THE HEALTH OF AUCKLAND'S NATURAL ENVIRONMENT IN 2015

TE ORANGA O TE TAIAO O TĀMAKI MAKAURAU

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Auckland Council
Te Kaunihera o Tāmaki Makaurau

HE MIHI

Ko Ranginui e tū iho nei te matua e whakamarumaru nei i a tātou.
Ko Papatūānuku e takoto ake nei te whaea i ahu mai ai tātou te tangata, te papa e noho nei hei tūrangawaewae mō tātou katoa.

Ko Tāne e tū rangatira mai nei hei whakahaumaru i te tangata.
Ko Tangaroa hei whakaāio i te iwi.
Ko te hā o Tāwhirimātea hei hā ora ki te tangata.

Ka heke, ka heke, ki a tātou te tangata.

Haere te wā, haere te wā, ka tini te tangata, ka mahue i a tātou ngā hononga ki te rangi, ki te whenua, ki te ngahere, ki te moana.

Nō tātou te haepapa kia tiakina te taiao, hei whakamana i ngā whakareanga o mua, hei oranga anō mō ngā whakareanga ā muri nei.

Kia mārama tātou ki ngā pānga o te tangata ki ngā huringa taiao. Mā roto noa mai i te pūtaiao me te mātauranga e whakaorangia anō ai te mauri me te wairua o te taiao.

Kua eke te wā e tū ai te tangata hei kaitiaki i te whenua, i te ngahere, i te moana. Nō tātou katoa te haepapa – hoake!

Tuia ki te rangi
Tuia ki te whenua
Tuia ki te moana
Tuia te here tangata
E rongo te pō, e rongo te ao

Tīhei mauri ora!

Ranginui, our sky father, provides our shelter from above.
Our earth mother, Papatūānuku, from whence all people originate, provides the foundations upon which we stand.

Tāne, god of the forests, stands as our protector.
Tangaroa, god of the seas, helps to calm us.
Tāwhirimātea, god of winds, provides the air we breathe.

We trace our descent from these gods.

Over time, we have multiplied, outgrowing our surroundings and forsaking our familial links to the sky, to the land, forests and seas.

We have a responsibility to care for our environment, to honour past generations and provide for those yet to come.

We must understand how we as people have changed our environment. Only through science and knowledge will we be able to restore its mauri and wairua.

Now is the time for us all to stand up as kaitiaki for our land, forests and seas. It is a responsibility we must all share – let us uphold it!

Bind the domain of the upper realm
Bind the domain of the land
Bind the domain of the seas
Bind the tapestry of life which affirms our connection to the natural world and to one another

Let there be life!

STATE OF ENVIRONMENT REPORT 2015

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FOREWORD – LEN BROWN
HEI TAKI KŌRERO

The sea – our harbours, beaches and islands. The land – our maunga, forests, streams and parks. These are the places Aucklanders hold in their hearts, the reason they love this city. As Auckland Council, it is our responsibility to protect these places and take especially good care of them for future generations.

As Auckland continues to grow, with forecasts adding another 700,000 people in the next 30 years, it is clear we need to take better account of our environment. Monitoring and public reporting of environmental indicators is critically important. It shows us where we are doing well and where we need to do more.

This State of the Environment report, the fourth Auckland-wide assessment since 1999, is the most up to date and comprehensive view of the health of our environment. It speaks of impressive gains in some areas and significant challenges in others. While air quality has progressively improved, marine and freshwater health has not. Native birds and plants are actively protected in the sanctuaries but under threat elsewhere.

The greatest source of impact on Auckland's environment is people: us. Our small, everyday choices add up to some sizeable effects. Together we can be a force for change. One of the great delights reading this report is seeing just how many groups of committed citizens are actively enhancing their corner of the world with projects like the King Tides Initiative, Enviroschools, Ark in the Park and Tiritiri Matangi.

In the five years since the last State of the Environment Report, a number of governance changes have been made in Auckland. The unified Auckland Council offers us an opportunity to tackle our environmental challenges in a coordinated and strategic way and to explore new partnerships. The establishment of the Tūpuna Maunga o Tāmaki Makaurau Authority to govern 14 Tūpuna Maunga is an important step along this path.

In the Auckland Plan, we have recognised the need for transformational change – to strongly commit to environmental action and green growth. This is essential to our ambition to be the world's most liveable city – te pai me te whai rawa o Tāmaki.

The challenge now is to empower our communities to unleash their energy for environmental improvement and find ways to move faster on some of our most pressing environmental problems. We also need to ensure that the continuing rapid growth of urban Auckland does not come at an environmental cost. As Auckland grows it must grow greener.

I commend this report to you as an important assessment of Auckland's environmental health and as a call to action for those of us who live in and love this place – because there is only one Auckland.

Len Brown
Mayor of Auckland

EXECUTIVE SUMMARY NGĀ TAKE MATUA

Auckland's natural environment is diverse and magnificent, from harbours, lakes and streams to productive soils, indigenous forest, ranges and islands. This environment and our historic heritage are key components of Auckland's liveability.

The region's projected growth will place pressure on the natural environment. This 2015 State of the Environment report is the first by Auckland Council. It highlights current and potential environmental issues, recent changes and long-term trends. It also provides a baseline and firm platform for considering the challenges of a growing Auckland.

Auckland has an excellent natural advantage in terms of air quality, a climate that promotes dispersion, no long-range sources of pollutants and low concentrations of them outside the urban area. In general Auckland's air quality is good, with pollutants generally below guidelines, standards and targets. However, from time to time these are breached.

Air quality has improved greatly in the last decades as a result of effective air quality management, including removing lead from petrol and lowering its benzene levels, increasing public transport options and use, and traffic management planning in the CBD.

However, population increase and the associated needs for transport and heating could see air quality trends reversed. For example, motor vehicles, especially those using diesel fuel, are the main source of particulate matter ($PM_{2.5}$, PM_{10}) and nitrogen dioxide (NO_2). Currently, the number of diesel vehicles in Auckland is on the rise as the population increases. So although levels of particulate matter and nitrogen dioxide have decreased in the region, we are still in danger of exceeding air quality guidelines and standards as vehicle numbers increase.

Auckland has areas of high biodiversity, namely on the well-managed islands and large tracts of remaining indigenous forest on the mainland. However, where the landscape has been modified, primarily by highly intensive farming activity and urban growth, this diversity is reduced. The numbers and impact of pest plants (weeds) and animals vary greatly across the region, but we are seeing reduced levels where management efforts are adequate.

Soil quality across the region is generally good, but some areas show a decline in soil function, particularly at agricultural and horticultural sites where there may be elevated phosphorus levels from fertilisers and compaction issues. Soil pollution is also elevated in rural Auckland (cadmium) and our growing urban areas where there are increased levels of nickel, lead and zinc.

Degraded marine and freshwater sites reflect past and present inputs of sediment and contaminants from urbanisation and industrial activities, and nutrients and sediments from rural activities. Freshwater monitoring shows a clear pattern between the catchment land use and water quality and ecological health. Sites in a poor state are generally in urban catchments, while those within native forest with little human influence support healthy and diverse biological communities.

The clear waters and sandy bottoms of many of Auckland's harbours and estuaries are being progressively lost to increasing amounts of fine sediment that muddies the waters and smothers sea life.

EXECUTIVE SUMMARY NGĀ TAKE MATUA

While some sites have healthy ecological communities, all harbour and estuary locations contain sites with moderate or poor ecology, even those farther from Auckland's urban centre. Sediment is muddiest, contaminants are highest and ecology is poorest in locations near older urban Auckland and in upper estuarine areas.

While decreases are occurring in some areas, contaminant concentrations in many areas are still above levels harmful to aquatic life. We therefore need a continued focus on removing contaminants at source and improving stormwater treatment. This will help affected areas to recover and prevent newly developed areas from suffering the same fate as the more degraded estuaries in the region's older developed catchments.

Auckland has a rich and diverse historic heritage. Our awareness of the amount and nature of historic heritage in the Auckland Council area is improving. The number of heritage items recorded in the council's Cultural Heritage Inventory and the New Zealand Heritage List have increased steadily over the past 10 years, as have Auckland Council's scheduled items. There has been a slow but steady increase in the amount of land being systematically surveyed and assessed for heritage sites and items.

There have been mixed results since the *2009 State of the Auckland Region* report, with some regional improvements in air quality and good progress in biodiversity values where indigenous forest and animals are being intensively managed. However, there remains the slow decline in the environmental health of our marine and freshwaters, reported in 2009, due to sediment and contaminant inputs, and the footprint of urban Auckland is expanding.

Big changes in environmental pressure will come in the near future as we face increasing population growth and urban intensification and expansion, all within a context of changing climate. The big challenge is how we consider environmental outcomes in the decisions we make both as an organisation and as individuals. Working with the environment rather than against it, we need to turn the challenges into opportunities for enhanced environmental and economic outcomes to benefit Aucklanders today and into the future.

INTRODUCTION
KUPU WHAKATAKI

Looking out at the Hauraki Gulf

The Auckland Plan sets a shared vision to be the world's most liveable city. Our environment is a key part of this liveability. Auckland's natural environment is diverse and magnificent. The waters in our lakes, streams and estuaries link our infinitely varied coast and harbours with extensive tracts of indigenous forest in the steep upland ranges. Sandwiched in between are the productive soils where we live and grow our food.

We all live in the environment, depend on the life-supporting resources it provides and are invested in its well-being. Because of this, we carry out environmental monitoring to measure the health of our environment and find out what needs attention – it's like a building condition assessment for our region or a check-up at the doctor's. Presenting the latest results from our environmental monitoring programmes, this report is a stock-take that highlights current and potential environmental issues, recent changes and long-term trends.

ABOUT THIS REPORT

State of the environment reporting has been undertaken by local, regional and central government in New Zealand since the Resource Management Act (RMA) 1991 was enacted. Section 35 obligates regional government to make publicly available a review of the results of its monitoring of the state of the environment and the effectiveness and efficiency of its policies at least once every five years.

In Auckland this has involved producing five-yearly reports in 1999, 2004 and 2010. Since 2011 these reports have been complemented by State of Auckland report cards. Since the *2009 State of the Auckland Region* report, data from Auckland Council's monitoring programmes have also been reported in two State of the Hauraki Gulf reports produced by the Hauraki Gulf Forum and a report on the changes in indigenous ecosystems and the environment within the Waitākere Ranges Heritage Area[1].

In this State of the Environment report, we cover a selection of key indicators, with a particular focus on those that:

- are aligned with the Auckland Plan
- inform and evaluate management initiatives
- report against national standards or guidelines.

The mauri of te taiao in Tāmaki Makaurau holds great significance for Mana Whenua as kaitiaki. Many of the monitoring results reported here will be of interest and value to Mana Whenua. Moving forward, we are committed to working together with Mana Whenua to develop further environmental monitoring and indicators that are useful to enable the role of kaitiaki.

This report is divided into four environmental domains: climate, air, land and water. Within each domain the suite of indicators is complemented by a range of more in-depth case studies. As well as our natural environment today, our historic natural and built heritage is an integral part of our sense of place; it is the link to our past. A final case study details our current understanding of Auckland's historic heritage.

This report is a compendium of the results of environmental monitoring programmes, bringing information across environmental domains into one document. More detail can be found in publications referenced at the end of each chapter in individual technical reports on the Auckland Council website **aucklandcouncil.govt.nz/EN/planspoliciesprojects/reports/Pages/home.aspx**
The base data are also progressively being made available via this website.

This is the first State of the Environment report by Auckland Council. It tracks changes over time and identifies issues. It provides a baseline and firm platform for considering the challenges of a growing Auckland.

Kia whakatōmuri te haere ki mua
To walk into the future our eyes must be fixed on the past

CHANGING AUCKLAND

The Auckland environment we live in today is the result of progressive waves of settlers who have left their mark. Over time we have gradually modified Auckland's environment to fit our needs.

Most of the foreshore along the Waitematā Harbour has been reshaped or reclaimed. Lowland landcover has changed from native forest to rural pasture and urban areas. As well as fragmenting and reducing habitat and resources for our native biodiversity on land, such massive changes in land use produced large amounts of sediment that washed into sheltered estuaries. This has made the water murkier and the sediment muddier, changing the habitats and affecting the biodiversity of our marine and freshwaters.

Farming, urban development and industrial activity have also produced a range of contaminants that have been transported from land and accumulated in Auckland's waterbodies. The introduction of pest animals and weed species has had a major impact on our native biodiversity on land.

A key environmental pressure in Auckland is population growth and the subsequent pressures on land and how it is used. Population growth and changes in land use are outlined here as a context for the environmental reporting in later chapters.

POPULATION GROWTH AND CHANGE

New Zealand's most populated region (1,415,550 people at the 2013 Census), Auckland is home to one-third of the country's population. It has a long history of population growth, fuelled by natural increase (births minus deaths) and net migration from overseas and other parts of the country.

Auckland accounted for just over half (51.6%) of the overall national growth between the 2006 Census and 2013 Census, with Auckland's population increasing by 110,589 in that time. This was an average annual growth rate of 1.2%, half that from the previous period between censuses (2.4%).

Auckland's population will continue to increase. Statistics New Zealand's projections suggest Auckland's population could reach 2.01 million by 2033, an increase of 517,300 over the next 20 years (medium series projections). A mix of migration and natural increase will continue to drive our growth. This is because Auckland has a higher birth rate and lower death rate than most other New Zealand regions, with a higher proportion of people in the main childbearing ages (15 to 44 years).

While the overall population is projected to grow, the rate of growth is projected to gradually slow down, across all scenarios. This is attributed to an ageing population, resulting in an increase in the number of deaths relative to births.

AGEING POPULATION

Auckland's population is relatively youthful compared with other parts of New Zealand, with high numbers in working age populations. However, the population is ageing, which means there will be numerically and proportionately more people in older age groups over the next few decades.

The region experienced a 26.9% increase in the number of residents aged 65 and over between 2006 and 2013, equating to an additional 34,608 older people since 2006. The proportion of Auckland's population aged 50 or older has also increased since 2006. This reflects national and global trends as people live longer and fertility rates decline. In addition, the large numbers of 'baby boomers' (those born between 1945 and 1965) are now reaching older age groups.

The proportion of people aged 5 to 19 has decreased and although there was growth in the numbers of people in these younger groups, they represent a smaller proportion of the total population.

INCREASING DIVERSITY

Auckland is home to a culturally diverse population. In the 2013 Census residents identified with over 100 ethnicities. There has been particularly high growth in the numbers who identified with an Asian ethnicity since the 2006 Census, from 234,279 in 2006 to 307,233 in 2013, representing almost a quarter (23.1%) of Auckland residents compared with 11.8% of New Zealand's total population.

While the largest proportion of Auckland's regional population identified with a European ethnicity (59.3%), this was relatively low compared with New Zealand as a whole (74.0%). About 1 in 10 Auckland residents (10.7%) identified as Māori and a slightly higher proportion identified with a Pacific peoples identity (14.6%).

In addition to population change, the way in which that population is distributed across Auckland and how we use the land is also changing. Land use is important in determining the nature and extent of pressures on Auckland's natural environment.

LAND COVER

The distribution of different land covers is shown in figure 1. There has been relatively little change in the proportions of broad land cover types for Auckland over recent years when measured using the land cover data base (figure 1 and table 1). The urban area of Auckland has progressively increased over time (figure 2) with an 11% increase between 1996 and 2012. Pastoral land remains the most extensive type of land cover 236,000ha or 48% of the region (figure 1).

LANDCOVER TYPE	AREA IN HECTARES				PROPORTION OF TOTAL			
	1996	2001	2008	2012	1996	2001	2008	2012
Built-up area	42,665	45,499	47,239	47,381	8.75	9.33	9.68	9.71
Exotic forest and scrub	50,658	55,047	55,522	55,116	10.39	11.29	11.38	11.30
Horticulture	11,542	11,721	12,431	12,412	2.37	2.40	2.55	2.54
Indigenous forest and scrub	120,338	120,366	120,557	120,542	24.67	24.68	24.72	24.71
Other	3,016	3,041	3,069	3,074	0.62	0.62	0.63	0.63
Parkland	8,520	8,249	8,000	8,007	1.75	1.69	1.64	1.64
Pasture	245,638	238,489	235,591	235,885	50.36	48.90	48.90	48.36
Wetlands and water	5378	5342	5345	5338	1.10	1.10	1.10	1.09

TABLE 1: Land cover for the Auckland region, taken from the Land Cover Data Base.

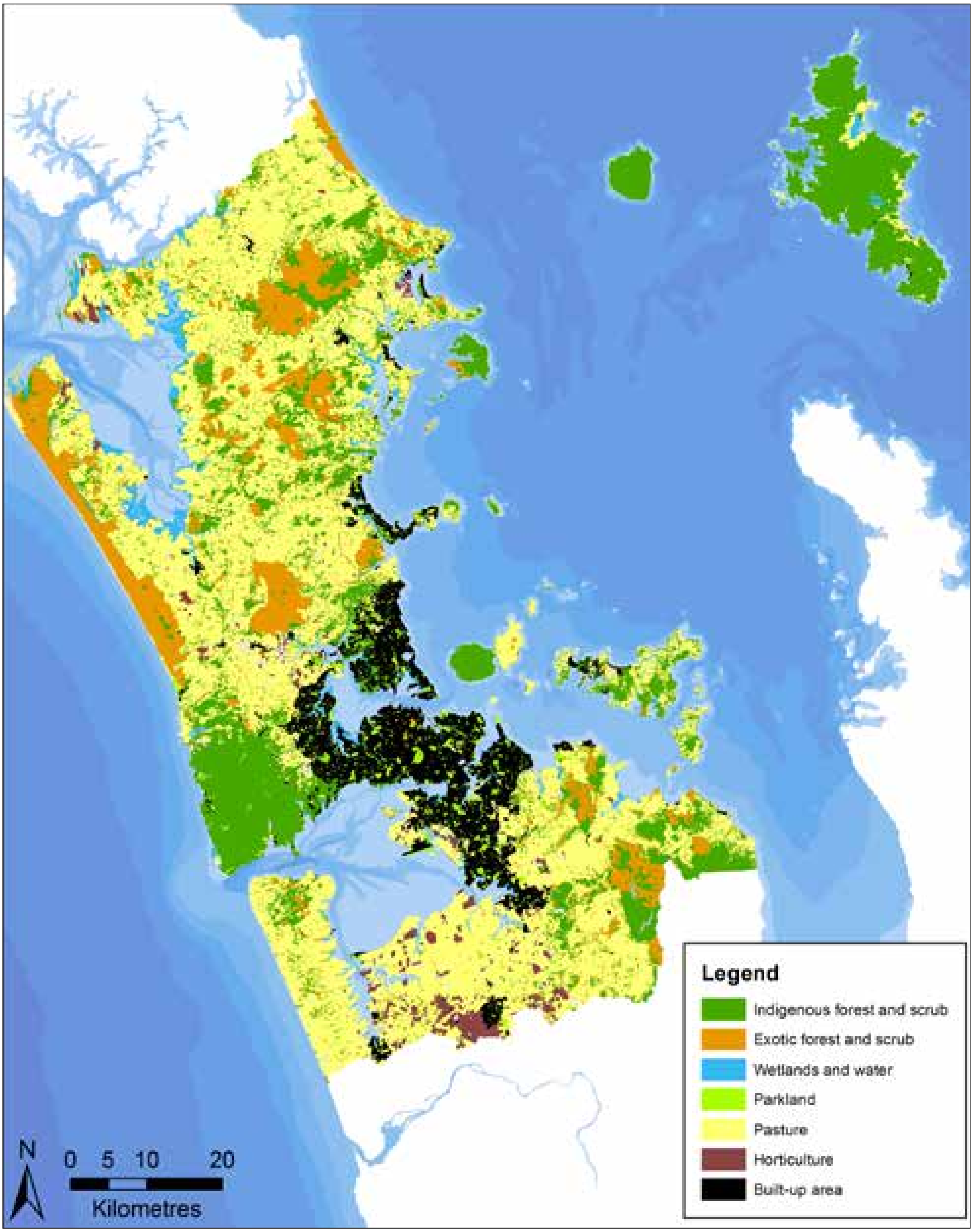


FIGURE 1: Distribution of Auckland's predominant land cover types.

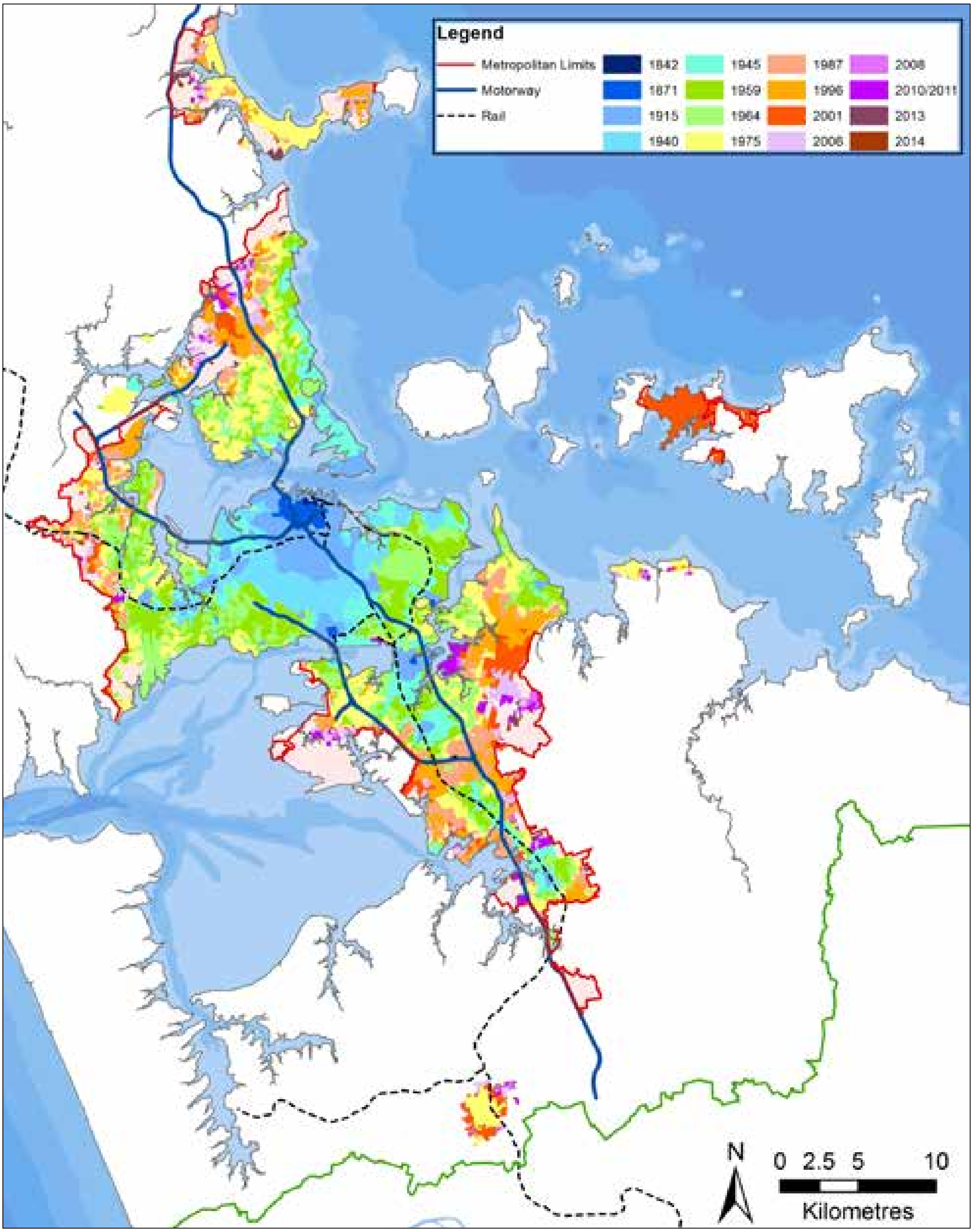


FIGURE 2: Historic urbanisation in the Auckland region,1842-2013.

LAND USE

Using land use descriptions from valuation information we can compile the actual land use of properties across the region. Inside the current urban limit (Metropolitan Urban Limit or MUL), over half the land area is used for residential purposes. Outside, rural industrial use accounts for more than half the land area. Rural industry encompasses agriculture, pastoral land, horticulture, market gardens and forestry operations. The lifestyle category makes up a quarter of the land use outside the current MUL.

LAND USE CATEGORY	% INSIDE MUL	% OUTSIDE MUL	% TOTAL REGION
Commercial	3.4	0.1	47,239
Community services	5.3	0.4	55,522
Industrial	9.4	0.3	12,431
Lifestyle	3.3	25.0	120,557
Unknown/other	7.8	6.2	3,069
Recreational	12.1	6.5	8,000
Residential	55.3	1.7	235,591
Rural industry	2.0	59.1	53.1
Transport	0.4	0.1	0.1
Utility services	0.9	0.6	0.7

TABLE 2: Actual land use (sourced from valuation information), as a proportion of inside and outside the current MUL (2015) and total region (Source: Auckland Council, March 2014).

HOUSING DENSITY

There were 473,451 occupied dwellings in Auckland at the 2013 Census, which is an increase of 33,750 dwellings (7.7%) since 2006. In Auckland, three-quarters of occupied private dwellings counted in the 2013 Census were separate houses (74.7% or 329,760 dwellings). Private dwellings joined to others (e.g. units, apartments and terraced housing) made up 24.8% of all occupied private dwellings (23.9% in 2006).

Auckland's urban area population has increased every census since 1986, from 19 persons per hectare in 1986 to 25 persons per hectare in 2013. Between the 2006 and 2013 censuses the persons per hectare increased from 23 to 25. The increase in the number of dwellings between 2006 and 2013 was particularly evident in a few areas of the region, including areas of urban expansion or renewal such as Flat Bush, Stonefields, Ōrewa and Greenhithe.

RURAL FRAGMENTATION AND LAND USE

While there has been little overall change in the relative proportions of different land cover types at the regional scale, there have been real changes in land use in rural Auckland. Rural fragmentation is the ongoing subdivision of rural land that leads to increasingly smaller land parcels. It increases settlement density and excludes land uses like pastoral farming that require large land parcels. Rural fragmentation has been measured by comparing the number and area (in hectares) of parcels outside the 1998 MUL, over a number of years.

The number of property parcels within rural Auckland increased by over 30% when the numbers in years 1998 and 2015 were compared. The data demonstrates that the greatest increase (70%) was in the 1 to 2ha category when years 1998 and 2015 were compared, followed by a 43% and 36% increase in the number of parcels between 0-0.5ha and 0.5 -1ha, respectively.

Furthermore, in 2015 over 90% of parcels fall within the combined 0 to 8ha category. There was a corresponding 7% decline in the number of land parcels over 8ha when years 1998 and 2015 were compared. The decrease in the number of large land parcels is driven by the expansion of the urban area outside the 1998 MUL in places such as Flat Bush, Karaka, Takanini and Hobsonville, and ad hoc and sporadic rural subdivision throughout rural Auckland.

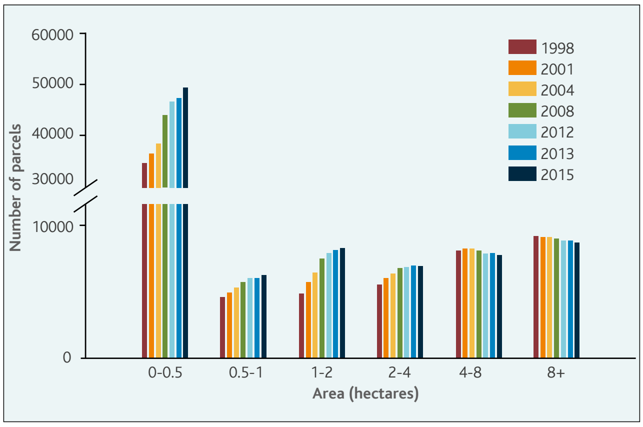


FIGURE 3: Changes in property parcel counts by size range for Auckland's rural area (outside 1998 MUL) between 1998-2015 (Source: Land Information New Zealand).

INTENSITY OF DAIRYING

The way Auckland's rural land is used for farming is also changing. For example, there has been a decline in dairy farm numbers and the effective dairy farming area and while stocking rate has slightly decreased (3%), the average herd size has increased by 32%, implying an increase in intensity.

Between 2001/02 and 2013/14, dairy farm numbers decreased by 41% and the effective dairy farm area decreased by 20%. However, more recently, the effective area increased by 5% between 2007/08 and 2013/14. The average dairy herd size in Auckland increased by 32% from 199 to 262 dairy stock between 2001/02 and 2013/14.

Furthermore, there has been a continual decline in livestock numbers used for pastoral farming activities. For example, the number of beef cattle, dairy cattle and sheep in Auckland declined by 33%, 27% and 43% respectively, between 2002 and 2013 (Source: Statistics New Zealand).

PERIOD	EFFECTIVE FARMING AREA (HA)	AVERAGE HERD SIZE	AVERAGE STOCKING RATE (COWS/HA)	NUMBER OF DAIRY FARMS
2001/02	61,393	199	2.34	564
2002/03	59,762	205	2.33	
2003/04	56,846	216	2.39	
2004/05	53,650	221	2.40	
2005/06	50,381	224	2.41	
2006/07	48,358	233	2.43	366
2007/08	46,361	240	2.46	
2008/09	47,383	245	2.43	
2009/10	45,672	244	2.40	
2010/11	46,947	248	2.36	
2011/12	46,282	249	2.37	360
2012/13	48,655	260	2.30	330
2013/14	48,826	262	2.27	
% change 2002-2013/14	-20%	32%	-3%	-41%

TABLE 3: Dairy farming area and farm number, herd size and stocking rate within the Auckland region, 2001/02-2013/14. (Source: Livestock Improvement Corporation and Statistics New Zealand).

References:
1. Bishop, C. D., Landers, T. J., Goldwater, N. P. (2013): Changes in indigenous ecosystems and the environment within the boundary of the Waitākere Ranges Heritage Area Act 2008: 2008-2013 report. Auckland Council Technical Report TR2013/003.

CASE STUDY: ECOSYSTEM BENEFITS

AUCKLAND'S NATURAL ENVIRONMENT IS WORKING FOR YOU

Getting active and enjoying one of Auckland's many bush walks

The natural environment is an integral part of who we are and why people choose to live and play in Auckland. Like all species, we are part of this environment and dependent on the habitats, communities and ecosystems that surround us. The Auckland Plan acknowledges that people and nature are inseparable; the air you breathe, food you eat and water you drink are all products of the natural environment sustaining us.

Our natural environment works hard to support our day-to-day lives. Clean air, food and water are examples of the products of ecosystem services. In simple terms, ecosystem services are the benefits people get from the natural environment, including goods (soil, food, animals, water and scenery) and services (functions such as water filtration, flood protection and pollination).

As well as the obvious benefits of a healthy environment – safe swimming, food and beautiful views – there are many other important benefits that are more difficult to see and count (e.g. the effects of a swim or bush walk) or are only needed in times of trouble (e.g. erosion protection during a big storm). As a consequence these benefits are often taken for granted and few are valued in monetary terms. This makes it difficult to account for how they are traded, lost or increased through decisions about the use of natural resources and the wider environment.

However, times are changing. The use of ecosystem service valuations is becoming more common in the wake of the global Millennium Ecosystem Assessment[1] and follow-on national assessments for countries such as the United Kingdom[2], Spain[3] and New Zealand[4]. Auckland Council has recognised the importance of ecosystem services in the Auckland Plan:

> "knowledge and account for ecosystem services when making decisions for Auckland."
>
> THE AUCKLAND PLAN – CHAPTER 7

CLASSIFYING ECOSYSTEMS

The Millennium Ecosystem Assessment introduced a classification for different types of ecosystem services that has been adopted, with some refinements, for most subsequent assessments at the national and regional level. Table 1 presents examples of the different categories of ecosystem benefits for two of Auckland's major environmental domains: land and coastal marine environments. Figures 1a-1c depict several common 'natural environments' in the Auckland urban area, along with some of the most important ecosystem processes in each location.

LAND ECOSYSTEM BENEFITS

Auckland's total land area of about 4900 km^2 (490,000 ha) includes a wide range of different ecosystem types, from highly modified urban ecosystems to ancient, mature native forests covering much of the Waitākere and Hunua ranges. Most of the large forest tracts are not harvested for timber or other forest products, as they are in the public conservation estate, but they have a critical role in performing ecosystem activities such as retaining sediment, absorbing carbon from the air and generating a clean water supply (figure 1). Smaller areas of forest, scrub and open green-space habitat within and around the city provide less carbon storage and other benefits than the large forest tracts, yet their recreational, health, educational and cultural values can be much higher, due to their relatively high accessibility and use. The landcover Indicator on page 76 includes an estimate of the ecosystem services provided by different landcover types for different parts of the region.

FIGURE 1: Forests such as this in the Waitākere Ranges are important sources of freshwater.

COASTAL ECOSYSTEM BENEFITS

Auckland's vast array of coastal ecosystems provide many benefits to Auckland residents and tourists alike. They not only produce the obvious goods, such as fish and shellfish, and recreational opportunities like swimming and sea kayaking, they also perform a number of activities that support humans. Many of the species living in coastal and estuarine soft sediments around the region play important roles in the cycling of sediments and, consequently, organic and inorganic contaminants.

NATURAL RESOURCE	LAND EXAMPLES	COASTAL MARINE EXAMPLES[5]
PRODUCTS FROM ECOSYSTEMS		
Food	Production of wild game, fruits and grains.	Kai moana or seafood gathering is a fundamental part of living in Auckland, from collecting shellfish like pipis, cockles and scallops to fishing for snapper and crayfish.
Raw materials	Production of timber, fuelwood, fodder and compost.	Extraction of sand, and shell hash for aquaria trade and landscaping.
Genetic and medicinal resources	Our land ecosystems are great sources of genes for potential plant pathogen resistance as well as genetic stock of our threatened biodiversity.	While no specific Auckland examples are currently being investigated, there is the potential for many marine organisms such as sponges to generate anti-cancer treatments.
Freshwater supply	Groundwater and river catchments collect and store freshwater.	
BENEFITS FROM ECOSYSTEM PROCESSES		
Preventing disturbance	Planted areas such as forests and shrublands stabilise the ground, decreasing impacts of floods and storms.	Coastal plants like mangroves and seagrass, and animals that create biological structures can reduce the impact of storms, waves and tides. Coastal plants help regulate the speed at which water runs off the land into estuaries and the sea.
Waste treatment, processing and storage	Wetlands and other ecosystems help remove excess nutrients and pollutants in the soil.	Animals and plants living in the mud and sand move sediment around, playing important roles in cycling nutrients and waste. Some waste can be broken down and removed, and some can be locked away and stored deeper in the sediment.
Retaining sediment	Forest, scrub, dunes and other plants help reduce erosion and thus the release of sediments.	Plant species such as mangroves and seagrass can prevent the erosion of intertidal sediments. Worms that form tube-mats can be important in stabilising sediments.

Regulating gas and climate	Plants act as carbon stores, taking in atmospheric carbon dioxide (CO_2), so forests and other land ecosystems help to regulate greenhouse gases.	The coastal and marine environment is important for balancing the air we breathe and regulating the climate. Gases like CO_2 dissolve into seawater and can be locked away in the shells of shellfish and other animals.
Pollination	Birds, bees and other animals pollinate indigenous vegetation and horticultural crops.	
Cycling nutrients	Soil invertebrates, fungi and microbes help break down and recycle dead vegetation, returning nutrients to the soil where new plants will grow.	The seabed and the animals living there are important for the recycling of nutrients. Their activity keeps the coastal system healthy and makes nutrients available, which underpins food production.
Biological control (the control and regulation of food web dynamics by the actions of key species)	Predatory birds and insects help to regulate species lower on the food chain, boosting resilience against pest outbreaks.	Marine predatory species regulate those lower on the food chain. For example, snapper feeding on urchins helps regulate the urchin population, which in turn helps prevent urchins overgrazing on kelp plants (kelp is an important contributor to productivity and habitat for many species).
Natural habitat for other species	Forests, wetlands and other ecosystems support a variety of indigenous species.	By producing shells and root structures and through other activities, animals and plants change the environment and provide space and shelter for other organisms to live in. Examples include oyster, horse mussel and mussel reefs, abundant bivalves creating shell hash, root structure from mangroves, seagrass meadows and worm tube-mats.
Resilience	The speed at which ecosystems and their communities can recover when disturbed by natural and human pressures is important for continued delivery of benefits. Ecosystem resilience and resistance, therefore, are vital supporting benefits underpinning the maintenance of all other benefits. They may be one of the most important ecosystem benefits in terms of sustaining life and our lifestyles.	

TABLE 1: Classification of important benefits from the Auckland region's ecosystems into general categories, with marine and land-based examples.

CULTURAL BENEFITS WE GET FROM ECOSYSTEMS		
Cultural and spiritual value		
Leisure and recreation	**Hiking, biking, caving, mountaineering, exploring parks, and many other activities.**	**Swimming, snorkelling, diving, sailing, boating, kayaking, fishing, and many other activities.**
Ecotourism	**Birdwatching, nature tours.**	**Diving, charters, whale and dolphin watching.**
Education and scientific knowledge		

TABLE 1: Classification of important benefits from the Auckland region's ecosystems into general categories, with marine and land-based examples.

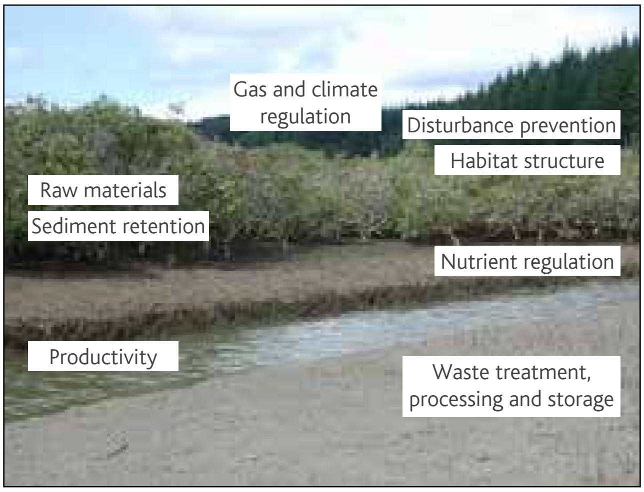


FIGURE 1A: Examples of ecosystem benefits provided by Tāmaki Estuary, Ōtāhuhu, Auckland[5].

FIGURE 1B: Examples of ecosystem benefits provided by Long Bay, East Coast Bays, Auckland[5].

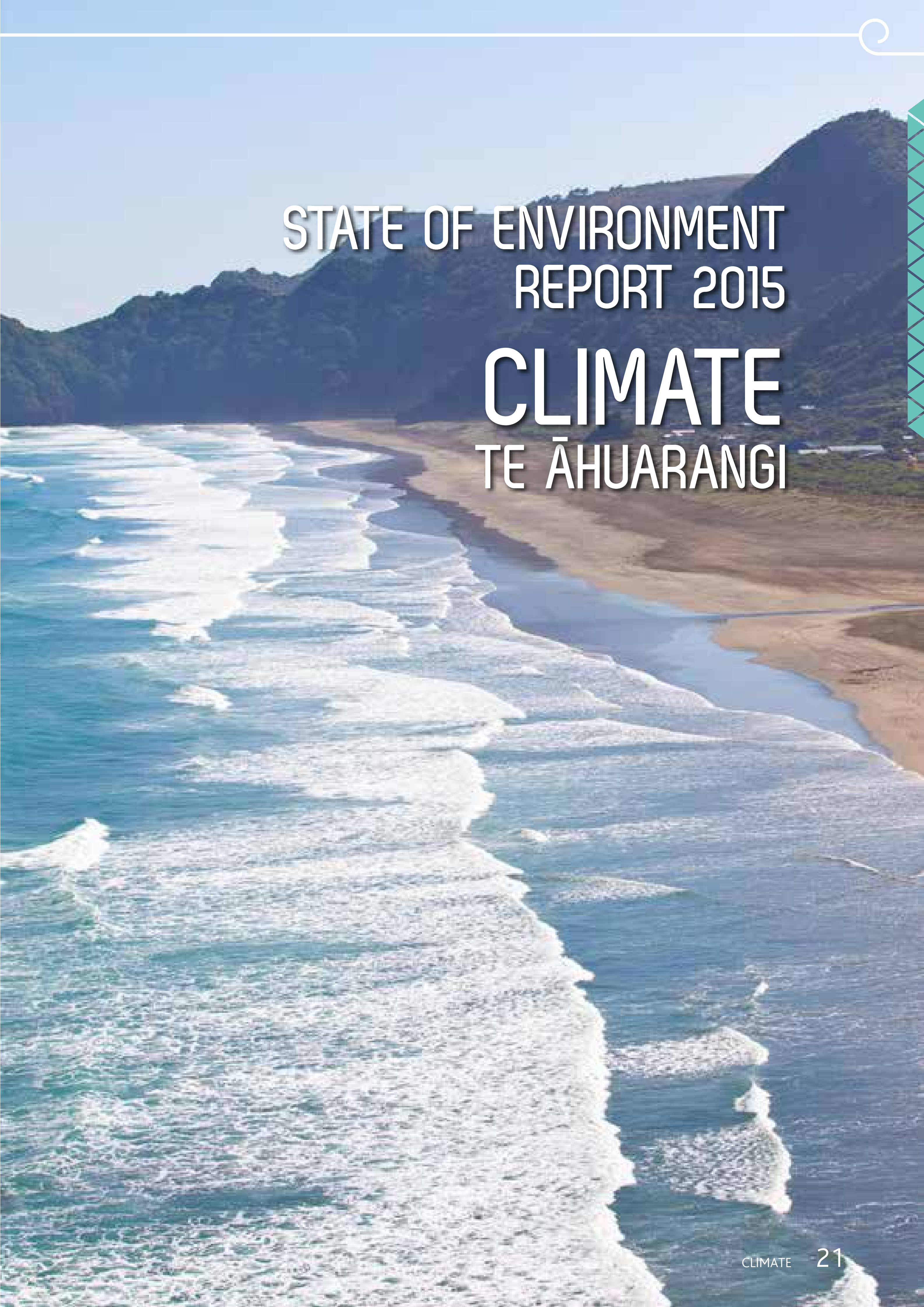
FIGURE 1C: Examples of ecosystem benefits from the Domain, Grafton, Auckland.

References:
1. Millennium Ecosystem Assessment (2005): Volume I. Island Press, Washington DC, USA. 917 pp.
2. UK National Ecosystem Assessment (2011): The UK National Ecosystem Assessment Technical Report. UNEP-WCMC, Cambridge. 1466 pp.
3. Sal A. G. 2009: EVALUACIÓN DE LOS ECOSISTEMAS DEL MILENIO DE ESPAÑA, Section III.17. AGROECOSISTEMAS.
4. Dymond J. R. (ed) (2013): Ecosystem Services in New Zealand: Conditions and trends. Manaaki Whenua Press, Lincoln, NZ. 539 pp.
5. Townsend, M.; Thrush, S. (2010): Ecosystem functioning, goods and services in the coastal environment. Prepared by the National Institute of Water and Atmospheric Research for Auckland Regional Council. Auckland Regional Council Technical Report 2010/033.

STATE OF ENVIRONMENT REPORT 2015

CLIMATE

TE ĀHUARANGI



AUCKLAND'S CLIMATE
TE ĀHUARANGI O TĀMAKI

Auckland's climate plays a key role in shaping our natural environment and how we use it.

The energy from the sun warms the earth's atmosphere and is the main driver of our global climate. Patterns of precipitation, wind and temperature give each region a specific set of climate characteristics.

Auckland has a maritime temperate or oceanic climate. Warm, humid summers and mild, wet winters with changeable weather conditions are typical for our city. February is the warmest month with an average temperature of 20°C. July is the coldest month with an average temperature of 11°C. January is the driest month with an average rainfall of about 80mm. July is the wettest month with an average rainfall of about 150mm.

WHY IS IT IMPORTANT TO US?

Climate is the main determinant of what life can be found in a particular area. The land, streams or seas and the life they support are subject to seasonal cycles of rain and drought, heat and cold, as well as prevailing winds and storms. Happening over longer time scales, natural cycles such as El Niño – La Niña add to the variability we experience in our climate and weather[1] (see Case study: long-term data on page 35).

Auckland's unique natural environment has been shaped by the climate and the resulting biodiversity and ecosystems now provide us with many of the characteristics we cherish, such as fresh water naturally filtered into the drinking water dams in the Waitākeres, long growing seasons for farmers, or simply clear warm waters for swimming and sailing. These ecosystem benefits and resources are an important part of what makes Auckland one of the world's most liveable cities.

CLIMATE AND WEATHER

We often confuse climate and weather and think that one hot summer is a sign of global warming. But these are very different things.

Weather is what you see outside at a particular place over a short period. It changes from season to season, day to day, and in Auckland even from one minute to the next.

Climate is the long-term average of that weather. It describes the weather pattern of a place over a long period, maybe 30 years or more. For example, although the weather in Auckland may be hot and dry today, Auckland's climate is generally mild and humid.

WHAT ARE THE ISSUES?

Our climate is changing. A large and growing body of evidence provides strong agreement within the climate science community about that. The same clear and consistent message of change comes through from a wide range of places including the International Panel on Climate Change[2], the New Zealand Prime Minister's Chief Science Adviser[3] and the Parliamentary Commissioner for the Environment[4].

For all of us living in the Auckland region and beyond, climate change is predicted to have far-reaching impacts throughout the air, land and water domains. The key climate change impacts have been identified for Auckland (table 1), and multiple agencies such as the Auckland

References:
1. Mullan, B., Wratt, D., Dean, S., Hollis, M., Allan, S., Williams, T. and Kenny, G. (2008): Climate Change Effects and Impacts Assessment: A Guidance Manual for Local Government in New Zealand, 2nd Edition. Ministry for the Environment, Wellington.
2. IPCC, 2014: Summary for policymakers. In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., and White, L.L. (eds.): Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1-32.
3. Office of the Prime Minister's Chief Science Advisor (2013): New Zealand's changing climate and oceans: The impact of human activity and implications for the future.
4. Parliamentary Commissioner for the Environment (2014): Changing climate and rising seas: Understanding the science.

Council[5], the Ministry for the Environment[1] and the Ministry for Primary Industries[6] acknowledge the importance of monitoring for climate change across a wide range of potential impacts.

DIRECT IMPACTS	INDIRECT IMPACTS
Temperature rise	Coastal hazards
Stronger westerly winds	Human health
Increasing storm events	Food production
Changes to precipitation	Drought
Sea level rise	Biodiversity and biosecurity
Ocean acidification	Flooding

TABLE 1: Climate change impacts projected for the Auckland region.[1]

The Auckland Plan outlines some of the changes predicted for our climate over the course of this century. See below for these and some other key climate change impacts predicted for Auckland over the next 100 years, and how we can monitor them.

- Temperature increase between 0.2°C and 2.5°C by 2040, and 0.6°C and 5.8°C by 2090 – air temperature records in Auckland extend back for more than 100 years at some locations and seawater temperature records for almost 30 years. From these we can monitor for change around the region (see the Temperature Indicator on page 24).
- Lower average annual rainfall patterns (decreasing between -1% and -3% by 2040, to -3% and -5% by 2090) – our monitoring stations record rainfall with records going back to the late 1800s. The records show a high level of variability but provide a good long-term record to be able to look for future change (see the Rainfall Indicator on page 28).
- More frequent drought conditions (from once every 20 years to every five years by 2080) – we have recently installed monitoring devices that will enable us to record soil moisture at point locations. This is a new initiative enabling more informed decision-making by land users or civil defence.
- More extreme weather events with more frequent heavy rainfall events and more frequent westerly winds – weather events are measured through weather stations around the region, and wave buoy monitoring helps us to better understand the implications of wave height.
- A rise in sea level of 18-59cm between 1990 and 2100 – the Ports of Auckland have tidal height measurements dating back to 1898, providing more than 100 years of tidal heights and giving us important information to be able to assess change (see Sea Level Rise Indicator on page 31).
- Ocean acidification – increasing CO_2 in the air is driving changes in the pH of the oceans, while local coastal conditions are also influenced by increased nutrient input from rivers. Auckland Council has been recording pH through the saline water quality programme (see Marine Water Quality Indicator on page 164) and is working to improve monitoring through initiatives such as the nationwide New Zealand Ocean Acidification Observation Network.

Auckland Council monitors several climate variables as part of other long-term State of the Environment monitoring programmes. They help us understand the patterns we see in other monitoring data. For example, changes in water temperature affect the plants and animals living in that water, and weather patterns have a big role in how air pollution is dispersed. If continued, these datasets may also now be useful in monitoring climate change in Auckland.

The potential benefits of understanding climate change impacts for Auckland include validating predictions from climate change models or making national and global predictions more specific to Auckland. Climate data is also used to inform civil defence across the region, while informing decisions about climate change adaptation planning and policy.

This chapter presents an analysis of our climate data as context for the rest of the monitoring data. This basis enables us to evaluate long-term trends and consider how these programmes might be used to monitor climate change into the future.

> “As the effects of climate change are still uncertain and subject to change over time, it will be necessary to monitor climate change projections and to gather local environmental data.
>
> THE AUCKLAND PLAN – CHAPTER 8”

References:
5. The Auckland Plan - Directive 8.5: “Monitor environmental change to inform risk”.
6. Hewitt, J.E. (2014): Development of a National Marine Environment Monitoring Programme (MEMP) for New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 141, Ministry for Primary Industries, Wellington.

TEMPERATURE INDICATOR

ARE OUR TEMPERATURES RISING?

View from Waiheke Island to Hauraki Gulf

Temperature is measured across many of our State of the Environment monitoring programmes including air, freshwater and marine. Some of our datasets are nearly 20 years old, enabling us to start using them to examine how temperature has changed over time. This makes them valuable datasets for considering climate change implications.

WHY DO WE MONITOR TEMPERATURES?

We monitor air temperature to understand how our climate and weather affects emissions to air. For example, when it's colder in winter, we expect higher concentrations of pollutants like PM_{10}, due to domestic heating from fires. When it's colder, conditions are often still and this prevents pollutants from all sources from dispersing. We've monitored air temperature for many years now, and we are starting to get enough data to investigate the relationship between air temperature and pollutants.

Water temperature strongly influences aquatic ecosystems. The plants and animals living in streams, lakes and our coastal waters are adapted to a certain temperature range and, for some, if the temperature rises they won't survive. Temperature-driven changes in chemical and physical processes will also limit the habitat suitable for some species to thrive in.

WHAT IS THIS INDICATOR?

This indicator consists of air temperature, sea surface temperature (SST) and freshwater temperature.

We measure air temperature as part of our Air Quality Monitoring Programme at 12 sites across Auckland (see Air chapter on page 37).

SST is a measure of the average temperature of the top metre of ocean. We began collecting SST data in the Manukau Harbour in 1987 as part of our Water Quality Monitoring Programme. Since then the site network has expanded to 36 sites including those in the Hauraki Gulf and Kaipara Harbour (see Marine Water Quality Indicator on page 164).

Stream and lake water temperatures are collected as part of our Freshwater Quality Monitoring Programme, which monitors 36 river sites, five lakes and nine groundwater sites (see Freshwater Quality Indicator on page 149).

HOW DO WE MONITOR TEMPERATURES?

We measure air temperatures at our meteorological monitoring stations automatically every 10 minutes. The instruments are mounted on 10m-tall towers to minimise influence from the ground and to standardise our measurements between sites.

For SST, we take measurements of the top metre of water using a handheld sensor with a probe that goes into the water either from a helicopter or boat. Samples at each site are taken monthly to give a picture of what is happening monthly, seasonally and annually.

Stream water temperatures are monitored continuously in some streams with permanently installed sensors. Other streams and lakes are visited monthly to collect water temperatures with a handheld sensor.

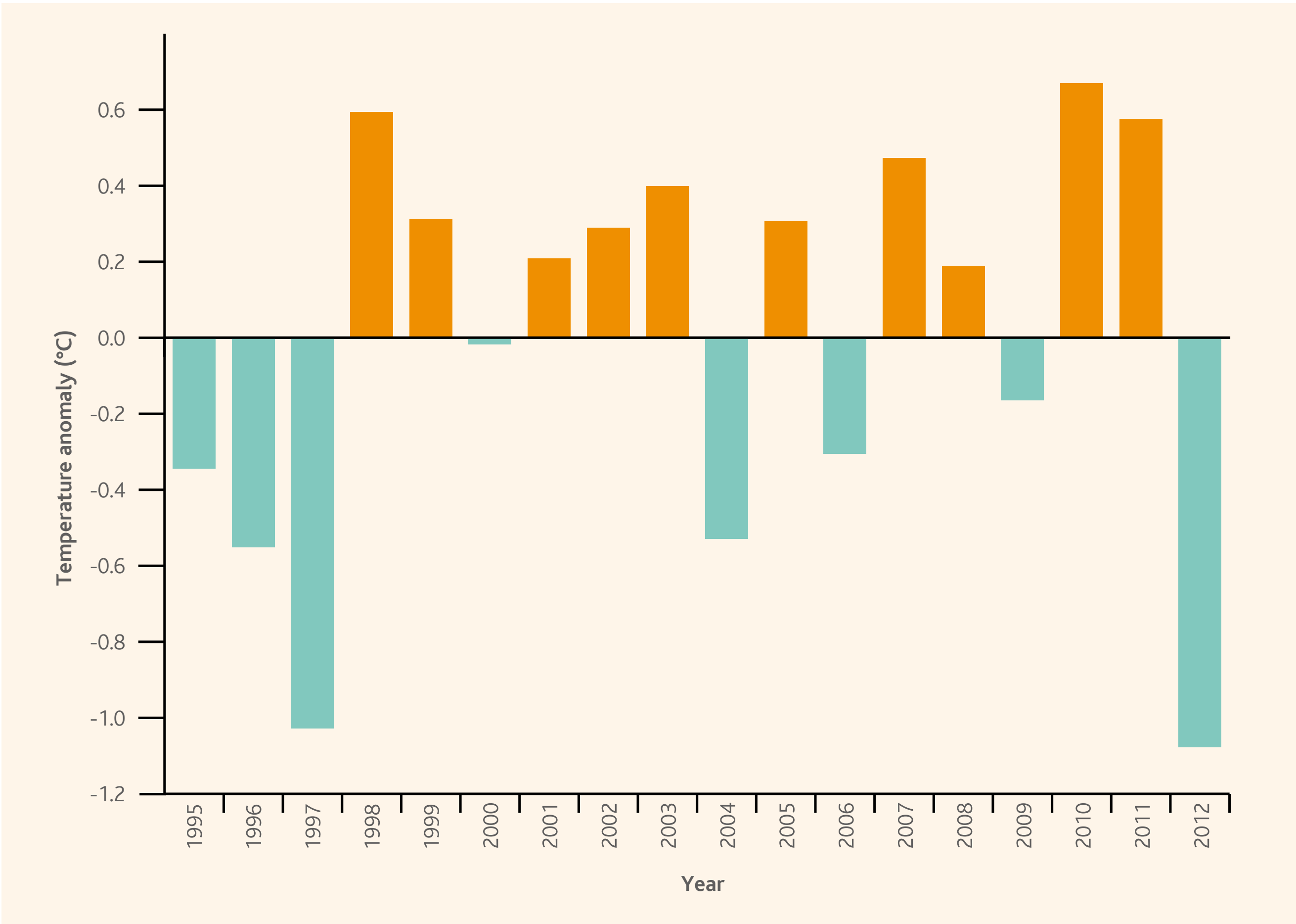


FIGURE 1: Annual air temperature anomalies (departure from long-term mean) at our Onehunga site, 1995-2012.

References:
1. IPCC (2014) & NOAA's Extended Reconstructed Sea Surface Temperature (ERSST) v3b (using global monthly and annual averages from 60°S to 60°N).

WHAT HAVE WE FOUND?

AIR TEMPERATURE VARIATIONS OF +/- 1°C

Over the monitoring period between 1995 and 2012, the average annual air temperature at our Onehunga site was 15.6°C. As the graph in figure 1 shows, average annual air temperatures may depart from the long-term average by up to +/- 1°C. Our datasets are still too short to confidently derive trends and compare them with the global average.

