Marsden Point Refinery: A Resource Consent Application to Renew 20 Resource Consents from the Northland Regional Council

Prepared for: ChanceryGreen on behalf of The New Zealand Refining Company Limited, trading as 'Refining NZ'

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FINAL DRAFT

ASSESSMENT OF ECOLOGICAL EFFECTS FOR AIR DISCHARGES FROM THE MARSDEN POINT OIL REFINERY

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ASSESSMENT OF ECOLOGICAL EFFECTS FOR AIR DISCHARGES FROM THE MARSDEN POINT OIL REFINERY

Contract Report No. 4977a

June 2020

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1. INTRODUCTION

Refining NZ own and operate the Marsden Point oil refinery. Operation of the plant requires various resource consents, which expire in 2022, and Refining NZ has decided to reapply in mid 2020. A 35-year term will be sought for the consents, including discharges to air, discharges to water, and discharges to land and groundwater.

Regular monitoring is required as part of existing resource consent conditions (AUT008319.01-06), to assess the effects of emissions authorised by the consent. The monitoring programme includes an assessment of the soil, vegetation, and lichens at Whangārei Heads. Photographic monitoring of lichens has occurred since 1976, with additional quantitative monitoring of lichens implemented in 1990. Monitoring of soil and vegetation has occurred since 2002. Wildland Consultants undertook the biannual ecological monitoring in 2016[1] and 2018[2].

Refining NZ has engaged various independent expert consultants to undertake technical assessments and prepare assessment of effects reports to support its application for resource consents, and requested that Wildland Consultants provide an assessment of the effects of the air discharges on terrestrial ecology. This report includes the following:

- Scope of report.
- Methods.
- Description of the existing environment.
- The re-consenting proposal and planning context.
- Assessment of effects on terrestrial ecology.
- Proposed monitoring regime for terrestrial ecology.
- Qualifications and experience of authors.

2. SCOPE OF REPORT

Ambient monitoring of sulphur dioxide (SO_2), nitrogen oxides (NO_X), and surface meteorology (winds, solar radiation, relative humidity, and temperature) is undertaken by Refining NZ. This report assesses the potential effects of SO_2 and NO_X discharges from Marsden Oil Refinery on terrestrial flora and fauna.

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1 Wildland Consultants 2017a: Quantitative monitoring study of lichens at Whangārei Heads, February 2017. *Wildland Consultants Ltd Contract Report No. 4230a*. Prepared for Refining NZ. 65 pp.
Wildland Consultants 2017b: Photographic monitoring of lichens at Whangārei Heads, February 2017. *Wildland Consultants Ltd Contract Report No. 4230b*. Prepared for Refining NZ. 29 pp.
Wildland Consultants 2017c: Quantitative monitoring study of soil and vegetation at Whangārei Heads, February 2017. *Wildland Consultants Ltd Contract Report No. 4230c*. Prepared for Refining NZ. 18 pp.

2 Wildland Consultants 2019a: Quantitative monitoring study of lichens at Whangārei Heads, December 2018. *Wildland Consultants Ltd Contract Report No. 4230d*. Prepared for Refining NZ. 66 pp.
Wildland Consultants 2019b: Photographic monitoring of lichens at Whangārei Heads, December 2018. *Wildland Consultants Ltd Contract Report No. 4230e*. Prepared for Refining NZ. 37 pp.
Wildland Consultants 2019c: Quantitative monitoring study of soil and vegetation at Whangārei Heads, December 2018. *Wildland Consultants Ltd Contract Report No. 4230f*. Prepared for Refining NZ. 23 pp.

The assessment of effects of the discharge on seabirds is outside the scope of this report, and is being addressed in the accompanying Coastal Bird Assessment[1].

3. METHODS USED FOR THE DESKTOP ASSESSMENT

3.1 Literature review

A literature review was undertaken with the purpose of identifying relevant information relating to the receiving environment of the air discharge, including the ecological context of the site. This literature review was identified as the first step in the ecological assessment of effects in order to determine what information could be obtained from existing studies and reports rather than undertaking a full large-scale field assessment in the potentially affected landscape around the Refinery.

Data was obtained on ecosystems, vegetation, flora (vascular and non-vascular), and fauna from the following sources:

- Terrestrial ecosystems and vegetation from the Manaia and Waipu Ecological Districts Protected Natural Areas Programme survey reports (Lux *et al*. 2007, Goldwater and Beadel 2010).
- Fish records in the local area using the New Zealand Freshwater Fish Database (NIWA 2019) and other sources.
- Lizard records for the local area, using the Department of Conservation herpetofauna distribution database.
- Bats and invertebrate records, including land snails, from the Department of Conservation Bioweb database.
- Flora records from the Auckland Museum herbarium and the Australasian Virtual Herbarium.

In addition, literature, including both national and overseas sources, was collated and reviewed to:

- Identify terrestrial taxa or taxonomic groups that may be present in the receiving environment and are likely to be sensitive to the effects of air pollution, particularly elevated levels of sulphur dioxide.
- Identify any published thresholds or critical loads[2] at which adverse effects on these taxa have been observed.

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1 Don G., Bioresearches Ltd: Refining NZ Re-consenting Application Coastal Bird Assessment. Bioresearches Ltd Contract Report 62434, Version 2, January 2020.

2 Ministry for the Environment 2000: Effects of air contaminants on ecosystems and recommended critical levels and critical loads. Prepared by Stevenson *et. al*. For the Ministry of the Environment's Review of the Ambient Air Quality Guidelines.

A review of the methods and results of the previous and current monitoring programme was also undertaken to determine whether the monitoring design is appropriate for the future intent as outlined in this report. Monitoring methods reviewed and critiqued included soil monitoring, vegetation monitoring, and lichen monitoring.

3.2 Determination of extent of assessment area

To determine the geographical extent of the terrestrial environment potentially affected by the proposed air discharges, modelling data from Tonkin and Taylor (2019) was utilised. The modelling data for the pollutants from the discharge included annual average of sulphur dioxide concentrations at ground level in micrograms per cubic metre (Figures 1a, 1b), annual sulphur deposition in kilograms per hectare per year (Figures 2a, 2b), annual average of nitrogen oxide concentrations at ground level in micrograms per cubic metre per year (Figures 3a, 3b), and annual nitrogen deposition in kilograms per hectare per year (Figures 4a, 4b). Modelling data was overlain on maps of Natural Areas in the Manaia (Goldwater and Beadel 2010) and Waipu (Lux *et al.* 2007) Ecological Districts.

In terms of the accuracy of the 0.5 $\mu g/m^3$ annual average contour-line for sulphur dioxide, as with any model it is a predictive tool that makes a simplification real world condition (atmospheric physics and chemistry in this instance) to predict ground level concentration. That said, Chilton (2019) explored the performance of the model and found that it is conservative, and generally over predicted actual concentration (Chilton 2019, Section 5.4.3).

This modelling is for the pollutants from the discharge, and to assess actual concentrations at a location, the discharge modelling needs to be summed with the ambient concentrations. Ambient concentrations are discussed further in Section 8.6.

This methodology resulted in changes in the extent of the receiving environment depending on the averaging period of the modelling data. For example, the annual average of 0.5 ug/m^3 for sulphur dioxide extends further north than the winter mean, and the winter mean extends further south in the Waipu Ecological District than the annual mean. The annual mean was used to define the boundaries of the receiving environment, as most of the literature pertaining to the effects of sulphur dioxide on ecosystems relates to annual averages (e.g. Mills *et al.* 2017). Defining the receiving environment in this way was also considered an acceptable proxy for the geographical extent of sulphur and nitrogen deposition, as the receiving environment for sulphur deposition (>1kg S/ha/yr) and nitrogen deposition (>0.1kg N/ha/yr) approximates or is smaller than the extent of the recieving environment of sulphur dioxide of 0.5 ug/m^3 or greater.

4. EXISTING ENVIRONMENT

4.1 Overview

For the purposes of this assessment, the existing environment is considered to incorporate all terrestrial ecosystems and ecosystem components in the surrounding landscape upon which the proposed activity might potentially affect (note that a conservatively 'generous' area has been evaluated). In keeping with legal advice provided to Refining NZ, this assessment has been undertaken as if the currently authorised discharge has been discontinued, and the current application is for a new activity (i.e. in simplistic terms, the Refinery is "turned off" today, and the effects assessment relates to "turning back on" the Refinery tomorrow). However, the assessment does consider legacy effects of past authorised discharges, including the current consent, as part of the state of the existing environment (Section 8.6).

Modelling data was utilised to determine the geographical extent of the terrestrial receiving environment, as outlined in Section 3.2. Based on the extent of air discharges of sulphur dioxide at an annual mean of 0.5 ug/m^3 or greater, the existing environment to be assessed includes approximately two-thirds of the Manaia Ecological District (southwards from Munro Bay and the northern end of Ocean Beach) and the northeastern parts of the Waipu Ecological District (from the Takahiwai Hills and Ruakaka Forest in the west, east to Marsden Point, and south to Ruakaka). This extent is shown in Figures 1-4.

By virtue of this extent, the receiving terrestrial environment for air discharges of sulphur dioxide, sulphur, and nitrogen, includes many natural areas that are of regional and local significance. This terrrestrial ecology of the existing environment is described below.

4.2 Vegetation and habitats within the terrestrial receiving environment of Manaia Ecological District

4.2.1 Overview

The following vegetation and habitat descriptions are extracts from the Manaia Ecological District Protected Natural Area Programme survey report (Goldwater and Beadel 2010).

This study recorded 155 ecological units in Manaia Ecological District, and these are listed in full in Table 6 of the Protected Natural Area Programme Report (Page 169), with representative units shown in bold. The following paragraphs describe the present-day vegetation patterns of Manaia Ecological District and highlight distinctive ecological units. Areas and habitats beyond the receiving environment of the discharge have been excluded.

4.2.2 Forests

Coastal forest is the most abundant indigenous habitat type in Manaia Ecological District, with four relatively large tracts of forest remaining: Manaia Ridge Scenic Reserve and surrounds (594 hectares), Taurikura Ridge Bush (212 hectares), Bream Head Scenic Reserve and surrounds (687 hectares) within the receiving environment, and Kauri Mountain Conservation Area and surrounds beyond the northern limit of the receiving environment (493 hectares). Most of the forest that occurs in Manaia Ecological District can be classed as coastal forest because of its close proximity to the sea.

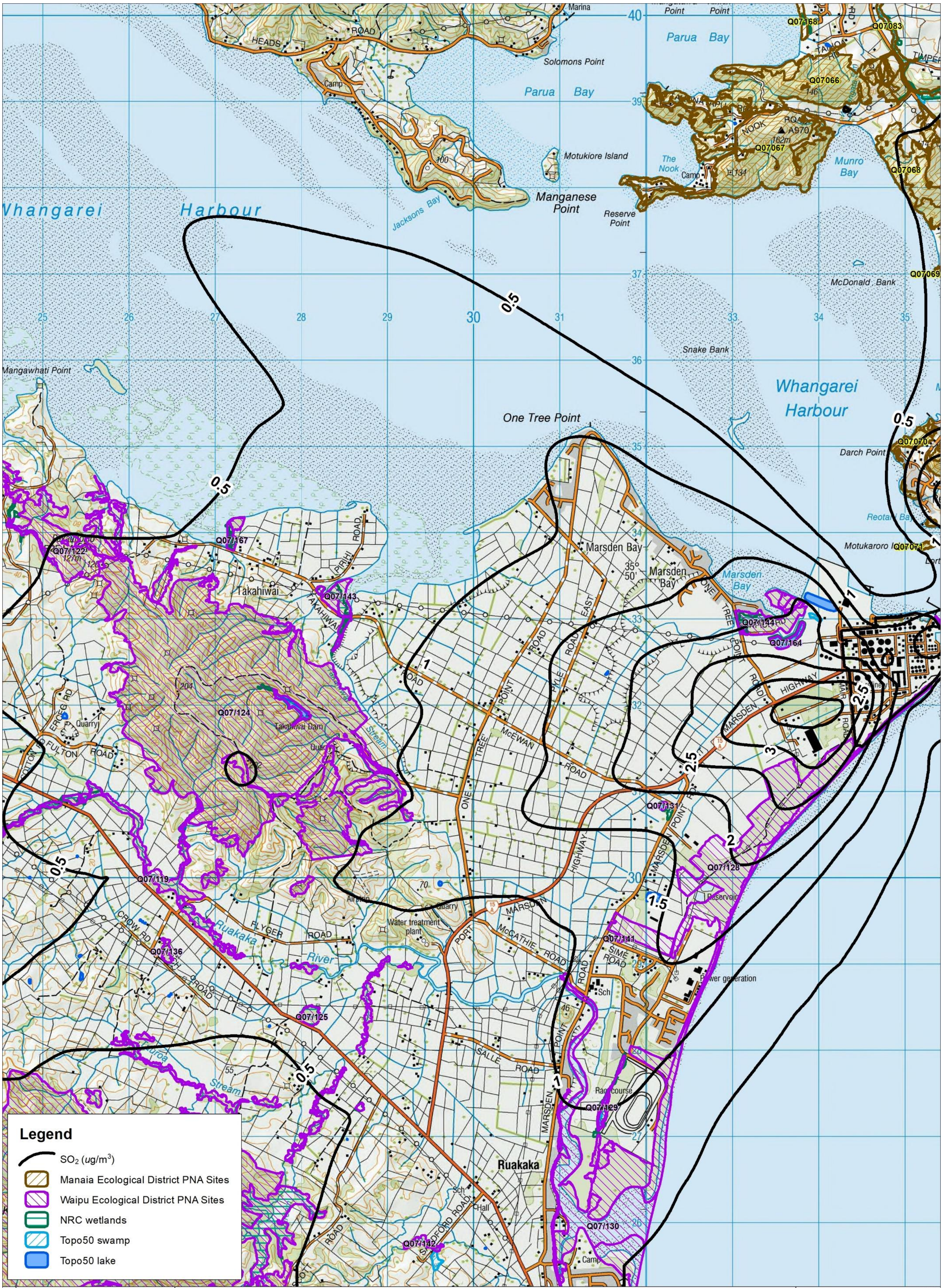

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Figure 1a: Predicted annual average SO_2 (ug/m^3) and natural areas of the Manaia and Waipu Ecological Districts within the receiving environment of the Marsden Oil Refinery air discharge

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Figure 1b: Predicted annual average SO_2 (ug/m^3) and natural areas of the Manaia and Waipu Ecological Districts within the receiving environment of the Marsden Oil Refinery air discharge

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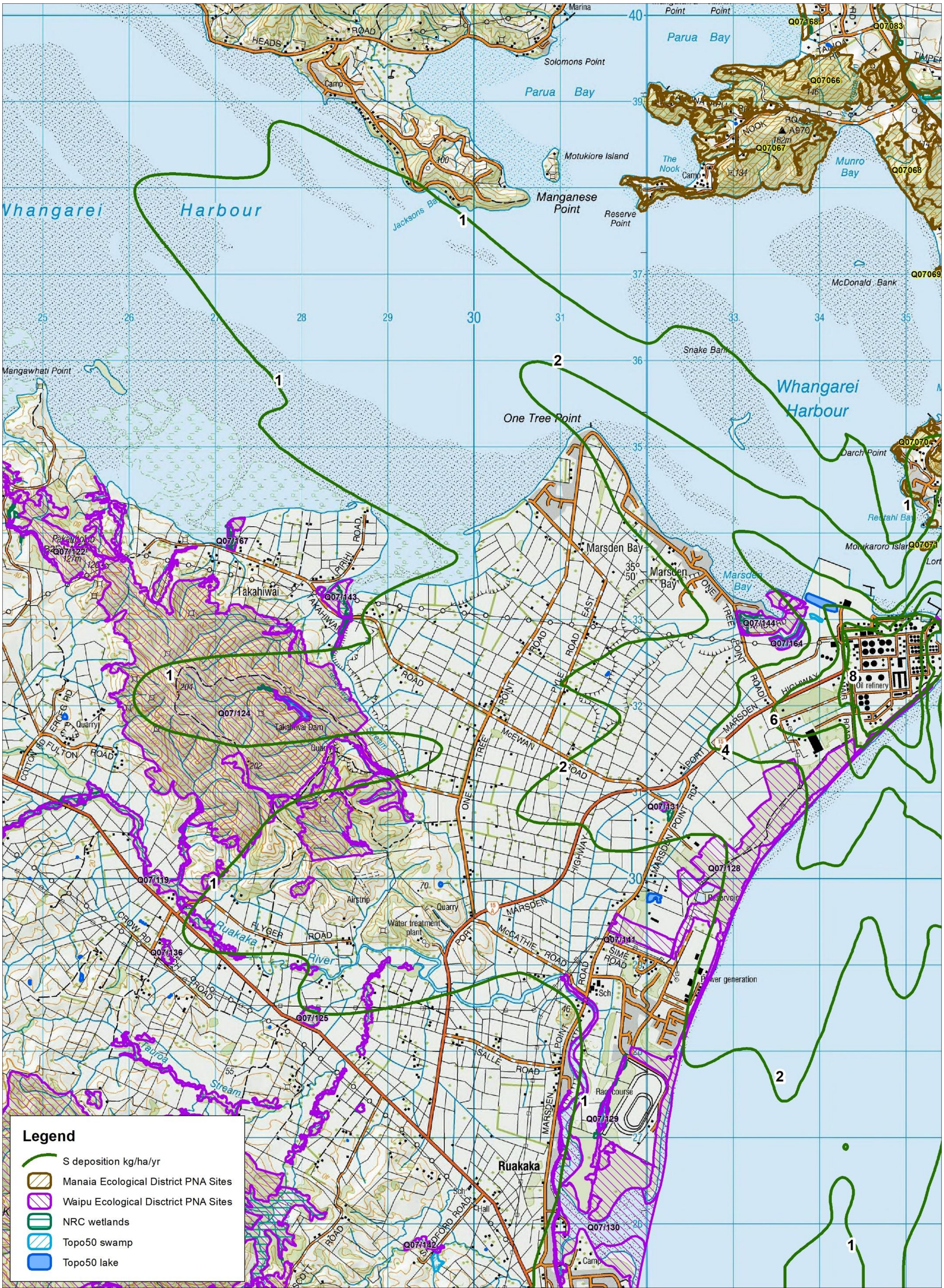

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Figure 2a: Sulphur deposition and natural areas of the Manaia and Waipu Ecological Districts within the receiving environment of the Marsden Oil Refinery air discharge

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Figure 2b: Sulphur deposition and natural areas of the Manaia and Waipu Ecological Districts within the receiving environment of the Marsden Oil Refinery air discharge

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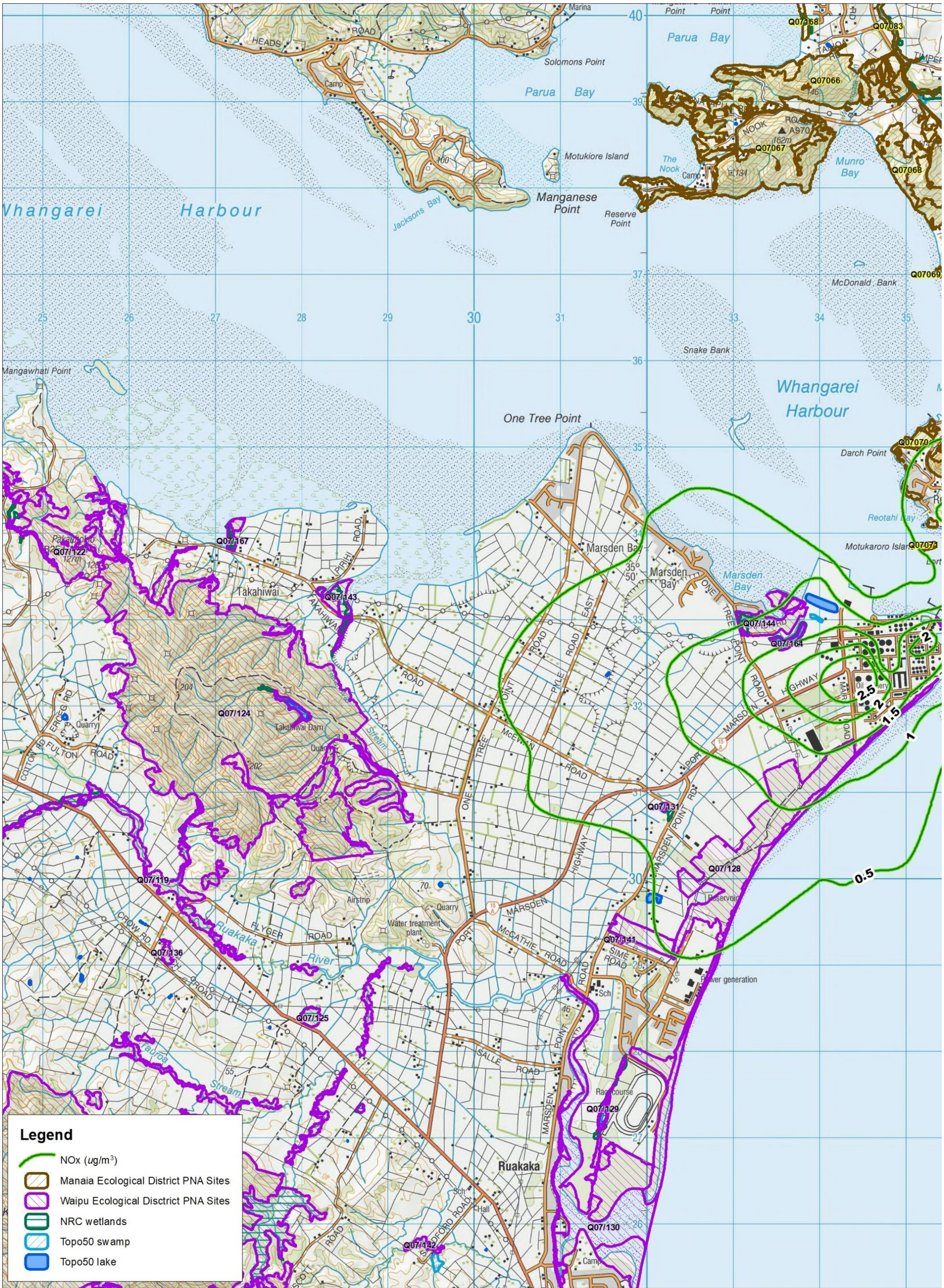

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3a 3b

Figure 3a: Predicted annual average NOx and natural areas of the Manaia and Waipu Ecological Districts within the receiving environment of the Marsden Oil Refinery air discharge

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3a 3b

Figure 3b: Predicted annual average NOx and natural areas of the Manaia and Waipu Ecological Districts within the receiving environment of the Marsden Oil Refinery air discharge

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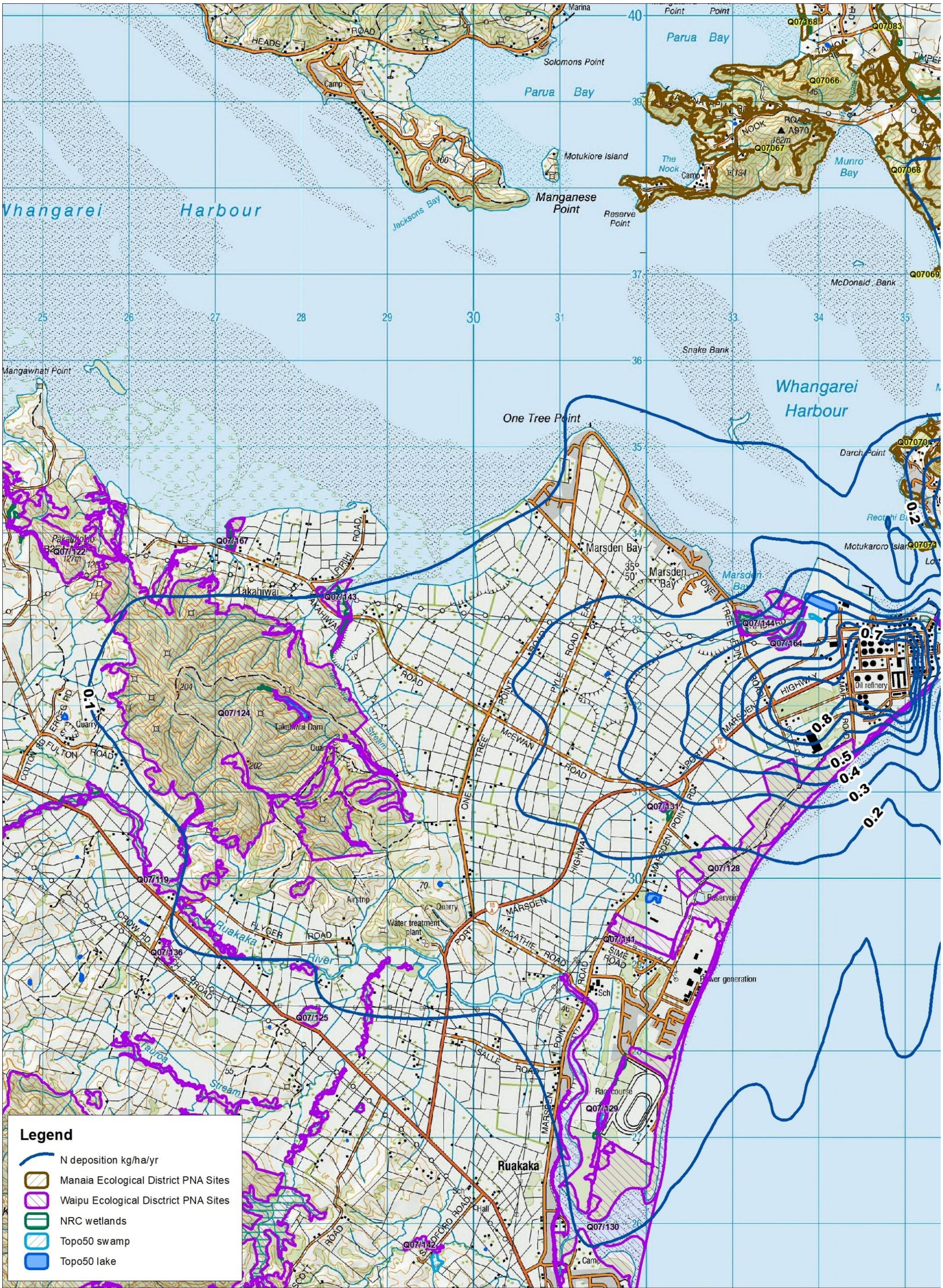

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File: Figure4_N.mxd

Figure 4a: Nitrogen deposition and natural areas of the Manaia and Waipu Ecological Districts within the receiving environment of the Marsden Oil Refinery air discharge

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4a 4b

Figure 4b: Nitrogen deposition and natural areas of the Manaia and Waipu Ecological Districts within the receiving environment of the Marsden Oil Refinery air discharge

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Broadleaved Forest

Coastal Forest

Dominant and co-dominant forest types include kōwhai, taraire, pūriri, mamaku, and pōhutukawa.

Kōwhai forest is present on steep hills at Bream Head Scenic Reserve and surrounds (Q07/074) with tī kōuka, karaka, rewarewa, kohekohe, nīkau, and māpou. Kōwhai is co-dominant with pōhutukawa, pūriri, and taraire at the same site, while at Taurikura Ridge Bush (Q07/073), kōwhai is co-dominant with pūriri, taraire, and rewarewa.

Taraire forest occurs on the south-facing slopes of Bream Head Scenic Reserve and surrounds (Q07/074), immediately above the coastal margin and in gullies. Pūriri, rewarewa, kōwhai, tī kōuka, tawa (including tawaroa), nīkau, and mamaku are associated species. Taraire is codominant with pūriri at Taurikura Ridge Bush (Q07/073), occurring with rewarewa, tī kōuka, karaka, and mamaku.

Pūriri is another common canopy species in coastal forest associations, occurring in steep gullies at Taurikura Ridge Bush (Q07/073) and Bream Head Scenic Reserve and surrounds (Q07/074), and on steep hillslopes at Manaia Ridge Scenic Reserve and surrounds (Q07/069). Pūriri is codominant with kānuka, taraire, and tōtara.

Mamaku forest is common at Manaia Ridge Scenic Reserve and surrounds (Q07/069), where it occupies recently disturbed areas. It is co-dominant with kauri, nīkau, pōhutukawa, tōtara, and rewarewa.

Pōhutukawa is a feature of the coastal cliffs along the southern shoreline of Bream Head Scenic Reserve and surrounds (Q07/074), and cliffs and scarps at the northern end of Ocean Beach Recreation Reserve and surrounds (Q07/075). On cliff faces and scarps, the canopy is usually fragmented with pōhutukawa occurring over harakeke, *Astelia banksii*, taupata, knobby clubrush, houpara, rengarenga lily, coastal toetoe, pōhuehue, grasses, and herbaceous plants such remuremu, makaokao, *Lobelia anceps*, and glasswort. In areas of forested hillslope, pōhutukawa is co-dominant with a range of species, including pūriri, taraire, tōtara, pūriri, and tawa.

Other Broadleaved Forest Types

Forest types that are likely to be beyond the immediate influence of coastal conditions are restricted to Timperly Road Bush (Q07/077), and Kauri Mountain Conservation Area and surrounds (Q07/078), =which lie beyond the northern limit of the receiving environment. Kānuka/mānuka is co-dominant with kauri, kōhūhū, pūriri, tōtara, tānekaha, and tōwai at Q07/078, while mamaku treefernland (included as a forest type) occurs at Q07/077. Tōtara, tōwai, kānuka, mānuka, kahikatea, tī kōuka, gorse, and pampas are associate species.

Kauri Forest

Kauri forest has been recorded from the receiving environment at Manaia Ridge Scenic Reserve and surrounds (Q07/069), and Bream Head Scenic Reserve and surrounds (Q07/074), although it also occurs in other parts of Manaia Ecological District which have not been fully surveyed. Kauri forest occupies ridges, steep slopes, and the tops of bluffs, where it commonly occurs with species such as tōtara, tānekaha, rewarewa, kānuka, and māmāngi.

4.2.3 Shrublands

Mānuka and kānuka shrublands comprise the second largest indigenous vegetation type (after coastal forest) in Manaia Ecological District. These shrublands provide important linkages between other habitats and buffering for large tracts of indigenous forest. Shrublands often contain high biodiversity values and provide important habitat for threatened and uncommon fauna and flora.

Kānuka or Mānuka Shrubland

Much of this shrubland type has formed on areas formerly covered in mixed forest, which were cleared by early human settlers. Kānuka/mānuka shrubland occurs in all of the larger mainland sites in Manaia Ecological District. Commonly associated species include pōhutukawa, pūriri, kauri, tōtara, rewarewa, kōwhai, tī kōuka, mamaku, mingimingi, gorse, and woolly nightshade.

Taupata Shrubland

On Mauitaha Island (part of Q07/080), at the eastern limit of the receiving environment, taupata shrubland occurs with harakeke, coastal mahoe, and emergent pōhutukawa. Taupata is codominant with kikuyu on Tarakanahi Island (part of Q07/079), and forms taupata-native iceplant rockland on Awaroa Island (Q07/170), which lies a short distance offshore at the northern end of Ocean Beach

Harakeke Flaxland

On Guano Island (part of Q07/080), also at the eastern limit of the receiving environment, harakeke flaxland occurs with taupata, *Cyperus ustulatus*, indigenous iceplant, *Crassula sieberiana*, and shore groundsel. On Moturaka Island (part of Q07/089), harakeke is present with *Cyperus ustulatus*, taupata, pōhuehue, *Baumea juncea*, knobby clubrush, *Asplenium haurakiense*, and *A. northlandicum*.

4.2.4 Estuarine wetlands

Two areas of saltmarsh occur in the Manaia Ecological District. Saltmarsh dominated by sea rush occurs near the creek at the northern end of Ocean Beach Recreation Reserve and surrounds (Q07/075).and, beyond the northern limit of the receiving environment, mangroves occur in Kiteone Road Saltmarsh (Q07/168), southeast of Parua Bay.

4.2.5 Freshwater wetlands

Fertile Wetlands

Fertile wetlands (or swamps) are fed by nutrient-rich ground and surface water, as well as rainwater. Their water levels vary seasonally and they are often flooded by water loaded with silt and nutrient when river or lake levels are high. In Manaia Ecological District, raupō reedland and associations of *Machaerina* species, harakeke, and *Bolboschoenus fluviatilis* are the most common ecological units within fertile wetlands. A representative example of harakeke flaxland in swamp is present in Whangārei Heads Road Wetland (Q07/083) within the receiving environment. This habitat type is particularly rare in Northland.

Gumland

Gumland is a very uncommon wetland type in Manaia Ecological District and throughout Northland; there is only one known site in the Ecological District. Gumlands are typically dominated by mānuka occurring on strongly leached, podzolised, infertile soils where drainage is impeded. Seasonally these areas become waterlogged in winter and are very dry in summer (Lux *et al.* 2009). Pure mānuka stands on gumland are found at one site in Manaia Ecological District: McDonald Coastal Shrubland (Q07/068). This site straddles the northern limit of the receiving environment. Associated species include *Gleichenia microphylla*, *Sticherus flabellatus*, *Dracophyllum lessonianum*, *Drosera auriculata*, *Baumea teretifolia*, *Schoenus tendo*, *S. brevifolius*, *Lepidosperma laterale*, *L. australe*, *Lycopodiella cernua*, *Microtis unifolia* agg., *Orthoceras novae-zeelandiae*, *Pterostylis graminea*, *Singularybas oblongus*, *Thelymitra carnea*, *Thelymitra longifolia*, and prickly hakea.

4.2.6 Rocklands

Rockland occurs mainly on the exposed coastal margins of Bream Head Scenic Reserve and surrounds (Q07/074), islands and rock stacks, and, beyond the northern limit of the receiving environment, at Kauri Mountain Conservation Area and surrounds (Q07/078). Exposed rocky outcrops and rock stacks are present within the receiving environment at Manaia Ridge Scenic Reserve and surrounds (Q07/069), Mt Aubrey Coastal Forest and Shrubland (Q07/070), and Bream Head Scenic Reserve and surrounds (Q07/074). Rockland vegetation is dominated by salt-resistant herbs such as native iceplant, glasswort, makaokao, remuremu, NZ celery, NZ spinach, Mercury Bay weed, shore groundsel, and *Pseudognaphalium luteoalbum*. Woody species such as pōhutukawa, karo, and taupata occur on Peach Rock Stack A and B (Q07/173 and Q07/174).

4.2.7 Dunelands

Dunelands in Manaia Ecological District are restricted to Smugglers Bay in Bream Head Scenic Reserve and surrounds (Q07/074) and Ocean Beach Recreation Reserve and surrounds (Q07/075), the latter of which is approximately 6.5 kilometres in length and comprises most of the eastern boundary of the ecological district. The dunelands are relatively small and narrow, but support a distinctive plant and animal community and provide habitat for many threatened species. The dunes are typical in being shaped and reshaped by erosion and deposition of sand brought about by wind and sometimes water movement (Wildland Consultants 2002).

- Dunes which are largely unvegetated may have sparse or frequent spinifex, while pīngao, tauhinu, shore bindweed, *Zoysia pauciflora*, knobby clubrush, and Pimelea villosa subsp. villosa, lupin, catsear, and purple groundsel are scattered throughout.

- Where foredunes are vegetated, spinifex is generally dominant, with occasional tauhinu, pīngao, *Pimelea villosa* subsp. *villosa*, knobby clubrush, shore bindweed, pōhuehue, lupin, purple groundsel, and marram grass.

- On back dunes, clumps of knobby clubrush are frequent. An interesting feature of this habitat type is the presence of the threatened Northland kānuka (*Kunzea linearis*), which occurs in discrete patches in the mid to northern part of the site. Flax and coastal toetoe are locally frequent, while *Coprosma macrocarpa* and karo are scattered throughout. Pampas, smilax, moth plant, and gorse are invading this part of the site.

- On consolidated dunes situated between the back dunes and farmland, pōhuehue and kikuyu grow in dense swards. Large patches of gorse are frequent, while lupin and apple of Sodom, and clumps of harakeke and knobby clubrush, are scattered throughout. The regionally significant fireweed *Senecio biserratus* occurs rarely. Where dunes have been heavily modified by stock, kikuyu, lotus, and buffalo grass are locally dominant.

- Saltwater paspalum is locally common along the shallow estuarine margins of the creek at the northern end of Ocean Beach Recreation Reserve and surrounds. It also occurs in occasional clumps in dune hollows

4.3 Vegetation and habitats within the receiving environment of Waipu Ecological District

4.3.1 Overview

The following vegetation and habitat descriptions are extracts from the Waipu Ecological District Protected Natural Area Programme survey report (Lux *et al.* 2007).

This study recorded 249 ecological units in Waipu Ecological District, and these are listed in full in Table 2 of the Protected Natural Area Programme Report (Page 266), with representative units shown in bold. The following paragraphs describe the present-day vegetation patterns of Waipu Ecological District and highlight distinctive ecological units. Areas and habitats beyond the receiving environment of the discharge have been excluded.

For the purpose of evaluation of representativeness and description, 'coastal' ecological units are those units which occur less than one kilometre from the coast, whereas 'inland' ecological units occur one kilometre or more from the coast. However, it must be acknowledged that this is an arbitrary division. Some 'inland' ecological units will also have some coastal influence, because of the narrowness of the Northland peninsula, and the fact that all areas within the Ecological District are within 16 kilometres of the coast.

4.3.2 Freshwater wetlands

Freshwater wetlands were documented at 24 sites within Waipu Ecological District covering a total of 116 hectares. It is considered that 16 of these are natural or semi-natural in origin, covering approximately 45 hectares. Constructed wetlands were included because they either support indigenous vegetation or provide habitat to indigenous fauna. Prior to agricultural clearance, riverine and palustrine wetlands are likely to have been relatively extensive on the *c*.7,000 hectares of alluvial plains and *c*.2,000 hectares of coastal duneland in Waipu Ecological District. It is estimated that in the whole of Northland only about 5% of the original freshwater wetlands (including lakes) remain, which is lower than the national estimate of 10% of freshwater wetlands remaining (Conning 2001).

Raupō reedland is the most common wetland vegetation type, and tends to be associated with valley floor alluvium (especially gullies in farmland), but also occurs around the margins of a dune lake margin and in a small dune slack. The presence of raupō is an indicator of moderate to high nutrient status and run-off often contributes to this in the Waipu Ecological District.

Coastal Freshwater Wetlands

Within the coastal zone there are only five ‘natural origin’ wetlands, each with a quite different character. Three of these occur within the receiving environment. McEwan Road (Q07/131) and Sime Road (Q07/141) Wetlands, within the receiving environment, are the two smallest; being tiny dune slack wetlands barely over half a hectare. The former has an island of mānuka shrubland at its centre surrounded by *Azolla filiculoides*-burr reed herbfield and *Eleocharis sphacelata* reedland; while latter is dominated by *Eleocharis sphacelata* reedland and *Machaerina articulata* reedland. The third natural wetland within the receiving environment is the only dune lake in the whole Eastern Northland Ecological Region. Ruakaka Racecourse Dune Lake (Q08/129) is mostly open water but has raupō and lake clubrush reedlands around the margins, all of which are infested with alligator weed.

Beyond the extent of the receiving environment, Doctor’s Hill Road Wetland (Q07/127) is by far the largest in the coastal zone (17.6 hectares of wetland habitat), filling a gully draining into Ruakaka River Estuary (Q07/130). Its main vegetation types are reed sweetgrass grassland (exotic) and raupō reedland, with small areas of *Machaerina articulata* reedland and bracken fernland.

Together with the two large constructed wetlands in the northern/central coastal dunelands of Waipu Ecological District (Northland Port Corporation Ponds Q07/164 and Semenoff Sand Supplies Ltd ponds Q07/128), these sites form an important wetland bird habitat network for species such as Australasian bittern. Small areas of marsh clubrush sedgeland also occur at the edges of some estuaries in freshwater seepages.

4.3.3 Estuarine vegetation and habitats

Estuarine vegetation occurs at five sites in Waipu Ecological District, as follows: two large river mouth estuaries on Bream Bay (Waipu River Estuary and Sandspit Q08/228 and Ruakaka River Estuary Q07/130), two small stream mouth estuaries on the southern margin of Whangārei Harbour (Blacksmith's Creek Estuary Q07/144 and Takahiwai Stream Estuary Q07/143)*[1], and another small site on the harbour margin (Takahiwai Saltmarsh and Shrubland Q07/167). Except for Waipu River Estuary and Sandspit, these sites are within the receiving environment of the air discharge.

Two vegetation types common to the four largest estuaries are mangrove shrubland and different combinations of oioi and sea rush (e.g. a mosaic of sea rush rushland and oioi rushland, or a more blended sea rush-oioi rushland type). Mangrove forest only occurs in upper reaches of the larger two estuaries of Waipu and Ruakaka, and even then, these are tiny stands compared with those present in other Northland estuaries.

Another widespread vegetation type is glasswort herbfield, which often occurs on upper tidal sandy substrates or shellbanks, or on the edges of sandy estuarine channels Glasswort may also occur in association with mangrove seedlings and pneumatophores, although it does not tolerate a lot of estuarine mud. The Waipu and Ruakaka estuariesare considered 'sandy estuaries' in terms of bird habitat (Richard Parrish, Department of Conservation, pers. comm.), and this is also reflected in the vegetation types present.

Ruakaka River Estuary has a few distinctive vegetation types including small areas of pure saltmarsh ribbonwood shrubland, *Austrostipa stipoides* tussockland, and some mānuka shrubland and gorse scrub perched on an estuarine island. Takahiwai Stream Estuary is perhaps the least disturbed estuarine system in Waipu Ecological District due to its relative remoteness from urban areas, but is relatively small. Blacksmith's Creek Estuary and Takahiwai Saltmarsh and Shrubland are more modified than the other three sites, the latter having been subject to widespread construction of drains.

4.3.4 Duneland vegetation and habitats

Waipu Ecological District has extensive Holocene and Pleistocene dunelands covering the wide sweep of Bream Bay from One Tree Point and Marsden Point in the north to Waipu Cove in the south, and extending inland for several kilometres. Wild duneland vegetation has been reduced to a strip that runs parallel to the beach. The strip can be as narrow as one metre (for example in front of beachfront buildings at Waipu Cove), or up to 800 metres wide (in the Ruakaka Conservation Area). Modifications which have restricted the duneland vegetation include roading, clearance for farming, grazing, industrial establishments, a power station, a golf course, a race course, a refuse station and landfill, campgrounds, recreational buildings, parkland, and residential housing. The majority of Waipu Ecological District dunelands are now dominated by exotic plant cover, although a moderate diversity of indigenous species and vegetation types remains.

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[1] Note that only these small parts of Whangarei Harbour are within Waipu Ecological District.

