REPORT

Tonkin+Taylor

Nelson North Wastewater Treatment Plant

Natural Hazards Assessment

Prepared for
Nelson City Council

Prepared by
Tonkin & Taylor Ltd

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Client summary

Tonkin & Taylor Ltd (T+T) has assessed the natural hazards that could affect the Nelson North Wastewater Treatment Plant (WWTP) for Nelson City Council. Our findings are described in the report and summarised in detail in Appendix A. Table 1 below summarises the natural hazard occurrence probability and key consequences at the site.

Table 1: Natural hazards summary for the Nelson North Wastewater Treatment Plant

Natural hazard		Feasible to cause ground damage at the WWTP site?	Present Day event Annual Exceedance Probability, AEP (Average Recurrence Interval, ARI in brackets) that is likely to cause significant damage	Probability of one occurrence in a 50 year time period	Key potential damages
Coastal storm inundation		Yes	>= 1% AEP (1 in 100 year). In the future, Sea Level Rise (SLR) will increase the frequency of damaging events	<39%	- Surface flooding and water damage to structures - Damage to low lying electrical systems - Loss of inflow if vulnerable Atawhai Rising Main (AMR) breaks
Coastal Erosion		Yes	NA, expected to occur as a cumulative effect of smaller events	>50%	- Erosion expected around the outlet/discharge chamber and interceptor box
Flooding		Yes	>= 1% AEP (1 in 100 year)	<39%	- Access to site may be hindered - Only limited damage expected - Increased inflows, or loss of inflow if vulnerable ARM breaks
Tsunami		Yes	~0.5% AEP (1 in 200 year). In the future, Sea Level Rise (SLR) will increase the frequency of damaging events	22%	- Significant damage to structures - Inundation with saltwater - Scour damage to surfaces and embankments - Loss of/difficult access to site - Debris inundation - Loss of inflow if vulnerable ARM breaks
Earthquake & related hazards	Fault rupture	No	NA	NA	NA
	Ground shaking	Yes	2% AEP (1 in 50 year)	64%	Earthquake damage at this level of shaking is likely to be controlled by liquefaction, refer below
	Liquefaction related hazards	Yes	2% AEP (1 in 50 year)	64%	- Significant damage to structures, including differential settlement - Lateral spreading of pond embankments, possibly causing leakage to the surrounding area - Scour damage to surfaces and embankments - Pipe breaks - Loss of inflow if vulnerable ARM breaks
	Cyclic softening of clays	Yes	1% AEP (1 in 100 year)	39%	- Significant damage to structures, including differential settlement
Wildfire hazards		Yes	TBC	TBC	- Cut off site access - Could jump from vegetation to buildings
Landslip/slope instability		No	NA	NA	NA

1 Introduction

Tonkin & Taylor Ltd (T+T) was engaged by Nelson City Council (NCC) to provide a report for the Nelson North Wastewater Treatment Plant (WWTP) summarising:

- Current state of various hazard models and results datasets that consider the area local to the WWTP.
- The natural hazards that may impact the site over a 50-year time horizon, based on current datasets (and any datasets that are being updated over the next two (2) months).
- What affect these may have on the site.

This work has been carried out under the terms and conditions outlined in our Contract 3906 with Nelson City Council (NCC). Approval to Proceed with this work was provided by NCC on 22 February 2023.

Section 2 to Section 8 below describe the current modelling and/or datasets available for each natural hazard, the likelihood of the hazard affecting the site, and potential effects on the site. A summary table is provided in Appendix A. Where applicable, T+T figures are provided in Appendix B.

2 Coastal storm inundation

2.1 Existing current hazard models/datasets

The latest coastal inundation reporting, which included modelling of potential inundation areas and a resulting dataset, is the T+T report '2022 Nelson Coastal Inundation Mapping Update - Phase A, Investigations', dated May 2022, T+T ref 1006718.2100. This report is currently in draft. The report and conclusions may be subject to amendments prior to final issue. This report considers the most up to date Sea Level Rise (SLR) and Vertical Land Movement (VLM) projections.

2.2 Probability of the WWTP site being affected within a 50-year time horizon

The likelihood of a single coastal storm event causing inundation at the site, expressed as the percent probability of occurrence once within a 50-year time window, derived from the report referenced above, is shown in Figure 2.1 below. Curves for Present Day (PD), 2050 with Sea Level Rise (SLR) assuming Shared Socioeconomic Pathway (SSP) 8.5, and 2080 SSP8.5 are included. The figure shows that:

- During the PD, around a 1% Annual Exceedance Probability (AEP, equivalent to a 1 in 100 year) coastal storm is required to inundate the ground around the WWTP buildings. This event has a 40% probability of occurring one time within a 50 year period.
- In the year 2050, assuming SSP8.5 SLR, around a 20% AEP coastal storm (equivalent to a 1 in 5 year event) is required to inundate the ground around the WWTP buildings. This event has >90% probability of occurring one time within a 50 year period.

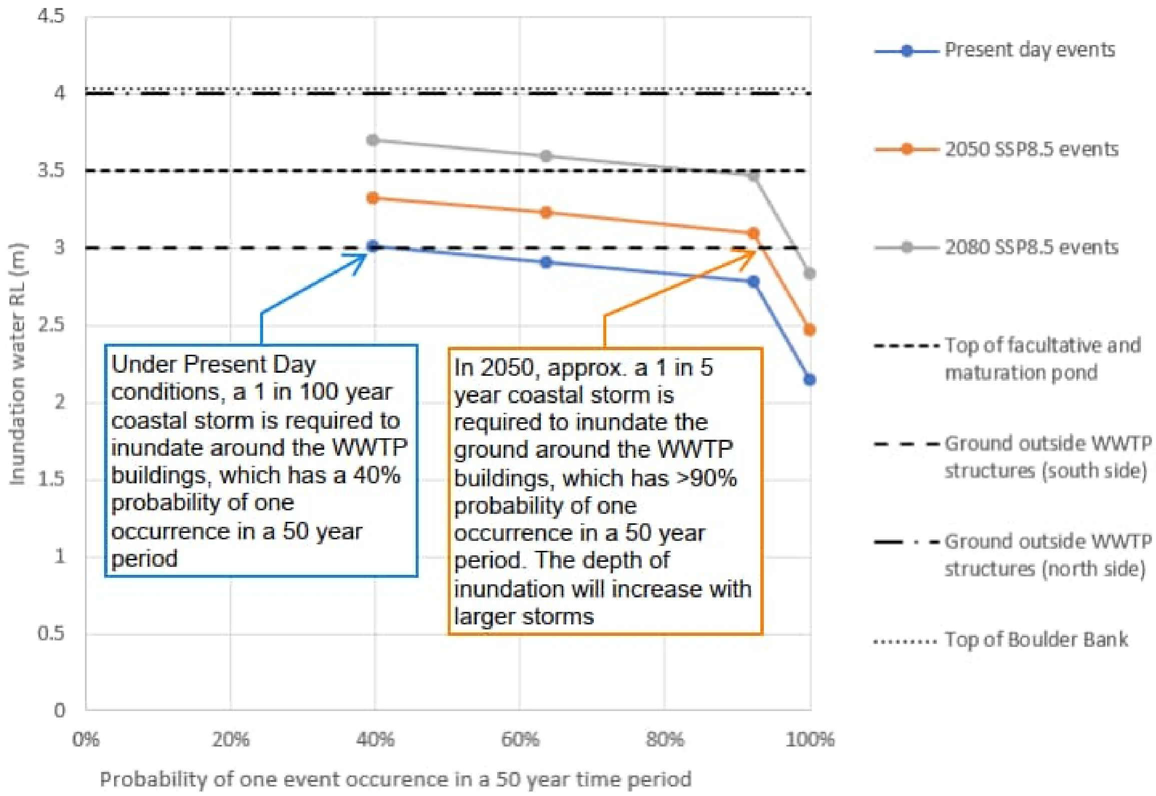

Figure 2.1: % probability of occurrence once within a 50-year time window

T+T Figure 1006675.0900-WWTP-F10, Appendix B, shows the inundation areas assessed by the latest modelling.

2.2.1 Potential coastal inundation effects at the site

Based on our knowledge of the site, and a literature search for types of damage that have been observed at historic examples of WWTP's subjected to coastal inundation, we expect that the following types of damage could occur at the site:

- Damage to structures
  - Flooding
  - Damage to low lying fixtures, items, and electrical systems.
- Saltwater intake due to inundation of upstream network.
- Surficial flooding around the WWTP buildings.
- Saltwater flooding of below ground installations, such as the inlet and bypass channel.
- Network impacts that could affect the WWTP:
  - There is a risk that coastal pumpstations and/or the Atawhai Rising Main (ARM) could be damaged, reducing or prohibiting inflows,
  - Conversely, there is a risk that there are very large inflows due to sudden stormwater influx into the wastewater network.

3 Coastal erosion hazard

3.1 Existing current hazard datasets

The latest coastal erosion reporting, which included modelling of potential inundation areas and a resulting dataset, is the T+T report 'Nelson City Coastal Erosion, Second Pass Assessment', dated January 2023, T+T ref 1006718.4000 v1. This report is currently in draft. The report and conclusions may be subject to amendments prior to final issue. This report considers the most up to date Sea Level Rise (SLR) and Vertical Land Movement (VLM) projections.

3.2 Probability of the WWTP site being affected within a 50-year time horizon

Based on our knowledge of the site, and the Coastal Erosion Hazard Area (CEHA) and mechanism described in the reporting, we have assessed the following potential affects at the site:

- By 2050, the outlet/discharge chamber, and the marine beacon mounting structure, lie within the CEHA.
- By 2080, the outlet/discharge chamber, the marine beacon mounting structure, lie within the CEHA.

T+T Figure 1006675.0900-WWTP-F11, Appendix B, shows the inundation areas assessed by the latest modelling.

3.2.1 Potential coastal erosion effects at the site

Based on our knowledge of the site, and a literature search for types of damage that have been observed at historic examples of WWTP's subjected to coastal erosion, we expect that the following types of damage could occur at the site:

- By 2050, the outlet/discharge chamber, and the marine beacon mounting structure, is at risk of erosion of the surrounding gravels, or inundation and impact damage from waves and entrained gravels.
- By 2080, the outlet/discharge chamber, the marine beacon mounting structure, and the inceptor box is at risk of erosion of the surrounding gravels, or inundation and impact damage from waves and entrained gravels.

4 Rainfall induced flooding

4.1 Existing current hazard models/datasets

There are multiple flood models for the catchments and rivers around Nelson. The WWTP lies within the bounds of the Wakapuaka Flood Model. The latest version of this model is described in the T+T report 'Nelson Flood Plain Model updates, Maitai/Brook/York and Wakapuaka flood models', dated 28 July 2021, T+T ref 870888.0012. The model was last updated in 2020, using the MfE 2017 climate change and SLR projections. It has not yet been updated to use the latest SLR and VLM projections. The largest flood event considered in the modelling is a 1% AEP (1 in 100 year) event.

4.2 Probability of the WWTP site being affected within a 50-year time horizon

The Wakapuaka Flood Model, described above, for both PD and 2070 RCP8.5, shows that the WWTP is not expected to be inundated by flood waters in up to 1% AEP events.

T+T Figure 1006675.0900-WWTP-F12, Appendix B, shows the inundation areas assessed by the latest modelling.

During events larger than 1% AEP, some inundation may occur, however the current modelling has not assessed what that AEP would be.

Based on the above, given the current datasets, it can be said that there is < 39% likelihood that the WWTP site will be inundated by a rainfall induced flood within a 50-year time period.

4.2.1 Assessment of observed case histories

We have reviewed evidence of the extent of the August 2022 flooding on the Wakapuaka flood plain, and compared this to the Present Day flood modelling results. Based on this, we have assessed that the August 2022 rainfall resulted in flooding between the calculated 1% (1 in 100 year) and 2% (1 in 50 year) AEP flood extents. The only effect on the WWTP that we are aware of at this time is that the daily wastewater inflow peaked on the 19th August at 55,270 m^3/d, 5-6 x the normal August daily inflow, and was diluted due to large amounts of stormwater entering the wastewater network. Historical photos of the Wakapuaka flood plain during the 2022 and 2011 floods are included below.