EAST COAST AND WEST COAST SEA SURFACE TEMPERATURES FOLLOW SIMILAR PATTERN

Over the last 20 years, annual average SST around Auckland have followed relatively similar patterns for both east and west coast harbours and also open coastal waters (figure 2). The annual average temperature across all sites was 17.11°C. But the further up the harbours and estuaries we look, the more the temperatures fluctuate. As with air temperature, longer term monitoring is needed to be confident about any trends or comparisons.

STREAM WATER TEMPERATURE IS AFFECTED BY LAND USE

The water temperatures of our urban streams in Auckland are quite different from the temperatures in forest streams. Forest streams don't heat up as much as urban streams because they are shaded from direct sun radiation by the forest canopy. Urban streams are more exposed to direct sun radiation. They also receive stormwater runoff from paved surfaces, which can get very hot in summer and heat up the stormwater running off into the streams. As a result, the water in urban streams can reach higher temperatures than the surrounding air (figure 3). Such land use effects on stream water temperatures are much stronger than global warming effects.

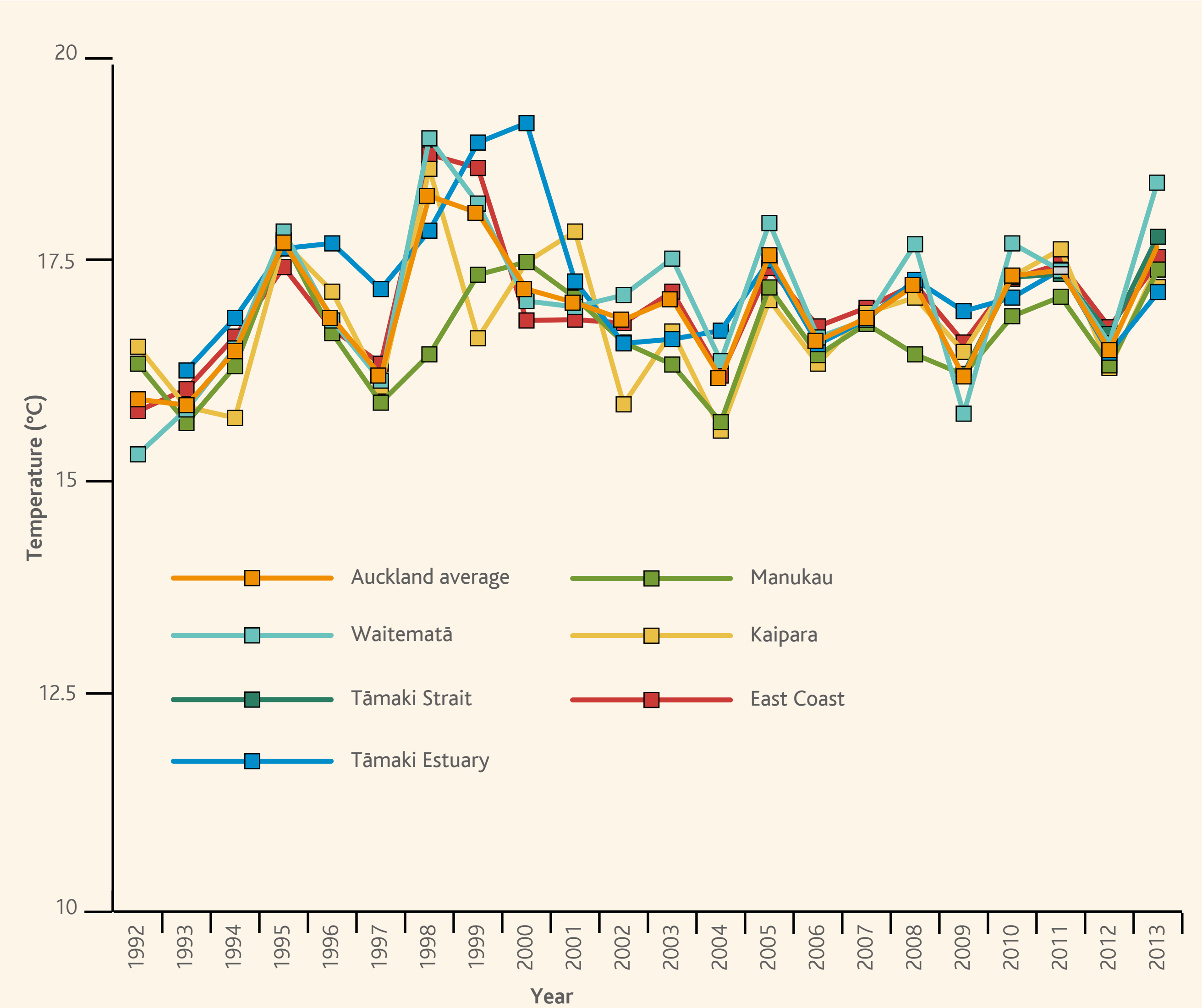


FIGURE 2: Annual average sea surface temperatures in Auckland. We have taken a starting point of 1992, a year when there was a good coverage of sites throughout the region. (Where monitoring began part-way through the year, the next full year's data for that site was used).

WHAT DOES THIS MEAN?

Are Auckland's temperatures rising? As the graphs in figures 1 and 2 show, there is great variation in average annual air and sea surface temperatures. Our temperatures are also influenced by long-term cycles such as the El Niño Southern Oscillation or the Interdecadal Pacific Oscillation (see long-term data case study on page 35).

Global average air temperatures have increased by about 0.2°C per decade in the last 30 years, and global average SST have increased by about 0.09°C per decade in the same period[1]. This may seem small but over time it's enough to melt ice caps and alter ecosystems. According to international climate models, average global air and SST are predicted to increase further.

Currently, our datasets are not long enough to provide a reliable answer – an apparent trend could be entirely due to natural variation or inter-decadal climate patterns rather than climate change. Freshwater temperatures are additionally influenced by land use. To get a better understanding of how climate change will affect our local environment we need to continue to collect climate data over the coming decades.

HIGHS AND LOWS

- The highest SST recorded from our monitoring programme was 27.5°C in February 1998, at Shelly Beach in the Kaipara Harbour.
- The lowest SST recorded from our monitoring programme was 8.8°C in June 2006, at Rangitopuni Creek in the Waitematā Harbour.

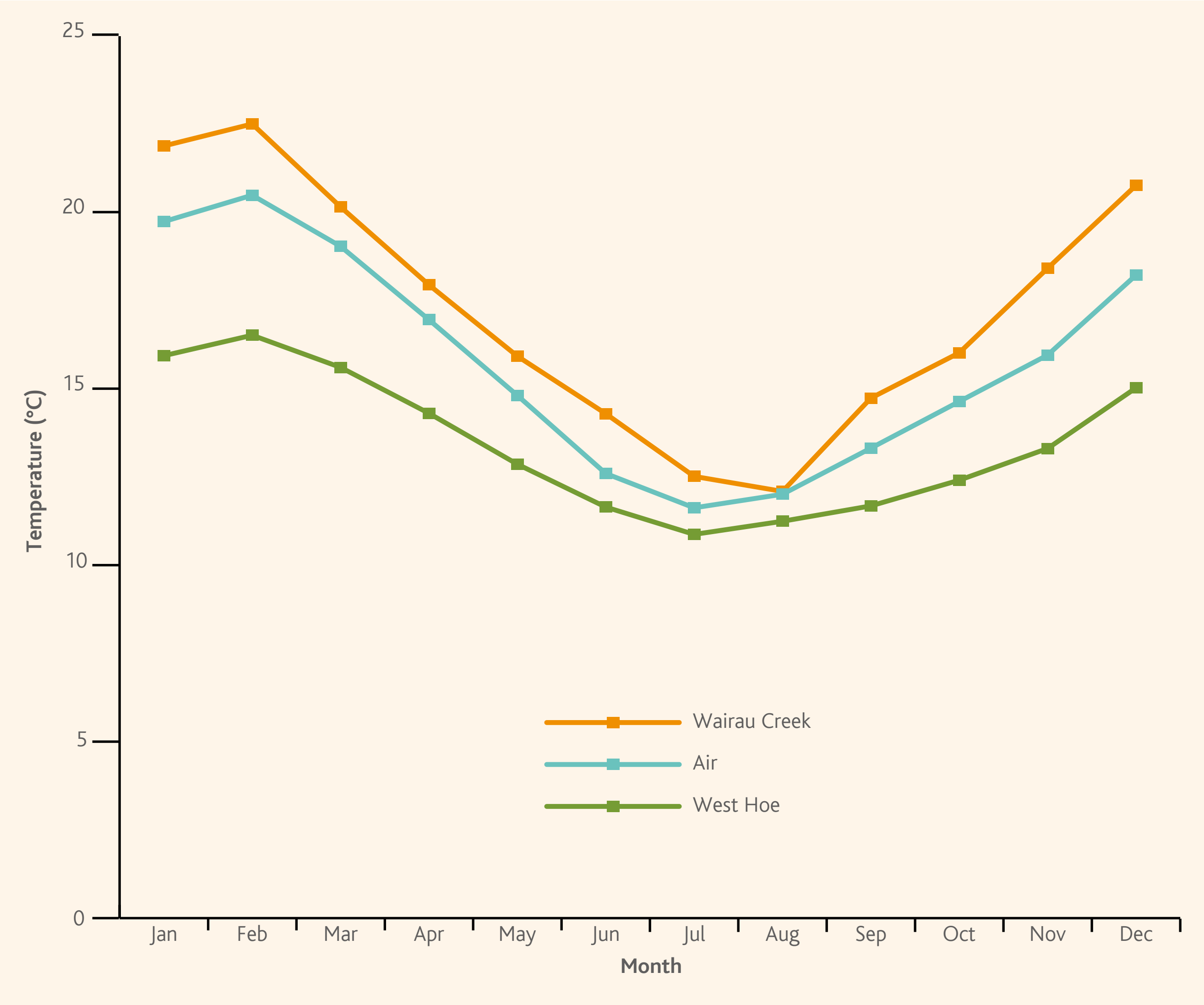


FIGURE 3: Average monthly water temperatures in an urban stream (Wairau Creek) are much higher than in a forest stream (West Hoe) and even higher than air temperatures.

RAINFALL INDICATOR

NO BIG SURPRISES WITH OUR RAINFALL SO FAR

Rain gauge

Although climate models predict more droughts and extreme rainfall with climate change, our monitoring programme has not revealed any such patterns in Auckland as yet. Local, national and international authorities advise councils to monitor rainfall closely and prepare for the impact of climate change.

WHY DO WE MONITOR RAINFALL?

Rain is the reason Auckland has such a lush environment. It is the life source of the potato farms in Pukekohe, the source of the water we drink, a resource for industry, the irrigation for our farms and the life force of our parks and gardens. The rain can also have negative effects – washing pollutants into streams, causing wastewater overflows and flooding.

To conserve and manage our use of water as Auckland grows we need to understand the natural variability of rain. To manage stormwater drainage and make reliable estimates of storm events we need to know the depths, durations and frequencies of rainfall events over several decades.

Our monitoring programme, which at some sites dates back to 1872, provides a reliable foundation for analysis. It will enable us to detect and respond to impacts of climate change as they arise. Our rainfall data is also used by MetService to calibrate their rainfall radar.

WHAT IS THIS INDICATOR?

Rainfall is measured as the depth of rainfall (mm) in a certain period. From these basic measurements we can derive daily, monthly or annual sums of rainfall. In this report we use annual rainfall, monthly rainfall, frequency of significant rainfall and duration of dry spells to describe the variations in rainfall over time.

We define a day as having significant rainfall, if the daily rainfall depth exceeds 95 per cent of all other daily rainfall depths on wet days. A wet day is defined as a day with at least 1mm of rainfall. The duration of dry spells is the number of consecutive dry days, i.e. days with less than 1mm of rainfall.

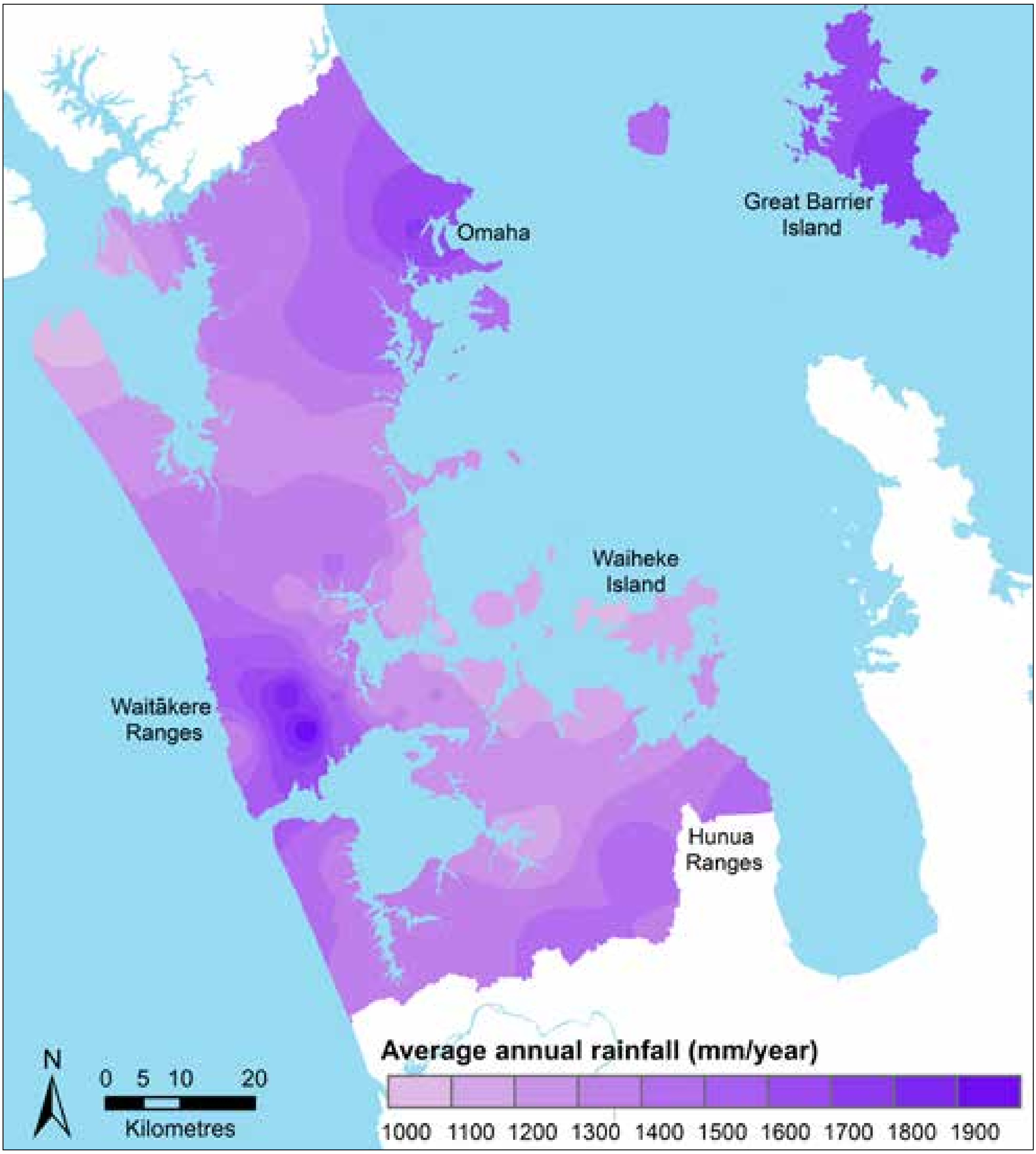


FIGURE 1: Average annual rainfall across the Auckland region (mm/year), 2009-2013.

HOW DO WE MONITOR THIS?

We monitor rainfall currently at around 70 sites across the region. Most of these sites are fully automated and transfer the data via telemetry to our database.

The length of data record varies considerably among the sites, the oldest being Albert Park, dating back to 1872.

WHAT HAVE WE FOUND?

Rainfall is highly variable from year to year and from site to site. Our monitoring programme has not yet revealed any long-term trends outside normal variability.

AVERAGE ANNUAL RAINFALL

- 1311mm = long-term regional average (that's the long-term average annual rainfall of all our sites)
- 1500mm to 2300mm = highest annual rainfall in the Waitākere Ranges
- 700mm to 1700mm = lowest annual rainfall on Waiheke Island.

Other high-rainfall areas include Great Barrier Island, Omaha in the north and the Hunua Ranges in the south of the region (figure 1).

HOW DO THE LAST FIVE YEARS COMPARE?

The average annual rainfall at all sites over the last five years was 1328mm, which is slightly above the long-term average. The year 2011 was a particularly wet year with 1584mm of rainfall, whereas 2009 and 2012 were drier than average.

MONTHLY RAINFALL

Not surprisingly the winter months (June to August) are usually the wettest with around 140mm of rain. In summer (December to February), monthly rainfall decreases to around 90mm (figure 2).

SIGNIFICANT RAINFALL

Auckland experienced on average seven to eight days with significant rainfall per year since records began, but the number can vary between one and twenty. The largest daily rainfall in the last five years was on 29 January 2011 when we measured 210mm of rainfall at Mt Tamahunga.

DURATION OF DRY SPELLS

The longest dry spell per year lasted on average for around 20 days. In the last five years, the longest dry spell occurred in February/March 2013 with 28 consecutive dry days on average; the North Shore even experienced up to 40 consecutive dry days. The dry conditions of this period were unusually widespread across New Zealand and drought status had been declared for the North Island by the Ministry for Primary Industries[1].

HOW HAVE THINGS CHANGED?

Our data doesn't show a consistent trend across the Auckland region. There is large natural variability in all the rainfall indicators from year to year and on longer time scales. At some sites, annual rainfall slightly decreased over time, whereas at other sites it slightly increased. Significant rainfall and dry spells are also highly variable and do not show a clear trend.

Climate change projections for the Auckland region indicate a decrease in average annual rainfall of up to 5% by 2090[2]. Spring rainfall is projected to decrease even by up to 12%. Aucklanders will have to be prepared for more extreme rainfall events and extended dry spells. To detect any future trends in rainfall, we will continue collecting high-quality rainfall data across the region and help build resilience for climate change in Auckland.

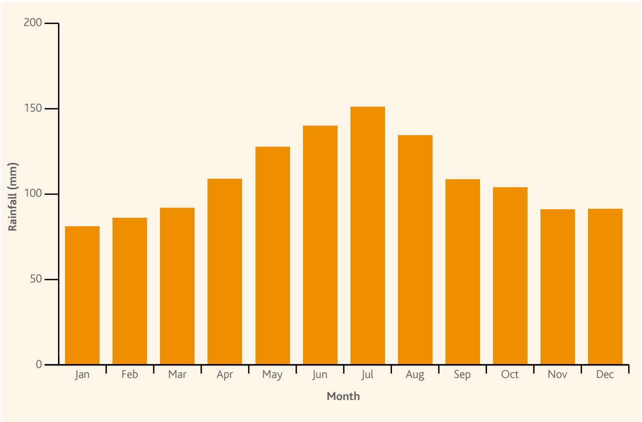


FIGURE 2: Average monthly rainfall in Auckland, 1872-2013.

References:

1. Porteous, A. and Mullan, B. (2013): The 2012-13 drought: an assessment and historical perspective. MPI Technical Paper No: 2012/18. Prepared for the Ministry for Primary Industries by NIWA.
2. Ministry for the Environment: Climate change predictions for the Auckland region. mfe.govt.nz/climate-change/how-climate-change-affects-nz/how-might-climate-change-affect-my-region/auckland

SEA LEVEL RISE INDICATOR

AUCKLAND'S TIDES ON THE RISE

From the seashore to Rangitoto Island

Over the last 100 years Auckland's sea level has been rising in line with global averages at a rate of approximately 1.5mm per year – that's about the width of an ant. Over a 70 year lifetime it adds up to about 10cm or a small hand span. That may not seem like much, but we don't yet know whether the rate of rise will stay the same or increase with further climate change. But sea level changes are sure to have a significant impact on the way we use and develop our coastlines in years to come.

The King Tides Auckland community initiative (**auckland.kingtides.org.nz**) uses the naturally occurring highest tides to illustrate what future sea levels might look like – today's king tides will become tomorrow's regular high tide.

WHY DO WE MONITOR THE SEA LEVEL?

Sea level rise is one of the key predictions in global change science. Data from monitoring programmes across the world shows that it really is happening. The storm-driven flooding of Tāmaki Drive in April 2014 illustrated the vulnerability of some of our lowland coastal areas and roads. Further sea level rise would intensify the impact of such events[1]. It could also affect maritime industries and activities such as boating and aquaculture.

We don't know yet whether sea levels will continue on their current trend or whether the rate will increase. But projections suggest that an increase of 0.5-1m above 1986-2005 averages is expected in New Zealand by the end of this century[2].

The Ministry for Environment[3] along with Auckland policy and planning documents and the New Zealand Coastal Policy Statement[4] advise councils to monitor sea level rise, take a precautionary approach to adaptation planning and increase resilience for communities, natural resources and built environments. Auckland Council[5] provides adaptation planning guidelines that consider sea level rise of up to 0.8m by the end of this century.

WHAT IS THIS INDICATOR?

Very simply, this indicator measures the sea level at the port of Auckland in Waitematā Harbour – tide observations (now collected by the Ports of Auckland) have been recorded for over 100 years at the port.

HOW IS SEA LEVEL MONITORED?

In 1898 someone at the port of Auckland had the bright idea of measuring the height of water in Waitematā Harbour. Sea levels have been monitored there consistently ever since. Nowadays the method is a little more technical than the first measurements (it is now measured every minute using a radar) but the basic idea is the same.

They didn't know about climate change in 1898. Now that we do, we are reaping the benefits of their foresight as we have a consistent and reliable dataset going back over a hundred years – a firm foundation for planning and decision-making.

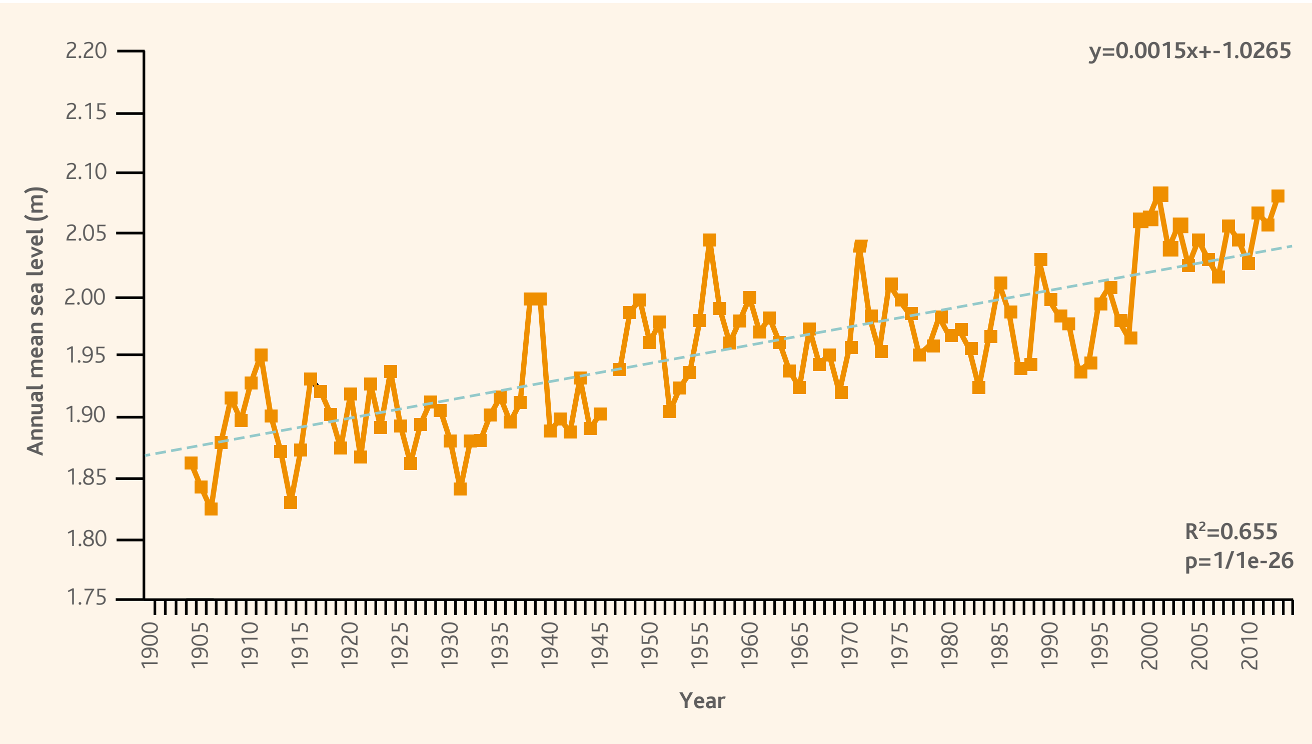


FIGURE 1: Annual mean sea level at the port of Auckland, 1903-2013 (orange line). Significant sea level rise of 1.5 mm/year illustrated by dashed blue trendline. Source: Ports of Auckland Ltd.

WHAT HAVE WE DISCOVERED?

SEA LEVEL RISE CONSISTENT WITH CLIMATE MODEL PREDICTIONS

Since 1903 sea levels have risen by about 1.5mm per year (figure 1). This is consistent with the global average observations and current international climate models. In certain emission scenarios these models further project rates will increase into the future[6].

SHORT-TERM VARIATION OF SEA LEVEL

Over short time scales, tidal height can vary significantly through the effects of, for example, seasonal temperature variation, tidal cycles and storm surges. To minimise the effect of this type of short-term variability on our reporting, we report mean annual sea levels.

Other sources of natural variation that influence sea level on larger time-scales include the El Niño-Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO)[7]. These natural cycles are important to consider when looking for trends in sea level rise, as is the more uniform glacial isostatic rebound – an artefact of the last ice age when glaciers deformed the earth's crust[7].

Vega Pulse Radar used to measure sea level

References:

1. Stephens, S., Wadhwa, S., Gorman, R., Goodhue, N., Pritchard, M., Ovenden, R. & Reeve, G. (2013): Coastal inundation by storm-tides and waves in the Auckland region. Report prepared by NIWA for Auckland Council.
2. Hollis, M. (2014): Climate Change. IPCC Fifth Assessment Report New Zealand findings. New Zealand Climate Change Centre.
3. Mullan, B., Wratt, D., Dean, S., Hollis, M., Allan, S., Williams, T. and Kenny, G. (2008): Climate Change Effects and Impacts Assessment: A Guidance Manual for Local Government in New Zealand, 2nd Edition. Ministry for the Environment, Wellington.
4. New Zealand Coastal Policy Statement 2010 - Policy 3(2): adopt a precautionary approach to use and management of coastal resources potentially vulnerable to effects from climate change.
5. Auckland Council (2014): Climate Change Adaptation Guidelines. Auckland Council.
6. IPCC, 2014: Summary for policymakers. In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., and White, L.L. (eds.): Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1-32.
7. Hannah, J., Bell, R., and Paulik, R. (2010). Sea Level Change in the Auckland Region. Prepared by Otago University for Auckland Regional Council. Auckland Regional Council Technical Report 2010/65.

IN SUMMARY
TE KĀPUINGA

Auckland's mild and humid climate plays an important role in making it one of the world's most liveable cities. The climate is also a major influence on our terrestrial, freshwater and marine ecosystems, affecting the plants and animals we find there.

By looking at long-term monitoring and information collected over extended time scales, we have been able to describe natural cycles in our climate indicators. This information shows that changes in ecology also follow some of these climate cycles. Equipped with long datasets, we can potentially look for similar cycles in urbanised areas, for instance in air quality.

Climate monitoring plays an important part in enabling us to evaluate and understand patterns and change in both our natural and built environments. This applies across the land, water and air domains in this report.

The climate data presented here tells a mixed story – one that also shows the need for better understanding of climate change impacts for our region. Temperature cycles and trends are specific to streams, seawater or air. And while sea levels have risen, rainfall figures do not show a long-term trend.

At the scale of global change science, our temperature datasets are short and provide only an initial snapshot that must be interpreted carefully. Differences in seasonal temperature ranges for urban and rural streams show the importance of interpreting data correctly. The air and sea surface temperature figures reported here fall within the Intergovernmental Panel on Climate Change projections for the end of this century.

In contrast, the only consistent feature of our rainfall data is a high degree of variability. The projections for Auckland over the next century suggest decreases in rainfall will vary both seasonally and by locality across the region. Our rainfall data has yet to show any clear trend.

The rising tides indicator using tidal height measurements shows a clear trend of rising sea level that has been occurring for more than 100 years. These rising sea levels are in line with local and global averages.

Auckland Council's long-term monitoring programmes give us the best opportunity to evaluate our climate, our ecology and the scale of any change in Auckland. Maintaining and building our long-term monitoring capacity is also key to evaluating both the direct and indirect climate change impacts, in the context of natural climate cycles.

With the changes predicted for our sea level, temperature and weather systems, we need to continue to evaluate and increase our understanding of how climate change projections are going to play out, providing an informed position for decisions on managing the risks, and building resilience to the projected changes[1,2].

WHAT CAN YOU DO?
ME PĒHEA TŌ ĀWHINA MAI?

The Auckland Low Carbon Action Plan outlines ways Aucklanders can work together to reduce our contribution to global climate change. Find out more from **aucklandcouncil.govt.nz/theaucklandplan**

References:
1. New Zealand Coastal Policy Statement – Objective 1: To safeguard the integrity, form, functioning and resilience of the coastal environment and sustain its ecosystems, including marine and intertidal areas, estuaries, dunes and land; Policy 3: adopt a precautionary approach to use and management of coastal resources potentially vulnerable to effects from climate change.
2. The Auckland Plan – Chapter 6, Auckland's response to climate change: priority 1 (mitigate climate change) and priority 2 (adapt to climate change).

CASE STUDY: LONG-TERM DATA

LONG-TERM MONITORING – OUR BEST CHANCE TO PREDICT THE FUTURE

Water quality monitoring buoy

Long-term monitoring allows us to separate out natural short-term variations, decipher long-term trends and understand the impact of human activity. When used with predictive models, long-term monitoring is our best chance of predicting the future, and offers a sturdy base for making informed decisions about the growth and protection of Auckland for generations to come.

WHY IS THE NATURAL WORLD SO HARD TO PREDICT?

Nature is full of variation. There are natural cycles on the scale of days, months, years and decades that change the temperature, the weather and the climate. All these cycles interact with and alter the environment.

There are obvious cycles like day and night, tides and seasons. There are weather cycles such as El Niño and La Niña (see figure 1) which repeat every three to seven years, and the Interdecadal Pacific Oscillation (IPO) that takes decades to cycle around. There are even cycles that last hundreds and thousands of years like the 'Milankovic cycles' caused by the 'wobble' of the earth around the sun.

Short-term variation can also be caused by natural events such as storms, floods or large waves, and by human activities, which can disturb natural cycles and alter the shape of coastlines.

To understand what's happening we need to be able to distinguish between the short-term variation, human causes and long-term trends.

And this takes time. An example may help. Imagine you are standing on a rough surf beach watching the waves. If you watch for a few minutes, you will notice the short-term cycle of waves rolling up and down the beach. But it could take an hour for you to notice whether the tide is moving in or out, and days to fully understand the cycle of tides. The short-term variation of waves masks the longer-term variation of tides. It's a similar situation in every one of our monitoring domains: land, water, air and climate. If we monitor for a few years, we will mostly see short-term variations (the waves) but if we monitor for decades, longer-term changes will start to emerge.

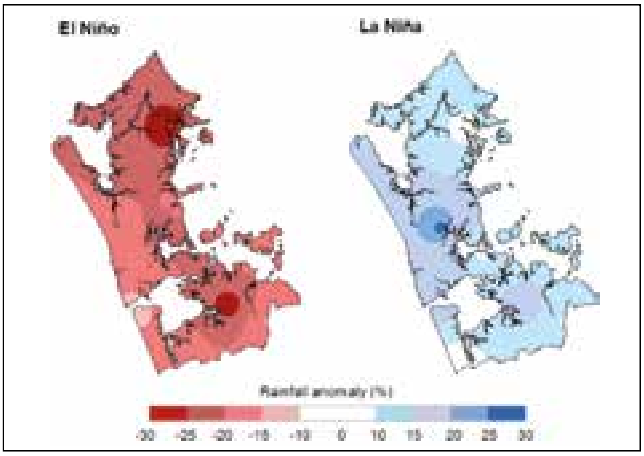


FIGURE 1: During strong El Niño years (left), summer rainfall in Auckland is about 20% below average. During strong La Niña years, spring rainfall is about 15% above average.

THE BENEFITS OF LONG-TERM MONITORING

We live in uncertain times. The climate is changing. The sea level is predicted to rise. Our city is surrounded by ocean. The population is growing. The city is changing.

Only by understanding the environment we live in can we ensure the safety, prosperity and health of our people into the future. Our aim is to at least maintain the current state and function of our ecosystems. Long-term monitoring is a critical tool. It gives us an opportunity to identify adverse changes before they swamp us. It provides us with baselines on which we can design legislation and monitor our progress. It gives us a nuanced picture of our current state and helps us predict where we are heading and legislate to minimise further degradation.

The value of long-term monitoring can be seen across all the domains in this report: land, water, air and climate. A good example comes from more than 25 years of monitoring the intertidal areas of the Manukau Harbour, and both the patterns of natural variation and the effect of management decisions[1]. These long-term datasets reveal a change in community composition linked to an improvement in the discharge from the wastewater treatment plant. We were able to tease this out from the influence of El Niño and other smaller-scale variability that occurs at each site.

Forest ecosystems - the indigenous ecosystem type that is naturally dominant on most of our land area - are dominated by trees with life spans of hundreds to thousands of years. Long-term monitoring is the only way to get an accurate indication of the impact of threats to, and health and vitality within, these ecosystems.

Some other examples of how long-term monitoring is increasing our understanding include:

- Important research questions about the contribution of climate variables to exceedances in air quality.
- Evaluating links between climate cycles and water quality, such as those between La Niña events and increased turbidity from suspended sediment in coastal waters, or links with elevated temperatures and nitrogen[1,2].
- How removing a major source of contaminants – lead in fuel – has led to significant reductions in harmful lead in both air and water (see lead case study, page 54).
- How data from more than 100 years of monitoring tidal heights for port operations can now be used to quantify sea level rise for Auckland.
- Baseline monitoring in streams enables the effects of land use change to be observed, including the efficacy of sediment retention policies around earthworks.

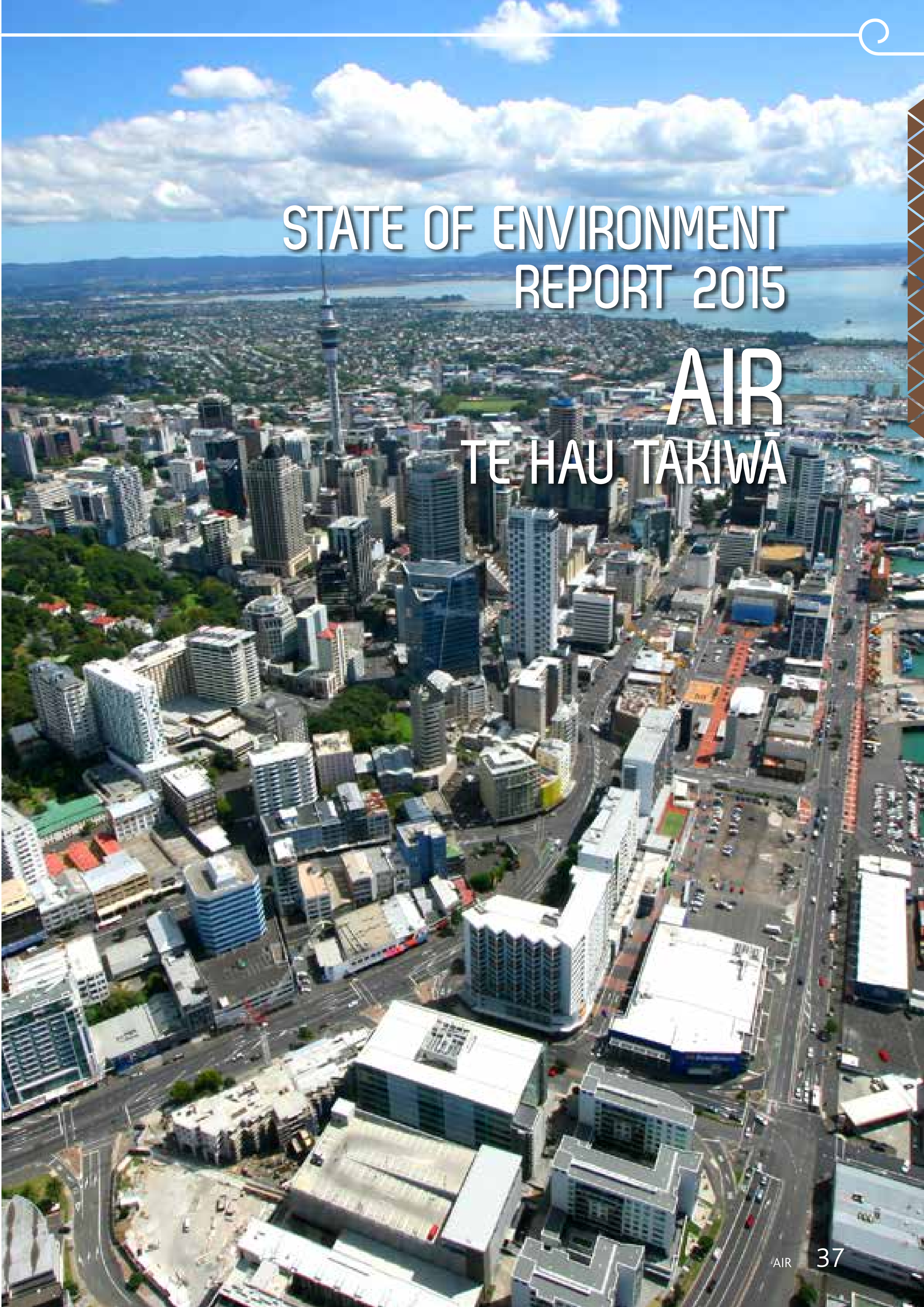
Long-term monitoring also provides an invaluable resource for New Zealand as a whole. It provides context, which enables more informed conclusions from short-term studies. It also offers an invaluable resource for international studies and allows us to compare our progress with the rest of the world.

THE LONGER, THE BETTER!

The longer we monitor, the more accurate our evaluations and predictions will be. If the monitoring data can tell us the order of magnitude of any change – for example, whether sea level rise is likely to be centimetres or metres – this will be invaluable information on which to base development decisions and policies.

Long-term environmental monitoring is our best chance of keeping Auckland and her natural environment safe and prosperous as we head into a future of uncertain climate.

References:
1. Hewitt, J. E., Thrush, S. F. (2010). Empirical evidence of an approaching alternate state produced by intrinsic community dynamics, climatic variability and management actions. Marine Ecology Progress Series. 413: 267-276.
2 Hewitt, J. E., Thrush, S. F. (2009). Reconciling the influence of global climate phenomena on macrofaunal temporal dynamics at a variety of spatial scales. Global Change Biology. 15: 1119-1129.

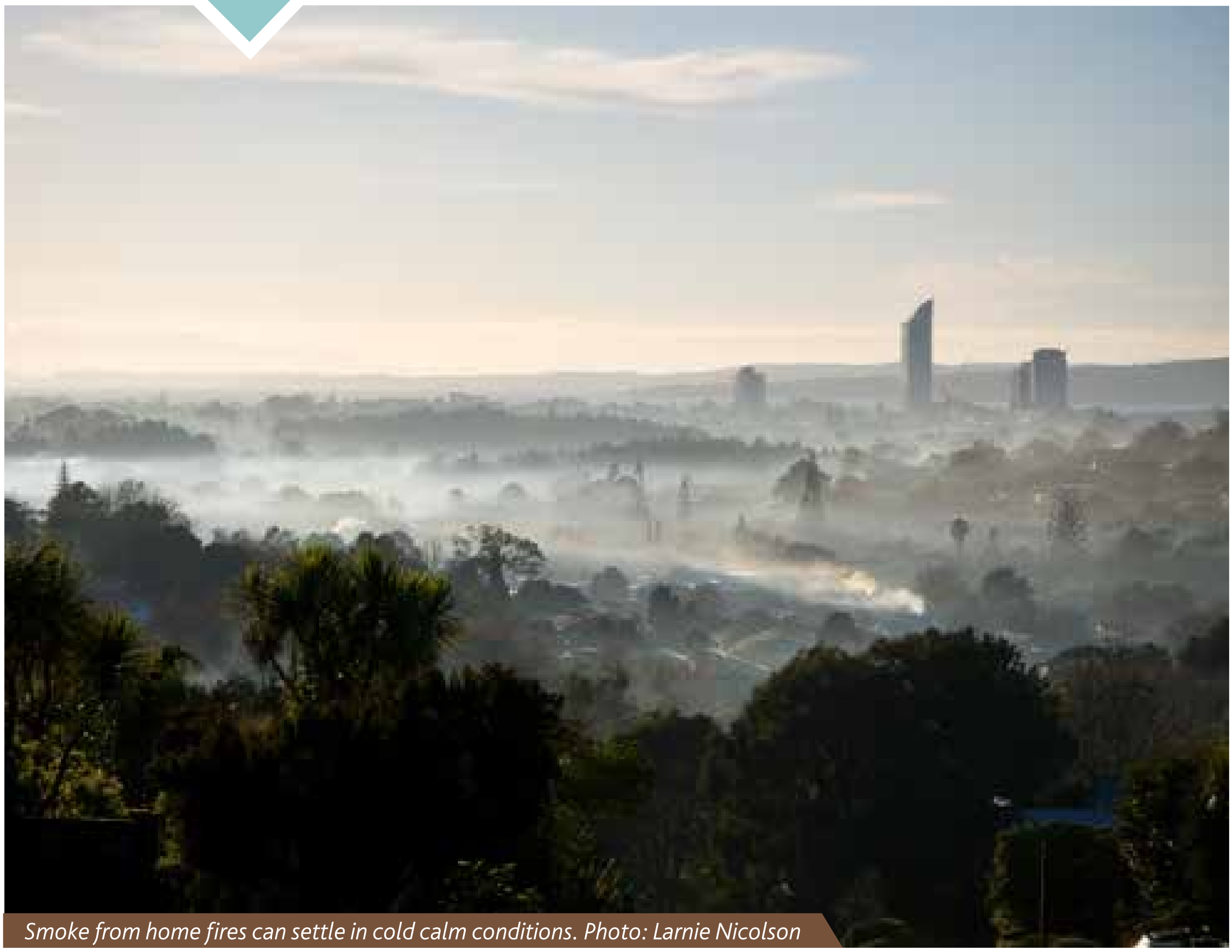


STATE OF ENVIRONMENT REPORT 2015

AIR

TE HAU TAKIWĀ

THE AIR WE BREATHE
TE HAU TAKI MANAWA



Smoke from home fires can settle in cold calm conditions. Photo: Larnie Nicolson

Auckland straddles a narrow isthmus between the Tasman Sea and Pacific Ocean, and our unique location means we have an enviable advantage for air quality. We have lots of wind to disperse pollutants, and the air that arrives here is relatively clean – there's no one upwind of us polluting it.

However, our daily activities put pressure on this natural advantage; the way we travel, the fuels we use, the way we heat our homes and our industries all impact on our air quality. If we don't keep an eye on all of this, and manage it appropriately, there's a danger that our natural advantage will be squandered.

Breathing clean air is critical to protecting our health. The cleaner the air is, the better it is for us to breathe. Reduced air quality has broad health impacts, ranging from nuisance to serious problems. The dominant health impacts of reduced air quality are respiratory and cardiovascular, and range from reduction in function (e.g. difficulty breathing) to reduction in activities, and increased hospitalisation and doctors' visits. Sensitive groups, such as children and the elderly, are especially susceptible.

In 2013, the World Health Organisation (WHO) classified outdoor air pollution and particulate matter (PM) as carcinogenic to humans. WHO considers outdoor air pollution a leading environmental cause of cancer deaths. In New Zealand, PM_{10} specifically was estimated in 2012 as responsible for 2300 deaths a year at a cost of $4.28 billion/year[1]. Gaseous pollutants, such as nitrogen dioxide (NO_2), can also have health impacts, causing irritation to the lungs and increased susceptibility to asthma.

Reduced air quality also affects the way Auckland looks. In winter, calm conditions cause pollutants to stay close to the ground, especially in the evenings when people are using their fireplaces. Emissions from vehicles and fireplaces can also cause an unsightly brown haze to form, especially around the CBD. Often these events also come with unpleasant smells.

There are three main sources of air pollution in Auckland: transport, domestic heating and industry. Natural sources such as sea salt are also present. Our monitoring programme also picks up natural events such as volcanic eruptions and even bushfires in Australia.

Vehicles of all types, on–road, off–road and in the sea, emit a range of pollutants, including tiny particles we call $PM_{2.5}$ and PM_{10} depending on their size. PM is emitted from vehicle exhaust, but is also generated from road dust, brake and tyre wear. Emissions from vehicles (especially diesels) also contribute nitrogen oxides (NOx), mainly nitric oxide (NO). Nitric oxide reacts in the atmosphere to form NO_2, which can cause the unpleasant brown haze and affects our health. Shipping traffic also has an impact, contributing mainly PM, NOx and sulphur dioxide (SO_2) to the air.

In winter, our major sources of air pollution are the emissions from the fireplaces many of us use to heat our homes. Burning solid fuels like wood and coal in open fireplaces and wood burners emits $PM_{2.5}$ and PM_{10}, and in winter we use our fires so much that PM emissions more than triple. $PM_{2.5}$ and PM_{10} have significant impacts on our health, so it's important for us to continue to reduce concentrations in our air.

Industry also emits pollutants to our air. The majority of these are from combustion processes – burning fuel for heat and steam to use in industrial processes. In summer, 25% of PM_{10} emissions is from industry, and in winter 7%.

Auckland Council runs programmes to keep an eye on the quality of our air. Some of our datasets date back to the 1960s and we hold one of the most comprehensive air quality datasets in New Zealand. We use these programmes to assess the state of our air, and to see if our air quality is improving. Data from our monitoring network is used to assess compliance with the National Environmental Standards for Air Quality (NES-AQ). Our monitoring programme comprises the following parameters:

- Particulate matter ($PM_{2.5}$ and PM_{10})
- Gaseous pollutants (oxides of nitrogen, carbon monoxide, sulphur dioxide, ozone)
- Volatile organic compounds (benzene, toluene, ethlybenzene, xylenes)
- Source apportionment of $PM_{2.5}$ and PM_{10}

Our permanent monitoring sites are distributed throughout the region to gain a representative picture of the range of pressures on air quality. We also monitor in areas where we expect high concentrations, to gain an idea of the worst case scenario, and in rural areas to assess background concentrations. Some sites are used for special purposes, such as investigating a specific local problem, or for research using special equipment. We estimate emissions from various human activities, including transport, home heating and industry, and their trends. The results, air emissions inventories, tell us what are the major causes of our air problems.

Auckland Council's air quality monitoring programme increases our understanding of the health of our air, and the impacts of this on our people. The four indicators in this chapter provide insight into Auckland's air quality state, trends and current research.

References:
1. Kuschel, G., Metcalfe, J., Wilton, E., Guria, J., Hales, S., Rolfe, K., Woodward, A. (2012). Updated Health and Air Pollution in New Zealand (HAPINZ); Volume 1 : Summary Report. at hapinz.org.nz

BENZENE POLLUTION INDICATOR

FALLING LEVELS OF CARCINOGENIC BENZENE IN AUCKLAND'S AIR

Vehicle emissions are a major source of benzene

Benzene is a known carcinogen, so controlling concentrations in the air we breathe is critical. Thankfully, by phasing out benzene in our petrol we have cut concentrations at urban monitoring sites by 75% since 2002. Sites monitored in Auckland now generally meet air quality standards.

WHY DO WE MONITOR BENZENE IN THE AIR?

Until recently benzene levels in petrol were relatively high, to make car engines run more smoothly. In the early 2000s however, when high concentrations in our air were discovered, strict laws were put in place to restrict its use. The air quality monitoring programme has tracked the declining concentrations in Auckland's air over the past decade. It quantifies the success of such source control approaches to pollution.

TARGETS

Locally, targets for benzene are set by the Proposed Auckland Unitary Plan (PAUP) and by the National Environmental Guidelines for Air Quality (NEG-AQ). Both have an annual average target for benzene of 3.6 µg m^{-3}. These targets give us clear goals for benzene in our air.

HOW DID BENZENE END UP IN OUR AIR?

Since the early 1900s lead was added to petrol to help the engine run smoothly and reduce wear and tear. But in the 1970s people began to realise it had serious health effects such as brain damage, and therefore in the 1990s lead began to be removed. By the year 2000 it was completely phased out in New Zealand. The problem was that without the lead, car engines didn't run so smoothly. So the petrol companies had the bright idea of adding benzene instead. Unfortunately, benzene is carcinogenic. It wasn't long before this became known and by the year 2003 benzene was reduced to minimal levels in our petrol. Our monitoring programme shows the results for air quality have been remarkable.

Benzene can also be present in low levels from natural sources like volcanoes and forest fires.

WHAT'S SO BAD ABOUT BENZENE?

Benzene (C_6H_6) is a clear, colourless and flammable liquid, with a petrol-like odour that can evaporate to form vapours in air. It has been long established as a group one human carcinogen, and chronic exposure is known to cause a range of cancers, in particular leukaemia. Benzene can also reduce the body's ability to produce red and white blood cells. Studies on animal have also shown significant mutations and fertility effects. Less severe health effects include headaches, dizziness, drowsiness, confusion and loss of consciousness (USEPA, 2002; 2009; WHO, 2010). Because of the serious health effects the World Health Organisation (WHO) has asserted that there is no safe level of exposure to benzene (WHO, 2010).

WHAT IS THIS INDICATOR?

This indicator uses data from five Auckland Council monitoring sites that take monthly readings of benzene. The data from these sites is used to calculate annual average concentrations, which we compare with the national and Proposed Auckland Unitary Plan guidelines to assess our progress.

HOW DO WE MEASURE BENZENE?

We use a method called passive sampling. It uses specially prepared 'sampling badges' that absorb the benzene and are processed at the laboratory to give a concentration.

Every month we take two readings at each monitoring site and take an average to get our monthly result. This method is reliable, flexible and inexpensive. However, it should be noted that passive sampling does not carry regulatory approval like many other air quality monitoring methods currently used by Auckland Council for monitoring particulate matter and gases. However, the ease of deployment, low cost and proven analytical methods allow greater monitoring coverage and enable us to monitor benzene in a very cost-effective manner.

WHAT HAVE WE FOUND?

In 2002, after the high concentrations of benzene were discovered, petrol companies were forced to phase out its use. The result is evident in the graph below. It shows how concentrations have fallen below the NEG-AQ and PAUP targets and stabilised. This is great news, but it appears that concentrations are still volatile, as seen by the spike in 2011. Careful management is still required to ensure concentrations continue to decline.

WHAT CAN YOU DO TO HELP?

- Drive your car less.
- See how your car compares at rightcar.govt.nz
- Keep your car tuned and running smoothly.
- Consider leaving the car at home and walk or cycle.
- Take the bus, train or ferry where possible.
- Consider carpooling to work.

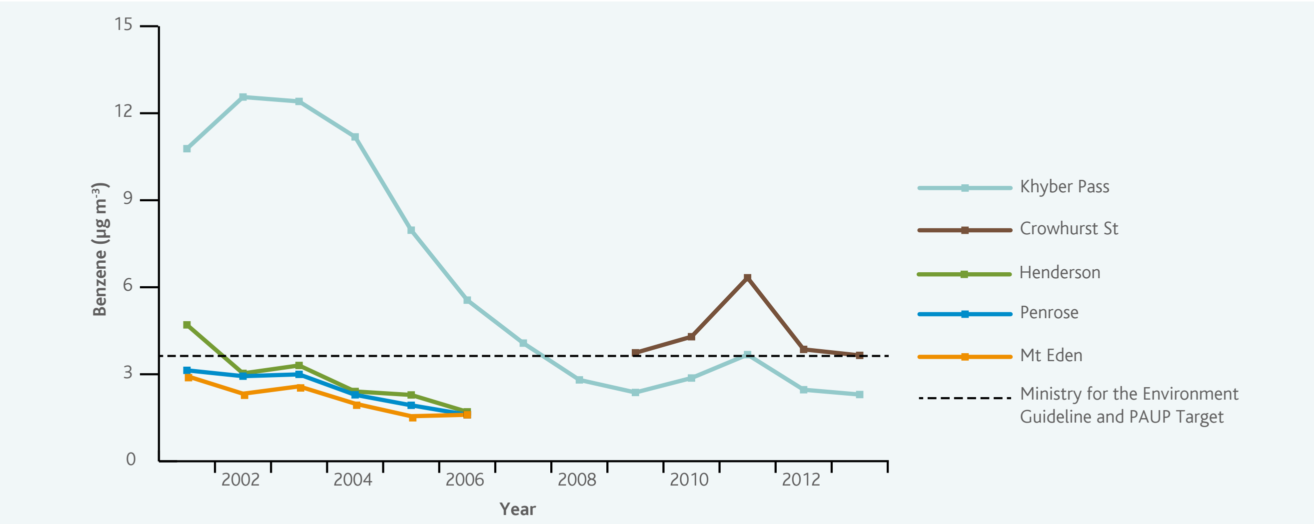


FIGURE 1: Annual average benzene concentrations at five monitoring sites, 2001-2013. The dotted line is the target of 3.6 µg m^{-3}.

References:

USEPA, 2002. Toxicological Review of Benzene (Non-cancer Effects): in support of summary information on the integrated risk information system (IRIS) October 2002. United States Environmental Protection Agency Report EPA/635/R-02/001F, Washington DC.

USEPA, 2009. TEACH Chemical Summary: Benzene. Retrieved from: epa.gov/teach/chem_summ/BENZ_summary.pdf World Health Organisation (WHO), 2010. Preventing disease through healthy environments: exposure to benzene: a major public health concern.

PARTICULATE MATTER INDICATOR

AUCKLAND'S PARTICULATE AIR POLLUTION ON THE DECLINE


Particulate monitoring instrument at Khyber Pass

According to a recent study, over 2000 New Zealanders die every year as a result of particulate air pollution, most of them in the cities. Thanks to fewer homes using solid fuels for heating and vehicle emissions improving, concentrations of harmful particulates in our air are declining. But air quality standards can still be breached near inner city roads and in areas with high numbers of wood burners.

WHY DO WE MONITOR PARTICULATE MATTER IN URBAN AIR?

In 2013 the World Health Organisation classified outdoor air pollution, including PM_{10}, as carcinogenic to humans.

In New Zealand an estimated 2300 people die from exposure to PM_{10} in urban areas and $4.28 billion are spent on related healthcare issues every year, according to a 2012 national study by Health and Air Pollution in New Zealand (HAPINZ)[1].

The main causes of health problems and death are cardiovascular and respiratory illnesses caused by small particles, which can lodge deep in the lungs when inhaled.

Over the past decade concentrations of PM_{10} in urban Auckland have significantly decreased due to source management programmes, cleaner fuels, less toxic vehicle emissions and declining use of solid fuels for home heating. But they are still of concern, and in certain areas still in danger of breaching air quality standards. So it is essential to continue to monitor carefully.

WHAT IS THIS INDICATOR?

Particulate matter (PM) comes in different sizes and includes both solids and liquids. The air we breathe is full of these tiny particles. Even on a pristine beach or in the bush the air contains fine particles of sea salt and pollen. But in urban areas most PM is from polluting sources such as vehicle exhaust and smoke from the indoor fires many of us use to heat our homes.

PPM$_{10}$ is a term for particles less than 10 microns in size – that's about one-fifth the width of a human hair. PM$_{2.5}$ particles are 2.5 micrometres or less – that's four times smaller again (figure 1). We measure concentrations of PM$_{2.5}$ and PM$_{10}$ as they allow us to draw a better picture of PM in our air.