For this study the dunelands of Waipu Ecological District were divided into two major sites: Ruakaka Dunelands (Q07/128 - from Marsden Point to the northern side of the Waipu River) and, beyond the receiving environment, the Waipu River Estuary and Sandspit (Q08/228 - from Waipu River Estuary to the southern end of Waipu Cove)[1]. The Ruakaka Dunelands are characterised by large areas of exotic gorse-pampas scrub on the backdunes, with scattered patches of bare sand, *Kunzea linearis* forest (a species of kānuka specific to coastal sandy soils), harakeke-gorse shrubland, radiata pine forest, maritime pine treeland, brush wattle-Chinese privet-māpou scrub, tree privet-Chinese privet scrub and several other smaller exotic vegetation types. The main vegetation types on the foredunes within this site are spinifex grassland, pōhuehue shrubland, pōhuehue-*Coprosma acerosa* shrubland, knobby clubrush-pōhuehue sedgeland, sweet vernal-harestail grassland, and harestail-gazania-marram grassland, all harbouring many exotic species. *Coprosma acerosa* is present at one site but was probably previously much more widespread in Waipu Ecological District (Lisa Forester, NRC, pers. comm.). The Ruakaka Dunelands have scattered remnants of the previously more common pingao sedgeland. Old records of *Pimelea arenaria* (1899) and hinarepe (sand tussock; *Poa billardierei*) (1973) at Ruakaka show that these species and their types were once present, however they have now almost completely disappeared from Waipu Ecological District sand dunes.

Some planting of indigenous species has occurred in recent times along Waipu Ecological District coast, probably with a view to restoring dune vegetation. This includes planting of locally sourced indigenous dune species within the Refinery site. Species recorded in plantings include pīngao, spinifex, hinarepe, toetoe, and *Carex testacea*. Planting appears to be quite limited in extent, although this can be difficult to determine over time if locally sourced species are used and natural ecological patterns are followed.

4.3.5 Alluvial landform vegetation

The area of indigenous vegetation on alluvial flats and gullies remaining in Waipu Ecological District is approximately 360 hectares, occurring within 28 different sites. These sites usually comprise several separate remnants. Alluvial flats are the most productive land and would have been the first to be cleared and maintained as farmland.

Coastal Alluvium Vegetation

The only indigenous vegetation recorded on coastal alluvium is kānuka shrubland adjacent to Takahiwai Stream Estuary (Q07/143) and at Blacksmith’s Creek Estuary (Q07/144), and a patch of mānuka-harakeke shrubland in the latter. All of the alluvial flats next to Ruakaka River Estuary (Q07/130) are devoid of indigenous vegetation.

Inland Alluvium Vegetation

The most common vegetation types present on broad alluvial river plains adjoining the coastal dunelands (Holocene and Late Pleistocene alluvium and/or estuarine deposits) are mixtures of secondary tōtara, kahikatea, and kānuka, as in the following: kahikatea

[1] Beyond the extent of the receiving environment, and not discussed further.

forest and treeland, kahikatea-tōtara forest and treeland, tōtara forest and treeland, tōtara-kānuka forest, kānuka-kahikatea forest, and tōtara-kahikatea forest. There is no mature forest remaining on alluvial flats. Tōtara and kahikatea are hardy podocarp species which are resistant to trampling and grazing, hence their dominance within grazed riparian forests and treelands along rivers in the Waipu Ecological District lowlands. Previously species such as taraire, tītoki, kōwhai, mānatu, pūriri, turepo, tī kōuka, karaka, māpou, matai, houhere, and pukatea would have formed a greater part of the normal canopy diversity of alluvial plain forests. At present, there are only very tiny remnants of the following habitat types which approximate the former vegetation (though in much poorer condition): taraire forest, tītoki-kōwhai-tōtara forest, tītoki-tōtara forest, pūriri-tōtara treeland, tōtara-taraire-kānuka treeland, kahikatea-pūriri treeland, and kōwhai-kahikatea forest.

Within small pockets of Holocene alluvium in smaller streams the main vegetation types are heavily dominated by kahikatea and nīkau, such as in kahikatea-nīkau forest in Q07/113, nīkau forest in Q08/222, and kahikatea forest in Q08/220 and Q07/147. There are occasional mature trees (especially kahikatea and tōtara) in these alluvial pockets within larger forest tracts.

4.3.6 Hill vegetation

Most terrain in Waipu Ecological District is hilly, and hill country is where most indigenous vegetation remains or has been allowed to regenerate since logging and burn-offs in the 1800s and 1900s. The series of east-west trending moderately dissected ranges still supporting large forest remnants begins with Takahiwai Forest (Q08/124) in the north and continues southwards through to Ruakaka Forest (Q07/121).

Coastal Hill Vegetation

Indigenous hill vegetation within the coastal zone occurs at Takahiwai Forest (Q07/124) (northern side) and Pakauhokio Knoll Forest (Q07/122) next to Whangārei Harbour in the north, and on low consolidated sand ridges next to Ruakaka River Estuary (Q07/130).

Takahiwai Forest (Q07/124) has one of the largest areas of coastal kānuka forest, with kauri-kānuka forest dominant on many of the ridges. These types are also common further inland, but here they are likely to have a different suite of species regenerating through them due to the coastal influence. Small patches of more diverse tōtara-pūriri forest and karaka-nīkau-kānuka forest remain in the gullies and gully heads. These broadleaf forest types would have been more extensive in the area before widespread human disturbance. Pakauhokio Knoll Forest (Q07/122) is mainly degraded kānuka forest.

Pleistocene consolidated sand ridges next to the two large estuaries have been largely cleared, but some parts still support relatively healthy pōhutukawa forest and treeland with associated species such as tōtara, houpara, karaka, kawakawa, kahakaha, *Astelia banksii*, karo, hangehange, *Coprosma macrocarpa*, mamaku, and harakeke. There are, however, some very weedy areas of tōtara-pōhutukawa forest at Ruakaka River Estuary (Q07/130) infested with species such as gorse, wild cherry, crack willow, woolly nightshade, brush wattle, radiata pine, and pampas.

4.4 Flora

4.4.1 Manaia Ecological District

A total of 628 vascular plant species (420 indigenous and 208 adventive) have been recorded in Manaia Ecological District (Goldwater and Beadel 2010) (Appendix 1). Of these, 42 are classified as Threatened or At Risk, and nine qualify as significant under Schedule 17C of the Whangarei District Plan (Table 1). Manaia Ecological District also has 72 regionally significant plant species (Table 2).

Table 1: Nationally threatened and At Risk plant taxa (as per classifications in de Lange *et al.* 2018) recorded in Manaia Ecological District (updated from Goldwater and Beadel 2010).

Scientific Name	Common Name	Plant Group	Threat Classification
Agathis australis	Kauri	Gymnosperm	Nationally Vulnerable
Blechnum molle		Fern	Naturally Uncommon
Blechnum zeelandicum		Fern	Naturally Uncommon
Brachyglottis kirkii var. *kirkii*	Kohurangi, Kirk's tree daisy	Dicots	Nationally Vulnerable
Calystegia marginata[2]		Dicots	Naturally Uncommon
Celmisia adamsii var. *rugulosa*		Dicots	Naturally Uncommon
Coprosma acerosa	Tarakupenga, sand coprosma	Dicots	Declining
Coprosma neglecta		Dicots	Naturally Uncommon
Dactylanthus taylorii[2]	Pua o te reinga	Dicots	Nationally Vulnerable
Ficinia spiralis[2]	Pingao	Sedges	Declining
Fuchsia procumbens[3]		Dicots	Naturally Uncommon
Hymenophyllum australe	Maku, filmy fern	Fern	Naturally Uncommon
Kunzea robusta	Kānuka	Dicots	Nationally Vulnerable
Kunzea linearis	Rawiri mānuka, kānuka	Dicots	Nationally Vulnerable
Lepidium oleraceum[1]	Nau, Cook's scurvy grass	Dicots	Nationally Endangered
Leptospermum scoparium agg.	Mānuka	Dicots	Declining
Lophomyrtus bullata	Ramarama	Dicots	Nationally Critical
Lophomyrtus obcordata	Rōhutu	Dicots	Nationally Critical
Metrosideros carminea	Akakura	Dicots	Nationally Vulnerable
Metrosideros diffusa	Rata	Dicots	Nationally Vulnerable
Metrosideros excelsa	Pōhutukawa	Dicots	Nationally Vulnerable
Metrosideros fulgens	Rata	Dicots	Nationally Vulnerable
Metrosideros perforata	Aka	Dicots	Nationally Vulnerable
Metrosideros robusta	Northern rata	Dicots	Nationally Vulnerable
Microlaena carsei		Grasses	Nationally Endangered
Myosotis spathulata		Dicots	Naturally Uncommon
Olearia angulata		Dicots	Naturally Uncommon
Peperomia tetraphylla		Dicots	Naturally Uncommon
Pimelea acra		Dicots	Naturally Uncommon
Pimelea tomentosa[2]		Dicots	Nationally Vulnerable
Pimelea villosa	Autetaranga	Dicots	Declining
Pisonia brunoniana	Parapara	Dicots	Relict
Pittosporum ellipticum		Dicots	Naturally Uncommon
Pittosporum virgatum		Dicots	Nationally Vulnerable

Scientific Name	Common Name	Plant Group	Threat Classification
Pomaderris paniculosa subsp. *novaezelandiae*[3]		Dicots	Nationally Endangered
Pseudowintera insperata	Northland horopito	Dicots	Nationally Critical
Scandia rosifolia	Kohepiro	Dicots	Nationally Critical
Senecio biserratus		Dicots	Declining
Senecio scaberulus[2]		Dicots	Nationally Critical
Sophora fulvida	Kōwhai	Dicots	Naturally Uncommon
Streblus banksii	Tūrepo	Dicots	Relict
Tetragonia tetragonioides[3]	Kōkihi	Dicots	Naturally Uncommon

[1] Species identified as having ‘Outstanding Value’ under Whangarei District Plan Schedule 17B.
[2] Species identified as having ‘High Value’ under Whangarei District Plan Schedule 17B.
[3] Species identified as having ‘Moderate-High Value’ under Whangarei District Plan Schedule 17B.

Table 2: Regionally significant plant taxa recorded in Manaia Ecological District (Goldwater and Beadel 2010).

Key: * = taxa not recorded recently (i.e. pre-1980s).

Taxon	Common Name	Plant Group
Adiantum aethiopicum	Maidenhair fern	Fern
Ascarina lucida var. *lucida*	Hutu	Dicot tree
Asplenium flabellifolium	Necklace fern	Fern
Asplenium gracillum		Fern
Asplenium hookerianum		Fern
Asplenium northlandicum		Fern
Blechnum triangularifolium		Fern
Beilschmiedia tawa (f. *B. tawaroa* sensu Wright)	Tawaroa	Dicot tree
Brachyglottis kirkii var. *angustior*	Kirk’s tree daisy	Dicot tree
Carex forsteri		Sedge
Carex ochrosaccus		Sedge
Cheilanthes distans		Fern
Cheilanthes sieberi		Fern
Chionochloa conspicua subsp. *cunninghamii*		Grass
Clematis foetida		Dicot vine
Collospermum microspermum		Monocot herb
Coprosma neglecta		Dicot shrub
Coprosma rigida		Dicot shrub
Coprosma rotundifolia		Dicot shrub
Coprosma tenuicaulis	Swamp coprosma	Dicot shrub
Corokia buddleioides	Korokio	Dicot shrub
Corokia cotoneaster	Korokio	Dicot shrub
Cyathea cunninghamii	Pūnui, gully tree fern	Fern
Dracophyllum sinclairii		Dicot shrub
Einadia triandra	Pigweed	Dicot herb
Epacris pauciflora		Dicot tree
Epilobium pallidiflorum		Dicot herb
Euchiton involucratus		Dicot herb
Fuchsia excorticata	Kotukutuku	Dicot tree
Geranium solanderi		Dicot herb
Grammitis billardierei		Fern
Grammitis ciliata		Fern
Hebe ligustrifolia (includes *H.* “Whangārei”)		Dicot shrub
Hebe macrocarpa var. *latisepela*		Dicot shrub
Hebe macrocarpa var. *macrocarpa*		Dicot shrub
Hebe parviflora		Dicot shrub

Taxon	Common Name	Plant Group
Helichrysum lanceolatum		Dicot shrub
Hydrocotyle microphylla		Dicot herb
Hymenophyllum lyalli		Fern
Hymenophyllum multifidum		Fern
Leionema nudum	Mairehau	Dicot shrub
Leptostigma setulosa		Dicot herb
Libertia grandiflora	Mīkoikoi	Monocot herb
Linum monogynum	Rauhuia	Dicot herb
Lophomyrtus obcordata	Rōhutu	Dicot tree
Loxsoma cunninghamii		Fern
Luzula banksiana var. *banksiana*		Rush
Melicytus novae-zelandiae	Coastal māhoe	Dicot shrub
Metrosideros carminea	Akakura, carmine rata	Dicot vine
Metrosideros robusta	Northern rata	Dicot tree
Myoporum laetum	Ngaio	Dicot tree
Nestegis apetala	Coastal maire	Dicot tree
Nestegis cunninghamii	Black maire	Dicot tree
Nestegis montana		Dicot tree
Olearia albida		Dicot tree
Ophioglossum coriaceum		Fern
Passiflora tetrandra		Dicot vine
Pennantia corymbosa	Kaikomako	Dicot tree
Phormium cookianum subsp. *hookeri*	Wharariki	Monocot shrub
Phyllocladus toatoa	Mountain toatoa	Dicot tree
Pouteria costata	Tawāpou	Dicot tree
Pseudowintera axillaris	Horopito	Dicot tree
Rubus schmidelioides var. *schmidelioides*	Bush lawyer	Dicot vine
Rubus squarrosus	Bush lawyer	Dicot vine
Senecio biserratus		Dicot herb
Senecio quadridentatus		Dicot herb
Sticherus cunninghamii		Fern
Suaeda novae-zelandiae		Dicot herb
Tetraria capillaris		Sedge
Triglochin striata	Arrow grass	Monocot herb
Toronia toru	Toru	Dicot tree
Urtica ferox	Ongaonga, tree nettle	Dicot shrub
Zoysia minima		Grass

4.4.2 Waipu Ecological District

A total of 611 vascular plant species (378 indigenous, 233 adventive) have been recorded in Waipu Ecological District (Lux *et al.* 2007) (Appendix 1). Of these, 29 are classified as Threatened or At Risk, and two qualify as significant under Schedule 17C of the Whangarei District Plan (Table 3). Waipu Ecological District also has 26 regionally significant plant species (Table 4).

Table 3: Nationally threatened and At Risk plant taxa (as per classifications in de Lange *et al.* 2018) recorded in Waipu Ecological District (updated from Lux *et al.* 2007).

Species	Common Name	Threat Classification
Agathis australis	Kauri	Nationally Vulnerable
Blechnum molle		Naturally Uncommon
Blechnum zeelandicum		Naturally Uncommon
Chionochloa bromoides		Naturally Uncommon
Coprosma acerosa	Tarakupenga, sand coprosma	Declining
Corybas rivularis		Naturally Uncommon
Corybas rotundifolius		Naturally Uncommon
Ficinia spiralis[1]	Pīngao	Declining
Halocarpus kirkii	Monoao	Relict
Kunzea robusta	Kānuka	Nationally Vulnerable
Kunzea linearis	Rawiri mānuka, kānuka	Nationally Vulnerable
Leptospermum scoparium	Mānuka	Declining
Lophomyrtus bullata	Ramarama	Nationally Critical
Metrosideros carminea	Carmine rata, akakura (AK 297995)	Nationally Vulnerable
Metrosideros diffusa	Rata	Nationally Vulnerable
Metrosideros excelsa	Pōhutukawa	Nationally Vulnerable
Metrosideros fulgens	Rata	Nationally Vulnerable
Metrosideros perforata	Aka	Nationally Vulnerable
Metrosideros robusta	Northern rata	Nationally Vulnerable
Mida salicifolia (incl. *M. s.* var. *myrtifolia*)	Mida, sandalwood	Declining
Nestegis apetala		Relict
Pimelea villosa		Declining
Pisonia brunoniana	Parapara	Relict
Poa billardierei	Sand tussock	Declining
Solanum aviculare var. *aviculare*	Poroporo	Nationally Vulnerable
Streblus ?banksii × *S. heterophyllus*		*Streblus banksii* - Relict
Syzygium maire	Swamp maire, maire tawake	Nationally Critical
Tetragonia tetragonioides[2]		Naturally Uncommon
Zostera muelleri subsp. *novazelandica*		Declining

[1] Species identified as having 'High Value' under Whangarei District Plan Schedule 17B.
[2] Species identified as having 'Moderate-High Value' under Whangarei District Plan Schedule 17B.

Table 4: Regionally significant plant taxa recorded in Waipu Ecological District (Lux *et al.* 2007).

Species	Common Name
Azolla filiculoides	
Brachyglottis kirkii var. *angustior*	
Coprosma acerosa	
Coprosma rigida	
Coprosma parviflora	
Cyathea cunninghamii	Gully tree fern
Epacris pauciflora	
Fuchsia excorticata	Tree fuchsia
Hebe macrocarpa var. *macrocarpa*	
Loxsoma cunninghamii	
Metrosideros carminea	Carmine rata
Metrosideros robusta	Northern rata
Nestegis apetala	Coastal maire
Nothofagus truncata	Hard beech
Oxalis magellanica	
Pelargonium inodorum	
Pennantia corymbosa	Kaikomako
Phormium cookianum	Wharariki
Plagianthus regius	Mānatu
Pouteria costata	Tawāpou
Pratia angulata	
Schizaea bifida	
Sparganium subglobosum	Burr reed
Suaeda novae-zelandiae	
Syzygium maire	Maire tawake
Triglochin striata	Arrow grass

4.5 Avifauna

4.5.1 Manaia Ecological District

Goldwater and Beadel (2010) provide records for 68 bird species[1] (46 indigenous, 22 introduced) in Manaia Ecological District, with records for an additional four bird species in eBird at two locations: Ocean Beach and Peach Cove Track (Appendix 2). North Island robin (*Petroica longipes*) and pōpokatea/whitehead (*Mohoua albicilla*) were released at Bream Head by the Bream Head Conservation Trust in April 2016 and May 2017 (Morgan *et al.* 2017).

Of these species, seven are classified by Robertson *et al.* (2017) as Threatened, 22 as At Risk, and two as non-resident Native-Migrant. Six species are regionally significant in Whangārei District (Honnor *et al.* 2011), and 17 qualify as significant under Schedule 17B of the Whangarei District Plan

[1] Including sea birds, as further discussed in the accompanying report by Graham Don.

Goldwater and Beadel (2010) identified three key features of Manaia Ecological District that make it important for terrestrial birds, including many threatened species:

- Close proximity of the Hen and Chicken Islands and the Poor Knights Islands.
- Coastal breeding and feeding sites for wetland birds.
- Large, significant areas of semi-contiguous forest.

Trapping of pest animals and translocation of North Island brown kiwi (*Apteryx mantelli*) by the Bream Head Conservation Trust and Whangārei Heads Landcare Forum has seen the kiwi numbers increase significantly within the last 10 years (Craig 2017). North Island brown kiwi is identified as having Outstanding Ecological Value under the Whangarei District Plan.

4.5.2 Waipu Ecological District

Lux *et al.* (2007) provide records for 104 bird species[1] (81 indigenous and 23 introduced) in Waipu Ecological District, with records for an additional 18 bird species in eBird from 10 locations (Marsden Bay Boat Ramp, Marsden Bay foreshore, Marsden Point-Papich Rd, Ormiston Road Ruakaka, Ruakaka Wildlife Refuge, Ruakaka-Mountfield Dam, Ruakaka-Wilson Dam, Waipu Cove, Waipu Wildlife Refuge, Waipu-Uretiti dune lakes) (Appendix 2).

Of these species, 10 are classified by Robertson *et al.* (2017) as Threatened, 26 as At Risk, 21 as Non-resident Native (either Coloniser, Migrant or Vagrant). Nine species are regionally significant in Whangārei District (Honnor *et al.* 2011), and 28 qualify as significant under Schedule 17B of the Whangarei District Plan.

4.6 Freshwater fauna

Twelve indigenous freshwater fish species have been recorded in Waipu Ecological District and four in Manaia Ecological District (Table 5), with five of these species classified as Threatened or At Risk by Dunn *et al.* (2018). Three freshwater invertebrate species have been recorded in each ecological district, with one classified as At Risk by Grainger *et al.* (2018). Banded kōkopu (*Galaxias fasciculatus*) is classified as regionally significant in Whangārei District (Honnor *et al.* 2011), while both banded kōkopu and shortjaw kōkopu qualify as significant under Schedule 17B of the Whangarei District Plan.

[1] Including sea birds, as further discussed in the accompanying report by Graham Don.

Table 5: Records from New Zealand Freshwater Fish Database and PNAP survey reports for Manaia Ecological District (Goldwater and Beadel 2010) and Waipu Ecological District (Lux *et al.* 2007).

Species	Common Name	National Threat Classification	Manaia Ecological District	Waipu Ecological District
Fish				
Anguilla australis	Shortfin eel	Not Threatened	Y	Y
Anguilla dieffenbachii	Longfin eel	At Risk-Declining	Y	Y
Anguilla sp.	Unidentified eel species	-	Y	Y
Carassius auratus	Goldfish	Introduced and Naturalised		Y
Cheimarrichthys fosteri	Torrentfish	At Risk-Declining		Y
Ctenopharyngodon idella	Grass carp	Introduced (Not listed)		Y
Cyprinus carpio	Koi carp	Introduced and Naturalised		Y
Galaxias fasciatus[2]	Banded kōkopu	Not Threatened	Y	Y
Galaxias maculatus	Inanga	At Risk-Declining		Y
Galaxias postvectis[1]	Shortjaw kōkopu	Threatened-Nationally Vulnerable		Y
Galaxias sp.	Unidentified galaxiid species	-		Y
Gambusia affinis	Gambusia	Introduced and Naturalised		Y
Gobiomorphus basalis	Cran's bully	Not Threatened		Y
Gobiomorphus cotidianus	Common bully	Not Threatened	Y	Y
Gobiomorphus gobioides	Giant bully	At Risk-Naturally Uncommon		Y
Gobiomorphus huttoni	Redfin bully	Not Threatened		Y
Gobiomorphus sp.	Unidentified bully species	-		Y
Mugil cephalus	Grey mullet	Not Threatened		Y
Retropinna retropinna	Common smelt	Not Threatened		Y
Scardinius erythrophthalmus	Rudd	Introduced and Naturalised		Y
Invertebrates				
Echyridella menziesii	Freshwater mussel	At Risk-Declining	Y	Y
Paranephrops planifrons	Kōura	Not Threatened	Y	Y
Paratya curvirostris	Freshwater shrimp	Not Threatened	Y	Y

[1] Species identified as having 'Outstanding Value' under Whangarei District Plan Schedule 17B.
[2] Species identified as having 'Moderate-High Value' under Whangarei District Plan Schedule 17B.

4.7 Herpetofauna

One indigenous frog species and 11 indigenous lizard species have been recorded in Manaia and Waipu Ecological Districts (Table 6). Hochstetter's frog (*Leiopelma hochstetteri* sensu stricto; classified as At Risk-Declining by Burns *et al.* 2018) is found southwest of the refinery in Maretu Forest and indigenous forest near Waipu Cave; both of these locations are beyond the extent of the receiving environment for the discharge. Eight lizard species are classified as Threatened or At Risk by Hitchmough *et al.* (2016). Forest gecko (*Mokopirirakau granulatus*) is also a regionally significant species in Whangārei District (Honnor *et al.* 2011). Hochstetter's frog and Macgregor's skink (*Oligosoma macgregori*) qualify as significant under Schedule 17B of the Whangarei District Plan.

Table 6: Records of live specimens from Bioweb Herpetofauna database, Manaia Ecological District (Goldwater and Beadel 2010) and Waipu Ecological District (Lux *et al.* 2007) PNAP survey reports, and a search of the spreadsheet accompanying the threat classification list for reptiles (Hitchmough *et al.* 2016)*.

Species	Common Name	Threat Classification	Manaia Ecological District	Waipu Ecological District
Frogs				
Leiopelma hochstetteri sensu stricto[2]	Hochstetter's frog	At Risk-Declining		Y
Ranoidea (Litoria) aurea	Green and golden bell frog	Introduced and Naturalised	Y	Y
Lizards				
Dactylocnemis pacificus	Pacific gecko	At Risk-Relict	Y	Y
Lampropholis delicata	Plague skink	Introduced and Naturalised		Y
Mokopirirakau granulatus	Forest gecko	At Risk-Declining	Y	Y
Naultinus elegans	Elegant gecko	At Risk-Declining	Y	Y
Oligosoma aeneum	Copper skink	Not Threatened	Y	Y
Oligosoma macgregori[2]	McGregor's skink	Recovering	PNAP report - H&C Islands	
Oligosoma moco	Moko skink	Relict	*Two confirmed recent specimens from Bream Head	
Oligosoma ornatum	Ornate skink	At Risk-Declining	Y	
Oligosoma smithi	Shore skink	Not Threatened	Y	Y
Oligosoma suteri	Egg-laying skink	At Risk-Relict	Record in sea (from Bream Island?)	
Oligosoma "Whirinaki"	-	Threatened-Nationally Critical	*New population found at Bream Head, likely to be conspecific	
Woodworthia maculata	Raukawa gecko	Not Threatened	Y	

Species	Common Name	Threat Classification	Manaia Ecological District	Waipu Ecological District
Turtles				
Caretta caretta[1]	Loggerhead turtle	Vagrant	Island in Whangārei Harbour	Y
Chelonia mydas[1]	Green turtle	Migrant	Y	Y
Dermochelys coriacea[1]	Leathery turtle	Migrant	Y	
Eretmochelys imbricata[1]	Hawksbill turtle	Vagrant	Y	Y
Snakes				
Pelamis platurus	Yellow-bellied sea-snake	Not Threatened	Y	Y

[1] Species identified as having 'Outstanding Value' under Whangarei District Plan Schedule 17B.
[1] Species identified as having 'High Value' under Whangarei District Plan Schedule 17B.

4.8 Bats

For Manaia Ecological District, there is an unconfirmed record of long-tailed bat (*Chalinolobus tuberculatus*; classified as Threatened-Nationally in O'Donnell *et al.* 2018) from Peach Cove in the early 1990s at Bream Head Scenic Reserve and surrounds. Bats have also been sighted by a resident at Ocean Beach on two occasions in 2008 (Goldwater and Beadel 2010).

A single survey undertaken in Manaia Ecological District in November 2013 did not find any bats (Department of Conservation Bat Distribution database, Version received 10 May 2018)[1].

There are no surveys recorded in the Department of Conservation Bat Distribution database for Waipu Ecological District. However, there are unconfirmed reports of bats from the southeastern Brynderwyn Hills (Lux *et al.* 2007).

The closest records of long-tailed bats in the Department of Conservation Bat Distribution database are in Whangārei Ecological District, which is immediately adjacent to both the Waipu and Manaia Ecological Districts (although there is the harbour between Whangārei Ecological District and Manaia Ecological District). The most recent of these records are from 2011.

Based on the home range of the long-tailed bat, and previous records as outlined above, it is possible this species is utilising habitat within the receiving environment.

4.9 Terrestrial invertebrates

A range of terrestrial invertebrate species are known from Manaia Ecological District, with several classified as Threatened or At Risk (Table 7). Most land snails are found in forest remnants, but one taxon is restricted to duneland and prostrate shrubland at Smugglers Bay (Goldwater and Beadel 2010). There are few records of invertebrates within Waipu Ecological District (Table 7).

[1] However, it is noted this was a Department of Conservation Tier 1 survey so would only have been a few nights using one ABM. Best practice for length of survey for longtailed bats is 14 nights.

Table 7: Records of indigenous terrestrial invertebrates from Manaia Ecological District (Goldwater and Beadel 2010) and Waipu Ecological District (Lux *et al.* 2007) PNAP survey reports, and searches of spreadsheets accompanying Department of Conservation threat classification list publications*.

Species	Common Name	Threat Classification	Manaia	Waipu
Beetles				
Actizeta sp.			Y	
Arthracanthus sp.			Y	
Brontopriscus pleuralis			Y	
Chaerodes sp.	Seaweed darkling beetle		Y	
Clivinia sp.			Y	
Ctenognathus sulcitarsis			Y	
Dicrochile maura			Y	
Eucolaspis sp.	Bronze beetle		Y	
Gnaphalopoda brookesi			Y	
Halyles sp.			Y	
Hexanodes vulgata			Y	
Hybolasius pedator			Y	
Hypharpax sp.			Y	
Kaveinga orbitosa			Y	
Kupeus arcuatus			Y	
Lagrioida brounii			Y	
Lasiorhynchus barbicornis	Giraffe weevil		Y	
Mecodema ?spiniferum	Carabid beetle		Y	
Mecodema manaia		At Risk-Declining	Y	
Mecodema sp. aff. *M. curvidens*	Carabid beetle		Y	
Mecyclothorax rotundicollis			Y	
Menimus oblongus	Darkling beetle	At Risk-Naturally Uncommon	Y	
Menimus obscurus	Darkling beetle	At Risk-Naturally Uncommon	Y	
Menimus thoracicus	Darkling beetle	At Risk-Naturally Uncommon	Y	
Nyxetes bidens	Two-spined weevil		Y	
Parabaris atratus			Y	
Paralissotes planus	Stag beetle		Y	
Phycosecis limbata			Y	
Phymatophaea fuscitarsis			Y	
Phymatophaea opiloides			Y	
Reichardtia pedatrix			Y	
Rhytisternus miser			Y	
Rhyzodiastes proprius			Y	
Sapintus aucklandensis			Y	
Scolopterus sp.	Four-spined weevil		Y	
Scopodes fossulatus			Y	
Stethaspis longicornis	Green chafer		Y	
Unas piceus	Weevil	Data Deficient	Y	
Waiputrechus cavernicola		Threatened-Nationally Critical		*
Xylophilus nitidus			Y	

Species	Common Name	Threat Classification	Manaia	Waipu
Land Snails				
Amborhytida dunniae		At Risk-Declining	Y	Y
Cytora cytora				Y
Cytora torquilla				Y
Delos coresia			Y	
Dosinea subrosea				Y
Liarea sp. 1 "Bream Head" (NMNZ M.158257) [syn. *Liarea egea* sp. "Bream Head"]		Threatened-Nationally Vulnerable	Y	
Liarea turriculata				Y
Liarea sp. 2 (NMNZ M.158258) [syn. *Liarea turriculata* "Manaia"]		At Risk-Relict	Y	
Paryphanta busbyi	Kauri snail	At Risk-Declining		Y
Phenacohelix giveni				Y
Phenacohelix giveni			Y	
Placostylus (*Maoristylus*) *hongii*		At Risk-Naturally Uncommon	Y	
Punctid attenuispira			Y	
Punctid corella			Y	
Punctid lampra			Y	
Punctidae sp. 164		Relict		Y
Punctidae sp. 223 (NMNZ M.151458)		Threatened-Nationally Critical	Y	
Punctidae sp. 64				Y
Punctidae sp.8 (NMNZ M.68410)		At Risk-Naturally Uncommon		*
Schizoglossa worthyae	Pāua slug	Threatened-Nationally Vulnerable	Y	Y
Charopidae sp. 75 (NMNZ M.096613) [syn. *Therasiella* aff. *elevata*]		At Risk-Naturally Uncommon	Y	
Therasiella sp. (*celinde* or *tamora*)				Y
Flies				
Anabarhynchus microphallus		At Risk-Naturally Uncommon		*
Lucilia sericata	Green blowfly		Y	
Bugs				
Bathyllus albicinctus			Y	
Carystoterpa ikana			Y	
Diomocoris ostiolum			Y	
Macroscytus australis			Y	
Novothymbris notata			Y	
Novothymbris sp.			Y	
Oncacontias vittatus	Forest shield bug		Y	
Tridiplous penmani			Y	
Lacewings				
Drepanacra binocula			Y	
Micromus tasmaniae	Tasmanian lacewing		Y	
Wētā				
Hemiandrus maia [syn. *H. furcifer*]	Ground wētā		Y	
Spiders				
Latrodectus katipo	Katipo spider	At Risk-Declining	Y	Y
Peripatus				
Peripatoides sp.	Peripatus		Y	

4.10 Acid sulphate soils

Acid sulphate soils have been identified by Whangārei District Council. Acid sulphate soils are naturally-occurring and formed around 5,000 to 10,000 years ago when the sea level was higher than it is today. Salts in seawater mixed with the land and these remained when the sea receded. Over time, the salts (most commonly sulphates) were broken down by bacteria into sulphides. When the land is disturbed, the sulphides can react with oxygen, resulting in sulphuric acid. This acid can leach into groundwater, which can have a number of implications on the surrounding environment.

Acidic groundwater can cause minerals to leach from soils and be discharged into the environment. Iron is a common metal leached from acid soils and can be seen as iron staining of soils.

Acid sulphate soils, and their location, may be of relevance to this review as they may have greater sensitivity to acidification than soils that are more neutral or alkaline, and coincide with areas of significant ecological values.

Acid sulphate soils can be sinks for sulphur and recent research (Macdonald *et al.* 2004) has shown they are also a source of atmospheric release for sulphur dioxide. Fluctuations in sulphur dioxide are reported to be linked to the temperature of the soil surface and moisture content of the soils (Kinsela *et al.* 2011).

There are several areas of acid sulphate soils in the receiving environment including low-lying lands near Marsden Point and on the eastern side of Whangārei Heads, as well as small pockets encompassing the residential areas of Whangārei Heads and Mcleod Bay. The location of acid sulphate soils closely approximates the gley soils mapped as blue and light blue in Figures 5a and 5b. Most of the acid sulphate soils within the receiving environment coincide with highly modified agricultural land, and is typically pasture.

4.11 Effects of human settlement on the receiving environment

To the southwest of the discharge point, on the coastal flats of the Waipu Ecological District, vegetation clearance and conversion to agricultural and industrial land uses has resulted in almost the complete loss of indigenous vegetation and habitats within approximately six kilometres of the discharge point. This pattern of a highly modified coastal plain, with indigenous habitats largely restricted to a narrow band of coastal dunes, several tidal inlets, and small freshwater wetlands in dune slacks, can be seen in Figure 1a. Larger tracts of indigenous vegetation occur on coastal hill country, the nearest area being the Takahiwai Hills, six kilometres to the west of the refinery.

In contrast, to the northeast of the discharge point, the receiving environment within the Manaia Ecological District encompasses areas of steep hill country. As a consequence, much of this area retains a high degree of indigenous vegetation cover. Most of the steeper land is indigenous forest and scrub, with remnant areas of coastal forest also occurring along the shoreline of Whangārei Harbour. On the western side of the main ridges, that run approximately northwest to south east, gentler slopes and small coastal flats are characterised by small settlements, and small areas of pasture grazed by sheep or beef cattle. To the east of this main ridge, larger tracts of pasture on the coastal flats behind Ocean Beach include both dairy farms and dry stock farms.

All natural areas within the receiving environment are adversely affected, to varying degrees, by pest plants and pest animals, and some are also subject to the effects of grazing. Where livestock have access to natural areas (e.g. the foothills of Mount Manaia and the Takahiwai Hills), browsing and trampling by livestock is likely to be the primary cause of biodiversity decline. The long-term prognosis for most areas that are grazed is the eventual loss of indigenous vegetation. Similarly, where natural areas are close to urban areas that provide a source of pest plants, these areas, without the implementation of a pest control programme, may see a gradual progression towards being dominated by pest plant species. This pattern is readily observable in small areas of coastal vegetation within or close to the coastal settlements from Parua Bay to Urquharts Bay.

Some areas within the receiving environment are actively managed for conservation purposes; these areas have no access by livestock, and low numbers of pest plants and pest animals, e.g. Manaia Scenic Reserve, Bream Head. These areas are the least modified areas within the terrestrial receiving environment, and are important refuges for Threatened and At Risk indigenous plants and fauna, and threatened ecosystem types.

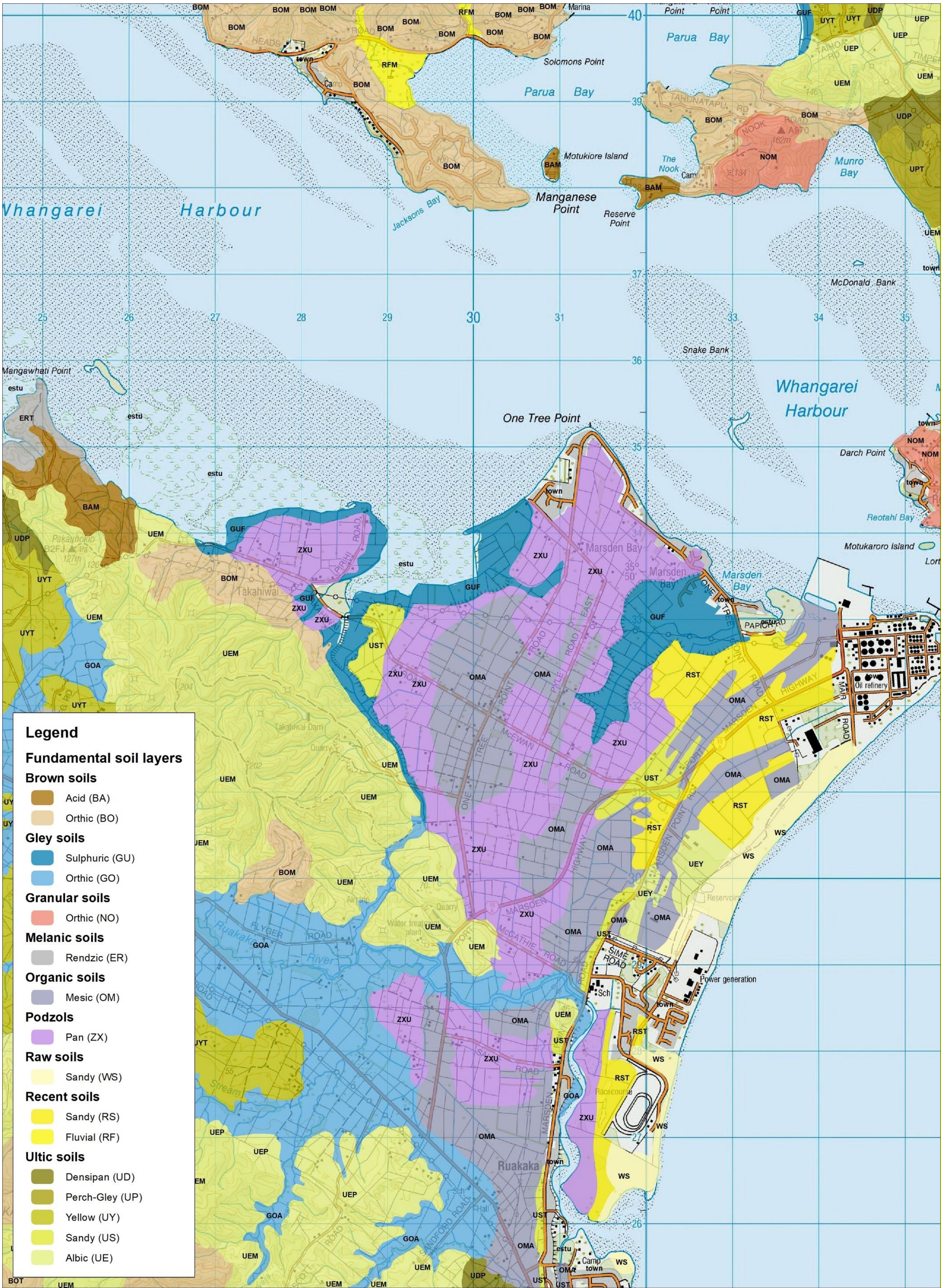

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Figure 5a: Soil types of the Manaia and Waipu Ecological Districts within the receiving environment of the Marsden Oil Refinery air discharge

0 1,000 2,000 m

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Scale: 1:40,000
Date: 17/06/2019
Cartographer: TP
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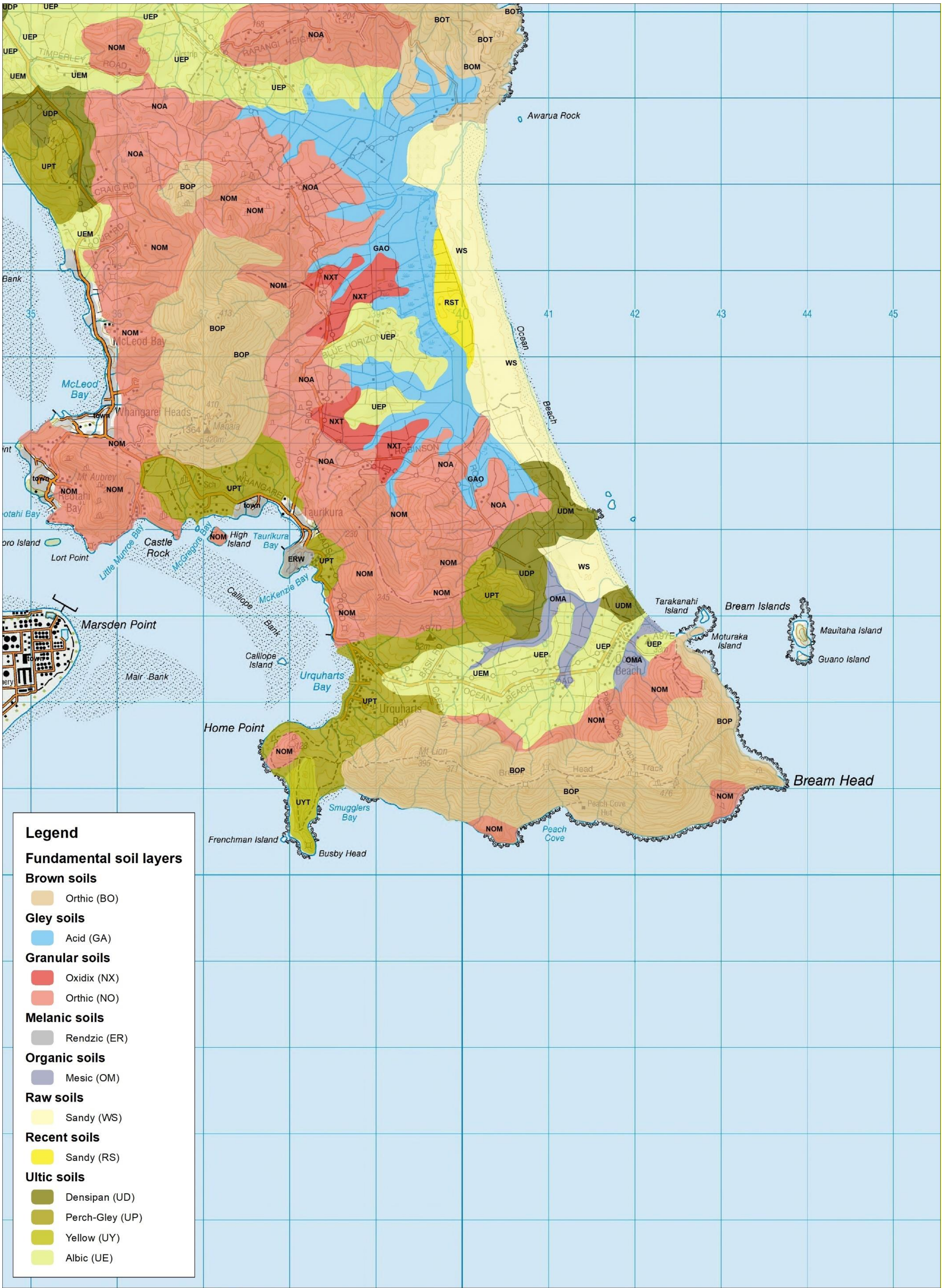

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Figure 5b: Soil types of the Manaia and Waipu Ecological Districts within the receiving environment of the Marsden Oil Refinery air discharge

0 1,000 2,000 m

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Date:	17/06/2019
Cartographer:	TP
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5. ECOLOGICAL VALUES AND SIGNIFICANCE

Existing information on the Manaia and Waipu Ecological Districts, including descriptions of all indigenous terrestrial ecosystems, provide a basis for assessing the ecological values and significance of habitats within the receiving environment of the air discharge. An understanding of ecological values also allows for an assessment of the levels of potential adverse effects, if an effect is likely, with potential adverse effects being of greater severity where areas of higher ecological values are potentially affected.