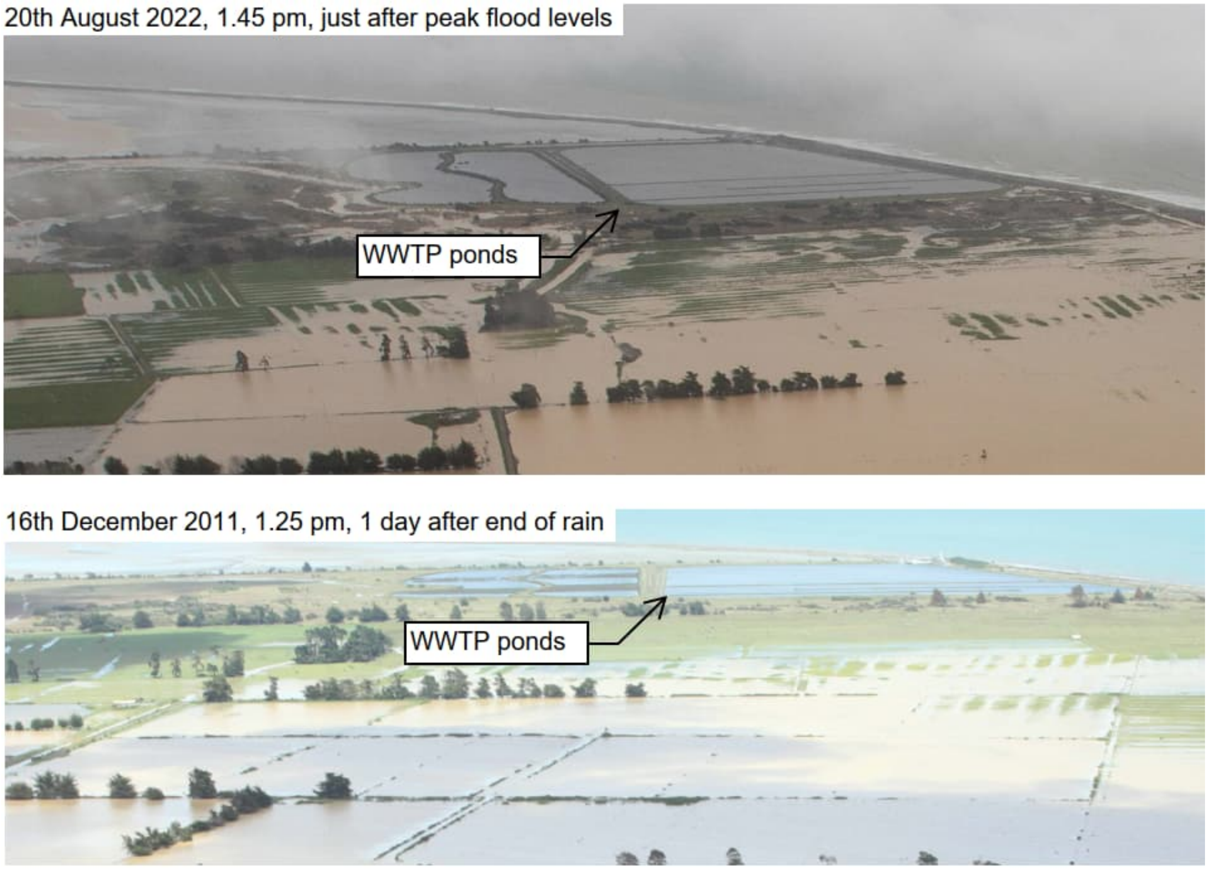

Figure 4.1: Historical photographs of the Wakapuaka flood plain, showing the WWTP typically being above the flood waters

4.2.2 Potential rainfall induced flooding effects at the site

Based on our knowledge of the site, and a literature search for types of damage that have been observed at historic examples of WWTP's that have been subjected to flooding, we expect that the following effects and/or types of damage could occur at the site:

- For up to approximately 1% AEP (1 in 100 year) events:
  - Increased inflows,
  - Access to and from Nelson may be difficult due to rainfall induced landslides on SH6.

- Events larger than 1% AEP are not considered in the current models and datasets. If such an event were to occur, there may be additional effects.

5 Earthquake and related hazards

5.1 Existing current hazard models/datasets

Earthquake and related hazards are a broad topic, and as such there are numerous models, reports, guidelines and design codes that describe the ground shaking that could occur at a site, which are listed below.

- The latest iteration of the New Zealand Seismic Hazard Model (NSHM)[i] was made live on nshm.gns.cri.nz on 17/10/2022. The NSHM presents the results of research on ground shaking hazard. It can be used to calculate the likelihood and strength of earthquake shaking that may occur in different parts of New Zealand over specified time periods.
- MBIE/NZGS Building Performance, Earthquake Geotechnical Engineering Practice, Module 1. Overview of the Guidelines, November 2021[ii]. This provides Peak Ground Acceleration (PGA) and earthquake Magnitude (M) values recommended for Geotechnical Assessment.
- NZS1170.5:2004, Structural Design Actions – Part 5: Earthquake actions, provides the current codified shaking demand for structural design. An update of B1/VM4, expected in November 2023 may replace the shaking demands specified in this document.

SLR is not expected to have a large effect on earthquake induced ground shaking, and is not typically discussed in the documents described above.

Earthquake induced ground shaking at the site may initiate additional ground damage mechanisms. The potential for these mechanisms has been assessed and reported on, or is being assessed, as described below:

- Liquefaction of sandy and non-plastic silty soils, assessed and reported on in the report 'Wastewater Treatment Plant Liquefaction Assessment', T+T, November 2022, T+T ref 1006675.0900. SLR may have some impact on this hazard, due to rising groundwater levels. The potential effects of SLR are not discussed in the report, and it is not known what effects SLR will have on the groundwater levels at the site. However, conservatively elevated groundwater levels were used for the analyses, and sensitivity calculations are held on file.
- Cyclic softening of heavily loaded clays (such as clays under building foundations), preliminary assessment carried and reported on in the report 'Wastewater Treatment Plant Liquefaction Assessment', T+T, November 2022, T+T ref 1006675.0900. SLR may have some small impact on this hazard, due to rising groundwater levels. The potential effects of SLR are not discussed in the report, and it is not known what effects SLR will have on the groundwater levels at the site.
- Fault Hazard Overlay, fault corridors assessed and reported on by Beca[iii] 'Revised Nelson Fault Hazard Deformation Overlay', Beca, 10 December 2021. SLR is not relevant to this hazard. The fault hazard corridors are shown visually on the NCC Nelson Geotechnical Hazards online GIS viewer[iv].

Liquefaction induced lateral spreading of the pond embankments is currently being assessed by T+T. We will assess and make allowance for conservative groundwater level in this work.

Earthquakes can also cause tsunamis that could impact the site. Tsunamis are discussed in Section 6.

5.2 Probability of the WWTP site being affected by earthquake induced ground shaking within a 50-year time horizon

Peak Ground Acceleration (PGA), described as a portion of gravity, is a useful measure of the earthquake induced ground shaking that may occur at a site. The AEP of a PGA occurring at a site can be derived from the NSHM and the MBIE/NZGS Guidelines referenced above. The stronger the PGA, the greater the surface affects and damage expected. The likelihood of a single earthquake event causing PGA at the site, expressed as the percent probability of occurrence once within a 50-year time window, derived from MBIE/NZGS Building Performance, Earthquake Geotechnical Engineering Practice, Module 1, is shown in Figure 5.1 below.

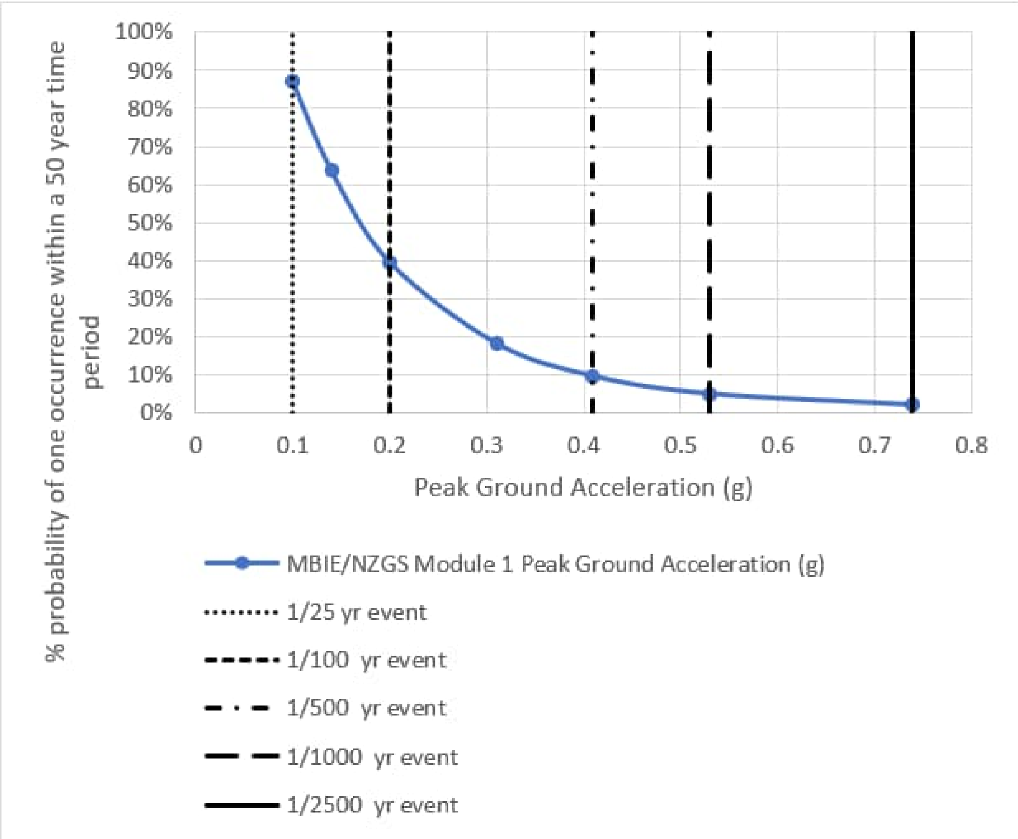

Figure 5.1: % probability of earthquake induced ground shaking at the site

5.2.1 Earthquake related ground damage mechanisms

Earthquake ground shaking is known to initiate additional ground damage mechanisms, including:

- Fault ruptures at the ground surface
- Liquefaction of sandy and non-plastic silty soils
- Liquefaction induced lateral spreading of the pond embankments
- Cyclic softening of heavily loaded clays (such as clays under building foundations)

These are discussed in the following sections.

5.2.1.1 Fault rupture

We have reviewed the NCC GIS online Nelson Geotechnical Hazards viewer, which shows the that fault lines are not mapped under the WWTP. Therefore, we do not consider that it is probable that the WWTP will be affected by fault rupture.

T+T Figure 1006675.0900-WWTP-F13, Appendix B, shows the inundation areas assessed by the latest modelling.

5.2.1.2 Liquefaction, cyclic softening, and lateral spreading

Ground shaking levels that could trigger liquefaction and cyclic softening of the soils underlying the site are described in the report T+T report referenced above. The probability of the site being affected by liquefaction and cyclic softening within a 50-year time period is shown in Figure 5.2 below.

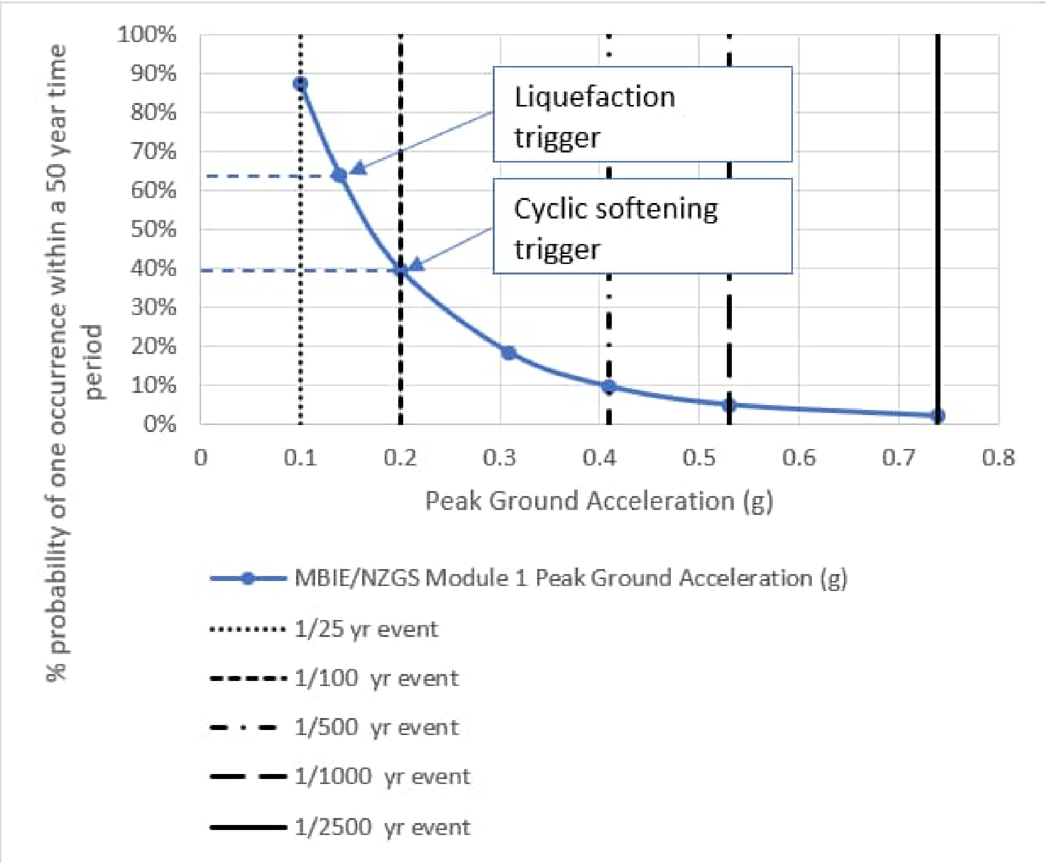

Figure 5.2: % probability of an earthquake triggering liquefaction and cyclic softening at the site

Once liquefaction has been triggered, lateral spreading may occur. This is likely to affect built up embankments, such as the pond and access road embankments, and channel margins. The amount of lateral displacement, slumping and cracking is likely to increase proportionally to stronger ground shaking. Assessment of the locations and amount of lateral spreading damage that is likely to occur at the site is currently being carried out by T+T.