FIGURE 1: Relative size of PM$_{2.5}$ and PM$_{10}$.

HOW DO WE MONITOR PARTICULATE MATTER?

We have 12 monitoring sites across the region that are continuously monitoring PM$_{2.5}$ and PM$_{10}$. These sites cover a range of land uses and emission sources.

To make sense of the data we compare concentrations at monitoring sites to national air quality standards and guidelines. Monitoring has been carried out since the early 1990s, so we can understand how air quality changes over time.

NEW AIR QUALITY INDEX – TRANSFORMING THE VALUE OF MONITORING DATA FOR AUCKLANDERS

In the past, the only time the general public has had access to air quality data has been when the levels exceed the recommended limits. There has been no way for people to access the rich resource of information streaming into our monitoring network all around Auckland every minute of the day.

We think this is a waste of good information and would like to open up this invaluable resource to everyone. Our solution is a simple index that translates the concentration of PM into a rating from low to very high. With such an index available online people who are particularly vulnerable to air pollution, such as those with respiratory illnesses, could consult the index before going out or planning a trip, to get an accurate picture of the air quality that day. This is a service that many other cities enjoy, including Melbourne, London and Vancouver. It would be easy and inexpensive to introduce to Auckland and would dramatically increase the value of our monitoring programme to the city.

We have chosen to use an index developed in the United Kingdom called the Daily Air Quality Index (DAQI). The index converts daily PM$_{2.5}$ and PM$_{10}$ data into a single value ranging from Low to Very High. These classifications correspond to health impacts, as shown on page 46 (figure 3). This indicator also presents annual average concentrations, and exceedances of the National Environmental Standard.

WHAT HAVE WE FOUND?

Good news: On most days (over 90%) PM$_{2.5}$ and PM$_{10}$ concentrations are rated Low on the index (figures 5 and 6, pages 47 and 48).

Urban areas still at risk: In some urban areas the occasional day showed higher health impacts. This is due to sources such as transport and home heating.

Rural areas low risk: In rural areas, such as Patumahoe and Whangaparaoa, health impacts from PM$_{2.5}$ and PM$_{10}$ are Low (figures 5 and 6).

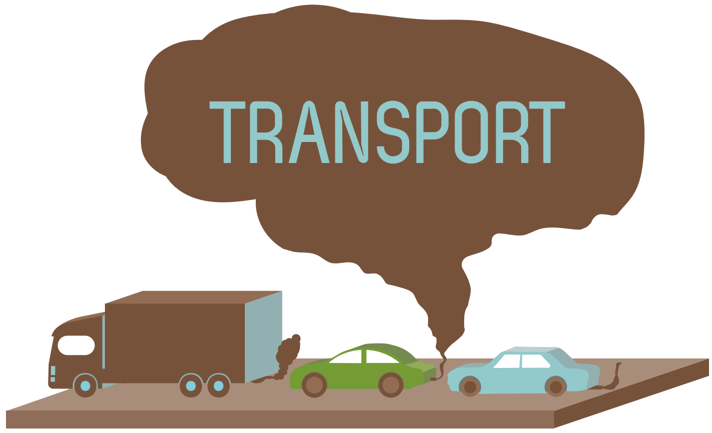
Home wood burners an issue: In the winter 72% of PM$_{10}$ came from domestic sources. The main culprit here is wood burners.

> "Reduce pollutant emissions (PM$_{10}$) by 50% by 2016 (based on 2006 levels) in order to meet national and international ambient air quality standards and guidelines, and achieve a further 20% reduction by 2040."
>
> THE AUCKLAND PLAN
> - CHAPTER 7

AUCKLAND'S TARGETS

The Proposed Auckland Unitary Plan sets out Auckland Ambient Air Quality Standards for a range of pollutants. For PM$_{10}$ it states that a daily average of 50 µg m^{-3} must not be exceeded more than once a year. Under the National Environmental Standards all airsheds must comply with the PM$_{10}$ standard by 2016. The Auckland Ambient Air Quality Standard for PM$_{2.5}$ is 25 µg m^{-3} (daily average). We also have Auckland Ambient Air Quality Standards for annual averages – PM$_{2.5}$ 10 µg m^{-3} and PM$_{10}$ 20 µg m^{-3} (figure 7, page 48).

Domestic use of solid fuel for heating, especially in winter, emits PM_{10}, $PM_{2.5}$ and NOx.



Burning fuel (petrol and diesel) for transport emits CO, NOx, PM_{10}, $PM_{2.5}$ and VOCs. Wear of tyres and brakes emits PM_{10} and $PM_{2.5}$.

NATURAL SOURCES

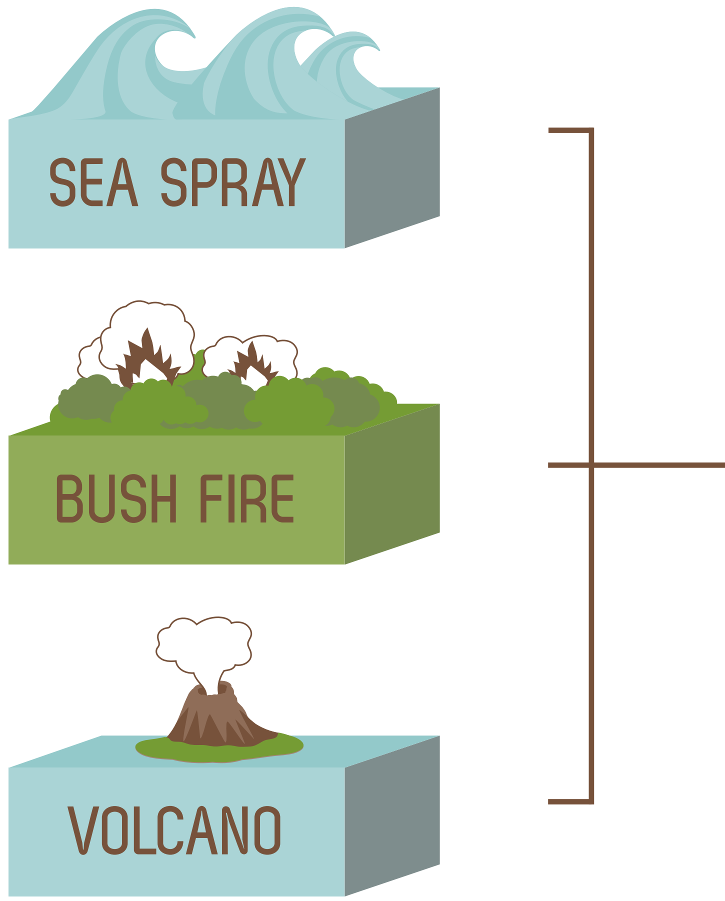
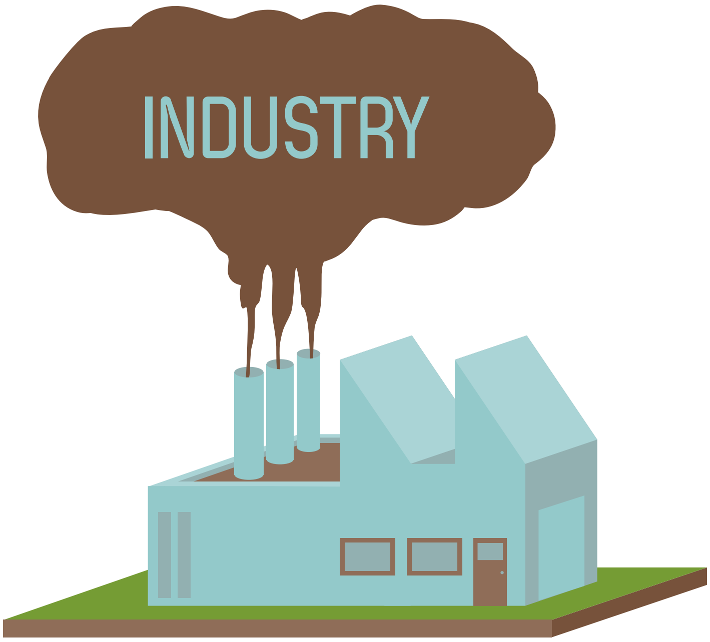


FIGURE 2: Sources and impacts of air pollution in Auckland.



Industrial activities discharge PM_{10}, $PM_{2.5}$, VOCs and NOx.

Burning fuel for shipping emits SO_2, PM_{10}, $PM_{2.5}$ and NOx, and contributes to secondary sulphates.

Auckland's air pollution harms our health. It may get worse as the population grows and more people live in urban areas.

HEALTH IMPACTS OF AIR POLLUTION

- Coughing
- Wheezing
- Bronchitis
- Chronic obstructive pulmonary disease (COPD)
- Reduced lung development
- Asthma
- Stroke
- Cancer
- High blood pressure
- Arteriosclerosis
- Heart attack.

$PM_{2.5}$ LEVELS

Based on the daily mean concentration for historical data.

INDEX BAND	1	2	3	4	5	6	7	8	9	10
	Low	Low	Low	Moderate	Moderate	Moderate	High	High	HIgh	Very High
$\mu g\ m^{-3}$	0-11	12-23	24-35	>36-41	>42-47	>48-53	54-58	59-64	65-70	71 or more

PM_{10} LEVELS

Based on the daily mean concentration for historical data.

INDEX BAND	1	2	3	4	5	6	7	8	9	10
	Low	Low	Low	Moderate	Moderate	Moderate	High	High	HIgh	Very High
$\mu g\ m^{-3}$	0-16	17-33	34-50	51-58	59-66	67-75	76-83	84-91	92-100	101 or more

RECOMMENDED ACTIONS AND HEALTH ADVICE

AIR POLLUTION BANDING	VALUE	ADVICE FOR THOSE AT RISK*	ADVICE FOR THE GENERAL POPULATION
LOW	1-3	**Enjoy** your usual outdoor activities.	**Enjoy** your usual outdoor activities.
MODERATE	4-6	Adults and children with lung problems, and adults with heart problems, **who experience symptoms**, should **consider reducing** strenuous physical activity, particularly outdoors.	**Enjoy** your usual outdoor activities.
HIGH	7-9	Adults and children with lung problems, and adults with heart problems, should **reduce** strenuous physical exertion, particularly outdoors, and particularly if they experience symptoms. People with asthma may find they need to use their reliever inhaler more often. Older people should also **reduce** physical exertion.	Anyone experiencing discomfort such as sore eyes, cough or sore throat should **consider reducing** activity, particularly outdoors.
VERY HIGH	10	Adults and children with lung problems, adults with heart problems, and older people, should **avoid** strenuous physical activity. People with asthma may find they need to use their reliever inhaler more often.	**Reduce** physical exertion, particularly outdoors, especially if you experience symptoms such as cough or sore throat.

FIGURE 3: DAQI classifications and health impacts. *Adults and children with heart or lung problems are at greater risk of symptoms. Follow your doctor's usual advice about exercising and managing your condition. It is possible that very sensitive individuals may experience health effects even on Low air pollution days.

WHERE DOES AUCKLAND'S PARTICULATE MATTER COME FROM?

Each year about 2500 tonnes of $PM_{2.5}$ and PM_{10} are emitted into Auckland's air (figure 2). In summer, transport is the biggest cause of air pollution, but in winter, home heating is the biggest problem; in fact, the amount of $PM_{2.5}$ and PM_{10} emitted into the air is tripled in winter. This is mainly caused by the wood burners many of us use to heat our homes. The amount of PM_{10} emitted in winter is nearly four times what is emitted in summer! There are also natural sources of PM_{10} such as sea salt, pollen, spores and wind-blown dust but the concentrations are insignificant compared with human sources.

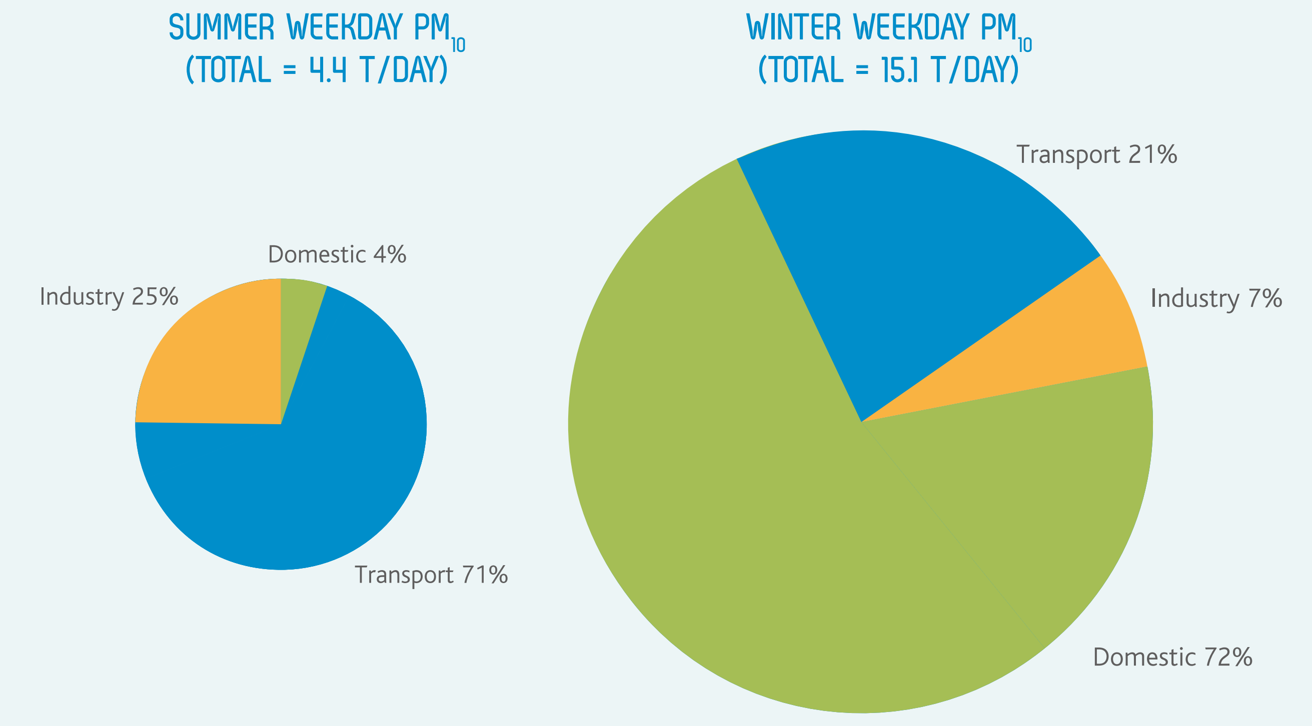


FIGURE 4: PM_{10} emissions in winter and summer.

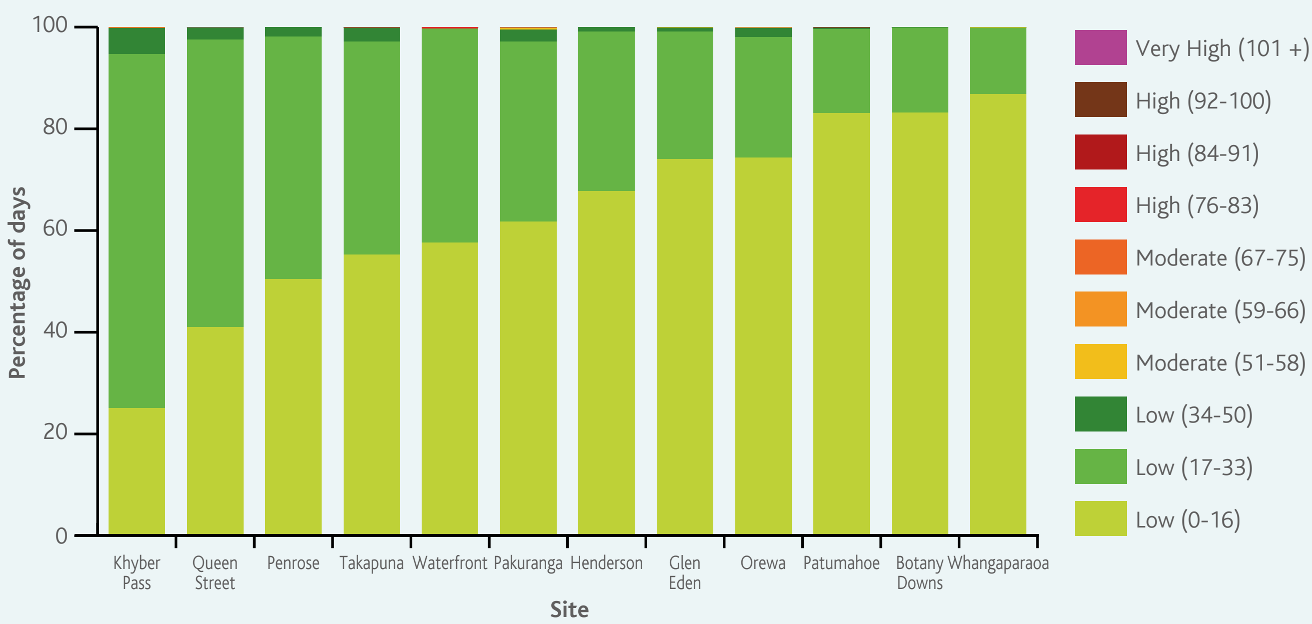


FIGURE 5: PM_{10} Daily Air Quality Index (DAQI), 2003-2013.

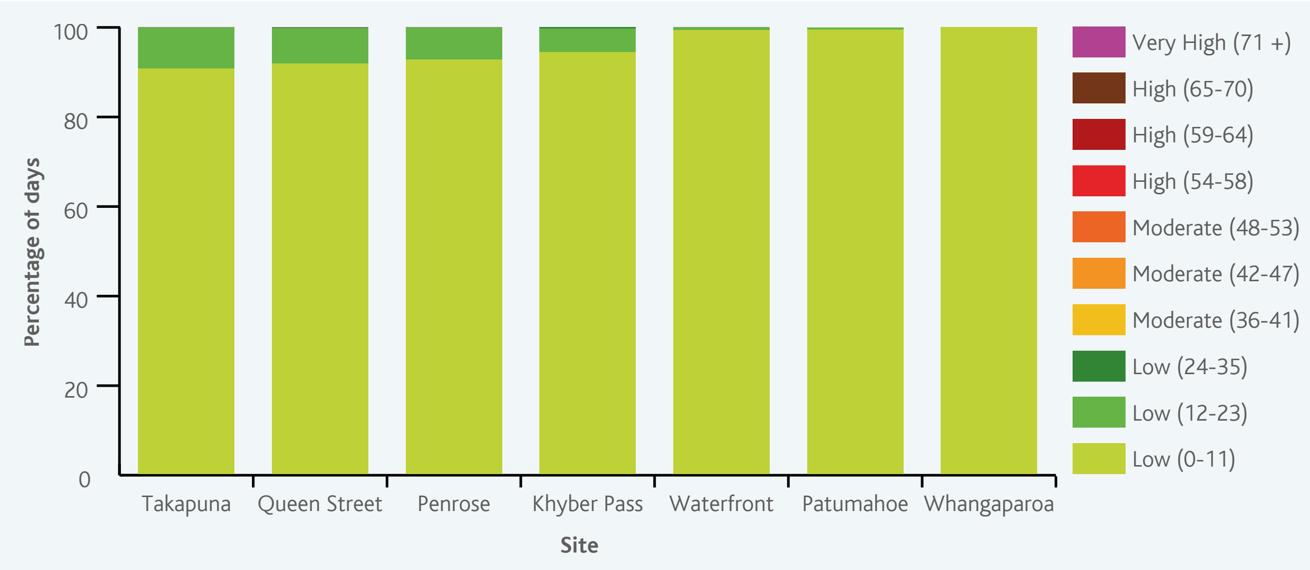


FIGURE 6: $PM_{2.5}$ Daily Air Quality Index (DAQI).

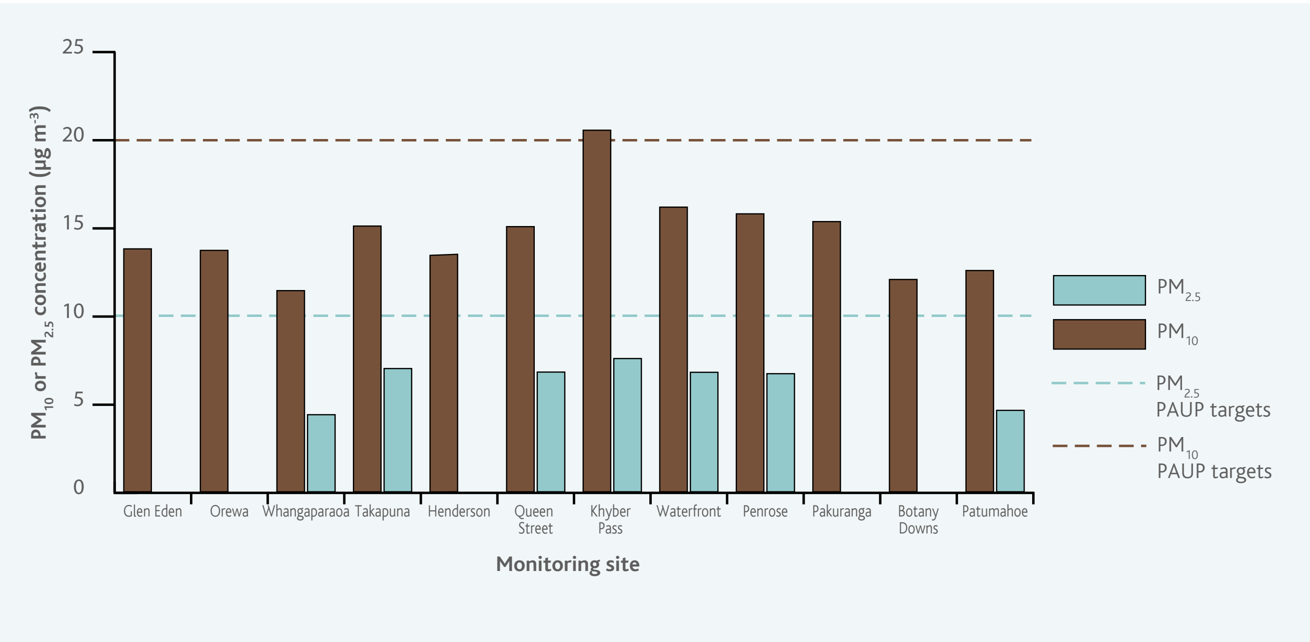


FIGURE 7: PM_{10} and $PM_{2.5}$ annual average concentrations in 2013.

In 2013, annual average $PM_{2.5}$ and PM_{10} concentrations at monitoring sites were below annual targets, with the exception of PM_{10} at Khyber Pass, which only just breached the annual target (figure 7).

HOW HAVE THINGS CHANGED? – A SUCCESS STORY IN MANAGING PARTICULATE POLLUTION

Thanks to improved vehicle technology and better fuel standards the average concentrations of PM_{10} have decreased at some urban sites. This is particularly evident at sites with high PM (from vehicle sources) such as Queen Street (figure 8), where concentrations have declined significantly since 1998.

EXCEEDANCES

The graph opposite (figure 9) tells a success story of reducing particulate pollution. It illustrates the number of times national air quality standards have been exceeded since 1998. In particular the number of exceedances for PM_{10} has gone from 17 days in 2005 to none in 2014. One exceedance is permitted per 12 month period. The number of exceedances recorded varies significantly from year to year, and we need to continue to monitor our air quality and put useful policy in place to ensure the exceedances decline.

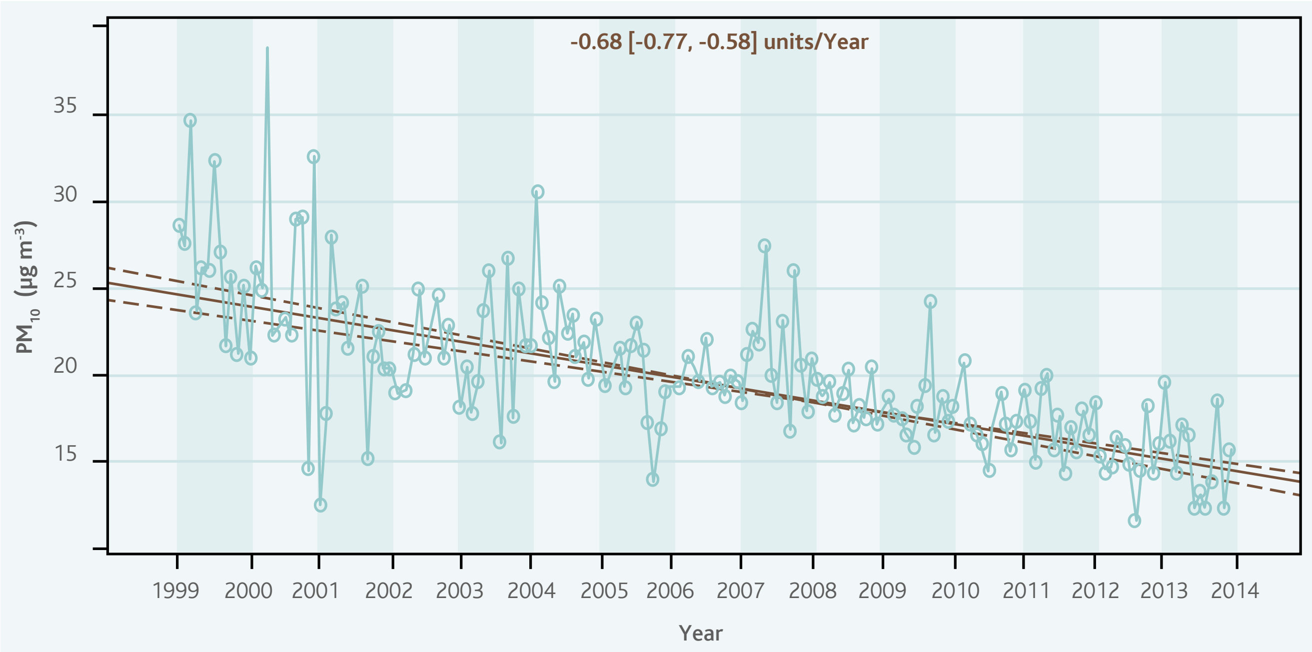


FIGURE 8: Declining PM_{10} concentration at Queen Street (traffic peak), 1999-2014.

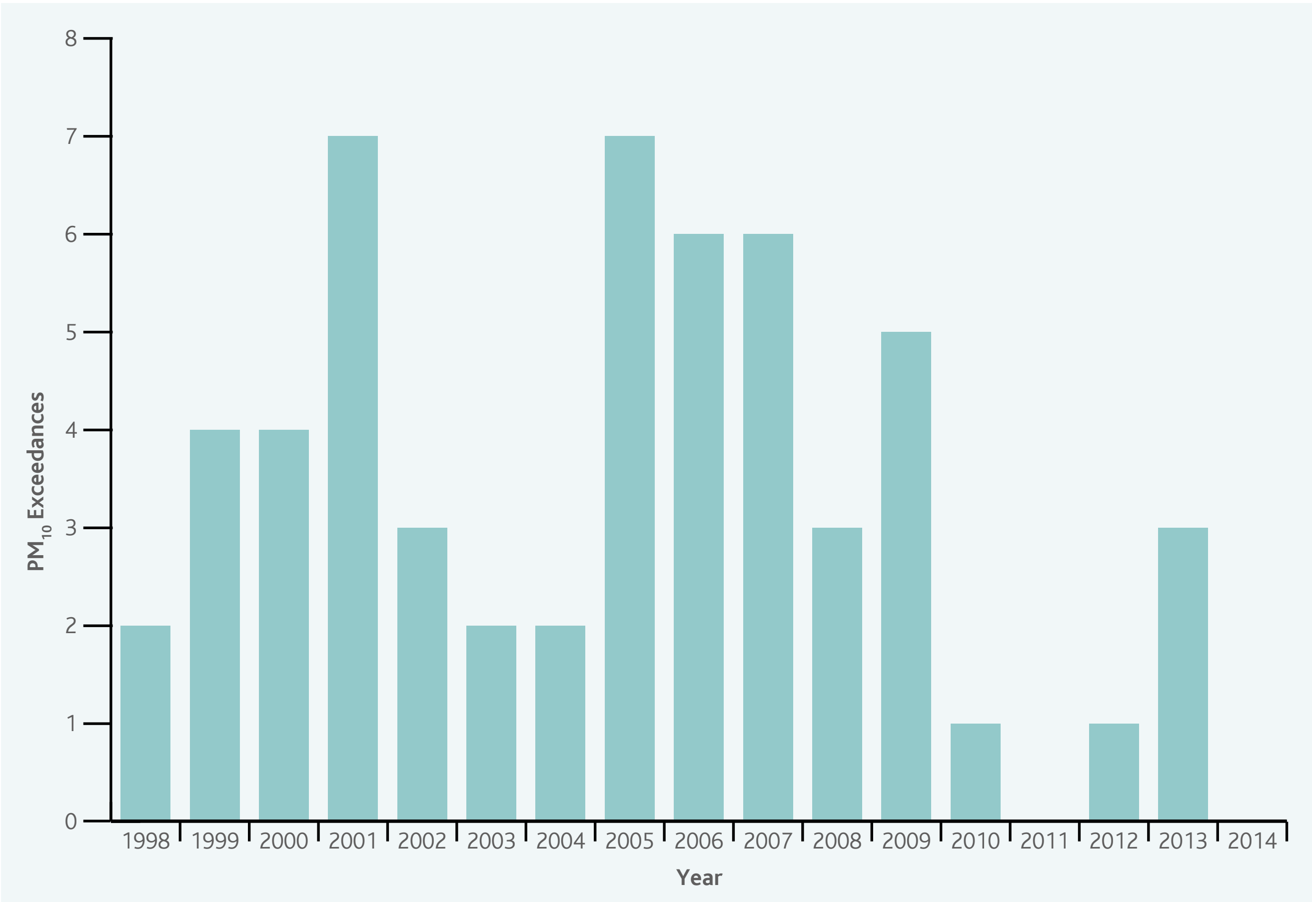


FIGURE 9: Exceedances of the National Environmental Standard for Air Quality (24hr average PM_{10}), 1998-2014.

References:
1. Kuschel, G., Metcalfe, J., Wilton, E., Guria, J., Hales, S., Rolfe, K., Woodward, A. (2012): Updated Health and Air Pollution in New Zealand (HAPINZ); Volume 1: Summary Report.

NITROGEN DIOXIDE POLLUTION INDICATOR

LEVELS OF NO_2 SAFE BUT COULD INCREASE AS AUCKLAND GROWS

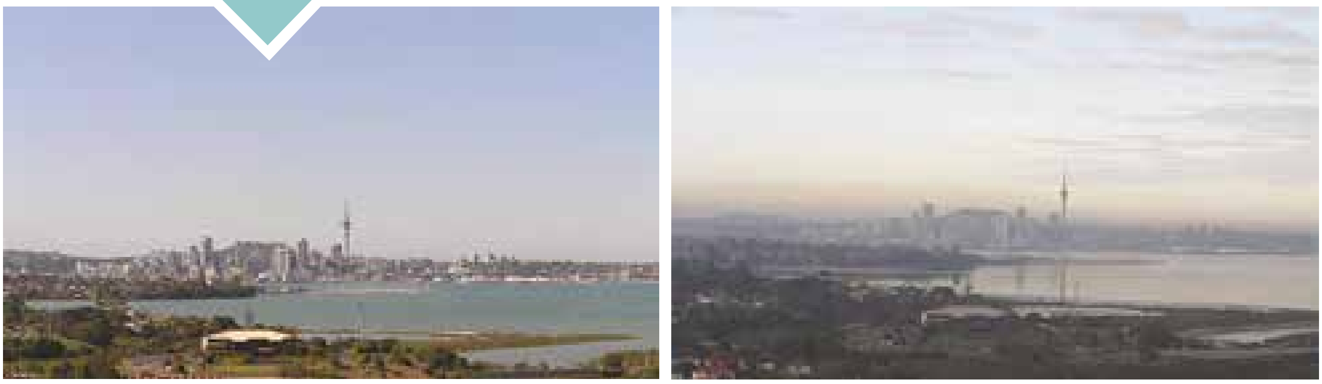


FIGURE 1: A clear day, left, compared with a hazy day.

Ever noticed the brown haze that sometimes blankets the city? The main cause is nitrogen dioxide (NO_2), a brown, pungent, acidic gas mainly formed from diesel engine emissions. Our monitoring programme has shown a significant drop in NO_2 across Auckland over the last decade, thanks to stricter vehicle emission standards and improved fuel quality. But with the predicted growth of Auckland and more vehicles on our roads, we need to watch out for higher levels.

WHY DO WE MONITOR NO_2?

Firstly, because it's bad for you. Nitrogen dioxide can irritate the lungs, increasing susceptibility to asthma and lowering resistance to respiratory infections. Long-term exposure to low levels of NO_2 can affect lung growth in children and damage plants.

It also looks bad. When nitrogen dioxide heats up in the sun it contributes to the formation of a brown haze that hangs over the city (figure 1).

Motor vehicles, especially those using diesel fuel, are the main source of NO_2. Currently, the number of diesel vehicles in Auckland is on the rise as the population increases. So although levels of NO_2 have decreased in the region, we are still in danger of exceeding safe limits as vehicle numbers increase. It is therefore essential that we monitor levels to assess the effectiveness of our current practices and policies.

WHAT IS THIS INDICATOR?

This indicator measures how much NO_2 is in our air using an Air Quality Index, just like the one we use for the Particulate Matter Indicator (page 46). The indicator is called the Daily Air Quality Index (DAQI) and was developed in the United Kingdom. It translates concentrations of NO_2 into ratings that relate to health impacts (see figure 2 next page).

This indicator also presents annual average concentrations, and exceedances of the National Environmental Standard.

TARGETS

According to the Proposed Auckland Unitary Plan and the National Standards, the level of NO_2 should not exceed an hourly average of 200 µg m^{-3} more than nine times a year. The 24-hour average standard is 100 µg m^{-3}, which must not be exceeded. The annual average target is 40 µg m^{-3}.

NITROGEN DIOXIDE

Based on the hourly mean concentration.

INDEX BAND	1	2	3	4	5	6	7	8	9	10
	Low	Low	Low	Moderate	Moderate	Moderate	High	High	HIgh	Very High
µg m^{-3}	0-67	68-134	135-200	201-267	268-334	335-400	401-467	468-534	535-600	601 or more

RECOMMENDED ACTIONS AND HEALTH ADVICE

AIR POLLUTION BANDING	VALUE	ADVICE FOR AT-RISK INDIVIDUALS*	ADVICE FOR THE GENERAL POPULATION
LOW	1-3	**Enjoy** your usual outdoor activities.	**Enjoy** your usual outdoor activities.
MODERATE	4-6	Adults and children with lung problems, and adults with heart problems, **who experience symptoms**, should **consider reducing** strenuous physical activity, particularly outdoors.	**Enjoy** your usual outdoor activities.
HIGH	7-9	Adults and children with lung problems, and adults with heart problems, should **reduce** strenuous physical exertion, particularly outdoors, and particularly if they experience symptoms. People with asthma may find they need to use their reliever inhaler more often. Older people should also **reduce** physical exertion.	Anyone experiencing discomfort such as sore eyes, cough or sore throat should **consider reducing** activity, particularly outdoors.
VERY HIGH	10	Adults and children with lung problems, adults with heart problems, and older people, should **avoid** strenuous physical activity. People with asthma may find they need to use their reliever inhaler more often.	**Reduce** physical exertion, particularly outdoors, especially if you experience symptoms such as cough or sore throat.

FIGURE 2: DAQI classifications and health impacts.

*Adults and children with heart or lung problems are at greater risk of symptoms. Follow your doctor's usual advice about exercising and managing your condition. It is possible that very sensitive individuals may experience health effects even on Low air pollution days.

HOW DO WE MONITOR NO_2?

NO_2 is continuously monitored at nine sites across the region, covering a range of land uses and emission sources. We collect this data with sophisticated gas analyser instruments, using international standard techniques. Monitoring has been carried out since the 1990s, so we can understand how air quality changes over time.

WHAT HAVE WE FOUND?

Auckland's air is in pretty good nick! Between 2003 and 2013, most monitoring sites fell in the low classifications at least 90% of the time (figure 3, page 34). In 2013, all monitoring sites were under the annual average target for NO_2 (figure 4).

The worst spots for NO_2 pollution are at Newmarket and the city centre (see figure 3). Concentrations at these locations occasionally exceed air quality standards and guidelines.

The concentrations in rural areas, such as Patumahoe (figure 5), are the lowest. Levels vary from day to day, seasonally, yearly and even within a day.

Winter concentrations are around double those of summer, usually due to still winter weather preventing dispersion. Concentrations are usually higher in the morning and evening because of peak travel times and poor dispersion of air at those times.

HOW HAVE THINGS CHANGED?

Over the last decade our monitoring data shows decreases in NO_2 concentrations at all the worst sites in Auckland. This is thanks to a coordinated effort by national standard setters and vehicle manufacturers to improve the efficiency of diesel engines. The graph opposite (figure 5) shows the decreasing levels of NO_2 at one of the worst sites, Queen Street. This is also due to a council planning project, which diverted traffic away from the pedestrian areas. At our background monitoring sites, concentrations are also declining.

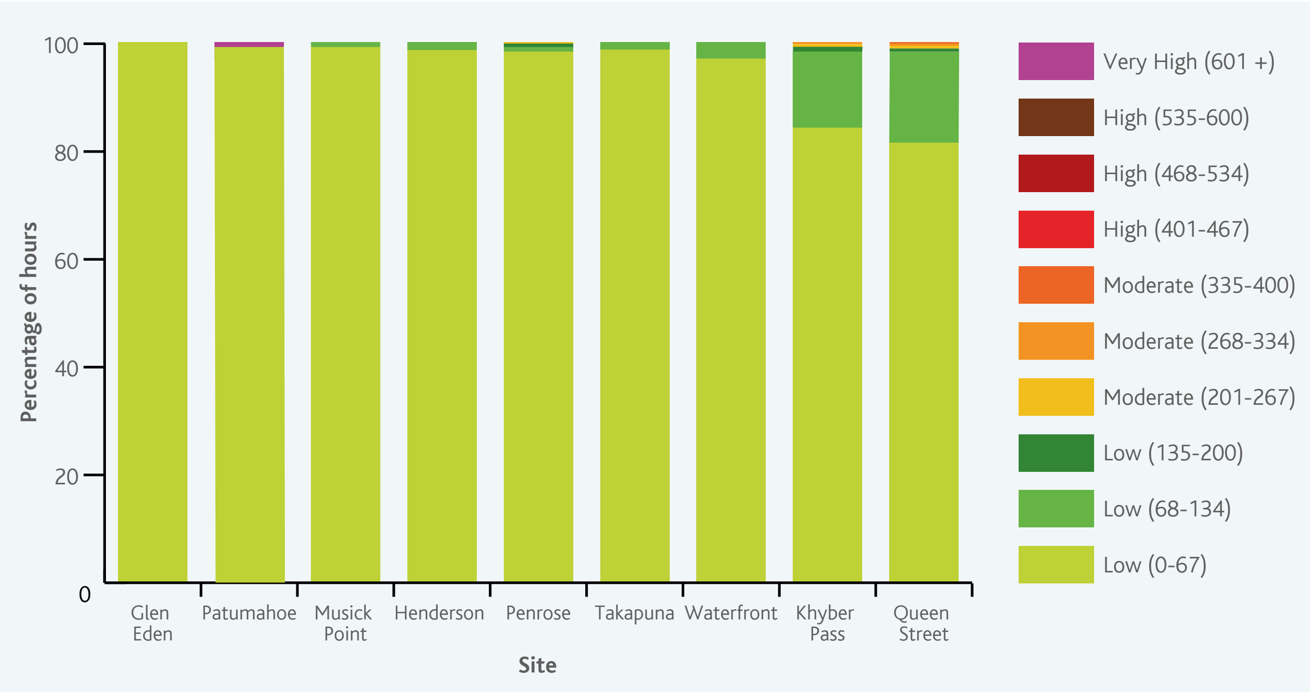


FIGURE 3: NO_2 Daily Air Quality Index (DAQI), hourly data, 2003-2013.

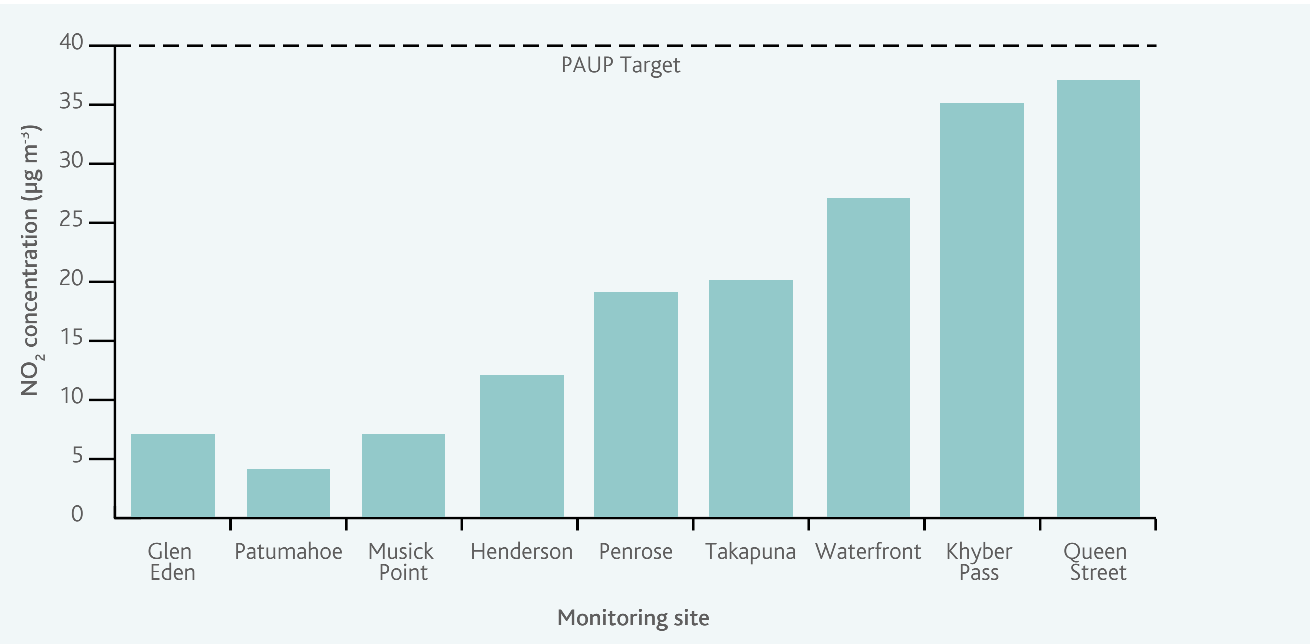


FIGURE 4: NO_2 average concentrations in 2013.

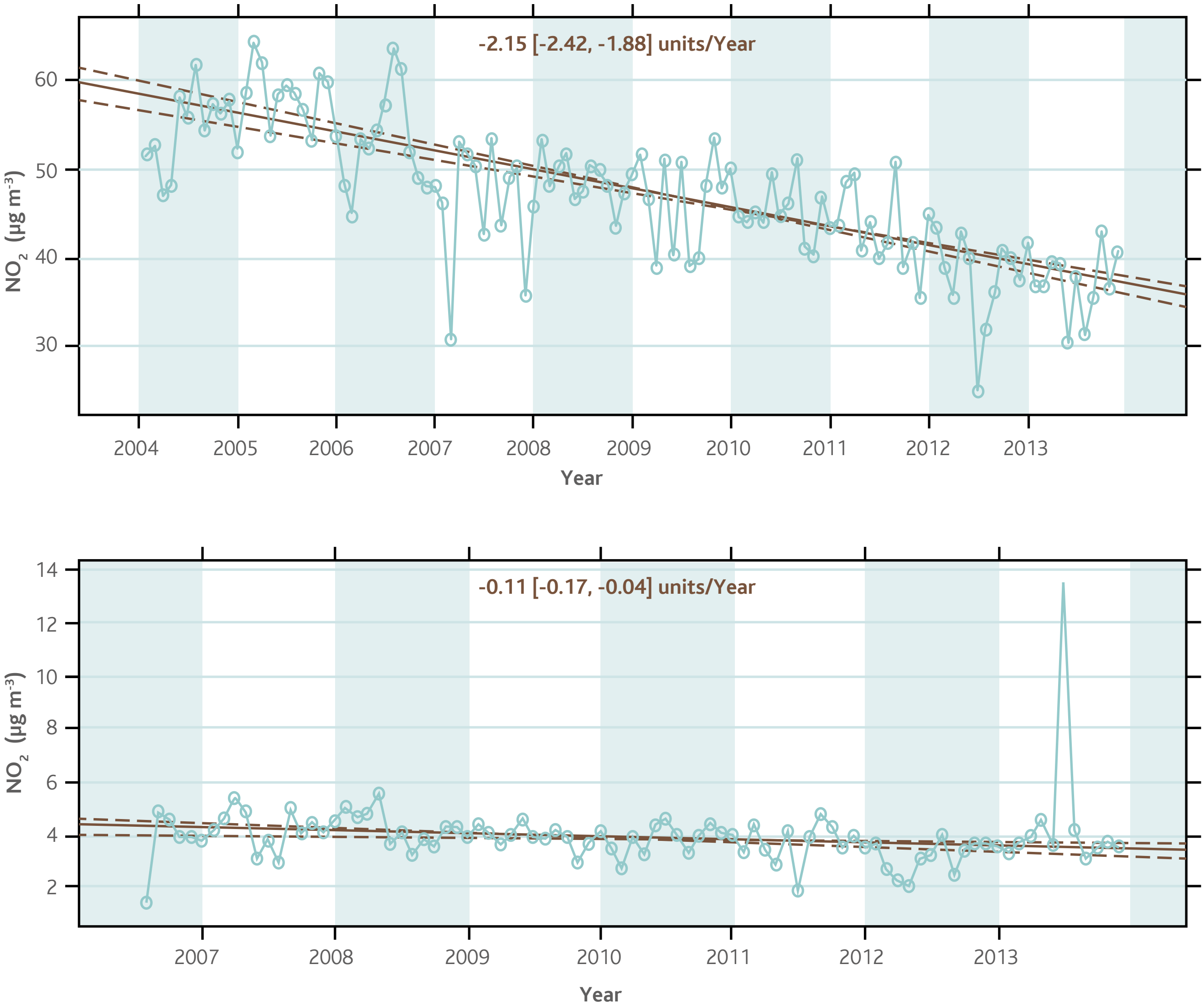


FIGURE 5: Trends in NO_2 at Queen Street (top) and rural Patumahoe (bottom).

EXCEEDANCES

As well as declining concentrations, exceedances of air quality standards and guidelines are declining. Between 2003 and 2008 several exceedances of NO_2 standards were recorded each year. However, from 2008 to 2013, there was only one day of NO_2 exceedances recorded in 2009, 2011 and 2012. No exceedances were recorded in 2013 or 2014. The National Environmental Standard allows for nine exceedances in a 12-month period.

SPOTLIGHT

HOW FAR DOES NO_2 TRAVEL?

The best way to reduce the health impacts of pollution is to keep people away from the sources. City planners are now applying this principle to urban design – placing schools, pedestrian areas, parks and shops away from busy roads and reducing the flow of traffic through popular areas.

To do this successfully you need to know how far away from a road you need to go before the pollution drops to a safe level. Our team has been doing some research to figure this out. We placed NO_2 sensors at different distances from three major roads (twelve around SH20 at Māngere, four around SH1 at Penrose and four around SH1 at Ōtāhuhu).

This is what we found out:

- Not surprisingly NO_2 concentrations fall, the further you go from the road.
- Concentrations are higher on the downward side of the motorway.
- NO_2 concentrations remain high up to 300 metres from the roadside.

These results will be a valuable resource for identifying pollution hotspots and improving future air quality monitoring. In particular it will provide important scientific evidence for formulating the Transport Corridor Separation air quality policy in the Proposed Auckland Unitary Plan.

CASE STUDY: THE SUCCESS STORY OF LEAD

INTERVENTION AND LESS-POLLUTED STREETS REDUCE LEAD CONCENTRATIONS

Fuel specifications are critical to lead concentration

Contaminants in our environment are a serious issue, but with commitment we can make a difference, as we have seen with lead. Because of its significant impact on health, such as reduced birth weights and severe respiratory disease, lead was outlawed from petrol in 1996 and levels in the environment declined greatly. However, new contaminants are emerging daily that we need to deal with.

WHERE DOES LEAD COME FROM AND WHAT ARE ITS EFFECTS?

Auckland Council monitors a range of contaminants in the environment, including lead in air, water, soil and sediment. Controlling the sources of lead has resulted in a significant decline in lead concentrations in the environment. Two areas where this decline is clearest are in our air and estuaries.

Exposure to lead from all sources is considered a major global health problem[2]. Health effects of lead are directly related to the level of lead in the blood. One of the most widely recognised effects of lead exposure is a decrease in intelligence and academic performance in children exposed to lead in their first few years of life. There is also a strong link between prenatal exposure and impaired mental function. Severe neurological impairments, such as seizures, mental impairments and behavioural disorders, are also reported for all age cohorts[3,4]. A growing body of evidence shows that relatively low levels of lead exposure cause adverse effects on renal and cardiovascular function in adults[5].

Lead is found in the environment from a range of sources, both in industrial areas and possibly in some of our home environments. For example, did you know that lead was once a common component of household paints? Some industries discharge lead to air (e.g. metal smelters). The historical use of lead as an additive to paint means that removal of old paint is a significant source. Soils and dust can also be contaminated with lead, which are easily inhaled.

Globally, the major source of lead concentrations in the environment has been leaded petrol. Phasing out its use has long been considered critical to reducing ambient concentrations and also within blood. Studies from the United States indicate that removing leaded petrol has had the greatest effect in reducing levels of lead in ambient air and therefore blood[6,7,8].

Reduction of lead in New Zealand petrol was also shown to have an impact on lead levels in blood[9]. However, phasing out leaded gasoline has not been an easy task, despite many countries (USA, Canada, Japan) making the first steps in the early 1970s[10]. In Australia the process was not completed until 2002 (National Fuel Quality Standards Act 2000). The United Nations Environment Program (UNEP) set a target of ending lead petrol availability by 2008[11,4]. In 2008 leaded petrol was still available in 16 countries. In early 2014 this had reduced to six[12].

IT'S SIMPLE: CONTROL SOURCES, CONTROL AMOUNT IN ENVIRONMENT

As we knew leaded petrol was a key source of lead in the air, New Zealand began controlling it in 1985, when unleaded petrol was first made available. We've kept a close eye on lead concentrations on land following this major change and our monitoring programme has shown its success (figure 1). This control was a great first step, but amounts of lead in the environment remained elevated until around 1996, when all leaded petrol was removed from sale. Concentrations in our air dropped quickly to very low levels.

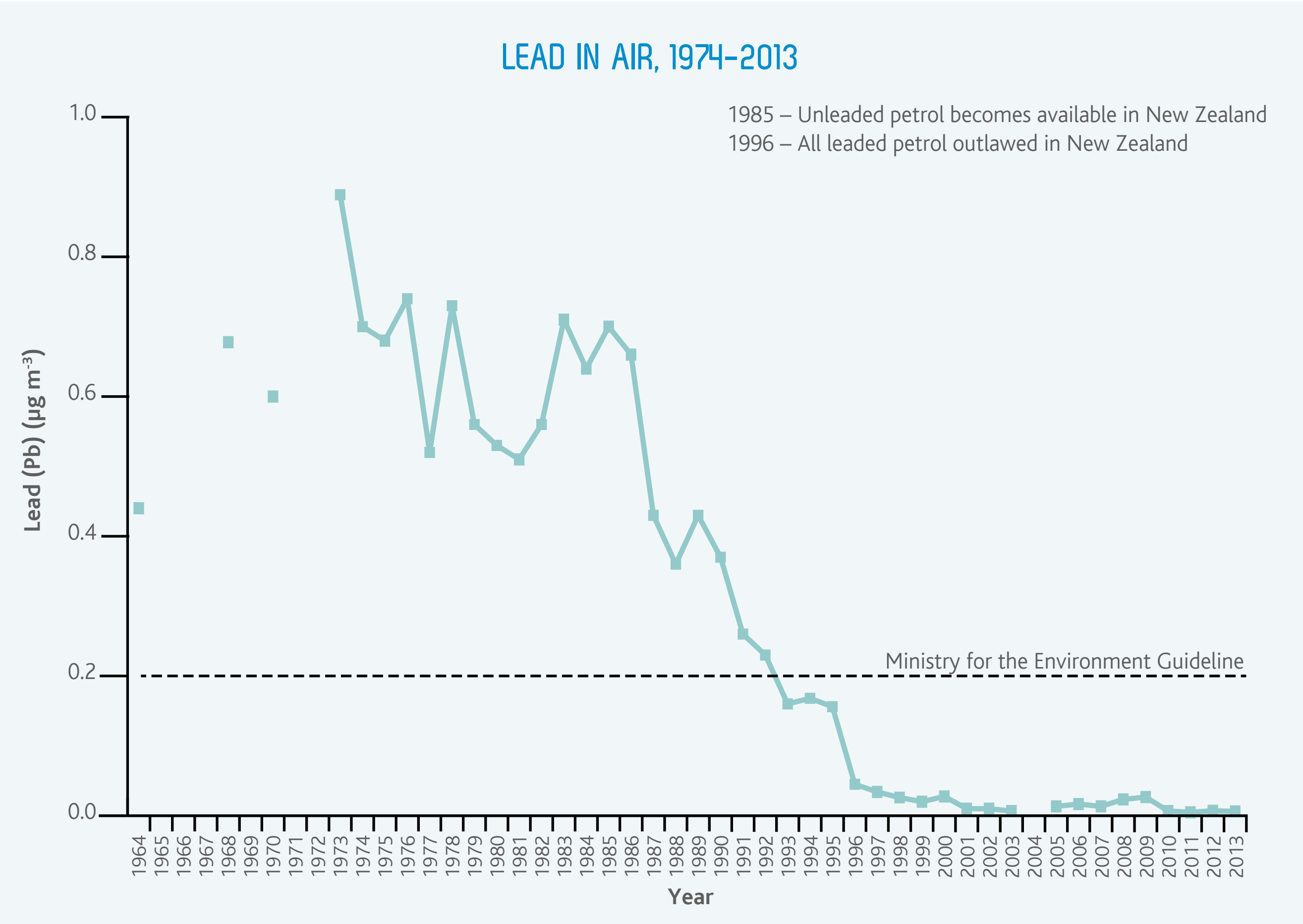


FIGURE 1: Lead in air, 1974-2013. Composite data from three sites in Penrose.

LEAD IN THE SEA: WHAT'S HAPPENING IN OUR ESTUARIES

Lead contamination is not confined to the land, so the marine sediment contaminant monitoring programme looks at what is happening in the sea. This provides information on how urban estuaries have responded to this significant lead source control intervention (see the sediment contaminants indicator). The story is again very positive, as data from this programme shows that concentrations of lead in estuary sediments have gradually decreased at most monitoring sites since 1998 when the monitoring began (figure 2). At some sites the trends may be too small or too short to be confident that they are 'real'. However, those trends that are large and consistent enough to be considered environmentally significant, are all decreases. Some of the largest decreases in lead have occurred at sites with the highest concentrations, particularly in estuaries with runoff from older industrialised catchments such as the Whau Estuary and Māngere Inlet (figure 2 and 3). This indicates that the more highly contaminated areas are recovering faster than less contaminated areas, but recovery is still considered slow. Once contaminants are in the environment it can take a long time to remove them, even when major sources are removed. That's why it's always better not to let them enter the environment in the first place!