Due to the extensive nature of the receiving environment, the extent of the discharge encompasses a wide range of ecological values, as mapped in Figures 1a and 1b. While it is recognised that areas of ecological value can and do lie outside of the sites identified as part of the Protected Natural Areas Programme (PNAP) survey reports (e.g. an area of exotic vegetation may have value as feeding and roosting habitat for indigenous avifauna), a focus on the potential effects on indigenous habitats is regarded as an acceptable approach for this assessment. This is further discussed in Section 8.4 below, which prescribes lower acceptable levels of pollutants for “natural vegetation” than more modified habitats.

A summary of the ecological values for each natural area within the receiving environment is provided in Table 8.

The ecological significance of the existing environment has also been considered, recognising that this gives a more binary view of the relative ecological value of an area, as an area can only be either assessed as significant, or not. The term ‘significant’ has other meanings in relation to the statutory context of an application, although the assessment criteria for assigning relative value and significance are generally similar. Due to the scale of this application, and wide geographical range for potential adverse effects, significance has been primarily considered at a regional scale, in accordance with the Regional Water and Soil Plan for Northland (operative) and the Proposed Northland Regional Plan (as described below).

Under the Resource Management Act 1991 (RMA), consent authorities (amongst others) are required to recognise and provide for the protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna as a matter of national importance (Section 6(c) of RMA). In order to address this matter, Councils need to identify and assess the significance of areas of indigenous vegetation and areas of indigenous fauna habitat on private and publicly owned land, termed Significant Natural Areas (SNAs).

5.1 Criteria for assessment of sites (Proposed Northland Regional Plan)

For the Northland Region, the review and identification of SNAs is currently being carried out for the Proposed Northland Regional Plan. Significance criteria for the identification of Significant Natural Areas (SNAs) are based on Appendix 5 of the Northland Regional Policy Statement and include representativeness, rarity/distinctiveness, diversity and pattern, and ecological context. The existing identified sites from the PNAP surveys are being used as a starting point for the SNA assessment. The sites assessed in Section 8.7 of this report are therefore considered to be significant at a regional scale.

The operative significance criteria for areas of significant indigenous vegetation, and significant habitats of indigenous fauna and significant indigenous wetlands, as outlined in Appendix 13B of the Regional Water and Soil Plan for Northland, have also been considered in this assessment. In this regard, it is noted that the new significance criteria in the Proposed Northland Regional Plan also encompass the existing significance criteria in the operative plan. On this basis, all areas meeting significance criteria in the operative plan should also be significant under the proposed plan.

5.2 Criteria for assessment of sites (Whangarei District Plan)

Schedule 17A of the Whangarei District Plan identifies habitat types of outstanding, high, moderate high, moderate, and potential value, and, in terms of Section 6(c) of the Resource Management Act, identifies sites as 'significant' if they are ranked as 'moderate' ecological value or above. These criteria can be regarded as identifying areas of local ecological significance, and include all indigenous habitats except those of potential value, that are "highly modified" and which "do not contain any species listed in Schedule 17B or 17C". A summary of the ecological value, and corresponding significance, of each natural area under these criteria is provided in Table 8. Where an area achieves Outstanding Ecological Value, the reasons for meeting this criterion are listed.

Schedule 17B of the Whangarei District Plan provides a list of fauna that are of outstanding, high, moderate high, and moderate value, and 17C provides a list of flora that are of outstanding, high, and moderate-high value. Presence of any of these species at a site meets the corresponding value for ecological value of a site (i.e. the presence of an "outstanding" species means the corresponding site meets the criteria for "outstanding" ecological value. All species contained in these schedules qualify as significant under the Whangarei District Plan criteria. Significant species present within the study area are identified in Section 4.4 (Flora) and Sections 4.5 to 4.9 (Fauna). In summary, the study area has nine plant species, 28 bird species, two fish species, one frog species, and one lizard species that are significant under these criteria.

Table 8: Natural areas, ecological values, and significance assessment (Whangarei District Plan and Northland Regional Plan) for the receiving environment of the refinery discharge. All sites are mapped in Figures 1-3, with site codes for identification (e.g. Q07/136).

Site Name	PNA No.	Significance, Ecological Value WDC Schedule 17	Significance NRP[1]	Ecological District	Representative Vegetation Types	Significant Flora	Significant Fauna	Special Features
Indigenous forest, Hewlett QEII Covenant	Q07/136	Yes, Moderate-High (17A.3 1)	*Yes*	Waipu	None	None	Not surveyed	Uncommon vegetation type on terrace on Late Pleistocene (last interglacial), alluvial and/or estuarine deposits (Lux *et al.* 2007).
Ruakaka River Forest Remnants	Q07/119	Yes. High (17A.1)	*Yes*	Waipu	Four representative vegetation types.	One Regionally Significant plant species.	Avifauna: One Threatened and Two At Risk species. Fish: Two At Risk and one Regionally Significant species.	Best example in the Waipu Ecological District of a nationally rare habitat type.
Takahiwai Forest Indigenous forest - Raupo reedland	Q07/124	Yes, Moderate-High (17A.3 1)	*Yes*	Waipu	Seven representative vegetation types.	Three Threatened, One At-Risk and Three Regionally Significant plant species.	Avifauna: One At Risk and two Regionally Significant (one of which was is a historical record) species. Fish: One At Risk and two Regionally Significant species.	Dissected hill country on Mesozoic greywacke (Waipapa Terrane) (Lux *et al.* 2007).
Pakouhokio Knoll Forest	Q07/122	Yes, Moderate-High (17A.3 1)	*Yes*	Waipu	None	Two Threatened plant species.	Avifauna: One At Risk species.	Holocene foredune, and coastal cliffs of Waiapa Complex greywacke and chert (Lux 2007).
Sandford Road Forest Remnants	Q07/142	Yes, Moderate-High (17A.3 1)	*Yes*	Waipu	None	None	None	Stream channels containing Holocene alluvium, cut into Late Pleistocene (last interglacial) constructional terrace on alluvial and/or estuarine deposits (Lux *et al.* 2007).
Tauroa Floodplain Forest Remnants	Q07/125	Yes, Moderate-High (17A.3 1)	*Yes*	Waipu	One representative vegetation type.	One Threatened plant species.	None	Terrace on Late Pleistocene (last interglacial), alluvial and/or estuarine deposits (Lux *et al.* 2007).
Blacksmith's Creek Estuary	Q07/144	Yes, High (17A.2 2)	*Yes*	Waipu	Four representative vegetation types.	One Threatened, one At-Risk and one Regionally Significant plant species.	Avifauna: One Threatened and one At Risk species.	Estuarine muddy and sandy intertiday flats and shellbanks (Lux *et al.* 2007).
Ocean Beach saltmarsh Ocean Beach swamp Indigenous vegetation on dunes - Ocean Beach	Q07/075	Yes, High (17A2.1, 17A2.2)	*Yes*	Manaia	Seven representative vegetation types.	Two Threatened, five At Risk and three Regionally Significant (of which one is a historic record) plant species.	Avifauna: Two Threatened (both historical records) and eight At Risk species. Herpetofauna: Two At Risk and one Regionally Significant species. Invertebrate: One At Risk species.	Holocene coastal dunefield of fixed and active transverse dunes and dune blowouts, with two headlands of Lower Miocene subvolcanic intrusions. Forested areas comprise coastal cliffs cut in Mesozoic greywacke and chert (Waipapa Group); Saltmarsh occupies valley floor wetland on Holocene alluvial depositsFreshwater wetlands occupy hollow on Holocene fixed sand dunes (Goldwater and Beadel 2010).
Awaroa Island	Q07/170	Yes. High. (17A.2.1)	*Yes*	Manaia	One representative vegetation type.	None.	Avifauna: Three At Risk species.	Seabird colonies on a sea stack.
Ruakaka River Estuary	Q07/130	Yes, Outstanding (17A1.1, 17A1.2), for providing habitat to numerous threatened species, including NZ fairy tern (Schedule 17B Outstanding Value species)	*Yes*	Waipu	Eleven representative vegetation types.	One Threatened and three At-Risk (one is a historic record) plant species.	Avifauna: Eight Threatened (one is a historic record) and 13 At Risk (one is a historic record) species. Invertebrates: One At Risk species. Herpetofauna: One At Risk species.	Estuarine sandy intertidal flats and channels, backed by cliffs cut in Pleistocene consolidated dune sand (Lux *et al.* 2007).
Takahiwai Saltmarsh	Q07/167	Yes, Moderate (17A.4.3)	*Yes*	Waipu	None	None	None	Holocene estuarine intertiday muddy sediments, backed by a low terrace underlain by Late Pleistocene (last integlacial) sandy estuarine deposits (Lux *et al.* 2007).
Northport Corporation Ponds	Q07/164	Yes, Outstanding (17A1.1), for providing important habitat to nationally critical Australasian bittern and grey duck	*Yes*	Waipu	One representative vegetation type.	None	Avifauna: Two Threatened, one At Risk and one Regionally Significant species.	Human-made (on Holocene dunefield).
Dune slack wetlands (McEwan Road)	Q07/131	Yes, High (17A2.2)	*Yes*	Waipu	Five representative vegetation types.	One At-Risk and two Regionally Significant plant species.	Avifauna: one Threatened species	Wetland in interdune hollow in Holocene coastal dunefield (Lux *et al.* 2007).
Dune slack wetlands (Sime Road)	Q07/141	Yes, High (17A2.2)	*Yes*	Waipu	Three representative vegetation types.	One Threatened and one At-Risk plant species.	Avifauna: One Threatened species	Wetland in hollow behind Holocene coastal dunefield.

Site Name	PNA No.	Significance, Ecological Value WDC Schedule 17	Significance NRP[1]	Ecological District	Representative Vegetation Types	Significant Flora	Significant Fauna	Special Features
Dune lake (Ruakaka Racecourse)	Q07/129	Yes, Outstanding (17A1.1, 17A1.2), for providing important habitat to numerous threatened species, including NZ fairy tern (Schedule 17B Outstanding Value species)	*Yes*	Waipu	Five representative vegetation types.	One Threatened plant species.	Avifauna: Three Threatened, seven At Risk and two Regionally Significant species.	Lake in interdune hollow on Holocene coastal dunefield.
Indigenous vegetation on dunes - Ruakaka Dunelands	Q07/128	Yes, High (17A2.1, 17A2.2, 17A2.3)	*Yes*	Waipu	Eight representative vegetation types.	Four At-Risk plant species.	Avifauna: One Threatened, five At Risk and one Regionally Significant species. Invertebrates: One Threatened species Herpetofauna: Two At Risk and one Regionally Significant species. Mammals: One At Risk (leopard seal, historical record) and one Regionally Significant species (fur seal).	Holocene coastal dunefield and beach sands (Lux *et al.* 2007).
High Island, forest	Q07/072	Yes, Moderate (17A4.2)	*Yes*	Manaia	None	Two Threatened and one At Risk plant species.	Avifauna: Four At Risk species. Invertebrates: One At Risk species.	Rocky islet comprising the eroded remnant of a Lower Miocene subvolcanic andesite intrusion (Goldwater and Beadel 2010).
Indigenous forest, Bream Head	Q07/074	Yes, Outstanding (17A1.1, 17A1.2), for providing important habitat to numerous threatened species, including North Island brown kiwi (Schedule 17B Outstanding Value species)	Yes	Manaia	38 representative vegetation types.	Eight Threatened, 14 At Risk and 27 Regionally Significant plant species.	Avifauna: Two Threatened, 14 At Risk and four Regionally Significant species. Mammals: One Threatened mammal species. Invertebrates: One Threatened, and four At Risk species. Herpetofauna: Six At Risk and one Regionally Significant species. Fish: One At Risk and Two Regionally Threatened species.	Hill country with prominent rocky pinnacles, mostly comprising part of the deeply eroded flank of a Lower Miocene andesitic stratovolcano, but with the eroded remnant of a Lower Miocene dacite dome forming the spur west of Mt. Lion (Matariki), . The area including Home Point comprises steep, bluffed coastal hills, mostly formed on an eroded Lower Miocene dacite dome, but with flank deposits of a Lower Miocene andesitic stratovolcano (all Coromandel Group) forming the northern hill. Smugglers Bay comprises eroded Holocene foredune at the back of pocket beach (Goldwater and Beadel 2010).
Indigenous forest without kauri, Manaia Scenic Reserve Indigenous forest (kauri) Manaia Scenic Reserve	Q07/069	Yes, Outstanding (17A1.1, 17A1.2), for providing important habitat to numerous threatened species, including North Island brown kiwi (Schedule 17B Outstanding Value species)	Yes	Manaia	28 representative vegetation types	Six Threatened, 16 At-Risk and 40 Regionally Significant (one of which is a historical record) plant species.	Avifauna: One Threatened, two At Risk and two Regionally Significant. Herpetofauna: Two At Risk species. Invertebrates: One Threatened and two At Risk species.	Steep, bluffed hill country with prominent rocky pinnacles, comprising part of the deeply eroded flank of a Lower Miocene andesitic stratovolcano (Coromandel Group), with much younger, unconsolidated, colluvial and landslide deposits present locally around the margins (Goldwater and Beadel 2010).
Mt. Aubrey Coastal Forest and Shrubland	Q07/070	Yes, Outstanding (17A1.2), for containing North Island brown kiwi (Schedule 17B Outstanding Value species)	Yes	Manaia	Two representative vegetation types	Four Threatened, five At-Risk and four Regionally Significant plant species.	Avifauna: Seven Threatened and one Regionally Significant bird species. Invertebrates: One At Risk species. Herpetofauna: One At Risk species.	Steep, bluffed hill country with prominent rocky pinnacles, comprising part of the deeply eroded flank of a Lower Miocene andesitic stratovolcano, with much younger, unconsolidated, colluvial and landslide deposits present locally around the margins. Darch Point (north-west of Mt. Aubrey) comprises steep coastal hillside of Lower Miocene massive, blocky andesite.

Site Name	PNA No.	Significance, Ecological Value WDC Schedule 17	Significance NRP[1]	Ecological District	Representative Vegetation Types	Significant Flora	Significant Fauna	Special Features
Timperly Road Bush	Q07/077	Yes, Outstanding (17A1.2), for containing North Island brown kiwi (Schedule 17B Outstanding Value species)	Yes	Manaia	Seven representative vegetation types.	Two Threatened and one At-Risk plant species.	Avifauna: Two At Risk and two Regionally Significant species.	Steep, isolated hill comprising the eroded remnant of a Lower Miocene dacite dome (Coromandel Group) (Goldwater and Beadel 2010).
Turikura Range Bush	Q07/073	Yes, Outstanding (17A1.2), for containing North Island brown kiwi (Schedule 17B Outstanding Value species)	Yes	Manaia	Eleven representative vegetation types.	Five Threatened, three At-Risk and four Regionally Significant plant species.	Avifauna: One Threatened, one At Risk and four Regionally Significant species. Invertebrates: One Threatened and one At Risk species. Fish: One Regionally Significant species.	Coastal hill country on eroded Lower Miocene dacite dome (Coromandel Group), with melange of Cretaceous to Oligocene sedimentary units (Mangakahia and Motatau complexes) forming the headland between Taurikura Bay and McKenzie Bay.
Wet heathlands (McDonald Road Shrublands)	Q07/068	Yes, Outstanding (17A1.1, 17A1.2) for threatened habitat type and for containing North Island brown kiwi (Schedule 17B Outstanding Value species)	Yes	Manaia	Three representative vegetation types	Three Threatened, one At-Risk and four Regionally Significant plant species.	Avifauna: Two At Risk species.	Coastal hills on an eroded, deeply weathered, Lower Miocene dacite some (Coromandel Group) (Goldwater and Beadel 2010).
Whangārei Heads Road Wetland	Q07/083	Yes, Moderate-High (17A.3 1)	Yes	Manaia	Two representative vegetation types	One At-Risk plant species.	Avifauna: One At Risk species.	Valley floor wetland on Holocene alluvial deposits (Goldwater and Beadel 2010).
Bream Islands Nature Reserve: Mauitaha Island and Guano Island, rockland and shrubland	Q07/080	Yes, High (17A2.2)	Yes	Manaia	Three representative vegetation types	Three Threatened and three Regionally Significant plant species.	Avifauna: Seven At Risk (one was a historical record) and one Regionally Significant bird species. Herpetofauna: Six At Risk and two Regionally Significant species.	Rocky islets comprising the eroded remnants of a Lower Miocene subvolcanic diorite intrusion (Goldwater and Beadel 2010).
Bream Islands Scenic Reserve: Moturaka Island and Tarakanahi Island, rockland and shrubland	Q07/079	Yes, Moderate (17A4.2, 17A4.3)	Yes	Manaia	Two representative vegetation types	One Regionally Significant plant species.	Avifauna: Six At Risk species.	Small rocky islands, formed of eroded Lower Miocene subvolcanic intrusions.
Frenchman Island, rockland and forest	Q07/171	Yes, Moderate-High (17A3.2)	Yes	Manaia	One representative vegetation type	One Threatened plant species.	Avifauna: One Threatened and two At Risk species.	Small rocky island formed of Lower Miocene dacite (Coromandel Group) (Goldwater and Beadel 2010).
High Island Stack A, rockland and forest	Q07/082	Yes, Moderate (17A4.3)	Yes	Manaia	None	One Threatened and One At-Risk plant species.	Avifauna: One At Risk species.	Rocky islet comprising the eroded remnant of a lower Miocene andesite dike (Goldwater and Beadel 2010).
Motukaroro Island, rockland and forest	Q07/071	Yes, Moderate-High (17A3.2)	Yes	Manaia	One representative vegetation type.	Two Threatened and one At-Risk plant species.	Avifauna: One Threatene and Three At Risk species.	Rocky islet comprising the eroded remnant of a lower Miocene subvolcanic andesite intrusion (Goldwater and Beadel 2010).
Rockland, Peach Cove Stack A	Q07/173	Yes, Moderate (17A4.3)	Yes	Manaia	One representative vegetation type.	One Threatened and one Regionally Significant plant species.	Not surveyed	Steep-sided rocky islet of Lower Miocene andesitic breccia (Coromandel Group) (Goldwater and Beadel 2010).
Rockland, Peach Cove Stack B	Q07/174	Yes, Moderate (17A4.3)	Yes	Manaia	None	None	None	Steep-sided rocky islet of Lower Miocene andesitic breccia (Coromandel Group) (Goldwater and Beadel 2010).

[1] Based on the significance crtieria outlined in the Proposed Northland Regional Plan.

5.3 Limitations

The following should be noted for the assessment of ecological significance at varying scales: all assessments are reliant on accurate information, such as the records for the presence of Threatened or At Risk species. The assessments provided here are on the basis of the best information available for each site, and additional investigation could result in information that increases the ranking of a site. It should also be noted that a site can, and often does, meet the criteria for significance at two or more scales (i.e. national, regional, and or local). Criteria also overlap between the criteria sets. For example, a site meets the 'rarity and distinctiveness' criteria for national significance if it contains a "locally uncommon habitat type".

6. METHODS FOR FIELD SURVEY

6.1 Overview

Following the review of literature and the existing monitoring regime, a site investigation was undertaken to provide further site-specific information to inform the assessment of ecological effects and potential new monitoring regime. This field survey included three components:

- Calcium carbonate content of freshwater habitats.
- Geology and lichen flora of a replacement control site.
- Effects of air discharges on lichens.

These components are described below.

6.2 Calcium carbonate content of freshwater habitats

Water testing of streams (Appendix 4) was undertaken at three sites to determine the calcium carbonate content, for the purposes outlined in Section 8.4.3. The sites tested were:

- A stream flowing from a wet heathland with acidic soils known as McDonald Coastal Shrubland (1735556E 6038263N).
- A stream that drains Bream Head and flows northwards across areas of acid sulphate soils to Ocean Beach (1741206E 6032339N).
- A channelised stream that flows into Blacksmith's Creek that drains coastal flats, including acid sulphate soils (1733102E 6032750N).

6.3 Geology and lichen flora of a replacement control site

The literature review identified that control and impact sites for monitoring of lichens should be of the same or similar geology, so that lichens are exposed to the same or similar degree of acid buffering provided by their substrates. However, in the existing monitoring programme, the control site has outcrops of sedimentary rocks, in contrast to the outcrops of igneous rocks at the monitoring sites (Appendix 10). Prior to the field survey, a potential new control site was therefore identified.

During the field survey, chemistry of the rocks at two existing monitoring sites (Mount Aubrey and Home Point) and the potential replacement control site (Ody Farm, northeastern slopes of Mount Manaia) were sampled and analysed for pH, acid neutralising capacity, and using the XRF Fusion technique (Appendix 3).

In addition to the chemical testing, the lichen flora at the potential replacement control site was also investigated to determine if it is an appropriate site for lichen monitoring. Investigation included a preliminary survey of the lichen flora and the identification of key indicator species.

6.4 Effects of air discharges on lichens

6.4.1 Chemical analysis

At Mount Aubrey, Home Point Upper, and the proposed replacement control site at Ody Road, 100 grams of foliage from *Parmotrema* species (wet weight) was collected and sent to Hills Laboratories for plant analysis and assessment of nickel. Full methods and results are presented in Appendix 5.

6.4.2 Assessment of lichen health at Whangarei Heads

Specimens of a range of lichen species were collected from Mount Aubrey, Home Point Upper, the proposed replacement control site at Ody Road, and from the grounds of the refinery. The collection techniques targeted the foliose and fruticose species present at each site, and included collection of material that appeared to be in good health and in poor health (if some specimens at the site had this appearance). These collections were then examined using laboratory techniques for any visual evidence of poor lichen health. Modenesi (1993) notes that common symptoms in lichens for sulphur dioxide pollution include bleaching and general thallus discolouration to brown, black, reddish, or yellow depending on lichen species. Experiments by Modenesi (1993) on *Parmotrema reticulatum* with and found that lichens exposed to sulphur dioxide developed chlorotic spots, with the edges of the lobes becoming reddish with a surface deposit of pruina - granular calcium oxalate, particularly at the lobe margins. Holopainen and Karenlampi (1984) noted that sulphur dioxide exposure resulted in damage to, and death of, green algae and cyanobacteria, which is structurally evident as surface bleaching. It should be noted that while symptoms consistent with air pollution can be assessed, a causal link between the symptoms and damage is difficult to confirm. The data set generated needs to be assessed with regards to the general patterns of damage, with regards to the modelled air discharges.

6.4.3 Assessment of lichen health in the Marsden Point area

The preliminary assessment of lichen health described above (refer to Section 8.6.5 for results), showed damage consistent with air pollution at sites close to the discharge point. As this damage occurred at sulphur dioxide levels less than the critical level for lichens on an annual basis (10 µg/m^3**),** lichen health in relation to maximum 24 hour averages for sulphur dioxide was further investigated for cortiolous (bark-dwelling) lichens at four sites in the Marsden Point area. The four sites spanned a concentration gradient for sulphur dioxide as follows:

- Grounds of refinery: *c*.81 µg/m^3 predicted maximum 24 hour average for sulphur dioxide.
- Rama Road: *c*.51 µg/m^3 predicted maximum 24 hr average for sulphur dioxide.
- Ruakaka River estuary margins, by Weka Street: *c*.21 µg/m^3 predicted maximum 24 hour average for sulphur dioxide.
- Ruakaka Beach Reserve: less than 21 µg/m^3 predicted maximum 24 hour average for sulphur dioxide (beyond modelled extent of receiving environment).

Ten specimens of *Parmotrema* species, and 10 specimens of *Ramalina celastri*, were collected from trees, *c*.1.5 metres above ground level, at each of the four sites. The first specimen of each species found on each tree was collected, without selection on the basis of appearance. An additional genus, *Heterodermia*, was present in the grounds of the refinery and at Ruakaka Beach Reserve, and was collected and analysed for these two sites.

Each specimen was examined and scored using to the following categories:

0 = normal morphology.
1 = Minor effects (slight bleaching).
2 = Moderate effects - significant bleaching, black spots, reproductive suppression.
3 = Significant effects - extensive bleaching, development abnormalities (e.g. lobules and soredia in wrong place), pruina production**.**

Data was presented graphically using histograms of damage score frequency.

7. THE RE-CONSENTING PROPOSAL

7.1 Overview

Refining NZ presently undertakes a number of activities at the Site. The Company is seeking to continue most of the resource consents necessary for the Refinery to exist and operate (referred to as '**the Proposal**' in the remaining sections of this report). This section of the report sets out the various operations and activities that are undertaken by Refining NZ at the Site.

7.2 Refining operations

The Refinery presently received and processes over 40 million barrels of crude oil per year. That crude oil is sourced from a number of different locations and suppliers and is delivered to the Site via ship. The Refinery produces a number of products, which include:

- Gasoline.
- Jet fuel A1/ Dual purpose kerosene.
- Diesel.
- Fuel oil.
- Bitumen.
- Sulphur.
- Carbon dioxide.

7.3 Refinery processes and discharges to air

Processes carried out in the Refinery are covered in detail in the accompanying Assessment of Environmental Effects, and summarised below:

- Separation: Shortly after being pumped ashore and stored in above-ground storage tanks, the crude oil is separated in process units via distillation.

- Conversion: Seperated crude oil is converting, via chemical reactions, to higher grade products, including sulphur products, bitumen, gasoline, diesel, and kerosene.

- Purification: Purification of a product may be required at any stage after separation to meet a final quality specification.

In association with these processes, there are five types of discharges from the Refinery to air. This section now addresses where those discharges are from and discusses the compounds/elements that are discharged. We also set out the management regime that the Company has adopted to ensure that any adverse effects associated with the discharges to air are minimised.

7.3.1 Sources of the discharges

There are five key discharges to air from the Site, being:

- From the furnaces that are used to heat the crude oil and intermediate products. These furnaces are fuelled with gas, fuel oil and asphalt, the combustion of which causes the emission of contaminants to air;

- Fugitive emissions from various activities[1] that are undertaken on the Site;

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[1] Including the crude distillation units, the high vacuum unit, the depropaniser, the butane deasphalting unit, the hydrocracker complex, the hydrogen manufacturing unit, the naphtha hydrotreater, the gasoil desulphuriser, the kerosene desulphuriser, the di-isopropanol amine treaters, the high vacuum unit / bitumen blowing unit, the sulphur recover units, the steam-raising boilers, the sour water strippers and the shell claus offgas treatment unit

- From the flaring of gases from the flare stacks. Flaring serves two purposes, being to safely burn gases that are emitted in an upset/emergency situation and/or excess gases. While Refining NZ operates with the objective of avoiding flares, they are an essential tool for responding safely to upsets and emergencies and thus need to be incorporated as part of the Proposal for which consent is sought;
- Smoke from the fires started (under controlled situations) to enable the training of firefighters (being those employed by the Refinery and the volunteer firefighters). All such exercises are undertaken in a dedicated training ground on the Site; and
- From sand/particle blasting activities that occur as part of the recurrent maintenance activities that are undertaken on site.

7.4 Management approach

As it has with its stormwater discharges, Refining NZ has implemented a number of management strategies to minimise the effects of its discharges to air. Those strategies include:

- Extending the durations between shutdowns at the Refinery. This has the effect of reducing the amount of catalysts that are used on the Site, which in turn minimises the times when a flare is required;
- All flares are monitored via a television link, and remedial measures are taken to minimise any smoke effects that arise;
- All vessels visiting the Refinery are advised of the Site's smoke minimisation requirements and the need for them to comply with those requirements;
- Operating an effective complaints system, which includes a hotline that operates for 24 hours of each day, 365 days of the year; and
- Actively working to minimise the smoke that is emitted as a consequence of the firefighting exercises. This includes burning only light hydrocarbon fuels, no longer undertaking ground fire practice, minimising the 'burn time' of the exercises, and no longer using authentic smoke in breathing apparatus training that is conducted at the Refinery. Refining NZ also only undertakes exercises during certain wind conditions to minimise impacts on surrounding nearby communities.

8. ASSESSMENT OF POTENTIAL EFFECTS ON TERRESTRIAL ECOLOGY

8.1 Background

An ecological assessment of effects is required when a proposed activity has the potential to affect ecosystems or their components. In the case of this application, it is recognised the air discharges from the Refinery have the potential to affect terrestrial ecosystem components of the surrounding environment, including soils, vegetation (including vascular and non-vascular plants and lichens), and fauna. The monitoring undertaken to date has not found any detectable change in lichens, soils, or chemistry of foliage that can be attributed to the Refinery's air discharges (Wildland Consultants 2017a, b, c; 2019a, b, c), and the re-consenting proposal is for a continuation of the currently-consented discharges. Given this, it is necessary to determine the potential level of adverse ecological effects and how these could be avoided, remedied, or mitigated in accordance with relevant statutory requirements, as required (refer to Section 8.8).

This assessment of ecological effects has been undertaken with consideration of assessment methods commonly referred to in New Zealand, such as the EIANZ (2018) Assessment Guidelines (Roper-Lindsay *et al.* 2018). The overall level of effects has been determined by considering the characteristics of the ecosystems within the receiving environment, pollutant concentrations, magnitude of effect, and proposed management, if any is required.

8.2 Approach

8.2.1 Overview

The terrestrial ecology of the identified receiving environment is relatively well-known, with extensive information outlined in the PNAP survey reports for the Manaia and Waipu Ecology Districts by Goldwater and Beadel (2010) and Lux *et al.* (2007) respectively (Section 4). For the purposes of this assessment, it was therefore generally considered that further field surveys to identify, map, and describe ecological values with regards to the air discharges would be of limited value. As outlined in Section 6, a field study was undertaken, with primary purposes of testing any assumptions regarding the potential sensitivity of the receiving environment, and testing the rationale for any changes to the existing monitoring regime.

The approach taken for the ecological assessment of effects aimed to establish the following:

- Potential adverse effects of sulphur dioxide, sulphur, nitrogen oxides, and nitrogen on terrestrial ecology.
- What level of pollutant discharge would cause these adverse effects, relative to ecosystem type and species groups present in the receiving environment?
- Whether the proposed discharges of pollutants from the Marsden Point Refinery are likely to exceed the levels at which adverse effects on terrestrial ecology may occur, including cumulatively over time.

In 1988, the UNECE Workshop on Critical Loads for Sulphur and Nitrogen in Skokloster, Sweden defined critical levels and loads as follows:

- **Critical levels:** The concentrations of pollutants in the atmosphere above which direct adverse effects on receptors such as plants, ecosystems or materials, may occur according to present knowledge.

- **Critical loads:** A quantitative estimate of an exposure, in the form of deposition, to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge.

8.2.2 Levels of potential effects for ecosystems

This assessment of the potential effects (magnitude and level) was primarily undertaken at an ecosystem level using published critical levels and critical loads for potentially affected terrestrial ecosystems. Stevenson *et al.* (2000, Page 40) note that the following is important for an assessment of effects:

"critical levels and critical loads address different effects, and compliance with one doesn't necessarily imply compliance with the other"

and

"critical loads for acidity and nitrogen vary depending on the ecosystem, whereas critical levels for sulphur dioxide, NOx and ammonia are set for all systems. Accordingly, ambient concentrations and annual deposition rates must be estimated and compared separately with the respective critical levels and critical loads to assess the likelihood of possible effects of air pollutants on any ecosystem".

The critical loads for ecosystems are based on

"detectable changes in structure and function of ecosystems and are intended to define loads below which any change is unlikely. They are derived from "data obtained from experimental and observational studies, and or dynamic ecosystem models calibrated with available data" (Stevenson et al 2000 p. 31).

This basis for determining critical loads has two important implications to note.

- Firstly, as critical loads are based on the pooling of data from multiple sources, critical loads are more reliable, and should be given greater weight in the assessment, than the threshold at which any one study documented an adverse effect.

- Secondly, the inherent uncertainty of critical loads needs to be recognised. The critical loads that have been published, and applied here, are based on European ecosystems. Critical loads may also be influenced by factors such as degree of human modification of the ecosystem, and local climate and soil (Stevenson *et al.* 2000). The use of critical loads for assessment of adverse effects on ecosystems should always use a conservative approach.

The following approach was therefore used to describe the level of potential adverse effects:

- Where the modelled concentrations of pollutants (from the discharge and ambient levels combined) are well below the critical load or critical level for an ecosystem at a site, the magnitude of effect was identified as 'negligible' as change is barely distinguishable and approximates a “no change” situation (or less than minor effect). If the magnitude of effect is negligible, the level of effect is also negligible, regardless of the ecological value of the ecosystem being assessed (i.e a negligible effect on both a low or high ecosystem results in a negligible level of effect).

- If the modelled concentration of pollutants (from the discharge and ambient levels combined) is close to the critical load or critical level for an ecosystem at a site, the magnitude of the effects and the value of the ecosystem was used to determine the level of the effect. To recognise uncertainty in modelled data, and incomplete knowledge of the ecosystems, a conservative approach is used if the modelled pollutants are close to but still below critical loads or critical levels. If this occurs, the magnitude of effect has been regarded as ‘low’ and “a minor shift away from baseline conditions”. The magnitude of effects has then been assessed with regards to the ecological value of the affected ecosystem (i.e. a low magnitude of effect on a “high” or “very high” value ecosystem is identified as a ‘moderate’ level of effect, and for ecosystems of “moderate” or low” ecological value are identified as “Low”.
- A method to identify level of effects for where pollutants met or exceeded the critical load for an ecosystem was not developed as this situation did not arise.

8.2.3 Identification of level of effects for species or species groups

With only a few exceptions, where critical loads or critical levels have been estimated for species or species groups particularly sensitive to pollutants (e.g. lichens), there are no published critical loads or critical levels to apply at a species or species group level (i.e. a critical level for avifauna or invertebrates). The approach described above has been applied where critical loads or critical levels have been published. Where critical levels or loads are based on individual studies that determined thresholds for an adverse effect, these are identified, acknowledging the greater uncertainty of this approach. A conservative approach was also applied for determining the level of effect on a species or species group, as per the method for ecosystems.

8.3 Potential adverse effects of SO_2 and NO_X on terrestrial ecology

8.3.1 Sources of SO_2 and NO_X

Sulphur dioxide (SO_2) and nitrogen oxides (NO_x) enter the atmosphere primarily through the combustion of fossil fuels (Driscoll *et al.* 2003). They are more harmful in combination than when present on their own (Committee on the Atmosphere and the Biosphere Board on Agriculture and Renewable Resources Commission on Natural Resources 1981). In contact with atmospheric moisture they form acids, which can fall to the ground as “acid rain”. Sulphur dioxide and nitrogen oxides can also enter ecosystems through dry deposition (Hoffmann *et al.* 2000).

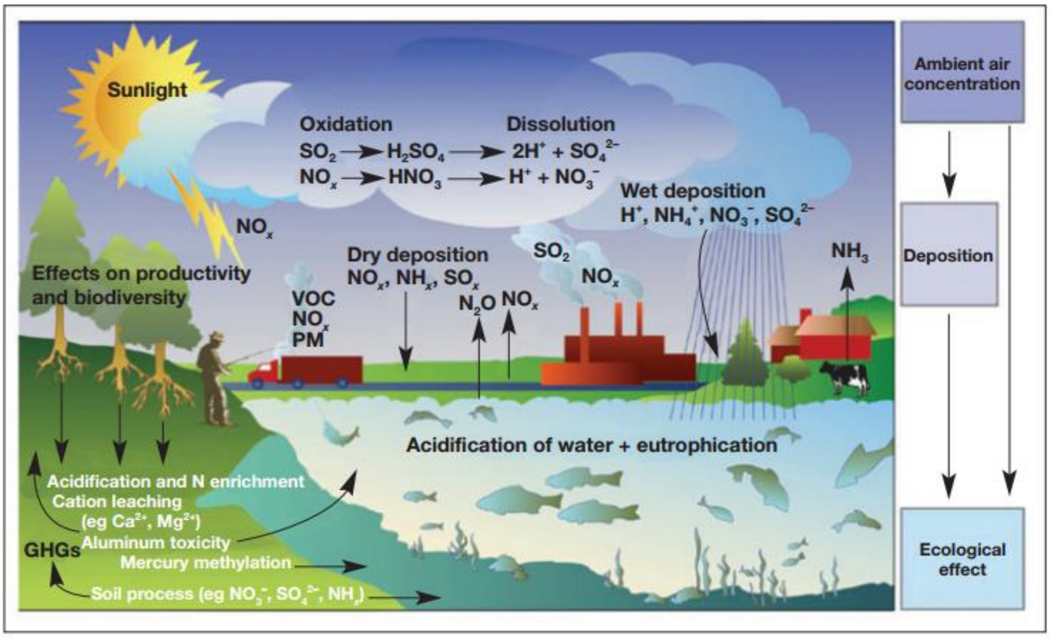

Figure 1. *Simplified diagram of the ecological effects caused by nitrogen and sulfur air pollution. VOC = volatile organic compound; PM = particulate matter; GHGs = greenhouse gases.*

Source: Figure is from Greaver *et al.* (2012).

8.3.2 Effects of sulphur dioxide and sulphur on plants and ecosystems

Sulphur dioxide (SO_2) mainly enters plants through leaf stomata, after which it is rapidly translocated through the plant where it affects photosynthesis, transpiration, and respiration. Net photosynthesis and transpiration may increase at low sulphur dioxide concentrations for short time periods, followed by a decrease in both the processes over time. High sulphur dioxide concentrations cause immediate decreases in these processes. Sulphur dioxide readily dissolves in the intercellular water to form sulphite (SO_3^{2-}) and bisulphite (HSO_3^-). These may be toxic to plants as they affect many biochemical and physiological processes.

Plant metabolism is affected by sulphur dioxide in a variety of ways including reduction in foliar chlorophyll concentration and damage can manifest as leaf chlorosis (yellowing of the leaves) and dead spots on leaves. Carbohydrate concentrations can be increased by low levels of sulphur dioxide and decreased by higher levels. The activity of enzymes may be increased or decreased by exposure to sulphur dioxide at different concentrations (Landis and Ho Yu 2004).

In plants and plant communities, resistance to sulphur dioxide pollution varies according to the plant species, the plant's stage of development, and other external factors such as soil, season, and temperature. These differing degrees of sensitivity can result in changes in interspecies competition, reduced abundance of sensitive taxa, and or the alteration of the structure and function of the community. Compared to woody species, herbaceous species can take up more sulphur dioxide per unit of biomass before adverse effects occur (Stevenson *et al.* 2000).

Metabolism of sulphur dioxide in the plant creates acidic conditions within plant tissues. In order to maintain internal pH, uptake of base cations from soils, and release of hydrogen ions into soils, is required. Soil acidification can occur in sites with low acid neutralising capacity and may decrease the supply and availability of base cations from the soil, adversely affecting both nutrient balances and the plant's ability to maintain internal pH (Stevenson *et al.* 2000).

The highest rates of sulphur dioxide uptake via stomata occur when moderate to high light conditions coincide with high plant water availability and low water vapour pressure deficits in the air. Stomatal transfer is limited under conditions of water deficit and at high temperatures. Consequently, stomatal opening and sulphur dioxide uptake may be greatest during winter, when ambient sulphur dioxide concentrations can be at their highest (Stevenson *et al.* 2000).

Various international studies have demonstrated the effects of sulphur dioxide on plant communities, for example:

- Conifer forests near a nickel and copper smelter in Russia have vanished, while those slightly further away have been damaged, due to emissions of sulphur dioxide and heavy metals (Zvereva and Kozlov 2000).

- At Wawa, in northern Ontario, vegetation has been severely damaged by sulphur dioxide pollution from an iron-sintering plant. The number of ground flora species declines markedly when approaching the pollution source, with a corresponding increase in sulphate in lake and pond waters and soluble sulphate in the surface soil (Gordon and Gorham 1963).

- Metabolism of both broadleaved and coniferous trees is influenced by sulphur dioxide, resulting in decreased photosynthesis and accelerated ageing of leaves and needles (Mohren *et al.* 1992 and references therein).

- Mohren *et al.* (1992) found that at average daily sulphur dioxide concentrations of $10 \mu g/m^3$, the short-term effects on growth of Douglas fir appeared to be minor, except near local sources and when episodes of high concentrations occurred under stable weather conditions.

- Cover of a few bryophyte species showed a clear response to nitrogen and sulphur deposition during 14 years of monitoring in a forest ecosystem, but for the bryophyte community as a whole the response was weak and ambiguous (Zechmeister *et al.* 2007).

8.3.3 Effects of nitrogen dioxide and nitrogen on plants and ecosystems

Nitrogen dioxide (NO_2) absorbed through the stomata is converted to NO_3^- and NO_2^- before being metabolised. NO_2 injury to plants may be due to either acidification or a photooxidation process. Symptoms exhibited by plants exposed to NO_2 are similar to those from sulphur dioxide, but much higher concentrations are required to cause acute injury. However, decreased photosynthesis has been demonstrated even at concentrations that do not produce visible injury.

Currently no *in situ* studies have demonstrated a significant toxic effect associated with dry deposition of NOx on semi-natural ecosystems at realistic ambient concentrations. However, sulphur dioxide may disrupt the detoxification rate of nitrite within plants and at elevated levels of both NO_X and SO_2, plants are subject to simultaneous damage by both nitrite and sulphite in various ways.

