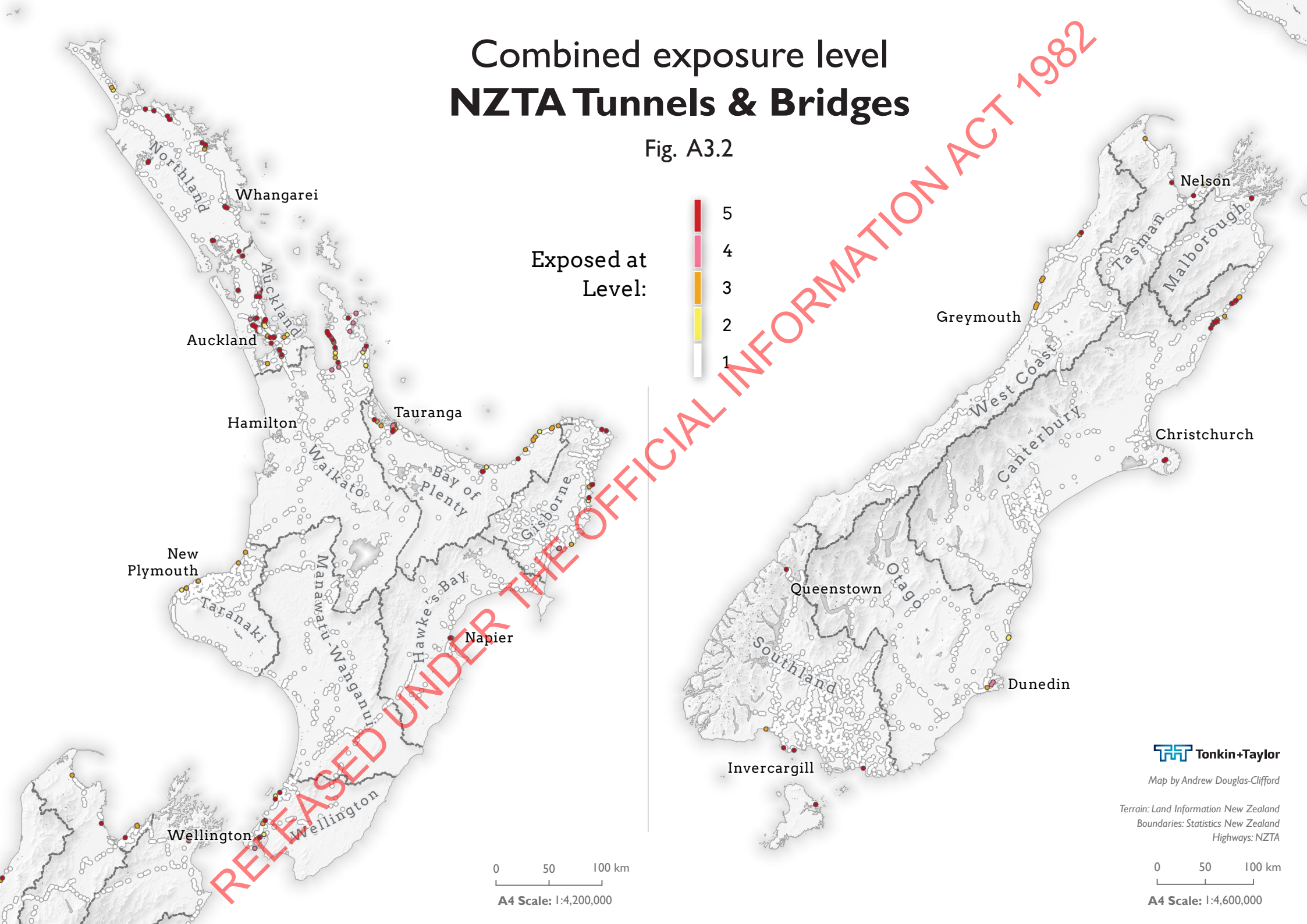*Highways: NZTA*

0   50   100 km

A4 Scale: 1:4,200,000

0   50   100 km

A4 Scale: 1:4,600,000

Combined exposure level
NZTA Road Culverts
Fig. A3.3
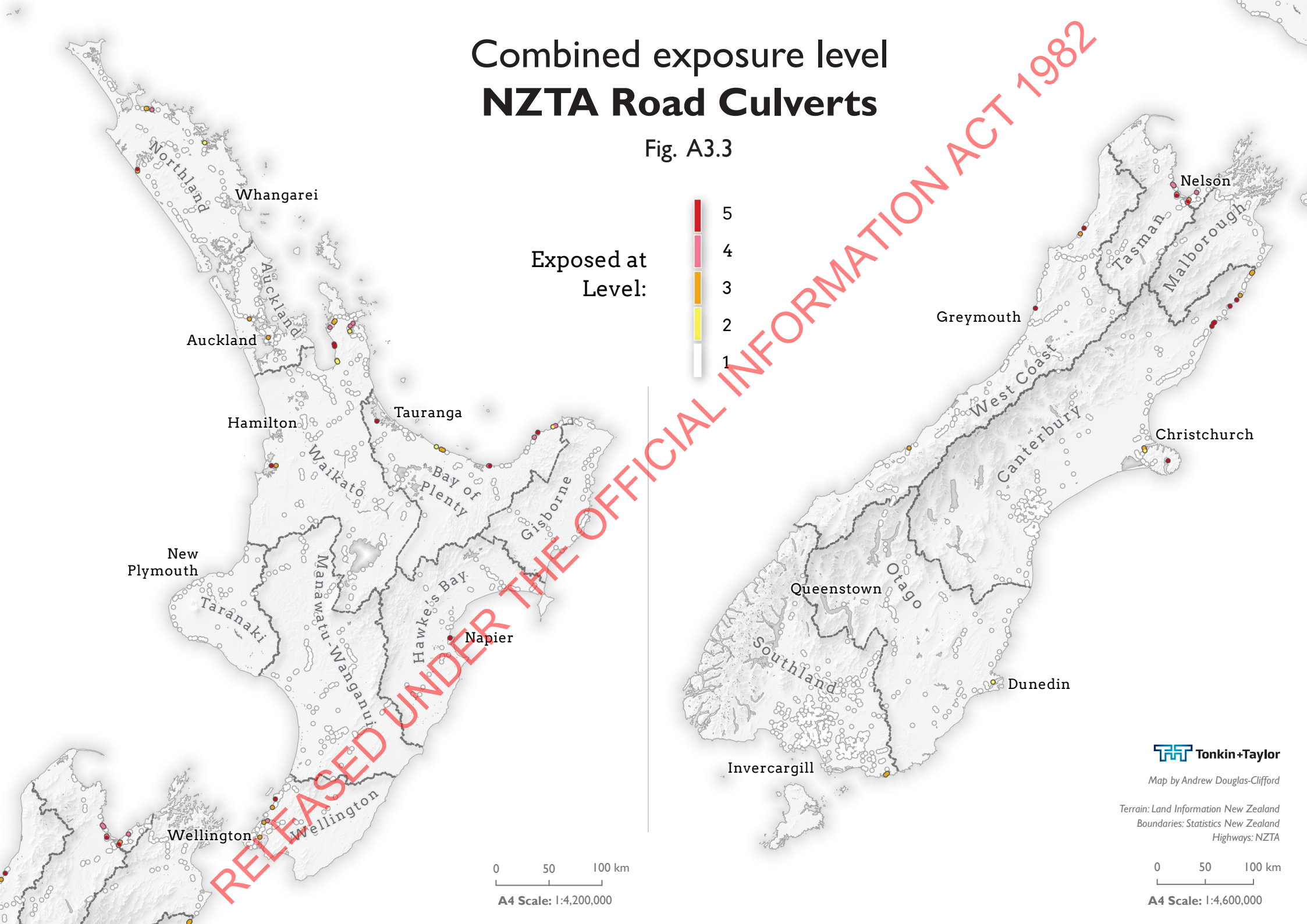
Exposed at Level:

- 5
- 4
- 3
- 2
- 1

Whangarei

Northland

Auckland

Auckland

Hamilton

Waikato

Tauranga

Bay of Plenty

Gisborne

New Plymouth

Taranaki

Manawatu-Wanganui

Hawke's Bay

Napier

Wellington

Wellington

Nelson

Tasman

Marlborough

Greymouth

West Coast

Canterbury

Christchurch

Queenstown

Otago

Southland

Dunedin

Invercargill

0   50   100 km

A4 Scale: 1:4,200,000

0   50   100 km

A4 Scale: 1:4,600,000

T·T Tonkin+Taylor

Combined exposure level
NZTA All Assets

Fig. A3.4

Exposed at Level:

- 5
- 4
- 3
- 2
- 1

Whangarei

Northland

Auckland

Auckland

Hamilton

Waikato

Tauranga

Bay of Plenty

Gisborne

New Plymouth

Taranaki

Manawatu-Wanganui

Hawke's Bay

Napier

Wellington

Wellington

Nelson

Tasman

Malborough

Greymouth

West Coast

Canterbury

Christchurch

Queenstown

Otago

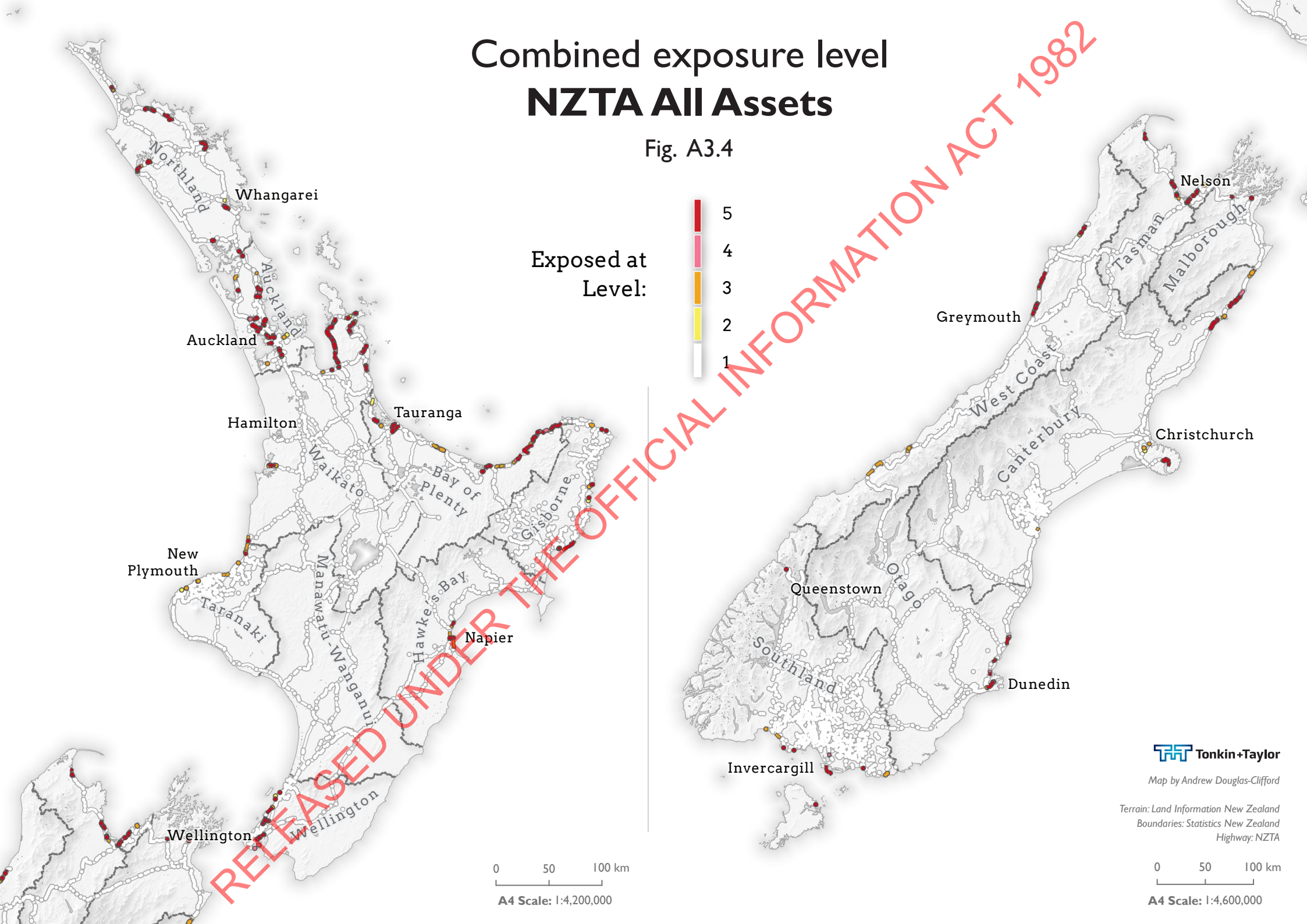Southland

Dunedin

Invercargill

Tonkin+Taylor

Map by Andrew Douglas-Clifford

Terrain: Land Information New Zealand
Boundaries: Statistics New Zealand
Highway: NZTA

0   50   100 km

A4 Scale: 1:4,200,000

0   50   100 km

A4 Scale: 1:4,600,000