DEALING WITH EMERGING POLLUTANTS

The management and resulting decrease of lead in the environment shows it is possible to reduce our impact on the environment through source control and intervention. Lead was once widely used in a range of products and applications and was considered safe. However, when studies and research showed exposure caused considerable

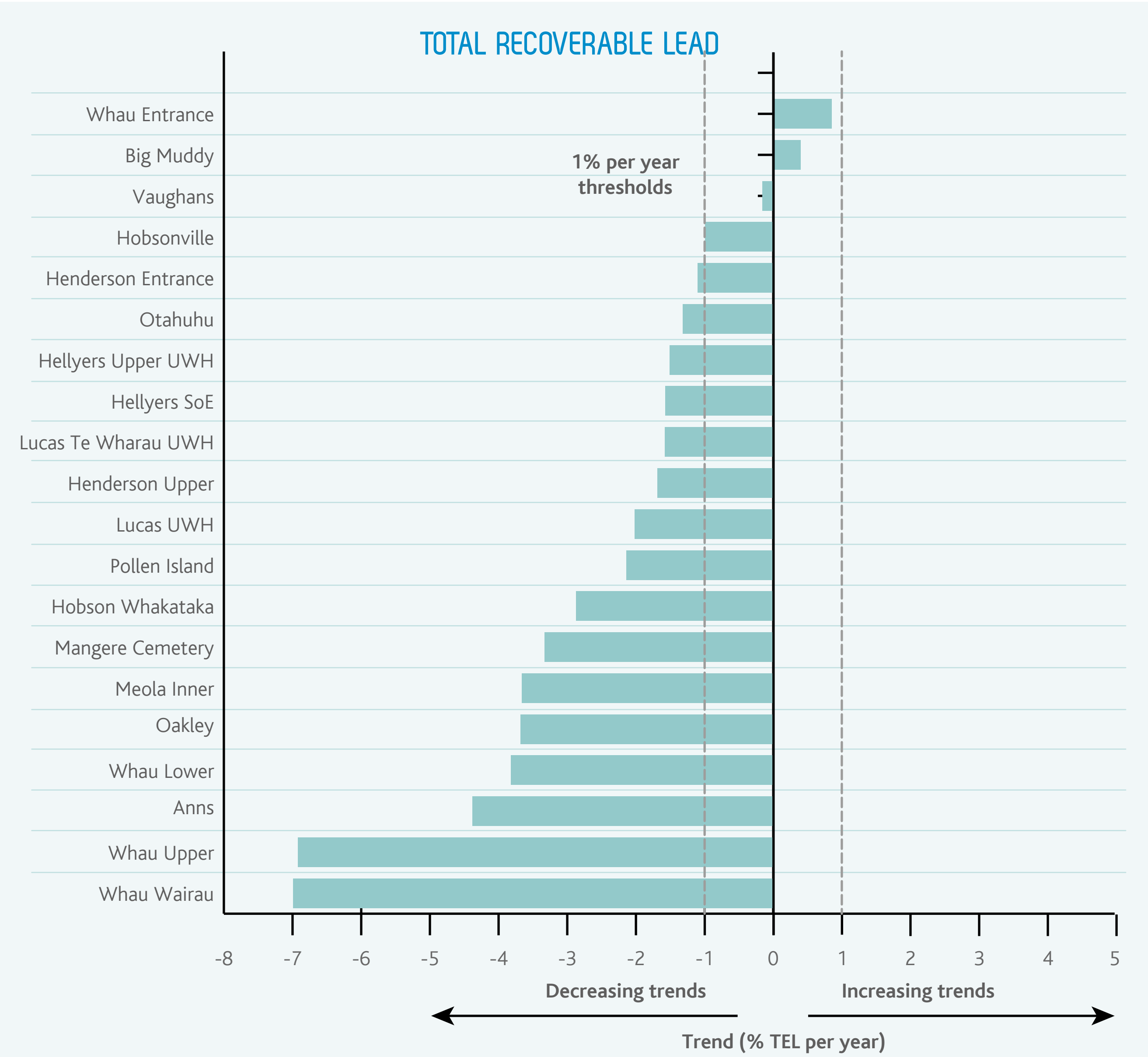


FIGURE 2: Trends in total recoverable lead (in the <500 µm sediment fraction) at sites where statistically significant changes have occurred. Trends are expressed as a percentage of the Threshold Effects Level (TEL) for each metal per year. A ±1% trend level is shown on the plots; trends less than this are unlikely to be of environmental significance.

health problems, New Zealand set out to reduce lead, and has been making great gains at achieving this goal.

While we have been getting a grip on lead, people produce, consume and use many other chemicals and synthetic compounds in their everyday lives. Some of these are currently monitored, but new contaminants from new products and processes could also begin building up in the environment, potentially causing adverse ecological or human health effects. These substances include such things as hormone system disruptors from some plastics, nanoparticles, pharmaceuticals and personal care products. As yet we aren't really sure about their effects and so we're investigating our options to monitor and better understand them. This is another reason why long-term monitoring of the environment is critical – we can use our data to investigate how changes in the resources and products we use translate into effects on the environment. That's also why these programmes need to be flexible and future-focused, so we can respond to changes in pressure on the environment as they arise.

For more information on the sources of lead in Auckland, see: Kennedy, P. and Sutherland, S. (2008): Urban Sources of Copper, Lead and Zinc. Auckland Regional Council Technical Report 2008.

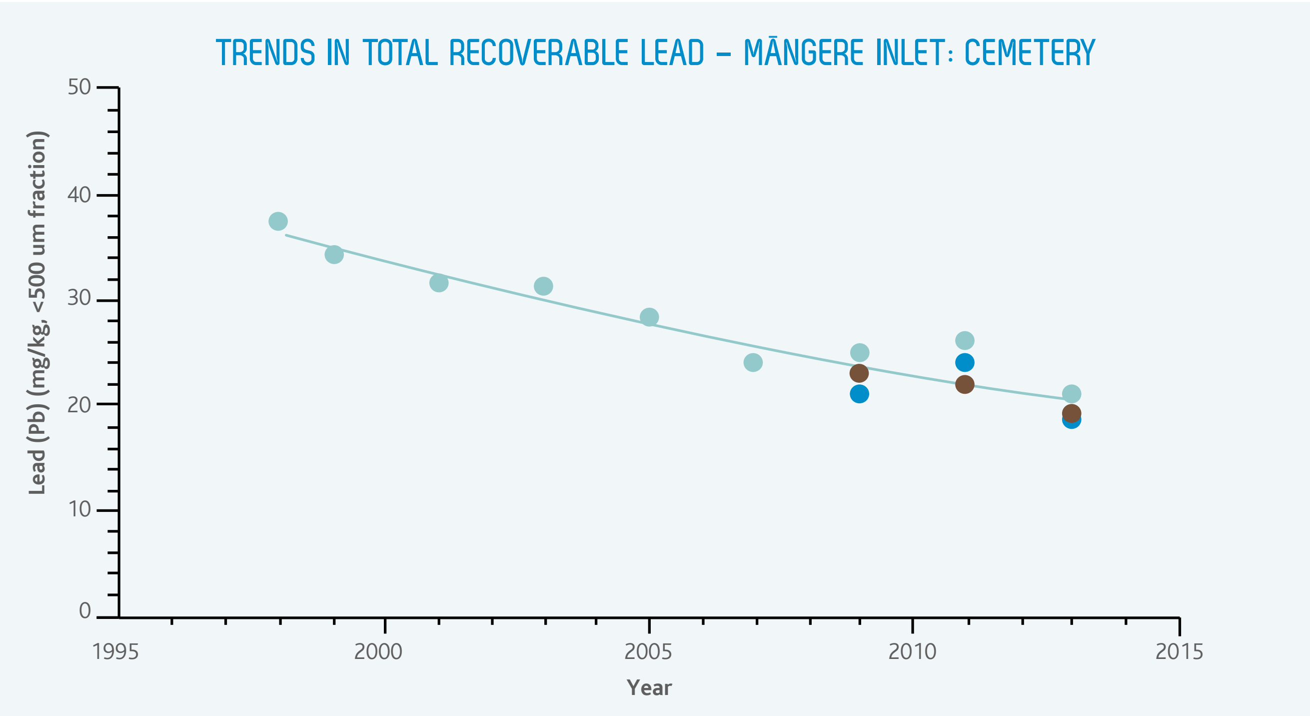


FIGURE 3: Trends in total recoverable lead concentrations (in the <500 um sediment fraction) at the Māngere Inlet Waikaraka Cemetery monitoring site 1998-2013. Years with more than one sample have different coloured dots.

References:

2. Tong, S., von Shirnding, Y. and Prapamontol, T. (2000): Environmental lead exposure: a public health problem of global dimensions. Bulletin of the World Health Organisation 78:9.
3. Centers for Disease Control and Prevention, National Center for Environmental Health (CDC). (2009): Fourth national report on human exposure to environmental chemicals.
4. United States Environmental Protection Agency (USEPA). (2006): Air quality criteria for lead. EPA/600/R-5/144aF. Research Triangle Park, NC. Retrieved from **ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=459555**
5. Spivey, A. (2007): The weight of lead: Effects add up in adults. Environmental Health Perspectives 115.
6. Pirkle J., Brody D., Gunter E., Kramer R., Paschal D., Flegal K. and Matte T. (1994): The decline in blood lead levels in the United States. The National Health and Nutrition Examination Surveys (NHANES). JAMA 1994, 272.
7. Stromberg U., Schutz A and Skerfving S. (1995): Substantial decrease of blood lead in Swedish children, 1978-94, associated with petrol lead. Occupational and Environmental Medicine. 52:11
8. Thomas V., Socolow R., Fanelli J. and Spiro T. (1999): Effects of reducing lead in gasoline: An analysis of the international experience. Environmental Science and Technology 33.
9. Walmsley T, Grant S, George P. (1995): Trends in adult blood lead levels in New Zealand, 1974 -1994. NZ Public Health Report 1995, 2:81-82.
10. Wilson, N., and Horrocks, J. (2008): Lessons from the removal of lead from gasoline for controlling other environmental pollutants: A case study from New Zealand. Environmental Health 7:1.
11. United Nations Environment Program (UNEP) (2002): Target 2008: Global elimination of leaded petrol. United Nations Environment Program, Nairobi, Kenya. Retrieved from: **unep.org/transport/pcfv/PDF/LeadReport-Brochure.pdf**
12. United Nations Environment Program (UNEP) (2014): Leaded petrol phase-out: Global status February 2014. Retrieved from: **unep.org/Transport/PCFV/pdf/Maps_Matrices/world/lead/MapWorldLead_April2014.pdf**

CASE STUDY: VEHICLE EMISSIONS

AUCKLANDERS NEED TO BREAK THE CAR HABIT TO MEET EMISSIONS TARGETS

Measuring vehicle emissions

Nine out of ten Aucklanders drive to work and no other cities can beat this record. This is damaging our health, the environment and our reputation as a liveable city. Our air monitoring programme suggests that although we have made promising reductions, we will need to break our car habit to meet the targets in the Auckland Plan and the Proposed Auckland Unitary Plan.

WHY WE NEED TO BEAT OUR CAR HABIT

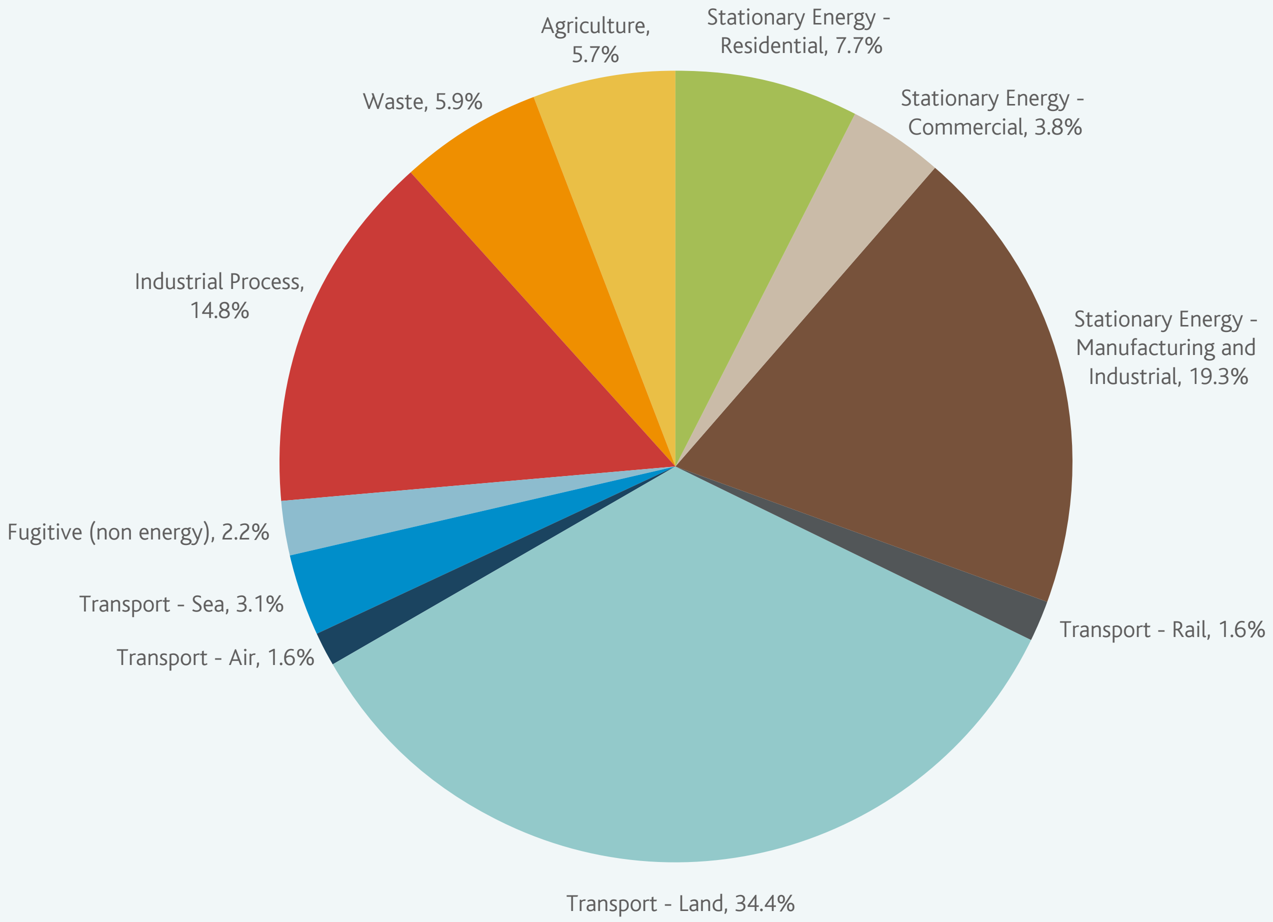
It is estimated that around 120 premature deaths occur in Auckland each year due to air pollution from vehicles, with an estimated social cost of $466 million per year. Vehicles are also the largest contributor to Auckland's greenhouse gas (GHG) emissions, making up more than a third of the region's total[1].

The Auckland Plan lays out a commitment and foundation for Auckland to be the world's most liveable city, with bold targets for reducing particulate matter (PM) emissions and GHG emissions (see Targets box opposite).

Over the past 15 years significant reductions have been made to particulate pollution from vehicles. This is mostly thanks to an increase in the efficiency of engines and

References:
1. Auckland Council (2014): Auckland's Energy Resilience and Low Carbon Action Plan.

AUCKLAND'S GREENHOUSE GAS (GHG) EMISSIONS PROFILE



cleaner fuels, enforced by regulations. But there are limits to this approach. As Auckland grows, the number of cars will too. There is a limit to how efficient you can make each car.

To meet the targets we will need to address our car habit and drive less.

OUR AIR MONITORING PROGRAMME – A MAP TO ACHIEVE OUR TARGETS

Over the past two decades, Auckland Council has been closely monitoring vehicle emissions. We have built up a robust long-term dataset that allows us to analyse trends, measure the result of policies and interventions, and evaluate progress towards our targets.

Monitoring provides a map to help us plan and navigate a path to reach our targets.

TARGETS

PM_{10}

- Reduce PM_{10} emissions by 50% by 2016 based on 2006 levels
- Reduce a further 20% by 2040.

Greenhouse gas

- Reduce GHG emissions by 40% by 2040 based on 1990 levels.

The Auckland Low Carbon Action Plan sets out the pathways and specific actions to achieve the targets. Targets have also been set to reduce the contributions from transport, which is the largest source of GHG emissions.

Measuring vehicle emissions

WHAT HAVE WE DONE?

Measuring vehicle emissions is a difficult challenge. Pollution in the air can come from many sources. To isolate the contribution from vehicles we need some very smart equipment. In our air monitoring programmes we use three methods:

REMOTE SENSING OF ON-ROAD VEHICLE EMISSIONS

This is the most direct measure. It uses a clever machine that sits right next to the road and uses laser beams to selectively measure emissions from vehicle exhaust pipes. It measures:

- carbon monoxide (CO)
- nitric oxide (NO)
- unburned hydrocarbons (HC)
- opacity (uvSmoke) as an indicator of fine particulates.

To find out which factors influence emissions most, we match the measured emissions to vehicle characteristics such as mileage, fuel type and year of manufacture.

This research programme is led by the National Institute of Water and Atmospheric Research Ltd (NIWA), which owns the equipment. This is a robust method to study vehicle emissions. It is co-funded by Auckland Council, NZ Transport Agency (NZTA), Ministry of Transport (MoT) and NIWA. It began in 2003 and has run three campaigns in 2005, 2009 and 2011[2], plus another one this year.

FINDING OUT THE ORIGIN OF PARTICULATE POLLUTION

This monitoring programme tells us what proportion of particulate pollution comes from vehicles, compared with other sources such as wood burners or even sea spray.

The research is conducted by the Institute of Geological and Nuclear Sciences Ltd (GNS Science) with funding from Auckland Council. The analysis requires an even more sophisticated machine that measures the elemental concentrations of the particles. Then a computer model is used to identify different sources of the particles. Samples are collected at five sites around Auckland: Queen Street, Khyber Pass Road, Penrose and Takapuna ($PM_{2.5}$ and PM_{10}), and Henderson (PM_{10} only).

The programme has been running for eight years over four to five sites across Auckland[3]. We now have a comprehensive dataset that allows us to analyse trends over time. This kind of information is very important to understanding the contribution of different pollution to human health, and effectively establishing reduction policies.

EMISSIONS INVENTORY

The third method uses data from NZTA's vehicle emissions model and Auckland Council's transport model to work out how much people are using their cars and the average distance they travel. This allows us to estimate vehicle emissions for specific years and make projections for the future[4].

GREENHOUSE GAS INDICATORS

The Auckland Low Carbon Action Plan sets out indicators for the contribution of Auckland's vehicle fleet to greenhouse gas emissions, including:

- vehicle kilometres travelled (VKT) per capita
- fossil fuel sales (including petrol and diesel).

More GHG is produced when we drive more and use more fuel. We collate VKT data from MoT and fuel data from Auckland Transport.

WHAT HAVE WE FOUND?

EMISSION REDUCTIONS FOR AUCKLAND'S VEHICLE FLEET

Figure 1 shows the results of the remote sensing programme. All of the measured emissions have fallen significantly for petrol vehicles since monitoring began in 2003 – a very encouraging result!

The results were less conclusive for diesel vehicles, although we did observe slight reductions in carbon monoxide and particulate pollution.

EMISSIONS HAVE PLATEAUED SINCE 2009

After dramatic improvements from 2003 to 2009 average emissions now appear to have plateaued. This is likely due to older vehicles remaining in the fleet, not being replaced by more efficient ones. This result flags a concerning issue. There is only so much change you can make by improving the efficiency of vehicles and fuel. As we reach the limits of this approach and the number of vehicles continues to rise, we will need to think of new ways to reduce emissions.

DOWNWARD TREND FOR PARTICULATE POLLUTION

Our second monitoring programme, analysing the origin of particulate pollution, showed an overall reduction in particulate emissions from the exhaust of the entire vehicle fleet over the last eight years. While the contributions from petrol vehicles have remained stable, those from diesel have gone down.

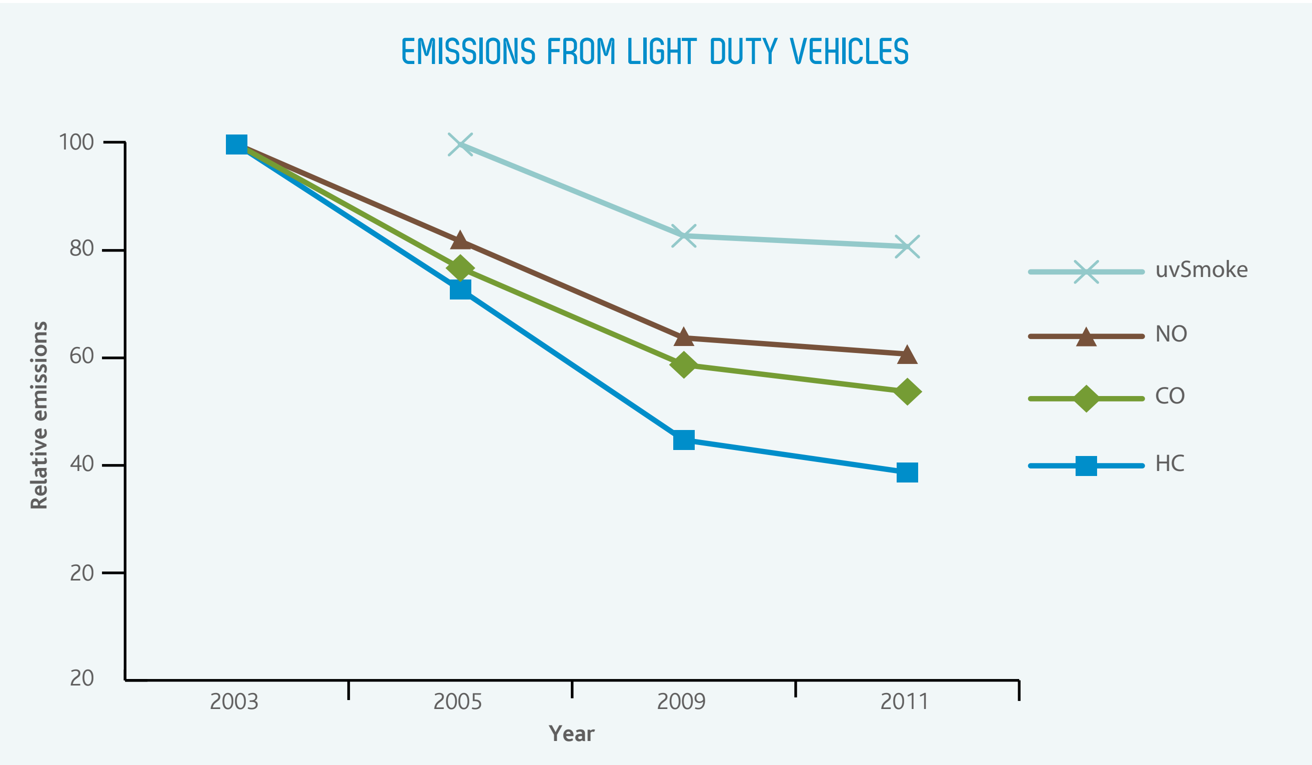


FIGURE 1: Trends of petrol vehicle emissions from the on-road remote sensing monitoring programme. For comparison, emissions of CO, HC and NO are scaled to 100 for 2003 and the uvSmoke result is scaled to 100 for 2005.

References:
2. Kuschel, G., Bluett, J. and Unwin, M. (2012): Trends in light duty vehicle emissions 2003 to 2011. Prepared by NIWA and Emission Impossible Ltd for Auckland Council. Auckland Council technical report TR2012/032.
3. Davy, P.K., Ancelet, T., Trompetter, W.J., Markwitz, A. (2014): Source apportionment and trend analysis of air particulate matter in the Auckland Region, GNS Science Consultancy Report 2014/194.
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DOWNWARD TREND IN FINE PARTICULATE POLLUTION ($PM_{2.5}$) FROM DIESEL VEHICLES

At three of the four test sites, Khyber Pass Road, Queen Street and Penrose, we observed a downward trend for $PM_{2.5}$ (figure 2) (Note that the trend at Penrose is for all motor vehicles, as the datasets here don't allow us to separate diesel vehicles from petrol vehicles). This widespread reduction is most likely due to fleet emission improvements. The one exception was Takapuna, where the trend is upward. This is most likely due to an increase in diesel vehicles in the area. This highlights a potential problem: the particulate pollution could go up again with more diesel vehicles on the roads despite the technological improvements.

MIXED RESULT FOR PM_{10} POLLUTION FROM DIESEL VEHICLES

Results for PM_{10} (larger particulate pollution) are less positive. We observed a downward trend at Penrose and Queen Street, which is positive, but apparent increases at Khyber Pass Road, Henderson and Takapuna (figure 3). These may be due to an increase in diesel vehicle numbers at Henderson and Takapuna and increased contributions of re-suspended road dust around the three sites. The trends at Penrose and Henderson are for all motor vehicles as from the dataset we are not able to separate diesel vehicles from petrol vehicles.

PROJECTIONS FALL SHORT OF TARGETS

Figure 4 shows the results of our third monitoring method using inventory data. The dotted trend line shows that our projected emissions reductions will fall short of the Auckland Plan target by 30%. This has important implications for the ability of Auckland Council to comply with the National Environmental Standard for PM_{10}.

WE DRIVE LESS BUT POLLUTION HAS INCREASED

Figure 5 shows how on a per capita basis the average Aucklander drives less now than a decade ago. Unfortunately this small improvement has been swamped by increases in the population and total number of vehicles. As a result the total vehicle kilometres travelled (VKT) have increased[5].

FUEL SALES ARE NOT DECLINING

Despite efforts to reduce vehicle use, the overall sales of petrol and diesel[6], and therefore greenhouse gas emissions from this fuel use, have hardly changed. Figure 6 shows the Auckland Low Carbon Action Plan's target and the sales over the past six years.

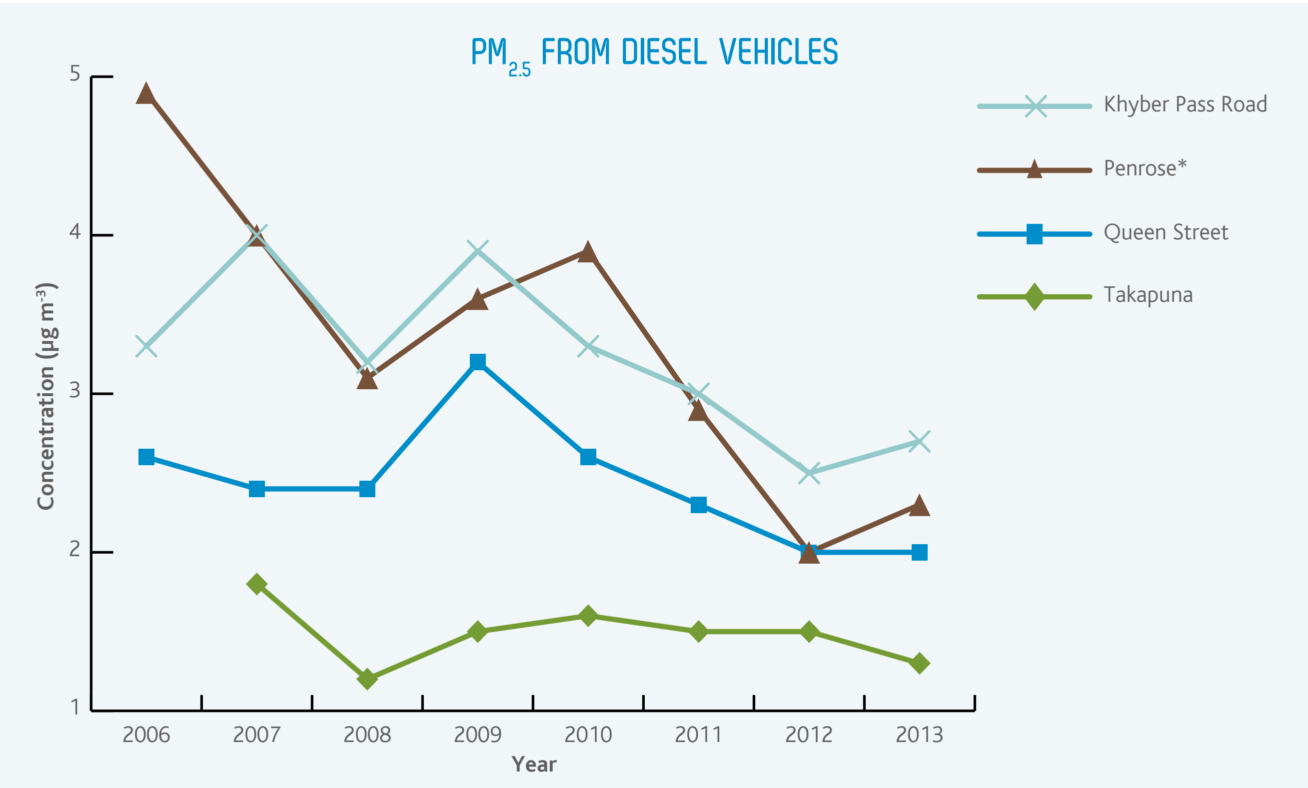


FIGURE 2: Trends of $PM_{2.5}$ from diesel vehicles. *The trend at Penrose is for all vehicles.

References:
5. Vehicle kilometres travelled (VKT) data were sourced from Ministry of Transport transport.govt.nz/ourwork/tmif/transport-volume/tv001/.
6. Fuel sales data were provided by Auckland Transport.

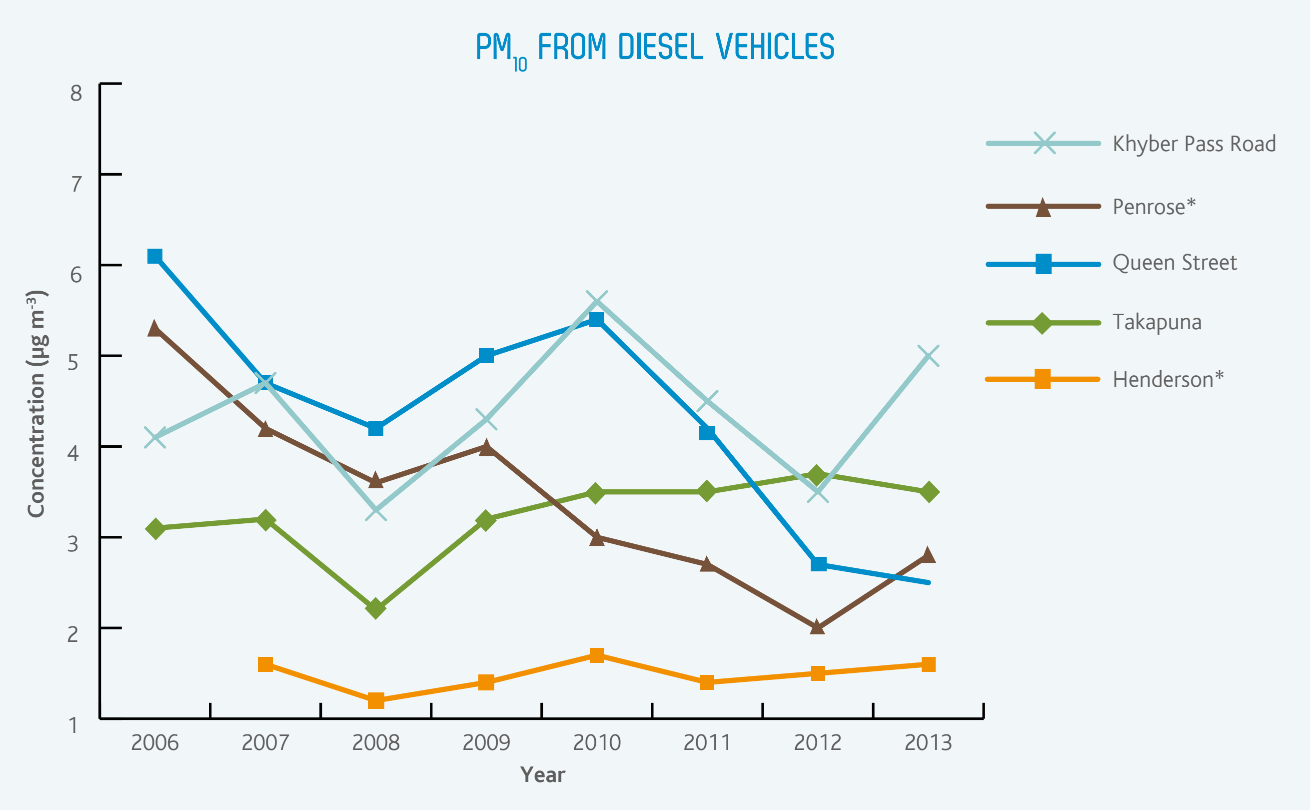


FIGURE 3: Trends of PM_{10} from diesel vehicles. *The trends at Penrose and Henderson are for all vehicles.

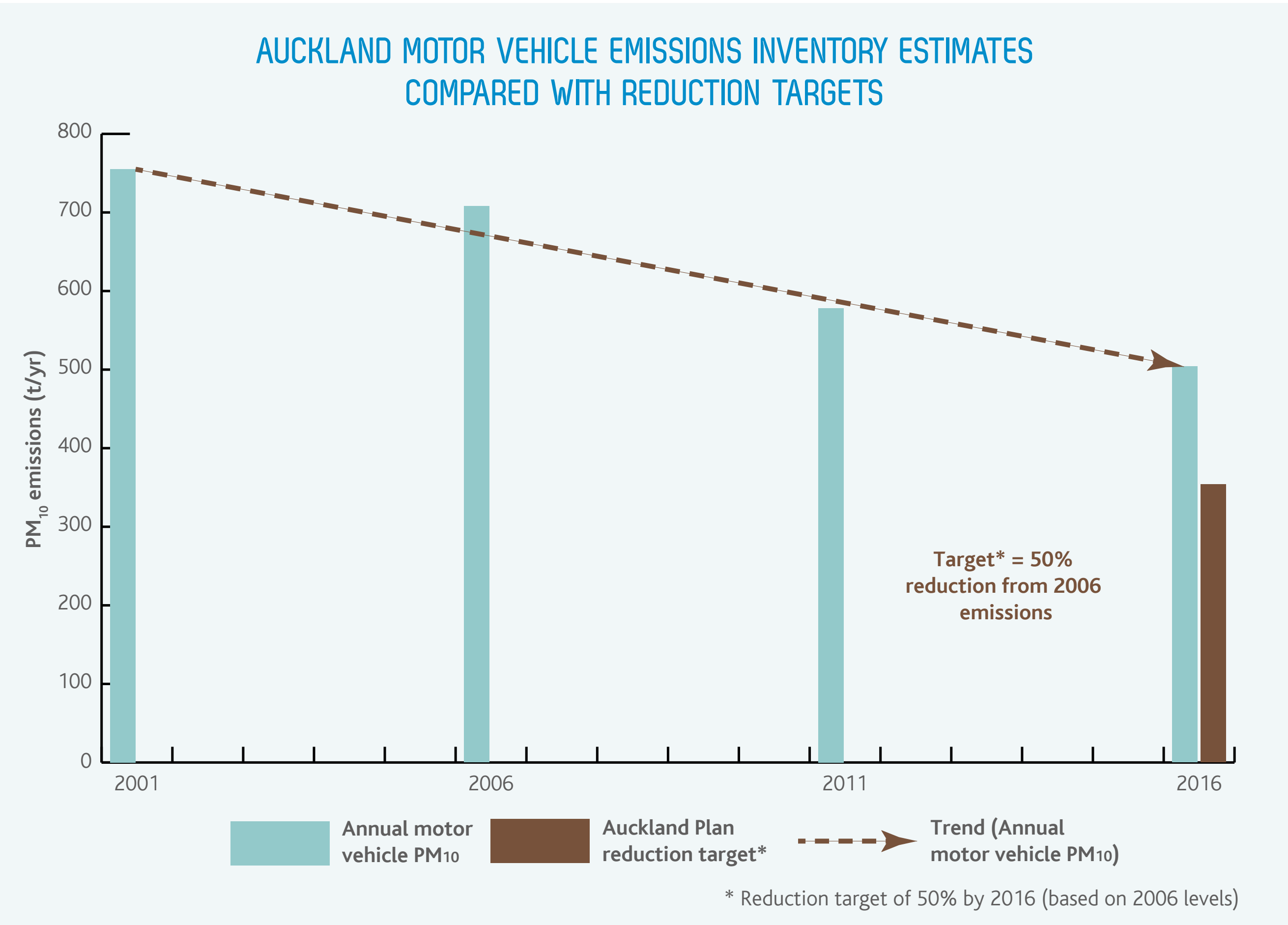


FIGURE 4: The vehicle PM_{10} emissions projections compared with Auckland Plan's emissions reduction target.

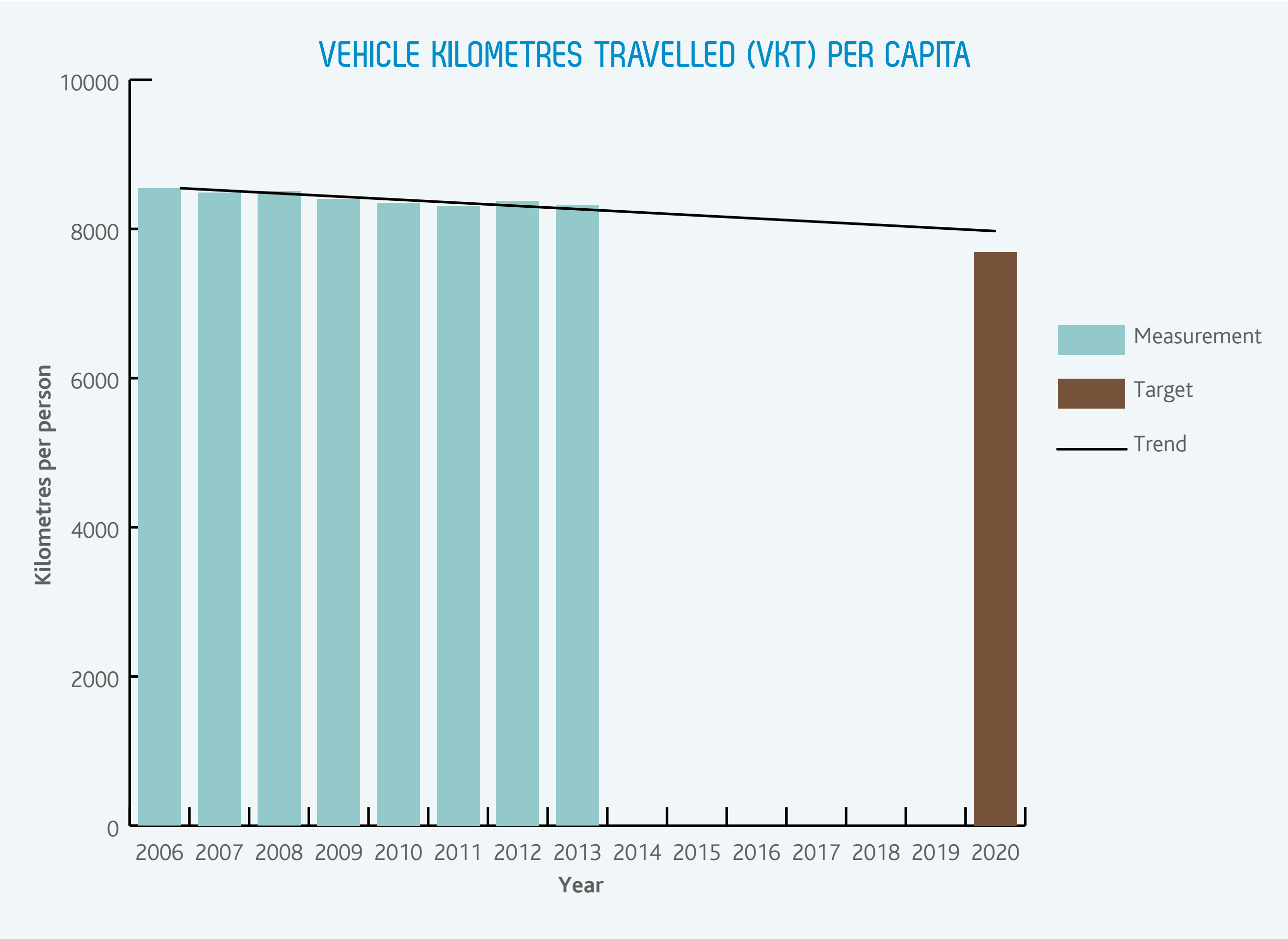


FIGURE 5: The vehicle kilometres travelled (VKT) per capita and the target of the Auckland Low Carbon Action Plan.

Measuring vehicle emissions

DIESEL AND PETROL SALES

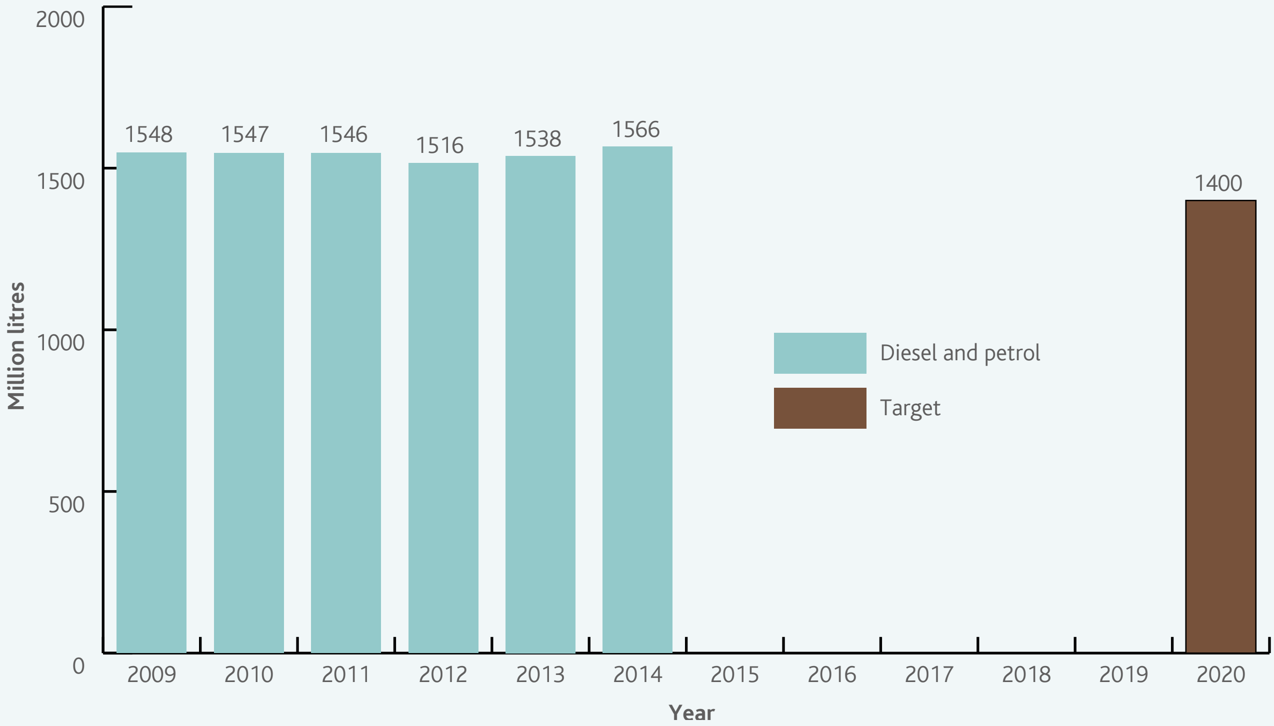


FIGURE 6: Sales of petrol and diesel and the target of the Auckland Low Carbon Action Plan.

EMISSIONS REDUCED: HOW DID WE DO IT?

How did Auckland reduce its emissions?

HERE ARE SOME REASONS:

- **Cars are becoming cleaner and more efficient.** This is an international trend reinforced by our government, which has set emissions standards.
- **Petrol and diesel are becoming cleaner**. Companies have put the work in to clean up their fuel with pressure from stricter government fuel standards.
- **More people are taking the bus.** Much of this is thanks to efforts to improve public transport and initiatives such as the walking school buses, which encourage children to walk to school.

Overall, travel per person has reduced. So we are on the way, but still need more of the combined effort of the commuters, the government, the oil companies and Auckland Council to achieve our emissions targets.

IN SUMMARY
TE KĀPUINGA

Auckland has an excellent natural advantage, a climate which promotes dispersion, no long-range sources and low concentrations of them outside the urban area. In general Auckland's air quality is good, with pollutants generally below guidelines, standards and targets. However, from time to time these are breached, so we need to keep up the good work to continually improve our air quality. This needs all of us to work together to reduce our impact on the environment.

Particulate matter in our air is usually at low levels, as described by our Air Quality Index. We're looking at using this index to report our data in real time, to everyone. Aucklanders would be able to stay informed about the concentrations in the city, and make decisions about their daily activities. We're doing well with PM concentrations, with all but one site meeting our annual average target in 2013. We need to find ways to reduce the exceedances of standards we record from time to time, and to ensure our concentrations continue to decline.

Our NO_2 concentrations are highest where lots of vehicles are concentrated, such as the CBD and Newmarket. Concentrations in these areas are usually below exceedances and guidelines, but as Auckland grows, and more and more vehicles continue using our roads, they may increase. See opposite for some simple steps to take – we can all help!

We've made fantastic progress since 2002 with our benzene concentrations. They declined from over three times the guideline at our peak monitoring site, and have remained below or close to below the guideline since 2008. This is great news for our air quality, and for all of us as it reduces the impact on our health. We have to be careful though – it won't take much to reverse these gains. Similarly, we have achieved incredible results with lead concentrations in our air – they're now significantly below the guidelines, having been dangerously high in the past. It shows if we control the sources carefully, we can make a real difference.

Overall, our air quality meets environmental standards and guidelines at most locations for most of time. It has improved greatly in the last decades as a result of effective air quality management. However, we still need to improve our air further for better health benefits for Aucklanders.

WHAT CAN YOU DO TO HELP?
ME PĒHEA TŌ ĀWHINA MAI

As Auckland grows and develops, more pressure will be put on our air quality. With more vehicles on our roads, more people living in Auckland and more industry, we will need to find new ways to manage our air quality. Every Aucklander can help! Here are some simple things everyone can do.

IN WINTER

- Operate your wood burner responsibly – burn dry, untreated timber, and remember that a smoky fire gives off less heat and wastes fuel. Don't burn rubbish or treated timber.
- Consider more efficient ways to heat your home – such as insulation and heat pumps.
- Investigate options to retrofit your home with cleaner technologies. Search Retrofit_Your_Home for details at **aucklandcouncil.govt.nz**

ALL SEASONS

- Keep your car tuned and running smoothly.
- Consider leaving the car at home and walk or cycle.
- Take the bus, train or ferry where possible.
- Consider carpooling to work.

CASE STUDY: STUDENT VOICE

OUR YOUNG PEOPLE – THE FUTURE GUARDIANS OF THE ENVIRONMENT

Drawing by Sam, Christ The King Catholic School

Environmental monitoring is a long-term game. By working with children and young people, Auckland Council hopes to inspire a generation with the passion and knowledge to care for our environment.

Nature doesn't work to human time scales. To answer the really important questions about our environment we have to unravel the complex patterns of weather, water, land and air. And for that we will need datasets spanning decades or even centuries. As Auckland expands and the pressure of environmental change and development intensifies, this work will become increasingly important.

Not only will our children and young people inherit the environmental problems we create, they will also acquire the responsibility to understand and solve them. Auckland Council is involved in a range of educational projects and activities to inspire and support children and young people.

“Put children and young people first and consider their well-being in everything that we do.”

THE AUCKLAND PLAN - DIRECTIVE 1.1

“We are environmental stewards – future generations will depend on how we manage the natural environment.”

THE AUCKLAND PLAN - CHAPTER 7

“Dramatically accelerate the prospects of Auckland's children and young people.”

THE AUCKLAND PLAN - SECTION 3.1.

ENVIROSCHOOLS – OUR CHILDREN TAKING ACTION

Auckland Council coordinates the Enviroschool programme throughout the region. Enviroschools is a nationwide not-for-profit trust, which supports young people to work together to regenerate our communities and ecosystems. Through this programme we support 197 early childhood centres and primary, intermediate and secondary schools. That covers almost 30% of the schools in Auckland and over 95,000 students. Students are supported to take action across a range of environmental restoration and monitoring projects – many in collaboration with the council.

FUTUREINTECH – SCIENTISTS IN SCHOOLS

Through this programme, run by the Institute of Professional Engineers (IPENZ), our scientists visit students at school and share experiences of what scientists do day to day. They also spend time discussing their interests and the potential of a career in science.

> Futureintech is an invaluable opportunity to connect our students with motivated and passionate scientists from a range of careers. The feedback from students and staff has and continues to be universally positive with the talks from FutureIntech Ambassadors not only raising awareness of scientific careers but also of the environmental issues that invited speakers tackle as part of their day to day roles and responsibilities.
>
> JAMES HENEGHAN, HEAD OF SCIENCE, TAKAPUNA GRAMMAR

Milford Kindergarten – planting trees

Learning Through Experience programme – investigating invertebrates

Learning Through Experience programme – detecting animal pests

Christ the King Catholic School student drawings – what I like to do in Auckland's environment

SPONSORING THE ANNUAL AUCKLAND CITY SCIENCE AND TECHNOLOGY FAIR

Every year, years 7 to 13 primary and secondary school students prepare scientific and technology investigation projects in response to an observation or a hypothesis. As well as providing monetary prizes, Auckland Council offers one prize winner a day as a scientist in the field. After spending the day stomping through mud, hiking to sites in a forest, identifying bugs in a stream or dashing over a harbour in a boat, the stereotype of the boring labcoat scientist is thoroughly gone and children get an experience of the excitement of real-life science.

Here's what some of the winners told us about their experience:

Tama Elliott – 2013 Scientist For a Day prize winner helping monitor water quality

> Thank you so much for this amazing prize that I have received at the Auckland Science and Technology Fair... It is definitely rewarding to spend a whole day with a scientist and see what it takes to be in this field of work. I am also excited to experience the interesting things and cool people that they get to work with daily. This prize has really given me a boost of confidence and encouragement to help me continue with my interest in science.
>
> BINH-MINH HA (2011)

> I am writing to acknowledge you and the rest of the Environment Department's generosity for awarding me and my friend, George, a Special Prize... I have always had a passion for science, and you've further encouraged me to continue with it through college, university, maybe even for a career! It is great to know that there are people out there who love science just as much as I do, and care enough about it to donate money for a prize. George and I were so excited to win the Silver Award for the Living World Special Prize for Years 7 and 8... You made all our hard work, effort and input worthwhile.
>
> CAMERON KELSO (2012)

RIMU scientists judging the science fair projects

2013 Auckland Council science fair award winners

SUPPORTING UNIVERSITY STUDENTS

Every summer Auckland Council's Research and Evaluation Unit (RIMU) takes on six university graduate students under the Student Partnership Programme to work with us, carrying out environmental monitoring tasks in the field, lab and office. After the summer we support them through their master's study, helping them to design their research and ground it in real world needs. We do this with a stipend, a science advisor and resources for their research. In return they do a project relating to Auckland's environment in an area of interest to the council. They may use our data and help us answer questions we wouldn't otherwise be able to tackle. It's a win-win arrangement. Since the programme started in 2006 several of the recipients have come to work for us after their university studies, and others are working in different areas of the council. Other parts of Auckland Council also offer similar opportunities.

Auckland Council staff support additional postgraduate masters and PhD students with scientific advice and expertise, and provide data for them to work with. Council staff also present lectures to undergraduate and graduate classes at Auckland's universities.

Here is what some of RIMU's students have had to say:

> It was a real privilege to be involved with RIMU through both work and study. Working with the terrestrial biodiversity monitoring programme I visited a range of forest and wetland environments across the Auckland region, which has inspired me to research the development of plant communities through restoration. The monitoring protocols from RIMU provided a framework for my thesis data collection, which is really useful.
>
> JESS REABURN

> I am researching the long-term trends and drivers of Auckland's coastal sediment with a particular emphasis on climate change. Without the monitoring data provided by RIMU my research wouldn't be possible.
>
> BLAKE SEERS

Jess Reaburn, MSc student, who investigated 'Forest restoration, how long does it take to recreate a native ecosystem from pasture?'

PROVIDING DATA FOR RESEARCH

There are no limits to the way students can use the data we collect on air quality, coasts, oceans, forests, wetlands, wildlife and pests, streams, lakes and our life-supporting soils. By closely aligning with Auckland's tertiary providers we can ensure that research has immediate practical implications for a particular environmental problem or knowledge gap for Auckland.

Our scientists have supported a variety of research projects from tracking seasonal growth of an algae on Great Barrier to the diversity and abundance of plants in urban backyards; from measuring the air quality in our buses to restoring the indigenous ecosystem, māuri and cultural values of Whenua Rangatira.

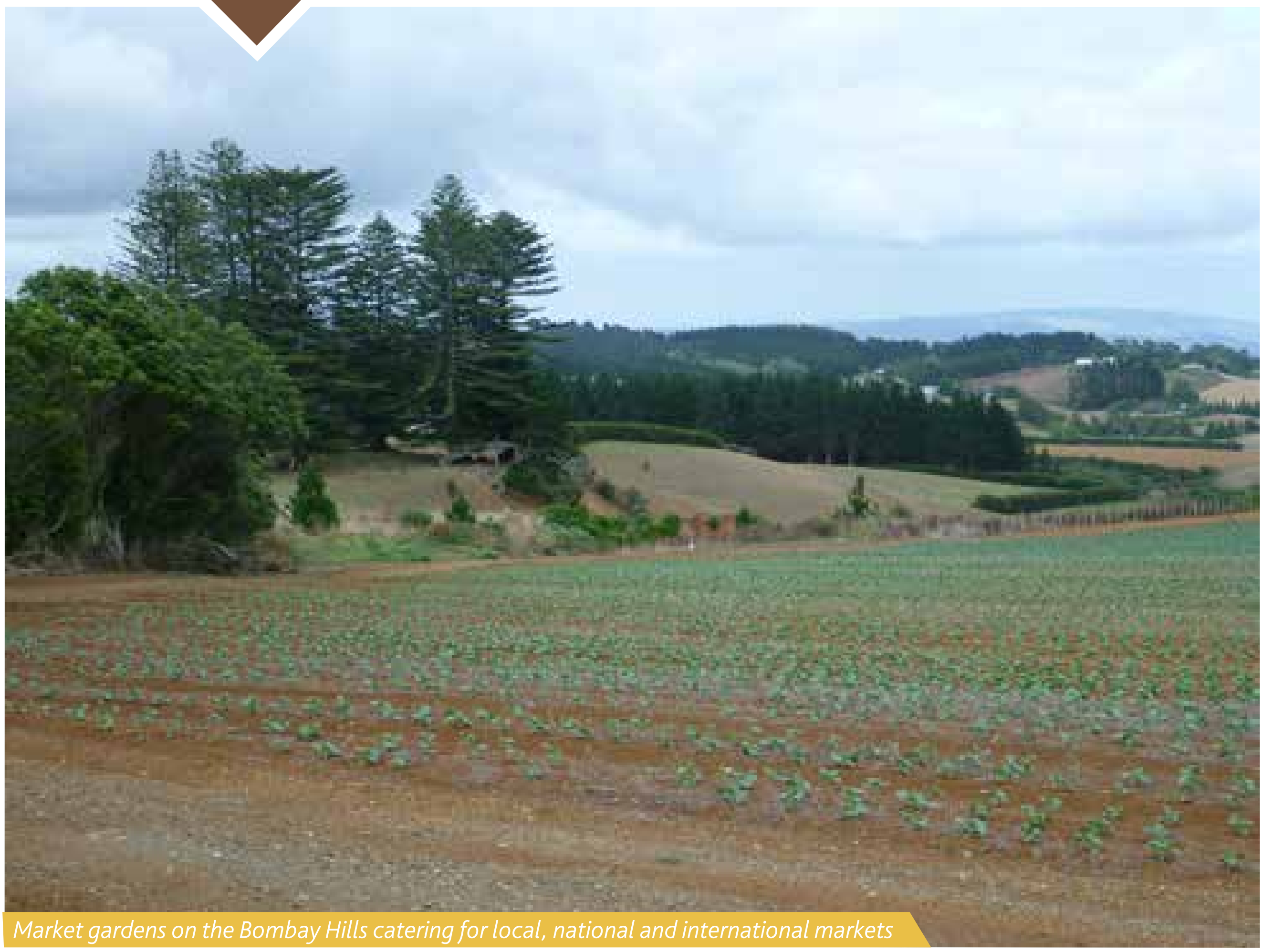
STATE OF ENVIRONMENT REPORT 2015

LAND

WHENUA

Grey warbler perching on a pōhutukawa tree. Photo: Michael Anderson

THE LAND WE LIVE AND RELY ON
TE WHENUA



Market gardens on the Bombay Hills catering for local, national and international markets

Auckland encompasses a diverse range of ecosystems and landforms. The region has about 4520km² of land-based ecosystems on the mainland and 500km² on the islands. An impressive variety of habitats ranges from dunelands and wetlands in lowland and coastal areas to extensive tracts of native forests on the rugged hills and 'mountains' of Te Waonui a Tiriwa and Te Waonui a Mataaoho (the Waitākere and Hunua ranges), and Aotea (Great Barrier) and Hauturu (Little Barrier) islands. Underneath, the ground tends to be made up of soft sandstones and mudstones, interspersed with much harder areas of greywacke and volcanic basalt. The soils lining the generally low lie of the land include some considered to be among the best agricultural resources in the country.