The species or species groups that are most sensitive to nitrogen deposition are those that are adapted to low fertility environments, where they have a competitive advantage over species that demand higher fertility enviroments. Adverse effects of nitrogen could therefore include shifts in the species composition of a receiving environment (e.g. declines in species that prefer low fertility environments such as mosses, lichens, heathland plants, and increases in species that generally favour higher fertility environments such as grasses) (Stevenson *et al.* 2000, Zechmeister *et al.* 2007).

8.3.4 Effects of sulphur dioxide and nitrogen dioxide on fauna

A literature review on potential effects of the air discharges on invertebrate and vertebrate fauna has been undertaken and is presented in detail in Appendix 6.

Overall, more studies have been undertaken on the effects of sulphur dioxide and nitrogen dioxide on invertebrates. Australian ant communities are strongly affected by sulphur dioxide in soil, while the abundance of earthworms, rove beetles, money spiders, carabid beetles, and amaurobiid spiders has been related to soil sulphur concentrations, although these were confounded by differences in vegetation. Acid rain can cause soil changes that affect a wide range of soil invertebrates, and moderate concentrations of sulphur dioxide and nitrogen dioxide may worsen the effects of sap-sucking insects on plants. Sulphur dioxide and nitrogen dioxide may affect the abundance of some invertebrates indirectly, by affecting the abundance of their natural enemies. Some insects may be resistant to the direct effects of contaminants because of low rates of cellular division. There is evidence of sulphur dioxide effects on rotifers, tardigrades, nematodes and on arthropod community composition and diversity.

A summary of the effects of pollutants on fauna, and levels at which adverse effects have been documented, is provided in Table 9.

8.4 Critical levels and loads of pollutants for terrestrial ecosystems

8.4.1 Critical levels for nitrogen oxides and sulphur dioxide

Critical levels for nitrogen oxides and sulphur dioxide in air (UN Economic Commission for Europe (UNECE) Convention on Longrange Transboundary Air Pollution (LRTAP)) are set out in Tables 10 and 11 below. The New Zealand Ministry for the Environment (2002) note that whilst the critical load/critical level concept is internationally accepted and applicable to New Zealand, the UNECE/WHO guidelines are based on research undertaken in Europe, in environments subject to high levels of human modification over many centuries. Application of these guidelines needs to take into account the possibility that critical loads and critical levels may differ in New Zealand, and consider any information relating specifically to the New Zealand region. Stevenson *et al.* (2000) state that for New Zealand ecosystems the critical level should be an annual mean of 30 $\mu g/m^3$ for nitrogen oxides, and an annual mean and winter mean of 20 $\mu g/m^3$ for sulphur dioxide.

Table 9: Summary of literature on pollutant effects on fauna.

Study Type	Taxon	Pollutant	Concentration Tested in Study	Concentration at Which Adverse Effect Observed	Description of Adverse Effect	Reference
Lab	Mouse	NO_2	0.5 - >5 ppm (940->9,400 µg/m^3) over 21 weeks	>5ppm (9,400 µg/m^3)	Loss of cilia and ciliated cells.	Graham *et al.* (1997).
				0.5-2 ppm (940-3,760 µg/m^3)	Changes in macrophages.	
Field	Mouse	SO_2	16-974 µg sulphur dioxide/m^3	Effect observed at polluted site (high concentration) and not at control site (low concentration)	Inflammatory processes and/or infection, behavioural changes e.g. reduced food and water intake, changes in cell type in tracheal epithelia.	Gorriz *et al.* (1996), Llacuna *et al.* (1993).
		NOx	0-50 µg nitrogen oxides/m^3			
Field	Bird	SO_2	16-974 µg sulphur dioxide/m^3	Effect observed at polluted site (high concentration) and not at control site (low concentration)	Decrease weight, inflammatory processes and/or infection, liver disease, possible changes in epithelial cilia.	Llacuna *et al.* (1996), Llacuna *et al.* (1993).
		NOx	0-50 µg nitrogen oxides/m^3			
Lab	Sheep	NO_2		5 ppm (9,400 µg m^{-3})	Pulmonary immune response adversely affected.	Graham *et al.* (1997).
Field	Ant	SO_2	70-120 mg sulphur dioxide/kg dry soil	Increased effect correlated with increased pollutant	Lowered abundance and species richness.	Hoffmann *et al.* (2000).
Lab	Bee	SO_2	0.14 and 0.28 ppm (367-734 µg/m^3) within controlled lab over several weeks	No critical value reported.	Reduction in activity at both treatment levels compared to control experiments without SO_2 input.	Ginevan *et al.* (1980).
Lab	Wasp	SO_2	3 ppm (7,860 µg/m^3) for 3 and 5 hours	No adverse effect observed.	No measurable effects on mortality or reproductive output.	Petters and Mettus (1982).
Lab	Wasp	SO_2	Fumigations of up to 100 nl l^{-1}	No adverse effect observed.	No measurable effect on ability to find prey.	Gate *et al.* (1995).
		NOx				
Field	Soil microarthropod	SO_2	Between 1 - 9 µg/m^3 per year over years tested	Sulphur concentration in test soil cores ranged from 41.75 to 65.43 mg kg^{-1}	Reduction in the total number of decomposers, compared to control sites.	Bressan and Paoletti (1997).

Study Type	Taxon	Pollutant	Concentration Tested in Study	Concentration at Which Adverse Effect Observed	Description of Adverse Effect	Reference
Field	Beetle	SO_2	SO_2 1.00 - 1.61×10^8 kg per year	Gradual increase in effect correlating with increase in pollutants. No critical values reported.	Parasitism rates higher at higher pollution levels near smelter. Egg and larval predation lower at higher pollution levels near smelter. Total beetle mortality caused by natural enemies higher in non-polluted sites.	Zvereva and Kozlov (2000).
		Nickel	3.2 - 4·0×10^6 kg per year			
Field	Grassland soil invertebrates	SO_2		245-1,030 µg/m^3	Estimated threshold levels for significant injury.	Lauenroth and Preston (1984).
Field	Soil-dwelling macro-invertebrates	soil sulphur	146, 345 (controls), 555, 2982, 6673 mg sulphur/kg soil	No critical value reported.	Absence of earthworms, lowered abundance/activity of rove beetles, money spiders, and two carabid species in higher sulphur soil levels.	Carcamo *et al.* (1998).
Field	Soil-dwelling macro-invertebrates	acidic (SO_4^{2-} and NO^-) deposition	SO_4 86-year cumulative: 81.5 88.1, and 101.9 kg/ha/year NO_3 30-year cumulative: 26.3, 31.4, and 35.8 kg/ha/year	Gradual increase in effect correlating with increase in pollutants. No critical values reported.	Lowered abundances of several groups.	Kuperman (1996).
Lab	Moss-dwelling invertebrates	SO_2	0.025 to 0.225 ppm (66-590 µg/m^3) within controlled lab over 18 months	Stronger effect observed in 0.225 ppm concentration compared to lower treatments.	Decrease in abundance and diversity of rotifers, tardigrades, and nematodes - potentially due to reduction in food resources.	Steiner (1995b).

Table 10: Critical levels for nitrogen oxides in air (UN Economic Commission for Europe (UNECE) Convention on Longrange Transboundary Air Pollution (LRTAP)) (Mills *et al.* 2017).

Group	Critical Level (Expressed as NO_2)	Averaging Period
All ecosystems[1]	30 µg/m^3	Annual
All ecosystems[1]	75 µg/m^3	24-hour mean

1 A quantitative differentiation between ecosystem sensitivities is uncertain, but the UNECE have proposed that natural and semi natural ecosystems are the most sensitive to nitrogen oxide levels, followed by managed forests, and then agricultural crops.

Table 11: Critical levels for sulphur dioxide in air for UN Economic Commission for Europe (UNECE) Convention on Longrange Transboundary Air Pollution (LRTAP)) (Mills *et al.* 2017) and for New Zealand ecosystems (Stevenson *et al.* (2000))

Group	Critical Level	Averaging Period (UNECE)	Averaging Period (New Zealand)
Lichens	10 µg/m^3	Annual mean	Annual mean
Forests	20 µg/m^3	Annual mean and Half-year mean (October-March)	Annual and winter mean
Semi-natural vegetation	20 µg/m^3	Annual mean and Half-year mean (October-March)	Annual and winter mean
Agricultural crops	30 µg/m^3	Annual mean and Half-year mean (October-March)	Annual and winter mean

8.4.2 Critical loads for nitrogen deposition

Critical loads for nitrogen deposition in British ecosystems are provided by APIS (2019) and the UNECE and WHO (Stevenson *et al.* 2000). Critical loads range from 5 kg N/ha-year for the most sensitive ecosystems, e.g. bogs, heathlands, alpine habitats, conifer-dominated forests, to 30 kg N/ha-year for the least sensitive ecosystems, e.g. saltmarshes, fertile wetlands, lowland meadows. A full summary of the critical loads for relevant habitats is provided in Appendix 6.

Current expert opinion suggests that for most New Zealand ecosystems with low nitrogen supply background levels of nitrogen inputs are about 1-5 kg N/ha-year, and that significant changes in New Zealand ecosystems may not occur below total nitrogen inputs of about 5 kg N/ha-yr (Stevenson *et al.* 2000).

8.4.3 Critical loads for acid deposition

Soils and ecosystem acidification in New Zealand in unlikely, based on the acid-neutralising capabilities of soils, and possible ranges of acid deposition. Stevenson *et al.* (2000) present critical loads for New Zealand catchments that are likely to have limited sources of alkalinity, and or low levels of alkalinity in their draining waters (Table 12). The lowest critical load for a catchment was 721 equiv/ha-year, for a stream with 13 g/m^3 as $CaCO_3$, Stevenson *et al.* (2000) state that:

"critical loads for acidity can be ignored unless it is known that the area requiring protection is likely to be sensitive to acid deposition, as indicated by very low levels of alkalinity in water draining from an area (for example less than 10mg/l as calcium carbonate)."

Table 12: Estimation of critical loads for acidity from catchment discharges in New Zealand (Stevenson *et al.* 2000).

Catchment	Alkalinity		Drainage Yield m/yr	Catchment Critical Load Equiv/ha-yr
	g/m^3 as $CaCO_3$	Equiv/m^3		
Haast, Roaring Billy	30	0.61	6.0	36,535
Opuha River, Skipton, Tekapo	17	0.35	0.7	2,263
Dunedin, Sutton Stream	13	0.25	0.3	721
Monowai, control gates	12	0.24	1.8	4,192
Buller River	23	0.47	1.7	7,903
Grey River, Dobson	16	0.32	3.0	9,471
Motueka River, Woodstock	41	0.81	1.1	8,670
Wairau River Tuamarina	20	0.40	1.1	4,260
Hutt River, Te Marua	19	0.38	1.1	4,180
Hunua lakes	14	0.28	1.3	3,640
Waikato River, Taupo	38	0.75	1.0	7,540

8.5 Critical pollutant loads and levels for individual taxa

The guidelines for critical loads and levels in Tables 10-13 are largely ecosystem-focused and, except for lichens (Table 11) and trees (Table 13), do not specify levels for species, or even species groups.

8.6 Effects of historic air discharges on terrestrial ecology

8.6.1 Approach

Baseline data for the presence and abundance of indicator species is not available for the oil refinery discharge. A brief assessment of the likely historic effects of the oil refinery discharge (1964-present) is therefore based on the following:

- Predicted concentrations of pollutants relative to the expected background levels for rural and urban environments in New Zealand.
- Diversity, chemistry and health of lichen communities within the receiving environment of the air discharge, and at a site beyond the extent of the air discharge, with particular reference to species known to be sensitive to air pollution.

8.6.2 Nitrogen dioxide and sulphur dioxide

Stevenson *et al.* (2000) provide a range of annual sulphur dioxide and nitrogen dioxide concentrations for sites across New Zealand that include urban and rural environments.

Sulphur dioxide ranges from less than 1 µg/m^3 at remote rural sites such as Arthurs Pass and Baring Head (0.6 and 0.8 µg/m^3 respectively), 0.9 µg/m^3 in smaller cities (e.g. Whangārei) to 5.5 µg/m^3 in larger cities (e.g. Christchurch).

Nitrogen dioxide ranges from less than 2.0 µg/m^3 at sites such as Arthurs Pass and Baring Head (1.7 and 1.8 µg/m^3 respectively), to 9.4 µg/m^3 in smaller cities (e.g. Whangārei) to 19.7 µg/m^3 in larger cities, e.g. Mount Eden, Christchurch.

The background annual ambient concentration for the receiving environment used for this assessment is 1.0 µg/m^3 for sulphur dioxide and 4 µg/m^3 for NO_2 (Tonkin and Taylor 2019).

Most of the receiving environment (i.e. further than two kilometres from the discharge point) is predicted to be exposed to less than 3.5 µg/m^3 for SO_2, and 5.0 µg/m^3 for NO_2, as an annual average, including both ambient concentrations and refinery discharges. These concentrations are similar to what can be expected in New Zealand for rural areas and smaller towns and cities such as Lincoln (3.3 µg/m^3 for SO_2) and Rotorua (3.3 µg/m^3 for NO_2) (Stevenson *et al.* 2000).

Within two kilometres of the oil refinery, the sum of the ambient concentration and discharge concentrations peaks at c. 5.0 µg/m^3 for SO_2 and c. 6.5 µg/m^3 for NO_2 as an annual average. For SO_2, this peak is higher than annual average concentrations for Invercargill or Rotorua (3.3 µg/m^3) and similar to that for Christchurch (5.5 µg/m^3). For NO_2, this peak is lower than all towns and cities listed by Stevenson *et al.* (2000), with annual concentrations for NO_2 ranging from 5.6 µg/m^3 at Lincoln, to 19.7 µg/m^3 in Mount Eden, Auckland (Stevenson *et al.* 2000).

Stevenson *et al.* (2000) note that even within urban areas that New Zealand SO_2 concentrations do not exceed the WHO (1996) critical level guidelines, and conclude that sensitive ecosystems are unlikely to be subject to "significant direct effects" in urban areas. Given that the peak concentration for SO2, combining the ambient and discharge concentrations is within the range expected for rural and urban areas, a significant historic effect of the existing discharge on ecosystems is unlikely.

8.6.3 Nitrogen deposition

Stevenson *et al.* (2000) noted that typical nitrogen loads in New Zealand forests are in the range of 1-5 kg N/ha/year, and the predicted background deposition rate for the receiving environment of the discharge is 1.15 kg N/ha/year (Tonkin and Taylor2019). However, for agricultural land with applications of nitrogen as part of pasture management, nitrogen deposition can be 25 kg/ha/year or more[1]. Where sites are within or on the boundary of pasture that receives fertiliser inputs, any nitrogen deposition attributable to discharge from the Refinery is likely to be a very small percentage of the overall nitrogen load, and consequently unlikely to have resulted in any detectable effects for indigenous ecosystems.

8.6.4 Sulphur deposition

Historic sulphur deposition, from the ambient sulphur loads and the air discharge combined, has not resulted in higher levels of soil sulphur at the monitored impact sites (Wildland Consultants 2019f).

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[1] A one-off application of nitrogen rich urea at 50 kilograms per hectare will provide 25 kilograms of nitrogen per hectare (Farmlands 2019).

8.6.5 Lichen diversity, chemistry, and health

The existing diversity and health of lichen communities, both within and beyond the receiving environment, can be used as an indication of the likely historic effects of discharges from the Refinery. This assessment draws on the results of the biannual quantitative lichen monitoring, as discussed in Section 9, and site investigations as described in Section 6.

Biannual Quantitiative Lichen Monitoring

Biannual monitoring of lichens confirms the presence of species sensitive to air pollutants at sites within the receiving environment of the discharge (Wildland Consultants 2017a, 2019a). For example, in 2018, *Pseudocyphellaria crocata* was present at Mount Aubrey, Home Point Upper, and Castle Rock, which have sulphur dioxide concentrations of 2.50-.50, 1.50-2.00, and *c*.3.00 µg/m^3 respectively, and at the proposed replacement control site at Ody Road (1.50 µg/m^3). The legacy effects of the proposed discharge allow for the persistence of sensitive lichen species at the monitoring sites in the Manaia Ecological District.

Chemical Composition

Sulphur concentration in the lichen tissue sampled was 0.13, 0.13 and 0.10% for Mount Aubrey, Home Point Upper, and Ody Road respectively, and nickel was 4.7, 3.3, and 12.7 mg/kg dry weight respectively. The similarity between sites of higher and lower sulphur dioxide concentration suggests that the existing discharge is unlikely to have resulted in elevated levels of sulphur in lichen tissue. The two sites within the receiving environment that were tested for nickel in lichen tissues had lower concentration of nickel than the proposed control site.

Health at Whangarei Heads and Refinery Grounds

Laboratory analysis of lichen tissues suggests that damage to lichens from the discharge may be occurring, and if so, is more frequent at the site of the discharge, where concentrations of pollutants reach their peak (Appendix 7). *Parmotrema* species were present at all four sites. The specimens collected from the refinery grounds (*c*. 3.5 µg/m^3 annual mean for sulphur dioxide, and *c*.81 µg/m^3 predicted maximum 24 hour average for sulphur dioxide[1]) showed a higher frequency of symptoms attributable to damage from air pollutants than the specimens from Home Point Upper (*c*.2.50 µg/m^3, *c*.60-80 µg/m^3 predicted maximum 24 hour average) and Mount Aubrey (2.00 µg/m^3 *c*.60-80 µg/m^3 predicted maximum 24 hour average)[2]. The *Parmotrema* specimens collected from Ody Road, at the boundary of the receiving environment, did not show any symptoms consistent with air pollution.

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1 Inclusive of the predicted ambient concentration of 1 µg/m^3 sulphur dioxide.

2 If the minor damage observed at Home Point and Mount Aubrey is attributable to air pollution, the likely adverse effects of this are less than minor. The low frequency of damage at these sites, relative to the Refinery grounds, raises questions as to whether the damage seen here is simply natural levels of damage (and not related to the discharge).

Health at Marsden Point Along a Discharge Concentration Gradient

Frequency of damage scores along a discharge concentration gradient from Marsden Point to Ruakaka are presented in Figure 6. Raw data is presented in Appendix 7. Lichens had the highest frequency of damage near the point of the discharge, within the grounds of the refinery. At this site, no lichen specimens had “normal morphology”, and the most common damage class for both *Parmotrema* and *Ramalina celastri* was “significant effects” (eight out of 10 and seven out of 10 specimens for *Parmotrema* and *Ramalina celastri*, respectively). At Rama Road, one kilometre to the southwest of the discharge point, no specimens were assessed as having the highest damage class of “significant effects”, and the most frequent damage class was “minor effects” (six out of 10 and five out of 10 specimens for *Parmotrema* and *Ramalina celastri*, respectively). It should be noted that the current lichen flora of habitats in or immediately adjacent to the refinery grounds is dominated by common lichen species that are characteristic of highly modified environments.

Key differences in damage were evident between the site in the refinery grounds and the three sites one kilometre or more from the plant at Rama Road. The frequency distributions for the sites exposed to *c.*41, *c.*21, and less than 21 µg/m^3 predicted maximum 24 hour average are similar, suggesting that the extent of a detectable effect on lichen communities is restricted to habitats within one kilometre of the discharge point.

Lichen health assessments showed a similar pattern for abnormalities and presence of particulates at the four study sites, and no clear pattern for the frequency of bleaching (Appendix 8).

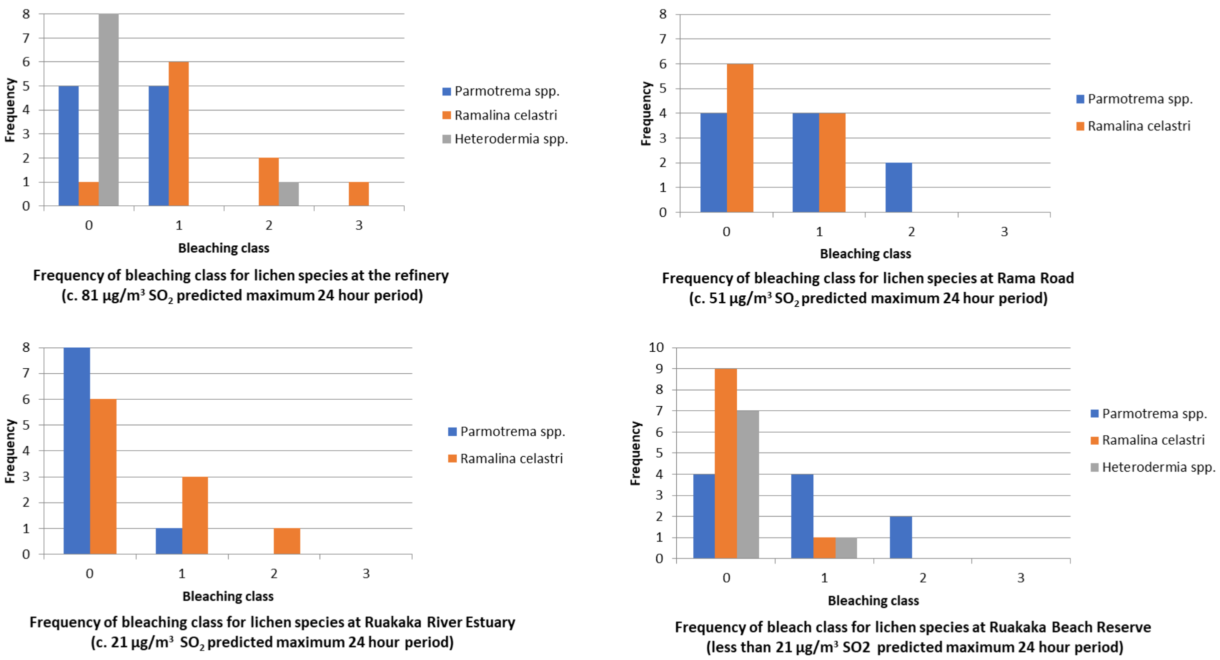

Figure 6: Frequency of lichen damage classes along a discharge concentration gradient from Marsden Point to Ruakaka.

8.6.6 Summary

The concentration of sulphur dioxide in the Marsden Point area of the receiving environment is, with regards to annual mean, similar to the pollution levels and effects experienced by New Zealand towns and small cities. Examination of lichens collected from the grounds of the refinery indicates that there is localised damage to lichens at this location. At this location, annual means for sulphur dioxide are below the levels at which a detectable effect on lichens is likely, but the predicted maximum 24 hour average is *c*.81 µg/m^3. It is possible that these 24 hour peaks are the cause of the lichen damage at the discharge point.

Some lichen species known to be sensitive to air pollution, such as *Pseudocyphellaria croctata* agg. and *Teloschistes flavicans*, persist at the quantitiative lichen monitoring sites within the receiving envirionment at Whangarei Heads where the predicted maximum 24 hour average for sulphur dioxide peaks at *c*.60-80 µg/m^3. Any legacy effects of the air discharge have therefore not led to the loss of these sensitive species within the receiving environment at Whangarei Heads.

8.7 Effects of proposed air discharge on terrestrial ecology

8.7.1 Overview

In line with international guidelines, the ecological values of the receiving environment, and the potential adverse effects of the discharge, are largely assessed at an ecosystem level. Effects are assessed at a taxonomic group level where these taxonomic groups are noted as sensitive to the effects of the modelled pollutants (e.g. lichens), or where literature includes reliable experimental studies of the effects of pollutants on the taxa being assessed. For the latter, it needs to be acknowledged that the accuracy of these levels is less certain.

8.7.2 Sulphur dioxide

<u>Ecosystems</u>

Total sulphur dioxide within the receiving environment of the oil refinery, as an annual mean at ground level, ranges from less than 1.5 µg/m^3 to *c*.5.0 µg/m^3 (Table 13). The highest peak of *c*.5.0 µg/m^3 occurs immediately to the southwest of the oil refinery in an area characterised by agricultural land use, industrial land use, and stands of exotic trees, dominated by macrocarpa (*Cupressus macrocarpa*) (Figure 1a). This area of highest sulphur dioxide concentration has no areas of indigenous vegetation or habitats, and is of low ecological value.

The natural areas exposed to the highest concentrations of sulphur dioxide are the northern end of the Ruakaka Dunelands (Q07/128, SO_2 *c*.4.0 µg/m^3), and the Northport Corporation Ponds (Q07/164, *c*.3.0 µg/m^3). Based on the critical levels for sulphur dioxide (10-30 µg/m^3; Table 11), the natural areas that are closest to the plant and exposed to the highest concentrations are likely to have no detectable effects resulting from sulphur dioxide emissions at an ecosystem level.

None of the peaks for sulphur dioxide as a predicted winter average exceed any of the peaks for annual average. As such, the shorter duration winter averages are not likely to result in any detectable effects on an ecosystem basis.

Species or Species Groups

Based on the literature review and the modelling undertaken, no bats, birds, herpetofauna or invertebrates within the receiving environment are likely to be exposed to concentrations of sulphur dioxide that exceed critical levels (Table 14). The air discharge is therefore unlikely to result in any detectable adverse effects for indigenous terrestrial fauna. However, it should be noted that the literature provides incomplete coverage on a species or species group basis, and more weight should be given to the effects of pollutants at an ecosystem level.

Level of Effect on Lichen Communities Close to the Discharge Point

Analysis of lichen health has indicated that the air discharge may be the cause of damage to lichens within the grounds of the Refinery, due to peaks in the predicted maximum 24 hour average for sulphur dioxide, that reach *c*.81 µg/m^3 at this location. Assessment of lichen health along a gradient of sulphur dioxide concentations suggests that this effect is very localised, and is restricted to common lichen species that would be expected to be present in highly modified environments. At Rama Road, one kilometre from the discharge point, the frequency of lichen damage classes was similar to sites at Ruakaka Estuary and Ruakaka Beach, that are close to or beyond the extent of the receiving environment.

The magnitude of the effect on lichen communities within or close to the refinery grounds can be described as 'low'[1], as the results of the lichen health assessment suggest that there is "a minor shift away from baseline conditions" for lichens. The magnitude of effect on the habitats present here as as a whole (i.e. plantings of indigenous and exotic trees which provide habitat for epiphytic lichens) can be described as 'negligible', as a reduction in the abundance or health of these lichens has a negligible effect on the feature as a whole.

The ecological values of the habitats and associated lichen communities within or close to the refinery grounds were scored as "low" for each of the four ecological attributes (EIANZ Table 4, p. 64), with an overall ecological value of 'negligible' (EIANZ Table 6, p. 69).

[1] Applying criteria provided in the EIANZ guidelines (Roper-Lindsay *et al*., 2018).

The level of effect on lichen communities close to the discharge point can be described by combining the magnitude of effect with the value of the ecological feature. A low or negligible magnitude effect on a feature of low ecological value can be described as having a "very low" level of effect. The EIANZ guidelines (Page 85) state that "very low-level effects can generally be considered to be classed as "not more than minor' effects. However, the EIANZ guidelines do not have a category for a "negligible" or "less than minor" level of effect, which is an appropriate assessment of the level of effect on habitats close to the refinery grounds, for the following reasons:

- The habitats comprise a mix of planted and exotic trees that are not recognised as a significant natural area in the Waipu Ecological District.
- If the lichens present here are of lower abundance or health due to the discharge, this would have a low level of effect for this small biotic component of the habitat.
- The modelled sulphur dioxide concentrations for these habitats are not predicted to cause any detectable effect for the habitats as a whole.

8.7.3 Sulphur

Ecosystems

Sulphur deposition within the receiving environment of the oil refinery, in kilograms per hectare per year, peaks at 11.8 kg S/ha/yr within the grounds of the refinery, the area of agricultural land and exotic trees described in Section 8.6.2 above, and at the northern end of Marsden Point. Except for the Ruakaka Dunelands (Q07/128), this is a highly modified area with low ecological value. Sulphur deposition then rapidly declines within two to four kilometres of the plant to *c*.6.8 kg S/ha/year, except for a small part of Mount Aubrey (Q07/071) that is predicted to receive 7.8 kg S/ha/yr. The outer limit of sulphur deposition, defined as 4.8 kg/ha/year (inclusive of the 3.8 kg S/ha/yr ambient deposition rate), includes parts of the Takahiwai Hills (Q07/124), Bream Head (Q07/074), and Mount Manaia (Q07/069).

As discussed in Section 8.4.3, the potential adverse effects of sulphur deposition can be assessed by screening the receiving environment for catchments that have less than 10 mg/l as calcium carbonate, and may be sensitive to acid deposition. Water chemistry results for the tested streams are presented in Appendix 4. The stream draining the coastal flats at Marsden Point, and receiving 5.8-7.8 kg S/ha/yr, had a pH of 7.1, and 50 g/m^3 as calcium carbonate ($CaCO_3$). The stream at Ocean View Road draining the northern side of Bream head a pH of 7.7 and 131 g/m^3 as calcium carbonate. These catchments represent a range of geologies (sandstone at Marsden Point and andesites and melange at Ocean Beach), and levels of carbonate are well in excess of levels that may indicate sensitivity to acid deposition. The stream draining McDonald Road Heathlands had a pH of 5.8 and 4.0 g/m^3 as calcium carbonate. This catchment may be sensitive to acid deposition, but is not within the predicted receiving environment for acid deposition (thereby only receiving the ambient deposition rate of 3.8 kg S/ha/yr. The receiving environment for sulphur is unlikely to include any ecosystems sensitive to acid deposition at the modelled concentrations. Effects on ecosystems from sulphur deposition are therefore likely to be less than minor.

Species

Based on the literature review, soil invertebrates within the receiving environment are unlikely to have critical levels for sulphur deposition that are exceeded by the soil sulphur levels at the monitoring sites (Table 14). The air discharge is therefore unlikely to result in any detectable adverse effects for soil invertebrates. However, it should be noted that the literature does not provide the loads at which other fauna groups are likely to be adversely affected by sulphur deposition. Therefore, assessment of the adverse effects of sulphur deposition needs to be assessed at an ecosystem level, based on the acid neutralising capacity of catchments (as described above). Based on the acid neutralising capabilities of these catchment systems, sulphur deposition is not expected to result in any detectable adverse effects on indigenous ecosystems or their associated terrestrial or aquatic species.

8.7.4 Nitrogen oxides

Ecosystems

Total nitrogen oxides within the receiving environment of the oil refinery, as an annual mean at ground level, are approximately 6.5 µg/m3 within *c*.500 metres of the discharge point, which then decline to concentrations less than 4.5 µg/m3 within one to two kilometres of the discharge point. Except for the northern end of the Ruakaka Dunelands (Q07/128) and the Northport Corporation Ponds (Q07/164) all identified Significant Natural Areas are exposed to concentrations less than 5.5 µg/m^3. The highest annual means for nitrogen oxides within the receiving environment, at 6.5 µg/m^3, are well below the accepted critical level for protection of ecosystems at 30µg/m^3. The discharge is therefore not expected to result in any detectable adverse effects for ecosystems due to nitrogen oxides.

Species or Species Groups

Based on the literature review and the modelling undertaken, no bats, birds or invertebrates present within the receiving environment are likely to be exposed to nitrogen oxides at concentrations that exceed critical levels (Table 15). Thedischarges to air from the Refinery are therefore unlikely to result in any detectable adverse effects for indigenous terrestrial fauna. However, it should be noted that the literature provides incomplete coverage on a species or species group basis; for example, no literature was found describing the effects of nitrogen oxides on herpetofauna. More weight should therefore be given to the assessment of effects of nitrogen oxides at an ecosystem level, which suggests that there will not be any detectable effects from the discharge.

8.7.5 Nitrogen

Ecosystems

Total nitrogen deposition within the receiving environment ranges from less than 1.25 kg N/ha/yr to *c.*1.95 kg N/ha/yr. The distribution of the deposition is similar to that for sulphur dioxide, with the highest peak occurring to the southwest of the oil refinery, in the area characterised by highly modified land uses. The natural areas exposed to the greatest deposition of nitrogen are the Ruakaka Dunelands (Q07/128, 1.55-1.95 kg N/ha/yr), the summit of Mount Manaia (Q07/069, *c.*1.65 kg N/ha/yr), and the upper slopes of Mount Aubrey-Reotahi (Q07/070, *c.*1.65-1.75 kg N/ha/yr). Most New Zealand ecosystems are nitrogen limited, with current loads in the range of 1-5 kg N/ha/yr. On this basis, Stevenson *et al.* (2000) suggest that prediction of no effect at deposition rates of up to 5 kg N/ha/yr would be a conservative approach, if the potential adverse effect being detected is an increase in exotic plant species. As the highest rates of deposition for nitrogen are 1.75 kg N/ha/yr at Mount Aubrey, and the environments most sensitive for nitrogen deposition are predicted to receive less than 1.65 kg N/ha yr (McDonald Coastal Shrubland, Q07/068, critical load based on ecosystem type 10-20 kg N/ha/yr), there are no likely adverse effects for terrestrial ecology due to nitrogen deposition.

Table 13: Assessment of effects of air pollutants from the Marsden Point Oil Refinery by site and ecosystem type.

Site	Ecological District	Habitat/ Ecosystem Type	Significance (NRPS)	Pollutant	Critical Level (reference[1])	Discharge Concentration/ Deposition for the Receiving Environment[2]	Total Concentration/ Deposition for the Receiving Environment (including ambient)	Critical Level or Load Met or Exceeded	Level of Effect
Indigenous forest, Hewlett QEII Covenant (Q07136)	Waipu	Forest	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	0.50- 1.00 µg/m^3	1.50-2.00 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	<0.50 µg/m^3	<4.50 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00 kg S/ha/yr	<4.80 kg S/ha/yr	No	Negligible
				N deposition	5-10 kg N/ha/yr [3] (Stevenson *et al.* 2000)	<0.10 kg N/ha/yr	<1.25 kg N/ha/yr	No	Negligible
Indigenous forest - Ruakaka River Forest Remnants (Q07119)	Waipu	Forest	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	0.50- 1.00 µg/m^3	<1.50-2.00 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	<0.50 µg/m^3	<4.50 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00 kg S/ha/yr	<4.80-4.80 kg S/ha/yr	No	Negligible
				N deposition	5-10 kg N/ha/yr [4] (Stevenson *et al.* 2000)	<0.10 kg N/ha/yr	<1.25 kg N/ha/yr	No	Negligible
Indigenous forest - Takahiwai Forest (Q07124)	Waipu	Forest	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	0.50-1.00 µg/m^3	1.50-2.00 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	<0.50 µg/m^3	<4.50 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00-2.00 kg S/ha/yr	<4.80-5.80 kg S/ha/yr	No	Negligible
				N deposition	5-10 kg N/ha/yr [5] (Stevenson *et al.* 2000)	<0.10-0.20 kg N/ha/yr	<1.25-1.35 kg N/ha/yr	No	Negligible
Pakouhokio Knoll Forest (Q07122)	Waipu	Forest	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	<0.50-0.50 µg/m^3	<1.50-1.50 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	<0.50 µg/m^3	<4.50 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00 kg S/ha/yr	<4.80 kg S/ha/yr	No	Negligible
				N deposition	5-10 kg N/ha/yr [6] (Stevenson *et al.* 2000)	<0.10 kg N/ha/yr	<1.25 kg N/ha/yr	No	Negligible
Sandford Road Forest Remnants (Q07/142)	Waipu	Forest	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	0.50-1.00 µg/m^3	1.50-2.00 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	<0.50 µg/m^3	<4.50 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00 kg S/ha/yr	<4.80 kg S/ha/yr	No	Negligible
				N deposition	5-10 kg N/ha/yr [7] (Stevenson *et al.* 2000)	<0.10 kg N/ha/yr	<1.25 kg N/ha/yr	No	Negligible
Tauroa Floodplain Forest Remnants (Q07125)	Waipu	Forest	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	0.50-1.00 µg/m^3	1.50-2.50 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	<0.50 µg/m^3	<4.50 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	1.00 kg S/ha/yr	4.80 kg S/ha/yr	No	Negligible
				N deposition	5-10 kg N/ha/yr [8] (Stevenson *et al.* 2000)	<0.10 kg N/ha/yr	<1.25 kg N/ha/yr	No	Negligible
Blacksmith's Creek Estuary (Q07144)	Waipu	Saltmarsh	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	2.00 µg/m^3	3.00 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	1.00-1.50 µg/m^3	5.00-5.50 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	2.00-4.00 kg S/ha/yr	5.80-7.80 kg S/ha/yr	No	Negligible
				N deposition	20-30 kg N/ha/yr[9] (Stevenson *et al.* 2000)	0.30-0.40 kg N/ha/yr	1.45-1.55 kg N/ha/yr	No	Negligible
Ruakaka River Estuary (Q07/130)	Waipu	Saltmarsh	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	0.50-1.00 µg/m^3	1.50-2.00 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	<0.50 µg/m^3	<4.50 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00-1.00 kg S/ha/yr	<4.80-5.80 kg S/ha/yr	No	Negligible
				N deposition	20-30 kg N/ha/yr[10] (Stevenson *et al.* 2000)	<0.10-0.20 kg N/ha/yr	<1.25-1.35 kg N/ha/yr	No	Negligible
Takahiwai Saltmarsh (Q07167)	Waipu	Saltmarsh	Yes	SO_2	20 µg/m3 (Mills *et al.* 2017)	0.50-1.0 µg/m^3	1.50-2.50 µg/m^3	No	Negligible
				NO_x	30 µg/m3 (Mills *et al.* 2017)	<0.50 µg/m^3	<4.50 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00 kg S/ha/yr	<4.80 kg S/ha/yr	No	Negligible
				N deposition	20-30 kg N/ha/yr[11] (Stevenson *et al.* 2000)	<0.10 kg N/ha/yr	<1.25 kg N/ha/yr	No	Negligible
Northport Corporation Ponds (Q07/164)	Waipu	Artificial pond	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	2.00-2.50 µg/m^3	c.3.00-3.50 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	c.1.50 µg/m^3	c.5.50 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	c.4.00 kg S/ha/yr	c.7.80 kg S/ha/yr	No	Negligible
				N deposition	15-30 kg N/ha/yr[12] (Stevenson *et al.* 2000)	c.0.50 kg N/ha/yr	c.1.65 kg N/ha/yr	No	Negligible

[1] Where two or more critical loads have been published, the lowest value is used here for a conservative approach.
[2] Where a site or species distribution has variable modelled pollutant concentrations, the range of values is used here for a conservative approach.
[3] Using forest habitats (general) and a lower value of 5 (as per APIS guidelines for sites with lichens as an important component).
[4] Using forest habitats (general) and a lower value of 5 (as per APIS guidelines for sites with lichens as an important component).
[5] Using forest habitats (general) and a lower value of 5 (as per APIS guidelines for sites with lichens as an important component).
[6] Using forest habitats (general) and a lower value of 5 (as per APIS guidelines for sites with lichens as an important component).
[7] Using forest habitats (general) and a lower value of 5 (as per APIS guidelines for sites with lichens as an important component).
[8] Using forest habitats (general) and a lower value of 5 (as per APIS guidelines for sites with lichens as an important component).
[9] Using the value for mid-upper saltmarsh.
[10] Using the value for mid-upper saltmarsh.
[11] Using the value for mid-upper saltmarsh.
[12] Using the value for rich fens.

Site	Ecological District	Habitat/ Ecosystem Type	Significance (NRPS)	Pollutant	Critical Level (reference[1])	Discharge Concentration/ Deposition for the Receiving Environment[2]	Total Concentration/ Deposition for the Receiving Environment (including ambient)	Critical Level or Load Met or Exceeded	Level of Effect
Raupo reedland (Takahiwai Forest) (Q07/124)	Waipu	Freshwater wetland: Rich fen	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	0.50-1.00 µg/m^3	1.50-2.00 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	<0.50 µg/m^3	<4.50 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	1.00-2.00 kg S/ha/yr	4.80-5.80 kg S/ha/yr	No	Negligible
				N deposition	15-30 kg N/ha/yr [1] (Stevenson *et al.* 2000)	0.10-0.20 kg N/ha/yr	1.25-1.35 kg N/ha/yr	No	Negligible
Dune slack wetlands (McEwan Road) (Q07131)	Waipu	Dune slack wetland	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	1.50-2.00 µg/m^3	2.50-3.00 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	0.50-1.00 µg/m^3	4.50-5.00 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	2.00-3.00 kg S/ha/yr	5.80-6.80 kg S/ha/yr	No	Negligible
				N deposition	10-20 kg N/ha/yr [2] (Stevenson *et al.* 2000)	0.30 kg N/ha/yr	1.45 kg N/ha/yr	No	Negligible
Dune slack wetlands (Sime Road) (Q07141)	Waipu	Dune slack wetland	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	1.50-2.50 µg/m^3	2.50-3.00 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	<0.50 µg/m^3	<5.50 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	2.00-4.00 kg S/ha/yr	5.80-7.80 kg S/ha/yr	No	Negligible
				N deposition	10-20 kg N/ha/yr [3] (Stevenson *et al.* 2000)	0.20 kg N/ha/yr	1.35 kg N/ha/yr	No	Negligible
Dune lake (Ruakaka Racecourse) (Q07129)	Waipu	Dune slack wetland	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	1.00 µg/m^3	2.00 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	<0.50 µg/m^3	<4.50 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	1.00-2.00 kg S/ha/yr	4.80-5.80 kg S/ha/yr	No	Negligible
				N deposition	10-20 kg N/ha/yr [4] (Stevenson *et al.* 2000)	0.10-0.20 kg N/ha/yr	1.25-1.35 kg N/ha/yr	No	Negligible
Indigenous vegetation on dunes - Ruakaka Dunelands (Q07128)	Waipu	Duneland	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	<0.50-3.00 µg/m^3	<1.50-4.00 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	<0.50-1.50 µg/m^3	<4.50-5.50 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	1.00-8.00 kg S/ha/yr	4.80-10.80 kg S/ha/yr	No	Negligible
				N deposition	8-20 kg N/ha/yr [5] (Stevenson *et al.* 2000)	0.10-0.80 kg N/ha/yr	1.25-1.95 kg N/ha/yr	No	Negligible
High Island, forest (Q07072)	Manaia	Forest	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	1.50 µg/m^3	2.50 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	0.50-1.00 µg/m^3	4.50-5.00 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	2.00-4.00 kg S/ha/yr	5.80-7.80 kg S/ha/yr	No	Negligible
				N deposition	5-10 kg N/ha/yr [6] (Stevenson *et al.* 2000)	0.20 kg N/ha/yr	1.35 kg N/ha/yr	No	Negligible
Indigenous forest, Bream Head (Q07/074)	Manaia	Forest	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	<0.50-1.50 µg/m^3	<1.50-2.50µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	<0.50-1.00 µg/m^3	<4.50-5.00 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00-1.00 kg S/ha/yr	<4.80-4.80 kg S/ha/yr	No	Negligible
				N deposition	5-10 kg N/ha/yr [7] (Stevenson *et al.* 2000)	<0.10-0.20 kg N/ha/yr	<1.25-1.35 kg N/ha/yr	No	Negligible
Indigenous forest without kauri, Manaia Scenic Reserve (Q07/069)	Manaia	Forest	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	0.50-2.00 µg/m^3	1.50-3.00 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	0.50-1.00 µg/m^3	4.50-5.00 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	1.00-4.00 kg S/ha/yr	4.80-7.80 kg S/ha/yr	No	Negligible
				N deposition	5-10 kg N/ha/yr[8] (Stevenson *et al.* 2000)	0.40 kg N/ha/yr	1.55 kg N/ha/yr	No	Negligible
Indigenous forest (kauri) Manaia Scenic Reserve (Q07069)	Manaia	Coniferous forest	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	0.50-2.50 µg/m^3	1.50-3.50 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	0.50-1.00 µg/m^3	4.50-5.00 µg/m^3	No	Negligible
				S deposition	<10 mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	1.00-2.00 kg S/ha/yr	4.80-5.80 kg S/ha/yr	No	Negligible
				N deposition	7-20 kg N/ha/yr [9] (Stevenson *et al.* 2000)	0.40 kg N/ha/yr	1.55 kg N/ha/yr	No	Negligible
Mt. Aubrey Coastal Forest and Shrubland (Q07070)	Manaia	Forest	Yes	SO_2	20 µg/m^3 (Mills *et al.* 2017)	1.50-2.50 µg/m^3	2.00-3.50 µg/m^3	No	Negligible
				NO_x	30 µg/m^3 (Mills *et al.* 2017)	<0.50-1.00 µg/m^3	<4.50-5.00 µg/m^3	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00-4.00 kg S/ha/yr	<4.80-7.80 kg S/ha/yr	No	Negligible
				N deposition	5-10 kg N/ha/yr [10] (Stevenson *et al.* 2000)	<0.20-0.60 kg N/ha/yr	<1.35-1.75 kg N/ha/yr	No	Negligible

[1] Using the value for rich fens.
[2] Using the value for dune slack pools, which has the same value as moist to wet dune slacks.
[3] Using the value for dune slack pools, which has the same value as moist to wet dune slacks.
[4] Using the value for dune slack pools, which has the same value as moist to wet dune slacks.
[5] Using lower value of 8 for stable dunes and upper value of 20 for shifting dunes.
[6] Using forest habitats (general) and a lower value of 5 (as per APIS guidelines for sites with lichens as an important component).
[7] Using forest habitats (general) and a lower value of 5 (as per APIS guidelines for sites with lichens as an important component).
[8] Using forest habitats (general) and a lower value of 5 (as per APIS guidelines for sites with lichens as an important component).
[9] Kauri forest being the European ecosystem equivalent of coniferous woodland.
[10] Using forest habitats (general) and a lower value of 5 (as per APIS guidelines for sites with lichens as an important component).