5.2.2 Potential earthquake effects at the site

Based on our knowledge of the site, and a literature search for types of damage that have been observed at historic examples of WWTP's subjected to strong earthquakes, we expect that the following types of damage could occur at the site:

- Damage to structures. Since 2004, structures are typically designed to have little to no damage in 4% (1 in 25 year) EQ events. Damage may be triggered at some level beyond this, and could be expected to progressively increase at higher shaking levels. Given that liquefaction ground damage is expected by 2% (1 in 50 year) shaking levels, and in lieu of detailed seismic assessments, this is also likely a reasonable trigger level for building damage to assume for this work. Types of damage that could occur include:

  - Liquefaction/cyclic softening induced differential settlement of foundations, resulting in building tilting and/or hogged floor slabs,
  - Liquefaction/cyclic softening induced floor slab cracking, including radial cracking in the digester slab,
  - Additional structural damage,
  - Sloshing effect of fluids stored in tanks during the time of shaking can cause severe structural damage.
- Shaking induced detachments of non-structural elements (e.g. sludge scrapers, baffles, aerators, mechanical mixers, chemical tanks, building fittings and fixtures, etc.).
- Loss of power supply.
- Pipe breaks at connections to or penetrations through structures.
- General pipe breaks due to strong ground shaking.
- Slumping and lateral spreading of the pond embankments, potentially causing loss of impounded contents.
- Slumping and lateral spreading of the access road embankment, prohibiting access to the site.
- Upstream network and other infrastructure effects:
  - Loss of inflow due to breaks along the Atawhai Rising Main (ARM),
  - At other WWTP's, influx of liquefied sand and silt has been noted as a damage contributor. The current ARM is likely to be damaged beyond operable during strong ground shaking. Once this pipe has been replaced, this could become a likely damage mechanism,
  - Loss of other critical upstream infrastructure, such as power, telecommunications,
  - Loss of or more difficult access, from damage to the access road embankment, and damage to SH6.

5.2.3 Assessment of observed case histories

Pierucci & Klemes, 2013[v], compiled data from 19 WWTP's that had been subjected to earthquakes, categorised the damaged into five 'Damage States, "DS"', and plotted the number of 'DS' against PGA. We have reproduced Figure 1 from this source (see Figure 5.3 below) and annotated the percent probability of the PGA occurring at this site once within a 50-year time period. Damage States are defined as follows:

- DS1 means no damage.
- DS2 is defined by malfunction of plant for a short time (less than three days) due to loss of electric power and backup power if any, considerable damage to various equipment, light damage to sedimentation basins, light damage to chlorination tanks, or light damage to chemical tanks. Loss of treated water quality may occur.
- DS3 is defined by malfunction of plant for about a week due to loss of electric power and backup power if any, extensive damage to various equipment, considerable damage to sedimentation basins, considerable damage to chlorination tanks with no loss of contents, or considerable damage to chemical tanks. Loss of treated water quality is imminent.
- DS4 is defined by the pipes connecting the different basins and chemical units being extensively damaged. This type of damage will likely result in the shutdown of the plant and loss of contents.

- DS5 is defined by the complete failure of all piping, or extensive damage to structures composing the WWTP.

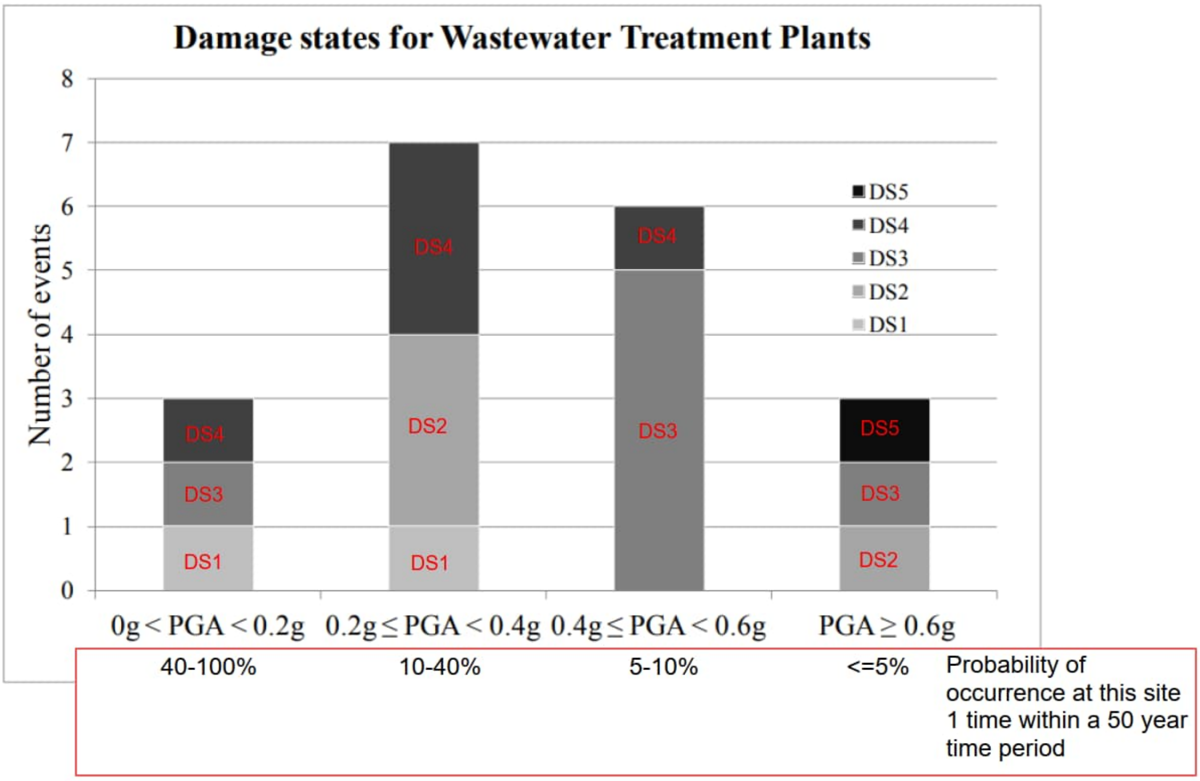

Figure 5.3: % probability of the PGA occurring at this site once within a 50-year time period

This work shows that a higher Damage State, DS4, can occur even at relatively low PGA. At this site, once liquefaction is triggered (~0.14g), the likelihood of pipe breaks rapidly increases (pipes in the vicinity of the access road and/or pond embankments are particularly at risk, e.g. the ARM), which could cause the WWTP to be offline for an extended period while repairs are carried out.

Complete plant failures (DS5) was only noted at PGA≥0.6, which has a probability of one occurrence during a 50-year time period of ≤5% at this site.

T+T is currently assessing the likely performance of the pond embankments during earthquakes, and this will be reported on separately. Beca reported on the performance of the Christchurch WWTP pond embankments following the Canterbury Earthquake Sequence[vi]. The key observations they made include:

- All of the 14 km of embankments experienced between 10 mm and approximately 1,500 mm of lateral deformation.
- 50 mm to 200 mm of crest settlements (up to 500 mm in isolated locations).
- Seepage through the embankments increased after each significant event.

In the February 2011 earthquake, the strength of the ground shaking recorded near the Christchurch WWTP, at the Pages Road Pumpstation, was close to the 1 in 500 year event shaking shown in Figure 5.2 for the Nelson North WWTP. Given the similarities between the two sites, this is a relevant example for the type and magnitude of damage that may occur during a similar size earthquake.

Figure 5.4 below shows aerial photography of the pond embankments after the February 2011 earthquake[1].

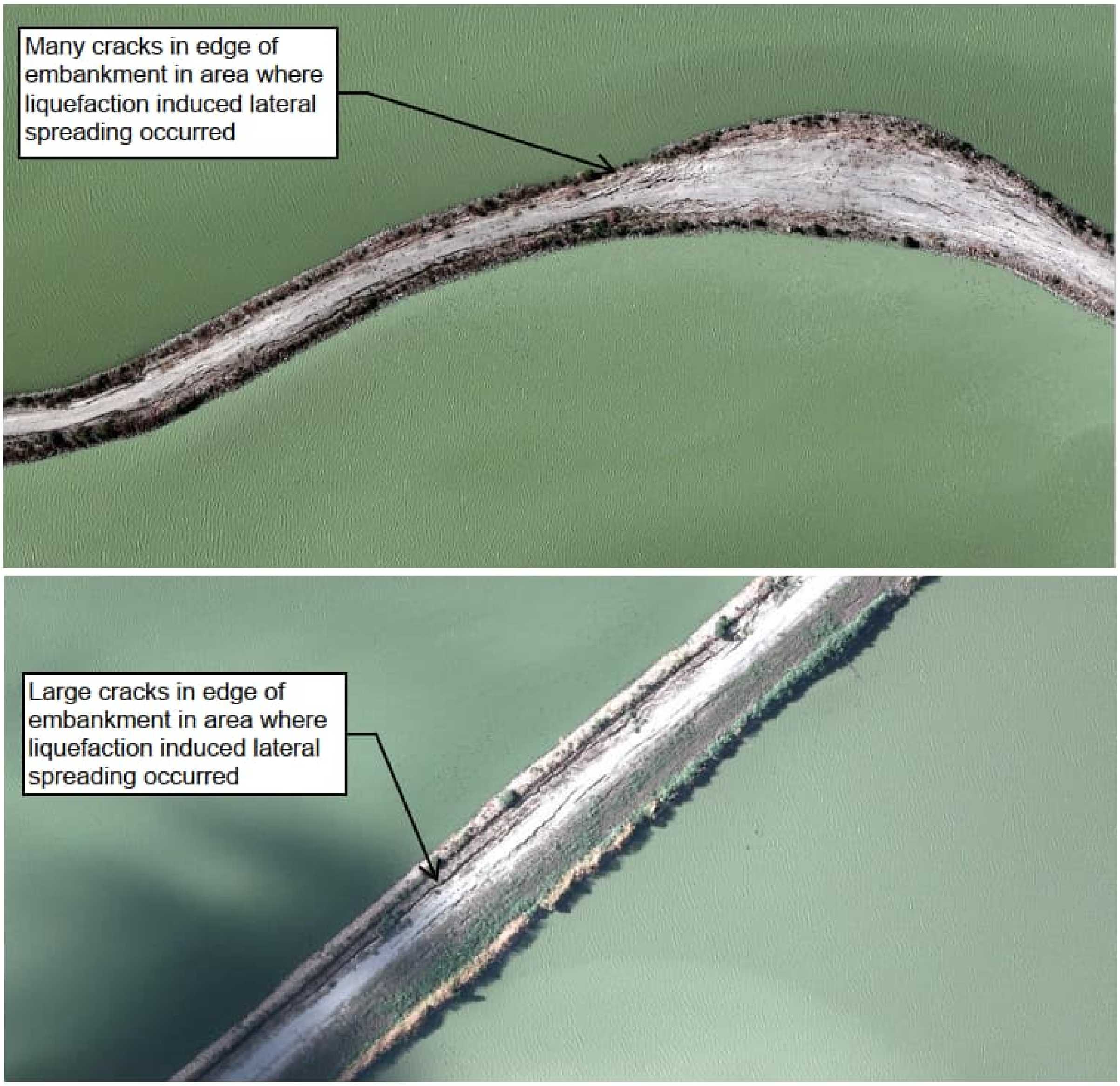

Figure 5.4: aerial photographs shown liquefaction induced lateral spreading damage in embankments at the Christchurch WWTP following the February 2011 earthquake[vii]

6 Tsunami damage

6.1 Existing current hazard datasets

The most up to date modelling and reporting regarding the potential for tsunamis affecting the site is the T+T report 'Tsunami bathtub modelling for wastewater network resilience assessments v3', Oct 22, T+T ref 1006675.0900. Additionally, a Level 3 hydrodynamic tsunami modelling project has been initiated, but results are not expected until late 2023 or 2024.