From tiny soil microbes to towering kauri trees, Auckland has amazing terrestrial (i.e. land) biodiversity. It contains at least 37 distinct types of land and freshwater ecosystems[1]. Collectively these ecosystems provide habitat for a wide variety of native plants, animals and microorganisms, most of which are unique to New Zealand. Biodiversity (kanorau koiora) is the word used to describe the sum of all these living parts; it includes the diversity of ecosystems, species within ecosystems and genetic variation within species. There are over 20,000 plant and animal species in the region, including arguably the rarest bird in New Zealand (Tara-iti, New Zealand fairy tern), a remnant population of Kōkako in the Hunuas, and the world's heaviest parrot (Kākāpō) and insect (Wētā punga or giant wētā) on Hauturu (Little Barrier Island). As well, there are a variety of reptiles, amphibians and our only native mammals (Pekapeka, bats). In fact, although Auckland covers only 2% of New Zealand's land mass, it is home to a high number of our threatened species, including about a fifth of the threatened terrestrial vertebrates and plants.

The quality of Auckland's natural environment is consistently ranked by Aucklanders as an integral part of their quality of life and what is great about the region[2,3]. Our land, soil and terrestrial biodiversity are important resources due to their intrinsic cultural and historic value, and the resources they provide which we rely on to live. We need good quality soils to grow our food, clean our water and support our forests, on which we rely for timber. Many of these benefits are linked: a real chicken and egg situation! For example, we need plants and invertebrates (biodiversity) to create soil, and we need soils for growing the plants that support the invertebrates, many of which pollinate the plants. As Auckland continues to grow it will put more pressure on our biodiversity and soil resources, so it is important we safeguard these resources. Biodiversity really is everyone's business, as it extends into all our backyards and neighbourhoods and is affected by nearly all our activities[4].

Safeguarding our land and soil resources means addressing legacy issues and the future challenges presented by our speedily growing city. Our planet has faced decades of persistent loss of biodiversity from human pressures. The main culprits are invasive species, habitat destruction, poor land management and pollution. The loss of indigenous biodiversity has been described as New Zealand's most pervasive environmental issue[5].

Auckland was once almost completely covered with lush forest. However, today less than 30% of the region is indigenous forest and shrubland, with most of the lowland forest fragmented into small patches.

There are still some amazing large tracts of native forest, such as in the Waitākeres, Hunuas and on Great and Little Barrier islands. These are all important reserves for our terrestrial biodiversity, and are nationally and globally significant for the values they protect. However, we shouldn't neglect the smaller patches of native habitat. Often these are remnants of rare and unusual ecosystems in lowland environments largely cleared of their native ecosystems. They can contain plants and animals different from those in the large forest tracts.

Kōkako on a tree fern

To protect and reduce the loss of our terrestrial biodiversity, and uphold the objectives of the Indigenous Biodiversity Strategy[6] and the Auckland Plan, it is imperative we have a good account of the extent and quality of biodiversity across the region. We've been tackling this through an extensive terrestrial biodiversity monitoring programme (TBMP), which provides the indicators and case studies reported here. The data in this chapter is just one part of the council's biodiversity activities. We also put considerable resources into discovering, protecting and managing native biodiversity, and threats to it. Examples include the extensive work of our biosecurity team, prioritised species management, regional ecosystem assessment programmes, and species protection and management in the parks network.

The last State of the Auckland Region report[7] identified the relatively large proportion of threatened species in the region, particularly on our offshore islands, in the Waitākere and Hunua ranges and at South Kaipara Head. Our latest count shows the region has 49 (20%) of New Zealand's threatened terrestrial vertebrate fauna and 169 (19%) of New Zealand's threatened plant species[8]. The major changes to Auckland's threatened terrestrial species since that last regional report are summarised in table 1.

References:
1. Singers N J D & Rogers G M (2014): A classification of New Zealand's terrestrial ecosystems. Science for Conservation 325. Department of Conservation, Wellington. 91 pp.
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COMMON NAME	SCIENTIFIC NAME	THREAT CLASSIFICATION	REASON FOR CHANGE
BIRDS			
Kākāpō	*Strigops habroptilus*	Nationally critical	Reintroduced
New Zealand shore plover	*Thinornis novaeseelandiae*	Nationally critical	Reintroduced
REPTILES			
Forest gecko	*Mokopirirakau granulatus*	Declining	Previously not threatened
AMPHIBIANS			
Hochstetter's frog (Great Barrier group)	*Leiopelma* aff. *hochstetteri* "Great Barrier"	Declining	Taxonomic change (species name split)
Hochstetter's frog (Northland/Warkworth group)	*Leiopelma* aff. *hochstetteri* "Northland"	Declining	Taxonomic change (species name split)
Hochstetter's frog (Waitākere goup)	*Leiopelma* aff. *hochstetteri* "Waitākere"	Declining	Taxonomic change (species name split)
PLANTS			
	Leptinella rotundata	Nationally vulnerable	Rediscovered

TABLE 1: Major changes to threatened terrestrial species in Auckland since the last State of the Auckland Region report[7] as a result of a threat classification change, reintroduction to the region, taxonomic change or a new survey discovery. 'Threat classification' [12, 13, 14].

Auckland Council has implemented a prioritisation protocol to maximise the number of threatened species being managed. The protocol helps assess the minimum effort required to secure the future of each species in the region, the cost and feasibility of management, and the likely success of management interventions. As a result, we are managing 38 species, up from the 14 the Biodiversity Team had targeted. This includes three fish, three lizard, 14 bird, one bat and 18 plant species (figure 1). Additional species are managed at various sites across the region as a result of other objectives, such as managing the suite of biodiversity values within regional parks, and local community initiatives.

The council runs terrestrial biodiversity and soil monitoring programmes across the region to provide data on the state and trends through time. The indicators in this report include:

- Land ecosystems
- Indigenous plants
- Birds
- Pest animals
- Pest plants (weeds)
- Soil health
- Soil trace elements.

The first five indicators relate to data collected in the TBMP, which includes 564 plots systematically established in forest, scrub, shrubland and wetland ecosystems across the region (figure 2). These ecosystems are the TBMP's current focus, as forest and scrub ecosystems are Auckland's dominant type of indigenous terrestrial ecosystem and were also the dominant (about 98% of the landscape) pre-human vegetation cover. Wetlands are one of the most modified ecosystems in the region and are also of key importance in providing a wide range of ecosystem services. We hope to add additional ecosystems (e.g. dunelands) as resources permit.

The TBMP is relatively young, with the first full complement of sites surveyed recently. This has allowed us to report on forest and scrub but not the wetlands, which will be reported on in the near future. For all five TBMP indicators, values have been calculated separately for 12 different parts of Auckland, termed 'ecological neighbourhoods'. These are areas with similar ecology – in other words, similar plants, animals and geological features – and are based on the existing Auckland region Ecological Districts[9,10]. We've made minor amendments to account for recent major changes in development and provide better spatial resolution within the Auckland metropolitan area[11].

The two soil indicators relate to data collected in the soil monitoring programme, which tracks trends over time on the effects of primary land uses on long-term soil quality. The programme's over 160 sites across the region represent the dominant land-use and soil types, such as pastoral (dairy, drystock, lifestyle blocks), exotic (pine) forestry, outdoor vegetable cropping and horticulture, as well as soil quality sites in indigenous bush sites.

The soil programme also contains sites from urban parks and reserves, from which data were first collected in 2012. Before then, the programme was largely focused on rural land, but with Auckland being the largest city in New Zealand, it was considered important to fill the knowledge gap on the status of soil quality sites and trace elements in urban areas.

The data collected across these various land use categories are used to characterise the soil's chemical, physical and biological attributes. Soil samples are collected across

FIGURE 1: *Leptinella rotundata*: This native herb was previously thought to be extinct in the region until 2010 when it was rediscovered in Auckland by Cameron Kilgour, 113 years after it was first found by Thomas Cheeseman. Auckland Council is now actively managing this 'critically threatened' plant species. Credit: Brenda Osborne.

FIGURE 2: A 20 by 20m plot in the terrestrial biodiversity monitoring programme (forest and scrub).

all sites to analyse for differences from natural levels. These may occur as the result of urban, agricultural and horticultural land use activities (e.g. vehicle emissions, fertilisers, grazing livestock and using pesticides).

Auckland Council's terrestrial biodiversity and soil monitoring programmes help us understand the health of our land environment, both the habitats above the surface and beneath in the soil. The indicators and case studies in this chapter provide details of the state of and current issues affecting our terrestrial and soil environments, identifying areas we are succeeding in, as well as those needing improvement.

References:

6. Auckland Council (2012): Auckland Council's Indigenous Biodiversity Strategy. Unpublished Auckland Council report. 42 pp.
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9. Kelly G C & Park G N (1986): The New Zealand Protected Natural Areas Programme. A scientific focus. New Zealand Biological Resources Centre Publication 4. Wellington, DSIR.
10. McEwen W M (ed). (1986): Ecological Regions and Districts of New Zealand (3rd edition). New Zealand Biological Resources Centre No. 5. Wellington, Department of Conservation. 161 pp.
11. The Tamaki Ecological District has been split into two parts: north/ west = urban north and south/ east = urban south. The highly developed parts of Rodney Ecological District, which include Orewa and the Whangaparaoa Peninsula, have been included as part of urban north.
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14. Robertson, H. A., Dowding, J. E., Elliott, G. P., Hitchmough, R. A., Miskelly, C. M., O'donnell, C. F. J., Powlesland, R. G., Sagar, P. M., Scofield, R. P. & Taylor, G. A. (2013): Conservation status of New Zealand birds, 2012. New Zealand Threat Classification Series 4. Wellington: Department of Conservation.

LANDCOVER INDICATOR

OVERALL LANDCOVER IS STATIC BUT SOME PLACES ARE CHANGING RAPIDLY

FIGURE 1: *Native scrub*

Mā te whenua ka ora te tangata, mā te tangata ka ora te whenua – Through the land the people will be nourished, through the people the land will be nourished.

At the regional scale there has been little change in landcover in the last 30 years, but regional averages mask important small-scale changes in some locations.

Auckland's land area, although relatively small, has an amazing diversity of terrestrial (land-based) habitats and ecosystems[1]. This ranges from tiny islets to forested mountaintops, beaches of a thousand colours and forms, diverse and precious wetlands, dunelands in abundance, and pest-free islands of global significance and renown. Measured at the regional level, the percentage landcover of native ecosystems has been quite stable over the last few decades. However, case-study data shows habitat fragments are still disappearing in some of the more intensively developed areas.

WHY DO WE MONITOR LANDCOVER?

The vast majority of native species require native habitat to survive, and these include species found nowhere else in the world. To effectively manage our resources, grow the economy and protect the environment, we need a proper inventory of Auckland's natural asset base.

This indicator's purpose is to provide a snapshot of the extent and condition of that base. Future monitoring will show us how the distribution and composition of our natural assets, measured using landcover (e.g. native forest vs pasture vs built-up urban land), change over time.

Cities are often regarded as 'biodiversity hotspots' because they are usually established in fertile lowland areas where the sea, rivers, and plains coincide[2]. Because fertile lowlands are valued for farming, they are the most highly disturbed and threatened types of ecosystems in New Zealand. For this reason it is particularly important to protect areas of native bush that remain in productive farmland and urban Auckland. Even though they may be small and fragmented, they contain rare species of particular biodiversity value[3,4].

WHAT IS THIS INDICATOR?

This indicator looks at the proportion of the region left in native vegetation cover. It zooms out to give us a broader picture of Auckland's landcover. It tells us the relative proportion of 27 different landcover types present in each of the 12 ecological neighbourhoods (see page 75). To derive a final score for each sub-regional area, the index value based on current landcover is compared to its maximum value (i.e. if all landcover was native) and expressed as a percentage. Results are presented by ecological neighbourhood to better detect change in specific areas of interest or importance.

The indicator is calculated by assigning each of the 27 landcovers a value from 0 to 1, based on their relative value to native plants and animals, protection of freshwater resources, and the level of environmental regulation and cultural values (or Ecosystem Services) they provide. The value of native landcover was set at 1. Medium index values (0.5) are associated with landcover in which native ecosystems are not dominant, but native plants and animals are still present (e.g. exotic forest, mixed exotic shrubland, urban parkland). These areas may also be important for erosion protection, soil formation, recreation, water purification etc. The least natural and/or highest intensity landcover types have low (<0.3) index values (e.g. transport infrastructure, built-up area, short rotation cropland).

HOW DO WE MONITOR TERRESTRIAL LANDCOVER?

This indicator uses the New Zealand Landcover Database (LCDB) version 4 as the base landcover map for the Auckland region. The LCDB is a map of the landcover of New Zealand, based on remote sensing of satellite imagery. It is funded by central government and provides the basis for better resource management decisions, more effective use of natural resources and improved environmental management. LCDB4 is based on 2012 satellite imagery and will be compared with future LCDB re-measures as they become available, probably every five to 10 years. There are two past versions of LCDB comparable with the LCDB4 data: 2001 (LCDB2) and 2008 (LCDB3).

Region-wide mapping of landcover using LCDB is supplemented with field-based mapping of landcover in sensitive locations and where LCDB does not have sufficient resolution to detect landcover change. In the last five years Auckland Council has more closely studied recent small-scale landcover change within the Waitākere Ranges Heritage Act Area[6] and the old North Shore City boundaries[7].

WHAT HAVE WE FOUND?

A map of different landcover types in Auckland is presented in the introduction to this report. Figure 5 shows the wide variations in landcover composition across the region. The results indicate that some ecological neighbourhoods (especially urban south) are acting as resource sinks, drawing on the food, freshwater, water supply, watershed protection, and air purification provided by other parts of the region (and the wider world).

In contrast, those parts of the region dominated by large tracts of indigenous forest are providing an abundant habitat for native plants and animals, and clean air and fresh water that is available to the rest of the region. Native-dominated, sub-regional areas include Aotea (Great Barrier), Hauturu (Little Barrier) and Waitākere ecological neighbourhoods. The other ecological neighbourhoods in the region are all largely rural. Their scores on this index are based on the general intensity and inputs of their farming systems, which are in turn based on the fertility and usefulness of the land for farming. On this basis, Hunua > Rodney > Kaipara > Āwhitu > Ōtamatea > Manukau.

Figure 2 shows the percentage breakdown of the most important landcover types in Auckland. Generally, about half of the region is exotic pasture associated with sheep and beef or dairy farming, about a quarter is characterised by mature indigenous forest or indigenous scrub (figure 1) that is regenerating towards mature forest (figure 3), and the remaining quarter is everything else.

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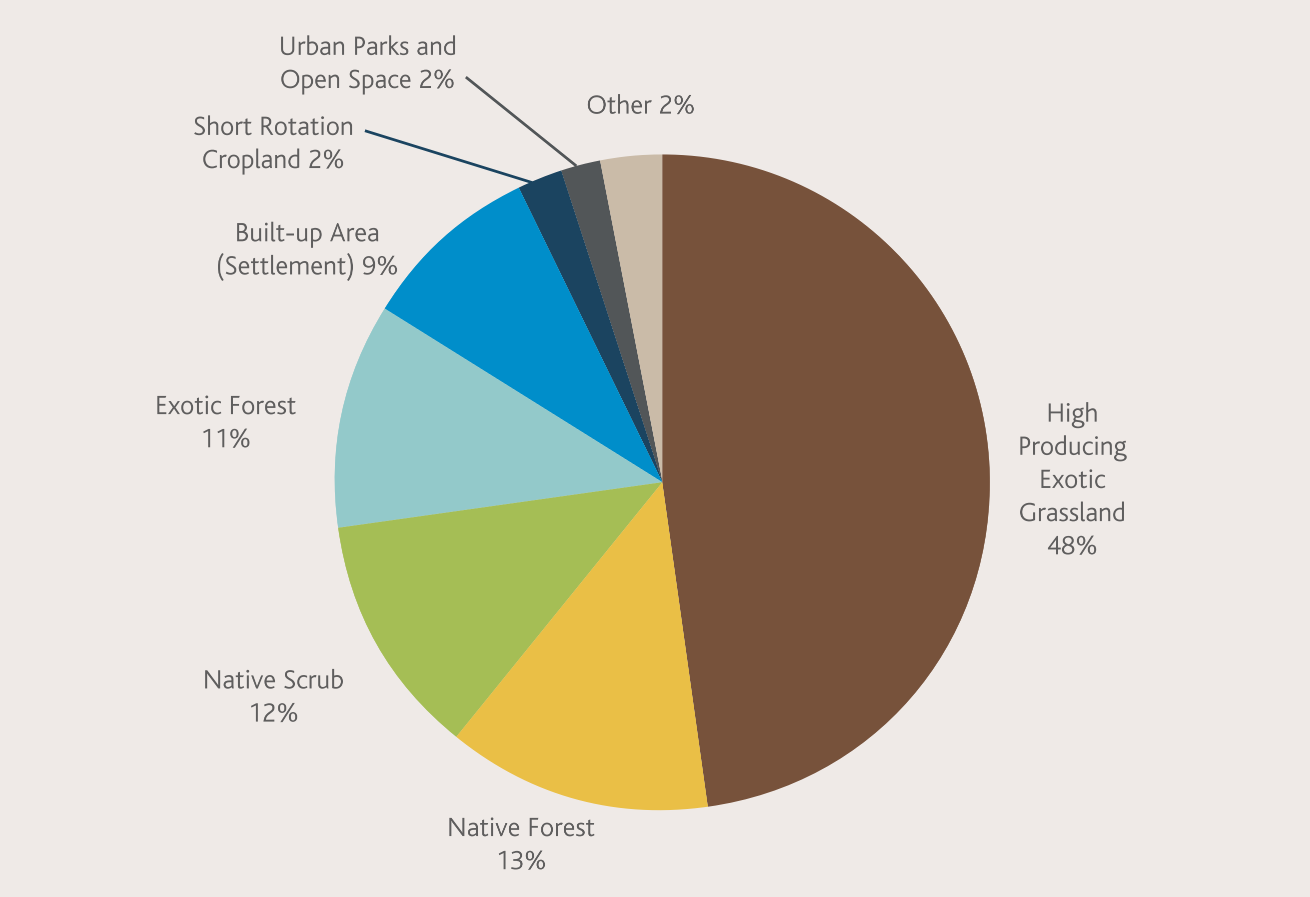

FIGURE 2: Auckland's landcover types.

HOW HAVE THINGS CHANGED?

At the regional scale, there has been relatively little change in the average landcover, as measured using this index, over the last 15 years (figure 4). These results imply that past land management regulations and practices have resulted in a stable pattern of landcover types whose relative proportions are being maintained over time. While there has been limited recent clearance, native ecosystems have been almost totally cleared in the past from some parts of the region; e.g. Manukau ecological neighbourhood has only 1.2% native forest cover. So the scattered and highly valuable remnants that remain are protected from further clearance by their location in reserves and/or by council rules.

However, studies of landcover clearance at the smaller scale have recorded higher rates of landcover change than those detected using the LCDB. For example, the actual clearance of forest and scrub vegetation in the Waitākere Ranges Heritage Act Area between 2001 and 2008 was 10 times higher than LCDB analysis suggested, although still relatively small at 0.03% of indigenous habitat/year[6]. Loss of forest and scrub vegetation within North Shore City from 2001 to 2008 measured using aerial photograph analysis was 50% higher than that recorded by LCDB analysis[7].

FIGURE 3: *Mature indigenous forest, Aotea (Great Barrier Island)*

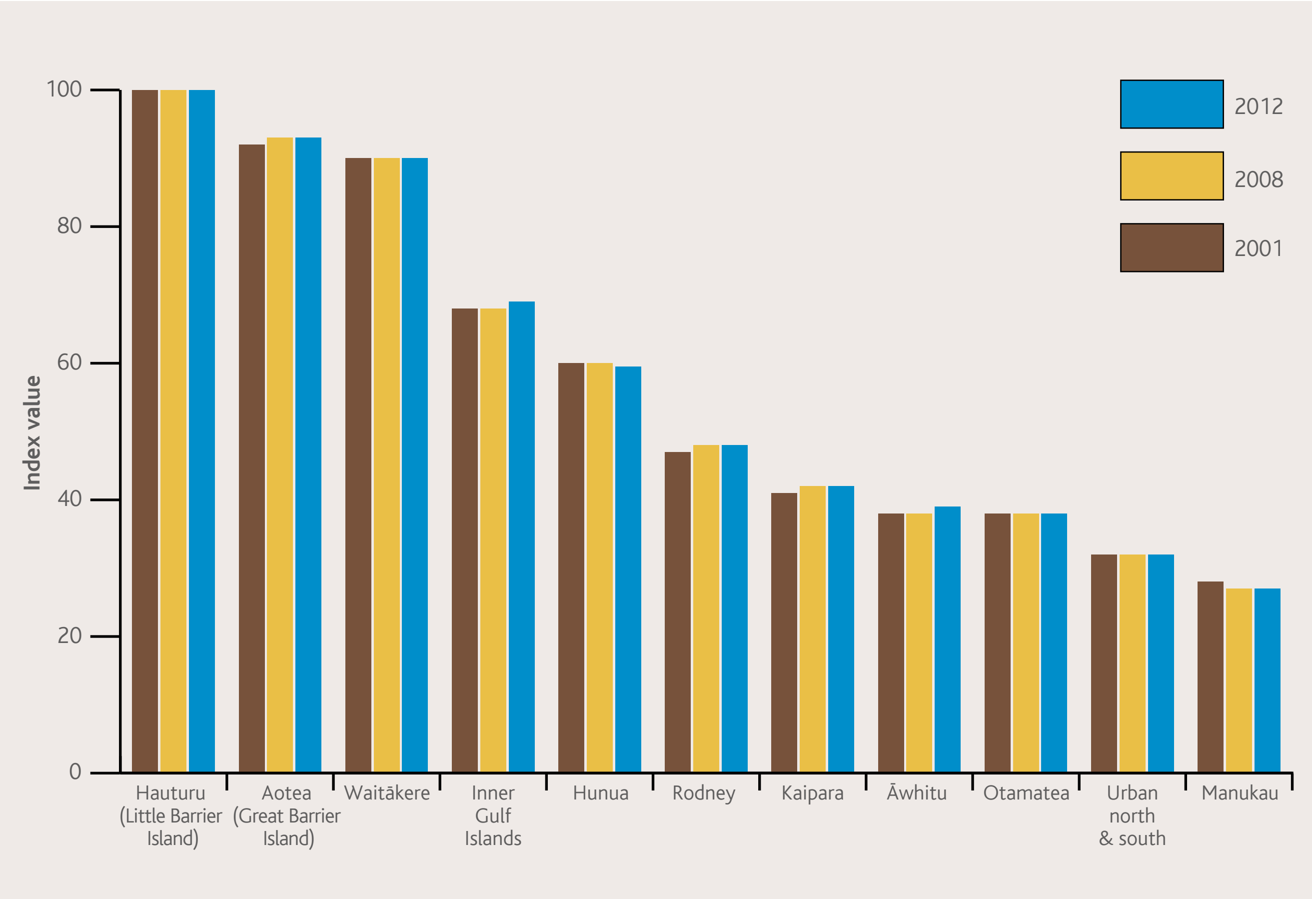

FIGURE 4: Change in extent and quality of native landcover in Auckland's ecological neighbourhoods 2001-2012.

This data suggests locations with intensive development pressure and biodiversity values require higher resolution and more targeted monitoring for timely detection of landcover changes.

The low rate of change in landcover from 2001-2012 doesn't mean the current landcover of Auckland is the same as the historical picture. Remote sensing landcover data was first collected in 1991, and we don't have a good picture of the rate of vegetation loss before this date.

It is clear from historic aerials, written descriptions and oral history that there have been massive changes in Auckland's landcover from pre-human times through to the 1970s and 80s[8]. However, this data does show the pace of this change slowed dramatically in the late 20th and early 21st centuries. Existing areas of native habitat are being maintained or increased in size with further restoration planting around their margins.

Figure 4 shows there has been little change in the average proportion of different landcover types over the last 15 years or so. But the ecological neighbourhoods are so large that the absolute change is significant for some areas. For example, urban north and south were the ecological neighbourhoods that recorded the greatest landcover change between 2001 and 2012. The main trend was for high production pasture, forest and scrub, and low stature exotic landcover to be replaced (2500ha lost over 11 years) by built-up urban area and transport infrastructure (+ 2220ha).

One pleasing outcome of all the restoration and enhancement work by the council and community groups over the last 15 years has been the increase (+ 400ha) in native ecosystems in the Auckland urban area. This has mostly come about through expansion planting around the margins of larger native remnants, and removing exotic forest and scrub and replanting with native forest plants.

References:

7. W Wright, R Simcock, C Bishop, M Brown. (2014): Vegetation cover changes with urban expansion and intensification in North Shore City 2001 – 2008, the impacts of vegetation protection provisions. Unpublished internal Landcare Research report.
8. Lindsay H, Byers S, Wild C. (2009): Auckland Protection Strategy. Nature Heritage Fund, Wellington, 82 pp.

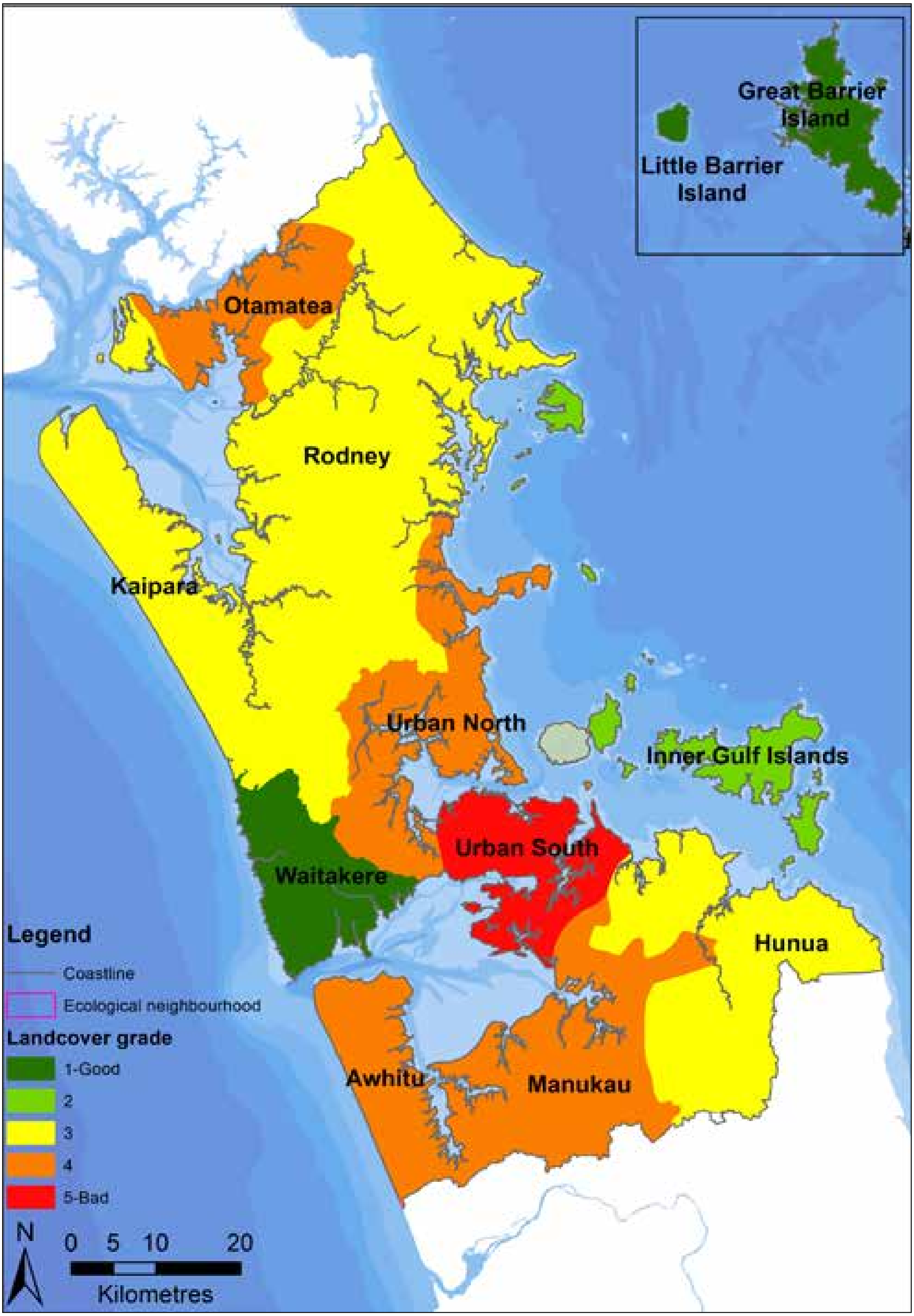

FIGURE 5: Landcover grade for Auckland's ecological neighbourhoods.

BIRDS INDICATOR

RESTORATION EFFORTS ARE BRINGING BACK THE BIRDS

New Zealand storm petrel in the Hauraki Gulf. Photo: Neil Fitzgerald

SPOTLIGHT: SEABIRD HOTSPOT

Auckland is internationally recognised as a 'seabird hotspot' as a result of the tremendous seabird diversity in our coastal waters, namely the Hauraki Gulf. Consequently, virtually all of Auckland's sea areas have been identified as Important Bird Areas[1]. Of the 86 seabird species which breed in New Zealand, 27 breed in Tíkapa Moana, (the Hauraki Gulf), four of these exclusively there[2].

One of the most exciting conservation stories in the last couple of decades has been the rediscovery of the New Zealand storm petrel *(Fregetta maoriana)* in the Hauraki Gulf (figure 5), a seabird presumed extinct for 108 years. Thanks to the efforts of a large group of collaborators, we were able to locate the breeding colony on Hauturu (Little Barrier Island) using state-of-the-art tracking gear, and are now working to secure the future of this endangered species[3]. The council is also designing and implementing a seabird monitoring programme across the region.

Have you ever wondered how many bird species are in Auckland's forests? Or how many native species there are compared with introduced birds in your neighbourhood? With the recent comprehensive forest, scrub and shrubland bird survey across the region you can find out. The survey took place over five years and reveals that Auckland has a wide diversity of birds, with native species the most common across many of the Hauraki Gulf islands as well as several mainland areas. Find the bird hotspots here!

WHY DO WE MONITOR BIRDS?

The enchanting raspy call of the tūī, the fluid notes of the korimako (bellbird), the haunting night-time call of the ruru (morepork). New Zealand has always belonged to the birds and when we hear their song we know we are home.

We are all aware of the beauty and cultural significance of birds, but we may not be aware of the silent ecosystem work they do, such as dispersing seeds and pollinating plants. They are also a great tool for measuring the health of our natural environment and its biodiversity, as they are relatively conspicuous and easy to identify.

Birds are a good indicator of ecosystem quality and condition as they are high up the food chain. If birds are doing well, it's likely that the bugs, worms, plants and other life forms they feed on down the chain are doing well too.

To protect our rare and invaluable birds from the pressures of urbanisation and human development, we need to take a systematic approach. This first baseline survey gives us a roadmap by which to track changes in bird communities, to help us improve Auckland's indigenous biodiversity.

THE AUCKLAND PLAN-STRATEGIC DIRECTION 7: ACKNOWLEDGE THAT NATURE AND PEOPLE ARE INSEPARABLE

Auckland Council's Indigenous Biodiversity Strategy vision is to see healthy and diverse ecosystems of plants and animals, where these ecosystems are functioning, threatened species are flourishing in natural habitats, and nature is connected across Auckland in linkages and sequences.

WHAT IS THIS INDICATOR?

The birds indicator tells us which are the most common birds seen/heard in native forest, scrub and shrubland ecosystems in the region and identifies the percentage of native to introduced species in different areas. Using bird data collected across the region as part of the terrestrial biodiversity monitoring programme (TBMP), this indicator summarises the state of the bird communities in each of the 12 ecological neighbourhoods (see page 75). Each area is scored on the average number of native and introduced bird species found there, with the highest scores for areas with mainly native species and lower scores for areas with mainly introduced birds.

HOW DO WE MONITOR BIRDS?

From 2009 to 2013 we collected 963 bird counts at 330 sites in forest, scrub and shrubland ecosystems across the Auckland region. Collecting data during each summer, we conducted three 10 minute bird counts (based on the Department of Conservation (DOC) national protocol), where an experienced birder identified all birds seen or heard during this period.

WHAT HAVE WE FOUND?

As one of the most comprehensive bird surveys ever to be completed in Auckland, it has an interesting story to tell.

HERE ARE SOME OF THE KEY FINDINGS:

- 61 different bird species were detected across Auckland
- 37 of those were native
- 21 of these bird species are endemic to New Zealand, meaning they are natives found nowhere else
- 17 were 'threatened' or 'at risk' species.

TOP 10 SPECIES

When looking at the total numbers of individual birds observed, half of the top 10 most common birds were natives, and the top three were all natives (figure 1):

- Tūī
- Grey warbler (Riroriro)
- Silvereye (Pihipihi).

NATURALNESS – NATIVE VERSUS INTRODUCED SPECIES

In terms of naturalness, which essentially means how close things are now in comparison with before humans arrived in New Zealand, we are mostly concerned with the amount of native versus introduced species.

NATIVE SPECIES

Not surprisingly the highest numbers of endemic birds (birds only found in New Zealand), such as tūī, grey warbler, New Zealand fantail (Pīwakawaka) and kererū (New Zealand pigeon), were found on island sites, where native species outnumbered introduced species (figure 2). This is likely a result of the amazing efforts of restoration teams enhancing their habitats, such as by controlling pests.

INTRODUCED SPECIES

There were similar numbers of introduced species across rural and urban sites, with less in the large tracts of mainland forest (e.g. Waitākere and Hunua).

RESTORATION EFFORTS ARE WORKING!

If we take a closer look on the map (figure 4), which is broken into the 12 ecological neighbourhoods, we see that the highest scoring areas are on Little Barrier (Hauturu) and Great Barrier (Aotea) islands, and in the larger mainland park areas in the Waitākere and Hunua ranges (figure 3). These areas tend to have large tracts of high-quality habitat and many have extensive pest animal management in place by the community, DOC and the council. So these data likely reflect the success of these conservation programmes (to find out more see the pest animals indicator, page 86).

One of the next major challenges for Auckland will be to make more restoration gains on the mainland. Just imagine what the bird life could be if we all helped to reduce the threats to our birds! Have a look at what you can do on page 124. The council will continue to keep a close eye on our birds as we repeat our bird counts over the next five to 10 years.

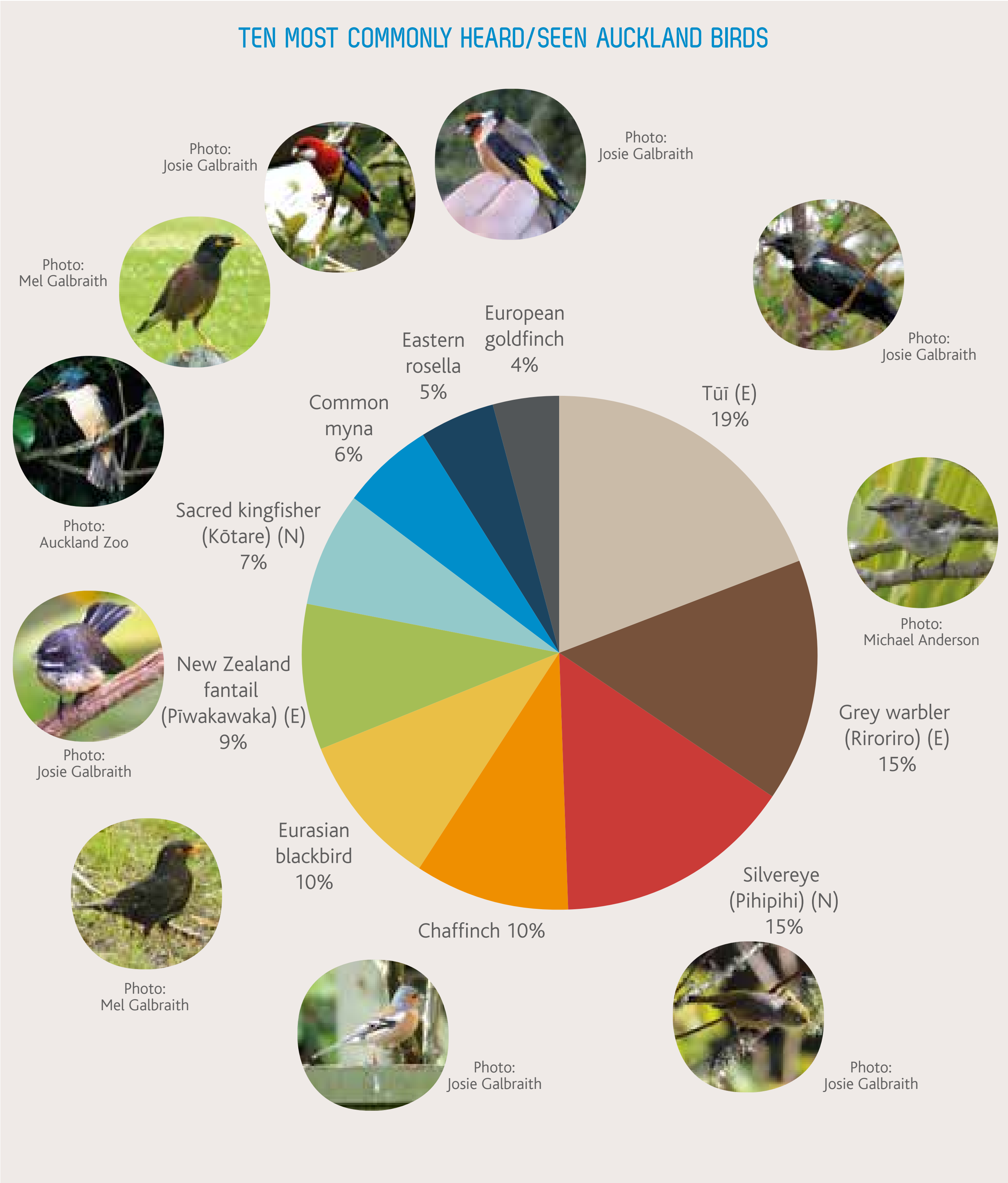

FIGURE 1: Ten most common birds heard/seen in counts at native forest, scrub and shrubland sites across Auckland. N = Native, E = Endemic (found only in New Zealand).

References:
1. Forest & Bird. (2014): New Zealand Seabirds: Important Bird Areas and Conservation. The Royal Forest & Bird Protection Society of New Zealand, Wellington, New Zealand. 72 pp.
2. Gaskin, C. P., and M. J. Rayner. (2013): Seabirds of the Hauraki Gulf: Natural History, Research and Conservation, Hauraki Gulf Forum, 141 pp.
3. Rayner, M.J., Gaskin, C.P., Fitzgerald, N.B., Baird, K.A., Berg, M., Boyle, D., Joyce, L., Landers, T.J., Loh, G., Maturin, S., Perrimen, L., Scofield, R.P., Simm, J., Southey, I., Taylor, G.A., Tennyson, A.J.D., Robertson, B.C., Young, M., Walle, R. & Ismar, S.M.H. 2015. Miniaturised radio telemetry to discover endangered seabird breeding grounds: a case study of the New Zealand storm petrel *Fregetta maoriana*, Ibis.

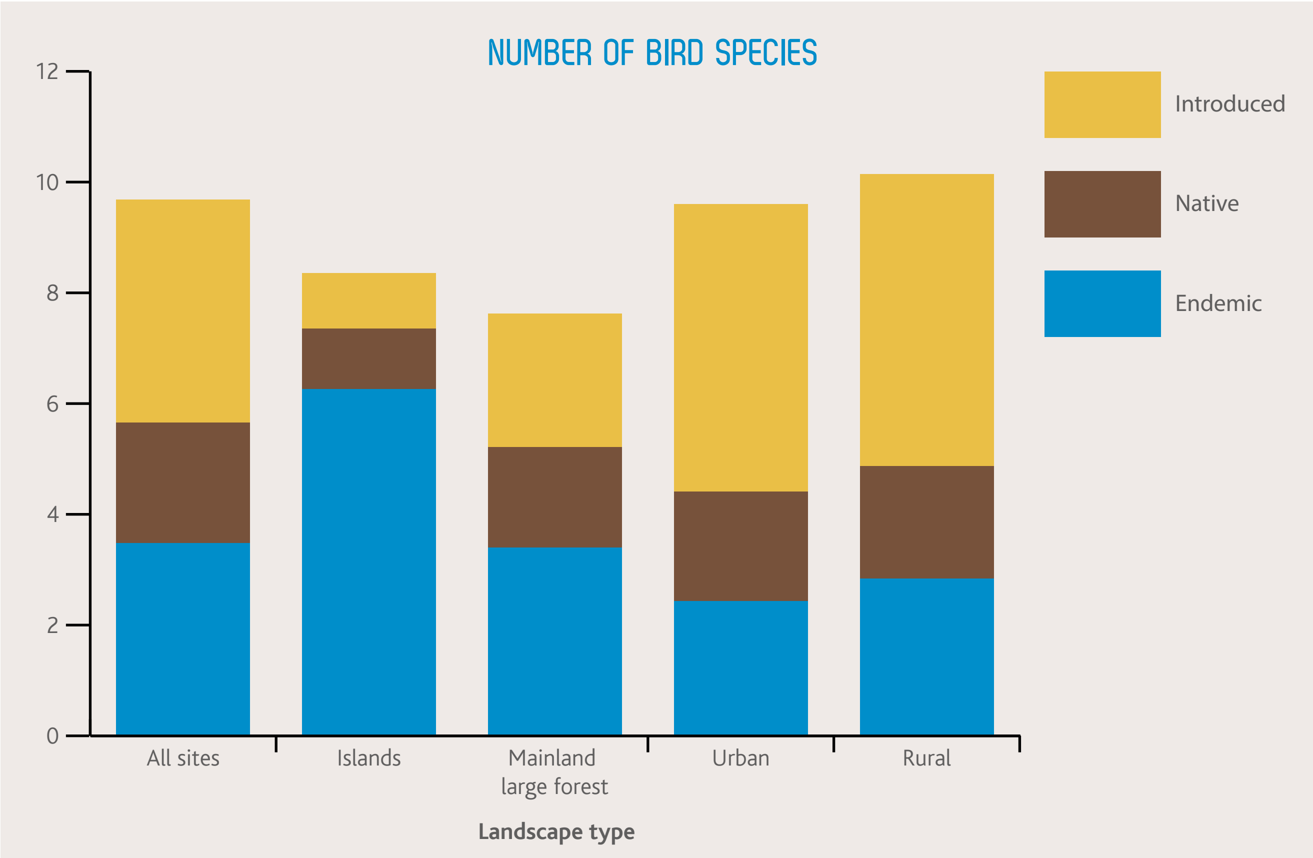

FIGURE 2: Average number of bird species heard/seen in counts at native forest, scrub and shrubland sites across Auckland, grouped by landscape type, 2009-2014.

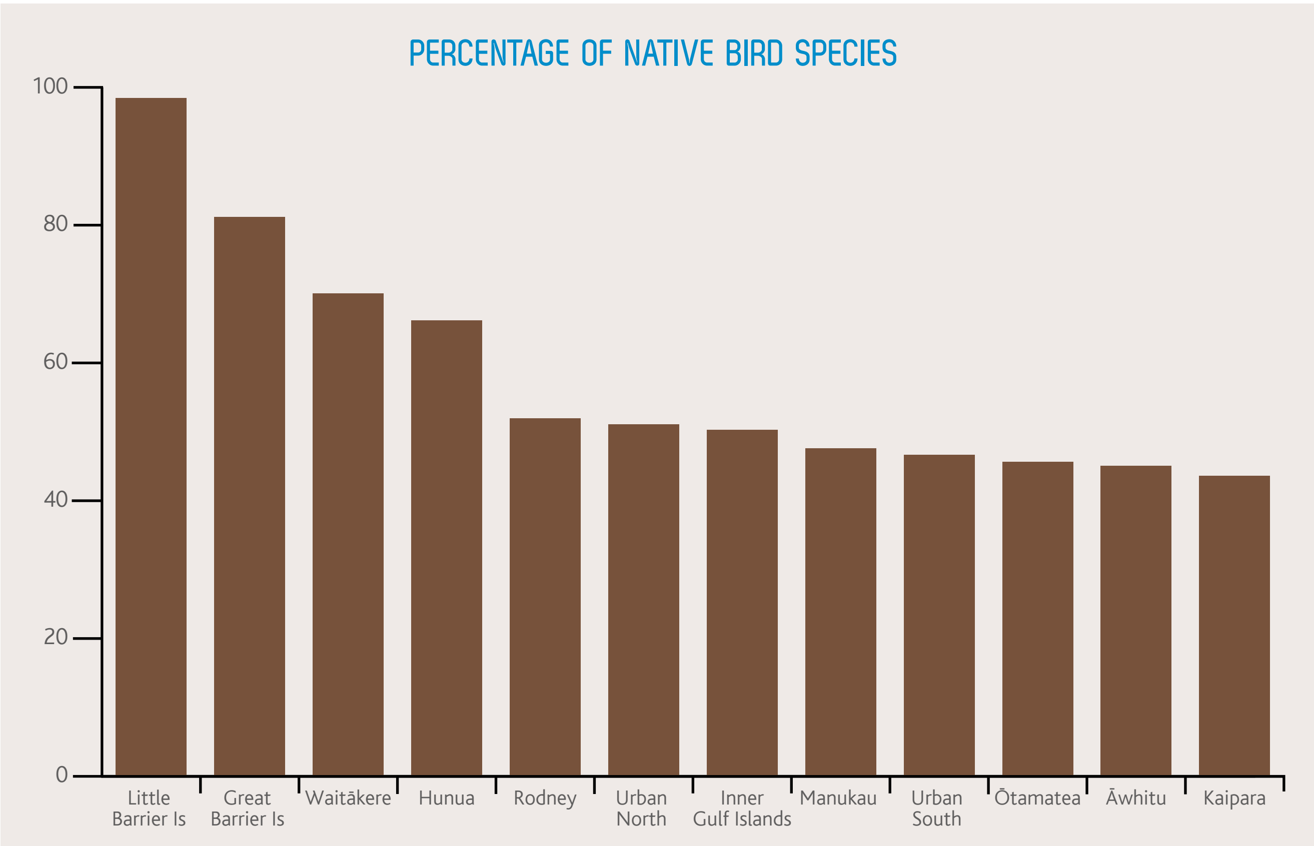

FIGURE 3: Average percentage of species heard/seen in bird counts at native forest, scrub and shrubland sites across Auckland, grouped by ecological neighbourhood, 2009-2014.

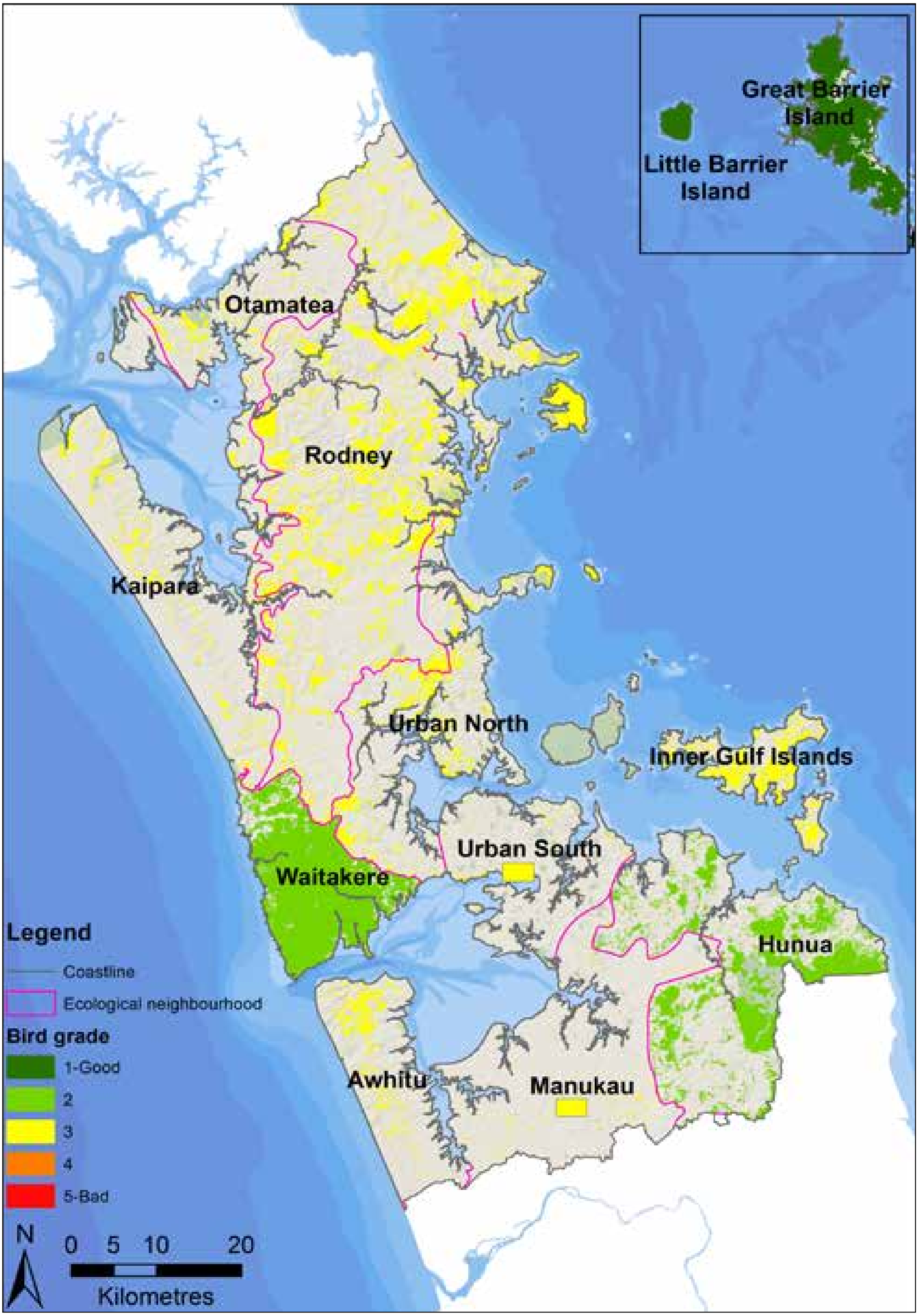

FIGURE 4: Bird grades grouped into the 12 ecological neighbourhoods.

PEST ANIMALS INDICATOR

PEST MANAGEMENT PROGRAMMES SUCCESSFUL BUT MORE WORK NEEDED

Possum eating bird egg. Photo: Ngā Manu Images

Aucklanders are making a difference in reducing pest animals in some of our most precious habitat for native species, as shown in Auckland Council's first regional survey of some of our worst pests (mice, rats, possums). In other areas, such as the Hunua Ranges, important species such as the rare kōkako remain under serious threat from pests. More systematic large-scale pest control measures will be needed to address these problems.

WHY DO WE MONITOR PEST ANIMALS?

New Zealand is famous for its unique biodiversity. Auckland is home to many unique plants and animals, such as the black petrel (Tāiko), which breeds only on Aotea (Great Barrier) and Hauturu (Little Barrier) islands, or the last remnant mainland population of kōkako in the Hunua Ranges. Our impressive biodiversity is the result of tens of millions of years of isolation from other land masses. However, as humans settled these lands they brought with them new plants, animals and diseases, which have threatened the indigenous species and their ecosystems (see Ecosystem Benefits Case Study, page 16). So it's important that we manage all our biosecurity risks to guarantee the survival of our native plants, animals and other life forms in perpetuity.

AUCKLAND COUNCIL IS COMMITTED TO REDUCING PEST ANIMALS

The Auckland Plan - Directive 7.5: Protect ecological areas, ecosystems and areas of significant indigenous biodiversity from inappropriate use and development, and ensure ecosystems and indigenous biodiversity on public and private land are protected and restored.

Our Regional Pest Management Strategy has the overall goal to assist and facilitate the regional community in creating and maintaining sustainable, pest-free, natural and man-made habitats.

To effectively manage pests it is important to understand where they are and how their presence changes over time, which in turn allows us to plan and implement effective biosecurity measures. Key pest animals are monitored across the region as part of the terrestrial biodiversity monitoring programme (TBMP).

WHAT IS THIS INDICATOR?

This indicator helps us identify where some of our most challenging pest animals are in Auckland, and in roughly what concentrations, so we know which areas need more attention.

FOCUS ON RATS, MICE AND POSSUMS

The council manages a range of pest animals, including pigs, goats and mustelids, where they are particularly problematic. However, this indicator takes a more systematic look at pest animals across the entire region, focusing on the whereabouts of the three major pest animals: mice, rats and possums. We're able to monitor these pests at this large scale at a relatively low cost by coupling the work with the TBMP. We use these results to show how pest animals vary across forest and scrub ecosystems in Auckland's 12 ecological neighbourhoods (see page 75), as well as relative to areas where biosecurity management is in place, so we can identify the areas needing more work.

HOW DO WE MONITOR PEST ANIMALS?

Finding and counting pests is a difficult challenge as they hide deep in the bush and don't answer roll calls. To solve this problem we are using an inexpensive method called chew cards (figure 1) to monitor mice, rats and possums.

Mouse on tree stump. Photo: Kat Reynolds

Two ship rats approaching a bird's nest. Photo: Ngā Manu Images

This relatively new and easy tool enables us to survey all three pests at once. The cards contain bait (for example, possums like peanut butter!) which attracts these pests to bite and chew the cards. As we know what each species' bites look like, we can then assess which pest has bitten each card.

We run surveys in late October to December, when we lay out a 'pest line' of 10 chew cards spaced 20 metres apart at every TBMP site. We return three days later to collect the chew cards and take them back to the lab to analyse.

Over the past five years we have laid out a total of 2210 chew cards across 221 sites on public and private land around Auckland.

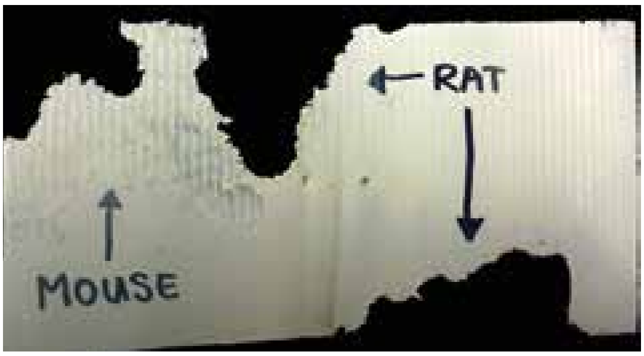

FIGURE 1: Example of chewed pest cards used in the council's regional pest animal survey work.