Site	Ecological District	Habitat/ Ecosystem Type	Significance (NRPS)	Pollutant	Critical Level (reference[1])	Discharge Concentration/ Deposition for the Receiving Environment[2]	Total Concentration/ Deposition for the Receiving Environment (including ambient)	Critical Level or Load Met or Exceeded	Level of Effect
Timperly Road Bush (Q07077)	Manaia	Forest	Yes	SO_2	20 $\mu g/m^3$ (Mills *et al.* 2017)	0.50 $\mu g/m^3$	1.50 $\mu g/m^3$	No	Negligible
				NO_x	30 $\mu g/m^3$ (Mills *et al.* 2017)	<0.50 $\mu g/m^3$	<4.50 $\mu g/m^3$	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00 kg S/ha/yr	<4.80 kg S/ha/yr	No	Negligible
				N deposition	5-10 kg N/ha/yr [1] (Stevenson *et al.* 2000)	<0.10 kg N/ha/yr	<1.25 kg N/ha/yr	No	Negligible
Turikura Range Bush (Q07073)	Manaia	Forest	Yes	SO_2	20 $\mu g/m^3$ (Mills *et al.* 2017)	1.00-2.00 $\mu g/m^3$	2.00-3.00 $\mu g/m^3$	No	Negligible
				NO_x	30 $\mu g/m^3$ (Mills *et al.* 2017)	<0.50-0.50 $\mu g/m^3$	<4.50-4.50 $\mu g/m^3$	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	1.00-2.00 kg S/ha/yr	<4.80-5.80 kg S/ha/yr	No	Negligible
				N deposition	5-10 kg N/ha/yr [2] (Stevenson *et al.* 2000)	0.10-0.40 kg N/ha/yr	1.25-1.55 kg N/ha/yr	No	Negligible
Ocean Beach swamp (Q07075)	Manaia	Freshwater wetland: Rich fen	Yes	SO_2	20 $\mu g/m^3$ (Mills *et al.* 2017)	0.50-1.00 $\mu g/m^3$	1.50-2.00 $\mu g/m^3$	No	Negligible
				NO_x	30 $\mu g/m^3$ (Mills *et al.* 2017)	<0.50 $\mu g/m^3$	<4.50 $\mu g/m^3$	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00 kg S/ha/yr	<4.80 kg S/ha/yr	No	Negligible
				N deposition	15-30 kg N/ha/yr[3] (Stevenson *et al.* 2000)	<0.10 kg N/ha/yr	<1.25 kg N/ha/yr	No	Negligible
Wet heathlands (McDonald Road Shrublands) (Q07068)	Manaia	Wet heathland	Yes	SO_2	20 $\mu g/m^3$ (Mills *et al.* 2017)	0.50 $\mu g/m^3$	1.50 $\mu g/m^3$	No	Negligible
				NO_x	30 $\mu g/m^3$ (Mills *et al.* 2017)	<0.50 $\mu g/m^3$	<4.50 $\mu g/m^3$	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.000 kg S/ha/yr	<4.80 kg S/ha/yr	No	Negligible
				N deposition	10-20 kg N/ha/yr [4] (Stevenson *et al.* 2000)	0.10 kg N/ha/yr	1.250 kg N/ha/yr	No	Negligible
Whangārei Heads Road Wetland (Q07083)	Manaia	Freshwater wetland: rich fen	Yes	SO_2	20 $\mu g/m^3$ (Mills *et al.* 2017)	0.50$\mu g/m^3$	1.0 $\mu g/m^3$	No	Negligible
				NO_x	30 $\mu g/m^3$ (Mills *et al.* 2017)	<0.50 $\mu g/m^3$	<4.50 $\mu g/m^3$	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00 kg S/ha/yr	<4.80 kg S/ha/yr	No	Negligible
				N deposition	15-30 kg N/ha/yr[5] (Stevenson *et al.* 2000)	0.10 kg N/ha/yr	1.25 kg N/ha/yr	No	Negligible
Ocean Beach saltmarsh (Q07/075)	Manaia	Saltmarsh	Yes	SO_2	20 $\mu g/m^3$ (Mills *et al.* 2017)	0.50-1.00 $\mu g/m^3$	1.50-2.00 $\mu g/m^3$	No	Negligible
				NO_x	30 $\mu g/m^3$ (Mills *et al.* 2017)	<0.50 $\mu g/m^3$	<4.50 $\mu g/m^3$	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00 kg S/ha/yr	<4.80 kg S/ha/yr	No	Negligible
				N deposition	20-30 kg N/ha/yr [6] (Stevenson *et al.* 2000)	<0.10 kg N/ha/yr	<1.25 kg N/ha/yr	No	Negligible
Awaroa Island (Q07170)	Manaia	Rockland	Yes	SO_2	20 $\mu g/m^3$ (Mills *et al.* 2017)	0.50 $\mu g/m^3$	1.50 $\mu g/m^3$	No	Negligible
				NO_x	30 $\mu g/m^3$ (Mills *et al.* 2017)	<0.50 $\mu g/m^3$	<4.50 $\mu g/m^3$	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00 kg S/ha/yr	<4.80 kg S/ha/yr	No	Negligible
				N deposition	2 kg N/ha/yr[7] (Stevenson *et al.* 2000)	<0.10 kg N/ha/yr	<1.25 kg N/ha/yr	No	Negligible
Bream Islands Nature Reserve: Mauitaha Island and Guano Island, rockland and shrubland (Q07080)	Manaia	Rockland	Yes	SO_2	20 $\mu g/m^3$ (Mills *et al.* 2017)	0.50 $\mu g/m^3$	1.50 $\mu g/m^3$	No	Negligible
				NO_x	30 $\mu g/m^3$ (Mills *et al.* 2017)	<0.50 $\mu g/m^3$	<4.50 $\mu g/m^3$	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00 kg S/ha/yr	<4.80 kg S/ha/yr	No	Negligible
				N deposition	2 kg N/ha/yr[8] (Stevenson *et al.* 2000)	<0.10 kg N/ha/yr	<1.25 kg N/ha/yr	No	Negligible
Bream Islands Scenic Reserve: Moturaka Island and Tarakanahi Island, rockland and shrubland (Q07079)	Manaia	Rockland	Yes	SO_2	20 $\mu g/m^3$ (Mills *et al.* 2017)	0.50-1.00 $\mu g/m^3$	1.50-2.50 $\mu g/m^3$	No	Negligible
				NO_x	30 $\mu g/m^3$ (Mills *et al.* 2017)	<0.50 $\mu g/m^3$	<4.50 $\mu g/m^3$	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00 kg S/ha/yr	<4.80 kg S/ha/yr	No	Negligible
				N deposition	2 kg N/ha/yr[9] (Stevenson *et al.* 2000)	<0.10 kg N/ha/yr	<1.25 kg N/ha/yr	No	Negligible
Frenchman Island, rockland and forest (Q07171)	Manaia	Rockland	Yes	SO_2	20 $\mu g/m^3$ (Mills *et al.* 2017)	0.50$\mu g/m^3$	1.50 $\mu g/m^3$	No	Negligible
				NO_x	30 $\mu g/m^3$ (Mills *et al.* 2017)	<0.50 $\mu g/m^3$	<4.50 $\mu g/m^3$	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	1.00 kg S/ha/yr	.80kg S/ha/yr	No	Negligible
				N deposition	2 kg N/ha/yr[10] (Stevenson *et al.* 2000)	0.10 kg N/ha/yr	1.25 kg N/ha/yr	No	Negligible

[1] Using forest habitats (general) and a lower value of 5 (as per APIS guidelines for sites with lichens as an important component).
[2] Using forest habitats (general) and a lower value of 5 (as per APIS guidelines for sites with lichens as an important component).
[3] Using the value for rich fens.
[4] New Zealand heathlands being the European ecosystem equivalent of upper Calluna heaths.
[5] Using the value for rich fens.
[6] Using the value for mid-upper saltmarsh.
[7] No value for ecosystems eniched by guano. Higher critical load for species rich neutral acid grasslands used as an equivalent.
[8] No value for ecosystems eniched by guano. Higher critical load for species rich neutral acid grasslands used as an equivalent.
[9] No value for ecosystems eniched by guano. Higher critical load for species rich neutral acid grasslands used as an equivalent.
[10] No value for ecosystems eniched by guano. Higher critical load for species rich neutral acid grasslands used as an equivalent.

Site	Ecological District	Habitat/ Ecosystem Type	Significance (NRPS)	Pollutant	Critical Level (reference[1])	Discharge Concentration/ Deposition for the Receiving Environment[2]	Total Concentration/ Deposition for the Receiving Environment (including ambient)	Critical Level or Load Met or Exceeded	Level of Effect
High Island Stack A, rockland and forest (Q07072)	Manaia	Rockland	Yes	SO_2	20 µg/m³ (Mills *et al.* 2017)	1.00-1.50 µg/m³	2.00-2.50 µg/m³	No	Negligible
				NO_x	30 µg/m³ (Mills *et al.* 2017)	0.50-1.00 µg/m³	4.50-5.00 µg/m³	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	2.00-4.00 kg S/ha/yr	5.80-7.80 kg S/ha/yr	No	Negligible
				N deposition	2 kg N/ha/yr[1] (Stevenson *et al.* 2000)	0.20-0.30 kg N/ha/yr	1.35-1.45 kg N/ha/yr	No	Negligible
Motukaroro Island, rockland and forest (Q07071)	Manaia	Rockland	Yes	SO_2	20 µg/m³ (Mills *et al.* 2017)	0.50-1.00 µg/m³	1.50-2.00 µg/m³	No	Negligible
				NO_x	30 µg/m³ (Mills *et al.* 2017)	0.50-1.00 µg/m³	4.50-5.00 µg/m³	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	2.00-4.00 kg S/ha/yr	5.80-7.80 kg S/ha/yr	No	Negligible
				N deposition	2 kg N/ha/yr[2] (Stevenson *et al.* 2000)	0.10-0.30 kg N/ha/yr	1.25-1.45 kg N/ha/yr	No	Negligible
Rockland, Peach Cove Stack A (Q07173)	Manaia	Rockland	Yes	SO_2	20 µg/m³ (Mills *et al.* 2017)	0.50 µg/m³	1.50 µg/m³	No	Negligible
				NO_x	30 µg/m³ (Mills *et al.* 2017)	<0.50 µg/m³	<4.50 µg/m³	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00 kg S/ha/yr	<4.80 kg S/ha/yr	No	Negligible
				N deposition	2 kg N/ha/yr[3] (Stevenson *et al.* 2000)	0.10 kg N/ha/yr	1.25 kg N/ha/yr	No	Negligible
Rockland, Peach Cove Stack B (Q07174)	Manaia	Rockland	Yes	SO_2	20 µg/m3 (Mills *et al.* 2017)	<0.50 µg/m³	<1.50 µg/m³	No	Negligible
				NO_x	30 µg/m³ (Mills *et al.* 2017)	<0.50 µg/m³	<4.50 µg/m³	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00 kg S/ha/yr	<4.80 kg S/ha/yr	No	Negligible
				N deposition	30 kg N/ha/yr[4] (Stevenson *et al.* 2000)	<0.10 kg N/ha/yr	<1.25 kg N/ha/yr	No	Negligible
Indigenous vegetation on dunes - Ocean Beach (Q07075)	Manaia	Duneland	Yes	SO_2	20 µg/m³ (Mills *et al.* 2017)	0.50-1.00 µg/m³	1.50-2.00 µg/m³	No	Negligible
				NO_x	30 µg/m³ (Mills *et al.* 2017)	<0.50 µg/m³	<4.50 µg/m³	No	Negligible
				S deposition	<10mg/L calcium carbonate in waters (Stevenson *et al.* 2000)	<1.00 kg S/ha/yr	<4.80 kg S/ha/yr	No	Negligible
				N deposition	8-20 kg N/ha/yr [5] (Stevenson *et al.* 2000)	<0.10 kg N/ha/yr	<1.25 kg N/ha/yr	No	Negligible

Table 14: Assessment of effects of air pollutants from the Marsden Point Oil Refinery by fauna species or species group.

Species	Pollutant	Level at Which Adverse Effect Detected	Discharge Concentration/ Deposition for the Receiving Environment	Total Concentration/Deposition for the Receiving Environment (including ambient)	Critical Level or Load Met or Exceeded?	Predicted Level of Effect
Bats (North Island long-tailed bat)[6]	SO_2	974 µg/m³ (Gorriz *et al.* 1996)	0.50-2.50 µg/m³	1.50-3.50µg/m³	No	Negligible
	NO_x	50 µg/m³ (Gorriz *et al.* 1996)	0.50-2.50 µg/m³	4.30-6.30 µg/m³	No	Negligible
Avifauna	SO_2	974 µg/m³ (Llacuna *et al.* 1996)	0.50-4.00 µg/m³	1.50-5.00 µg/m³	No	Negligible
	NO_x	50 µg/m³ (Llacuna *et al.* 1993)	0.50-2.50 µg/m³	4.50-6.50 µg/m³	No	Negligible
Herpetofauna	SO_2	123-385 µg/m³ (Read 1998)	0.50-4.00 µg/m³	1.50-5.00 µg/m³	No	Negligible
Bee	SO_2	367 µg/m³ (Ginevan *et al.* 1980).	0.50-4.00 µg/m³	1.50-5.00 µg/m³	No	Negligible
Wasp	SO_2	No effect observed at 7,860 µg/m³ (Petters and Mettus, 1982).	0.50-4.00 µg/m³	1.50-5.00 µg/m³	No	Negligible
Soil invertebrates	SO_2	245 µg/m³ (Lauenroth and Preston, 1984)[7]	0.50-4.00 µg/m³	1.50-5.00 µg/m³	No	Negligible
	S	62.3 kg/ha/year (Kuperman 1996)[8]	1.00-8.00 kg S/ha/year	4.80-11.80 kg S/ha/year	No	Negligible
	N	31.4 kg/ha/year (Kuperman 1996)[9]	0.10-0.80 kg N/ha/year	1.15-1.95 kg N/ha/year	No	Negligible
Moss-dwelling invertebrates	SO_2	66 µg/m³ (Steiner 1995b)	0.50-4.00 µg/m³	1.50-5.00 µg/m³	No	Negligible

[1] No value for ecosystems enriched by guano. Higher critical load for species rich neutral acid grasslands used as an equivalent.
[2] No value for ecosystems enriched by guano. Higher critical load for species rich neutral acid grasslands used as an equivalent.
[3] No value for ecosystems enriched by guano. Higher critical load for species rich neutral acid grasslands used as an equivalent.
[4] No value for ecosystems enriched by guano. Higher critical load for species rich neutral acid grasslands used as an equivalent.
[5] Using lower value of 8 for stable dunes and upper value of 20 for shifting dunes.
[6] No literature for bats, mice were used instead
[7] No effect at 12 µg/m³ (Steiner, 1995b),
[8] Significantly reduced abundance of invertebrates compared to 55.2 kg/ha/yr
[9] Significantly reduced abundance of invertebrates compared to 26.3 kg/ha/yr

Table 15: Assessment of effects of air pollutants from the Marsden Point Oil Refinery by flora species or species group.

Species	Pollutant	Level at Which Adverse Effect Detected	Annual Concentration/Deposition for the Receiving Environment	Critical Level Met or Exceeded?	Predicted Level of Effect
Indigenous conifers (e.g. kauri)	N	10-15 kg N/ha/year	Maximum of 1.75 kg N/ha/year reached within indigenous forest (Q07/070)	No	Negligable
Lichens (cyanobacterial)	SO_2	10 µg/m³ as an annual mean (Mills *et al.* 2017)	Maximum of 5.0 µg/m³ immediately southwest of discharge point	No	Negligable
	N	5-10 kg N/ha/year in forests in humid climates (decline)	Maximum of 1.75 kg N/ha/year reached within indigenous forest (Q07/070)	No	Negligable
Mosses	N	10-20 kg N/ha/year in wet heathlands[1]	c. 1.25 kg N/ha/year at McDonald Road Shrublands	No	Negligable
Gumland plant species (e.g. *Epacris pauciflora*, *Tetraria capillaris*, *Dracophyllum lessonianum*)	N	10-20 kg N/ha/year in wet heathlands[2]	c. 1.25 kg N/ha/year at McDonald Road Shrublands	No	Negligable

[1] Noted for mosses in upland Calluna heaths, an equivalent of New Zealand wet heathlands (Stevenson *et al.* 2000).
[2] Using the value for heather in upland Calluna heaths as a proxy (Stevenson *et al.* 2000).

Historically, prior to human settlement and the arrival of mammalian predators including rats (*Rattus* species), mice (*Mus* musculus), and mustelids (*Mustela* species), many coastal ecosystems were driven by seabirds, and the nutrients transferred by them from sea to land (via guano). Loss of seabird colonies has resulted in marked decreases in nitrogen deposition and soil fertility, with cascading, adverse effects on ecosystem processes (Fukami *et al.* 2006). Lower fertility of soils from islands without nesting seabirds has been well documented for New Zealand (e.g. Fukami *et al.* 2006, Mulder *et al.* 2009), and nitrogen deposition rates have been measured for seabird ecosystems in the Falkland Islands (Bokhorst *et al.* 2007). On Anchorage Island, seabirds deposited *c*.1.0 kg N/ha over a three month summer nesting period. This figure can be used as a conservative estimate for historical annual nitrogen deposition rates for sites within the receiving environment that formerly supported species of similar breeding season length such as ōi (grey-faced petrel), noting that for some environments, multiple seabird species using a site will lengthen the breeding season and the total annual nitrogen load. Where nitrogen is deposited by the oil refinery at sites such as rocky islets and headlands (e.g. Peach Cove Stack A, Q07/173), and steep ridges (e.g. Mount Manaia, Q07/069, Bream Head, Q07/074), total nitrogen deposition up to the predicted maximum of 1.75 kg N/ha/yr may have a positive ecological effect.

<u>Species or Species Groups</u>

Based on the literature review and the modelling undertaken, no soil invertebrates or flora species sensitive to nitrogen deposition within the receiving environment are likely to be exposed to nitrogen at concentrations above critical loads (Table 16). The air discharge is therefore unlikely to result in any detectable adverse effects for indigenous terrestrial fauna and flora. However, it should be noted that the literature provides very incomplete coverage for nitrogen deposition on a species or species group basis, and more weight should be given to the effects of this pollutant at an ecosystem level. Nitrogen deposition may also have localised positive effects in ecosystems where guano-depositing bird species have been reduced or lost.

8.7.6 Assessment of alternatives

An assessment of alternatives for the air discharge has been prepared by Thomson (2019). The only feasible means to reduce emissions of sulphur dioxide is to reduce the sulphur in the fuels burnt at the site. This would “result in a significant increase in operational costs and/or significant refining margin destruction” (Thomson 2019). Further reduction in sulphur dioxide emissions is possible, but is not justified given that the adverse effects that arise as a consequence of the discharge, such as adverse effects on terrestrial ecology, are less than minor. Thomson concludes that the methods for discharges to air are “effective, fit for purpose, and the best practicable options”, and recommends that the existing controls and limits are retained.

8.7.7 Summary

Potential adverse effects of discharges of sulphur dioxide, nitrogen dioxides, sulphur, and nitrogen on terrestrial ecology in the receiving environment have been assessed. This included the identification of critical levels and critical loads for each ecosystem type present, and comparison of these values to the modelled levels of the pollutants being discharged from the Refinery for each natural area. Identification and comparisons of critical levels and critical loads were also carried out for species groups likely to utilise habitat within the receiving environment, where possible based on existing literature, although more weighting has been given to ecosystem-based information.

Based on this assessment, it is expected that the concentrations of sulphur dioxide and nitrogen oxides, and deposition rates of sulphur and nitrogen, are below the levels at which adverse effects are likely to occur for significant indigenous vegetation and significant habitats of indigenous fauna. Adverse effects on significant natural areas are likely to be avoided, and, as such, mitigation actions are not considered necessary. These conclusions have been reviewed as part of the Cultural Effects Assessment for the application[1], and generally accepted in relation to the expected less than minor effects on terrestrial ecology.

Adverse effects on the lichen flora of habitats within or adjacent to the oil refinery grounds are likely, based on visual examination of lichens collected during this study. However, the lichen flora close to the oil refinery typically grows on exotic trees within highly modified environments of low ecological value, such as amenity gardens and shelterbelts. These habitats are unlikely to support lichen species that are Threatened or At Risk. Actual or potential adverse effects on lichens in close proximity to the plant can be regarded as of little consequence on an ecological basis, and is an effect that is very localised.

This assessment of effects for indigenous ecosystems, and the lichen communities of the Whangārei Heads area, is consistent with monitoring of soil, vegetation and lichens that has been undertaken to date in relation to the Refinery activity. It is proposed to continue an established monitoring regime for terrestrial ecology. The purpose of this monitoring will be to confirm this assessment of effects in relation to potential adverse effects on terrestrial flora and fauna, with a particular focus on lichens as bio-indicator species. The proposed methodology for the continued monitoring regime is outlined in the following section of this report.

9. MONITORING REGIME FOR POTENTIAL EFFECTS ON TERRESTRIAL ECOLOGY

9.1 History of monitoring

Refining NZ are required to undertake regular monitoring as part of their resource consent conditions (AUT008319.01-06), to monitor the effects of emissions authorised by the consent. The monitoring programme includes an assessment of the soil, vegetation, and saxicolous (rock-dwelling) lichens at Whangārei Heads. Photographic monitoring of lichens has occurred since 1976 (Bioresearches 1976), with additional quantitative monitoring of lichens implemented in 1990 (Bioresearches 1990). Monitoring of soil and vegetation has occurred since 2002 (Bioresearches 2002). Wildland Consultants completed the monitoring for the 2017 and 2018 rounds (Wildland Consultants 2017a, b, c; and 2019a, b, c).

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[1] Prepared by Patuharakeke Te Iwi Trust Board as part of the Mana Whenua Engagement Process in relation to the Reconsenting of Refining NZ's Operations at Marsden Point.

Further information on the previous monitoring regime, and proposed changes to this regime moving forward, are provided in Appendix 10.

9.2 Proposed quantitative lichen monitoring sites for consent proposal

Quantitative monitoring of lichens should be continued on a biannual basis at the sites in Table 16.

Table 16: Proposed quantitative lichen monitoring sites at Whangārei Heads.

Station	Site Name	Elevation (m)	Geology	Distance From Refinery (km)	SO_2 Annual Mean ($\mu g/m^3$) (sum of Discharge and Ambient)
1	Mount Aubrey	160	Andesitic volcaniclastics with lava flows and associated andesite, diorite, and granodiorite intrusions.	1.9	c.3.5 $\mu g/m^3$
2	Reotahi	20	Andesitic volcaniclastics with lava flows and associated andesite, diorite, and granodiorite intrusions.	1.3	c.2.5 $\mu g/m^3$
3	Castle Rock	60	Andesitic volcaniclastics with lava flows and associated andesite, diorite, and granodiorite intrusions.	1.8	c.3.0 $\mu g/m^3$
4	Taurikura	5	Landslide material from Mount Manaia.	3.1	c.3.0 $\mu g/m^3$
5	Urquharts Jetty	60	Andesitic volcaniclastics with lava flows and associated andesite, diorite, and granodiorite intrusions.	3.3	c.3.0 $\mu g/m^3$
6	Home Point Upper	120	Andesitic volcaniclastics with lava flows and associated andesite, diorite, and granodiorite intrusions.	3.0	c.2.0 $\mu g/m^3$
7	Ody Road (Control Site)	40	Andesitic volcaniclastics with lava flows and associated andesite, diorite, and granodiorite intrusions.	6.3	c.1.5 $\mu g/m^3$
9	Mount Lion	320	Andesitic volcaniclastics with lava flows and associated andesite, diorite, and granodiorite intrusions.	4.7	c.2.5 $\mu g/m^3$

9.3 Photographic monitoring of lichens

Lichen growth rates were formerly estimated from photographs using a scale bar, with as few as two measurements per site. Recent revisions to the methods for the photographic monitoring of lichens include measurements of lichen growth rates in the field, and increasing the sample size to a minimum of five measurements per species per site. This will both reduce measurement error, and, from 2020 onwards, increase the sample size that can be compared between years to a minimum of five per species per site.

9.4 Quantitative monitoring of vegetation and soils

The three soil sampling sites are on Orthic Granular Soils (Mount Aubrey), Orthic Brown Soils (Mount Manaia), and Orthic Brown Soils (Kauri Mountain), which is the control site (Figure 5). Granular soils have a heavy clay content and are derived from the weathering of volcanic material, and are naturally low in nutrients and sulphate. Brown soils have a dark grey-brown topsoil and develop from more recent weathering in areas of humid climate (Landcare Research 2019). Some differences in soil chemistry may occur between Mount Aubrey and the other two sites due to differences in soil composition, but the other two sites are both Orthic Brown Soils. Monitoring should continue at the three existing sites, noting that it is the inter-year comparisons for each site that will be the most sensitive for potential detection of any changes potentially attributable to the air discharges.

9.5 Continuation of monitoring

It is understood that Refining NZ proposes to formally incorporate all of the above suggested improvements to the monitoring regime as part of its application for resource consents to authorise its discharges to air.

10. CONCLUSION

Refining NZ is applying for resource consent to continue their existing discharges to air, discharges to water, and discharges to land and groundwater. For this consent application, a full assessment of potential environmental effects is being undertaken. Wildland Consultants was commissioned to provide an assessment of effects of the air discharges on terrestrial ecology.

This assessment has drawn on existing ecological studies of the receiving environment, which encompasses parts of both the Manaia and Waipu Ecological Districts. The extent of the receiving environment has been defined based on the modelling of air discharges from the Refinery. Potential ecological effects on the ecosystems and species groups within the receiving environment have been considered on a pollutant-by-pollutant basis, with a literature review providing the basis for identification of potential effects.

Concentrations and deposition of pollutants in the air discharges are lower than the critical levels and critical loads at which detectable adverse ecological effects on terrestrial fauna and vegetation are predicted to occur within the receiving environment. We therefore do not expect that the air discharges will result in any detectable adverse effects for indigenous terrestrial ecosystems. The air discharge is probably the cause of some adverse effects for lichens within one kilometre of the discharge point at Marsden Point. However, this adverse effect is very localised, and restricted to modified habitats of low ecological value. The level of effect of the air discharge on habitats at Marsden Point is less than minor.

To acknowledge the uncertainties in the setting of critical loads and levels for New Zealand environments, and the small risk that adverse effects on terrestrial ecology may occur, it is proposed to continue monitoring the potential effects of air discharges on terrestrial ecology. This monitoring is in accordance with statutory requirements, and will require the biannual measurement, collection, and analysis of soils, lichens, and vegetation. The existing monitoring programme has been reviewed and critiqued, with an amended monitoring regime proposed to ensure the potential adverse effects of air discharges on terrestrial ecology are effectively monitored and managed throughout the life of the consent.

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VASCULAR PLANT SPECIES RECORDED IN MANAIA AND WAIPU ECOLOGICAL DISTRICTS

Scientific Name	Common Name	Plant Group
Indigenous Species		
Acaena anserinifolia	Piripiri	Dicot
Acianthus sinclairii		Orchid
Ackama rosifolia	Makamaka	Dicot
Adiantum aethiopicum	Huruhuru tapairu, maidenhair fern	Pteridophyte
Adiantum cunninghamii	Huruhuru tapairu, maidenhair fern	Pteridophyte
Adiantum diaphanum	Huruhuru tapairu, maidenhair fern	Pteridophyte
Adiantum fulvum	Huruhuru tapairu, maidenhair fern	Pteridophyte
Adiantum hispidulum	Huruhuru tapairu, maidenhair fern	Pteridophyte
Adiantum viridescens	Huruhuru tapairu, maidenhair fern	Pteridophyte
Agathis australis	Kauri	Gymnosperm
Alectryon excelsus subsp. *excelsus*	Titoki	Dicot
Alseuosmia banksii		Dicot
Alseuosmia macrophylla	Toropapa	Dicot
Alseuosmia quercifolia		Dicot
Apium prostratum subsp. *prostratum*	Tuutae kooau, NZ celery	Dicot
Apodasmia similis	Oioi	Rush
Aristotelia serrata	Makomako, wineberry	Dicot
Arthropodium cirratum	Rengarenga	Monocot (other than grasses, sedges, rushes and orchids)
Arthropteris tenella		Pteridophyte
Ascarina lucida var. *lucida*	Hutu	Dicot
Asplenium bulbiferum	Mouku, hen and chicken fern	Pteridophyte
Asplenium flabellifolium	Necklace fern	Pteridophyte
Asplenium flaccidum	Makawe	Pteridophyte
Asplenium gracillimum	Petako-paraharaha	Pteridophyte
Asplenium haurakiense		Pteridophyte
Asplenium hookerianum	Petako-paraharaha	Pteridophyte
Asplenium lamprophyllum	Petako-paraharaha	Pteridophyte
Asplenium northlandicum		Pteridophyte
Asplenium oblongifolium	Huruhuruwhenua	Pteridophyte
Asplenium polyodon	Petako	Pteridophyte
Astelia banksii	Kakaha	Monocot (other than grasses, sedges, rushes and orchids)
Astelia solandri	Kowharawhara	Monocot (other than grasses, sedges, rushes and orchids)
Astelia trinervia	Mauri	Monocot (other than grasses, sedges, rushes and orchids)
Austrostipa stipoides		Grass
Avicennia marina subsp. *australasica*	Manawa, mangrove	Dicot
Baumea articulata		Sedge
Baumea juncea		Sedge
Baumea rubiginosa		Sedge
Baumea tenax		Sedge
Baumea teretifolia		Sedge
Beilschmiedia tarairi	Taraire	Dicot
Beilschmiedia tawa	Tawa	Dicot
Beilschmiedia tawa (including *B. tawaroa*)	Tawaroa	Dicot
Blechnum chambersii	Rereti	Pteridophyte
Blechnum filiforme	Panako	Pteridophyte
Blechnum fraseri		Pteridophyte

Scientific Name	Common Name	Plant Group
Blechnum membranaceum		Pteridophyte
Blechnum minus	Swamp kiokio	Pteridophyte
Blechnum molle		Pteridophyte
Blechnum novae-zelandiae	Kiokio	Pteridophyte
Blechnum procerum		Pteridophyte
Blechnum triangularifolium		Pteridophyte
Blechnum zeelandicum		Pteridophyte
Bolboschoenus fluviatilis	Purua grass	Sedge
Brachyglottis kirkii var. *angustior*	Kohurangi, Kirk's tree daisy	Dicot
Brachyglottis kirkii var. *kirkii*	Kohurangi, Kirk's tree daisy	Dicot
Brachyglottis repanda	Rangiora	Dicot
Callitriche muelleri		Dicot
Callitriche stagnalis	Starwort	Dicot
Calochilus sp.		Orchid
Calystegia marginata		Dicot
Calystegia sepium	Pohue	Dicot
Calystegia soldanella	Panahi	Dicot
Calystegia tuguriorum	Powhiwhi, native bindweed	Dicot
Cardamine debilis agg.	Panapana	Dicot
Carex breviculmis		Sedge
Carex dissita		Sedge
Carex flagellifera	Manaia	Sedge
Carex forsteri		Sedge
Carex lambertiana		Sedge
Carex lessoniana	Toetoe-rautahi	Sedge
Carex ochrosaccus		Sedge
Carex ovalis	Oval sedge	Sedge
Carex pumila		Sedge
Carex raoulii		Sedge
Carex solandri		Sedge
Carex spinirostris		Sedge
Carex testacea		Sedge
Carex virgata	Purei	Sedge
Carmichaelia australis	NZ broom	Dicot
Carpodetus serratus	Putaputaweta	Dicot
Celmisia adamsii var. *rugulosa*		Dicot
Centella uniflora		Dicot
Cheilanthes distans		Pteridophyte
Cheilanthes sieberi		Pteridophyte
Chionochloa bromoides		Grass
Chionochloa conspicua subsp. *cunninghamii*		Grass
Clematis cunninghamii	Ngakau-kiore	Dicot
Clematis foetida	Akakaiku	Dicot
Clematis forsteri	Poangana	Dicot
Clematis paniculata	Puawananga	Dicot
Collospermum hastatum	Kahakaha	Monocot (other than grasses, sedges, rushes and orchids)
Collospermum microspermum		Monocots (other than grasses, sedges, rushes and orchids)
Coprosma acerosa	Tarakupenga, sand coprosma	Dicot
Coprosma arborea	Mamangi	Dicot
Coprosma areolata		Dicot
Coprosma grandifolia	Kanono	Dicot
Coprosma lucida	Karamu, glossy karamu	Dicot
Coprosma macrocarpa × *C. propinqua*		Dicot
Coprosma macrocarpa subsp. *minor*	Karamu	Dicot

Scientific Name	Common Name	Plant Group
Coprosma neglecta		Dicot
Coprosma propinqua		Dicot
Coprosma propinqua × *C. robusta*		Dicot
Coprosma repens	Taupata	Dicot
Coprosma rhamnoides		Dicot
Coprosma rigida		Dicot
Coprosma robusta	Karamu	Dicot
Coprosma rotundifolia		Dicot
Coprosma spathulata subsp. *spathulata*		Dicot
Coprosma tenuicaulis	Hukihuki, swamp coprosma	Dicot
Cordyline australis	Tī kōuka, cabbage tree	Monocot (other than grasses, sedges, rushes and orchids)
Cordyline banksii	Ti ngahere, forest cabbage tree	Monocot (other than grasses, sedges, rushes and orchids)
Cordyline pumilio	Dwarf cabbage tree	Monocot (other than grasses, sedges, rushes and orchids)
Coriaria arborea var. *arborea*	Tutu	Dicot
Corokia buddleioides	Korokio	Dicot
Corokia cotoneaster	Korokio	Dicot
Cortaderia splendens		Grass
Corynocarpus laevigatus	Karaka	Dicot
Cotula australis	Soldier’s button	Dicot
Cotula coronopifolia	Bachelor’s button	Dicot
Crassula sieberiana		Dicot
Ctenopteris heterophylla		Pteridophyte
Cyathea cunninghamii	Punui, gully tree fern	Pteridophyte
Cyathea dealbata	Ponga, silver fern	Pteridophyte
Cyathea medullaris		Pteridophyte
Cyathea smithii	Katote, soft tree fern	Pteridophyte
Cyperus brevifolius	Globe sedge	Sedge
Cyperus congestus	Purple umbrella sedge	Sedge
Cyperus eragrostis	Umbrella sedge	Sedge
Cyperus ustulatus f. *ustulatus*	Toetoe, upokotangata	Sedge
Dacrycarpus dacrydioides	Kahikatea	Gymnosperm
Dacrydium cupressinum	Rimu	Gymnosperm
Dactylanthus taylorii	Pua o te reinga	Dicot
Deparia petersenii subsp. *congrua*		Pteridophyte
Deyeuxia avenoides		Grass
Dianella nigra	Turutu	Monocot (other than grasses, sedges, rushes and orchids)
Dichelachne crinita	Patiti, plume grass	Grass
Dichondra repens	Mercury Bay weed	Dicot
Dicksonia squarrosa	Wheki	Pteridophyte
Diplazium australe		Pteridophyte
Diplodium alobulum		Orchid
Disphyma australe subsp. *australe*	Horokaka	Dicot
Dodonaea viscosa	Akeake	Dicot
Doodia australis	Pukupuku	Pteridophyte
Dracophyllum latifolium	Neinei	Dicot
Dracophyllum sinclairii		Dicot
Drosera auriculata	Wahu, sundew	Dicot
Drosera hookeri	Wahu, sundew	Dicot
Drymoanthus adversus		Orchid
Dysoxylum spectabile	Kohekohe	Dicot
Earina autumnalis	Raupeka	Orchid
Earina mucronata	Peka-a-waka	Orchid
Einadia triandra		Dicot

Scientific Name	Common Name	Plant Group
Elaeocarpus dentatus	Hinau	Dicot
Eleocharis acuta		Sedge
Eleocharis sphacelata	Kuta	Sedge
Entelea arborescens	Whau	Dicot
Epacris pauciflora	Tumingi	Dicot
Epilobium pallidiflorum	Tawarewa	Dicot
Euchiton audax		Dicot
Euchiton collinus		Dicot
Euchiton delicatus		Dicot
Euchiton involucratus		Dicot
Ficinia nodosa	Wiwi	Sedge
Ficinia spiralis	Pingao	Sedge
Freycinetia banksii	Kiekie	Monocot (other than grasses, sedges, rushes and orchids)
Fuchsia excorticata	Kotukutuku	Dicot
Fuchsia procumbens		Dicot
Gahnia lacera	Tarangarara	Sedge
Gahnia pauciflora	Takahikahi	Sedge
Gahnia xanthocarpa	Tupari-maunga	Sedge
Gaultheria antipoda	Tawiniwini	Dicot
Geniostoma ligustrifolium var. ligustrifolium	Hangehange	Dicot
Geranium homeanum	Pinakitere	Dicot
Geranium solanderi	Matuia-kumara	Dicot
Gleichenia dicarpa	Tangle fern	Pteridophyte
Gleichenia microphylla	Waewaekaka, swamp umbrella fern	Pteridophyte
Gonocarpus incanus	Piripiri	Dicot
Gonocarpus montanus	Piripiri	Dicot
Grammitis billardierei		Pteridophyte
Grammitis ciliata		Pteridophyte
Griselinia littoralis (unconfirmed)	Kapuka	Dicot
Griselinia lucida	Puka	Dicot
Haloragis erecta subsp. *erecta*	Toatoa	Dicot
Hebe ligustrifolia (includes *H.* “Whangārei”)	Koromiko	Dicot
Hebe macrocarpa var. *latisepala*	Koromiko	Dicot
Hebe macrocarpa var. *macrocarpa*	Koromiko	Dicot
Hebe parviflora	Tree hebe, koromiko taranga	Dicot
Hebe stricta var. *stricta*	Koromiko	Dicot
Hedycarya arborea	Porokaiwhiri, pigeonwood	Dicot
Helichrysum lanceolatum	Niniao	Dicot
Hibiscus sp.[33]		Dicot
Histiopteris incisa	Matata, water fern	Pteridophyte
Hoheria populnea	Houhere, lacebark	Dicot
Huperzia varia		Pteridophyte
Hydrocotyle elongata		Dicot
Hydrocotyle microphylla		Dicot
Hydrocotyle novae-zeelandiae var. *novae-zeelandiae*		Dicot
Hymenophyllum australe	Maku, filmy fern	Pteridophyte
Hymenophyllum demissum	Maku, filmy fern	Pteridophyte
Hymenophyllum dilatatum	Maku, filmy fern	Pteridophyte
Hymenophyllum flexuosum	Maku, filmy fern	Pteridophyte
Hymenophyllum lyallii	Maku, filmy fern	Pteridophyte
Hymenophyllum multifidum	Maku, filmy fern	Pteridophyte
Hymenophyllum rarum	Maku, filmy fern	Pteridophyte
Hymenophyllum revolutum	Maku, filmy fern	Pteridophyte