[1] Aerial imagery taken from the CCC Christchurch Liquefaction Information website, [Christchurch Liquefaction Information (canterburymaps.govt.nz)](), June 2023

Climate change is expected to increase the exposure level of the WWTP to tsunamis, as the background sea level will increase, meaning smaller and more frequent tsunamis are likely to overtop the Boulder Bank. Tsunami scenarios that incorporate climate change are expected to be assessed during the Level 3 hydrodynamic tsunami modelling project.

6.2 Probability of the WWTP site being affected within a 50-year time horizon

The likelihood of a single tsunami impacting and inundating the site, expressed as the percent probability of occurrence once within a 50 year time window, based on our modelling described in the report referenced above, is shown in Figure 6.1 below.

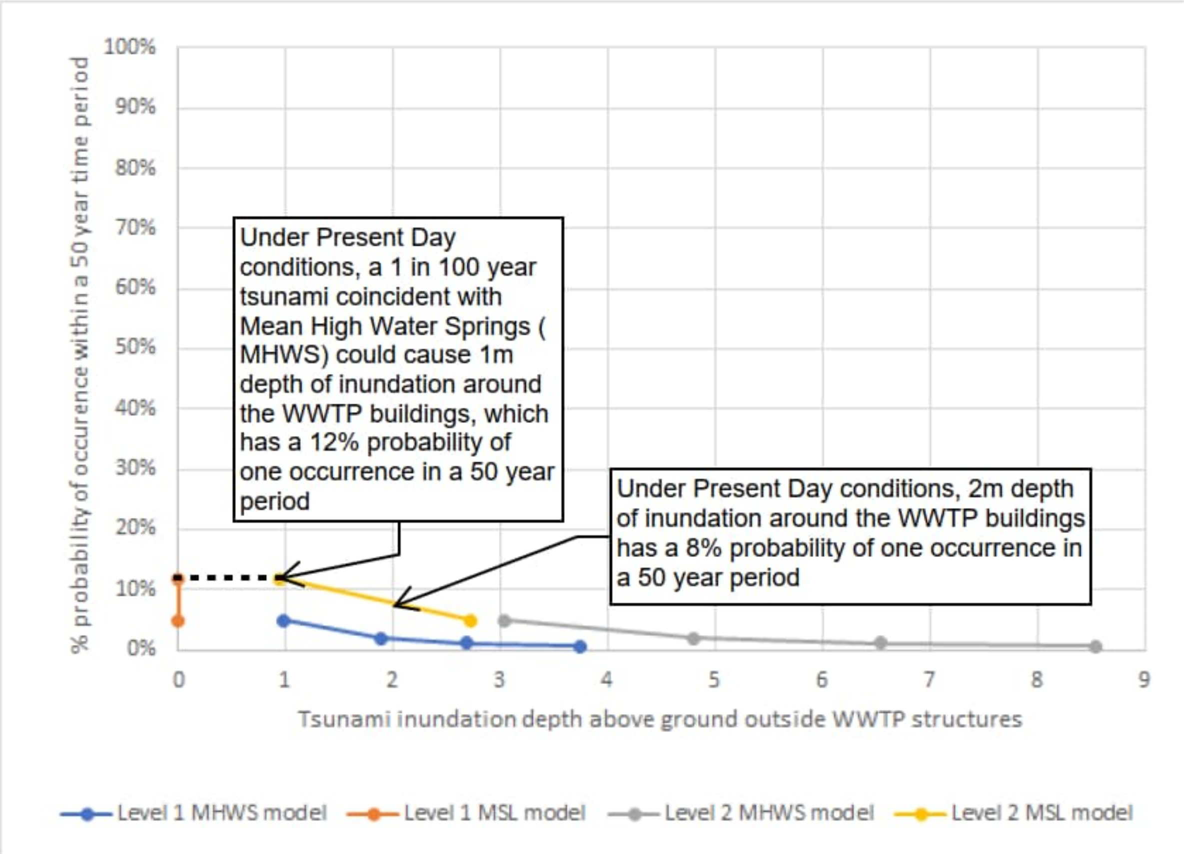

Figure 6.1: % probability tsunami inundation at the site

T+T Figure 1006675.0900-WWTP-F14, Appendix B, shows the inundation areas assessed by the latest modelling.

6.2.1 Potential tsunami effects at the site

Based on our knowledge of the site, and a literature search for types of damage that have been observed at historic examples of WWTP's subjected tsunami's, we expect that the following types of damage could occur at the site:

- Damage to structures, which could include some or all of the following damage mechanisms[viii]:
  - Non-structural damage, e.g. water damage to cladding and internal fixtures
  - Flooding damage and debris inundations
  - Damage/failure of electrical systems
  - Structural and cladding damage due to water and entrained debris impact

  - Building deflection/displacement
  - Progressive collapse
  - Foundation damage
  - Building washed away, sometimes the foundations remain
- Damage to surfaces features, which could include some or all of the following damage mechanisms:
  - Scour and inundation damage to the ocean outfall pipe
  - Scour and erosion damage, possibly loss of, the access road embankment
  - Scour and erosion damage, possibly breaches in, the pond embankments
  - Scour of the ground surface
- Damage to the wastewater network and treatment systems, including:
  - Breaks in the ARM along exposed areas
  - Saltwater and debris inundation of the upstream wastewater network, including the ARM and pumpstations, reducing or prohibiting WWTP inflows
  - Damage to the upstream wastewater network, including the ARM and pumpstations, prohibiting WWTP inflows
  - Saltwater ingress into activated sludge[ix]
- Loss of other critical upstream infrastructure, such as power, telecommunications:
  - Loss of or more difficult access, from damage to the access road embankment, and damage to SH6

6.2.2 An assessment of observed case histories

Matsuhashi, Ikuo, Fukatani & Yokota[x] surveyed damage to wastewater treatment plants following the Great East Japan Earthquake and Tsunami, which occurred on March 11, 2011. Pipes and manholes are susceptible to both earthquake and tsunami damage, however the findings from that event were that damage to this type of infrastructure were primarily attributed to the earthquake effects, rather than the tsunami, as shown by Figure 6.2 below.

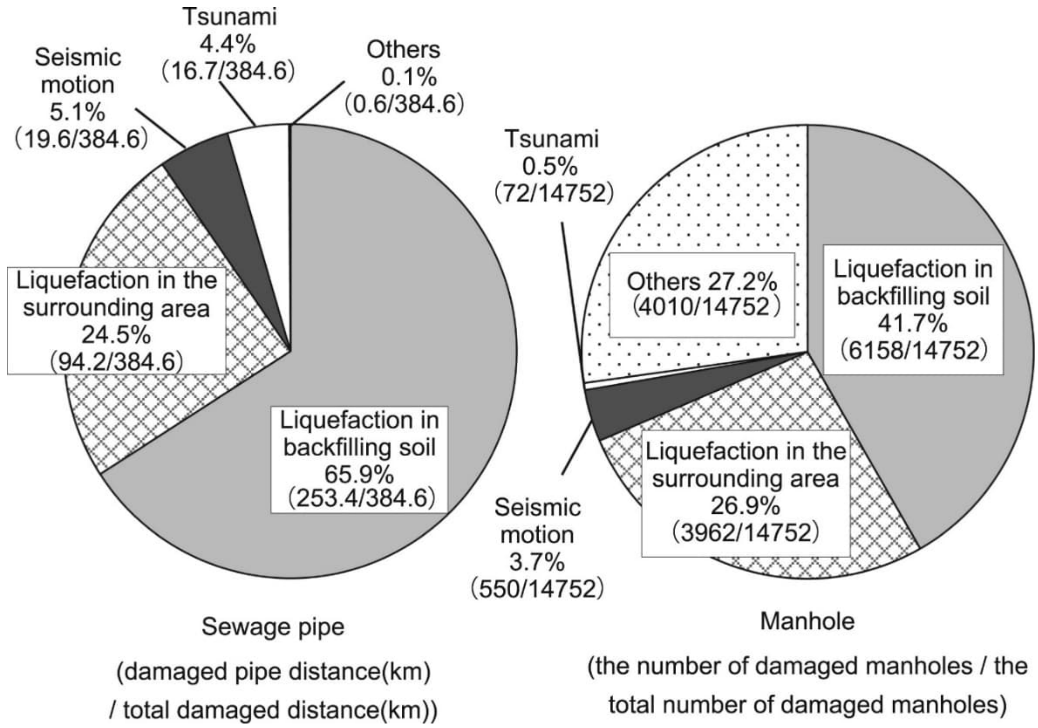

Figure 6.2: portion of pipe and manhole damage attributed to tsunamis from the Great East Japan Earthquake and Tsunami, March 11, 2011

Additionally, this research found that a high portion of the damage to wastewater treatment plants and pumping stations was directly attributed to the tsunami portion of the event, as shown in Figure 6.3 below. Table below describes the damages to wastewater treatment plants and pumping stations that were observed.

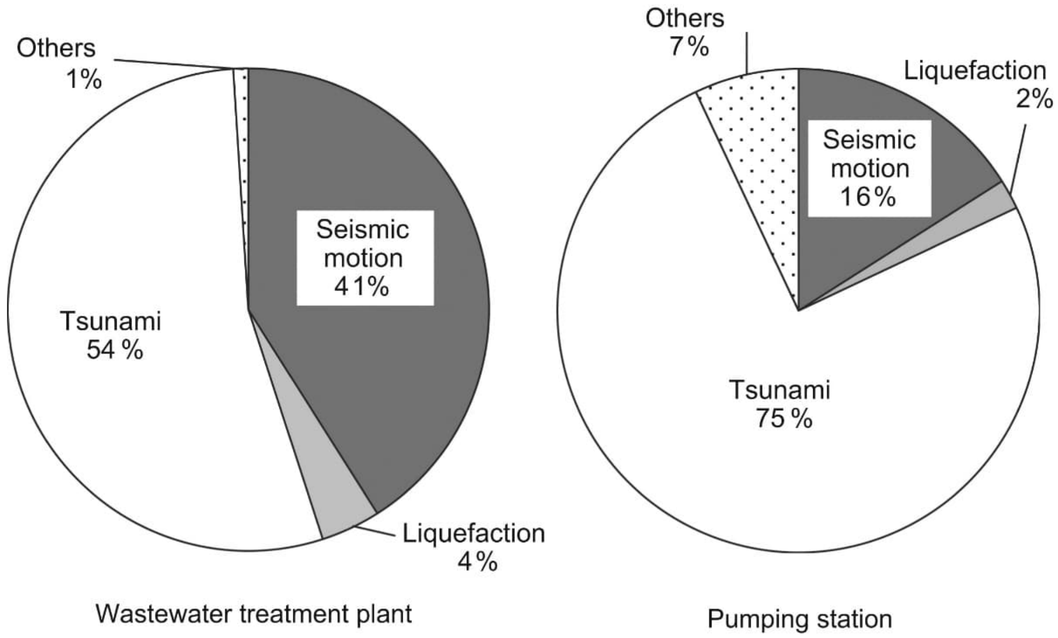

Figure 6.3: portion of pipe and manhole damage attributed to tsunamis from the Great East Japan Earthquake and Tsunami, March 11, 2011

Table 6.1: Tsunami damage mechanisms in wastewater treatment plants and pumping stations from the Great East Japan Earthquake and Tsunami, March 11, 2011, taken from Matsuhashi, Ikuo, Fukatani & Yokota

Table 3. Tsunami damage factors in wastewater treatment plants and pumping stations.

Damage factors	Wastewater treatment plants Damage rate (%)	Pumping stations Damage rate (%)	Examples
Inundation	42 (106/235)	39 (86/221)	Pumping motor, control panel, Private electric generator, incoming panel, automatic dust filtration, blower, etc.
Wave force	35 (88/235)	33 (72/221)	Gas tank, pump building, pillar of gate, shelter cover, pipe, etc.
Floating debris	23 (59/235)	28 (63/221)	Shutter, aeration tank, structural wall, etc.

Note: The total number of damaged facilities includes overlaps in the cases where two or more different damage factors determined in the same facility.

7 Wildfire hazards

7.1 Existing current hazard datasets

Fire and Emergency NZ (FENZ) report on the yearly wildfire occurrences nationally[xi]. The number of wildfires that occurred in the Nelson/Tasman/Marlborough areas for both the 2020/2021, and 2019/20 fire seasons are presented. AEP's and Recurrence Intervals of single events are not discussed or described.

7.2 Probability of the WWTP site being affected within a 50-year time horizon

There is insufficient data to describe the probability of an event occurring at the WWTP site.

7.2.1 Potential wildfire effects at the site

There is potential for wildfire to jump from nearby vegetation to the WWTP structures. This could cause severe damage and disruption.