WHAT HAVE WE FOUND?

So are mice, rats and possums everywhere in Auckland? In short, the answer is no. Our results revealed the presence of these three major pest animals varied greatly across the region (figures 2 and 3).

OUTSTANDING

There are some magnificent gems out there with absolutely none of these pests: for example, Hauturu (Little Barrier Island), the Mokohinau Islands, Rangitoto and Motutapu islands, and Tiritiri Matangi Island. These successes are thanks to ongoing pest eradication and management programmes on these islands, much of which is community driven.

VERY GOOD

Sites with very low levels of these pests include Ark in the Park (a partnership between Forest and Bird and the council at Cascade Kauri Park in the Waitākere Ranges), Glenfern and Windy Hill (two biodiversity sanctuaries on Great Barrier Island), and the Kōkako Management Area (KMA) in the Hunua Ranges. These successes are once again thanks to the incredible efforts of community groups, combined with those of the council.

There are also other areas in the region with low levels of these pest animals, but which are not directly monitored in our chew card programme. These include Tāwharanui and Shakespear regional parks and other council parkland, as well as smaller areas with regular pest control activities, many driven by community groups. Keep up the good work!

NEEDS IMPROVEMENT

Our data from regional parkland just outside the Ark in the Park and the KMA shows we have some work to do. This is particularly true in the Hunua Ranges where there are fairly high levels of these three pests (almost 60% of the cards in the Hunuas showed rats present). In fact this area is now a priority in our biosecurity programme since it has such valuable biodiversity.

WHAT DOES THIS MEAN?

Auckland's status regarding these three major pests is relatively good in our highly managed areas (e.g. Ark in the Park, KMA, Glenfern, Windy Hill), but not as good in other areas such as the Hunua and Ōtamatea ecological neighbourhoods. Note that although we detected high levels of rats and mice on Aotea (Great Barrier Island), this may be the result of a sampling error in the dataset, which is biased to more developed parts of the island at this stage. However, the full baseline measures for Aotea will be completed in 2016 when we can have another look using a more representative dataset.

So on one hand our regional programme shows some great results, demonstrating how effective our community, DOC, and council-driven pest management operations can be when the resources and effort are applied. On the other hand it shows there is a lot more work to do to protect our native biodiversity from these pests across parts of the region.

HOW HAVE THINGS CHANGED?

Completing our first full set of baseline measures is a landmark achievement for Auckland Council being the first comprehensive regional survey of mice, rats and possums in Auckland. It has given us a good understanding of where these pests are in the region. As follow-up monitoring is completed over the next 5-10 years we will feel the full benefit of this work. We will see how pest animal numbers change across Auckland, what areas are doing well or not as well, and why. This information will help inform regional pest management activities to achieve the best outcomes, most prudent use of resources and effort, and further improvements in indigenous biodiversity.

The pest-free status of a number of Auckland's islands, as well as the very low pest levels in our highly managed sites on the mainland, shows that by making a commitment to reducing pests we can succeed. The more Aucklanders get involved and the more we work together, the better the results will be. Our baseline survey will help guide our pest control efforts to ensure success. The proof of this hard work will be the chorus of bird calls and the sight of kererū, robins, geckos and other native species filling our forests again for future generations to enjoy.

SPOTLIGHT/PROFILE

No matter how difficult and large a problem may be, it all comes down to getting together and tackling it as a team. There are dozens of community restoration groups in Auckland working hard to reduce pest animals, both on our beautiful islands and mainland. One of the best repositories of information about these groups is Nature Space (**naturespace.org.nz**), which currently has an incredible 79 restoration groups listed for Auckland... and there are actually a lot more out there! It is this critical mass that is making the difference to Auckland's biodiversity, as is clear from the significant success stories at places like Ark in the Park (Waitākere Ranges), Shakespear, Tiritiri Matangi Island, and Glenfern and Windy Hill on Aotea (Great Barrier Island). The proof certainly is in the pest-free pudding with these community-powered projects!

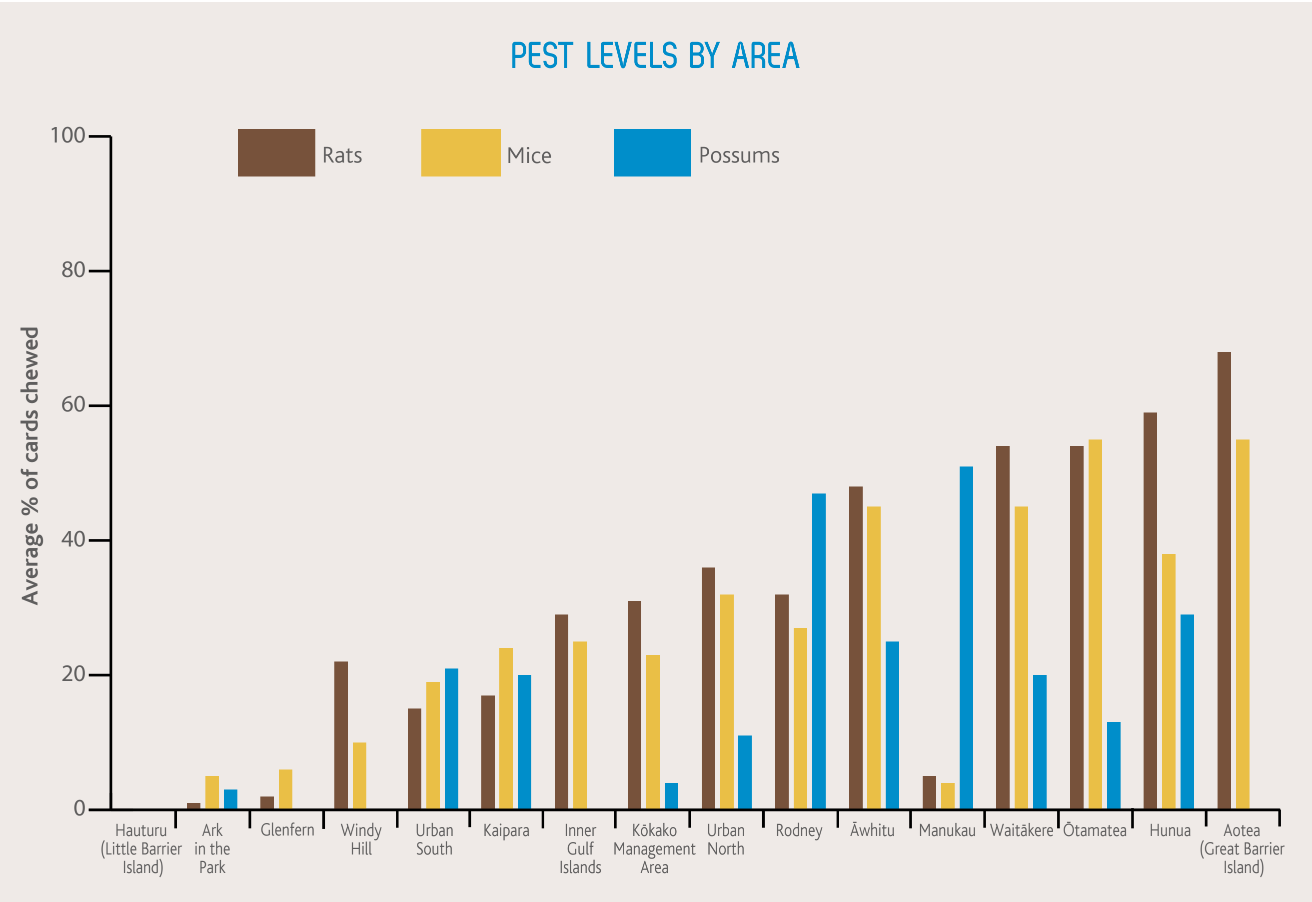

FIGURE 2: Average percent of cards chewed by rats, mice and possums per area.

FIGURE 3: Pest animals grade for Auckland's 12 ecological neighbourhoods.

INDIGENOUS PLANTS INDICATOR

THE FIRST MEASURE OF OUR NATIVE FORESTS

FIGURE 1: *Ponga or silver fern, with epiphytes, Āwhitu Regional Park*

Indigenous plants form the physical structure of land-based ecosystems and are the energy source for all animal life on land. Auckland's forest and scrub ecosystems are richly diverse, thanks to the diversity of geology, landforms and climate in the places they grow[1,2]. The first ever region-wide measure of forest diversity and health highlights the damage to our remaining native forest from historical logging and fragmentation.

WHY DO WE MONITOR INDIGENOUS PLANTS?

New Zealand is internationally regarded as a 'biodiversity hotspot'[3]. Our indigenous plants and animals are world treasures. When humans first discovered New Zealand it was a forest-covered world; adrift and isolated for 80 million years, and populated with many plant and animal species that seemed to belong to the age of dinosaurs, rather than the modern world.

Of the 59 different types of indigenous forest ecosystems identified throughout New Zealand, 12 are in the Auckland region[2,4]. Today only a small fraction of many of these incredible ecosystems remain. Ninety per cent of Auckland's forest ecosystem types are critically endangered, rare or threatened[2]. To save these world treasures from extinction we need to act quickly. By conducting the first baseline survey of indigenous plants, we have taken the first step.

WHAT IS THIS INDICATOR?

This indicator gives us an idea of the diversity and condition of native plants, within native forest and scrub habitat, in different parts of Auckland. It's like a regular doctor's check-up – taking note of the health of each area.

HOW DO WE MONITOR INDIGENOUS PLANTS?

We literally go out and count and measure plants. We use standard techniques that DOC and Landcare Research use, which give high-quality results comparable to national measures. Field crews establish permanent plots 20 by 20m in size – about the size of a netball court – across a representative sample of different forest types. Within these areas we count and measure all the species and record how healthy each is. In five or 10 years we can go back and see how the patient is doing.

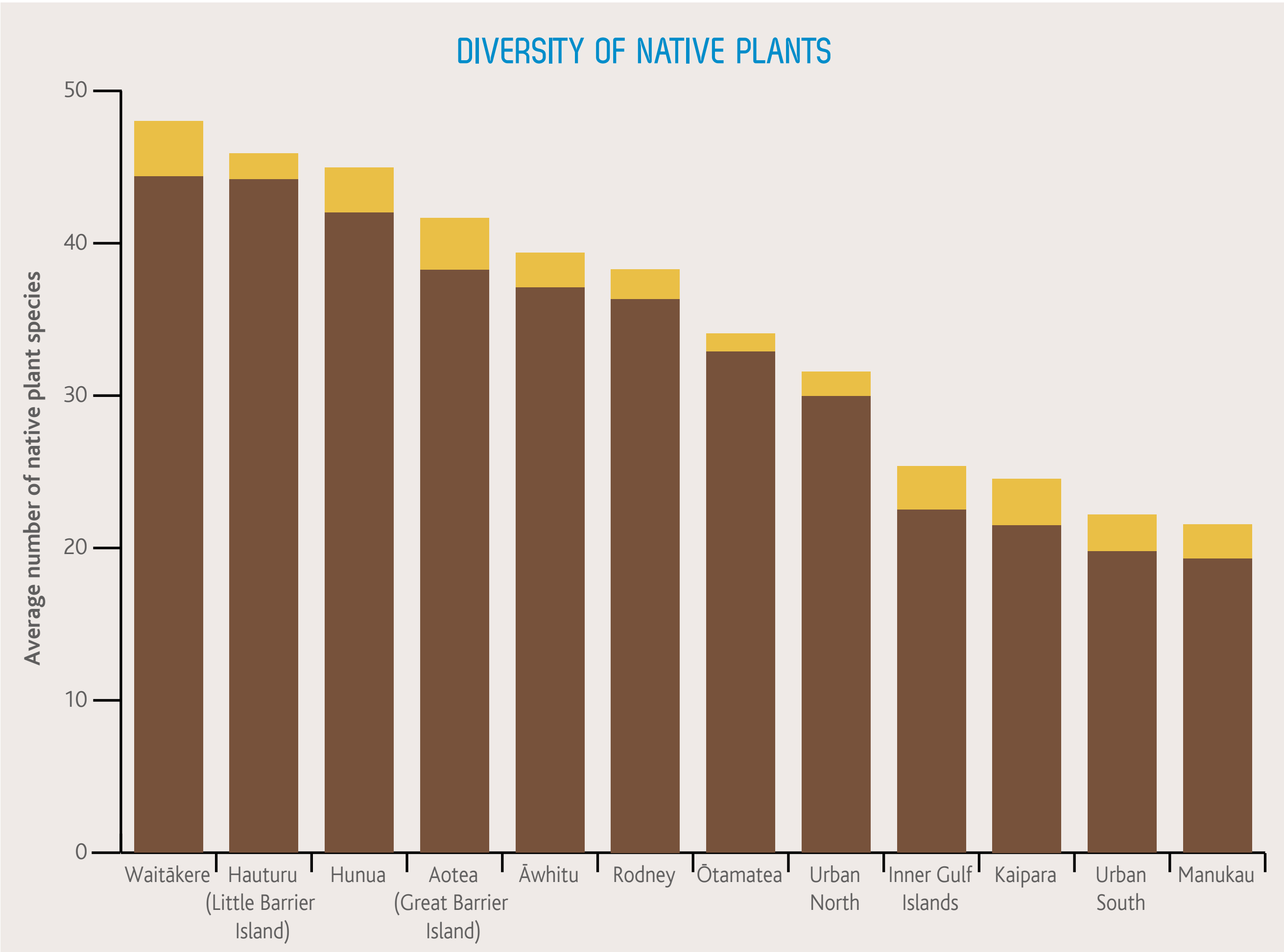

FIGURE 2: Average native plant diversity within plots for Auckland's ecological neighbourhoods. Yellow sections of each bar show positive standard errors above average values.

These measurements enable us to work out a number of different indicators about the health of an area. The overall indicator score presented below is a combined average of these three 'sub-indicators':

1. Plant diversity – how many different species are present in each plot. On the whole, the more species present, the healthier the plot.
2. Dieback of native trees and saplings – how many native trees appear to be dying in each plot. A certain amount of dieback is healthy as decaying wood releases nutrients and provides habitat for different species. But widespread dieback implies the forest is under some type of stress.
3. The ratio of native to exotic species – this is a measure of 'naturalness'.

The Auckland region includes a range of ecological neighbourhoods (see page 75), each of which has very different biodiversity values and development pressures. Because of this, we work out an individual score for each neighbourhood.

WHAT HAVE WE FOUND?

The survey results show forest ecosystems in landscapes that have been more modified by high-intensity farming activity and urban growth have, on average, lower plant diversity (figure 2) and naturalness, and higher tree and sapling mortality. This is not surprising as past ecological research suggests ecosystems that have been fragmented and isolated are also more degraded and modified in terms of their habitat quality for indigenous plants and animals. However, we were surprised by the dramatic differences between plots in modified and unmodified landscapes.

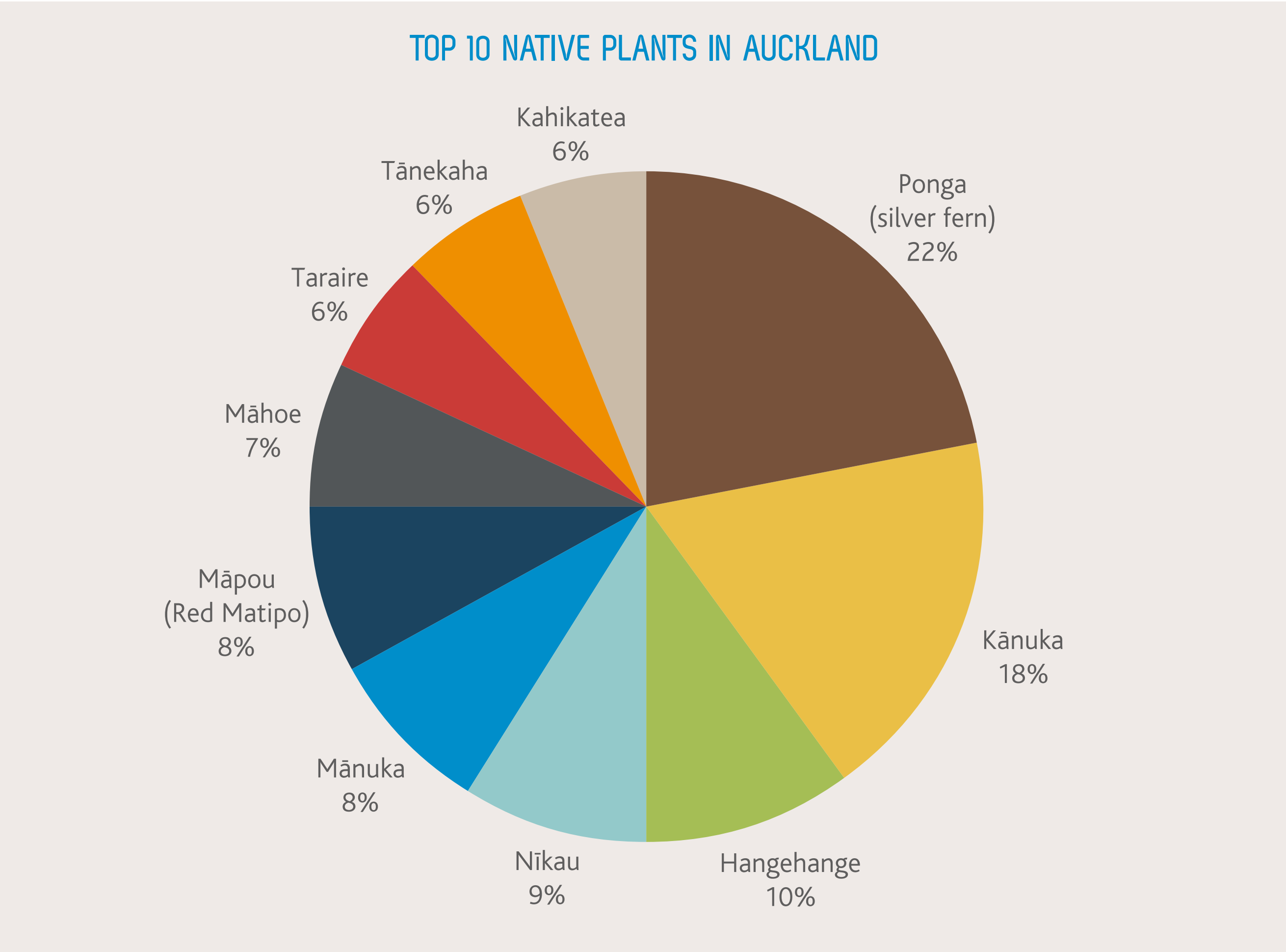

FIGURE 3: Relative importance (/100) of the top 10 indigenous plant species in Auckland's forest and scrub vegetation.

Figure 4 shows the native plant biodiversity score for forest and scrub vegetation in different parts of Auckland. This gives an overall measure (from 1 to 100) of the health of the area, incorporating diversity, naturalness and dieback of native species. Figure 4 also shows the area of native-dominated forest and scrub habitat in each ecological neighbourhood.

Figures 2 and 4 show there is considerable variation in diversity and condition of native forest in the region. Each plot in the large tracts of relatively unmodified, mature, native forest that characterise the Waitākere and Hunua ranges and Hauturu (Little Barrier Island) has an average of more than 40 indigenous plant species.

At the other end of the scale, the Manukau ecological neighbourhood has an average of just 19 indigenous plant species per plot. Native forest and scrub vegetation in Manukau has been almost completely cleared to make way for farms and urban growth, and the small remnants are (on average) only 40% as diverse in native plant species as forest habitat on Hauturu (figure 2).

The Manukau, Kaipara and Urban South ecological neighbourhoods all scored less than 50. All three have intensive agricultural or urban development due to their generally lowland, flat and fertile character. The relatively high score for the highly built-up Urban North ecological neighbourhood is a result of the significant pockets of good-quality urban forest remaining in the Upper Harbour and Kaipātiki local board areas.

The most diverse forest plot was in the hills above Harataonga Bay, Aotea (Great Barrier Island). It recorded an impressive 64 native plant species[5] in a 400m^2 area. The least diverse forest plot was in urban forest in Harbutt Reserve, Mt Albert. Only five different native plant species were recorded at this location, which is characterised by tree privet forest – there were more than 20 exotic plant species in the same plot. However, the four most common birds there were native species (silvereye, tūī, New Zealand fantail and sacred kingfisher). This proves that while many urban forest areas are weedy, they can still be valuable for native plants and animals.

WHAT IS THE MOST IMPORTANT NATIVE FOREST PLANT IN AUCKLAND?

Exactly how to define the 'most important plant' is a moot point: Most dominant in terms of the plant biomass? Most widespread? Highest number of individual plants recorded? Common across a range of different size classes (e.g. trees, saplings, seedlings) or dominant in just one? For the purposes of this indicator, importance values were derived from an average of these four measures of abundance. Figure 3 presents summary data on the region's most important native plants. The winner is ponga (figure 1), or silver fern, a suitably emblematic species that is widespread in forest and scrub throughout the Auckland region.

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2. Singers, N., Osborne, B., Hill, K., Lovegrove, T., Jamieson, A.,Webb, C., Hill, S., Andrews, J., Sawyer, J.W.D., Boow, J. (2013): Indigenous terrestrial and freshwater ecosystems of Auckland, V6.1 – Oct 2014. Unpublished Auckland Council report. 104 pp.
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4. Lindsay H, Byers S, Wild C, (2009): Auckland Protection Strategy. Nature Heritage Fund, Wellington, 82 pp.
5. This is the total species diversity of ferns, conifers and flowering plants within the plot. It does not include mosses, liverworts and lichens, nor an in-depth survey of epiphytic plant species in the forest canopy. The actual number of native plant species present within this (and other) plots is therefore likely to be somewhat larger than what we recorded.

FIGURE 4: Native plant grade for Auckland's ecological neighbourhoods.

PEST PLANTS INDICATOR

WEEDS IN THE FORESTS – A GROWING PROBLEM

FIGURE 1: *A patch of weed-dominated urban vegetation. Giant reed and Japanese honeysuckle smothering a tī kōuka (cabbage tree).*

Auckland has more than 1100 naturalised exotic plant species, compared with 400 or so natives[1], and many of them could become pest plants (weeds). Weeds displace native plants, alter soil chemistry and drastically reduce food for native animals. Results from the first representative, region-wide sample of weed impacts on native forest and scrub show that, fortunately, our large tracts of native forest are quite resistant to weed invasion. The impact is most severe in rural and urban landscapes.

WHY DO WE MONITOR WEEDS?

Weeds are exotic plants that cause damage and disruption to native ecosystems and agriculture. The north of New Zealand, and especially Auckland, is afflicted with many weeds that are rare or unheard of in frostier upland or cooler parts of the country. Of New Zealand's 26,500 plant species (not including mosses and related plants), only 9% (about 2500) are native. More than 1100 exotic plants have naturalised in the Auckland Region and new introductions are continual, with around four new species becoming naturalised every year[1,2]. Many of these introduced species could become weeds.

References:
1. Landcare Research Press Release, (2006): "Attitude change prescribed for weedy Auckland". Snoop. "Auckland has the dubious honour of being the weediest city in the world, with 220 weeds (and climbing)."
2. Esler A, (1988): The naturalisation of plants in urban Auckland, New Zealand 6. Alien plants as weeds. New Zealand Journal of Botany 26 (4) 585-618.

UNWANTED STOWAWAYS AND UNINTENDED CONSEQUENCES

The weeds that now infiltrate our ecosystems mostly arrived as farm and garden plants that people thought would be useful, or as stowaways that came with the useful plants. A classic Auckland example is tree privet. Introduced from China in 1958 as an ornamental or hedging plant, it now displaces native plants across many hundreds of hectares of the region and is the most common weed in Auckland's urban forest areas.

Weeds such as pine, wattle, pampas and privet outcompete and displace adult native trees, seedlings and shrubs. Other weed species, such as climbing asparagus, tradescantia and ginger, can suppress the regeneration of indigenous seedlings and saplings. Auckland's urban forest reserve network is the scene of an intense battle between native and exotic plants for space, nutrients and light. The involvement of council and community groups is essential to stem the 'green tide' of weeds and protect our native ecosystems and the invaluable benefits they provide.

WHAT IS THIS INDICATOR AND HOW DO WE MONITOR IT?

This indicator uses the same network of forest monitoring plots as for the indigenous plant indicator – a representative sample of native scrub, forest and shrubland ecosystems from throughout the region. The only difference is that in this indicator we focus on weeds or plant pests.

Our 'weediness index' has been calculated from a number of underlying factors to represent how abundant and widespread the weeds are in each ecological neighbourhood[3] (see page 75). The index ranges from 1 to 100, with 1 representing forest or scrub almost totally comprising pest plant species and 100 meaning there are no pest plants present.

WHAT HAVE WE FOUND?

Figure 4 shows the relative weediness of forest and scrub ecosystems in the 12 ecological neighbourhoods (see page 75).

THE GOOD: OFFSHORE ISLANDS AND STEEP, FORESTED HILLCOUNTRY

Hauturu (Little Barrier Island) is the least weed-affected part of the region and the values recorded in its plots are the standard against which all other locations are judged. Not even one exotic species (weedy or otherwise) was recorded in the 22 locations sampled on Hauturu. This doesn't mean there are no weed species on the island – the coastal cliff vegetation, for example, needs careful monitoring for invasion of weeds such as pampas and boneseed. But this result does mean that exotic plants are at such low densities in the main forest block that they didn't register within the plot network.

Hunua and Waitākere ecological neighbourhoods also have very few weeds. Most exotic species detected there were not weeds. That is, they were small, non-woody herb and grass species (e.g. wall lettuce, Yorkshire fog or lotus) that do not threaten the integrity of the dominant forest and scrub ecosystems.

Tree privet at Pūrewa Creek. Photo: Mike Wilcox

> "Invasive pests and weeds pose the greatest single threat to biodiversity on land, surpassing even habitat loss. Weed invasions threaten the long-term viability of many of New Zealand's natural habitats, particularly lowland and coastal plant communities..."
>
> NEW ZEALAND BIODIVERSITY STRATEGY 2000

Reference:
3. The weediness index is derived from the average of five underlying indicators: Average native: exotic species ratio of plots; Average native: weedy species ratio of plots; Average native: weedy stem ratio of plots; Average native: weedy sapling ratio of plots; Average native: weedy seedling ratio of plots.

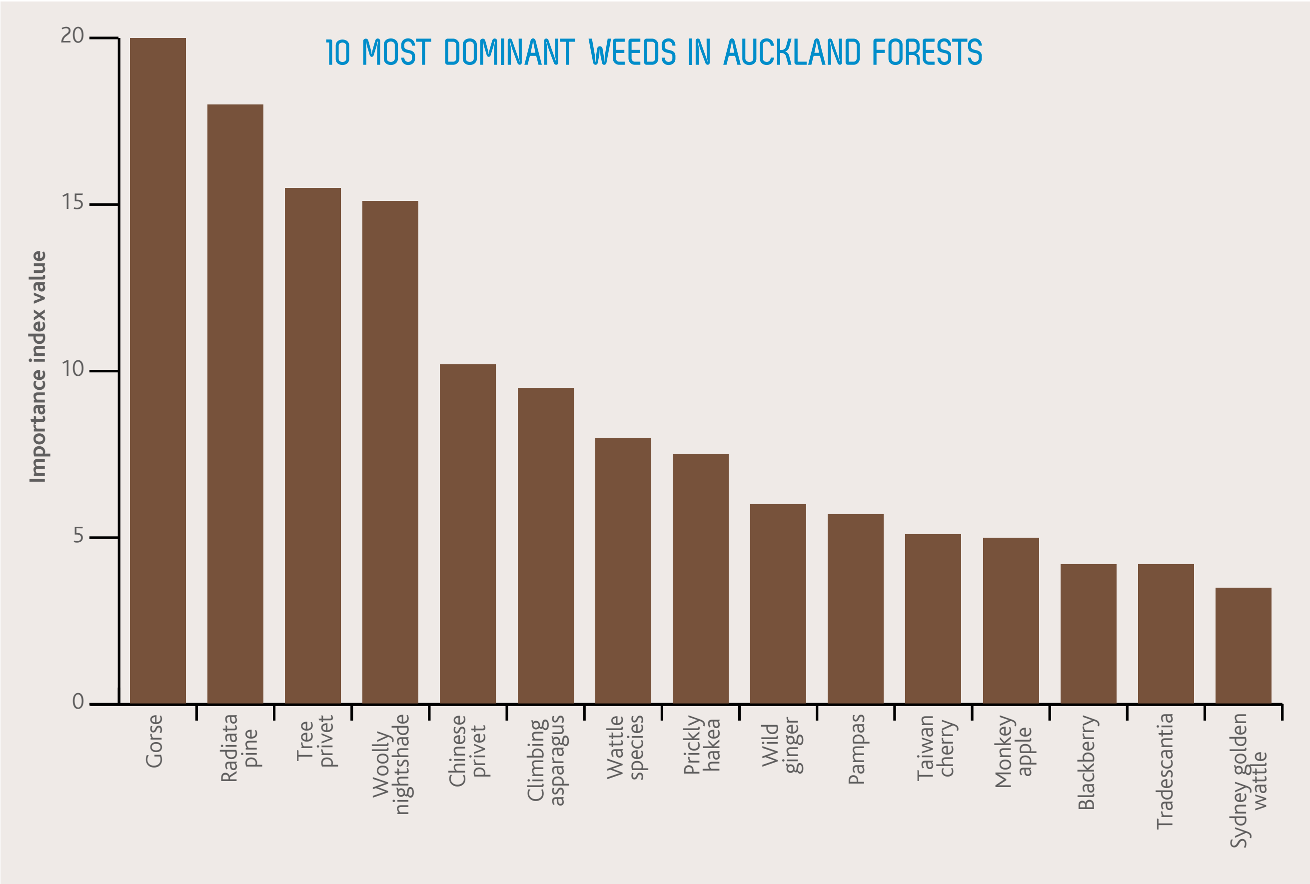


FIGURE 2: Relative importance (/100) of the 10 worst weeds in Auckland's forest and scrub ecosystems.

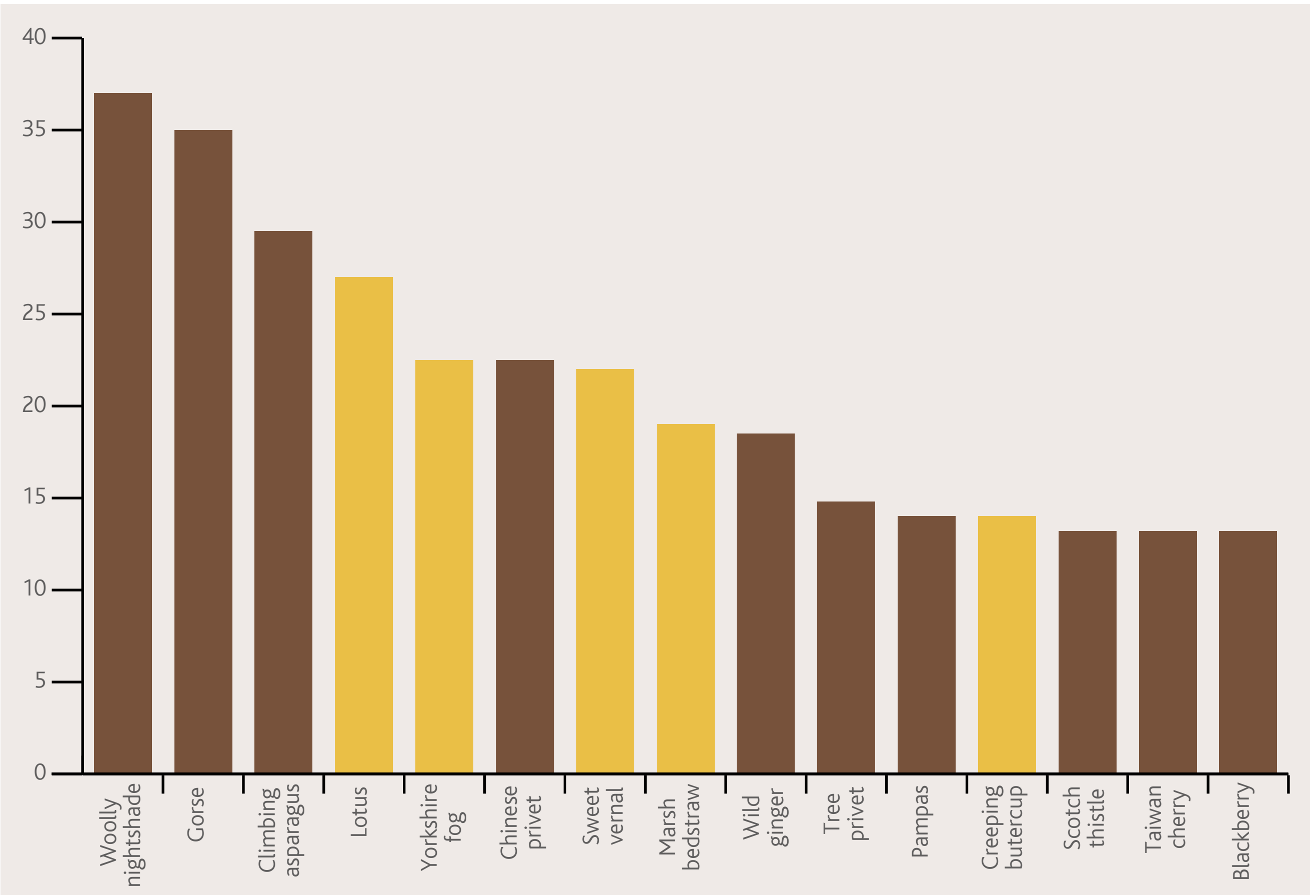


FIGURE 3: Percentage frequency in plots of the 15 most widespread exotic plants in Auckland's forest and scrub ecosystems.

THE UGLY: FOREST PATCHES IN THE URBAN AREA

In contrast the forest and scrub vegetation of the Auckland urban area is heavily compromised by weeds. Up to 15% of all tree stems, 34% of all saplings and 20% of all seedlings we recorded in forest and scrub within the Metropolitan Urban Limits (figure 4) were exotic or weedy plant species. Monitoring future changes in weediness in these locations will help inform council weed policy and control work. Monitoring weeds in the urban environment is especially important given the many benefits the urban forest provides (see Urban Forest Case Study).

Some areas in the Manukau ecological neighbourhood are seriously affected by weeds. As most of this sub-regional area has been cleared for farmland, the remaining fragments of native habitat are very small. The edges of these fragments are especially vulnerable to ongoing weed invasion from the surrounding landscape.

THE REST

The remaining six ecological neighbourhoods fall between the two extremes already outlined. In these largely rural locations, with their patchy mosaic of pastural farming, plantation forestry and native habitat, the impact of weeds is usually linked to the proportion of farmland versus native vegetation.

Rodney ecological neighbourhood has more large native remnants, and it scored much higher (80) on the weediness index than the more developed lowland farmland of Kaipara, Ōtamatea, Waiheke and Āwhitu ecological neighbourhoods (index values of 61-67).

Aotea (Great Barrier Island) has an unexpectedly bad weediness score (73), given its large tracts of native forest. This probably represents a sampling error in the dataset, which is biased to more weedy parts of the island. The full baseline for Aotea will not be complete until 2016.

THE WORST WEEDS

Figure 2 shows the 15 worst forest and scrub weed species detected in all plots across the Auckland region. The importance of individual weed species is based on the number of different plots in which the weed was found (i.e. frequency) and the abundance of the weed (i.e. density and size of individuals) in plots where it was found.

SPOTLIGHT/PROFILE

Not all exotic plants are bad news for indigenous ecosystems. Many of our most beloved garden plants and street trees are exotic species, such as Norfolk pine, London plane, sweet scented (non-invasive) jasmine and black locust. And even weed species produce benefits, such as carbon sequestration, protection of soil, air and water purification, recreational opportunities and habitat for native animals. This is especially true in highly modified landscapes with almost no native ecosystems.

Figure 3 shows the most widely distributed exotic species in forest and scrub vegetation throughout the region. Included among the weeds (brown bars) are a number of non-weedy exotic species (yellow bars) that are tolerated by most and appreciated by many.

Climbing asparagus, a common weed in urban forest
Photo: Mike Wilcox

FIGURE 4: Weed grade for Auckland's ecological neighbourhoods.

SOIL HEALTH INDICATOR

PRODUCTIVE RURAL SOILS ARE OVER-FERTILISED AND COMPACTED

Typical rural land that is sampled in the soil monitoring programme

Auckland's land and soil are some of the best in the country and a valuable, non-renewable resource. They provide us with food, timber, and recreational and tourism opportunities, and have important cultural and historic value. While some elements of soil quality are good, monitoring shows that over-fertilisation and overly compact agricultural and horticultural soils are increasing the risk of nutrient and sediment loss in surface runoff to freshwater and marine environments.

WHY DO WE MONITOR SOIL HEALTH?

Soils are an often overlooked ecosystem or component of ecosystems, yet soil is one of our most valuable natural assets. It is incredible how many benefits it yields:

- It grows our food and feeds our animals.
- It absorbs and filters pollutants such as phosphorus, nitrogen and other pollutants and locks them away.
- It provides a home for billions of organisms, each doing vital work: microbes break down locked-away nutrients and make them available to plants; worms burrow through the soil, increasing aeration and drainage and enabling roots to grow deeper.

- It regulates greenhouse gas emissions by sequestering carbon from the air, and supports plant growth that makes oxygen.
- It grows trees, which provide shelter, timber and food and absorb more greenhouse gases.
- It helps us fight diseases – most of our antibiotics have been found in the soil.

DID YOU KNOW?

- There are more microorganisms in a teaspoon of soil than there are people on earth: soil hosts 25% of the planet's biodiversity.
- The weight of worms underground healthy soil equates to the weight of livestock grazing above ground.

The healthier the soil, the more nutritious the food, and the more effectively it filters water, accommodates bugs, absorbs greenhouse gases and performs all its other work. It is therefore essential we monitor the soil resource to ensure it is a fully functioning ecosystem in terms of agronomic yield, and also because what happens on land will ultimately affect the health of the receiving waterways.

WHAT IS THIS INDICATOR?

Healthy soil is a complex network of chemical (e.g. nutrients), physical (e.g. air and water) and biological (bugs and microbes) properties. We use many soil parameters to measure and capture a complete picture of soil health:

- **Soil density** – Soils can range from being very light and peaty to heavier and denser clay. We have guideline ranges for each soil type, which recognise these characteristics.
- **Soil pH** – Soil has to be just the right balance between acidic and alkaline conditions, otherwise it is not habitable for many microbes, nematodes, insects and molluscs, which all play an important role in recycling nutrients. A very alkaline soil can cause deficiencies for some micronutrients that are important for plant growth. In contrast, a severely acidic soil can change the properties of micronutrients that could cause toxicity problems.
- **Organic carbon (OC)** – is a soil nutrient that comes from dead and decaying plants and animals. Organic carbon stabilises the soil and it can hold more water and nutrients. Also, the more carbon the soil contains, the more carbon it absorbs from the atmosphere – so it's a reinforcing cycle.
- **Total nitrogen (TN)** – Nitrogen helps plants grow and stimulates microbial activity, but you have to have the right amount. Too much and it could leak into ground water and contaminate waterways if there is not enough carbon in the soil. Not enough and it causes deficiencies in plants.
- **Anaerobic mineralisable nitrogen (AMN)** – is a measure of how much organic nitrogen can become available to plants and is an indicator of microbial biomass.
- **Olsen P – Plant Available Phosphorus** – Olsen P is a measure of the plant-available form of phosphorus (P) present in the soil. Phosphorus is an essential nutrient to help plants grow and is added in fertiliser. However, when too much phosphorus fertiliser is added to the soil it can get washed into the water when it rains. Olsen P is a very good indicator of how much fertiliser farmers are applying and how much the plant needs. Most horticultural and agricultural soils have Olsen P levels that are too high.
- **Macroporosity** – tells us about the physical structure of the soil and how aerated it is. It is related to density, but it's a more sensitive indicator. Most agricultural and horticultural soils fall below the recommended guidelines, which is a sign of a compacted soil.

HOW DO WE MONITOR SOIL HEALTH?

We monitor soil health by running a series of tests on soil samples from selected sites across the region. We choose sites based on their land use (native bush, horticulture, plantation forestry, pasture and urban) and their soil type. Each year we focus on sites representing a different land use (see table 1), so it takes five years to cover the five land uses. So far, we have completed 15 years of monitoring and have two complete sets of rural data for each land use for comparison. As we add to the data in years to come, this will improve our ability to determine trends in land uses, and changes (improvement or degradation) in soil quality and trace elements over time.

FIGURE 1: A profile of a Warkworth clay loam soil typically found in north Auckland.

LAND USE	YEAR FOR SAMPLING
Drystock	2015
Plantation forestry	2016
Native bush + urban	2017
Horticulture	2018
Dairy	2019

TABLE 1: Schedule for soil sampling by land use.

WHAT HAVE WE FOUND?

While some elements of soil quality are good, other elements are in decline, so the soil is not functioning as well as it could. The most worrying indicators include Olsen P and macroporosity. Compact soils and high levels of phosphorus from fertilisers can wash into waterways when it rains, polluting receiving waterbodies.

HIGH OLSEN P

Olsen P was the indicator of most concern, with more than half the horticultural and pastoral sites exceeding the upper limit (figure 2). This is a direct result of farmers and growers applying too much fertiliser. Average concentrations of Olsen P increased (P <0.001) from 37 mg/kg (range 1-200mg/kg) to 44 mg/kg (range 2-181mg/kg) for sampling periods pre and post 2000, respectively. It is very important that we address this issue as the flow-on effects are serious. When phosphorus is released into waterways it can potentially cause algae blooms, which will not only have a negative environmental and ecological impact but will also prevent us from enjoying our rivers and coastal environment. There is also no benefit from applying too much phosphorus fertiliser because the plant can only take up so much of it.

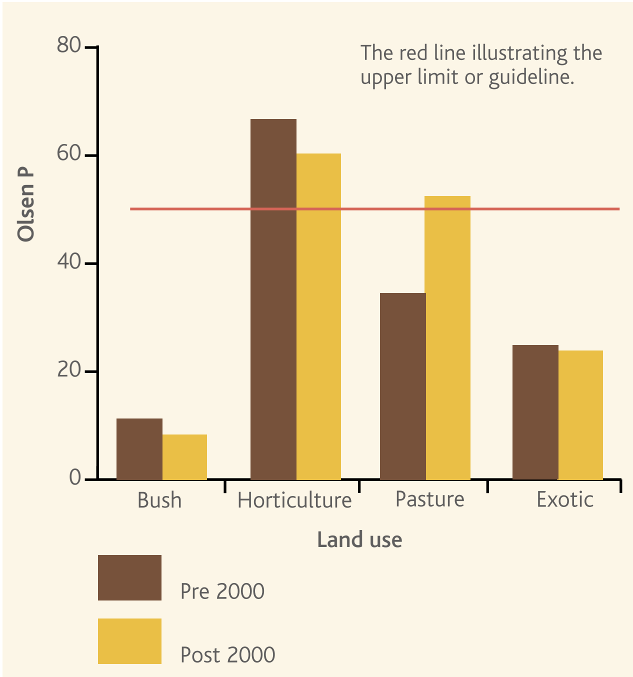


FIGURE 2: Mean concentrations of Olsen P for sampling periods pre and post 2000.

LOW SOIL MACROPOROSITY

Low soil macroporosity, an indication of soil compaction, is also an issue for more than half the pastoral and horticultural sites in the region. It results from over-grazing of livestock, continuous use of tractors, and so on. Unfortunately when soil is compact, more phosphorus can be lost to waterways when it rains. So low macroporosity exacerbates the problem of high phosphorus levels because a compact soil is less able to drain and infiltrate water.

For pastoral sites more than half the soil samples failed to meet the guideline (8%) for macroporosity (that means less than 8% of large pores are contained in the soil). Figure 3 shows that anything below the red line fails to meet the guideline for soil macroporosity which is the case for pastoral and horticulture sites. Macroporosity decreased from 12% to 8% (P<0.001) for sampling periods pre and post 2000 respectively, indicating a significant increase in soil compaction (figure 3).

Soil compaction also affects the agronomic potential of crops and pasture. For example, a unit increase in macroporosity can have a 1.8% increase in spring relative pasture yield.

OTHER SOIL QUALITY OBSERVATIONS

There were no negative changes in soil pH and bulk density despite significant differences pre and post 2000. No significant differences were observed for organic carbon (OC), total nitrogen (total N) and anaerobic mineralisable nitrogen (AMN) (table 2).

That said, Organic C and AMN levels are considered low for specific land uses that fall under the horticultural land use category. For example, horticultural land encompasses orchards, vineyards and market gardening sites that have been grouped together in order to conduct more robust statistical analysis with a larger sample size. However, when market garden sites are separated, levels of Organic C and AMN for this land use are low which is attributed to the highly intensive land use activity associated with continuously working up the soil through rotary hoeing, deep ripping and harvesting. So we need to look at how certain activities impact soil health, and find solutions.

SOIL IS A PRIORITY

An important new policy in the Proposed Auckland Unitary Plan encourages 'land management practices that retain the physical and chemical capability of soils', recognising the significance of this valuable resource. B8.2.5.

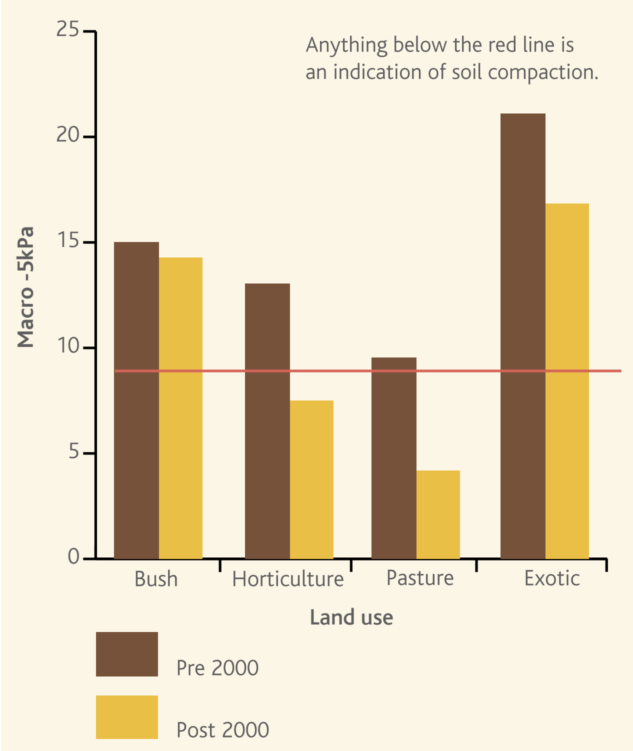


FIGURE 3: Mean macroporosity for sampling periods pre and post 2000.

SOIL PARAMETER	PRE 2000	POST 2000	P VALUE
pH	5.85	5.96	<0.05
AMN* (mg/kg)	145	153	NS
Organic carbon (%)	7.24	6.84	NS
Total nitrogen (%)	0.54	0.53	NS
Bulk density (g/cm^3)	0.92	0.98	<0.001

TABLE 2: Changes in soil quality parameters, pre and post 2000.
*Anaerobic mineralisable nitrogen. NS = not significant.

Reference:
Curran-Cournane, F. (2015): Soil quality state and trends in New Zealand's largest city after 15 years. International Journal of Environmental, Ecological, Geological and Geophysical Engineering 9, 227-234 http://waset.org/publications/10001081/soil-quality-state-and-trends-in-new-zealand-s-largest-city-after-15-years.


Land used for viticulture on Waiheke Island

HOW RURAL LAND USE AFFECTS NUTRIENT AND SEDIMENT RUNOFF TO WATERWAYS

POSSIBLE ISSUES

Animal defecation
(Nutrient and sediment loss to waterways when it rains).

High phosphorus and nitrogen fertiliser use
(Nutrient loss through surface runoff and subsurface drainage).

Compaction and pugging
(phosphorus and sediment loss).

Cultivation and bare soil
(sediment loss).

Forest harvesting
(sediment loss).

POSSIBLE SOLUTIONS

Fence off streams and water ways.

Apply lower rates of fertiliser more frequently to reduce runoff.

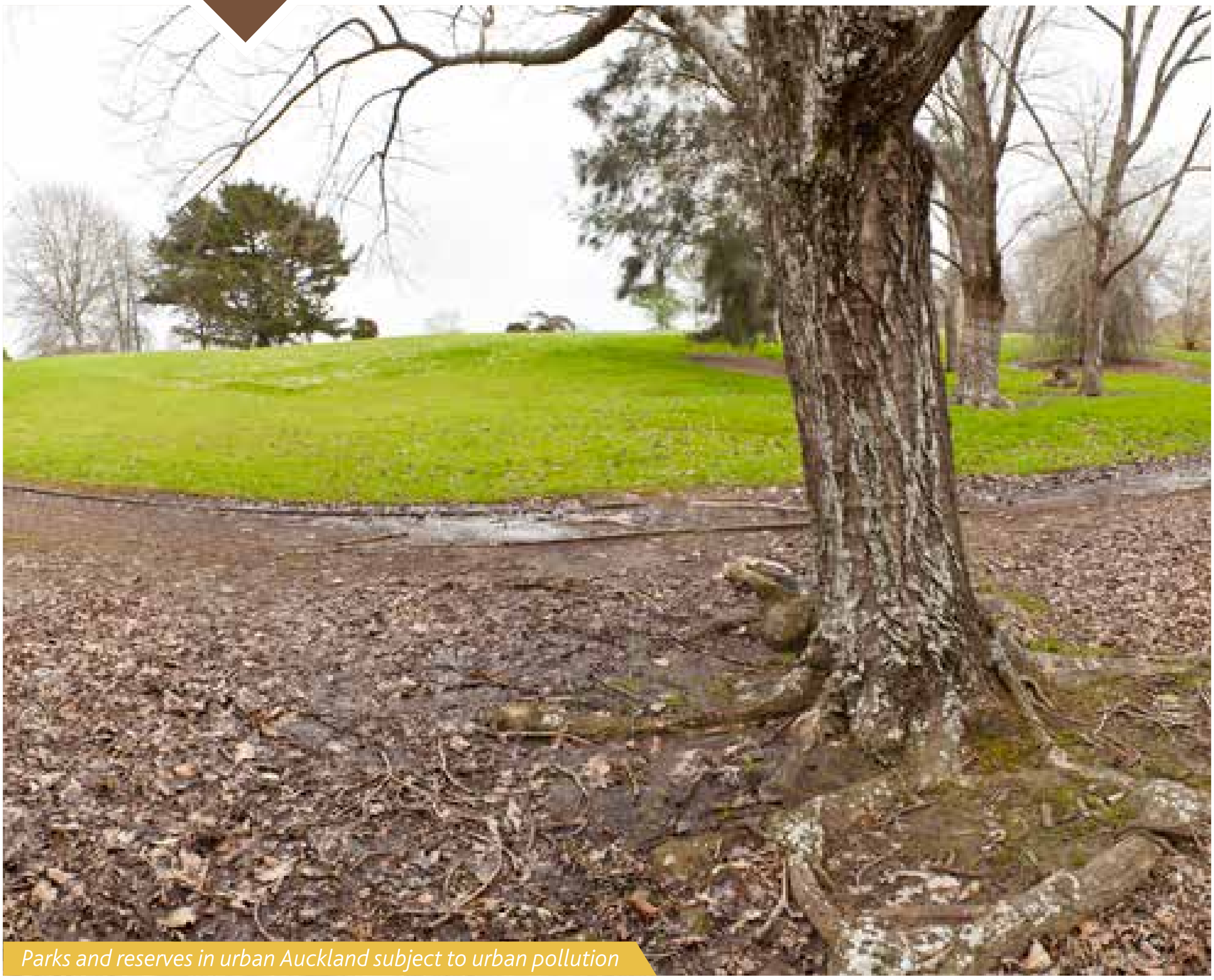
Apply good stock management practice during wet weather, for example lower stocking rates.

Leave vegetation buffer strips along stream margins and plant cover crops on bare land.

Leave riparian buffers during forest harvesting. Use sediment retention ponds. Good forest harvesting management during wet weather.

TRACE ELEMENT SOIL INDICATOR

MODERATE POLLUTION IN AUCKLAND'S SOILS



Parks and reserves in urban Auckland subject to urban pollution

Auckland's soils are moderately polluted – and we need to keep an eye on them. Our monitoring is showing that, overall, urban areas have the highest concentrations of trace elements, which can largely come from vehicle wear and tear, fuel emissions and the disposal of chemicals. However, we found that concentrations of cadmium, copper and mercury are higher in rural Auckland.

WHY DO WE MONITOR TRACE ELEMENTS IN AUCKLAND'S SOIL?

Although trace elements are naturally occurring in soils, they can have serious health and environmental effects when present in high concentrations as they accumulate over time as a result of human activity. Trace elements are used in all kinds of products and technologies (table 1). A well-known historic example of trace element pollution is the use of lead in petrol. Lead was a common ingredient in petrol until the 1980s when its serious neurotoxic health effects were realised. From the soil it can be taken up by plants and subsequently ingested by animals. Trace elements can also get washed off the soil into the marine environment. If trace elements such as cadmium enter the food chain, they can accumulate in our livers and kidneys and over a lifetime contribute to disease.

To keep rural Auckland productive, protected and environmentally sound, it is imperative that the integrity of the soil is not compromised and functions to its full capacity. This will help keep us on track to meet Auckland Plan targets to increase the value added to the Auckland economy by rural sectors, including rural production, by 50% by 2040 (The Auckland Plan – Chapter 9).

MAJOR SOURCES AND USES OF TRACE ELEMENTS

- **Arsenic** – wood preservatives and alloys
- **Cadmium** – phosphorus-based fertiliser, alloys and batteries
- **Chromium** – wood preservatives, pesticides, alloys and dyes
- **Copper** – copper-based fungicides and pesticides, wood preservatives, paints
- **Lead** – lead-based paints and petrol, batteries, metal products
- **Mercury** – alloys, drugs and antiseptics
- **Nickel** – alloys and batteries
- **Zinc** – wood preservatives, facial eczema ointments for livestock, car tyre threads, alloys and paints.

It is very important that the soil pH does not become too acidic (see soil health indicator). This will increase the solubility and mobility of these elements, which can then leak into the environment or be taken up by plants and potentially enter the food chain.

TABLE 1: Major sources and uses of trace elements.

WHAT IS THIS INDICATOR?

The trace element soil indicator encompasses a suite of trace elements including arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb) and zinc (Zn). We monitor levels at 160 sites representing major rural and urban land uses and soil types in Auckland.

POLLUTION INDEX

To provide some context to the results, we have used a Pollution Index (PI), which compares concentrations of each element to their concentrations in an undisturbed sample (we used a sample of concentrations from minimally disturbed areas of native forest as the control). The rating on the Pollution Index indicates how much higher the concentration of the element is compared with the native control sample (e.g. PI = 3 indicates three times the concentration compared with the control.)

0-1 = Low PI

1-3 = Moderate PI

above 3 = High PI

To give an overall pollution rating we combine levels of all the contaminants into a Mean Integrated Pollution Index (IPI).

HOW DO WE MONITOR TRACE ELEMENTS?

Using the same sites as for the soil health indicator, we take soil samples back to the laboratory and run tests to measure each trace element.

WHAT HAVE WE FOUND?

- Worst polluted = Urban sites: IPI = 2.9 (this means that on average, levels of trace elements are almost three times higher than in native forest)
- Rural pasture: IPI = 2.7
- Horticulture: IPI = 2.6
- Least polluted = Plantation forestry: IPI = 0.9 (this is similar to native bush because the two land uses tend to be similar until it is time to harvest a forest). See figure 1.