Scientific Name	Common Name	Plant Group
Hymenophyllum sanguinolentum	Piripiri, filmy fern	Pteridophyte
Hypolepis ambigua		Pteridophyte
Ichthyostomum pygmaeum	Piripiri	Orchid
Isachne globosa	Swamp millet	Grass
Isolepis cernua		Sedge
Isolepis habra		Sedge
Isolepis prolifera		Sedge
Juncus edgariae	Wi	Rush
Juncus kraussii var. *australiensis*	Wi, sea rush	Rush
Juncus planifolius		Rush
Juncus sarophorus	Wi	Rush
Knightia excelsa	Rewarewa	Dicot
Kunzea ericoides	Kānuka	Dicot
Kunzea linearis	Rawiri mānuka, kānuka	Dicot
Lachnagrostis billardierei	Perehia	Grass
Lachnagrostis filiformis	Perehia	Grass
Lagenifera cuneata		Dicot
Lastreopsis glabella		Pteridophyte
Lastreopsis hispida		Pteridophyte
Lastreopsis velutina		Pteridophyte
Laurelia novae-zelandiae	Pukatea	Dicot
Leionema nudum	Mairehau	Dicot
Lepidium oleraceum	Nau, Cook's scurvy grass	Dicot
Lepidosperma australe		Sedge
Lepidosperma laterale		Sedge
Leptecophylla juniperina var. *juniperina*	Prickly mingimingi	Dicot
Leptospermum scoparium agg.	Mānuka	Dicot
Leptostigma setulosa		Dicot
Leucopogon fasciculatus	Mingimingi	Dicot
Leucopogon fraseri	Patōtara	Dicot
Libertia grandiflora	Mikoikoi	Monocot (other than grasses, sedges, rushes and orchids)
Libocedrus plumosa	Kawaka	Gymnosperm
Lindsaea linearis		Pteridophyte
Linum monogynum	Rauhuia, linen flax	Dicot
Litsea calicaris	Mangeao	Dicot
Lobelia anceps	Punakuru	Dicot
Lophomyrtus bullata	Ramarama	Dicot
Lophomyrtus obcordata	Rohutu	Dicot
Loxogramme dictyopteris		Pteridophyte
Loxsoma cunninghamii		Pteridophyte
Luzula picta var. *picta*		Rush
Lycopodiella cernua	Maatukutuku	Pteridophyte
Lycopodium deuterodensum	Puakarimu	Pteridophyte
Lycopodium volubile	Waewaekoukou	Pteridophyte
Lygodium articulatum	Mangemange	Pteridophyte
Macropiper excelsum subsp. *excelsum*	Kawakawa	Dicot
Melicope simplex	Poataniwha	Dicot
Melicope ternata	Wharangi	Dicot
Melicytus macrophyllus		Dicot
Melicytus micranthus	Mahoe-wao	Dicot
Melicytus novae-zelandiae	Coastal mahoe	Dicot
Melicytus ramiflorus subsp. *ramiflorus*	Mahoe	Dicot
Metrosideros carminea	Akakura	Dicot
Metrosideros diffusa	Rata	Dicot
Metrosideros excelsa	Pohutukawa	Dicot

Scientific Name	Common Name	Plant Group
Metrosideros fulgens	Rata	Dicot
Metrosideros perforata	Aka	Dicot
Metrosideros robusta	Northern rata	Dicot
Microlaena avenacea	Bush rice grass	Grass
Microlaena carsei		Grass
Microlaena polynoda		Grass
Microlaena stipoides	Patiti, meadow rice grass	Grass
Microsorum pustulatum	Kowaowao, hounds tongue fern	Pteridophyte
Microsorum scandens	Mokimoki	Pteridophyte
Microtis unifolia agg.	Maikaika	Orchid
Morelotia affinis		Sedge
Muehlenbeckia australis	Puka	Dicot
Muehlenbeckia complexa	Pohuehue	Dicot
Myoporum laetum	Ngaio	Dicot
Myosotis spathulata		Dicot
Myrsine australis	Mapou	Dicot
Myrsine salicina	Toro	Dicot
Nematoceras macranthum		Orchid
neozelandicum		Pteridophyte
Nertera dichondrifolia		Dicot
Nestegis apetala	Coastal maire	Dicot
Nestegis cunninghamii	Black maire	Dicot
Nestegis lanceolata	White maire	Dicot
Nestegis montana		Dicot
Olearia albida	Tanguru	Dicot
Olearia angulata		Dicot
Olearia furfuracea	Akepiro	Dicot
Olearia rani var. *rani*		Dicot
Ophioglossum coriaceum		Pteridophyte
Oplismenus hirtellus subsp. *imbecillis*		Grass
Orthoceras novae-zeelandiae	Maikaika	Orchid
Oxalis exilis		Dicot
Oxalis magellanica		Dicot
Oxalis rubens	Sand oxalis	Dicot
Ozothamnus leptophyllus	Tauhinu	Dicot
Paesia scaberula	Matata	Pteridophyte
Parietaria debilis		Dicot
Parsonsia capsularis	Akakiore	Dicot
Parsonsia heterophylla	Akakaikiore	Dicot
Passiflora tetrandra	Kohia	Dicot
Pelargonium inodorum	Kopata	Dicot
Pellaea rotundifolia	Tarawera, button fern	Pteridophyte
Pennantia corymbosa	Kaikomako	Dicot
Peperomia tetraphylla		Dicot
Peperomia urvilleana		Dicot
Persicaria decipiens	Tutunawai	Dicot
Phormium cookianum subsp. *hookeri*	Wharariki, mountain flax	Monocot (other than grasses, sedges, rushes and orchids)
Phormium tenax	Harakeke, flax	Monocot (other than grasses, sedges, rushes and orchids)
Phyllocladus toatoa	Toatoa	Gymnosperm
Phyllocladus trichomanoides	Tānekaha	Gymnosperm
Pimelea acra		Dicot
Pimelea tomentosa		Dicot
Pimelea villosa	Autetaranga	Dicot
Pisonia brunoniana	Parapara	Dicot
Pittosporum cornifolium	Tawhirikao	Dicot
Pittosporum crassifolium	Karo	Dicot

Scientific Name	Common Name	Plant Group
Pittosporum ellipticum		Dicot
Pittosporum eugenioides	Tarata	Dicot
Pittosporum tenuifolium	Kohukohu	Dicot
Pittosporum umbellatum	Haekaro	Dicot
Pittosporum virgatum		Dicot
Plagianthus divaricatus	Makaka, saltmarsh ribbonwood	Dicot
Pneumatopteris pennigera	Pakau	Pteridophyte
Poa anceps agg.		Grass
Poa imbecilla		Grass
Podocarpus hallii	Hall's tōtara	Gymnosperm
Podocarpus totara	Tōtara	Gymnosperm
Polystichum neozelandicum subsp.		Pteridophyte
Polystichum sp.		Pteridophyte
Pomaderris amoena		Dicot
Pomaderris kumeraho	Kumarehou	Dicot
Pomaderris paniculosa subsp. *novaezelandiae*		Dicot
Pomaderris. prunifolia var. *egderleyi*		Dicot
Pouteria costata	Tawapou	Dicot
Prumnopitys ferruginea	Miro	Gymnosperm
Prumnopitys taxifolia	Matai	Gymnosperm
Pseudognaphalium luteoalbum agg.	Pukatea	Dicot
Pseudopanax arboreus	Whauwahupaku, five-finger	Dicot
Pseudopanax crassifolius	Horoeka, lancewood	Dicot
Pseudopanax crassifolius × *P. lessonii*		Dicot
Pseudopanax lessonii	Houpara	Dicot
Pseudowintera axillaris	Horopito	Dicot
Pseudowintera insperata	Northland horopito	Dicot
Pteridium esculentum	Rarahu, bracken	Pteridophyte
Pteris comans		Pteridophyte
Pteris comans × *P. macilenta*		Pteridophyte
Pteris macilenta	Sweet fern	Pteridophyte
Pteris saxatilis		Pteridophyte
Pteris tremula	Turawera, shaking brake	Pteridophyte
Pterostylis banksii	Tutukiwi	Orchid
Pterostylis graminea		Orchid
Pyrrosia eleagnifolia	Leather-leaf fern	Pteridophyte
Quintinia serrata	Tawheowheo	Dicot
Ranunculus reflexus	Maruru	Dicot
Rhabdothamnus solandri	Taurepo	Dicot
Rhopalostylis sapida	Nīkau	Monocot (other than grasses, sedges, rushes and orchids)
Ripogonum scandens	Kareao, supplejack	Monocot (other than grasses, sedges, rushes and orchids)
Rubus australis	Tataramoa	Dicot
Rubus cissoides agg.	Tataramoa, bush lawyer	Dicot
Rubus schmidelioides var. *schmidelioides* (unconfirmed)	Akatataramoa, bush lawyer	Dicot
Rubus squarrosus		Dicot
Rytidosperma biannulare		Grass
Rytidosperma gracile		Grass
Samolus repens var. *repens*	Makaokao	Dicot
Sarcocornia quinqueflora	Ureure, glasswort	Dicot
Scandia rosifolia	Kohepiro	Dicot
Schefflera digitata	Pate	Dicot
Schizaea fistulosa		Pteridophyte
Schoenoplectus tabernaemontani	Kapungawha	Sedge

Scientific Name	Common Name	Plant Group
Schoenus apogon		Sedge
Schoenus brevifolius		Sedge
Schoenus maschalinus		Sedge
Schoenus nitens		Sedge
Schoenus tendo	Wiwi	Sedge
Selliera radicans	Remuremu	Dicot
Senecio biserratus		Dicot
Senecio glomeratus	Pukatea	Dicot
Senecio hispidulus		Dicot
Senecio lautus var. *lautus*		Dicot
Senecio minimus		Dicot
Senecio quadridentatus		Dicot
Senecio scaberulus		Dicot
Singularybas oblongus		Orchid
Solanum americanum	Raupeti	Dicot
Solanum sp.		Dicot
Sophora chathamica	Kōwhai	Dicot
Sophora fulvida	Kōwhai	Dicot
Spinifex sericeus	Kowhangatara, spinifex	Grass
Stellaria parviflora	Kohukohu	Dicot
Sticherus cunninghamii	Waekura	Pteridophyte
Sticherus flabellatus		Pteridophyte
Streblus banksii	Turepo	Dicot
Streblus heterophyllus	Turepo	Dicot
Suaeda novae-zelandiae		Dicot
Tetragonia implexicoma		Dicot
Tetragonia tetragonioides	Kokihi	Dicot
Tetraria capillaris		Sedge
Thelymitra colensoi		Orchid
Thelymitra cyanea		Orchid
Thelymitra longifolia	Maikuku	Orchid
Thelymitra pauciflora	Slender sun orchid	Orchid
Tmesipteris elongata		Pteridophyte
Tmesipteris lanceolata		Pteridophyte
Tmesipteris sigmatifolia		Pteridophyte
Tmesipteris tannensis		Pteridophyte
Toronia toru	Toru	Dicot
Trichomanes reniforme		Pteridophyte
Trichomanes sp.		Pteridophyte
Triglochin striata	Arrow grass	Monocot (other than grasses, sedges, rushes and orchids)
Typha orientalis	Raupo	Monocot (other than grasses, sedges, rushes and orchids)
Uncinia banksii	Matau	Sedge
Uncinia uncinata	Kamu matau a Maui	Sedge
Urtica ferox	Ongaonga, tree nettle	Dicot
Vitex lucens	Pūriri	Dicot
Wahlenbergia littoricola subsp. *vernicosa*		Dicot
Wahlenbergia violacea	Rimuroa	Dicot
Winika cunninghamii		Orchid
Zoysia minima		Grass
Zoysia pauciflora		Grass
Adventive Species		
Acacia dealbata	Silver wattle	Dicot
Acacia mearnsii	Black wattle	Dicot
Acacia melanoxylon	Tasmanian blackwood	Dicot
Acacia paradoxa	Kangaroo acacia	Dicot

Scientific Name	Common Name	Plant Group
Acanthus mollis	Bear's breeches	Dicot
Achillea millefolium	Yarrow	Dicot
Agave sp.		Monocot (other than grasses, sedges, rushes and orchids)
Ageratina adenophora	Mexican devil	Dicot
Ageratina riparia	Mist flower	Dicot
Ageratum houstonianum		Dicot
Agrostis stolonifera	Creeping bent	Grass
Aira caryophyllea subsp. *caryophyllea*	Silver hairy grass	Grass
Allium triquetrum	Onion weed	Monocot (other than grasses, sedges, rushes and orchids)
Allium vineale var. *compactum*		Monocot (other than grasses, sedges, rushes and orchids)
Allocasuarina littoralis	She-oak	Dicot
Ammophila arenaria	Marram	Grass
Anagallis arvensis	Scarlet pimpernel	Dicot
Anthemis cotula	Stinking mayweed	Dicot
Anthoxanthum odoratum	Sweet vernal	Grass
Araujia sericifera	Moth plant	Dicot
Arctotheca calendula	Cape weed	Dicot
Aristea ecklonii	Aristea	Monocot (other than grasses, sedges, rushes and orchids)
Artemisia verlotiorum	Chinese mugwort	Dicot
Arum italicum	Italian arum	Monocot (other than grasses, sedges, rushes and orchids)
Arundo donax	Giant reed	Grass
Asparagus asparagoides	Smilax	Monocot (other than grasses, sedges, rushes and orchids)
Asparagus scandens	Climbing asparagus	Monocot (other than grasses, sedges, rushes and orchids)
Aster subulatus	Sea aster	Dicot
Atriplex prostrata	Orache	Dicot
Axonopus fissifolius	Narrow-leaved carpet grass	Graes
Azolla pinnata	Ferny azolla	Pteridophyts
Banksia intermedia		Dicot
Bellis perennis	Lawn daisy	Dicot
Berberis glaucocarpa	Barberry	Dicot
Blackstonia perfoliata		Dicot
Briza minor	Shivery grass	Grass
Bromus diandrus	Ripgut brome	Grass
Bromus willdenowii	Prairie grass	Grass
Cakile maritima	Sea rocket	Dicot
Calystegia silvatica	Greater bindweed	Dicot
Canna indica	Canna lily, Indian shoot	Monocot (other than grasses, sedges, rushes and orchids)
Cardamine sp.		Dicot
Centaurium erythraea	Centaury	Dicot
Cerastium fontanum subsp. *vulgare*	Mouse-ear chickweed	Dicot
Ceratophyllum demersum	Hornwort	Dicot
Chrysanthemum segetum	Corn marigold	Dicot
Cirsium arvense	California thistle	Dicot
Cirsium vulgare	Scotch thistle	Dicot
Conium maculatum	Hemlock	Dicot
Conyza sumatrensis	Broad-leaved fleabane	Dicot
Cortaderia jubata	Purple pampas	Grass
Cortaderia selloana	Pampas	Grass
Cotoneaster glaucophyllus	Cotoneaster	Dicot
Crepis capillaris	Hawksbeard	Dicot

Scientific Name	Common Name	Plant Group
Crocosmia × crocosmiiflora	Montbretia	Monocot (other than grasses, sedges, rushes and orchids)
Cynodon dactylon	Indian doab	Grass
Dactylis glomerata	Cocksfoot	Grass
Daucus carota	Wild carrot	Dicot
Delairea odorata	Cape ivy	Dicot
Dipogon lignosus	Mile-a-minute	Dicot
Ehrharta erecta	Veldt grass	Grass
Elaeagnus ×reflexa	Elaeagnus	Dicot
Epilobium tetragonum		Dicot
Eragrostis brownii	Bay grass	Grass
Erigeron karvinskianus	Mexican daisy	Dicot
Eriobotrya japonica	Loquat	Dicot
Erodium cicutarium	Storksbill	Dicot
Erythrina ×sykesii	Coral tree	Dicot
Euphorbia peplus	Milkweed	Dicot
Festuca rubra		Grass
Foeniculum vulgare	Fennel	Dicot
Fragaria vesca	Wild strawberry	Dicot
Freesia refracta	Freesia	Monocot (other than grasses, sedges, rushes and orchids)
Fumaria muralis	Scrambling fumitory	Dicot
Furcraea spp.		Monocot (other than grasses, sedges, rushes and orchids)
Galeobdolon luteum	Aluminium plant	Dicot
Galium aparine	Cleavers	Dicot
Galium divaricatum	Slender bedstraw	Dicot
Gamochaeta coarctata	Purple cudweed	Dicot
Geranium robertianum	Herb Robert	Dicot
Geranium sp.	Geranium	Dicot
Gladiolus undulatus	Gladiolus	Monocot (other than grasses, sedges, rushes and orchids)
Glyceria declinata	Blue sweetgrass	Grass
Glyceria maxima	Reed sweetgrass	Grass
Gunnera tinctoria	Chilean rhubarb	Dicot
Hakea drupacea		Dicot
Hakea salicifolia	Willow-leaved hakea	Dicot
Hakea sericea	Prickly hakea	Dicot
Hedera helix	Ivy	Dicot
Hedychium gardnerianum	Kahili ginger, wild ginger	Monocot (other than grasses, sedges, rushes and orchids)
Helminthotheca echioides	Oxtongue	Dicot
Holcus lanatus	Yorkshire fog	Grass
Hydrangea macrophylla	Hydrangea	Dicot
Hypochoeris radicata	Catsear	Dicot
Impatiens sodenii	Shrub balsam	Dicot
Jacobaea vulgaris	Ragwort	Dicot
Jasminum sp.		Dicot
Juncus articulatus	Jointed rush	Rush
Juncus bufonius var. *bufonius*	Toad rush	Rush
Juncus effusus var. *effusus*	Soft rush, leafless rush	Rush
Juncus tenuis var. *tenuis*	Track rush	Rush
Kniphofia uvaria	Red hot poker	Monocot (other than grasses, sedges, rushes and orchids)
Lactuca serriola	Prickly lettuce	Dicot
Lagurus ovatus	Harestail	Grass
Lapsana communis	Nipplewort	Dicot
Lathyrus latifolius	Everlasting pea	Dicot
Leontodon taraxacoides	Hawkbit	Dicot

Scientific Name	Common Name	Plant Group
Lepidium didymum	Twin cress	Dicot
Leucanthemum vulgare	Oxeye daisy	Dicot
Ligustrum lucidum	Tree privet	Dicot
Ligustrum sinense	Chinese privet	Dicot
Linum bienne	Pale flax	Dicot
Linum monogynum	Rauhuia, linen flax	Dicot
Lolium perenne	Rye grass	Grass
Lonicera japonica	Japanese honeysuckle	Dicot
Lotus angustissimus	Slender birdsfoot trefoil	Dicot
Lotus pedunculatus	Lotus	Dicot
Lupinus arboreus	Lupin	Dicot
Lycium ferocissimum	Boxthorn	Dicot
Lythrum hyssopifolia	Hyssop loosestrife	Dicot
Malus ×domestica	Apple tree	Dicot
Malva sp.	Mallow	Dicot
Matricaria discoidea	Rayless chamomile	Dicot
Melilotus indica	King Island melilot	Dicot
Mentha pulegium	Penny royal	Dicot
Miscanthus nepalensis	Himalayan fairy grass	Grass
Monstera deliciosa	Fruit salad plant	Dicot
Myosotis sylvatica	Garden forget-me-not	Dicot
Nasturtium officinale	Watercress	Dicot
Nephrolepis cordifolia	Tuber ladder fern	Pteridophyte
Nerium oleander	Oleander	Dicot
Ochna serrulata	Mickey Mouse plant	Dicot
Orobanche minor	Broomrape	Dicot
Osteospermum fruticosum	Rain daisy, dimorphotheca	Dicot
Oxalis corniculata	Horned oxalis	Dicot
Parapholus incurva	Sickle grass	Grass
Paraserianthes lophantha	Brush wattle	Dicot
Paspalum dilatatum	Paspalum	Grass
Paspalum urvillei	Vasey grass	Grass
Paspalum vaginatum	Saltwater paspalum	Grass
Passiflora tripartita var. *mollissima*	Banana passionfruit	Dicot
Pennisetum clandestinum	Kikuyu grass	Grass
Persicaria maculosa	Willow weed	Dicot
Phoenix canariensis	Phoenix palm	Monocot (other than grasses, sedges, rushes and orchids)
Phytolacca octandra	Inkweed	Dicot
Pinus contorta	Contorta pine	Gymnosperm
Pinus pinaster	Maritime pine	Gymnosperm
Pinus radiata	Radiata pine	Gymnosperm
Plantago australis	Swamp plantain	Dicot
Plantago coronopus	Buck's-horn plantain	Dicot
Plantago lanceolata	Narrow-leaved plantain	Dicot
Plantago major	Broad-leaved plantain	Dicot
Poa annua	Annual poa	Grass
Polypogon monspeliensis	Beard grass	Grass
Populus nigra	Lombardy poplar	Dicot
Populus sp.	Poplar	Dicot
Prunella vulgaris	Selfheal	Dicot
Pyracantha sp.		Dicot
Ranunculus repens	Creeping buttercup	Dicot
Ranunculus sp.		Dicot
Raphanus raphanistrum subsp. raphanistrum	Wild raddish	Dicot
Roldana petasitis	Velvet groundsel	Dicot
Rosa sp.	Climbing rose	Dicot

Scientific Name	Common Name	Plant Group
Rubus sp. (*R. fruticosus* agg.)	Blackberry	Dicot
Rumex acetosella	Sheep's sorrel	Dicot
Rumex conglomeratus	Clustered dock	Dicot
Rumex obtusifolius	Broad-leaved dock	Dicot
Rytidosperma pilosum	Hairy wallaby grass	Grass
Rytidosperma racemosum	Danthonia	Grass
Sagina procumbens	Pearlwort	Dicot
Salix fragilis	Crack willow	Dicot
Salix matsudana	Tortured willow	Dicot
Schedonorus arundinaceus	Tall fescue	Dicot
Selaginella kraussiana	Creeping clubmoss, selaginella	Pteridophyte
Senecio bipinnatisectus	Australian fireweed	Dicot
Senecio elegans	Purple groundsel	Dicot
Senecio skirrhodon	Gravel groundsel	Dicot
Senecio sylvaticus	Wood groundsel	Dicot
Senecio vulgaris	Groundsel	Dicot
Senna multiglandulosa	Buttercup bush	Dicot
Sigesbeckia orientalis	Indian weed	Dicot
Silene gallica	Catchfly	Dicot
Sisyrinchium iridifolium	Purple-eyed grass	Monocot (other than grasses, sedges, rushes and orchids)
Solanum linnaeanum	Apple of Sodom	Dicot
Solanum mauritianum	Woolly nightshade	Dicot
Solanum nigrum	Black nightshade	Dicot
Sonchus asper	Prickly puha	Dicot
Sonchus oleraceus	Puha, sow thistle	Dicot
Sporobolus africanus	Ratstail	Grass
Stellaria media	Chickweed	Dicot
Stenotaphrum secundatum	Buffalo grass	Grass
Taraxacum officinale	Dandelion	Dicot
Thunbergia alata	Black-eyed Susan	Dicot
Torilis arvensis	Spreading hedge parsley	Dicot
Tradescantia fluminensis	Tradescantia	Monocot (other than grasses, sedges, rushes and orchids)
Trifolium pratense	Red clover	Dicot
Trifolium repens	White clover	Dicot
Tropaeolum majus	Garden nasturtium	Dicot
Ulex europaeus	Gorse	Dicot
Verbena bonariensis	Purple-top	Dicot
Veronica anagallis-aquatica	Water speedwell	Dicot
Veronica arvensis	Field speedwell	Dicot
Veronica serpyllifolia	Turf speedwell	Dicot
Vicia sativa	Vetch	Dicot
Vinca major	Periwinkle	Dicot
Watsonia sp.	Watsonia	Monocot (other than grasses, sedges, rushes and orchids)
Wisteria sinensis	Wisteria	Dicot
Zantedeschia aethiopica	Arum lily	Monocot (other than grasses, sedges, rushes and orchids)

APPENDIX 2

AVIFAUNA RECORDED IN MANAIA AND WAIPU ECOLOGICAL DISTRICTS

Sources: Manaia Ecological District PNAP survey report (Goldwater and Beadel 2010), Waipu Ecological District PNAP report (Lux *et al.* 2007), eBird, Morgan *et al.* (2017).
Significance as recorded in PNAP survey reports, Honner *et al.* (2011), and Whangarei District Plan Schedule 17B.

Species Name	Common Name	National Threat Classification 2016	Significance	Manaia Ecological District	Waipu Ecological District
Acridotheres tristis	Myna	Introduced and Naturalised		eBird, PNAP	eBird, PNAP
Alauda arvensis	Skylark	Introduced and Naturalised		eBird, PNAP	eBird, PNAP
Anarhynchus frontalis	Wrybill; ngutuparore	Threatened-Nationally Vulnerable	Significant under WDP (High Value species)		eBird, PNAP
Anas chlorotis	Pāteke, brown teal	At Risk-Recovering	Significant under WDP (Outstanding Value species)		PNAP
Anas gracilis	Tete; grey teal	Not Threatened	Recorded as Regionally Significant in Lux *et al.* (2007)		eBird, PNAP
Anas platyrhynchos	Mallard	Introduced and Naturalised		PNAP	eBird, PNAP
Anas platyrhynchos (Domestic type)	Mallard (domestic type)	Introduced and Naturalised			eBird
Anas platyrhynchos ×superciliosa	Mallard × grey duck (hybrid)	Not Threatened			eBird
Anas rhynchotis	Australasian shoveler; kuruwhengi	Not Threatened	Recorded as Regionally Significant in Honner *et al*. (2011) and Lux *et al.* (2007)		eBird, PNAP
Anas superciliosa	Grey duck, pārera	Threatened-Nationally Critical		PNAP	eBird, PNAP
Anatidae sp. (dabbling duck sp.)	Dabbling duck sp.	N/A			eBird
Anser anser	Graylag goose	Introduced and Naturalised			eBird
Anthornis melanura melanura	Bellbird; korimako; makomako	Not Threatened	Recorded as Regionally Significant in Goldwater and Beadel (2010), Honner *et al*. (2011) and Lux *et al.* (2007)	eBird, PNAP	PNAP
Anthus novaeseelandiae novaeseelandiae	New Zealand pipit; pīhoihoi	At Risk-Declining		eBird, PNAP	eBird, PNAP

Species Name	Common Name	National Threat Classification 2016	Significance	Manaia Ecological District	Waipu Ecological District
Apteryx mantelli	North Island brown kiwi	At Risk-Declining	Significant under WDP (Outstanding Value species)	PNAP	PNAP
Ardea modesta	White heron; kotuku	Threatened-Nationally Critical			eBird, PNAP
Arenaria interpres	Turnstone	Non-resident Native - Migrant			eBird, PNAP
Aythya novaeseelandiae	New Zealand scaup	Not Threatened	Recorded as Regionally Significant in Honner *et al*. (2011) and Lux *et al.* (2007); Significant under WDP (Moderate Value species)		eBird, PNAP
Botaurus poiciloptilus	Australasian bittern, matuku	Threatened-Nationally Critical	Significant under WDP (High Value species)	PNAP	eBird, PNAP
Bowdleria punctata vealeae	North Island fernbird, mātātā	At Risk-Declining	Significant under WDP (Moderate Value species)	PNAP	eBird, PNAP
Branta canadensis	Canada goose	Introduced and Naturalised			eBird, PNAP
Bubulcus ibis	Cattle egret	Non-resident Native - Migrant			eBird
Cairina moschata (domestic type)	Muscovy Duck (domestic type)	Introduced (Not listed)			PNAP
Calidris acuminata	Sharp-tailed sandpiper	Non-resident Native - Migrant	Significant under WDP (Moderate Value species)		PNAP
Calidris alba	Sanderling	Non-resident Native - Vagrant			eBird, PNAP
Calidris canutus	Huahou, lesser knot	Threatened-Nationally Vulnerable	Significant under WDP (Moderate Value species)		eBird, PNAP
Calidris ferruginea	Curlew sandpiper	Non-resident Native - Vagrant	Significant under WDP (Moderate Value species)		PNAP
Calidris mauri	Western sandpiper	Non-resident Native - Vagrant			PNAP
Calidris melanotos	Pectoral sandpiper	Non-resident Native - Vagrant			eBird, PNAP
Calidris ruficollis	Red-necked stint	Non-resident Native - Migrant	Significant under WDP (Moderate Value species)	PNAP	eBird, PNAP
Callipepla californica	California quail	Introduced and Naturalised		eBird, PNAP	eBird, PNAP
Carduelis carduelis	Goldfinch	Introduced and Naturalised		eBird, PNAP	eBird, PNAP
Carduelis chloris	Greenfinch	Introduced and Naturalised		PNAP	PNAP
Carduelis flammea	Redpoll	Introduced and Naturalised			PNAP
Catharacta antartica lonnbergi	Brown skua; hakoakoa	At Risk-Naturally Uncommon			eBird, PNAP

Species Name	Common Name	National Threat Classification 2016	Significance	Manaia Ecological District	Waipu Ecological District
Charadrius bicinctus bicinctus	Banded dotterel; tūturiwhatu	Threatened-Nationally Vulnerable	Significant under WDP (Moderate-High Value species)	eBird, PNAP	eBird, PNAP
Charadrius obscurus aquilonius	Northern New Zealand dotterel; tūturiwhatu	At Risk-Recovering	Significant under WDP (High Value species)		eBird
Chlidonias albostriatus	Black-fronted tern	Threatened-Nationally Endangered			PNAP
Chlidonias leucopterus	White-winged black tern	Non-resident Native - Migrant		PNAP	eBird, PNAP
Chrysococcyx lucidus lucidus	Shining cuckoo, pīpīwharauroa	Not Threatened	Recorded as Regionally Significant in Honner *et al*. (2011)	eBird, PNAP	eBird, PNAP
Circus approximans	Australasian harrier, kahu	Not Threatened		PNAP	eBird
Columba livia	Rock pigeon	Introduced and Naturalised			eBird, PNAP
Coprotheres pomarinus	Pomarine skua	Non-resident Native - Migrant		PNAP	PNAP
Cyanoramphus novaezelandiae novaezelandiae	Red-crowned kākāriki; kākāriki	At Risk-Relict	Recorded as Regionally Significant in Lux *et al.* (2007); Significant under WDP (Moderate Value species)	PNAP	eBird, PNAP
Cygnus atratus	Black swan	Not Threatened			eBird
Cygnus olor	Mute swan	Introduced and Naturalised		eBird, PNAP	eBird, PNAP
Egretta novaehollandiae	White-faced heron	Not Threatened		eBird, PNAP	eBird, PNAP
Egretta sacra sacra	Reef heron, matuku moana	Threatened-Nationally Endangered	Significant under WDP (Moderate-High Value species)	eBird, PNAP	eBird, PNAP
Emberiza citrinella	Yellowhammer	Introduced and Naturalised		PNAP	PNAP
Eudynamys taitensis	Long-tailed cuckoo, koekoeā	At Risk-Naturally Uncommon	Significant under WDP (Moderate Value species)	eBird, PNAP	eBird, PNAP
Eudyptula minor iredalei	Northern little blue penguin, kororā	At Risk-Declining		PNAP	PNAP
Falco novaeseelandiae ferox	Bush falcon	At Risk-Recovering		eBird, PNAP	eBird, PNAP
Fringilla coelebs	Chaffinch	Introduced and Naturalised			PNAP
Gallirallus australis greyi	North Island weka	At Risk-Recovering	Significant under WDP (High Value species)	PNAP	eBird, PNAP

Species Name	Common Name	National Threat Classification 2016	Significance	Manaia Ecological District	Waipu Ecological District
Gallirallus philippensis assimilis	Banded rail, moho-pereru	At Risk-Declining	Significant under WDP (Moderate-High Value species)	eBird, PNAP	eBird, PNAP
Gerygone igata	Grey warbler, riroriro	Not Threatened		eBird, PNAP	eBird, 2
Gymnorhina tibicen	Australian magpie	Introduced and Naturalised		eBird, PNAP	eBird, PNAP
Haematopus finschi	New Zealand pied oystercatcher; torea	At Risk-Declining		eBird, PNAP	eBird, PNAP
Haematopus unicolor	Variable oystercatcher; torea, toreapango	At Risk-Recovering	Recorded as Regionally Significant in Lux *et al.* (2007); Significant under WDP (Moderate Value species)	eBird, PNAP	eBird, PNAP
Hemiphaga novaeseelandiae	Kukupa, NZ pigeon	Not Threatened	Recorded as Regionally Significant in Goldwater and Beadel (2010) and Honner *et al*. (2011); Significant under WDP (High Value species)	eBird, PNAP	eBird, PNAP
Himantopus himantopus leucocephalus	Pied stilt, poaka	Not Threatened			eBird
Himantopus leucocephalus × *novaezelandiae*	Pied × black stilt (hybrid)	N/A		eBird, PNAP	eBird, PNAP
Hirundo neoxena	Welcome swallow	Not Threatened		eBird, PNAP	eBird, PNAP
Hydroprogne caspia	Caspian tern, taranui	Threatened-Nationally Vulnerable	Significant under WDP (Moderate-High Value species)	eBird	eBird
Larus bulleri	Black-billed gull	Threatened-Nationally Critical		eBird, PNAP	eBird, PNAP
Larus dominicanus dominicanus	Black-backed gull, karoro	Not Threatened		eBird, PNAP	eBird, PNAP
Larus novaehollandiae scopulinus	Red-billed gull, tarāpunga	At Risk-Declining			PNAP
Limosa haemastica	Hudsonian godwit	Non-resident Native - Vagrant			eBird, PNAP
Limosa lapponica	Bar-tailed godwit	At Risk-Declining	Significant under WDP (Moderate Value species)		eBird
Macronectes halli	Northern giant petrel	At Risk-Recovering		PNAP	eBird, PNAP
Meleagris gallopavo	Wild turkey	Introduced and Naturalised		Morgan *et al.* (2017)	
Mohoua albicilla	Whitehead, pōpokotea	At Risk-Declining		eBird, PNAP	eBird, PNAP

Species Name	Common Name	National Threat Classification 2016	Significance	Manaia Ecological District	Waipu Ecological District
Morus serrator	Australasian gannet, tākapu	Not Threatened	Recorded as Regionally Significant in Honner *et al*. (2011)	eBird, PNAP	PNAP
Nestor meridionalis septentrionalis	North Island kaka	At Risk-Recovering		PNAP	eBird, PNAP
Ninox novaeseelandiae novaeseelandiae	Morepork; ruru	Not Threatened			eBird, PNAP
Numenius madagascariensis	Eastern curlew	Non-resident Native - Vagrant			PNAP
Numenius phaeopus	Whimbrel	Two subspecies - Non-resident Native - Vagrant or Migrant		eBird, PNAP	eBird, PNAP
Passer domesticus	House sparrow	Introduced and Naturalised			eBird, PNAP
Pavo cristatus	Peafowl	Introduced and Naturalised		PNAP	eBird
Pelagodroma marina	White-faced storm petrel, takahikare-moana	At Risk-Relict		PNAP	eBird
Pelecanoides urinatrix urinatrix	Northern diving petrel	At Risk-Relict	Recorded as Regionally Significant in Goldwater and Beadel (2010)	Morgan *et al.* 2017	
Petroica longipes	North Island robin	At Risk-Declining		eBird, PNAP	PNAP
Petroica macrocephala toitoi	Tomtit; miromiro; pied tit	Not Threatened	Recorded as Regionally Significant in Goldwater and Beadel (2010), Honner *et al*. (2011) and Lux *et al.* (2007)		PNAP
Phaethon lepterus	White-tailed tropicbird	Non-resident Native - Vagrant			PNAP
Phaethon rubricauda	Red-tailed tropicbird; amokura	At Risk-Recovering		eBird, PNAP	eBird, PNAP
Phalacrocorax carbo novaehollandiae	Black shag; kawau	At Risk-Naturally Uncommon		PNAP	eBird, PNAP
Phalacrocorax melanoleucos brevirostris	Little shag, kawaupaka	Not Threatened		PNAP	eBird, PNAP
Phalacrocorax sulcirostris	Little black shag	At Risk-Naturally Uncommon		eBird, PNAP	eBird, PNAP
Phalacrocorax varius varius	Pied shag; kāruhiruhi	At Risk-Recovering		PNAP	eBird, PNAP
Phasianus colchicus	Ring-necked pheasant	Introduced and Naturalised			eBird, PNAP
Platalea regia	Royal spoonbill; kotuku-ngutupapa	At Risk-Naturally Uncommon	Significant under WDP (High Value species)	eBird, PNAP	eBird, PNAP
Platycercus eximius	Eastern rosella	Introduced and Naturalised		eBird	eBird, PNAP

Species Name	Common Name	National Threat Classification 2016	Significance	Manaia Ecological District	Waipu Ecological District
Pluvialis fulva	Pacific golden plover	Non-resident Native - Migrant	Significant under WDP (Moderate Value species)		eBird, PNAP
Poliocephalus rufopectus	New Zealand dabchick; weweia	At Risk-Recovering	Significant under WDP (High Value species)	eBird, PNAP	eBird, PNAP
Porphyrio melanotus	Pūkeko	Not Threatened			PNAP
Porzana pusilla affinis	Marsh crake; koitareke	At Risk-Declining		PNAP	eBird, PNAP
Porzana tabuensis plumbea	Spotless crake; pūweto	At Risk-Declining	Significant under WDP (Moderate Value species)		eBird
Procellaria sp.	Procellaria sp.	N/A		eBird	eBird
Procellariidae sp. (shearwater sp.)	Shearwater sp.	N/A		eBird, PNAP	eBird, PNAP
Prosthemadera novaeseelandiae novaeseelandiae	Tūī	Not Threatened		PNAP	eBird, PNAP
Prunella modularis	Dunnock	Introduced and Naturalised			eBird
Pterodroma cookii	Cook's petrel	At Risk-Relict	Significant under WDP (Moderate-High Value species)	PNAP	PNAP
Pterodroma macroptera gouldi	Grey-faced petrel, oi	Not Threatened	Recorded as Regionally Significant in Goldwater and Beadel (2010), Honner *et al*. (2011) and Lux *et al.* (2007)	eBird	eBird
Puffinus bulleri	Buller's shearwater	At Risk-Naturally Uncommon	Significant under WDP (High Value species)		eBird
Puffinus carneipes	Flesh-footed shearwater	Threatened-Nationally Vulnerable		PNAP	eBird
Puffinus gavia	Fluttering shearwater	At Risk-Relict			eBird
Puffinus griseus	Sooty shearwater	At Risk-Declining			eBird
Puffinus sp. (black-and-white shearwater sp.)	Black-and-white shearwater sp.	N/A		eBird, PNAP	eBird, PNAP
Rhipidura fuliginosa placabilis	North Island fantail, pīwakawaka	Not Threatened		eBird	eBird, PNAP
Stercorarius parasiticus	Arctic skua	Non-resident Native - Migrant			eBird, PNAP
Sterna nereis davisae	New Zealand fairy tern	Threatened-Nationally Critical	Significant under WDP (Outstanding Value species)	eBird, PNAP	eBird, PNAP

Species Name	Common Name	National Threat Classification 2016	Significance	Manaia Ecological District	Waipu Ecological District
Sterna striata striata	White-fronted tern, tara	At Risk-Declining	Significant under WDP (Moderate-High Value species)		PNAP
Sternula albifrons sinensis	Eastern little tern	Non-resident Native - Migrant			eBird
Sternula albifrons/nereis	Little/Australian fairy tern	N/A			eBird
Streptopelia chinensis	Spotted dove	Introduced and Naturalised		eBird, PNAP	eBird, PNAP
Streptopelia roseogrisea	Barbary dove	Introduced and Naturalised		eBird, PNAP	eBird, PNAP
Sturnus vulgaris	Starling	Introduced and Naturalised		eBird, PNAP	eBird, PNAP
Synoicus ypsilophorus	Brown quail	Introduced and Naturalised			eBird, PNAP
Tachybaptus novaehollandiae	Australian little grebe	Non-resident Native - Coloniser	Recorded as Regionally Significant in Honner *et al*. (2011) and Lux *et al.* (2007); Significant under WDP (Moderate Value species)	eBird, PNAP	eBird, PNAP
Tadorna variegata	Paradise shelduck, pūtangitangi	Not Threatened			eBird
Thalasseus bergii	Great crested tern	Non-resident Native - Vagrant			PNAP
Thinornis novaeseelandiae	New Zealand shore plover; tuturuatu	Threatened-Nationally Critical		eBird, PNAP	eBird, PNAP
Todiramphus sanctus vagans	New Zealand kingfisher; kotare	Not Threatened			PNAP
Tringa cinerea	Terek sandpiper	Non-resident Native - Vagrant			PNAP
Tringa hypoleucos	Common sandpiper	Non-resident Native - Vagrant			PNAP
Tringa nebularia	Greenshank	Non-resident Native - Vagrant		eBird, PNAP	eBird, PNAP
Turdus merula	Blackbird	Introduced and Naturalised		eBird, PNAP	eBird, PNAP
Turdus philomelos	Song thrush	Introduced and Naturalised		eBird, PNAP	eBird, PNAP
Vanellus miles	Spur-winged plover	Not Threatened		eBird, PNAP	eBird, PNAP
Zosterops lateralis	Silvereye, tauhou	Not Threatened		eBird, PNAP	eBird, PNAP

APPENDIX 3

CHEMICAL ANALYSIS - GEOLOGY

Tim Martin

Wildland Consultants Ltd

Suite 2
94-96 White Street
Rotorua,
New Zealand

Lab Ref	WP007176
Client Ref	
Project	DEFAULT
Cost Code	
Status	Final
Received	02/07/19
Reported	11/07/19
Samples	3
First Sample	Ody Farm
Last Sample	Home Point
Pages	5

Copy

Notes

Authorised by

Nick Lees
Operations Manager

On behalf of:

The results in this analytical report pertain to the samples provided to this laboratory for preparation and/or analysis as requested by the client. This document is issued by the company subject to its General Conditions of Services (www.sgs.com/generalconditions). Attention is drawn to the limitations of liability, indemnification and justifications issues established therein.

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Member of the SGS Group

Lab Ref WP007176
Client Ref
Project DEFAULT
Reported 11/07/19
Status Final
Page Page 2 of 5

ANALYTICAL REPORT

Scheme	pH_S_1_2	CLA48V	CLA48V	XRF78S	XRF78S	XRF78S
Units	PH	KG/T	%	%	%	%
Detection Limit	2.00	-1,000.00	-100.00	0.01	0.01	0.01
Upper Limit	14.00	1,000.00	100.00	100.00	100.00	100.00
	pH (1:2) aged	ANC kg	ANC %CaCO3	SiO2	Al2O3	Fe2O3
Ody Farm	6.9	12	1.2	55.1	16.6	7.68
Mt Aubrey	7.4	20	2.0	58.8	17.0	6.64
Home Point	6.8	12	1.2	58.6	18.4	6.31

- not analysed / -- element not determined / I.S. insufficient sample / L.N.R. listed not received

Results are not intended for commercial settlement purposes.

Lab Ref	WP007176
Client Ref	
Project	DEFAULT
Reported	11/07/19
Status	Final
Page	Page 3 of 5

ANALYTICAL REPORT

Scheme	XRF78S	XRF78S	XRF78S	XRF78S	XRF78S	XRF78S
Units	%	%	%	%	%	%
Detection Limit	0.01	0.01	0.01	0.01	0.01	0.01
Upper Limit	100.00	100.00	100.00	100.00	100.00	100.00
	CaO	MgO	SO3	K2O	Na2O	MnO
Ody Farm	5.82	7.90	0.06	1.25	2.18	0.13
Mt Aubrey	6.23	5.29	0.01	1.33	2.68	0.11
Home Point	5.81	3.07	<0.01	1.60	3.17	0.10

- not analysed | -- element not determined | I.S. insufficient sample | L.N.R. listed not received

Results are not intended for commercial settlement purposes.