7.2.2 An assessment of observed case histories

On 1 November 2021, two trickling filters at the Christchurch Wastewater Treatment Plant caught fire. An investigation later found that the probable cause was ignition of maintenance tape or the roof structure with a heating tool[xii]. The effect of this fire on the plant operation was that the trickling filters were out of commission for an extended period of time. This had subsequent effects on the treatment process that are not described here, but notably resulted in odour problems for nearby residents.

8 Landslide hazards

8.1 Existing current hazard datasets

The most up to date assessment and reporting regarding the potential for slope instability affecting the site is the 'NCC Slope Instability Overlay Report', Beca 2021[xiii].

Slope instability caused by lateral spreading is described in Section 5.2.1.2.

8.2 Probability of the WWTP site being affected within a 50-year time horizon

We have inspected the NCC Geotechnical Hazards Map GIS, which contains overlays from the report referenced above, and note that slope instability hazard areas are not shown at the site.

T+T Figure 1006675.0900-WWTP-F15, Appendix B, shows the slope instability hazard areas from the GIS viewer.

8.2.1 Potential landslide effects at the site

The effects of slope instability caused by lateral spreading is described in Section5.2.2. No additional landslide affects are expected at the site.

9 Applicability

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

We understand and agree that our client will submit this report as part of an application for resource consent and that Nelson City Council as the consenting authority will use this report for the purpose of assessing that application.

Tonkin & Taylor Ltd
Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
D Andrews	M Foley
....	....
Dan Andrews Geotechnical Engineer	Mark Foley Project Director

DJA
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Appendix A WWTP natural hazards summary table

Natural hazard	Data source*	Includes latest SLR and VLM data?	Feasible to cause ground damage at the WWTP site?	Event Annual Exceedance Probability, AEP (equivalent Average Recurrence Interval, ARI in brackets) that is likely to initiate damage	Probability of damage causing event occurring within a 50 year time period
Coastal storm inundation	T+T report '2022 Nelson Coastal Inundation Mapping Update - Phase A, Investigations', dated May 2022, T+T ref 1006718.2100. Currently in draft. Report and conclusions may be subject to amendments prior to final issue.	Yes	Yes	Present Day: Larger than a 1% AEP (1 in 100 year) storm required to initiate any damage	Present Day: <39%
				By 2050, assuming RCP8.5 SLR:	By 2050, assuming RCP8.5 SLR:
				63% AEP (1 year) AEP storm could inundate the wetland ponds	100%
				Larger than a 1% AEP (1 in 100 year) storm required to cause any other damage	<39%
				By 2080, assuming RCP8.5 SLR:	By 2080, assuming RCP8.5 SLR:
				A 63% AEP (1 year) storm could inundate the wetland ponds	100%
				A 5% AEP (1 in 20 year) storm required to inundate platform around buildings and potentially some water over BBD	92%
				A 2% AEP (1 in 50 year) storm overtops BBD and could cut off access to the site for the duration of the storm	63%
				Larger than a 1% AEP (1 in 100 year) storm required to inundate the facultative and maturation pond	<39%
Coastal Erosion	T+T report 'Nelson City Coastal Erosion, Second Pass Assessment', dated January, T+T ref 1006718.4000. Currently in draft. Report and conclusions may be subject to ammendments prior to final issue.	Yes	Yes	NA	By 2050 assuming RCP8.5: >50% probability of erosion expected around the outlet/discharge chamber, and the marine beacon mounting structure
					By 2080 assuming RCP8.5 SLR: >50% probability of erosion expected around the inceptor box is at risk of erosion of the surrounding gravels, or inundation and impact damage from waves and entrained gravels
Flooding	2021 Wakapuaka Flood plain modelling results, T+T report 'Nelson Flood Plain Model updates, Maitai/Brook/York and Wakapuaka flood models,' dated 28 July 2021, T+T ref 870888.0012	No - has MfE 2017 SLR values. Not currently updating model	Yes	Present Day and 2070 RCP8.5:: - larger than a 1% AEP (1 in 100 year) flood event. A 1% AEP flood would cause similar levels of disruption to the August 2022 storm - Very high inflows - Similar to August 2022, aged AC pipes in poor conditions could rupture (such as ARM)	<39%
Tsunami	T+T report 'Tsunami bathtub modelling for wastewater network resilience assessments v3', Oct 22, T+T ref 1006675.0900 Additionally, a Level 3 hydrodynamic tsunami modelling project has been initiated, but results are not expected until late 2023 or 2024.	No, only Present Day scenarios modelled	Yes	Present Day: - Saltwater may inundate the wetland ponds in 0.6-0.7% AEP (1 in 150 year) events	28%
				- At around 0.5% AEP (1 in 200 year) and larger events, expect tsunami water inundation on the ground at the WWTP, wave impact on structures and equipment, potential for electrical shorts, overtopping of the facultative and maturation pond embankments, ground scour. Severity of these effect scaling with wave size	22%

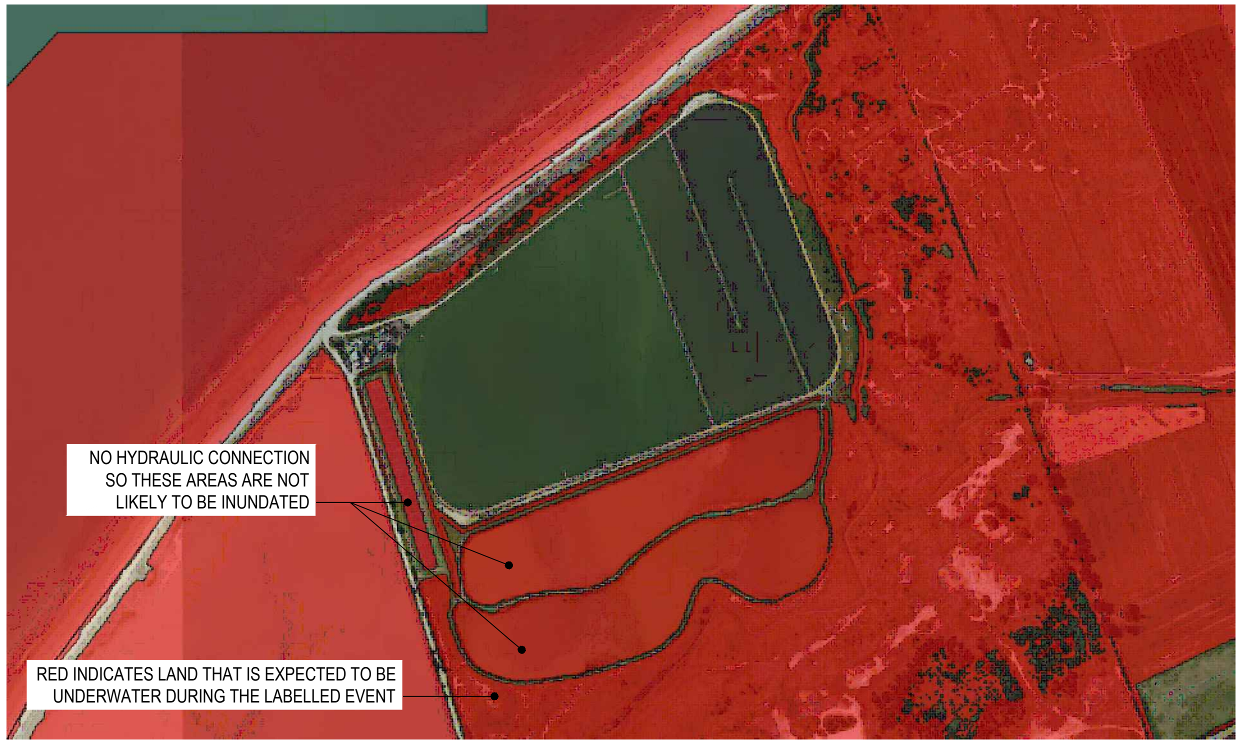
Notes * Refer to original work/referenced reports for limitations

Natural hazard		Data source*	Includes latest SLR and VLM data?	Feasible to cause ground damage at the WWTP site?	Event Annual Exceedance Probability, AEP (equivalent Average Recurrence Interval, ARI in brackets) that is likely to initiate damage	Probability of damage causing event occurring within a 50 year time period
Earthquake & related hazards	Fault rupture	Revised Nelson Fault Deformation Overlay, Beca, 10 December 2021	NA	No	NA	NA
	Ground shaking (causing direct damage to structures and horizontal infrastructure)	- 2022 GNS National Seismic Hazard Model - MBIE/NZGS Building Performance, Earthquake Geotechnical Engineering Practice, Module 1. Overview of the Guidelines, November 2021 - NZS1170.5:2004, Structural Design Actions – Part 5: Earthquake actions	NA	Yes	- Since 2004, structures are typically designed to have little to no damage and remain serviceable following 4% (1 in 25 year) EQ events. Damage may be triggered at some level beyond this, and could be expected to progressively increase at higher shaking levels. Given that liquefaction ground damage is expected by 2% (1 in 50 year) shaking levels, and in leiu of detailed seismic assessments, this is also likely a reasonable trigger level for building damage to assume for this work - Expect isolated pipe breaks to occur by 4% to 1.3% (1 in 75 year) EQ events, this includes ARM (Atawhai Rising Main) ruptures. Expect the frequency of pipe breaks to increase at higher shaking levels - Potential to lose inflow due to ARM rupture	Approx. 64% probability of an EQ event strong enough to trigger damage that is potentially disruptive. Expect greater damage for larger events that are less likely to occur.
	Liquefaction related hazards, including ground strain and surface settlement and co-seismic displacement/lateral spreading of the pond embankments	Wastewater Treatment Plant Liquefaction Assessment, T+T, November 2022	Report does not directly discuss what affect SLR may have on liquefaction potential at the site. However, the liquefaction analyses were carried out using a high groundwater table, so the main conclusions likely capture the effects can be expected. Also, groundwater level sensitivity analyses are presented in the report and held on TT files, so the effect can be simply assessed.	Yes	Liquefaction triggered at 4% (1 in 25 year) to 2% (1 in 50 year) AEP events, with majority of the susceptible soils fully triggered by 1% (1 in 100 year) events. Inspecting the triggering curves, take a 2% AEP event as the event which is likely to initiate liquefaction induced ground damage. Expect the following types of damage: - Pipe ruptures, this includes ARM ruptures - Potential to lose inflow due to ARM rupture - Differential settlement of ground and structures - Lateral spreading of pond embankments. Work is underway to assess the likely magnitude of movement. Expect cracking, slumping and crest settlement, potentially allowing contents to discharge to fields - Lateral spreading of the Boulder Bank Drive (BBD) embankments. Expect cracking, slumping and crest settlement, potentially rupturing the ARM and cutting off access to the site	64%
	Earthquake induced cyclic softening of clays	Wastewater Treatment Plant Liquefaction Assessment, T+T, November 2022. A single CPT test log assessed only	This hazard not affected by this	Yes	Cyclic softening triggered at 4% (1 in 25 year) to 1% (1 in 100 year) AEP events, fully triggered by 0.2% (1 in 500 year) events. Inspecting the triggering curves, take a 1% AEP event as the event which is likely to initiate cyclic softening induced ground damage. This phenomenon is less well understood than liquefaction. Case histories typically show differential settlement of structures on shallow foundations.	39%
Vegetation (pertinent to wildfire hazards)		Mapped vegetation areas (provided by NCC in 2019) New Zealand Wildfire Summary, 2020/21 Wildfire Season Update, Scion	No	Yes	- Cut off access to site for around 1 day - Could jump from vegetation to buildings. - Get advice from FENZ on safe vegetation setback distance or vegetation control measures	TBC, could be simply controlled via vegetation management
Landslip/slope instability		'NCC Slope Instability Overlay Report', Beca 2021	No	No	No (seismic stability of pond and BBD embankments outlined in EQ section)	NA