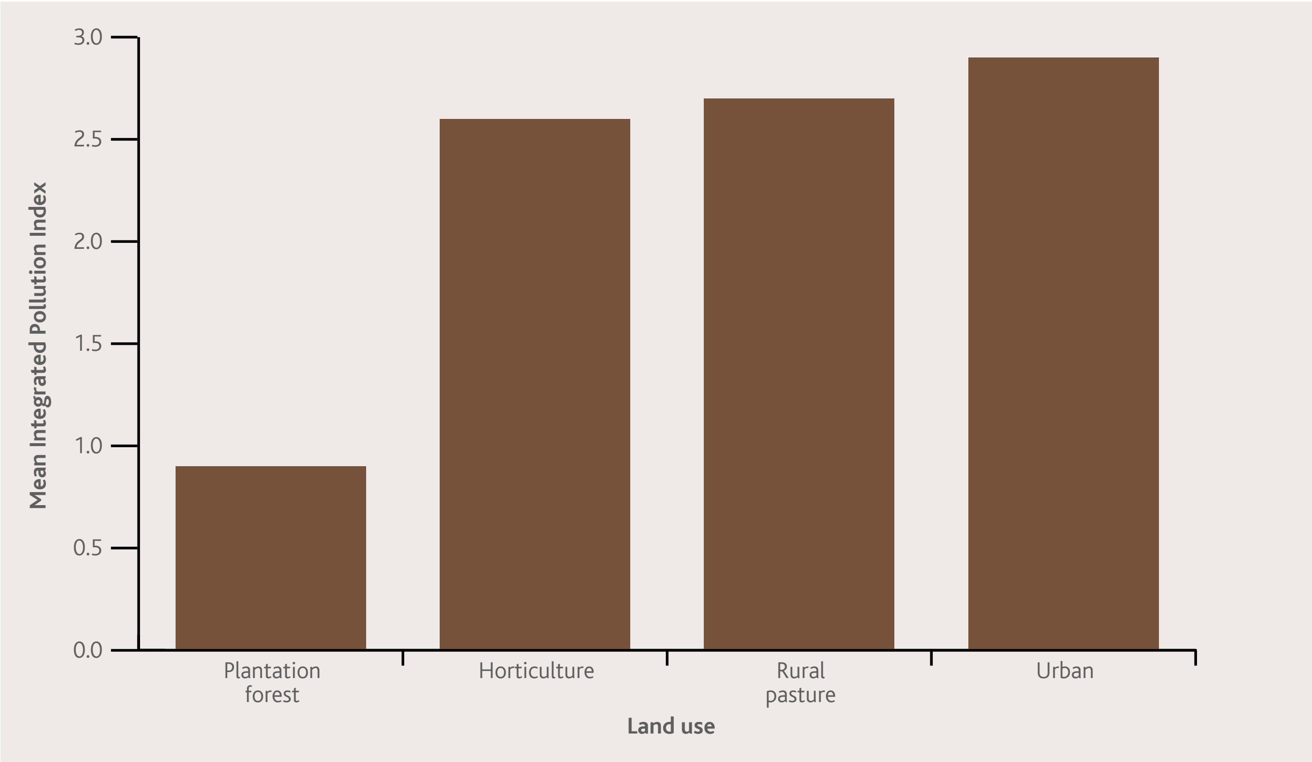


FIGURE 1: Mean Integrated Pollution Index for land uses across rural and urban Auckland using native bush sites as a baseline/control. 0-1 = Low, 1-3 = Moderate, Above 3 = High.

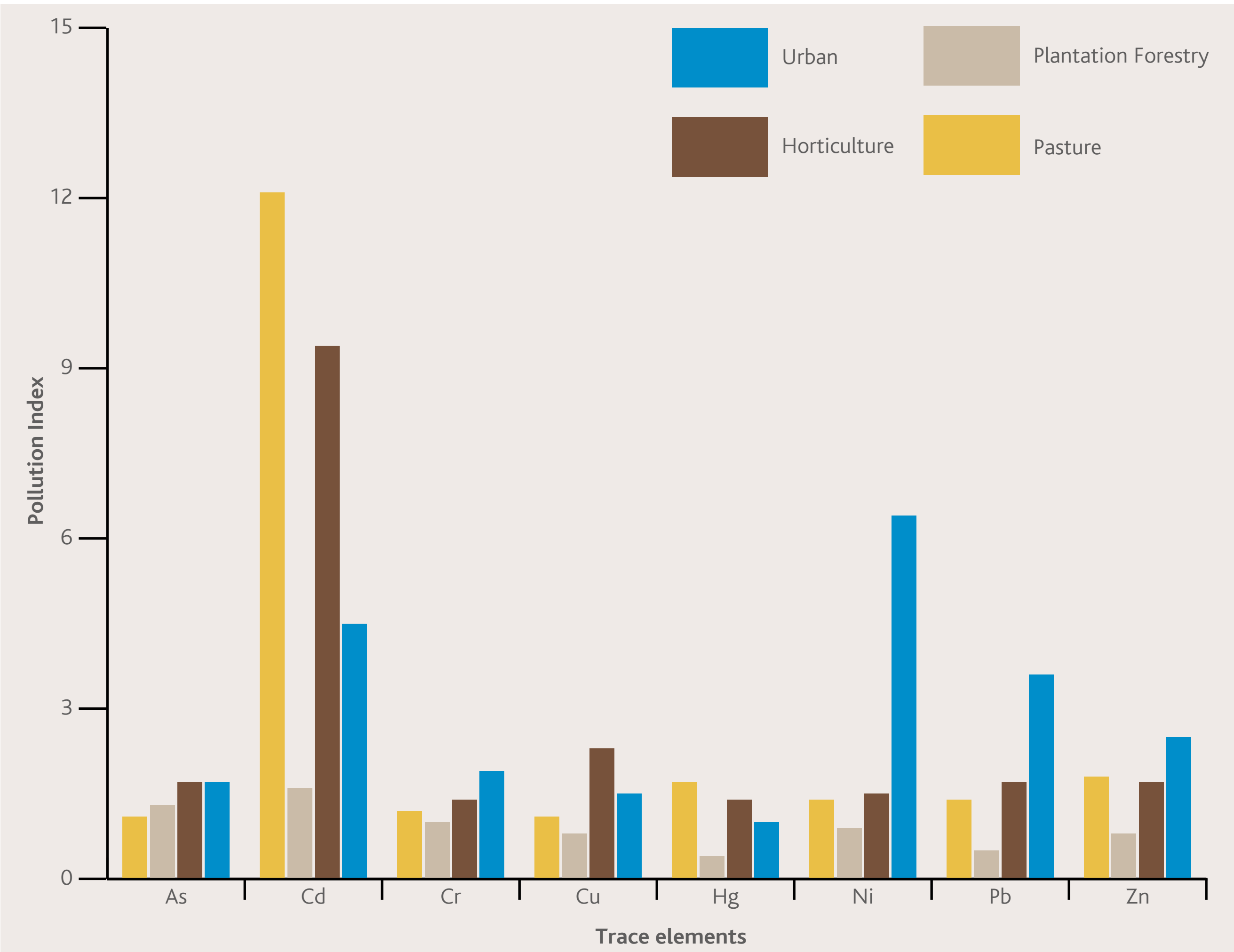


FIGURE 2: Pollution Index by trace element and land use across urban and rural Auckland. 0-1 = Low, 1-3 = Moderate, Above 3 = High.

URBAN SOILS – THE MOST POLLUTED

Urban soils showed higher levels of arsenic, chromium, lead, nickel and zinc (figure 2). Many of these trace elements can come from vehicle wear and tear and the disposal of chemicals and fuels. For example, the wearing and tearing of tyre threads is a major source of zinc.

CADMIUM A CONCERN IN RURAL SOILS

Although the overall ratings were lower for rural soils, they showed elevated levels of cadmium, copper and mercury (figure 2), which can have concerning health and environmental implications.

Rural pollution index averages:

Cadmium – average PI = 8.6

Copper – average PI = 1.5

Mercury – average PI = 1.3

At the worst sites we recorded pollution values over 20 for cadmium on the Pollution Index. That's over 20 times the natural levels, and considering that cadmium is a known carcinogenic, we need to make sure that levels do not increase over time.

Phosphorus fertilisers are a major source of cadmium and, along with our observation of high levels of plant available phosphorus, this suggests that the overuse of fertiliser at horticultural and pastoral soil sites is an issue that needs to be watched.

Levels of copper were highest at orchard sites, which can be explained by the common use of copper-based fungicides.

HOW HAVE THINGS CHANGED?

Within the last 15 years of soil monitoring we have collected two complete sets of data for each rural land use type, which only gives us one past result with which to compare the latest concentrations. Although small increases in cadmium, copper, nickel and zinc were observed, the changes in the actual concentrations (mg/kg i.e. different units to the Pollution Index) were not significant (table 2).

TRACE ELEMENT (MG/KG)	PRE 2000	POST 2000
Arsenic	3.7	3.6
Cadmium	0.38	0.40
Chromium	11.7	11.5
Copper	14.9	15.6
Lead	11.9	11.4
Nickel	3.77	4.03
Zinc	20.7	23.7

TABLE 2: Changes in trace element concentrations pre and post 2000.

Although caution is recommended when only two sampling periods are being used to determine changes in soil quality, it is a useful starting point that identifies the soil quality parameters and trace elements of most concern. As soil monitoring continues over time, a longer record of this data will enable more confident identification of where soil problems exist and where to target resources. This will also help inform our progress towards the Auckland Plan targets.

References:
Curran-Cournane, F., Lear, G., Schwendenmann, L. & Khin, J. (2015): Heavy metal soil pollution is influenced by the location of green spaces within urban settings. Soil Research (accepted DOI: 10.1071/SR14324).
Curran-Cournane, F. (2015): Soil quality state and trends in New Zealand's largest city after 15 years. International Journal of Environmental, Ecological, Geological and Geophysical Engineering 9, 227-234 waset.org/publications/10001081/soil-quality-state-and-trends-in-new-zealand-s-largest-city-after-15-years.

CASE STUDY: KAURI DIEBACK

KIA TOI TŪ TE KAURI – KEEP KAURI STANDING

Kauri grow to more than 50m tall, with trunk girths of over 10m, and can live for over 2000 years.

Ko te kauri he whakaruruhau mō te Iwi katoa – The kauri is a shelter for all peoples
Kia toi tū he whenua – So that the land is restored
Kia toi tū he kauri – So that the kauri stands proud

BACKGROUND

Kauri is a much-loved tree species with a special place in New Zealand's history. It shapes the character and function of forests; it is a taonga tuku iho of the Māori ancestral spiritual world, and it has cultural importance to all New Zealanders.

But all is not well with kauri. The sad fact is that historical commercial harvesting and land clearance have left us with only 1% of our majestic pre-European kauri forests. And that 1% is now threatened by an invasive disease that kills kauri indiscriminately.

Kauri dieback is caused by a soilborne microorganism called Phytophthora taxon Agathis (PTA), see figure 1. Although we believe it has been killing kauri since the 1970s, only recently has research been able to identify PTA and its role in kauri dieback. PTA infects kauri roots and damages the tissues carrying nutrients and water within the tree, effectively starving it to death. Symptoms include yellowing foliage, thinning canopies, dead branches and rapid tree death (figure 2).

PTA kills kauri of all sizes, from the smallest seedlings to the oldest giant forest trees. We are also yet to observe any natural resistance to the disease, which means in time all kauri could succumb to it. Kauri forest is critically important to all New Zealanders and as it is vulnerable, it needs our protection.

In 2008 PTA was declared an Unwanted Organism under the Biosecurity Act and is now subject to a national long-term management programme.

FIGURE 1: Soilborne microscopic spores of PTA (magnified 400 times). Photo: Scion Research.

FIGURE 2: Symptoms of kauri dieback.

KAURI DIEBACK IN AUCKLAND

Kauri plays a vital role in Auckland's culture, history, landscapes and ecosystems. Protection and kaitiakitanga of kauri from further decline and disease has been prioritised by mana whenua of Tāmaki Makaurau. The few original kauri trees left in Auckland are among the region's most spectacular trees and are environment-shapers, exerting a strong influence on the native species living with them. However, since the discovery of kauri dieback in the Waitākere Ranges in 2008, the disease has proven to be a rapidly increasing pest issue affecting many of the last remaining kauri stands in Auckland.

An estimated 13,500 hectares (both public reserves and private land) containing kauri are affected by kauri dieback.

Over the last five years, extensive kauri health surveys throughout regional and local parkland in the Auckland region have been completed. Sadly, the disease was found to be widespread throughout the Waitākeres and is now present in most catchments.

Ongoing surveys since 2010 estimated up to 13% of dense areas of kauri forest in the Waitākeres were already affected. Disease distribution is higher in areas more regularly visited by walkers, with areas such as Piha and Cascade Kauri being the most affected. There is a positive correlation between the track network and kauri dieback zones (figure 3), showing that humans are a significant factor in the spread of the disease. Kauri dieback will have long-term effects on the ecosystem if it continues to spread unabated and uncontrolled.

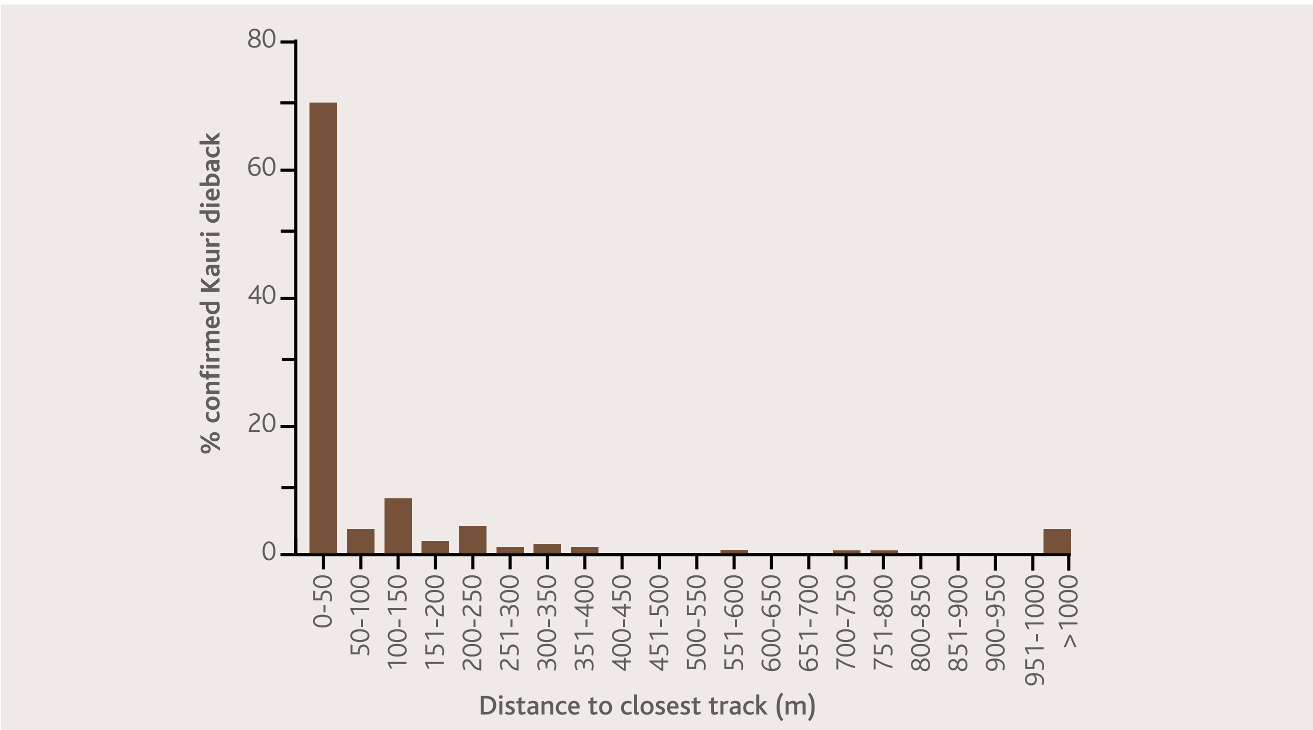


FIGURE 3: Proximity of kauri dieback disease to tracks in the Waitākere Ranges Regional Park.

Kauri dieback is also an increasingly important issue for private landowners who have the trees on their land (figure 4). Over 500 private properties have been inspected since 2009, almost 100 of them recording kauri dieback symptoms. Almost half of all affected properties are in the Waitākere Local Board area.

Observations by many landowners suggest kauri dieback has been visibly emerging since the late 1990s on the Auckland mainland, with continued spread resulting in new infection sites. Thousands of trees have already succumbed at many sites, causing a health and safety issue for landowners as standing dead trees are often close to buildings, roads and people's activities. Expensive tree removal and safe disposal is a direct economic impact to affected landowners.

The extent of kauri dieback now includes large areas of the Waitākere Ranges, Aotea (Great Barrier Island), and rural fragments in Rodney and on the Āwhitu Peninsula in the south. However, the disease remains undetected in kauri forest in locations such as the Hunua Ranges, many of the other Hauraki Gulf islands (including Hauturu/Little Barrier, Waiheke, Kawau and Pōnui), and northern regional parks such Tāwharanui, Shakespear and Wenderholm.

FIGURE 4: Trees succumbing to kauri dieback on private land in the Rodney Local Board area (north Auckland).

FIGURE 5: Cleaning stations for visitors to use, such as this one at Hunua Ranges Regional Park, have been installed at kauri parks and reserves across the region.

CASE STUDY: URBAN FOREST

AUCKLAND'S URBAN FOREST – REMNANTS OF AN ANCIENT WORLD

Urban forest on Maungawhau (Mt Eden) and surrounding suburbs.

Before humans arrived, the Auckland urban area had been covered in lush tall forest for most of the last 15,000 years[1,2,3]. In a few precious patches the only legacy of this majestic world remains. Auckland's urban forest provides us with clean air and water, places to walk and run and play, to seek solitude (relatively speaking) or to interact with native plants and animals; every day, right in the city. It's important we protect it.

WHAT IS URBAN FOREST?

In its widest sense 'urban forest' includes almost all trees and shrubs within a city[3] but in this case study we have focused on larger patches of forest (not including planted trees in streets, parks and gardens). These come in three main types:

- Enclaves of natural forest that have survived 150 years of urban development.
- Mixed communities of native and exotic plants that have spontaneously re-colonised sites previously cleared of woody vegetation.
- Restored and/or planted native scrub and forest.

Often you will find two or three of these different types within the same patch of urban forest, as new plantings and spontaneous regeneration often occur around a core of older, more natural forest.

AUCKLAND'S UNIQUE URBAN FORESTS

(Sites described below are marked with a red star in figure 1, page 118)

TARAIRE FOREST AT KIRKS BUSH

Mature taraire forest, with other native tree species such as kohekohe, pūriri, tōwai, tawa and rimu, covered large parts of south Auckland in pre-human times. Around 98% of this forest type has been cleared from this area, because the land was highly valued for farming and building settlements. This means remnants like those at Kirks' Bush are incredibly valuable for their biodiversity, as well as great places to unwind. This forest is an example of Auckland ecosystem type WF[4].
Photo: Mike Wilcox

MANUREWA NATIVE FOREST REMNANTS

Like most mature native forest, these types are now very rare in urban Auckland. Some excellent examples of mature tōtara , puriri, kahikatea-pukatea and kanuka forest are found in a cluster of council reserves in Manurewa. These include the Botanic Gardens, Hillcrest Grove, Orford Park and David Nathan Park. The tōtara, regenerating kanuka and kahikatea-pukatea forest is a successional community, meaning the tōtara and kanuka will be replaced by other (hopefully native!) trees slowly over time. These forest patches contain examples of Auckland ecosystem types WF7, WF8 & VS2[4].

LAVA FOREST IN WITHIEL THOMAS RESERVE

Indigenous lava forest grows on recent lava flows that have yet to develop a proper soil. Nationally, lava forest is uncommon. The few remnants in urban Auckland – most notably at Gribblehirst Park and Maungawhau (Mt Eden) – represent the last 0.5%[5] of an indigenous ecosystem type that has been almost totally removed. This forest is an example of Auckland ecosystem type WF7 variant 2[4].
Photo: Mike Wilcox

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KAURI FOREST IN CHATSWOOD RESERVE

The network of reserves in the Chatswood - Birkenhead area contain the best example of kauri-podocarp forest in urban Auckland. This is also the only place in urban Auckland where you will see hard beech forest. Much of this forest is young (less than 150 years), but it includes pockets of kauri and hard beech forest that is much older (400-plus years). This mature forest represents the pre-human vegetation of the urban North Shore. The forest shown here is an example of Auckland ecosystem type WF11[4].

GUMLAND SCRUB, WAIKUMETE CEMETERY

Gumlands grow where climate, acidic leaf litter, infertile parent rock and time have combined to create a low-nutrient, waterlogged soil substrate that will not support tall forest. Gumland vegetation is characterised by low scrub, sedgeland and fernland. The best example in Auckland is at Waikumete Cemetery. This gumland is an example of Auckland ecosystem type WL1[4].

PŪRIRI CATHEDRAL GROVE, SMITHS BUSH

Kahikatea forest is found in locations with a high water table, such as wet depressions and flat terraces beside major water courses. These same landforms are perfect for farming and building houses, and kahikatea forest has therefore been almost entirely cleared from urban Auckland. One of the best examples is Smiths Bush, a green urban oasis of soaring trees and raucous tūī, right beside the northern motorway. Nestled within the kahikatea is a magnificent stand of pūriri (pictured). Smith's Bush contains examples of Auckland ecosystem types MF2 and WF7[4].

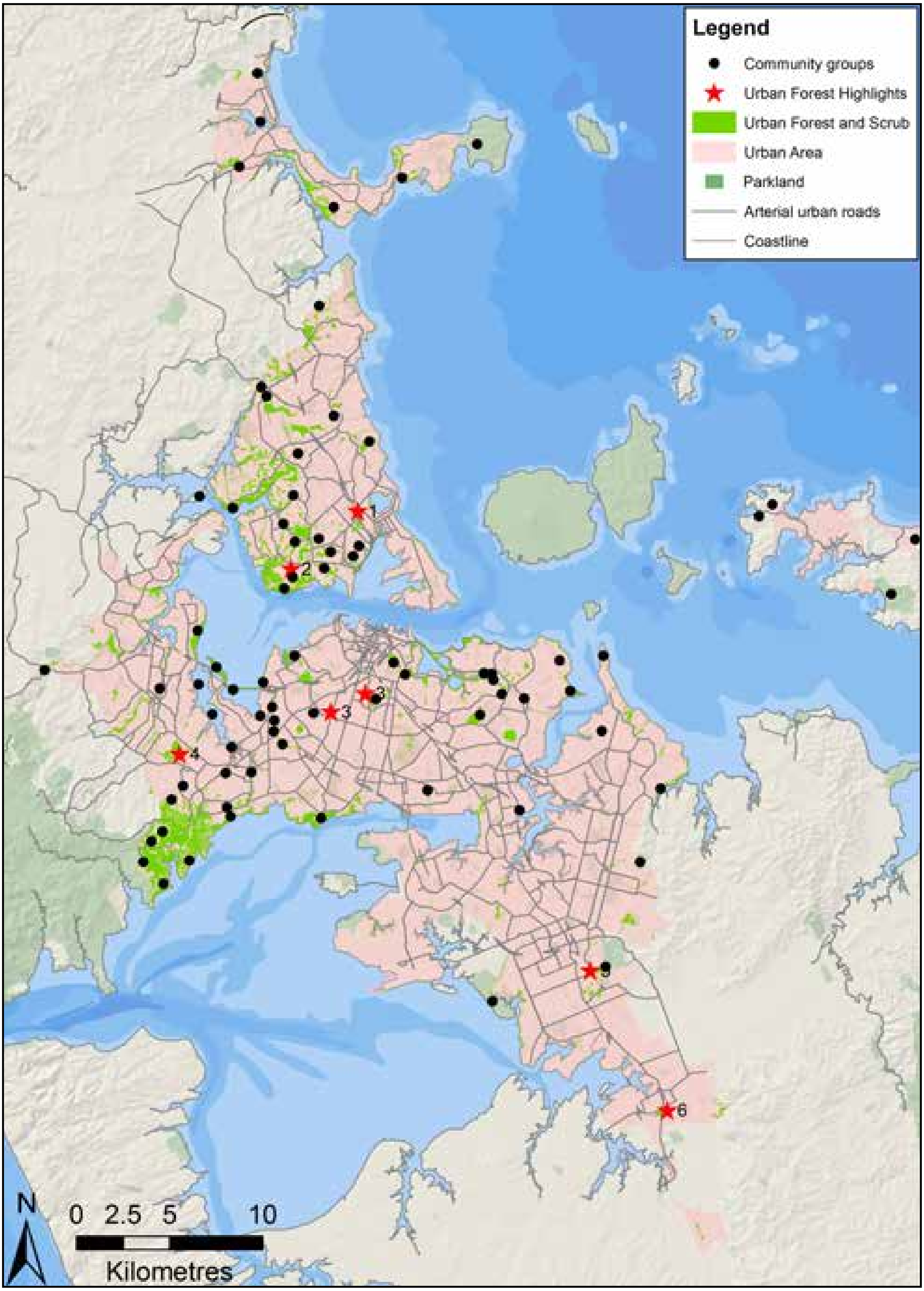

FIGURE 1: Distribution of Auckland's urban forest remnants greater than about 1ha in size. Includes urban forest highlights (red stars) and locations with active community groups (black dots).

WHAT HAVE URBAN FORESTS EVER DONE FOR YOU?

Just in case you're thinking, 'urban forest is all very nice, but it's not as important as building new houses', here are some ways you might not have thought about in which urban forest can improve the liveability of a city:

- Increases property values.
- Cools the city by reducing the 'heat island effect'.
- Absorbs carbon, reducing our carbon footprint.
- Cleans pollution from air and water.
- Improves our health and well-being – shown by numerous international studies[6,7,8,9].
- Provides beauty and shelter.
- Contributes importantly to the cultural health (māuri) of the land.
- Provides great places to play, walk, run, cycle, amble and unwind.
- Provides a barrier that reduces dust and noise pollution from roads and industry.
- Provides a habitat for wildlife, filling the city with birds.
- Conserves and maintains rare and unusual native biodiversity.
- Provides resources (e.g. flax/harakeke) for weaving and other uses.

Contact with nature is a basic human need for spiritual and emotional well-being. Most of the world's most liveable cities, and many others, have recognised the importance of urban forest by assigning targets for minimum percentage forest cover in different types of urban environment (see Liveable Cities Case Study). Auckland has a natural advantage with its large established green spaces, which comprise around 25% of the urban area. Green space includes areas of urban forest, wetland and treeland ecosystems, as well as pasture-dominated parks and sportsfields. Some of these exotic pasture dominated open spaces provide excellent opportunities for expanding and enhancing our current stock of urban forest through restoration planting. For example, the many maunga (volcanic cones) scattered throughout the city contain hundreds of hectares of kikuyu dominated grassland.

WHAT HAVE WE FOUND?

THE PROBLEM WITH WEEDS

One of the main problems with Auckland's urban forest is weeds. Auckland's mild, moist climate, large population and worldwide trade links have ensured a steady stream of plant invaders over the years. Woody species like pine and tree privet dominate, but climbing asparagus (a strangling climber) was the most widespread weed in all urban forest plots.

Figure 2 shows the 10 most important weed species, based on their relative biomass, density and frequency, in our urban forest. It's a real United Nations of weeds! The relative dominance of each weed species in figure 2 was calculated from an average of its relative percentage biomass, density and frequency.

NATIVE BIRDS IN OUR URBAN FORESTS

To work out the most common birds in our urban forest we conducted 10-minute bird counts at each location. The top 10 bird species recorded included five natives, three of which are found only in New Zealand (see figure 3). Three of the top four were native (silvereye, tūī and grey warbler). Another study[10] in the Auckland Domain counted native birds more commonly than introduced species. This may reflect the larger size of the forest fragment at the Domain compared with our sample locations.

Although at this stage we only have baseline measures and cannot assess changes over time, the results indicate there is a moderate amount of native birds out there in the urban forest, making it valuable for biodiversity.

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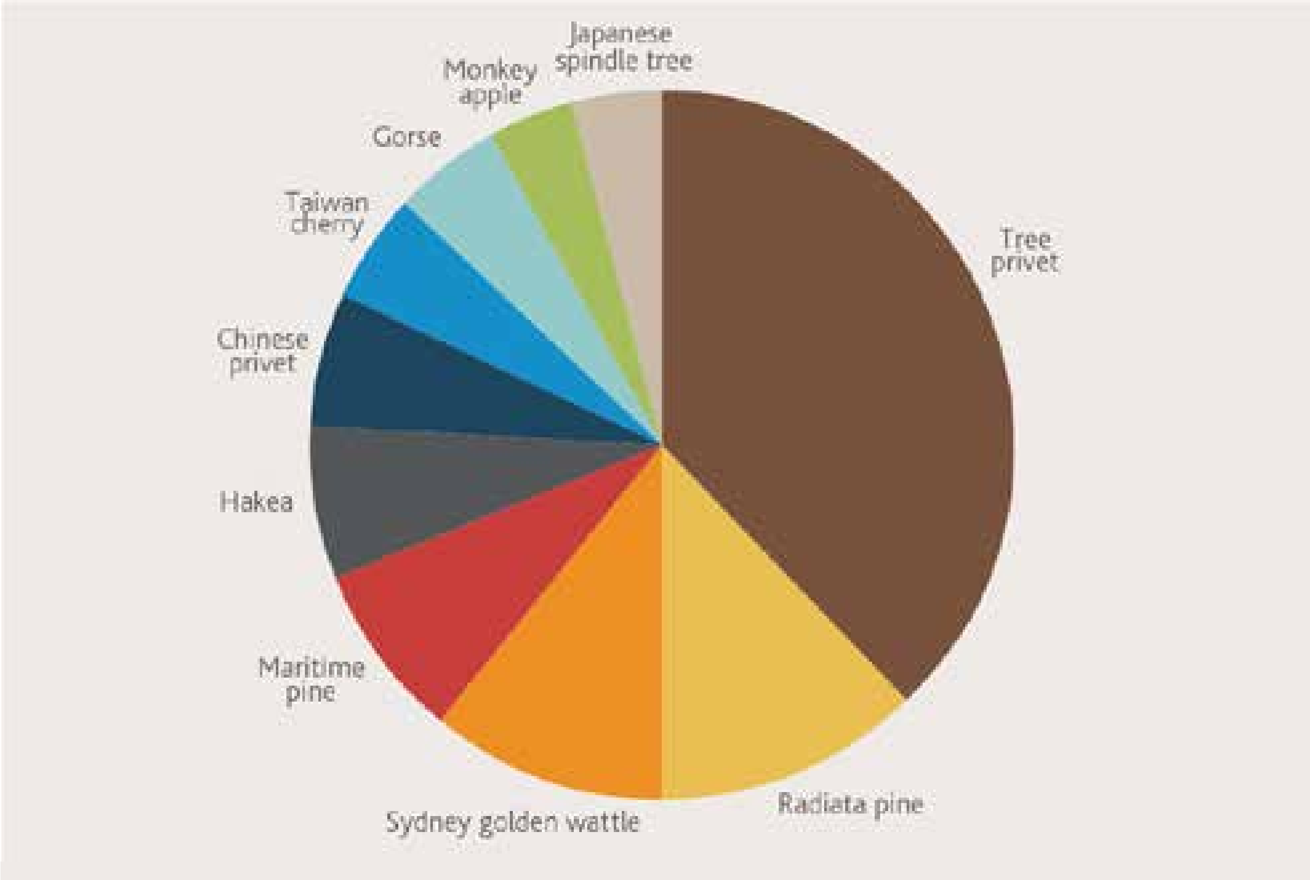

FIGURE 2: Top 10 native plants (by importance value) in Auckland's urban forest.

URBAN FORESTS HAVE HEALTHY SOILS

As part of our soil monitoring programme (see soil health indicator, page 101) we monitored the health of soil at 60 sites within urban Auckland. Of these, the 10 urban forest sites had the lowest levels of pollutants such as trace elements. This suggests that, in line with overseas experimental evidence, [11,12,13] tree canopy cover is an effective buffer that captures and protects against airborne pollutants.

Using these findings we were able to develop a Pollution Index (PI) using urban forest sites as the baseline[14]. The relative health of urban forest soil is shown in figure 4.

WHAT CAN YOU DO TO HELP?

The main thing you can do is love your urban forests, use them and do what you can to protect them. There is nothing so powerful as the passion and action of a community to bring a forest back to life.

Urban areas, being close to large populations of people, are ideal for restoration projects. There are currently more than 50 community-based ecosystem restoration projects in the Auckland area.

Auckland Council is also working hard to improve biodiversity on parkland through our operational restoration activities and also by working closely with community restoration groups, providing support and advice where we can. All these concerted efforts can have a significant impact on improving urban biodiversity, so that we see more kererū flying about, hear the iconic song of the kōkako, and encounter other amazing native species such as the beautiful Auckland green gecko.

We encourage you to get out there and get involved! A great place to start is Nature Space (**naturespace.org.nz**) to see what's happening close to your neighbourhood. Or have a look on the Ecoevents website (**ecoevents.org.nz**) to see what environmental events you can join in on in Auckland.

References:
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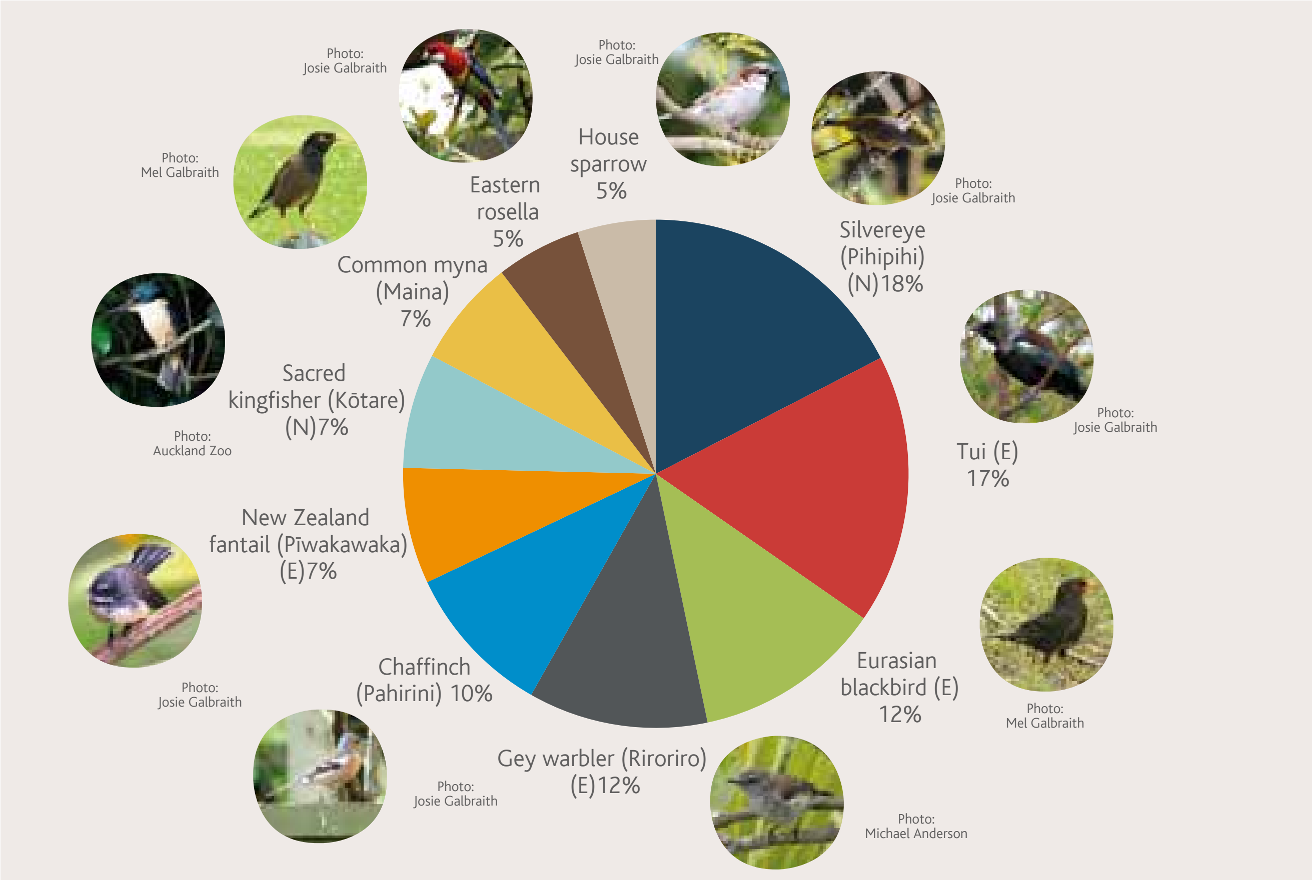


FIGURE 3: Ten most common birds heard/seen in counts at sites in Auckland's urban forest. N = Native, E = Endemic (found only in New Zealand).

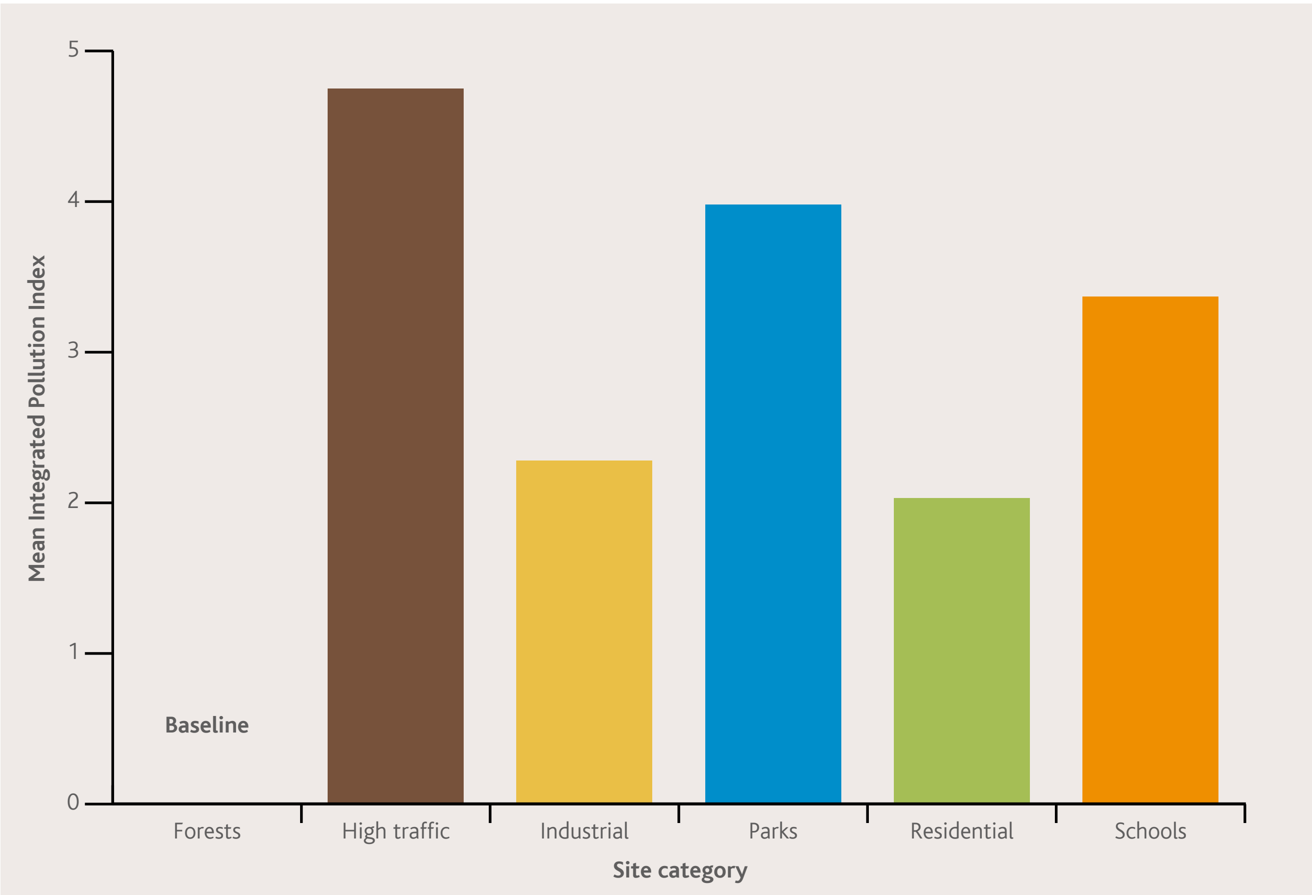


FIGURE 4: Mean Integrated Pollution Index (IPI) across urban land use categories in Auckland using urban forests as a baseline.

IN SUMMARY
TE KĀPUINGA

Children from Milford Kindergarten planting trees

Auckland's soils and terrestrial biodiversity are essential natural resources we rely on to live. The land section of this report presents results from our first comprehensive baseline measure of the health of forest, scrub and shrubland, the dominant land ecosystems in our region. When combined with information from the Land Cover Database (LCDB) and comprehensive soil quality programme, these data are our best landscape-scale measurements of the general health of, and threats to, our natural assets.

Our land indicators tell an interesting story. Auckland's landcover in general has remained the same over the last decade, with little change in the balance of farmland versus native forest, and scrub versus exotic forestry.

But in specific areas we are seeing some more dramatic changes, particularly on the city margins where urban growth is replacing high–production pasture.

In general, terrestrial biodiversity monitoring in our remaining forest, scrub and shrubland ecosystems shows high biodiversity in the larger forests such as in the Waitākere and Hunua ranges. This is also evident on Hauraki Gulf islands where native habitat remains and control efforts mean there is a lack of animal pests. However, on the mainland there is reduced diversity of native plants and birds in areas more modified by high-intensity farming and urban growth, and higher tree and sapling mortality and dieback. These results are not surprising, as past research suggests ecosystems that have been fragmented and isolated are also more degraded and modified in terms of their habitat quality for indigenous plants and animals.

These results reinforce the need to protect the remaining areas of ecologically significant native habitat, both on public and private land. Ultimately we need to increase the size as well as the connectivity between our remaining habitat patches to create a buffer around these important areas. This would also enable our mobile species, such as kākā, bellbirds and robins, to move between forest fragments and increase their populations on the mainland.

Arguably the greatest single threat to Auckland's indigenous biodiversity on land is pests. Our regional pest plant (weed) and pest animal surveys have identified significant variability across the region, particularly regarding weeds. The larger native forest tracts are resistant to invasion and had few weeds, whereas the urban and rural forest patches were more exposed and showed much higher infestation levels. We found gorse, radiata pine and tree privet to be the three most dominant and widespread weeds in our native forest, scrub and shrubland ecosystems.

To make progress in controlling weeds we all need to continue to work together to stomp them out in our backyards, as well as in the larger forests such as regional parks. It's vital we continue to monitor and understand better the impact of weeds on our threatened species and ecosystems, so we can react swiftly to new threats and implement practical and more efficient weed management.

Our pest animal regional survey of mice, rats and possums identified that successful biosecurity management can be very effective in keeping down the populations of these pests. An example is the great work being done at places like Ark in the Park (in the Waitākere Ranges), Glenfern and Windy Hill (on Aotea/Great Barrier Island), as well as the high biodiversity values of pest-free islands such as Hauturu (Little Barrier Island). There's more work to be done, particularly in our precious Hunuas Ranges where Auckland's only mainland remnant population of kōkako resides. Reducing pest animals is one of the key aims we need to make progress towards if we want stable and healthy populations of all our native birds, invertebrates and other threatened and at-risk species.

The soil monitoring programme showed that while some elements of the soil are good, others are in decline, so the soil is not functioning as well as it could. The key soil quality indicators of most concern are elevated concentrations of Olsen P (phosphorus) and low macroporosity in pastoral and horticultural land. This is telling us that too much phosphorus fertiliser is being applied and our soils are suffering from compaction.

Overly fertilised and compact soils are more at risk of sediment and nutrients washing off the surface of land when it rains and potentially entering freshwater or marine systems. There is no benefit of applying too much phosphorus fertiliser because the plant can only take up so much of it. An overly compact soil will also often result in reduced pastoral or crop production for the farmer in the following growing season.

Overall our soil trace elements appear to be relatively stable over the years. But at individual sites exceedances of cadmium and copper were most apparent in rural Auckland. Phosphorus fertilisers are a major source of cadmium, so there are multiple benefits in using less of these fertilisers on farmland. Potential and common sources of trace elements in an urban setting are vehicle emissions. These elements are added to gasoline or contained in engines and galvanised parts, tyres and lubricating oils, coal and fuel combustion, paint and local industry processes, as well as coming from current and past use of fertilisers and pesticides. Reducing private vehicle use, and increasing use of public transport will contribute to reducing the accumulation of trace elements such as arsenic, chromium, lead, nickel and zinc in our urban soils.

Auckland is known for having some of the best soils in New Zealand, particularly for food production; however, they represent only a small proportion of the region's total land area. Unfortunately, this small proportion of the best land is vulnerable to urban encroachment, and also to rural subdivision and the expansion of lifestyle blocks. The latter fragments the rural landscape over time, which for economic purposes requires large parcels of land to operate. Habitat fragmentation is also considered to be a major threat to the indigenous biodiversity in our region, another indirect effect of rural fragmentation.

The terrestrial biodiversity and soil monitoring programmes have provided good baseline data including some trend information about the overall state of our land resources, and areas we need to improve in. We will need to maintain this evidence base to evaluate how our natural assets are responding to the different threats and pressures our speedily growing city will face, and ensure we meet environmental objectives of plans and policies.

WHAT CAN YOU DO TO HELP?
ME PĒHEA TŌ ĀWHINA MAI

Whether you live in a rural or urban area, on an island or the mainland, there are many opportunities to help restore Auckland's indigenous biodiversity, as well as maintain our soils and the benefits our land resources provide for all of us. Here are a few suggestions.

- If you are a landowner, particularly a rural one, find out about the biodiversity values on your land and the measures you could take to protect and improve them. Have a look here to start your thinking:
  - **aucklandcouncil.govt.nz/EN/environmentwaste/biodiversity/pages/biodiversityonyourproperty.aspx**
- Remove any weeds on your property and replace them with native species appropriate for your location. Encourage your friends, neighbours and work colleagues to do the same! Here's a link to a useful guide about controlling weeds:
  - **aucklandcouncil.govt.nz/EN/environmentwaste/biosecurity/pages/controllingpestplants.aspx**
- Pest animals continue to be a major threat. Learn more about them and what you can do to help here:
  - **aucklandcouncil.govt.nz/EN/environmentwaste/biosecurity/Pages/pestanimals.aspx**
  - **aucklandcouncil.govt.nz/EN/environmentwaste/biosecurity/Pages/controllingpestanimals.aspx**
- Join one of the many community restoration groups in the region, such as the Waitākere Ranges Ark in the Park, Shakespear and Tāwharanui's open sanctuaries, or other activities in other regional and local parks.
  - One of the best repositories of information about community restoration groups is Nature Space, so have a look at their website to find out what's happening close to your neighbourhood: **naturespace.org.nz**
- Have a look at the ecoevents website to see what environmental events you can join in on in Auckland:
  - **ecoevents.org.nz**
- Learn about biodiversity in Auckland and New Zealand. Here's a good place to start:
  - **aucklandcouncil.govt.nz/EN/environmentwaste/biodiversity/Pages/home.aspx**
- Get out there and enjoy our wonderful biodiversity in places like the impressive Waitākere Ranges, Shakespear and Tāwharanui's open sanctuaries, or Tiritiri Matangi. Visit some of the urban forest sites listed in the case study (page 102), especially if you are taking the kids. All are tranquil oases of native biodiversity right in the city. Can you tell which birds are native or introduced at these sites? Here's an excellent resource to help you learn about all of New Zealand's birds:
  - **nzbirdsonline.org.nz/**
- Be part of the next Garden Bird Survey! **landcareresearch.co.nz/science/plants-animals-fungi/animals/birds/garden-bird-surveys**
- Help look after our precious soils.
  - Farmers and growers – apply less fertiliser. If you're not sure how much is enough, most fertiliser companies will send an expert to analyse your soil and tell you how much you need to use. It's easy, quick, and will likely save you money and help protect the environment. For more advice on land management practice, contact the Land and Water Advisors at Auckland Council.
  - Use your car less, and dispose of solid waste, old paints and fuels responsibly.

CASE STUDY: BETTER URBAN DESIGN

USING NATURAL SYSTEMS IN URBAN DESIGN

Wynyard Quarter

Transport options that match your lifestyle, swimmable streams and beaches, flood protection, clear harbours, cycle lanes and walking paths along bushy urban streams, clean healthy air, communal gardens with fruit trees and vegies. These are just some of the benefits of using natural systems in urban design – one of the most promising ideas for making Auckland the most liveable city in the world.

WHY USE NATURAL SYSTEMS IN URBAN DESIGN?

So many of the environmental issues discussed in this report have their roots in the way we design and build our urban environment.

- Traffic jams up the city, which was built for cars rather than people.
- Urban areas covered in impervious concrete, asphalt and steel overheat and are vulnerable to flooding.

- Contaminants, which run off roads and roofs, wash into streams and rivers, polluting the water and the ecosystems surrounding them.
- Biodiversity is lost in concrete jungles, and native plants lose out to weeds.
- Sewage overflows into waterways from combined sewer and stormwater pipes.
- Harbours and rivers become muddy from sediment runoff from earthworks.
- Highly productive land is being lost to urban development.

Compared with some other cities in the world, Auckland is in pretty good condition. But we sit at a turning point in our development. In the next 30 years our population is forecast to increase by 700,000 people – that's another 50 per cent on top of the current population. This will require an extra 324,000 homes, nearly double the current number of homes in Wellington (ARTM, Scenario I 8b).

This is a massive opportunity for Auckland. If we get it right, we could make Auckland the most liveable city in the world. But if we continue using old development techniques, the expansion could seriously degrade the city, tipping existing environmental and social problems such as transport, water and air pollution into a critical state.

To be the world's most liveable city Auckland needs to use natural systems in urban design.

WHAT DOES USING NATURAL SYSTEMS IN URBAN DESIGN MEAN?

Using natural systems in urban design is a whole new approach to building cities that work with nature rather than against it. This approach could provide for Auckland's housing needs while enhancing our environment and improving the way we live. The Auckland Plan reinforces this approach in Directive 10.7: "All urban development should take into account environmental design principles".

WHAT WOULD THIS LOOK LIKE IN PRACTICE?

ROADS AWAY FROM PEOPLE

Building schools, residential areas and other facilities away from busy roads and slowing down traffic in populated areas reduces the danger of disease due to air pollution. Let's build urban areas for people, not cars.

WATER SENSITIVE DESIGN

This is an approach to urban development that uses natural processes and the properties of water to enhance, rather than threaten, urban living. Three key ways it achieves this are:

- **Replacing concrete with vegetation:** Unlike concrete and steel, soil and plants have miraculous properties. They filter and drain water, preventing floods and stopping contaminants from entering our waterways; they absorb chemicals, exhale oxygen, store carbon and provide beauty and respite from the city. Using natural systems in urban design makes use of 'green roofs' and areas of vegetation in urban developments to perform these multiple functions.
- **Removing contaminants at source:** Urban development can be a major source of pollution in waterways. Water sensitive design reduces earthworks, limits impervious surfaces and uses materials that produce fewer contaminants.
- **Using the streams, not covering them:** Streams with riparian vegetation can form natural corridors through urban areas. They provide safe routes for cycling and walking, filters for contaminants, veins of clean air, biodiversity and birdlife through the city. Using natural systems in urban design makes use of natural features like streams rather than covering them.

USE TECHNOLOGY TO FIND SOLUTIONS

Sometimes finding the most effective solution can be complicated. When using natural systems in urban design we make use of computer modelling and other technologies to find the best places to build roads and buildings, and the best ways to build them.

URBAN AGRICULTURE

Community gardens encourage city dwellers to participate in growing fruit and vegetables in their neighborhoods, supplementing rural production. This is a great way to encourage community engagement and sustainability.

The Auckland Plan and the Proposed Auckland Unitary Plan call for us to sustainably manage our rural land and manage the effects of development to protect and enhance air and water quality and the life-supporting capacity of ecosystems. The examples across water, soil and air in the following case studies show how using natural systems during planning and development can achieve these goals, improving environmental outcomes and enhancing Auckland's liveability.

CASE STUDY: BETTER URBAN DESIGN

NEW TECHNIQUES TO PREDICT THE EFFECTS OF DEVELOPMENT

Auckland will need a smart development strategy to accommodate another 700,000 people in 30 years without degrading the environment. But predicting how different development strategies will affect the environment, culture and economy is incredibly complex and difficult.

Fortunately, we have computers to help. Researchers at the National Institute for Water and Atmospheric Research (NIWA) and Cawthron Institute have developed a decision support system (DSS) which models how our streams and harbours will react in different urban development scenarios. This project is part of a research project called Urban Planning that Sustains Waterbodies.

INTRODUCING THE DSS – OUR REAL-LIFE SHERLOCK HOLMES...

The DSS is a prediction tool. It puts together all the research and evidence we have so far about the effects of development on waterbodies and applies that knowledge to new development scenarios. You feed in information about land use, the existing environment and earthworks and stormwater treatment options, and the DSS produces data on the likely effects on water and sediment quality, ecosystem health, amenity values and other factors.

Although the model will incorporate social, cultural and economic effects, these aspects are still being developed, so here we have focused purely on environmental effects.

MODELLING DEVELOPMENT EFFECTS IN THE SOUTHERN RUB

Auckland Council has been using the DSS to assess the effects of urban growth on streams and estuaries within the Southern Rural Urban Boundary (the Southern RUB) – an area that will see massive expansion in the coming decades (see figures 1 and 2).

The study covered more than 250 square kilometres of mainly rural land in the southern part of Auckland, with Papakura to the north and Pukekohe to the south. This area is home to several streams, which flow north and west from the southern and eastern parts of the study area to the high-value estuaries of the Pāhurehure Inlet in the south-eastern Manukau Harbour. The development would add over 40,000 new homes and increase the percentage of urban land in the area from 5% to 18% (figure 2).

We tested four different development options: no further development, business-as-usual development and best possible practice with and without riparian planting of stream banks. The DSS generated the likely effects of each strategy on environmental indicators of water quality, stream ecology, sediment quality and estuary ecology in 50 years' time. Predictions presented here are for the lower Oira Creek catchment and the Inner Drury Creek Estuary (figure 1), an area predicted to change from 100% rural to 80% urban over this 50-year time frame (figure 2).

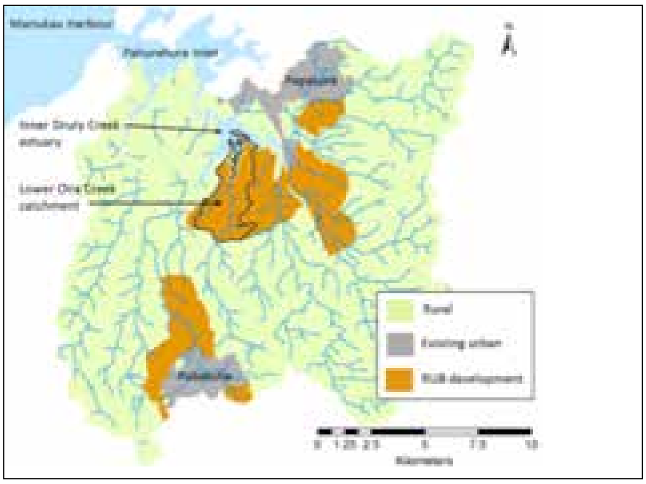


FIGURE 1: Map of the Southern RUB study area.

FIGURE 2: Projected land use change from rural to urban land use in the study areas.

WHAT DID WE FIND?

The results were a reality check and showed that Auckland's environmental issues are already serious and could worsen if we continue with business-as-usual development practice[1]. They also confirmed the benefits of using natural systems in urban design.

But while effects from the development itself could be mitigated with the best possible earthworks and stormwater treatment, several environmental indicators are predicted to worsen over time, due to the effects of land use outside the development area.

OPTION 1: NO DEVELOPMENT

Even if no further homes are built, the DSS predicts environmental indicators would worsen. The streams and estuaries in the Southern RUB are already showing elevated levels of metals and high sediment runoff.