Lab Ref WP007176
Client Ref
Project DEFAULT
Reported 11/07/19
Status Final
Page Page 4 of 5

ANALYTICAL REPORT

Scheme	XRF78S	XRF78S
Units	%	%
Detection Limit	0.01	0.01
Upper Limit	100.00	100.00
	TiO2	P2O5
Ody Farm	0.61	0.10
Mt Aubrey	0.65	0.11
Home Point	0.75	0.13

- not analysed | -- element not determined | I.S. insufficient sample | L.N.R. listed not received

Results are not intended for commercial settlement purposes.

Lab Ref	WP007176
Client Ref	
Project	DEFAULT
Reported	11/07/19
Status	Final
Page	Page 5 of 5

DESCRIPTION

ES_NEPM103_1_2 : Paste pH in soil by NEPM103 1:2 extract

CLA48V : Determination of ANC, TAP and NAPP of Soils/Rocks

XRF78S : XRF Analysis - Fusion Technique

CHEMICAL ANALYSIS - WATER

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Certificate of Analysis

SPv1

Client:	Wildland Consultants Limited	**Lab No:**	2200726
Contact:	Dr Tim Martin C/- Wildland Consultants Limited PO Box 46299 Herne Bay Auckland 1011	**Date Received:**	29-Jun-2019
		Date Reported:	03-Jul-2019
		Quote No:	
		Order No:	
		Client Reference:	
		Submitted By:	Dr Tim Martin

Sample Type: Aqueous

	Sample Name:	#1 Ocean View Rd 27-Jun-2019 10:30 am	#2 McDonald Rd Heathland Stream 27-Jun-2019 11:30 am	#3 Hinemoana Lane 27-Jun-2019 12:30 pm		
	Lab Number:	2200726.1	2200726.2	2200726.3		
pH	pH Units	7.7	5.8	7.1	-	-
Total Alkalinity	g/m^3 as $CaCO_3$	131	4.0	50	-	-
Carbonate	g/m^3 at 25°C	< 1.0	< 1.0	< 1.0	-	-

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
pH	pH meter. APHA 4500-H^+ B 23rd ed. 2017. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1-3
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) 23rd ed. 2017.	1.0 g/m^3 as $CaCO_3$	1-3
Carbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 23rd ed. 2017.	1.0 g/m^3 at 25°C	1-3

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental

APPENDIX 5

LICHEN CHEMISTRY

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Certificate of Analysis

Client:	Wildland Consultants Limited	**Lab No:**	2200725	svgpv1
Address:	PO Box 46299 Herne Bay Auckland 1011	**Date Received:**	29-Jun-2019	
		Date Reported:	03-Jul-2019	
		Quote No:	99166	
		Order No:		
		Client Reference:		
Phone:	09 360 6083	**Submitted By:**	Dr Tim Martin	

Plant Analysis Results

	Sample Name:	Ody Farm	Mt Aubrey	Home Point			
	Lab Number:	2200725.1	2200725.2	2200725.3			
	Sample Type:	General, Non-specified NZ	General, Non-specified NZ	General, Non-specified NZ			
	Sample Type Code:	P10	P10	P10			
Nitrogen*	%	1.3	1.2	0.9	-	-	-
Phosphorus	%	0.12	0.07	0.10	-	-	-
Potassium	%	0.2	0.2	0.2	-	-	-
Sulphur	%	0.13	0.13	0.10	-	-	-
Calcium	%	0.95	0.74	1.05	-	-	-
Magnesium	%	0.28	0.23	0.20	-	-	-
Sodium	%	0.125	0.189	0.296	-	-	-
Iron	mg/kg	6,720	4,590	8,320	-	-	-
Manganese	mg/kg	310	151	132	-	-	-
Zinc	mg/kg	45	28	38	-	-	-
Copper	mg/kg	12	12	15	-	-	-
Boron	mg/kg	8	9	9	-	-	-

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Certificate of Analysis

Client:	Wildland Consultants Limited	**Lab No:**	2200818	SPv1
Contact:	Dr Tim Martin	**Date Received:**	29-Jun-2019	
	C/- Wildland Consultants Limited	**Date Reported:**	12-Jul-2019	
	PO Box 46299	**Quote No:**	99166	
	Herne Bay	**Order No:**		
	Auckland 1011	**Client Reference:**	Lichen analysis	
		Submitted By:	Dr Tim Martin	

Sample Type: Plant Material (dry)

Sample Name:		Ody Farm 26-Jun-2019 3:00 pm	Mt Aubrey 26-Jun-2019 4:30 pm	Home Point 27-Jun-2019 9:00 am		
Lab Number:		2200818.1	2200818.2	2200818.3		
Nickel	mg/kg dry wt	12.7	4.7	3.3	-	-

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Plant Material (dry)

Test	Method Description	Default Detection Limit	Sample No
Biological Materials Digestion	Nitric and hydrochloric acid micro digestion, filtration.	-	1-3
Nickel	Oven dried at 62°C overnight (residual moisture typically 5%) by the Agriculture Division. Biological materials digestion. Analysis by ICP-MS.	0.10 mg/kg dry wt	1-3

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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CA Jones

Crystal Jones BSc
Client Services Manager - Food & Bioanalytical

APPENDIX 6

LITERATURE REVIEW ON ADVERSE EFFECTS OF SO_2 AND NO_X ON TERRESTRIAL ECOLOGY

The information outlined in this appendix provides detailed literature review to accompany the conclusions drawn in the assessment of effects within this report (Section 8: Assessment of potential effects on terrestrial ecology).

1. EFFECTS OF SULPHUR DIOXIDE AND NITROGEN DIOXIDE ON FAUNA

1.1 Effects of sulphur dioxide and nitrogen dioxide on invertebrate fauna

Studies Across Multiple Taxonomic Groups

Lauenroth and Preston (1984) estimated that threshold levels for significant injury to grassland soil invertebrates by sulphur dioxide are in the range 245-1,030 $\mu g/m^3$.

The effect of soil sulphur levels on soil-dwelling macroinvertebrates around a Canadian sour gas processing plant was investigated by Carcamo *et al.* (1998). The presence of invertebrates was analysed 50, 150, and 250 metres from the plant. The amount of sulphur detected decreased as the distance from the plant increased. At the site 50 metres from the plant, earthworms were the most affected family, being completely absent; rove beetles (Staphylinidae) and money spiders (Linyphiidae) also had lowered abundance and activity. Two species of carabid beetle (*Scaphinotus marginatus* and *Platynus decentis*) were less common near the plant, but overall numbers of all carabids were not affected. The amaurobiid spider *Callioplus euoplus* was also less common up to 150 metres from the plant. Near the sour gas plant, high levels of contaminants had altered the plant communities, leaving areas of ground bare, and differences in the invertebrate communities could have been due to direct or indirect effects of sulphur.

Invertebrates were also analysed at two remote locations where sulphur levels were lower but still detectable. These locations had vegetation communities very similar to each other. In these sites, linyphiid spiders were less common under the higher sulphur conditions. Their habit of creating sheet webs near the ground may make them highly susceptible to pollution, and they may be a useful biomonitoring group. Carcamo *et al.* (1998) noted that not all species affected by high sulphur levels will be affected to the same degree by moderate sulphur levels.

Kuperman (1996) studied a pollution gradient in oak-hickory forest, along which high long-term levels of acidic (sulphate and nitroxylate) deposition had led to changes in the soil chemistry. Sulphate deposition rates were studied over 86 years and nitroxylate deposition over 30 years. Abundances of earthworms, gastropods, dipteran larvae, termites, and predatory beetles differed along a gradient, and the research suggested reduced abundance of decomposers had led to increased amounts of soil organic matter in the more polluted areas. The abundance of earthworms, snails, and beetles was significantly lower where deposition was equal or greater to 62.3 kilograms of sulphur per hectare per year and 31.4 kilograms of nitrogen per hectare year, compared to a site that received 55.2 and 26.3 kilograms of sulphur and nitrogen per hectare per year respectively (Kuperman 1996).

Effects of sulphur dioxide fumigation on moss-dwelling invertebrate communities were studied by Steiner (1995b). Aquatic rotifers, tardigrades, and nematodes were found to decrease in number with increasing sulphur dioxide concentrations. Exposure studies showed a similar trend to the fumigation experiments, but were subject to much greater within-treatment variation. Steiner (1994) studied the aquatic fauna of moss along a pollution gradient. The abundance of water bears (or tardigrades) and rotifers was not affected by sulphur dioxide levels, but tardigrade species richness decreased with increasing pollution levels (Steiner 1994). In both of the above studies, two species of nematodes and a tardigrade were strongly negatively affected by air pollution, and could be used as indicator species (Steiner 1994). Arthropod communities were less affected by the same gradients in air contaminants, although there was a trend towards decreasing species richness and more uniform communities (especially for beetle mites) with increasing pollution (Steiner 1995a).

In a study undertaken by Hohl *et al.* (2001), water bear and rotifer density was higher up-wind of a coal-burning power plant, and nematode diversity was higher down-wind. Of the water bears, *Ramazzotlius* sp. was found only upwind, and therefore could be used as an indicator species.

<u>Beetles</u>

To determine whether rates of parasitism and predation on herbivorous insects change in response to pollution-induced increases in herbivore abundance, Zvereva and Kozlov (2000) studied the leaf beetle *Melasoma lapponica* in forests near a nickel and copper smelter in Russia where the major emissions comprised sulphur dioxide and heavy metals (nickel, copper, and cobalt). Distributions of sulphur dioxide and heavy metals followed similar spatial and temporal patterns. The beetle was more common close to the smelter, and parasitism rates were higher near the smelter. However, egg and larval predation rates were higher further from the smelter, which led to total beetle mortality being higher in these non-polluted sites (Zvereva and Kozlov 2000).

<u>Aphids</u>

Sulphur dioxide emissions can place plants under stress, increasing amino acid levels in their phloem, which in turn can increase the feeding efficiency of stem-feeding aphids, causing additional stress on the plant (Holopainen *et al.* 1995). Neuvonen and Lindgren (1987) found that numbers of aphids on silver birch trees subjected to the simulated acid rain (3.5% sulphuric acid) increased significantly compared to aphids on control trees on four out of eight occasions, with increases being more marked when there was little natural rain (Neuvonen and Lindgren 1987). However, it should be noted that "four out of eight occasions" could be easily due to chance alone.

Aphids (*Macrosiphon rosae*) feeding on rose bushes under sulphur dioxide, nitrogen dioxide, and ozone concentrations of 25, 40, and 25 µg/m^3, respectively, gained more weight than aphids feeding under ambient conditions in five out of six cases (Dohmen 1985). The response to increases in sulphur dioxide levels was bell-shaped, with high concentrations leading to reductions in aphid performance (Holopainen *et al.* 1995, Warrington 1987).

Ants

In Australia, ant abundance and species richness has been negatively correlated with sulphur dioxide levels (Hoffmann *et al.* 2000). However New Zealand has a low number of indigenous ant species compared to Australia and these findings may not be applicable here.

Bees and Wasps

The effect of sulphur dioxide on the flight activity of the bee *Lasioglossum zephrum* was investigated by Ginevan *et al.* (1980) by exposing a group of bees to 0.14 and 0.28 ppm (367-734 µg/m^3) sulphur dioxide, and comparing the activity of these groups of bees to a control group. Sulphur dioxide was found to lead to a gradual reduction in the activity of the bees, believed to be due to a progressive wasting of the flight muscles.

Gate *et al.* (1995) studied the effect of air contaminants on the ability of a parasitoid wasp (*Asobara tabida*) to find their insect prey, the fruit fly *Drosophila subobscura*. Sulphur dioxide and nitrogen dioxide did not impair the parasitoid's ability to find their prey, but ozone did, possibly through reducing the wasps' ability to detect prey.

Another species of parasitic wasp, *Bracon hebetor*, was exposed to 3 ppm (7,860 µg/m^3) sulphur dioxide for periods of three and five hours, and the reproductive output of these wasps was compared to that of wasps not exposed to sulphur dioxide (Petters and Mettus 1982). No mortality of the wasps or reduction in their reproductive output was induced. Insects may be resistant to such contaminants due to low rates of cellular division occurring within them (Petters and Mettus 1982).

Microarthropods

Bressan and Paoletti (1997) investigated the effects of sulphur dioxide fallout from an oil-fired power plant in Italy on leaf litter decomposition rates and soil microarthropods. High sulphur dioxide deposition sites showed a reduction in the total number of decomposers, with *Collembola* appearing to be a robust bioindicator of pollution fallout.

Land Snails

Acidification of the soil by sulphur dioxide has the potential to adversely affect shell formation in terrestrial snails due to less calcium being available. Soil calcium and other nutrients such as magnesium, phosphate, and nitrates are released when soil bacteria break down decaying plant matter. This process is inhibited by soil acidification, particularly as a result of mobilisation of soil aluminium ions and lowering of soil pH (U.S. Department of Agriculture 2011).

In the Netherlands, Graveland and van der Wal (1996) found that where acid deposition had caused a decline of soil calcium on poor soils, snail density correlated with the calcium content and to a lesser extent the pH of the litter layer. Liming of a calcium-poor forest soil with few snails resulted in snail densities comparable to those on calcium-rich soils after four years. The decline in snail density in forests on poor soils was thought to be the cause of increases in eggshell defects in birds who preyed on them.

Gärdenfors *et al.* (1995) found a similar effect of soil acidification and decreases in soil calcium on land snail density in coniferous forests in Sweden. Concentrations of certain elements in shells were dependent on acidity in the environment in which the snails lived, suggesting that shells from different localities and time periods can be used as bio-indicators.

1.2 Effects of sulphur dioxide and nitrogen dioxide on vertebrate fauna

Small Mammals and Birds

Studies in polluted European sites have shown that small mammals and birds can experience a range of adverse effects, particularly on the respiratory system, in sites that are polluted with sulphur dioxide and nitrogen oxides. However, small sample sizes, confounding contaminants, and the lack of suitable control sites mean that these effects cannot be readily attributed to sulphur dioxide and nitrogen oxides. Significant long-term populations of avifauna have been recorded nearby at least three New Zealand sites experiencing elevated ambient sulphur dioxide concentrations: Sulphur Bay, Rotorua (Siegel *et al.* 1986), Tiwai Point (Wildland Consultants 2004), and Marsden Bay (Wildland Consultants 2003).

Lizards

Few studies have been undertaken to assess the effects of pollutants on lizards. However, for Australian geckos, recovery of populations when sulphur dioxide levels dropped to 123 $\mu g/m^3$ (as a daily maximum) suggests that compared to other biota of the receiving environment, that lizards may have relatively high tolerance of sulphur dioxide (Read 1998).

Aquatic Fauna

Acid rain can lead to the loss of calcium from soils, increased mobilisation of aluminium, and accumulation of sulphur and nitrogen in soils, from where they leach into waterways. This leads to the acidification and increased aluminium concentrations of surface waters, which can lead to decreases in diversity and abundance of aquatic life (Driscoll *et al.* 2003).

Biota can be influenced directly by changes in water quality during both short acidic episodes and longer-term sustained periods of acidification: they are affected indirectly by alterations to the balance of acid-sensitive and acid-tolerant species at different trophic levels. Together, the chemical and biological alterations result in adverse effects on some biogeochemical processes including the increased mobilisation and leaching of biologically-active elements such as mercury, copper, and zinc (Muniz 1990).

Acidification of freshwater and saline habitats (pH changes as small as 0.5) can affect the olfactory abilities of fish and macroinvertebrates, leading to impaired behavioural responses, with potentially far-reaching consequences for population dynamics and community structure (Leduc *et al.* 2013).

In poorly buffered, soft-water systems of the Netherlands that are highly sensitive to acidifying precipitation, the number of species, percentage of waters occupied, and the reproductive success of amphibians were negatively affected by low pH (<4.0) attributed to acidic precipitation resulting from anthropogenic emissions of SO_2, NO_X and NH_3 (Leuven *et al.* 1986).

Acidification can adversely affect microbial decomposition of organic matter and species diversity of zooplankton, increase the growth of filamentous algae, alter the balance of diatoms, result in the loss of fish due to recruitment failure, and cause the accumulation of manganese and mercury in fish. Short-term events (episodes) of extreme acidity and/or large concentrations of water-soluble aluminium have led to major fish kills (Muniz 1990).

2. CRITICAL LOADS FOR NITROGEN DEPOSITION

Critical loads for nitrogen deposition in British ecosystems are provided by APIS (Table 1) and the UNECE and WHO (Table 2). Critical loads range from 5 kg N/ha-year for the most sensitive ecosystems, e.g. bogs, heathlands, alpine habitats, conifer-dominated forests, to 30 kg N/ha-year for the least sensitive ecosystems, e.g. saltmarshes, fertile wetlands, lowland meadows.

Current expert opinion suggests that for most New Zealand ecosystems with low nitrogen supply background levels of nitrogen inputs are about 1-5 kg N/ha-year, and that significant changes in New Zealand ecosystems may not occur below total nitrogen inputs of about 5 kg N/ha-yr (Stevenson *et al.* 2000).

Table 1: Critical load values for nutrient nitrogen deposition (APIS 2019) (http://www.apis.ac.uk/indicative-critical-load-values).

Habitat Type (EUNIS code)	Critical load (CL) range (kg N/ha/yr)	Value Recommended for Use at Screening Stage of Assessment (kgN/ha/yr)	Value Recommended for Use at Detailed Assessment Stage (kgN/ha/yr)
Marine Habitats			
Mid-upper saltmarshes (A2.53)	20-30	20	20
Pioneer & low-mid saltmarshes (A2.54 and A2.55)	20-30	30	30
Coastal Habitats			
Shifting coastal dunes (B1.3)	10-20	10	10
Coastal stable dune grasslands (grey dunes) (B1.4)	8-15	8	Acid dunes = 8 Calcareous dunes = 10
Coastal dune heaths (B1.5)	10-20	10	10
Moist to wet dune slacks (B1.8)	10-20	10	Low base availability = 10 High base availability = 15

Habitat Type (EUNIS code)	Critical load (CL) range (kg N/ha/yr)	Value Recommended for Use at Screening Stage of Assessment (kgN/ha/yr)	Value Recommended for Use at Detailed Assessment Stage (kgN/ha/yr)
Inland Surface Waters			
Softwater lakes (permanent oligotrophic waters) (C1.1)	3-10	Seek site specific advice	Seek site specific advice
Dune slack pools (permanent oligotrophic waters) (C1.16)	10-20	10	10
Permanent dystrophic lakes, ponds and pools (C1.4)	3-10	Seek site specific advice	Seek site specific advice
Mire, Bog, and Fen Habitats			
Raised & blanket bogs (D1)	5-10	5	Apply guidance
Valley mires, poor fens and transition mires (D2)	10-15	10	10
Rich fens (D4.1)	15-30	15	15
Montane rich fens (D4.2)	15-25	15	15
Grasslands and Tall Forb Habitats			
Sub-atlantic semi-dry calcareous grassland (E1.26)	15-25	15	15
Non-Mediterranean dry acid and neutral closed grassland (E1.7)	10-15	10	10
Inland dune pioneer grasslands (E1.94)	8-15	8	Acid dunes = 8 Calcareous dunes = 10
Inland dune siliceous grassland (E1.95)	8-15	8	Acid dunes = 8 Calcareous dunes = 10
Low and medium altitude hay meadows (E2.2)	20-30	20	20
Mountain hay meadows (E2.3)	10-20	10	10
Moist and wet oligotrophic grasslands:			
Molinia caerulea meadows (E3.51)	15-25	15	15
Heath (*Juncus*) meadows & humid (*Nardus stricta*) swards (E3.52)	10-20	10	10
Moss & lichen dominated mountain summits (E4.2)	5-10	5	7
Alpine and subalpine acid grasslands (E4.3)	5-10	5	5
Alpine and subalpine calcareous grasslands (E4.4)	5-10	5	5
Heathland, Scrub, and Tundra			
Arctic, alpine and subalpine scrub habitats (F2)	5-15	5	5
Northern Wet Heaths (F4.11)			
U' *Calluna*-dominated wet heath (upland moorland)	10-20	10	10
'L' *Erica tetralix* dominated wet heath (lowland)	10-20	10	10
Dry heaths (F4.2)	10-20	10	10
Forest Habitats (general) (use if not one of specific forests in section below)			
Broadleaved woodland (G1)	10-20	10	10
Coniferous woodland (G3)	5-15	5	10
(Use 5 if lichens/free-living algae important features of the site).			

Habitat Type (EUNIS code)	Critical load (CL) range (kg N/ha/yr)	Value Recommended for Use at Screening Stage of Assessment (kgN/ha/yr)	Value Recommended for Use at Detailed Assessment Stage (kgN/ha/yr)
Forest Habitats (specific)			
Fagus woodland (beech) (G1.6)	10-20	10	15
Acidophilous *Quercus*-dominated woodland (oak) (G1.8)	10-15	10	10
Meso- and eutrophic *Quercus* woodland (G1.A)	15-20	15	15
Pinus sylvestris woodland south of the taiga (G3.4)	5-15	5	12

Table 2: Empirical WHO and UNECE critical loads for nitrogen deposition and related effects (Stevenson *et al.* 2000).

Ecosystem	CLO (kg N Ha-1 yr-1)	Impact
Wetlands		
Shallow Soft-water lakes*	5-10##	Decline of isoetid aquatic plant species.
Ombrotropic (raised) bogs*	5-10#	Decrease typical mosses, increase tall gramminoids, N accumulation.
Mesotropic fens	20-35#	Increase tall gramminoids, decline diversity.
Species-Rich Grasslands		
Calcareous grasslands	15-35#	Increase tall grass, decline diversity.
Neutral acid grasslands	20-30#	Increase tall grass, decline diversity.
Montane-subalpine grasslands	10-15(#)	Increase tall graminoids, decline diversity.
Heathlands		
Lowland wet-heathland	17-22#	Transition heather to grass.
Species-rich heaths/acid grasslands	10-15#	Decline sensitive species.
Upland *Calluna* heaths	10-20(#)	Decline heather, mosses and lichen; N accumulation.
Arctic and alpine heaths*	5-15(#)	Decline lichen, mosses and evergreen dwarf shrubs, increase in grasses.
Lowland dry heathland	15-20##	Transition heather to grass; functional change; N accumulation; litter production.
Trees and Forest Ecosystems		
Coniferous	10-15##	Nutrient imbalance (acidic; low nitrification rate).
Coniferous	20-30#	Nutrient imbalance (acidic; mod-high nitrification rate).
Deciduous trees	15-20#	Nutrient imbalance; increase shoot/root ratio.
Acidic coniferous forests	7-20##	Changes ground and flora and mycorrhizas; increased leaching.
Acidic deciduous forests	10-20#	Changes ground flora.
Calcareous forests	15-20(#)	Changes ground flora.
Acidic forests*	7-15(#)	Changes ground flora and leaching.
Forest in humid climates	5-10(#)	Decline lichen and increase free-living algae.

* Unmanaged, natural system.
Reliable: When a number of published paper of various studies show comparable results.
Quite Reliable: when results of some studies are comparable.
(#) Expert Judgement: When no data is available for type of ecosystem. The N critical load is based upon expert judgement of ecosystems which are likely to be more or less comparable with this ecosystem.

APPENDIX 7

LICHEN DAMAGE AND DIVERSITY ASSESSMENT

Lichen damage and diversity assessment for specimens collected 19 June 2019.
Observations consistent with air pollution are shown in bold.

Table 1: Lichens collected from the Refinery Grounds

Species	Observations
Dirinaria applanata	**Very pruinose, some discolouration (black spots), black particulate matter on surface. One thallus has a lower density of soralia than usual, one has soredia erupting from cortex surface rather than limited to soralia.**
Flavoparmelia haywardiorum	No obvious abnormalities
Heterodermia speciosa	**Lobes smaller than usual, browning and blackening of lobes, soredia erupting from cortex surface rather than being limited to soralia, black particulate matter on surface.**
Parmotrema perlatum	**Discoloration of lobes and lobe apices (browning). Unusual soredial development - soredia erupting from cortex surface rather than being limited to soralia, bursts of lobule development from cortex surface, pustulate ridges on one thallus. Surface of cortex “dirty”.**
Parmotrema reticulatum	**Thallus thickened, leathery and cracked in part. Cortex discoloured – darker olive-green and yellow-green, with bleached patches (depigmented, loss of algae). Blackened areas on cortex also. Distortion of lobes, particularly where soredia are (enlarged soralia). Unusual lobe formation (pseudophyllida or lobules). One specimen has soredia erupting from the surface of the cortex rather than in discrete soralia. Some invertebrate grazing.**
Ramalina celastri	**Stunted lobes with ragged ends.**
Usnea rubicunda	**Stunted thallus, fibrils not well-developed.**

Table 2: Lichens collected from Mount Aubrey

Species	Observation
Coccocarpia palmicola	No apparent abnormalities
Heterodermia cassarettiana	**Some browning of cortex.**
Leucodermia leucomelos (*Heterodermia leucomela*)	**Some bleaching of cortex and over-development of soralia.**
Parmotrema austrocetratum	Thallus breaking down and discoloured (rust-coloured). Black spotting on upper surface. Could be parasitic fungus.
Parmotrema cetratum	No apparent abnormalities
Parmotrema reticulatum	Thallus breaking down, cortex discoloured (rust-coloured), **soredia erupting from breaks in upper cortex rather than in discrete soralia,** black spotting on upper surface, deformation of lobes into multi-pronged laciniae with soralia. Rust colour could be parasitic fungus.
Parmotrema subtinctorum	**Some minor bleaching.**
Podostictina pickeringii	**Some minor bleaching**
Porina exocha	**Some browning of cortex.**
Pseudocyphellaria coriacea	**Some bleached spots where algae have been lost. Some lobe edges browned.**
Pseudocyphellaria crocata agg. 3	No apparent abnormalities
Ramalina celastri	**Some minor bleaching of thallus branches.**
Stereocaulon ramulosum	No apparent abnormalities
Usnea rubicunda	No apparent abnormalities
Usnea sp.	No apparent abnormalities
Xathoparmelia isidiigera	Older parts of thallus browned.

Table 3: Lichens collected from Home Point

Species	Observation
Chrysothrix xanthina	Leprose, so hard to tell
Cladia gorgonea	No apparent abnormalities
Parmotrema reticulatum	Extensive rust and pink coloration of cortex – looks like parasitism by a fungus. Some distortion of soralia, but soredia not erupting through cortex outside soredia. **Some very minor bleaching** – mostly spots associated with central blackening.
Pseudocyphellaria crocata agg 2	No apparent abnormalities
Ramalina celastri	No apparent abnormalities
Stereocaulon ramulosum	No apparent abnormalities
Usnea rubicunda	No apparent abnormalities
Xanthoparmelia isidiigera	Some black spots and discoloration

Table 4: Lichens collected from Ody Road

Species	Observation
Chrysothrix xanthina	Leprose form (like a powder) – difficult to determine if damaged
Cladia gorgonea	No apparent abnormalities
Cladonia darwinii	No apparent abnormalities
Cladonia furcata	No apparent abnormalities
Heterodermia japonica	No apparent abnormalities
Heterodermia obscurata	One thallus parasitized by fungus
Leptogium cyanescens	No apparent abnormalities
Pannaria elixii	No apparent abnormalities
Parmelia sp.	No apparent abnormalities
Parmotrema austrocetratum	No apparent abnormalities
Parmotrema reticulatum	No apparent abnormalities
Physcia poncinsii	**Some bleaching evident**
Pseudocyphellaria crocata agg. 1	No apparent abnormalities
Pseudocyphellaria crocata agg. 2	No apparent abnormalities
Podostictina pickeringii	No apparent abnormalities
Stereocaulon ramulosum	No apparent abnormalities
Usnea c.f. *undulata*	No apparent abnormalities
Xanthoparmelia furcata	No apparent abnormalities
Xanthoparmelia isidiigera	No apparent abnormalities
Xanthoparmelia pulla agg.	No apparent abnormalities

MARSDEN POINT LICHEN HEALTH ASSESSMENT - RAW DATA

Key to Overall Damage Score		Key to Bleaching, Abnormalities, Particulates	
0 =	Normal morphology	0 =	Absent
1 =	Minor effects (sl. Bleaching)	1 =	Traces or very localised
2 =	Moderate effects - significant bleaching, black spots, reproductive suppression	2 =	Moderate amounts
3 =	Significant effects - extensive bleaching, development abnormalities (e.g. lobules and soredia in wrong place), pruina production	3 =	Extensive or dense

Species	Tree	Side	Overall Damage Score	Bleaching	Abnormalities	Particulates	Notes
P. perlatum 1	1	N	3	0	2	3	No soredial development
P. perlatum 2	1	S	3	0	3	3	Leathery, roughened, microlobulate cortex, failing to produce soredia
P. perlatum 3	2	N	3	0	2	1	Stunted and poorly developed
P. perlatum 4	2	S	3	1	3	3	Cortex rugulate and lobulate
P. reticulatum 5	3	N	3	1	3	1	Thickened and rugulate cortex, extra soralial soredia
P. reticulatum 6	3	S	2	0	2	2	Some black patches, soredia not well developed
P. reticulatum 7	4	N	3	1	3	3	Cortex rugulate and soredia on deformed laciniae
P. reticulatum 8	4	S	3	1	3	3	Cortex rugulate and soredia erupting from cracks
P. reticulatum 9	5	N	2	1	2	3	Some dead patches, poor development of soredia
P. reticulatum 10	5	S	3	0	3	3	Thickened and brittle cortex, bluish, lack of soralia.
R. celastri 1			3	2	3	3	Leathery branches, odd laminal apothecial initials, pruina, bleaching.
R. celastri 2			3	1	3	3	Leathery branches, odd laminal apothecial initials, pruina, bleaching.
R. celastri 3			3	3	3	3	Deformed side branches, split pseudocyphellae, extensive bleaching

Species	Tree	Side	Overall Damage Score	Bleaching	Abnormalities	Particulates	Notes
R. celastri 4			3	1	3	3	Malformed branches and apothecia, odd apothecial initials - appearing serediate.
R. celastri 5			3	1	3	3	Developmental abnormalities, pruina, bleaching
R. celastri 6			3	1	3	3	Stunted and poorly developed
R. celastri 7			3	2	2	2	Bleaching and pruina.
R. celastri 8			1	1	1	1	Relatively normal with some bleaching.
R. celastri 9			2	1	3	3	Odd side branch proliferation, pruinose areas, some bleaching.
R. celastri 10			0	0	0	2	Relatively normal
H. speciosa 1	1	N	1	0	1	2	Slightly stunted and slight blackening of cortex.
H. speciosa 2	1	S	1	0	1	2	Upper surface blackened
H. speciosa 3	2	N	1	0	1	3	Upper surface blackened
H. speciosa 4	2	S	1	0	1	2	Upper surface blackened
H. speciosa 5	3	N	1	0	1	2	Slightly blacked upper surface
H. speciosa 6	3	S	3	2	3	3	Lobules proliferating from soralia, surface bleaching.
H. speciosa 7	4	N	1	0	2	2	Upper surface slightly blackened
H. speciosa 8	4	S	3	0	3	3	Upper surface blackened, soralia poorly developed, thallus stunted.
H. speciosa 9	5	N	3	0	3	3	Upper surface blackened, soralia poorly developed, thallus stunted.
H. speciosa 10	5	S	1	0	2	3	Some lobule development from soralia, thallus discoloured and stunted.
P. reticulatum 1	1	N	1	1	1	3	Unusual soralia development, minor bleached areas.
P. austrocetratum 2	1	S	0	0	0	1	normal morphology
P. reticulatum 3	2	N	1	1	1	2	Unusual soralia development, minor bleached areas.
P. reticulatum 4	2	S	2	2	1	2	Surface pale and bleached.
P. reticulatum 5	3	N	1	0	1	2	Some unusual soredia development
P. reticulatum 6	3	S	0	0	0	1	Normal development
P. reticulatum 7	4	N	2	1	1	2	Some bleached and lobulate areas.
P. reticulatum 8	4	S	1	1	1	1	Upper surface wrinkled, minor bleaching.
P. reticulatum 9	5	N	1	0	1	1	Damaged specimen - white patches probably grazed by invertebrates.
P. reticulatum 10	5	S	1	2	1	2	Moderate bleaching.

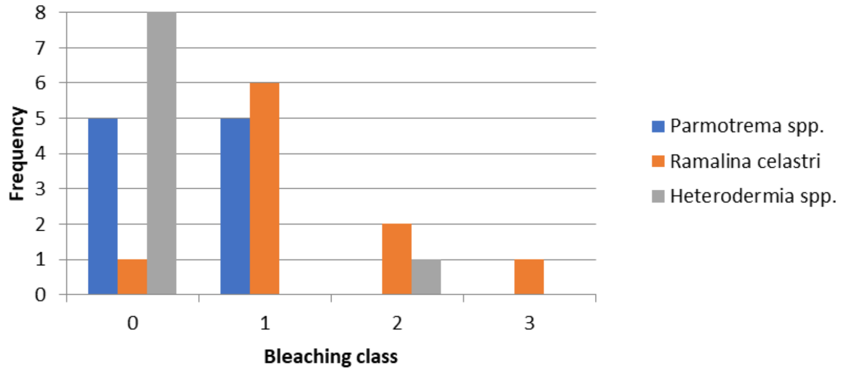
Species	Tree	Side	Overall Damage Score	Bleaching	Abnormalities	Particulates	Notes
R. celastri 1			0	0	0	0	Normal development
R. celastri 2			1	0	1	0	Few abnormalities
R. celastri 3			2	1	2	1	Some malformed and distorted branches, minor bleaching.
R. celastri 4			0	0	0	1	Normal development
R. celastri 5			0	0	0	0	Normal development. Fungal attack in one area.
R. celastri 6			1	0	1	0	Older parts distorted and split. Possible fungal attack.
R. celastri 7			1	1	0	0	Normal morphology, minor bleaching.
R. celastri 8			1	1	1	1	Lace-like windowing and minor bleaching.
R. celastri 9			0	0	0	0	Large healthy thallus
R. celastri 10			1	1	1	0	Minor splitting of branches at pseudocyphellae and minor bleaching.
P. reticulatum 1	1	N	0	0	0	1	Normal development
P. reticulatum 2	1	S	0	0	0	0	Normal but with fungal attack.
P. reticulatum 3	2	N	1	0	1	0	Some malformation but probably due to fungus. Dead P. austrocetratum present.
P. reticulatum 4	2	S	1	0	2	0	Bumpy upper surface - pinkish - due to fungal infection.
P. reticulatum 5	3	N	1	0	1	0	Lumpy upper cortex, signs of fungal infection.
P. reticulatum 6	3	S	1	0	1	0	Some damaged and lobulate areas.
P. reticulatum 7	4	N	2	0	2	1	Some dead patches and stunted soralia
P. reticulatum 8	4	S	0	0	0	0	Normal but with fungal attacked areas.
P. reticulatum 9	5	N	1	1	1	0	Minor bleaching and fungal attack on soralia.
P. reticulatum 10	5	S	0	0	0	0	Normal morphology. P. crinitum also present.
R. celastri 1			0	0	0	0	Normal but with fungal attacked areas.
R. celastri 2			0	0	0	0	Normal but with fungal attacked areas.
R. celastri 3			0	0	0	0	Normal but with fungal attacked areas.
R. celastri 4			0	0	0	0	Normal, some tip damage. R. peruviana also present.
R. celastri 5			1	1	1	0	One bleached thallus, some fungal tip damage.
R. celastri 6			1	1	1	0	Minor bleaching and minor fungal damage.
R. celastri 7			0	0	0	0	Normal but with fungal attacked areas.
R. celastri 8			0	0	0	0	Normal but with fungal attacked areas.
R. celastri 9			1	2	0	0	Normal morphology, extensive bleaching.
R. celastri 10			1	1	0	0	Normal morphology, some bleaching.

Species	Tree	Side	Overall Damage Score	Bleaching	Abnormalities	Particulates	Notes
H. japonica 1	1	N	0	0	0	0	Normal development
H. japonica 2	1	S	1	0	1	0	Orange/pink patches with black dots due to fungus but still scored 1
P. perlatum 1	1	N	0	0	1	1	Slight wrinkling centrally, lobes thin
P. perlatum 2	1	S	0	1	0	1	Minor bleaching but otherwise normal
P. reticulatum 3	2	N	1	1	0	2	Bleaching on cortex.
P. reticulatum 4	2	S	3	2	2	3	Dead black patches, bleaching, soredia erupting from cracks
P. reticulatum 5	3	N	1	1	1	3	Normal lobes, soredia mainly missing, black spotting, some bleaching
P. reticulatum 6	3	S	2	0	2	1	Thin and brittle cortex, pruina, odd margins.
P. reticulatum 7	4	N	1	0	1	1	Lumpy upper cortex.
P. reticulatum 8	4	S	1	1	1	1	Thickened and roughened upper cortex.
P. perlatum 9	5	N	1	0	1	2	Poor soredial development.
P. reticulatum 10	5	S	2	2	1	3	Damaged cortex, extensive bleaching.
R. celastri 1			1	0	2	1	Broken branch tips and regeneration, pruina, proliferation of apothecial initials
R. celastri 2			2	0	1	0	Ragged branch tips, sl. Deformed and stunted. Coastal specimen?
R. celastri 3			1	0	1	0	Stunted, but otherwise normal, possibly coastal specimen?
R. celastri 4			1	0	1	0	Normal looking but some branch proliferation and brken branch tips
R. celastri 5			0	0	0	0	Normal morphology
R. celastri 6			0	0	0	1	Normal morphology
R. celastri 7			1	1	0	0	Minor bleaching
R. celastri 8			0	0	1	0	Thallus a bit stunted and some evidence of fungal attack.
R. celastri 9			1	0	1	0	Tips attacked by fungus, deformed apothecia
R. celastri 10			2	0	2	0	Tips attacked by fungus, deformed apothecia, proliferating apothecial initials
H. japonica 1	1	N	0	0	0	0	Small but normal
H. japonica 2	1	S	0	0	0	0	Small but normal
H. speciosa 3	2	N	0	0	1	1	Some localised black/brown patches
H. speciosa 4	2	S	0	0	0	2	Small but normal

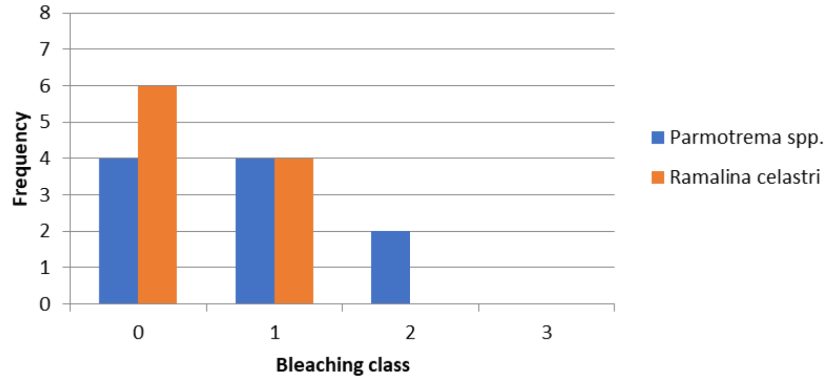
Species	Tree	Side	Overall Damage Score	Bleaching	Abnormalities	Particulates	Notes
H. japonica 5	3	N	0	0	0	0	Normal morphology
H. japonica 6	3	S	0	0	0	1	Normal morphology
H. speciosa 7	4	N	0	0	0	1	Normal morphology. H. japonica also present.
H. speciosa 8	5	N	1	1	0	1	Minor bleaching

APPENDIX 9

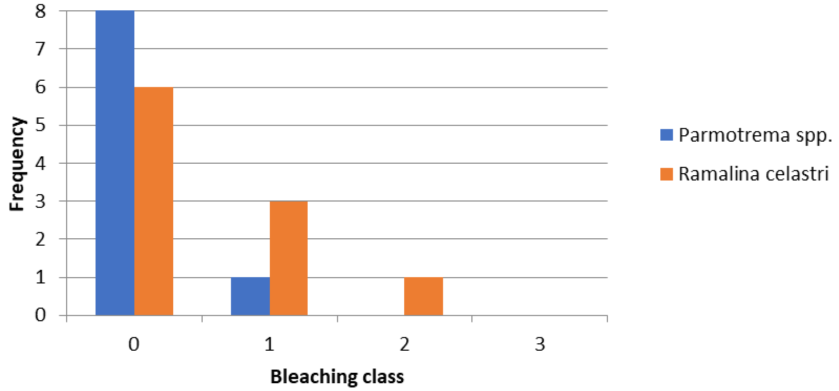
MARSDEN POINT LICHEN HEALTH ASSESSMENT - DATA ANALYSIS



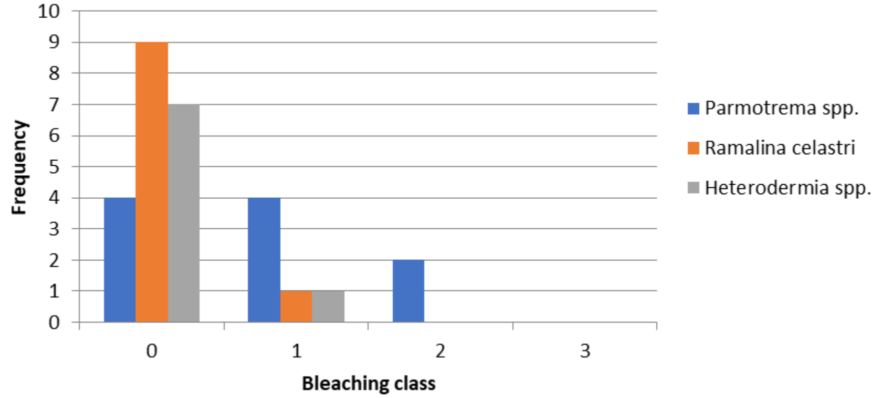
Frequency of bleaching class for lichen species at the refinery (c. 81 µg/m³ SO_2 predicted maximum 24 hour period)



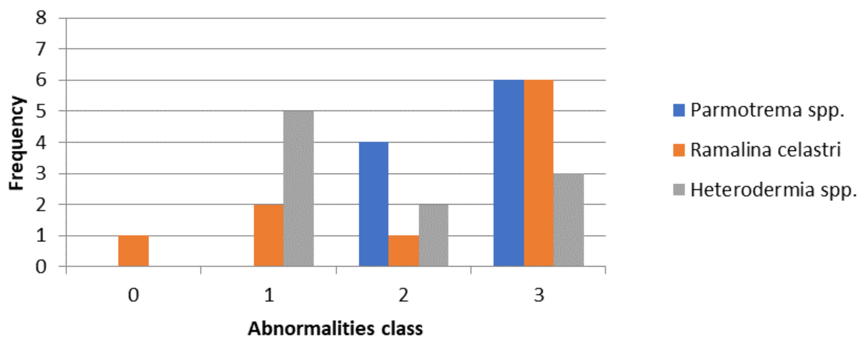
Frequency of bleaching class for lichen species at Rama Road (c. 51 µg/m³ SO_2 predicted maximum 24 hour period)