Notes * Refer to original work/referenced reports for limitations

Appendix B Tonkin + Taylor figures

DRAFT COASTAL INUNDATION AREA, 2050 RCP8.5 100 YEAR EVENT



DRAFT COASTAL INUNDATION AREA, PD 100 YEAR EVENT

DRAFT COASTAL INUNDATION AREA, 2080 RCP8.5 100 YEAR EVENT

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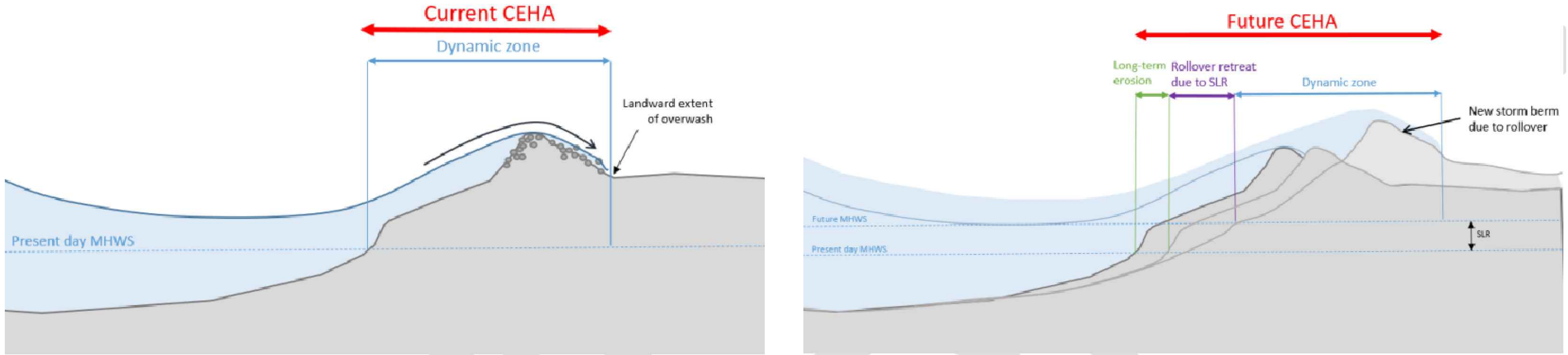
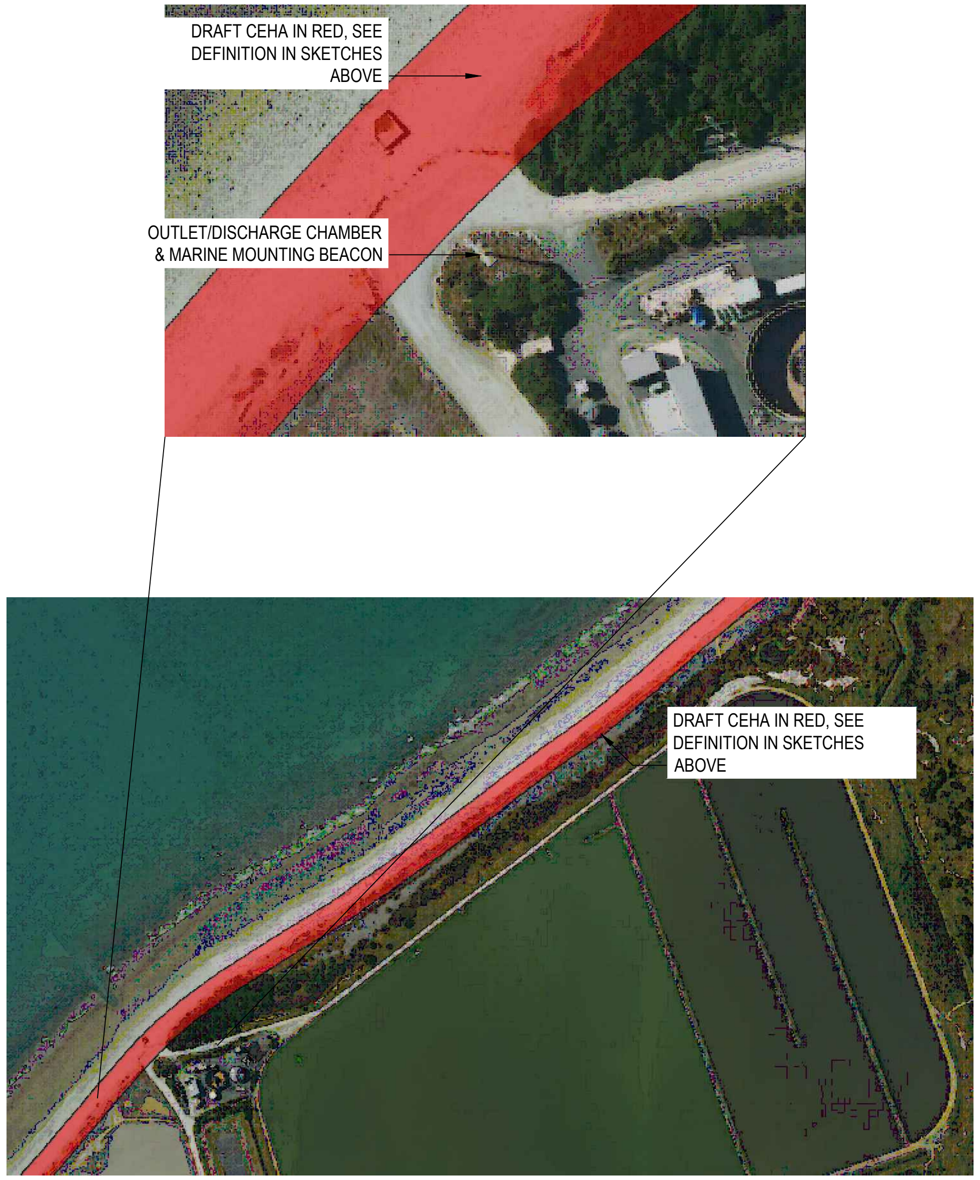
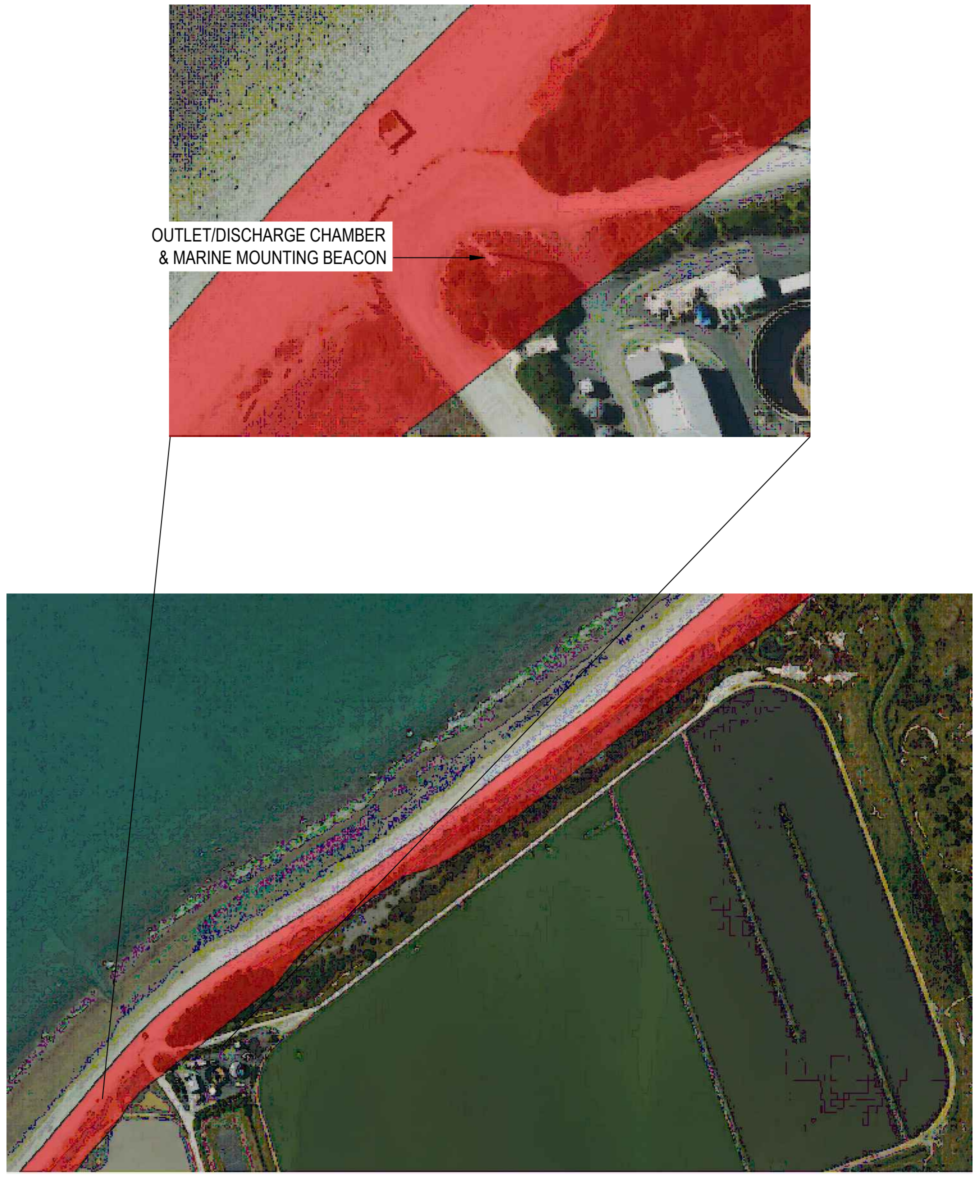
PROJECT WASTEWATER TREATMENT PLANT
TITLE DRAFT COASTAL INUNDATION AREA
SCALE (A3) NTS FIG No. 1006675.0900-WWTP-F10 REV 1