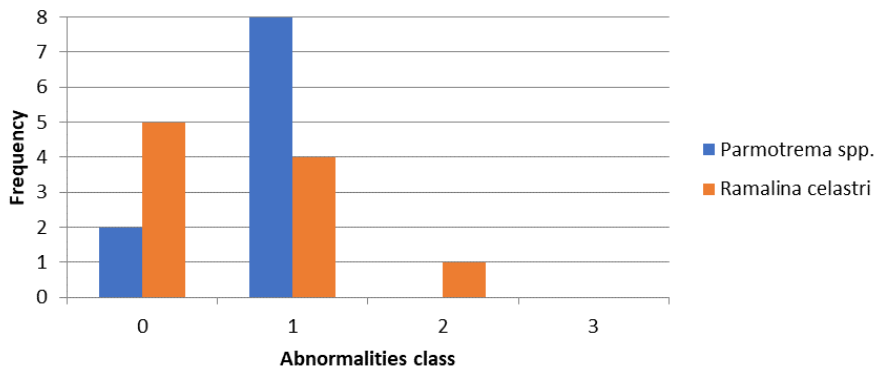
Frequency of bleaching class for lichen species at Ruakaka River Estuary (c. 21 µg/m³ SO_2 predicted maximum 24 hour period)



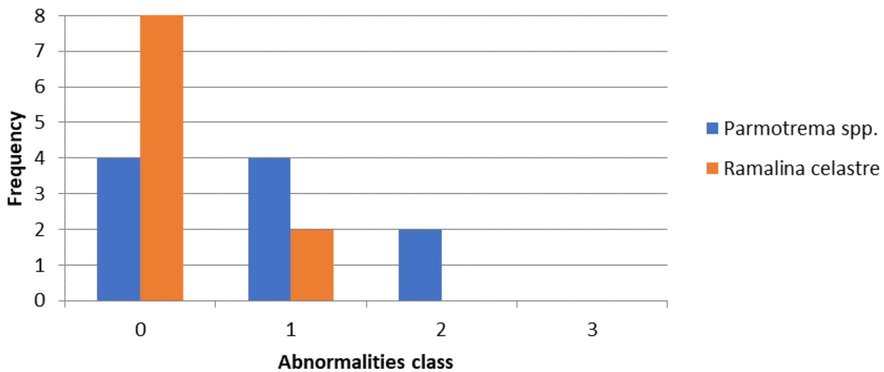
Frequency of bleach class for lichen species at Ruakaka Beach Reserve (less than 21 µg/m³ SO2 predicted maximum 24 hour period)



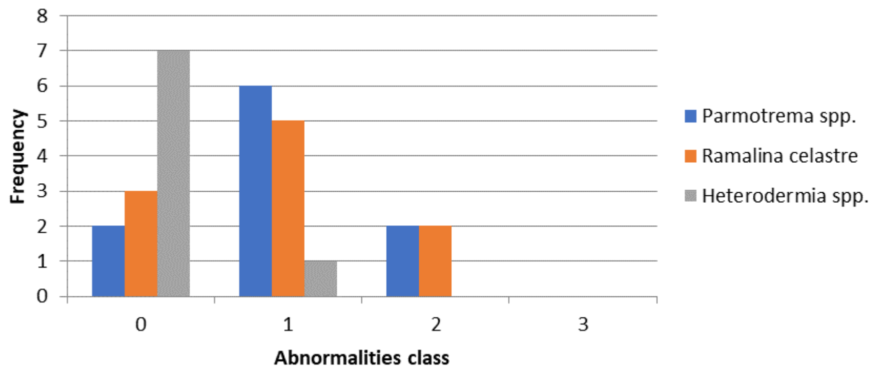
Frequency of abnormalities class for lichen species at the refinery (c. 81 μg/m³ SO_2 predicted Maximum 24 hour period)



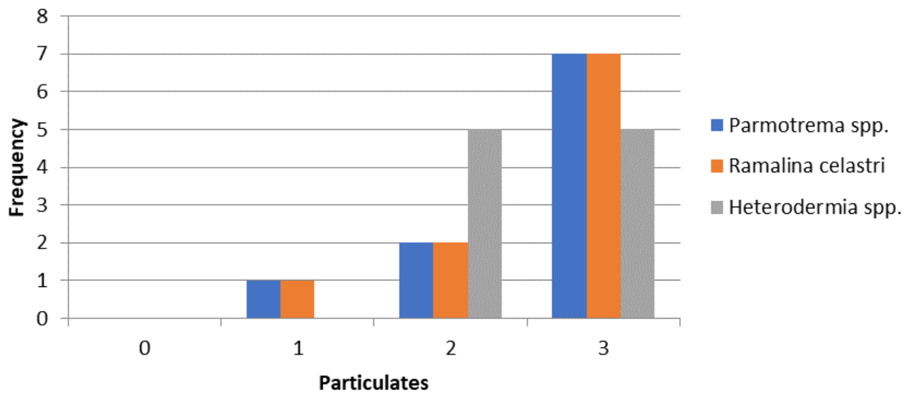
Frequency of abnormalities class for lichen species at Rama Road (c. 51 μg/m³ SO_2 predicted maximum 24 hour period)



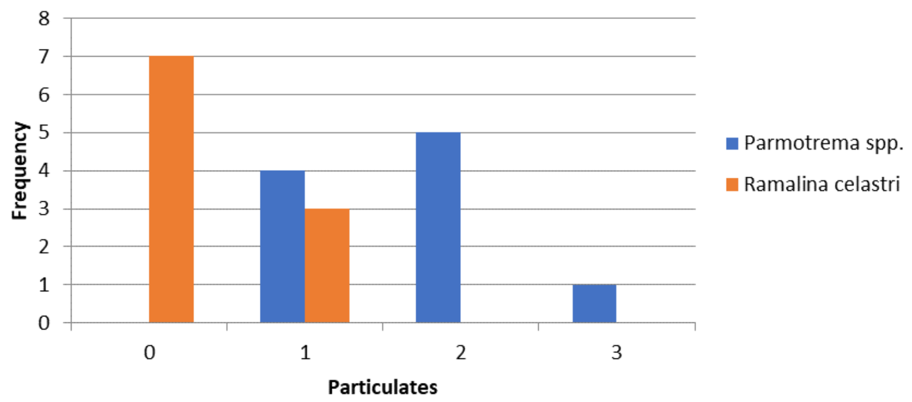
Frequency of abnormalities class for lichen species at Ruakaka River Estuary (c. 21 μg/m³ SO_2 predicted maximum 24 hour period)



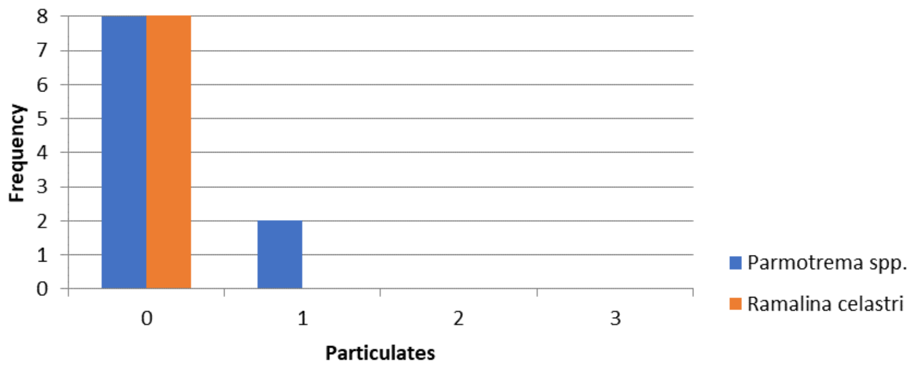
Frequency of abnormalities class for lichen species at Ruakaka Beach Reserve (less than 21 μg/m³ SO2 predicted maximum 24 hour period)



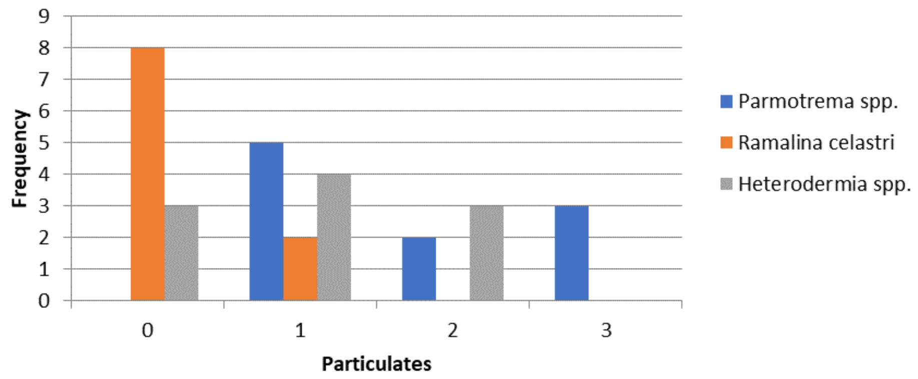
Frequency of particulate class for lichen species at the refinery (c. 2.0 annual average PM10 deposition kg/ha/year)



Frequency of particulate class for lichen species at Rama Road (c. 1.4 annual average PM10 disposition kg/ha/year)



Frequency of particulate class for lichen species at Ruakaka River Estuary (c. 0.2 annual average PM10 disposition kg/ha/year)



Frequency of particulate class for lichen species at Ruakaka Beach Reserve (c. 0.2 annual average PM10 disposition kg/ha/year)

REVIEW OF EXISTING MONITORING REGIME

1. HISTORY OF MONITORING

Refining NZ are required to undertake regular monitoring as part of their resource consent conditions (AUT008319.01-06), to monitor the effects of emissions authorised by the consent. The monitoring programme includes an assessment of the soil, vegetation, and saxicolous (rock-dwelling) lichens at Whangārei Heads. Photographic monitoring of lichens has occurred since 1976 (Bioresearches 1976), with additional quantitative monitoring of lichens implemented in 1990 (Bioresearches 1990). Monitoring of soil and vegetation has occurred since 2002 (Bioresearches 2002). Wildland Consultants completed the monitoring for the 2017 and 2018 rounds (Wildland Consultants 2017a, b, c; and 2019a, b, c).

2. QUANTITATIVE LICHEN MONITORING

The existing monitoring regime for lichens at Whangārei Heads is described in detail in Wildland Consultants (2019) and is not repeated here in full. The following extracts from this report provide a summary of key points relevant to the scope of this overview.

2.1 Lichens as bioindicators

Lichens are sensitive to atmospheric pollutants such as sulphur dioxide (SO_2), nitrous oxide (NO), nitrogen dioxide (NO_2) and ammonia (NH_3) making them useful bioindicators and/or biomonitors of anthropogenic atmospheric air pollution (De Temmerman *et al.* 2001, Pescott *et al.* 2015). In polluted environments, lichens accumulate or are affected by a range of pollutants, including the above-mentioned gases, and these can be measured either directly by analysing lichen thallus material for nitrogen, sulphur, polyaromatic hydrocarbons (PAHs) or metals (Conti and Cecchetti 2001; Glavich and Geiser 2008), or by effects on individual lichen indicator species or species assemblages (e.g. Nimis *et al.* 1990).

The mode of action of most atmospheric pollutants is well known. Sulphur dioxide is oxidised in the atmosphere to sulphite ions (SO_3^{2-}), which then form liquid sulphuric acid (H_2SO_4) and sulphate (SO_4^{2-}) aerosols (often through interaction with ammonia) (Pestcott *et al.* 2015). Sulphites are acidic and particularly toxic to most lichens (Pestcott *et al.* 2015). Acidification is caused by wet deposition via rain or mist and dry deposition via particulate materials (Greaver *et al.* 2012). Nitrous oxide is converted to NO_2 in the atmosphere and both are then converted to nitric acid (HNO_3) and nitrates. These are acidic and contribute to eutrophication. Ammonia is more biologically available as the ammonium ion (NH_4^+), which also contributes to eutrophication (Pestcott *et al.* 2015). Acidophilic lichens tend to be very sensitive to nitrogen deposition, and where this occurs there is a shift to N-tolerant lichens (Greaver *et al.* 2012). Nitrogen can be deposited as particles or in solution as reduced, oxidised or organic compounds (Greaver et al 2012).

2.2 Potential indicator species for monitoring

Lichen species sensitive to atmospheric pollutants are well documented (e.g. Hawksworth 1973; Seaward 1993; Peterson *et al.* 1992). In general, lichens with cyanobacterial symbionts tend to be sensitive to sulphur dioxide, with examples including cyanobacterial species of *Lobaria*, *Sticta*, *Pseudocyphellaria*, and *Leptogium* (Glavich and Geiser 2008; Peterson *et al.* 1992; Seaward 1993; Cameron *et al.* 2007). In addition, pendant fruticose lichens with algal symbionts are generally more sensitive than foliose or crustose lichens. Examples include species of *Usnea* (Rose 1973; Hawksworth *et al.* 1973, Peterson *et al.* 1992; Seaward 1993) and the endangered *Teloschistes flavicans* (Hawksworth and Rose 1970; Laundon 1973). As noted above, *Usnea* species (mainly *U. subfloridana* in the United Kingdom) are sensitive to sulphur dioxide, but can sometimes survive at the edges of lower blanket pollution levels, and are re-establishing in parts of the UK as pollution levels decline (Seaward 1993). There are also a number of crustose and foliose species which are known to be intolerant of sulphur dioxide. Examples include the crustose *Lecanora muralis* (Seaward 1993) and foliose species such as *Parmotrema crinitum* and *P. perlatum* (Baddeley *et al.* 1973; Morgan-Huws and Haynes 1973; Rose 1973). Several papers provide lists of lichen species known to be sensitive to sulphur dioxide (e.g. Hawksworth 1973 (UK); Seaward 1993 (UK); Peterson *et al.* 1992 (USA)).

Daly (1970) studied the effects of sulphur dioxide levels on bryophytes and lichens in Christchurch. He found that the number of lichen species declined along a transect the closer the survey site was to the centre of Christchurch. Some species were clearly very sensitive and others more tolerant, and where species were found on both trees and stone walls, it appeared that some of them were protected by possible buffering by the chemistry of the wall and were found further along the transect (although the paper does not differentiate between basalt, concrete, bricks and granite, which are all very different chemically). Daly (1970) indicated that a mean average winter sulphur dioxide level of 50 $\mu g\ m^{-3}$ caused some reduction in sensitive species.

The New Zealand lichen Mycobiota has the same or similar species as those recorded in other parts of the world as being sensitive to sulphur dioxide. Comparing the list of recorded species from the Whangārei Heads sites with the lists of lichens known to be sensitive to sulphur dioxide suggests the following possible candidate species to be investigated as potential biodindicators:

- *Pseudocyphellaria crocata* agg. This species has been recorded as being sulphur dioxide-sensitive in Canada (Cameron *et al.* 2007) and is cyanobacterial (N-fixing lichens are known to be more sensitive, Richardson and Cameron 2004).
- *Parmotrema reticulatum*. Recorded by Modenesi (1993) as being sulphur dioxide-sensitive. Related *Parmotrema* species are well-known as being sensitive (Baddeley *et al.* 1973).
- *Usnea* species are well known as being sulphur dioxide-sensitive, and fruticose lichens are usually very sensitive due to a high surface area (Baddeley *et al.* 1973, Rose 1973).

- Other cyanobacterial lichens such as *Coccocarpia pellita*, *Leptogium cyanescens* and *Pannaria elixii* are also likely to be sensitive.
- *Teloschistes flavicans* is known from Mt Lion but not present in the plot. This species is known to be very sensitive (Gilbert and Purvis 1996).
- The genus *Stereocaulon* has both green algae and cyanobacteria and is fruticose, so could be sensitive.

2.3 Rationale for existing monitoring programme

Previous monitoring of air pollution for the oil refinery has focussed on the detection of changes in lichen communities, i.e. diversity and composition. This approach aligns with the ecological indicator concept discussed by De Temmerman *et al.* (2001) as any change will be the integrated result of climate and pollution effects over a long period of time.

For ecological indicators to be useful, they must meet certain criteria. Indicators should be able to be assessed easily and quantified, and for plant-based studies, the substrate should be uniform between study sites. When using lichens as indicators, restriction of substrates to rock alone is insufficient to ensure substrate uniformity. Studies have shown that across sites with the same climate and air pollution characteristics, lichen communities can differ significantly between rock types, and along altitudinal gradients (e.g. Asta *et al.* 2002).

Hawksworth *et al.* (1973) noted that species of *Caloplaca* and *Collema* could withstand higher sulphur dioxide levels if growing on calcareous rocks. Calcareous or otherwise alkaline substrates such as mortar and cement can buffer against acidic deposition (e.g. sulphur dioxide) (Gilbert 1970, Seaward 1993). Substrates with higher calcium levels can protect against the sulphur dioxide damage (Nieboer and Kershaw 1983). Conversely, volcanic rocks with low levels of calcium do not provide a buffer against acidic deposition, and the effects of sulphur dioxide on the lichens that grow on them.

Air pollution studies that utilise lichen communities on a specific rock type at the same altitude are therefore more likely to be successful at detecting effects than studies that utilise a wide range of rock types and or altitudes across the monitoring sites. Site selection for detection of air pollution effects from a point source should also avoid potentially confounding factors, such as proximity to major roads (Larsen *et al.* 2006), and eutrophication effects due to cattle grazing (Giordani and Brunialti 2015).

Use of the same observer between monitoring rounds is also helpful (de Temmerman *et al.* 2001); differences in botanical skills can cause significant errors, and species diversity is often underreported, even when sampling occurs within a predetermined plot. Any changes in lichen communities, which coincide with a change in observer(s), should be treated with caution, particularly for long-term studies (Giordani and Brunialti 2015).

There are two key approaches for the detection of the potential effects of emissions on lichen health and abundance:

- Measurement and analysis of change between years (a temporal approach) for a series of marked plots; or
- A 'snapshot' to evaluate effects by studying sites at differing distances from the emission source (a spatial approach).

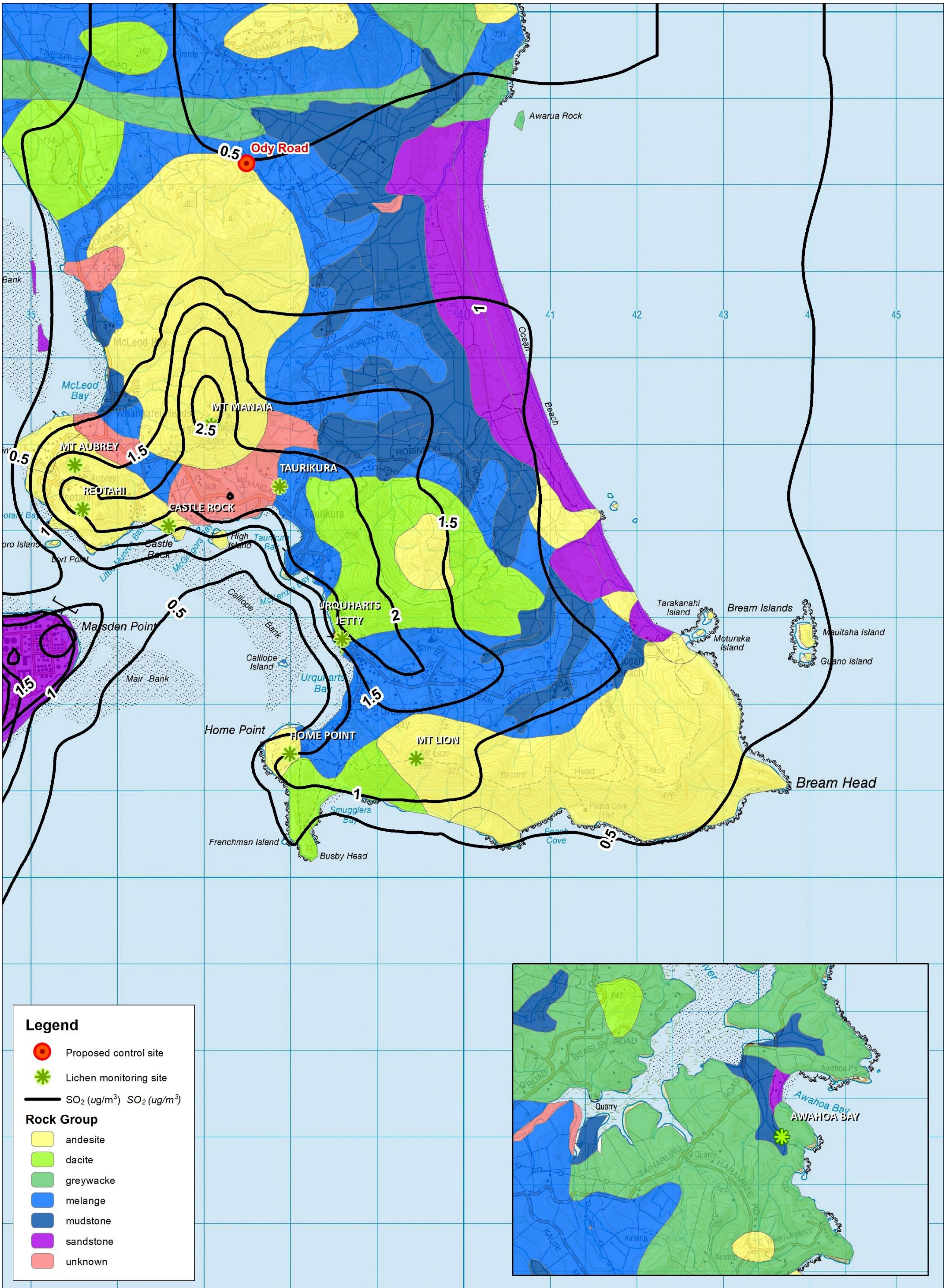
The temporal approach requires the same plots to be assessed during each monitoring event, so that data from each monitoring event can be compared to prior rounds.

2.4 Number and location of study sites

Quantitative monitoring of lichens is undertaken biannually at nine study sites (Table 1 below). Figure 7 provides a map of the study sites, the underlying rock types, and annual mean for sulphur dioxide.

Table 1: Existing lichen monitoring sites at Whangārei Heads.

Station	Site Name	Elevation (m)	Geology	Distance From Refinery (km)	SO_2 Annual Mean (µg/m^3) (Sum of Discharge and Ambient)
1	Mount Aubrey	160	Andesitic volcaniclastics with lava flows and associated andesite, diorite, and granodiorite intrusions.	1.9	c.2.5 µg/m^3
2	Reotahi	20	Andesitic volcaniclastics with lava flows and associated andesite, diorite, and granodiorite intrusions.	1.3	c.2.5 µg/m^3
3	Castle Rock	60	Andesitic volcaniclastics with lava flows and associated andesite, diorite, and granodiorite intrusions.	1.8	c.2.5 µg/m^3
4	Taurikura	5	Landslide material from Mount Manaia.	3.1	c.3.0 µg/m^3
5	Urquharts Jetty	60	Andesitic volcaniclastics with lava flows and associated andesite, diorite, and granodiorite intrusions.	3.3	c.2.5 µg/m^3
6	Home Point Upper	120	Andesitic volcaniclastics with lava flows and associated andesite, diorite, and granodiorite intrusions.	3.0	c.2.0 µg/m^3
7	Awahoa Bay (Control Site)	20	Volcaniclastic sandstone and argillite with minor conglomerate, basalt, chert, and red and green siliceous argillite.	11.1	c.1.0 µg/m^3
8	Mount Manaia	400	Andesitic volcaniclastics with lava flows and associated andesite, diorite, and granodiorite intrusions.	3.4	c.3.0 µg/m^3
9	Mount Lion	320	Andesitic volcaniclastics with lava flows and associated andesite, diorite, and granodiorite intrusions.	4.7	c.2.5 µg/m^3



Data Acknowledgment
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Figure 7: Geology of the Manaia and Waipu Ecological Districts within the receiving environment of the Marsden Oil Refinery air discharge and the location of the quantitative lichen monitoring sites

0 1,000 2,000 m

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Scale: 1:40,000
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The study design selected the measurement and analysis of change between years (the temporal approach) as long term sulphur concentrations in the study area are below the threshold expected to affect sensitive lichens, with no gradient effects (Bioresearches 2015). The study design was intended to enable the following:

- Quantification of abundance, in terms of occurrence and percentage cover.
- Comparison between stations for each species at each monitoring event.
- Determination of change through time (i.e. between surveys) for each species at each station (Bioresearches 2015).

The control station at Awahoa Bay was predicted to show no effect of sulphur dioxide on lichen communities, and, if an effect on lichen communities was shown for a monitoring round, it is expected that further investigation would occur to determine if this change was attributable to sulphur dioxide concentrations.

Geologies of the study sites were determined using QMap (Edbrooke and Brooke 2009) in 2017. Notably, the control site is of a different rock type than the sites closer to the oil refinery. The control site, on the basis of geology and associated degree of acidic buffering, may support a different lichen flora from the sites closer to the refinery, and be more or less sensitive to the effects of sulphur dioxide due to the type of substrate.

2.5 Recent revisions of the methods

Location of Plots

Prior to 2017, a plot of 0.5 metres × 0.5 metres, subdivided into 100 50 × 50 millimetre quadrats, was randomly located 20 times within a sampling area between 0.5-1.5 metres above the ground. Two-hundred samples were then obtained per station by randomly taking 10 quadrat positions per frame. Within each of the 200 sample quadrats, the species of foliose and fruticose lichens[1], and their percentage cover, was recorded (Bioresearches 2015). The percentage cover was also estimated for mosses, and for crustose lichens, leprose lichens, and bare rock. Previous monitoring did not account for the percentage cover of vascular species.

In 2017, each 0.5 metres × 0.5 metres plot was marked permanently, using a concrete drill, bolts, and a masonry adhesive. This was done to reduce variability due to plot placement between monitoring rounds. These permanently-marked plots were then reassessed in 2018, and will be the plot locations to be used for all future monitoring rounds.

Identification of Lichens

In 2017, except for the site at Mount Manaia where collection of specimens is not permitted, one specimen of each species was collected from each of the sites where it occurred. The specimens were then identified to either genus or species level using a

[1] Sampling in 2017 and 2018 also revealed the presence of squamulose lichens (*Cladonia* spp). This growth form had not previously been recorded as present. For comparability with previous data these were grouped with fruticose lichens as they have branching fruiting structures.

range of laboratory techniques, including microscopy, chemical testing, and DNA testing.

In 2018, with the exception of the site at Mount Manaia, specimens were collected of all species not identifiable to species-level in the field.

The 2017 survey identified new species and genera not previously recorded in this study, corrected the identification of some species, and updated the names of species to reflect modern nomenclature. Changes and additions to the previously-reported lichen flora are described by Wildland Consultants (2017). Eight genera of foliose or fruticose lichen species were recorded for the first time during the 2017 monitoring round: *Pannaria*, *Phaeophyscia*, *Cladonia*, *Physcia*, *Leptogium*, *Parmelia*, *Punctelia*, and *Coccocarpia*. Some of these genera are of low frequency, and may possibly have not been present in previous sampling quadrats, e.g. *Coccocarpia*. Other newly-recorded genera are distinctive, have foliose or fruticose growth forms, and occur relatively frequently within at least one site, e.g. *Cladonia*, *Pannaria*.

To aid comparability between 2017 and earlier monitoring events, the total combined percentage was also analysed for foliose and fruticose species, on the premise that different observers will largely assign lichens to these broad groups correctly.

From 2018 onwards, revisions to the methods made in 2017 allow for greater comparability between years, e.g. 2017 in comparison with 2018.

Results of 2018 Monitoring

The 2018 monitoring round generated data that could be evaluated against the quantitative lichen monitoring data collected in 2017.

In 2018, the cover and frequency of lichens, mosses, and liverworts, and other variables varied by species and site, but patterns in distribution and dominance were very similar to those observed in 2017.

There were statistically-significant differences in the cover and frequency of several lichen species and species groups between 2017 and 2018. As in 2017, decreases for foliose or fruticose lichen species were typically accompanied by increases in another foliose or fruticose species, indicating that changes are probably attributable to the natural dynamics or succession of the lichen communities. Except for Mount Aubrey, where a decline in the lichen community appears to be driven by long-term successional processes, no sites show a consistent decline for all foliose species, which, if it had occurred, could be indicative of air pollution effects. Some sites are characterised by relative long-term stability in lichen cover and frequency, including Urquharts Jetty, 3.3 kilometres from the refinery, and Home Point Upper, 3.0 kilometres from the refinery.

The monitoring data does not reveal an effect of air pollution on lichen cover and frequency between 2017 and 2018, which is also supported by the results of the photographic lichen monitoring undertaken in 2018 (Wildland Consultants 2019a), as addressed below.

3. PHOTOGRAPHIC MONITORING

Photographic monitoring of lichens at Whangārei Heads is described in detail in Wildland Consultants (2017b and 2019b). The following extracts from these reports provide a summary of key points relevant to the scope of this review.

3.1 Location of sites

Photographic monitoring of lichens is undertaken at the following six sites, as per the methods described in Wildland Consultants (2017):

- Mount Aubrey.
- Reotahi.
- Mount Manaia.
- Urquharts Jetty.
- Home Point (upper).
- Home Point (lower).

3.2 Results

Change in the lichen communities in the photographic plots, between 2017 and 2018, is characterised by the growth or decline of colonies that is attributable to natural successional processes. At one site, Mt Aubrey, the effects of the sampling timing and effects of adjacent vegetation growth were observable for both lichen and vascular plant species, with changes in colour, mortality and subsequent sloughing off from the rock face. At most sites, including Reotahi, Urquharts Jetty, Home Point Upper, and Home Point Lower, the lichen communities are remarkably stable over multiple monitoring events, including the last two monitoring rounds in 2017 and 2018.

Growth rates for the period 2017-2018 are similar to the long-term average growth rates since the study began. On this basis, recent emissions from the refinery are unlikely to have affected lichen growth rates at Whangārei Heads.

4. SOILS AND VEGETATION

Monitoring of soils and vegetation at Whangārei Heads is described in detail in Wildland Consultants (2017c and 2019c). The following extracts from these reports provide a brief summary of key points relevant to the scope of this review.

4.1 Location of study sites

Vegetation (i.e. vegetated cover made up of vascular plants) and soil sampling is undertaken biannually at three sites, as per the methods described by Bioresearches (2015):

- Mount Aubrey.
- Mount Manaia.
- Kauri Mountain.

4.2 Results

In the absence of baseline data (the refinery started operating in the 1960s), monitoring data since 2003 has not revealed an increase in sulphur or nitrogen in soils or leaf tissue at Mount Manaia and Mount Aubrey between 2003 and 2017. Levels of sulphur and nitrogen at the all of the sites have been highly variable.

As stated in previous monitoring reports, observed differences in the soil nitrogen between sites could be related to differing levels of soil moisture and pH, rather than a result of refinery emissions. Furthermore, differences in soil characteristics (for example, soil nitrate nitrogen is higher at Mount Aubrey than the other sites) could affect the concentrations of variables measured in plant tissues.

It is therefore concluded that there have not been any effects on soils and vegetation that can be attributed to refinery emissions.

5. CHANGES TO EXISTING MONITORING REGIME

5.1 Scope of critique

A critique of the methods was provided as part of the 2017 monitoring reports (Wildland Consultants 2017a, b, c) and, subsequent to this, some revisions to the methods were made in both 2017 and 2018 (primarily to increase comparability between monitoring rounds). The scope of this critique is broader, and considers additional potential changes, including possible revision of methods and study locations, to improve the rigour of the monitoring regime.

5.2 Previous critique of the monitoring programme

Stevenson *et al.* (2000) provide a brief review and critique of the existing air quality monitoring programme for Marsden Point Oil Refinery, noting the following:

- A lack of correlation of the lichen monitoring results with levels of sulphur dioxide.
- No analysis has been undertaken of the levels of sulphur dioxide in the lichens at the study sites.
- No established link between growth rates and changes at the study sites and ambient sulphur dioxide levels.
- A decline in lichens at the control site.
- That the study would be greatly enhanced by including annual reviews of meteorological records.

Most of these criticisms can now be addressed by the inclusion and correlation of air quality data (from both measured and modelled data sets) in the analysis of the lichen, vegetation, and soils monitoring results. Air quality modelling of annual and winter sulphur dioxide concentrations could also be correlated with analysis of sulphur concentrations in lichen tissues at the study sites, i.e. to determine if lichens have higher levels of sulphut at sites with elevated levels of sulphur dioxide. Inclusion of these two components would address the concerns raised in that review, and would increase the likelihood that any changes can be linked to their probable cause.

5.3 Quantitative monitoring of lichens

Location of the Control Site

With the changes to the monitoring programme implemented in 2017 (identification of lichens to species level, and the permanent marking of all plots so that variability between rounds due to changes in plot locations is reduced), the primary remaining issue with the existing lichen monitoring programme is the suitability of the control site. Modelling of sulphur dioxide concentrations in 2019 (Tonkin and Taylor 2019) confirmed that the control site at Awahoa Bay is located where sulphur dioxide concentrations are less than 0.5 µg/m^3 for both annual average and winter average. However, in contrast to the other monitoring sites, which are all igneous rocks (Allen 1950), the rock outcrops at this location are sedimentary rocks described by Allen (1950) as greywackes and argillites, or by Edbrooke and Brooke (2009) as "volcaniclastic sandstone and argillite with minor conglomerate, basalt, chert, and red and green siliceous argillite". Argillite is a fine-grained sedimentary rock (mapped as mudstone in Figure 7) with variable alkali content.

A field survey, with associated analysis of geology (Appendix 3), lichen chemistry (Appendix 6), and lichen diversity (Appendix 6), confirmed that a site on Ody Road on the northeast flanks of Mount Manaia (Figure 7) is a suitable replacement control site. The site is of similar geology to those within the receiving environment, and is predicted to have an annual mean sulphur dioxide concentration of approximately 1.5 µg/m^3 (the predicted discharge plus ambient level). This site is located in the area of lowest sulphur dioxide concentrations within the receiving environment that is still on the same geological formation (andesite) as the monitoring sites further to the south. Further north of here, the underlying geology transitions to sedimentary rocks. Concentrations of nitrogen, sulphur, and calcium in the lichen tissues were broadly similar across the three sites at Ody Road, Mount Manaia, and Home Point. The site at Ody Road includes species that are indicators of air pollution (Section 9.2.2), including *Leptogium cyanescens*, *Pannaria elixii*, *Pseudocyphellaria crocata*, *Usnea c.f. undulata*, *Stereocaulon ramulosum*.

Lichen Monitoring at Mount Manaia

Quantitative monitoring of lichens at the existing monitoring site on Mount Manaia is warranted, given that it coincides with one of the highest predicted peaks in sulphur dioxide concentrations (*c*.3.50 µg/m^3 annual mean). However, monitoring at Mount Manaia is not worthwhile unless permission is granted to permanently mark the plot locations, and to collect samples for identification, as these steps are necessary to collect meaningful data at this site. The importance of Mount Manaia as a monitoring site should be discussed again with the Department of Conservation and relevant iwi, and if permission is not granted, monitoring at the site should be discontinued.

APPENDIX 11

QUALIFICATIONS AND EXPERIENCE OF AUTHORS

Tim Martin is the project manager and lead author of this report, with assistance from **Jessica Reaburn**, **Dr Dan Blanchon** (lichen identification and analysis) and **William Shaw** (technical advice and peer review).

Dr Tim Martin - Principal Ecologist
Wildland Consultants Ltd

Tim Martin is a well-qualified and very experienced ecologist based at our Auckland office. He obtained an MSc (Hons) for his research on the ecology of the tree *Ascarina lucida* in northern New Zealand, and then a PhD from the University of Auckland, investigating the effects of storms on indigenous forests in central and southern North Island. He has excellent knowledge of North Island ecosystems and vegetation types, including vegetation dynamics, plant species distributions, threatened plant species, naturalised flora, and the mechanisms that drive vegetation change. Tim has considerable experience in a diverse range of ecological projects to complement his excellent botanical skills, including the mapping and ecological evaluation of forest, wetland, and estuarine habitats, ecological restoration, survey and monitoring of lichens, reptiles and freshwater fish, and monitoring of environmental effects.

Tim undertook and reported on the last two rounds of air quality monitoring using lichens for New Zealand Refining at Marsden Point (2017 and 2018), and the Huntly Power Plant for Genesis Energy (2016 and 2018). He is familiar with the lichen flora of the receiving environment, and the rationale and methods for the air quality monitoring being undertaken. He has designed, implemented, and or reviewed monitoring programmes for a wide range of consents, including wastewater discharges, vegetation clearance, and discharges to air.

He has specialist knowledge of the ecology of the Northland Region, and has co-authored protected natural area survey reports for several ecological districts, including the Tangihua, North Rodney, and the Waipu Ecological Districts, the latter of which falls within the receiving environment of the air discharge. He has prepared detailed ecological assessments for several areas within the receiving environment, including the Ruakaka Racecourse, McEwan Road Wetland, the Marsden to Oakleigh rail link, and estuarine habitats within Whangārei Harbour.

Tim has prepared technical assessments and/or prepared management plans for a wide range of projects, including discharges to air, transmission lines, mines, quarries, subdivisions, waste water discharges, water abstraction schemes, large-scale roading projects (Peka Peka to Otaki Expressway, Puhoi to Warkworth, Huntly Bypass, Mt Messenger, Manawatu Gorge), water reservoirs, dairy conversions, plan changes, and rail corridors. Tim has presented evidence at planning hearings (10), the Environment Court (3), and High Court (1). He has represented a wide range of clients at hearings, including district councils (e.g. New Plymouth District Council, SH3 at Mount Messenger, consent granted), mining companies (e.g. Sandglass Corporation and Coastal Resources Limited, Mangawhai, Environment Court, consents granted), transport companies (e.g. Kiwirail, Marsden Point to Oakleigh rail link, consent granted) and land developers (e.g. Carter Holt Harvey, Ararimu subdivision, consent granted). He is currently representing the Department of Conservation in relation to the proposed Manawatu Gorge Bypass on State Highway 3. He is familiar with the preparation and delivery of expert evidence, expert conferencing, "hot-tubbing", and cross-examination. He was previously employed as a lecturer in ecology at the Auckland University of Technology, and has taught field courses in Northland, Auckland, Coromandel, central North Island, and the West Coast of South Island. He has also managed weed surveillance and control programmes in the Hauraki Gulf for the Department of Conservation, assessed the health of forest remnants in the Rodney District for the Auckland Regional Council, and worked in the Auckland Museum herbarium.

Jessica Reaburn - Senior Ecologist
Wildlands Consultants Ltd

Jessica is an experienced ecologist based in the Auckland office. She has completed a MSc with First Class Honours at the University of Auckland, studying the development of plant communities within restoration plantings in Auckland Regional Parks. Jessica has a sound knowledge of vegetation assessment techniques, indigenous and exotic terrestrial plant species, freshwater streams and riparian vegetation, and also has considerable experience in significance assessments of terrestrial ecosystems.

Jessica has in-depth knowledge of the resource consenting process resulting from previous work in the land development sector, and has been undertaking a variety of ecological assessments and monitoring works since 2011. She has prepared Assessments of Ecological Effects for a range of developments, including subdivisions, construction of dwellings, commercial developments, vegetation removal, stream piping and diversions, and cleanfills. Jessica also has experience in freshwater environments including Stream Ecological Valuations (SEVs), electric fishing, fish capture and relocation, and fish passage design and monitoring.

Jessica has undertaken extensive terrestrial ecological monitoring work within the Auckland Region, including acting as team leader and lead botanist through several seasons of forest and wetland biodiversity monitoring for Auckland Council. Jessica's ecological restoration experience includes the preparation of planting plans for diverse environments, including wetland, riparian, and terrestrial projects.

Dr Dan Blanchon - Botanist, Lichenologist
Position: Associate Professor, Unitec New Zealand

Dan completed an MSc in botany revising the lichen genus *Ramalina* for New Zealand at the University of Auckland, quickly followed by a PhD in botany at the same institution, studying the systematics, cytology and breeding systems of the New Zealand iris (*Libertia*). He teaches botany, biosecurity, ecology and biodiversity courses in the Bachelor of Applied Science. Dan has a research background in lichen systematics and the morphology, and anatomy and evolution of native plants. Current research projects focus on studying the systematics and ecology of lichens and native plants in New Zealand, examining the ecology of invasive plants, and identifying new treatments for imported plant material identified as potential biosecurity hazards. Dan is recognised throughout New Zealand for his skills in the field of lichenology. Dan has a demonstrated research record in non-vascular plants, and lichens in particular, with 29 peer-reviewed papers in this field. He has extensive experience in the collection and curation of herbarium specimens, and over nearly 13 years has contributed *c*.7,000 specimens, with *c*.4,000 non-vascular plants and lichens, to the Unitec Herbarium. The Unitec Herbarium now holds a significant reference collection for the identification of lichens.

William Shaw - Principal Ecologist and Director
Wildland Consultants Ltd

William is a nationally-recognised leader in the fields of ecological effect assessment, assessment of ecological significance, threat management, and management of natural areas, for a wide range of New Zealand's environments. He has worked on many infrastructure projects and has a good understanding of the types of potential ecological effects and how to address them. He has undertaken assessments of environmental effects for land subdivision, landfills, prisons, roads, hydro-electricity production, new jetties, walking tracks, bridges, and stream diversion. Large-scale roading projects that William has provided ecological advice for the Mount Messenger Bypass on State Highway 3, Waikato Expressway, the Taupō Eastern Arterial, Rotorua Eastern Arterial, SH47 (Turangi-Taumarunui), SH5 (Rotorua-Tirau, Taupō-Napier), SH1 (Desert Road), Strategic Roading at Tauranga (various sites), and the Auckland Central Motorway Junction. These roading projects included involvement in the resource consent process, development of mitigation packages, granting of consent, and auditing of consent conditions. William has been Principal Ecologist and a Director of Wildland Consultants since 1996. He was previously employed as a scientist specialising in vegetation ecology, mapping and natural area management by the Department of Conservation and the Forest Research Institute of New Zealand. William has considerable expertise in ecological research and ecological management, having also worked as a senior manager in a government department. His work has included extensive field studies throughout New Zealand (including its offshore islands), and more widely in the Pacific. He also worked in a consultancy business in Christchurch, with particular reference to nature conservation in both urban and rural areas. As a scientist, he played an important role in management planning for natural areas, undertaking extensive botanical and biological surveys and conservation management assessments. He is the author of more than 500 ecological and botanical papers, reports, technical evidence, articles, and species lists. He is a Crown-appointee to Te Pua O Whirinaki Regeneration Trust, working with Ngāti Whare. He is a previous member of the Whirinaki Conservation Park Advisory Committee (member five years, Chairperson three years), and the East Coast National Parks and Reserves Board. William has also lectured in ecology, nature conservation and natural area management to tertiary level students of Resource Management, and undergraduate Parks and Recreation students at Lincoln University and Waiariki Polytechnic.

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