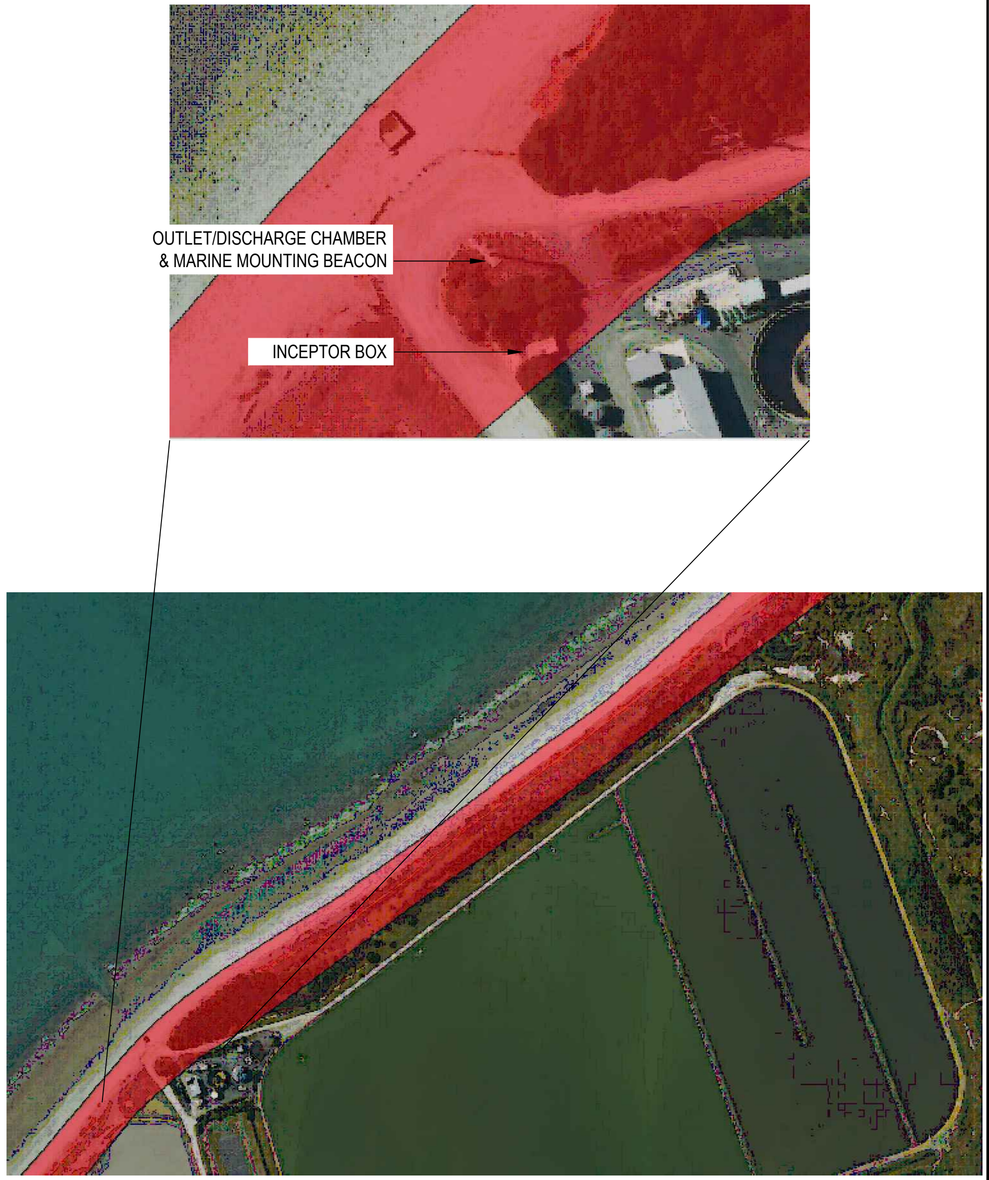
DEFINITION SKETCHES FOR DRAFT CEHA



DRAFT CEHA, PD, 5% AEP



DRAFT CEHA, 2050, SSP8.5, 5% AEP



DRAFT CEHA, 2080, SSP8.5, 5% AEP

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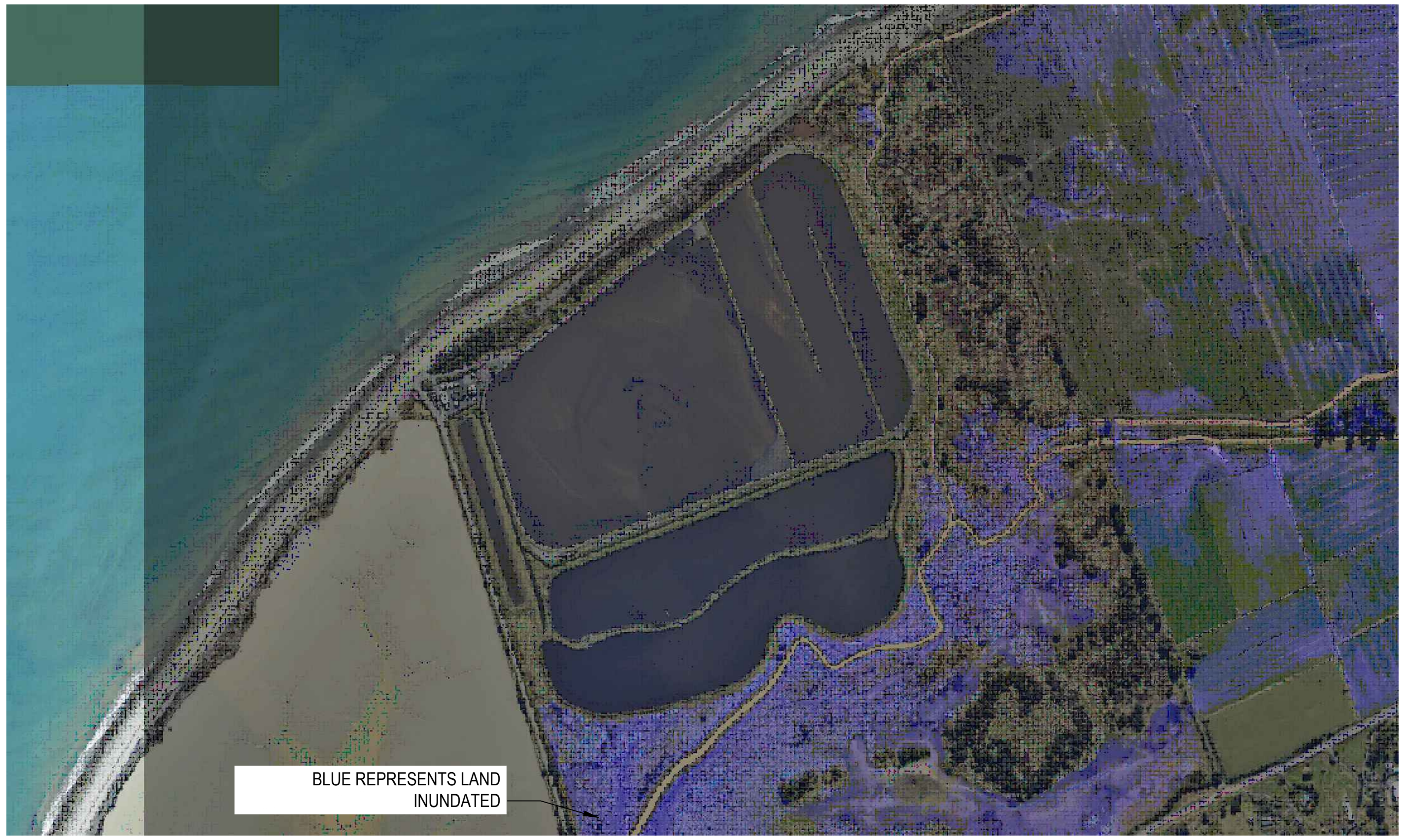
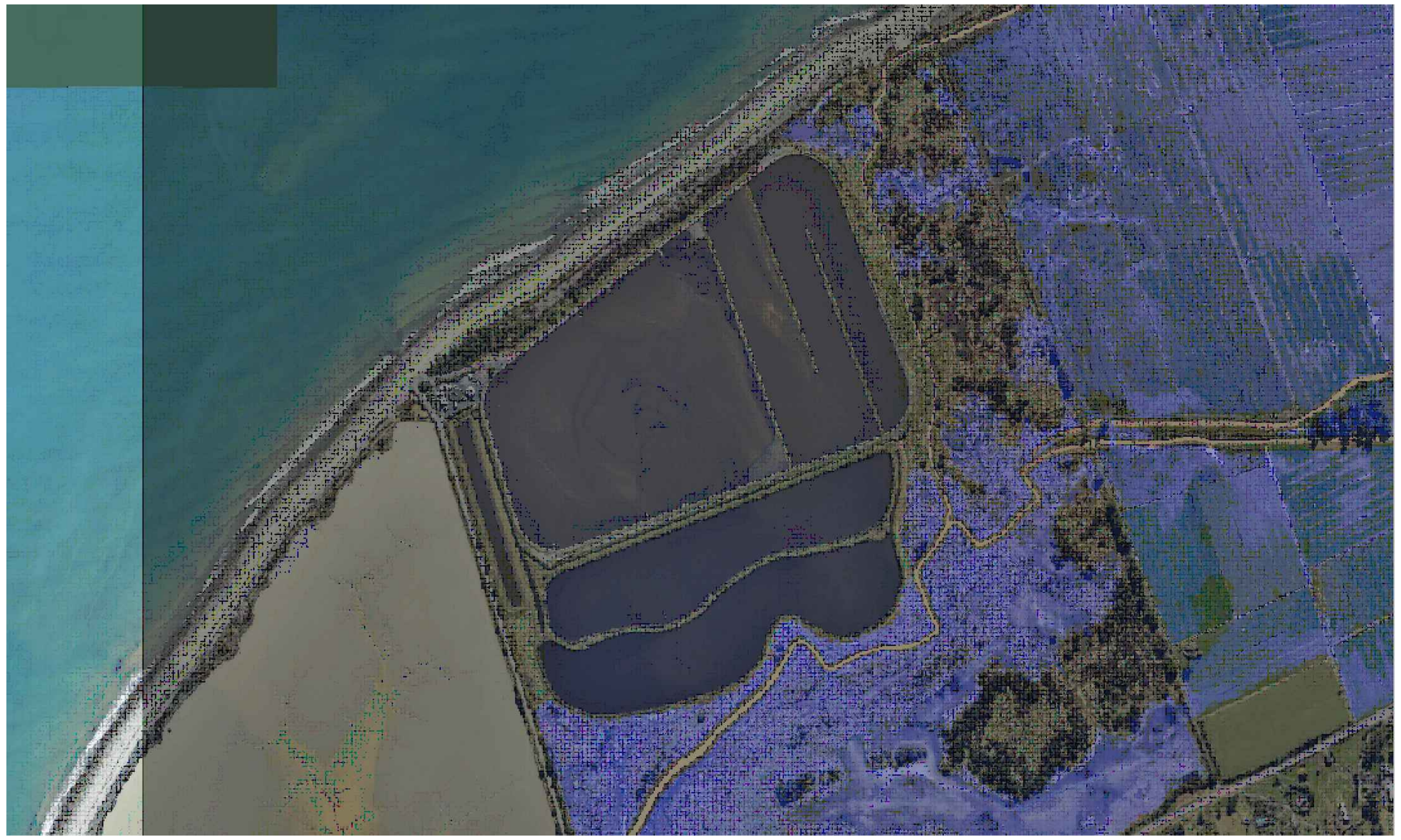
PROJECT **WASTEWATER TREATMENT PLANT**
TITLE DRAFT COASTAL EROSION HAZARD AREA (CEHA)
SCALE (A3) NTS FIG No. 1006675.0900-WWTP-F11 REV 1



RAINFALL FLOOD INUNDATION AREA, PD 100 YEAR EVENT



RAINFALL FLOOD INUNDATION AREA, 2070 RCP8.5 100 YEAR EVENT

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TITLE RAINFALL FLOOD INUNDATION AREA

SCALE (A3) NTS FIG No. 1006675.0900-WWTP-F12 REV 1

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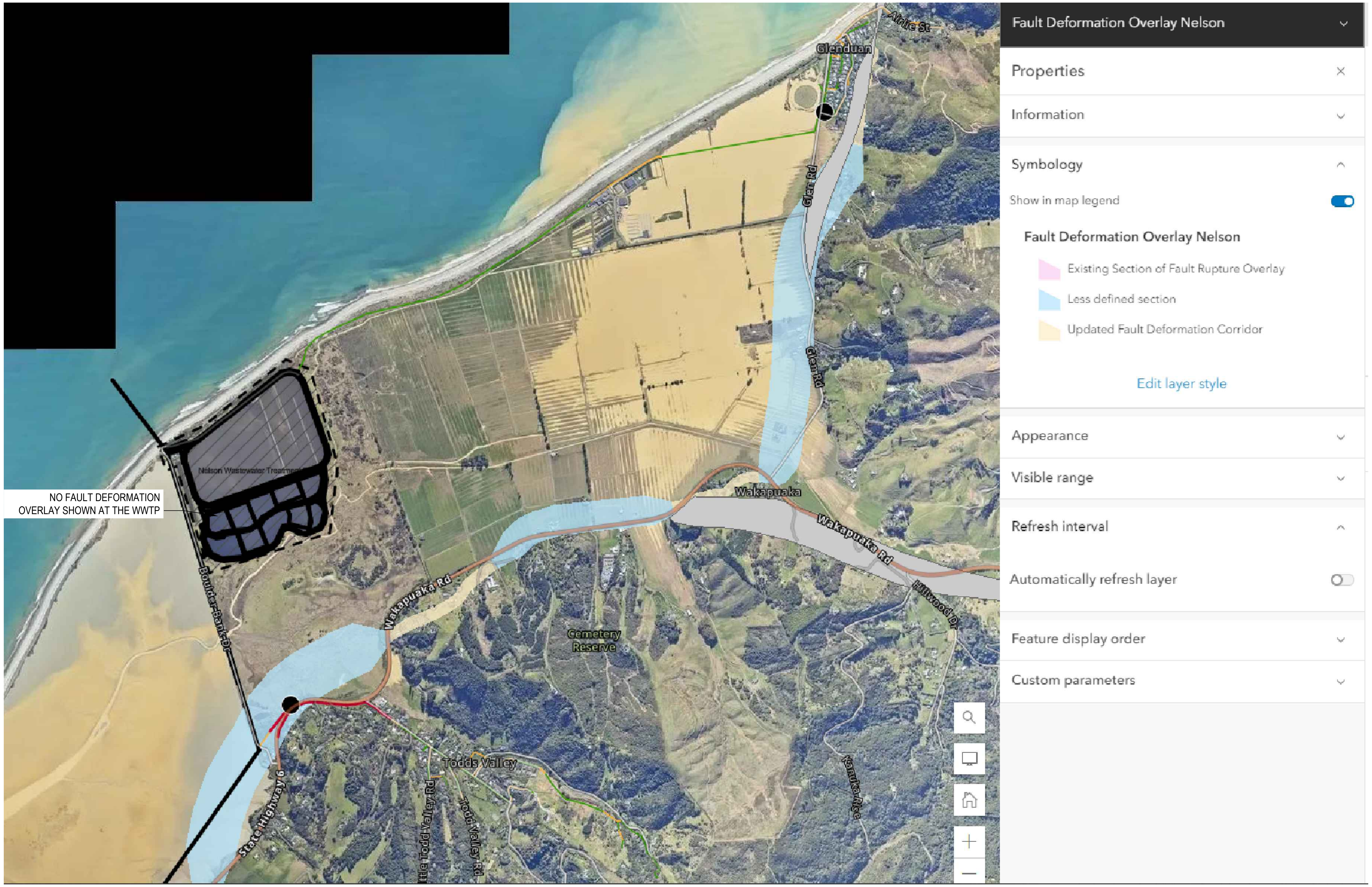

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CLIENT	NELSON CITY COUNCIL
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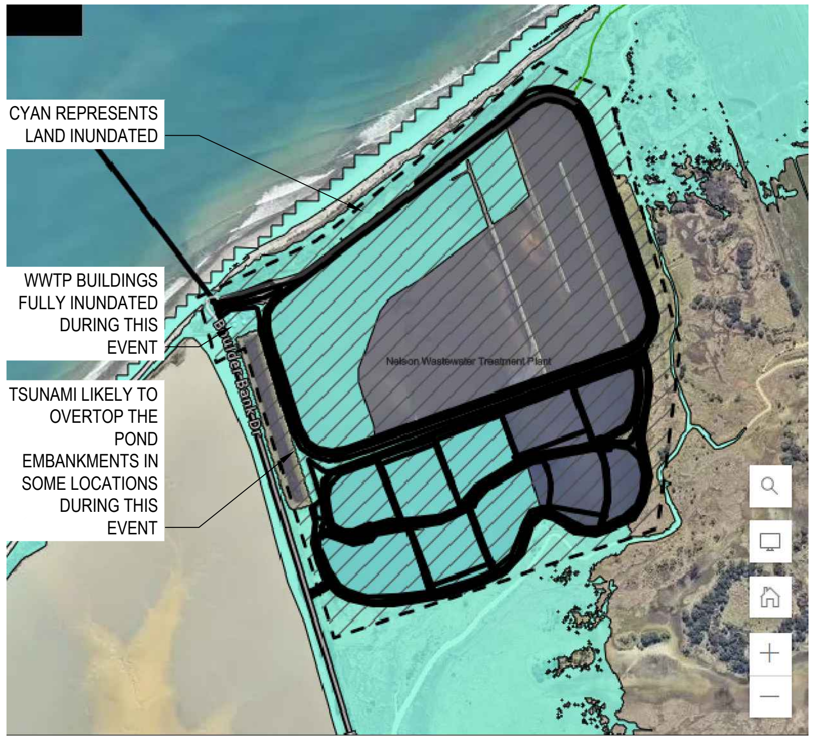
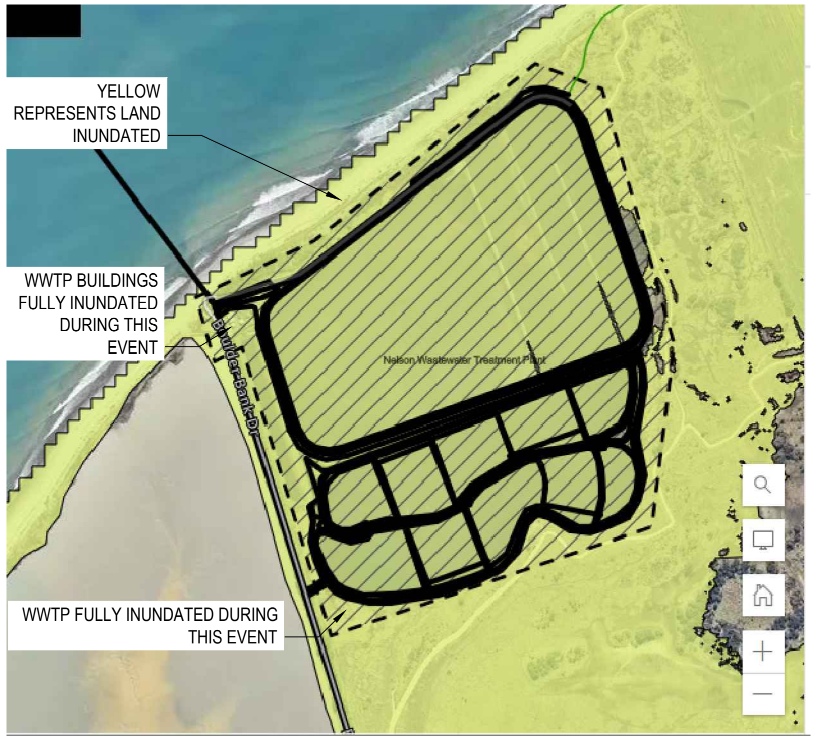
TITLE	FAULT DEFORMATION OVERLAY
SCALE (A3)	NTS
FIG No.	1006675.0900-WWTP-F13
REV	1

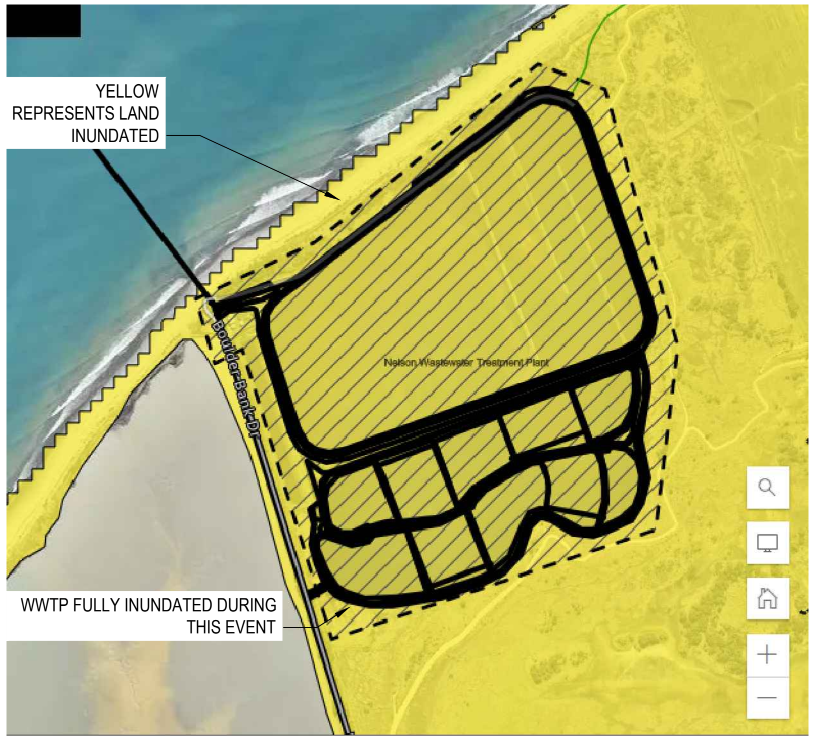


LEVEL 2 ASSESSMENT, 100 YR WAVE, MSL
CONDITIONAL AEP = 0.25%
12% PROBABILITY OF 1 OCCURRENCE IN A 50 YEAR TIME PERIOD

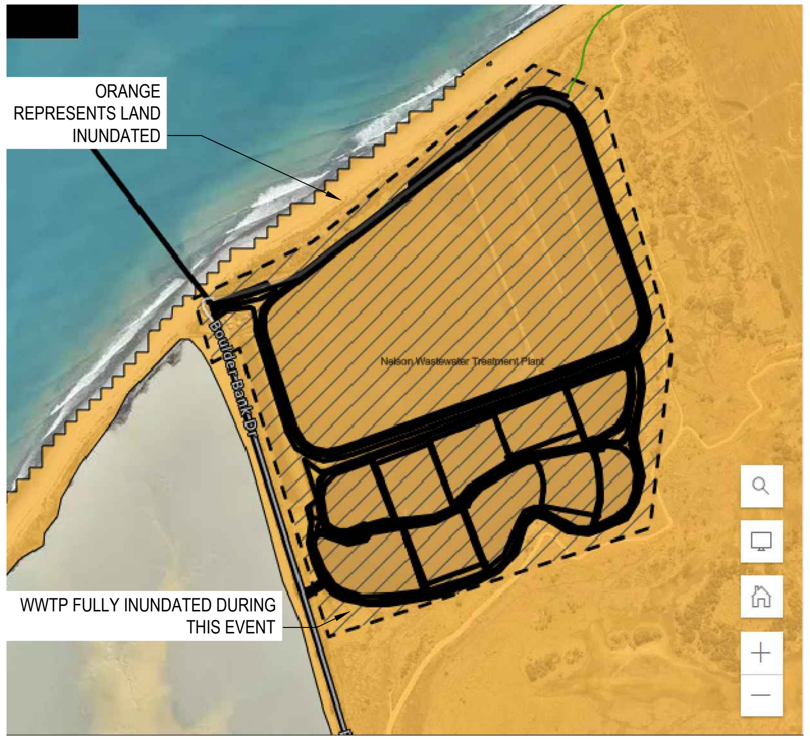


LEVEL 2 ASSESSMENT, 250 YR WAVE, MSL
CONDITIONAL AEP = 0.10%
5% PROBABILITY OF 1 OCCURRENCE IN A 50 YEAR TIME PERIOD

LEVEL 2 ASSESSMENT, 100 YR WAVE, MHWS
CONDITIONAL AEP = 0.10%
5% PROBABILITY OF 1 OCCURRENCE IN A 50 YEAR TIME PERIOD



LEVEL 2 ASSESSMENT, 250 YR WAVE, MHWS
CONDITIONAL AEP = 0.04%
2% PROBABILITY OF 1 OCCURRENCE IN A 50 YEAR TIME PERIOD



LEVEL 2 ASSESSMENT, 500 YR WAVE, MHWS
CONDITIONAL AEP = 0.02%
1% PROBABILITY OF 1 OCCURRENCE IN A 50 YEAR TIME PERIOD

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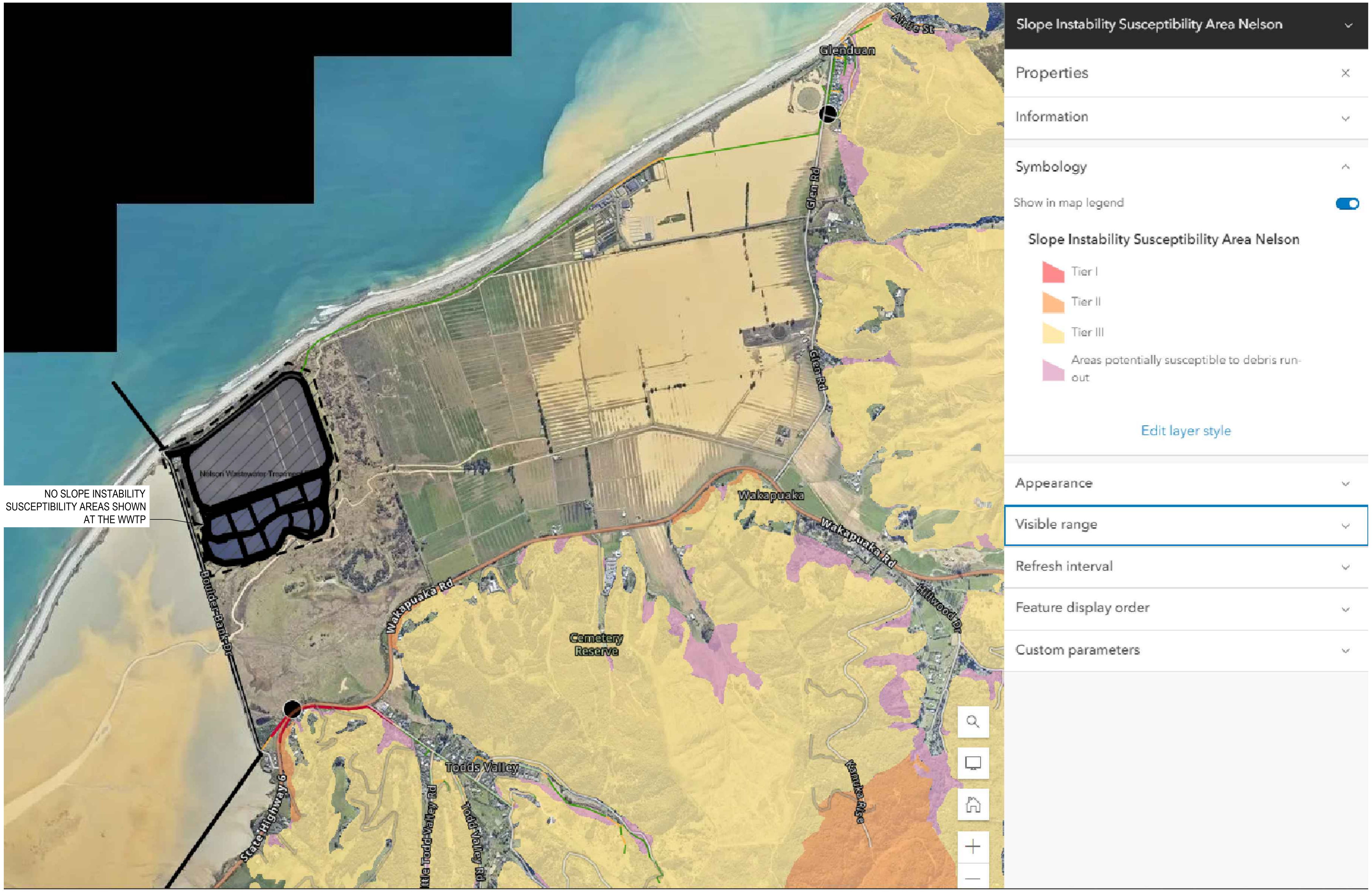
PROJECT	**WASTEWATER TREATMENT PLANT**
TITLE	TSUNAMI INUNDATION AREAS LEVEL 2 ASSESSMENT RESULTS
SCALE (A3)	NTS
FIG No.	1006675.0900-WWTP-F14
REV	1



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PROJECT WASTEWATER TREATMENT PLANT

TITLE SLOPE INSTABILITY SUSCEPTIBILITY AREA NELSON

SCALE (A3) NTS FIG No. 1006675.0900-WWTP-F15 REV 1

Appendix C References

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[xiii] Nelson Slope Instability Overlay Report, 9 December 2021, Beca, LOW-RES-NCC-Slope-Instability-Overlay-Report-final-versoin-signed-off-BECA-0522-A2886084.pdf (nelson.govt.nz)