In the next 50 years these baseline effects would worsen in Drury Creek Estuary even without the predicted development. This is due to ongoing runoff of metals from existing urban areas and sediment from existing rural areas. These results can be seen in the decline of all the estuarine indicators under the 'no development' scenario (figure 4) and would reduce the health of Drury Creek Estuary from 'moderate' to 'poor' over the study period.

Reference:
1. Moores, J., Cameron, M., Harper, S., and Batstone, C. (2013): Urban planning that sustains waterbodies: southern RUB case study. Prepared by NIWA and Auckland Council's Research, Investigations and Monitoring Unit. Auckland Council working report, WR2013/006.

OPTION 2: BUSINESS-AS-USUAL DEVELOPMENT

This is the worst-case scenario. If we continue current development approaches to earthworks and stormwater treatment, the streams and estuaries will suffer to a greater degree than if there was no development at all (figures 3 and 4).

OPTIONS 3 AND 4: BEST POSSIBLE STORMWATER AND EARTHWORKS TREATMENT AND RIPARIAN PLANTING

If 'best possible' earthworks and stormwater treatment and maximum riparian planting were used, the DSS predicts that the effects from the development itself could be mitigated or even improved. But as with the no development scenario there would still be a decline in the estuarine indicators, due to effects from existing urban and ongoing rural land use (figures 3 and 4).

WE NEED TO ADDRESS THE EFFECTS OF EXISTING LAND USE

This is a sobering result. It means that if we want to maintain and improve our waterways, we have to address the effects from existing land use as well as the effects of any new development.

A coordinated approach is needed, including:

- Additional riparian fencing and planting in rural areas (to address inputs of sediment).
- Additional stormwater treatment in existing urban areas (to address inputs of metals).

These techniques would need to be applied across all catchments draining to the wider Pāhurehure Inlet.

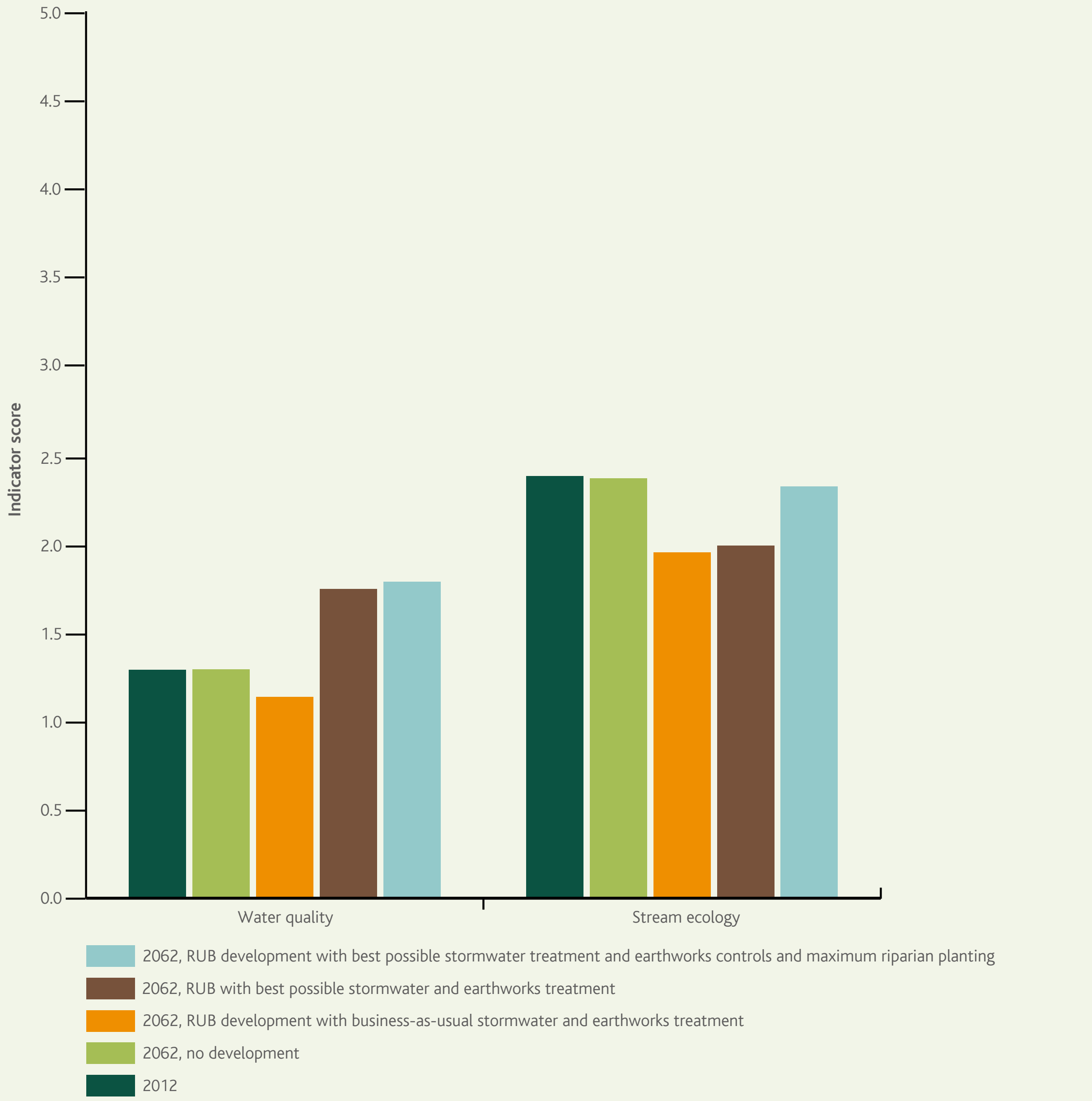


FIGURE 3: Freshwater indicators – Lower Oira Creek. Note: the higher the indicator score, the better the quality of the environment. Scores can range from zero to five.

USE EVEN SMARTER NATURAL SYSTEMS IN URBAN DESIGN

Fortunately, there are even more urban design ideas that can be used, for example, Water Sensitive Design (WSD) approaches such as cluster housing, the use of green roofs and water filtration through vegetation to clean and slow stormwater. This would likely lead to further improvements in stream water quality and ecology. Modelling of comprehensive WSD approaches is currently under development in the DSS but you can read about the actual outcomes from WSD approaches in the Flat Bush case study that follows.

APPLYING OUR FINDINGS TO OTHER DEVELOPMENTS

The findings from the current study are also applicable to other sheltered estuarine receiving environments in Auckland including those in RUB development areas in the north and west. We will also need a coordinated approach involving WSD and additional catchment management outside the area to be developed if we want to maintain and improve our waterways in these areas.

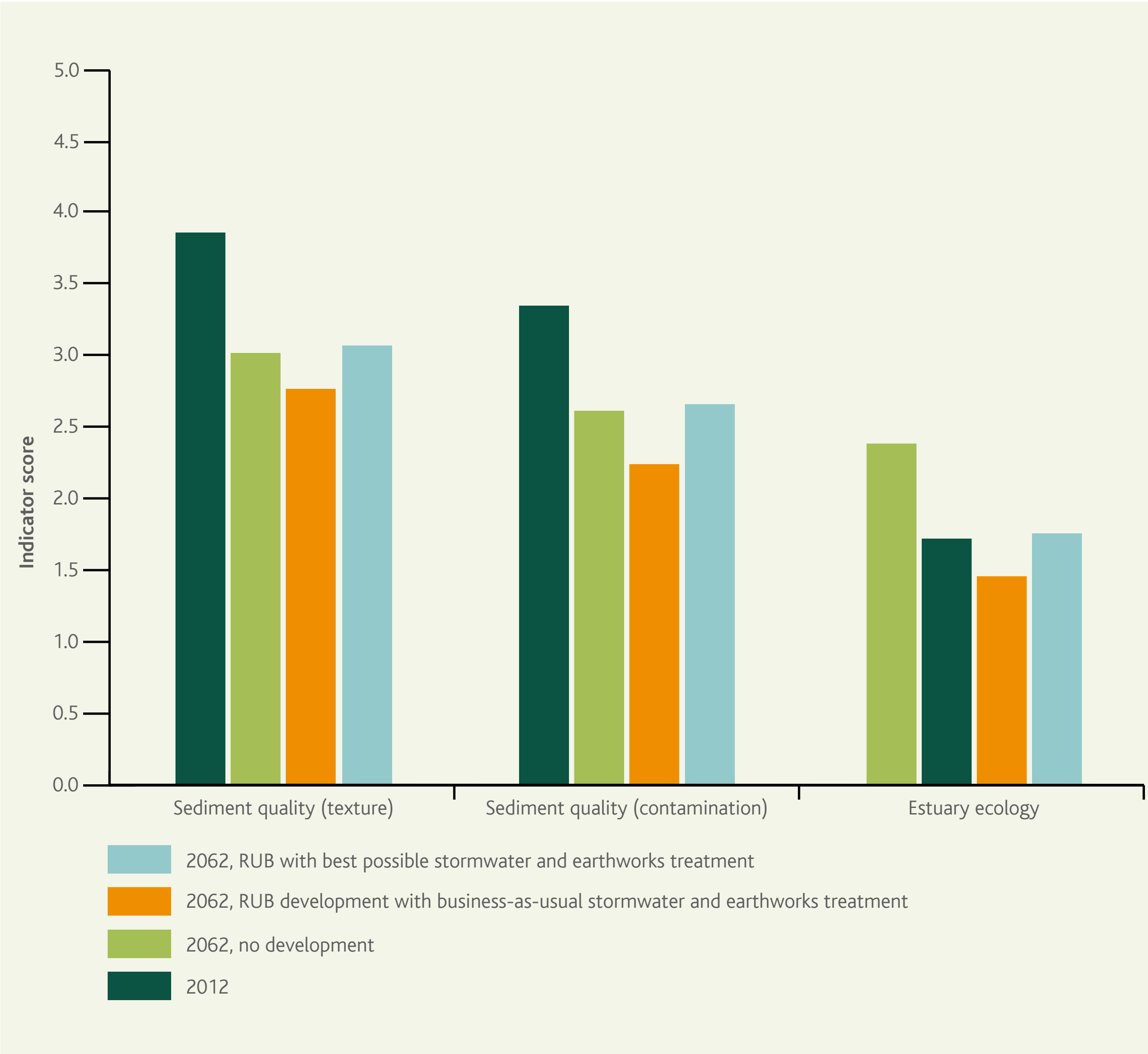


FIGURE 4: Estuarine indicators – Inner Drury Creek Estuary. Note: the higher the indicator score, the better the quality of the environment. Scores can range from zero to five.

CASE STUDY: BETTER URBAN DESIGN

WATER SENSITIVE DESIGN

Barry Curtis Park, Flat Bush

Water is one of the earth's most precious resources. But traditional urban development has often treated it as a problem to get rid of as quickly as possible. The award-winning Flat Bush development in south-east Auckland shows us the possibilities of a new approach called water sensitive design, which works with natural freshwater systems rather than against them.

As well as alleviating environmental issues such as flooding and sediment runoff, the Flat Bush development is creating a beautiful environment with large green spaces, recreation areas and a network of cycling and walking pathways. Not only do these things make it a great place to live, they will help our rivers and streams stay healthy and swimmable for future generations.

In 2007 the Flat Bush project was recognised with a gold award at the International Liveable Community Awards held in London.

ABOUT THE FLAT BUSH DEVELOPMENT

Flat Bush is the country's largest and most comprehensively planned new town. The development is taking shape on 1700 hectares of land and by 2025 is expected to house at least 36,000 people.

From day one the development has had a strong focus on connecting people and the environment, and water sensitive design (WSD) has been applied on a large scale from the outset. Instead of piping streams underground and covering urban areas in impermeable surfaces like concrete and tarmac, developers have used the miraculous natural properties of soil, plants and wetlands. Twenty-seven per cent of the catchment has been set aside to be protected and enhanced, including 45km of gullies and streams. It is also planned to substantially increase the amount of native bush in the catchment.

Flat Bush – protected riparian margins

At the heart of the community, next to the town centre, lies the 94ha Barry Curtis Park. From here a network of 'green fingers' branches out through the development. Sustainable transport is a priority and many of the green fingers incorporate cycling and walking pathways along protected streams. In some areas 'rain gardens' are used to treat stormwater instead of it being discharged directly to streams, and sewage is kept separate from stormwater. Ponds, wetlands and stream bank planting are also used to filter and treat stormwater.

HOW DOES WATER SENSITIVE DESIGN COMPARE WITH OLD APPROACHES?

Water Sensitive Design sounds nice. But what real difference does it make? Dr Marjorie van Roon, a researcher from the University of Auckland, has used an innovative paired catchment approach to evaluate the environmental outcomes of the Flat Bush development.

She compared stream health in headwater Flat Bush development areas (sub-catchments) that use various amounts of Water Sensitive Design, with other sub-catchments with similar biological, physical, land use and housing characteristics, but where traditional development approaches were used. Information about each sub-catchment is outlined in table 1.

Dr van Roon assessed stream health by monitoring the presence of macroinvertebrates – creepy crawlies like insects, crustaceans, snails and worms, which play key roles in maintaining stream ecosystems. By combining data on many species at each site, she was able to assign each site a single measure of ecological health. This measure, called the 'Quantitative Macroinvertebrate Community Index for soft bottom streams', gives an overall idea of the health of the stream and therefore the effectiveness of each development approach.

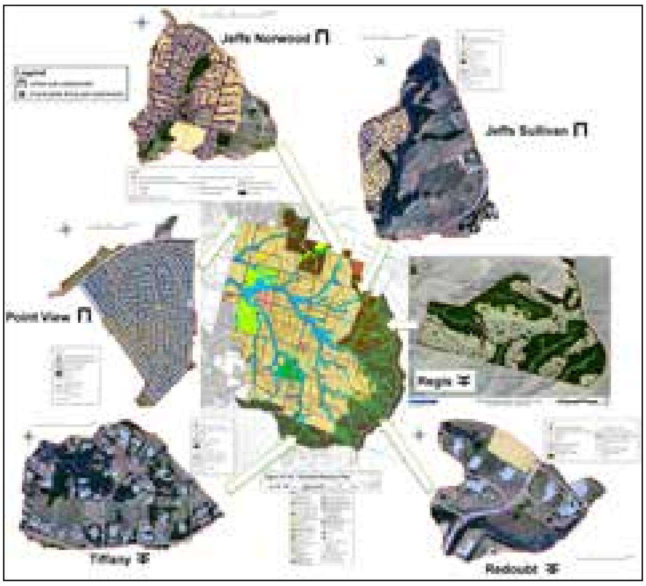


FIGURE 5: Location and type of sub-catchments studied in the Flat Bush development area.

The results confirm that WSD really does work, but only when multiple WSD approaches are used simultaneously. For both urban and countryside living developments, the catchments with the greatest use of WSD consistently display better stream health than those where conventional development or only partial WSD has been used[2] (figures 2 and 3).

WANT TO FIND OUT MORE ABOUT WATER SENSITIVE DESIGN?

For further information on how to use WSD see Auckland Council's new Water Sensitive Design Manual[4] on the Auckland Design Manual website. **aucklanddesignmanual.co.nz**

There is also a WSD framework available, which Dr Marjorie van Roon has outlined in her 2010 thesis. This offers a useful guide for ways to plan, design and build to promote healthy catchments. As yet no New Zealand development has implemented all the recommended methods outlined in van Roon 2010 simultaneously – this provides a great opportunity for the next big development in Auckland to be the first!

LOT DENSITY		URBAN AVERAGE LOT 400 – 500M^2				COUNTRYSIDE AVERAGE LOT 5000M^2		
NAME		Jeffs Sullivan	Jeffs Upper Norwood	Jeffs Lower Norwood	Point View	Regis	Tiffany	Redoubt
YEAR SUBDIVIDED		2003 – ongoing	2003	2003 – 2007	1980s	2004	1985	1990
CLUSTERING OF HOUSES (Y/N)		Yes	Yes	Yes	No	Yes	No	No
AREA (HA)		34	14	89	39	17	25	6.5
STORMWATER	TREATMENT	Ponds offline of riparian vegetation	Diverted out of sub-catchment	Stream diverted, pond in channel with wetland	No treatment	Raingardens on individual lots, roads piped	No treatment	No treatment
	DISCHARGE METHOD	Controlled flow to stream	Diverted out of sub-catchment	Pond surface overflow to stream	Direct flow to piped stream	Raingardens, trickle irrigation of roads to riparian vegetation	Overland flow to stream	Overland flow to stream
LONG-TERM IMPERVIOUSNESS (%)		40	40	40	60	17	15	17
RIPARIAN VEGETATION	TYPE	Mature forest	Mature forest	Mature forest	Nil	Re-afforested 2005	Patchy forest	Shrub
	MEAN WIDTH (M)	70	89	79	Nil	100	74	7
% OF SUB-CATCHMENT IN TREES (2012)		22	20	11	3	60	29	11

TABLE 1: Water Sensitive Design (WSD) relevant characteristics of Flat Bush sub-catchments compared for urban and countryside living separately. Greater intensity of colour shading indicates greater degree of WSD. The degree of WSD relates to criteria set out in van Roon 2010[3].

References:

2. van Roon, M.R. and Rigold, T. in prep. Urban Design and WSUD in comparative Auckland residential catchments determine stream ecosystem condition. Paper submitted to the Urban Water Journal.

3. van Roon, M.R. (2010). Low Impact Urban Design and Development: ecological efficacy as a basis for strategic planning and its implementation. PhD Thesis, University of Auckland.

QUANTITATIVE MACROINVERTEBRATE COMMUNITY INDEX SB (QMCI-sb) VERSUS YEAR FOR URBAN SUB-CATCHMENTS

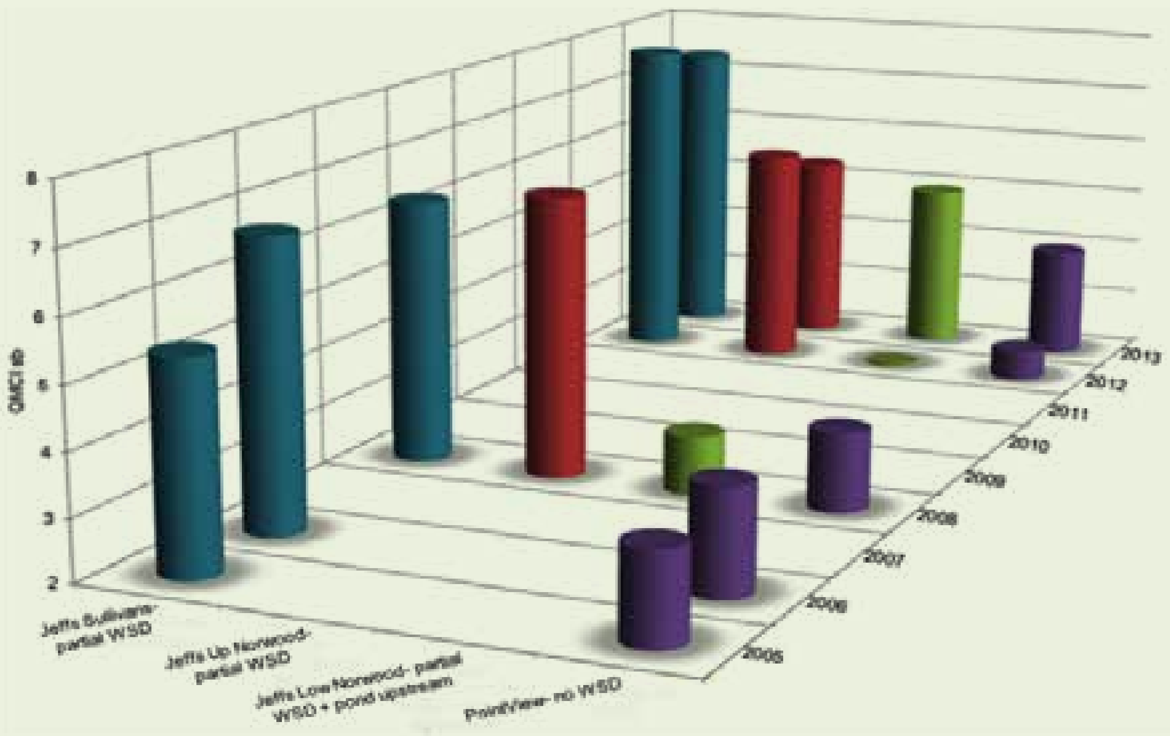


FIGURE 6: Urban stream ecological health as indicated by Quantitative Macroinvertebrate Community Index for soft-bottomed streams, 2005-2013.

References:
4. Lewis, M., James, J., Shaver, E., Blackbourn, S., Leahy, A., Seyb, R., Simcock, R., Wihongi, P., Sides, E., & Coste, C. (2015): Water sensitive design for stormwater. Auckland Council Guideline Document GD2015/004. Prepared by Boffa Miskell for Auckland Council.

QUANTITATIVE MACROINVERTEBRATE COMMUNITY INDEX SB (QMCI-sb) VERSUS YEAR FOR COUNTRYSIDE LIVING SUB-CATCHMENTS

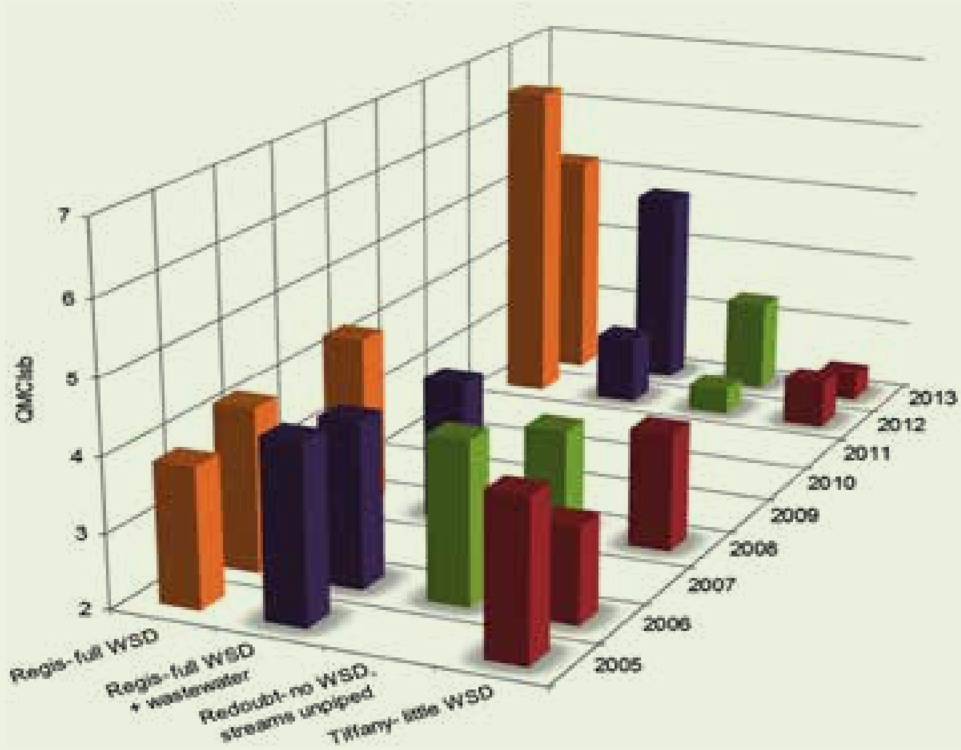


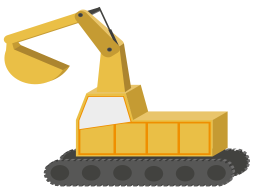
FIGURE 7: Countryside living stream ecological health as indicated by Quantitative Macroinvertebrate Community Index for soft-bottomed streams, 2005-2013. Note that 'Regis full WSD' is an average of three sites in that catchment. 'Regis full WSD + wastewater' receives discharge from a wastewater treatment plant so has been graphed separately to account for this influence.

NEW TECHNIQUES TO PREDICT THE EFFECTS OF DEVELOPMENT

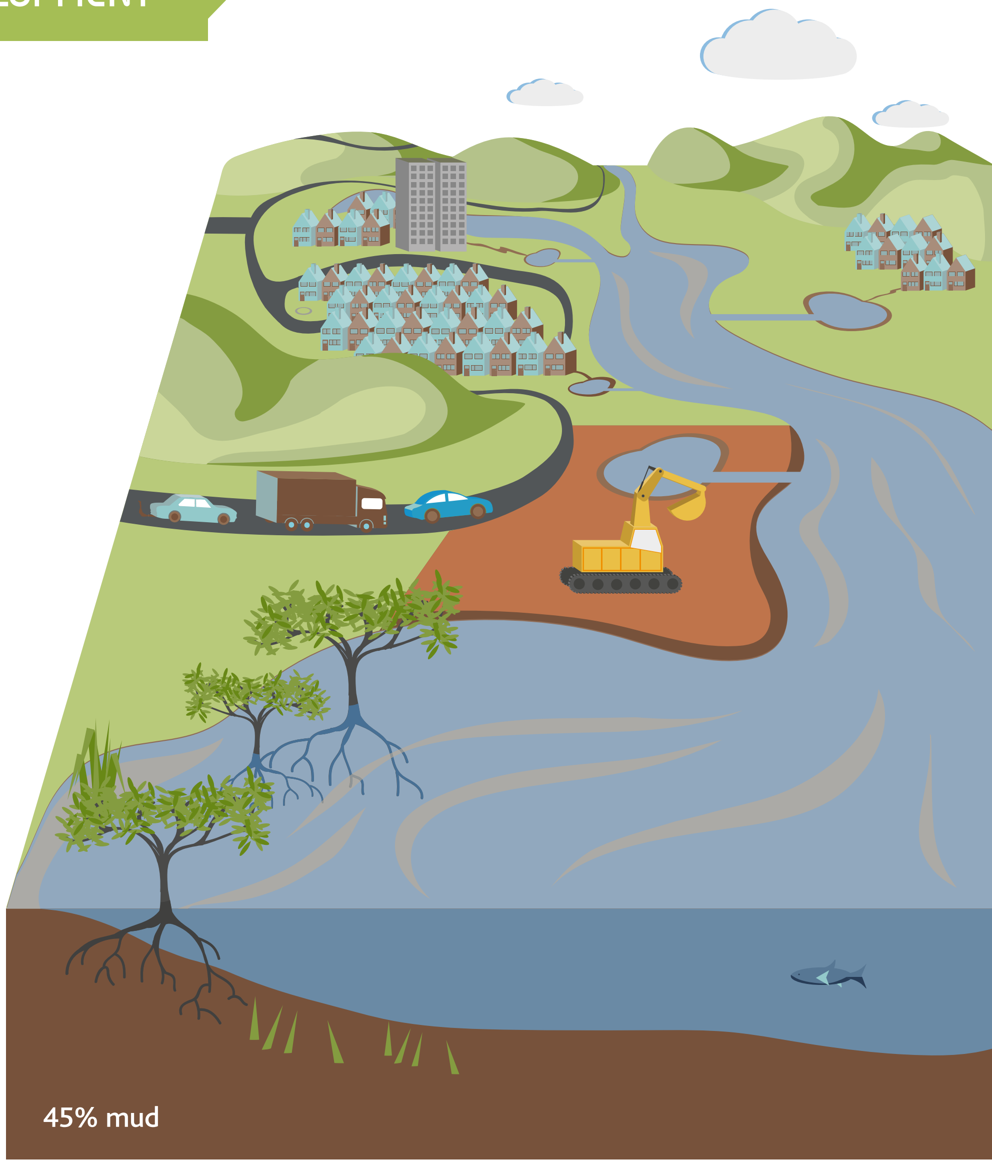
BASIC TREATMENT APPROACH

Basic treatment ponds for both:

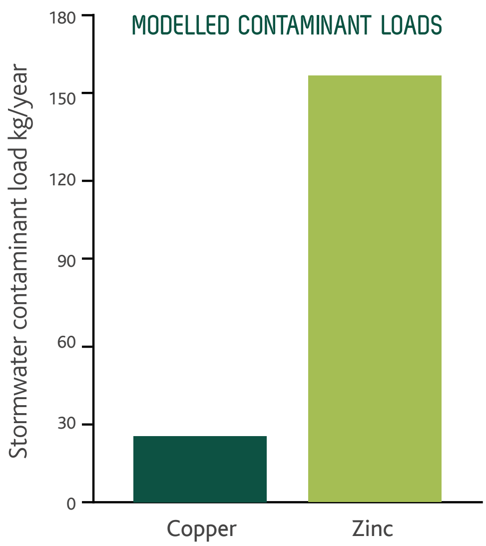
- Sediment runoff from earthworks during development.
- Metals runoff from stormwater after development.

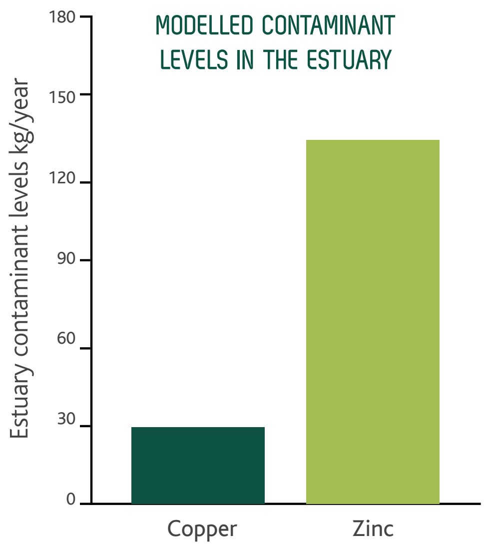


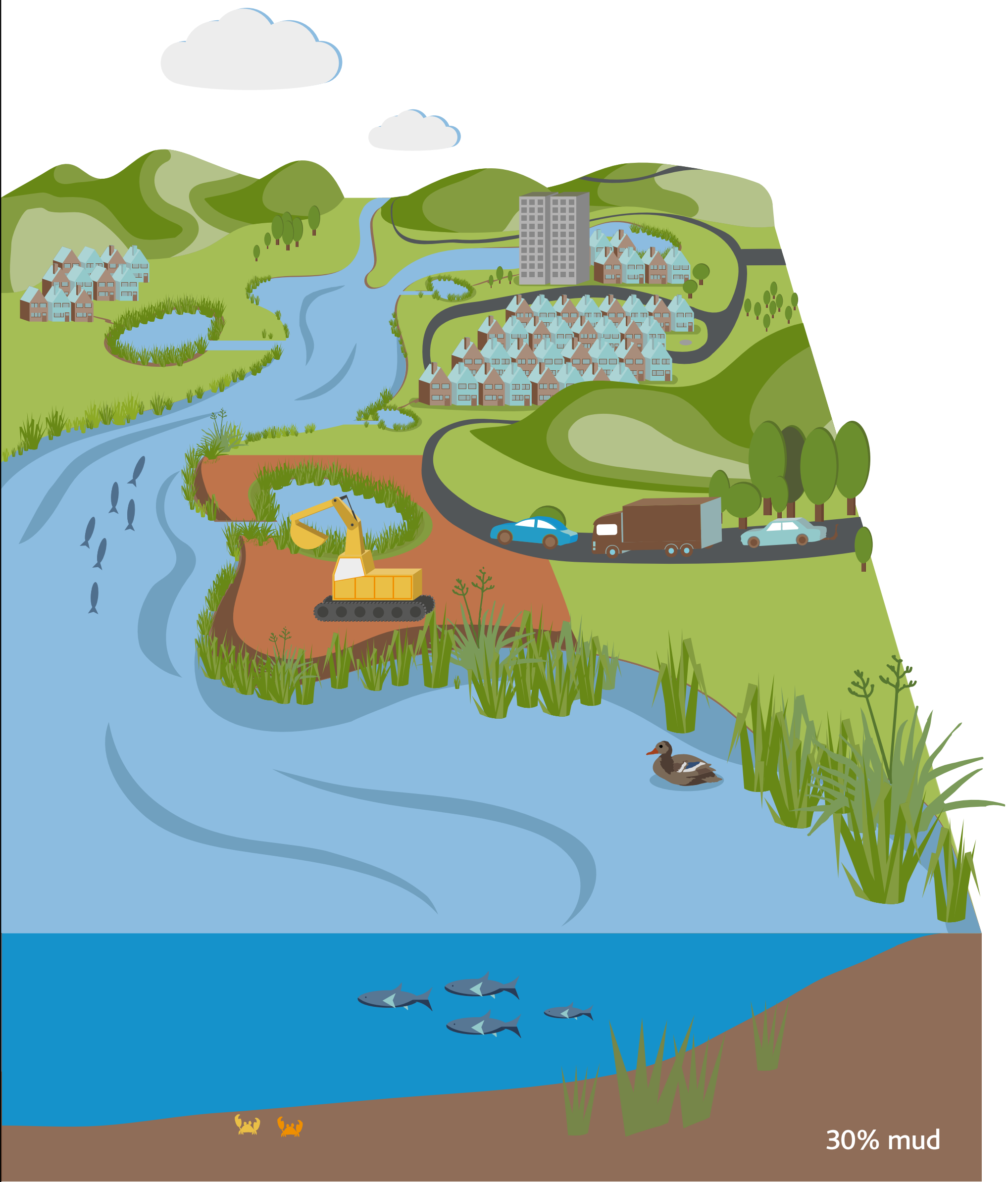
Modelled earthworks sediment load = 267 tonnes/year.



For further information see the case study on page 127.



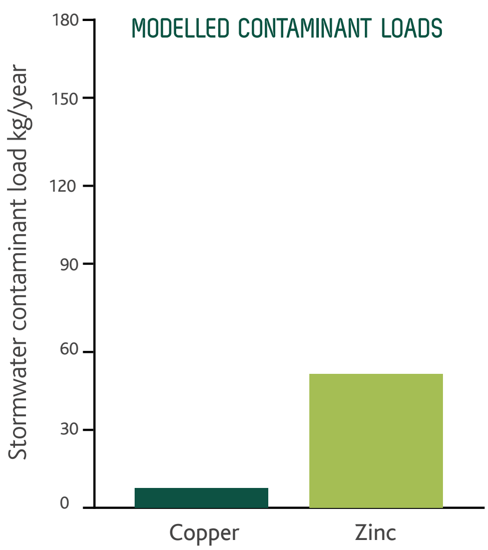


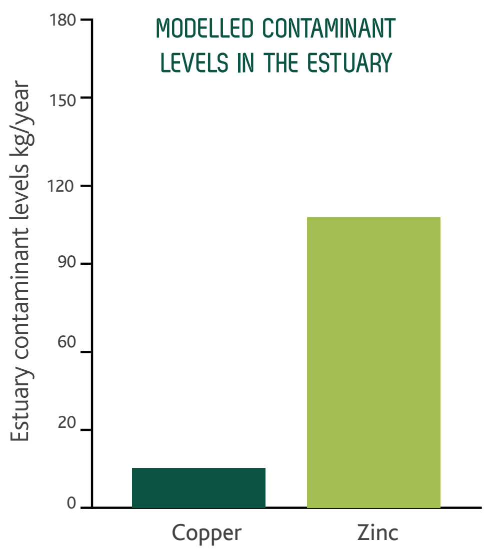


BEST POSSIBLE END OF PIPE TREATMENT APPROACH

- Using enhanced treatment ponds with wetlands and increased sediment removal for earthworks during development.
- Specialised treatment devices or wetlands for metals removal from stormwater after development.
- More use of natural systems such as wetlands and riparian planting.
- Note that even better outcomes could be achieved using the approaches outlined in the 'Water Sensitive Design' case study.

Modelled earthworks sediment load = 108 tonnes/year.





CASE STUDY: BETTER URBAN DESIGN

SAVING THE BEST LAND FOR GROWING FOOD

South Auckland around Pukekohe has some of the most productive land in the country, with prime agricultural land also in other parts of the Franklin and Rodney areas. But as the city expands, some of our best food-growing areas are destined for urban development. If we want Auckland to remain a self-sufficient and resilient food producing region, we should protect the best land for the rural activities that rely on it.

To date, 8.3% (10,399ha) of Auckland's high-class, elite and prime land has been built on; over 8% between 1975 and 2012[5]. This is because the flat or gently rolling hills and relatively free draining soils are easy to build on. Expected growth indicates these trends will continue, and potentially at a faster rate, as the population increases. It is important to note that not all land is the same, with only a small proportion representing the best, most versatile, multiple-use land. The danger is that expanding the urban area onto the best land will undermine the long-term sustainability of our food-growing areas. A related threat is the uncontrolled, ad hoc and sporadic subdivision of rural land, which has an adverse cumulative effect on the productivity of our natural soil resources.

These trade-offs need to be considered in future growth planning decisions for Auckland. Smart planning should consider moving urban development away from the most versatile land and containing rural subdivision to identified areas such as country side living zones. This will ensure a viable rural Auckland and maintain the integrity of our valuable soil resources.

CASE STUDY: BETTER URBAN DESIGN

CLEANING UP QUEEN STREET

Over the past decade the quality of air in Queen Street has dramatically improved. Several factors have contributed to this, including better national emission standards that have progressively reduced vehicle emissions (for more information see the vehicle emissions case study).

But thanks to improvements in urban design there have been additional improvements in air quality in Queen Street over and above those observed Auckland-wide. Between 2006 and 2008 Queen Street was extensively upgraded. As well as improving the transport network, the developers focused on reducing the volume and speed of traffic along this busy stretch of road. The graphs opposite show how concentrations of particulate pollution have gone down as a result, making Queen Street a more healthy and pleasant place to be.

AUCKLAND'S GROWTH – AN INCREDIBLE OPPORTUNITY

Never before has Auckland been faced with such challenges and opportunities as the rapid expansion of the city now offers. These case studies have highlighted how using natural systems in urban design can maintain or even improve the quality of our air, land and water resources. To achieve meaningful environmental outcomes on a city-wide scale it will take a high level of intervention, but the outcome could be the world's most liveable city. The choice is ours to make.

References:
5. Curran-Cournane F, Vaughan M, Memon A, Fredrickson C. (2014): Trade-offs between high class land and development: Recent and future pressures on Auckland's valuable soil resources. Land Use Policy, 39, 146-154.

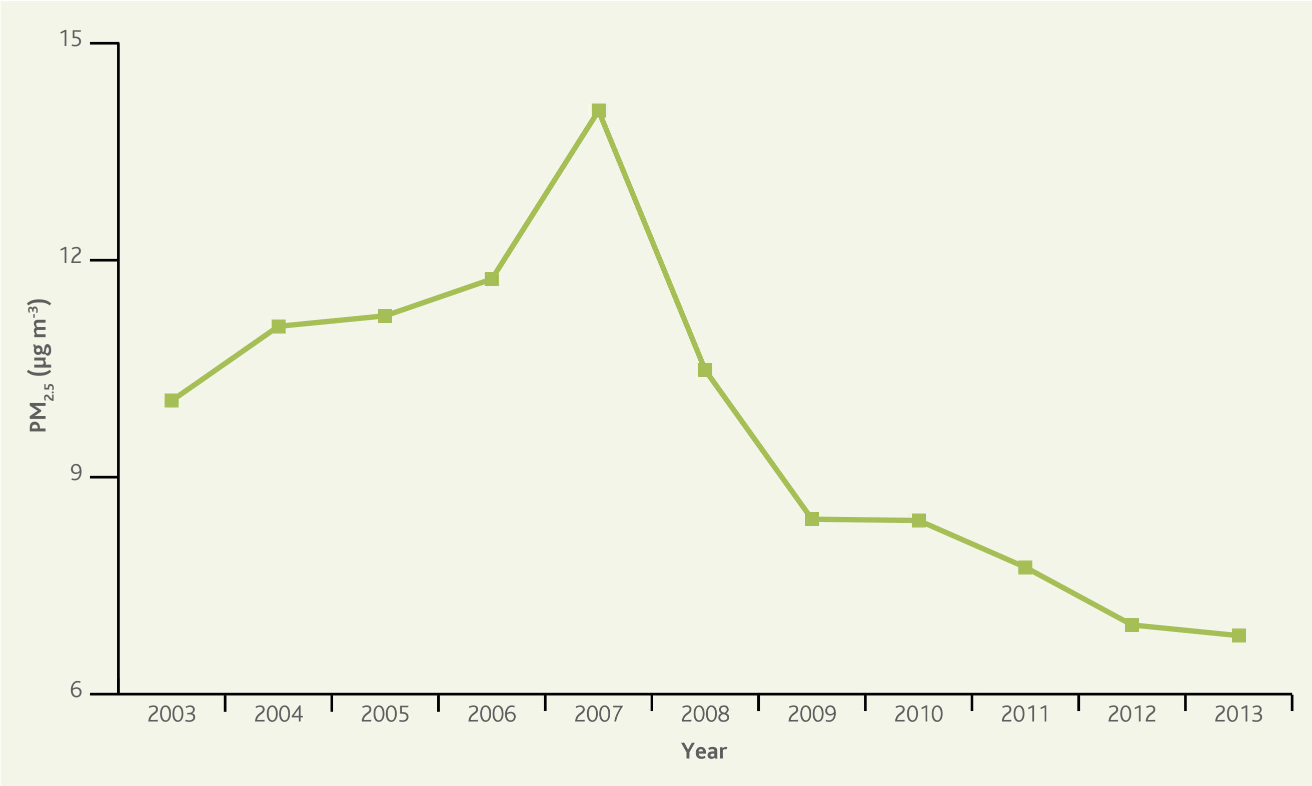
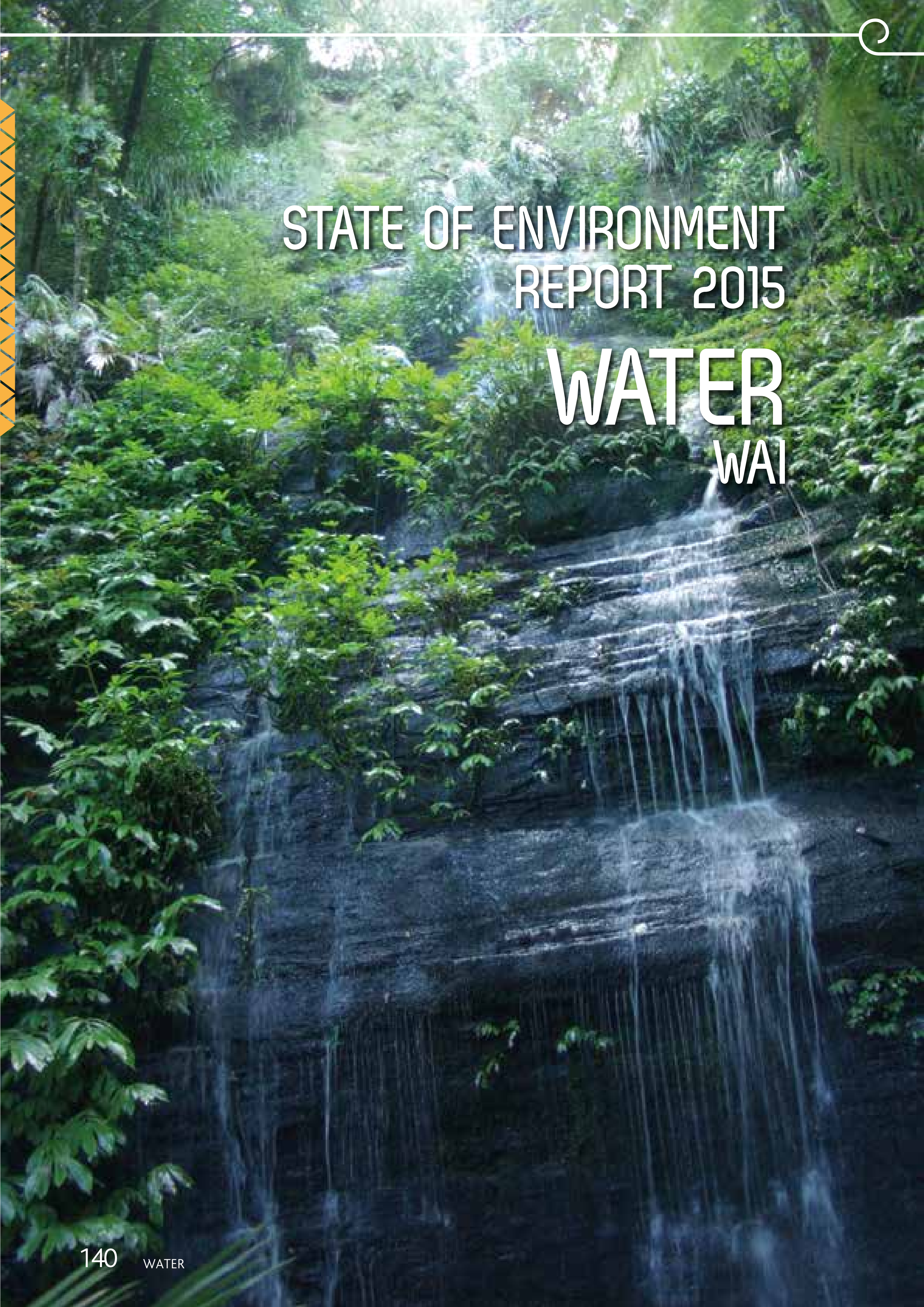


FIGURE 8: Trend in annual average particulate matter <2.5µm in diameter ($PM_{2.5}$) at Queen Street.

FIGURE 9: Trend in annual average particulate matter <10µm in diameter (PM_{10}) at Queen Street.



STATE OF ENVIRONMENT REPORT 2015

WATER

WAI

OUR RIVERS, OUR LAKES, OUR SEAS
NGĀ KŌAWA, NGĀ HĀROTO, NGĀ MOANA


Helensville Riverside Walkway

Auckland is home to twin coasts lined with beaches and estuaries, three large harbours (including Kaipara, one of the largest in the southern hemisphere) and the islands of the Hauraki Gulf. In total there are 11,117 km² of ocean and 1800km of coastline. The region also boasts 16,500km of permanently flowing rivers, 72 natural and artificial lakes, and many aquifers providing essential resources for our people and animals. The Auckland region is 75% water with the city situated within an isthmus between the Waitematā and Manukau harbours. This urban positioning provides magnificent views and connections with the water, but has also had a strong influence on the health of our freshwater and marine environments.

We value our rivers, lakes and seas for many reasons, including swimming, drinking water, enjoyment of the beautiful views and the diversity of plants and animals. Our freshwater and marine environments hold immense cultural significance for Māori. These water environments offer many other benefits Aucklanders depend on, such as food (fish and shellfish), cultural and recreational opportunities, and a range of 'hidden' benefits that are not as obvious.

For example, in rivers the small invertebrate communities, largely invisible to the naked eye, play a crucial role in the freshwater food chain, which ultimately affects the health and survival of larger freshwater species such as fish and eels. In the marine environment shellfish (such as pipi and cockles) not only filter and clean up the water but also form part of the food chain for other marine species (such as fish) that we then enjoy.

Our marine and freshwater environments support a vast array of biodiversity. The west coast is home to the critically endangered Māui dolphin and at least 22 species of whales and dolphins have been recorded in the Hauraki Gulf, an area also internationally recognised as a seabird biodiversity hotspot. The region is also home to more than 195 fish species. Our estuaries and river mouths provide habitats for feeding and breeding for a diverse range of species above and below the water, including coastal and migratory birds. Our freshwater environments include rivers, lakes and groundwater, which sustain numerous animals, plants and invertebrates including koura (freshwater crayfish), mudfish and caddisflies to name just a few.

The last State of the Auckland Region report (Auckland Regional Council, 2010) identified issues including high sediment and other contaminant loads in Auckland's rivers and estuaries. Auckland Council has since included sediment reduction targets in the Auckland Plan, proposed stormwater rules to reduce contaminant discharges and identified areas of degraded marine water in the Proposed Auckland Unitary Plan.

Maintaining the health of our freshwater and marine ecosystems involves addressing historical issues and confronting current and future challenges as the population of our city grows. Of critical importance for management is an understanding of the quantity and quality of the region's resources. Every year, kilometres of permanent streams are lost to consented development activities, and tonnes of sediment, with associated metals such as copper and zinc, are discharged into streams and the sea.

Land use activities have a large impact on freshwater and marine water quality. Many land uses generate direct and indirect contaminant discharges, which include sediments, metals, nutrients and biological wastes (organic and faecal material). These have the potential to degrade water quality and affect the health and survival of the resident species. It is important to remember that water flows from the mountains to the sea (Ki uta ki tai) showing the connectivity between our actions on land and their impact on the health of our freshwater and marine environments. Other human pressures on our aquatic environments include invasive species, habitat destruction, over-harvesting and litter pollution.

Litter, particularly plastics, is an ongoing and widespread problem for Auckland's marine environment. The State of the Hauraki Gulf Report (2014) showed that most of the litter found near Auckland comes from activities on land but that fishing-related materials are a major source farther away from the city. Most of the litter ending up on beaches around the Gulf is from plastics, which remain in the environment for a long time and can be transported over long distances. This litter degrades habitats, fouls our beaches and can be lethal when swallowed by marine and bird life. Auckland Council produced the Auckland Waste Management and Minimisation Plan in 2012 and is committed to reducing waste through the Waste Minimisation and Innovation Fund, which supports projects to reduce the amount of waste going to landfill.

The council runs a number of programmes to monitor the state of our marine and freshwater environments, and to describe the trends over time. There are nine key indicators we monitor:

- General water quality: marine
- General water quality: freshwater (rivers, lakes and groundwater)
- Bathing beach water quality
- Ecology: marine and freshwater
- Contaminants in marine sediment
- Marine sediment muddiness
- Water consumption
- River flows.

The Freshwater Monitoring Programme aims to describe the quantity (flow) and quality of the region's freshwater resources and assess the effects; our use of them and environmental stressors on them. Similarly, the Marine Monitoring Programme describes the quality of the marine environment and aims to identify environmental stressors affecting it. They measure water condition and quality using a combination of physical, chemical and biological characteristics. Our marine dataset is one of the most comprehensive long-term datasets for coastal marine quality in New Zealand.

The council's marine and freshwater monitoring programmes increase our understanding of the health of our waters, the habitats and the organisms living there. The indicators and case study in this chapter provide insight about the state, trends and current research in Auckland's marine and freshwater environments to show us how we are doing at managing these precious resources.

RIVER FLOW INDICATOR

KEEPING OUR TAPS FLOWING AND CROPS GROWING

Flow monitoring site at the Hoteo river

We have around 16,500km of permanent rivers and streams in the Auckland region. They are core to our economy, culture and environment. We use the water for drinking and irrigation and we swim and fish in some. As Auckland's population continues to grow and the demand for water increases, it is important that we monitor and understand the flow of our rivers to keep them healthy for generations to come.

WHY DO WE MONITOR RIVER FLOW?

If the level of water in our rivers drops below a certain level, our economy, ecosystems and lifestyles are at risk. Particularly during summer, some of our rivers are at risk of falling dry. When this happens the ecosystems in and around them and the resources they provide are threatened.

The Proposed Auckland Unitary Plan[1] sets out minimum flow levels to ensure healthy ecosystems and water supply.

There are many factors influencing the flow of rivers including rainfall, sunshine hours and use. Our monitoring helps us to understand the changes and long-term trends so we can protect and use this essential resource into the future.

WHY DOES AUCKLAND HAVE SO MANY SMALL RIVERS?

In Auckland we have plentiful rainfall, relatively low surface elevations and short distances to the sea. The result is a large number of streams and rivers, most of them relatively small.

Gauging flow at the Tamahunga river

HOW DO WE MEASURE RIVER FLOW?

River flow is monitored automatically at 49 sites across the Auckland region. The data is collected through a range of sensors and sent to Auckland Council by a telemetry network.

WHAT IS THIS INDICATOR?

There are several ways to describe the flow quantity and variability across the region. In this report we use three measures, which are all calculated from daily flow measurements. Flow is defined as the volume of water that passes a fixed point in a given amount of time.

To calculate the daily flow we take an average of flow measurements over each day. From this we calculate three measures:

- **Mean Annual Flow** – the average daily flow over a whole year.
- **Annual Flood** – the highest flow measurement recorded in the year.
- **Low Flow Days** – a measure of how often the stream level got dangerously low. It is measured as the number of days below the Mean Annual Low Flow (MALF). MALF represents the average of the lowest flow measurement from each year since the monitoring programme began.

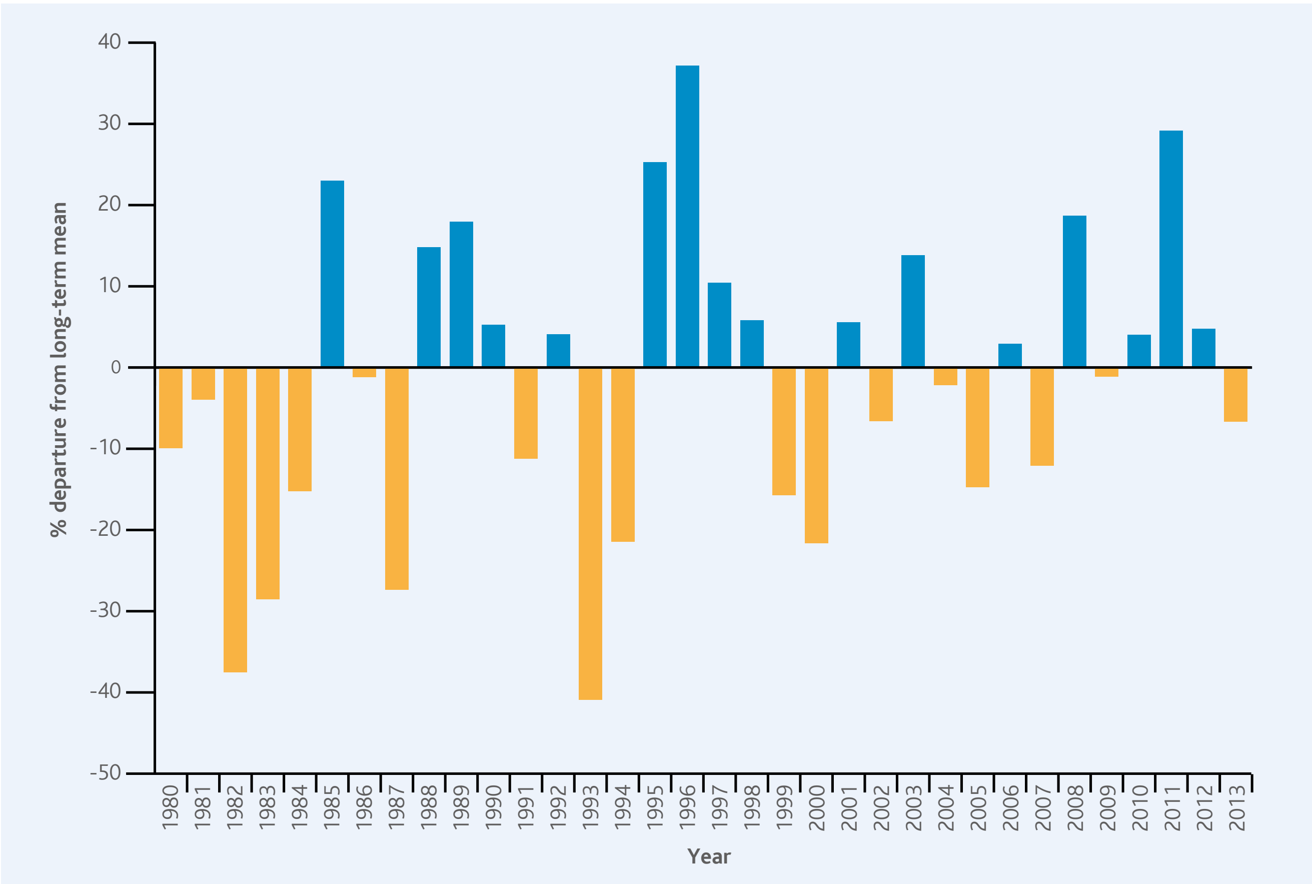


FIGURE 1: This shows how Auckland's river flow (averaged over all sites) has varied over the last 25 years.

WHAT HAVE WE FOUND?

NO LONG-TERM TRENDS OBSERVED

As you can see in figure 1, the flow of rivers is highly variable from year to year. For example, 1993 was 40% below the long-term mean and 1996 was almost 40% higher. Over the past five years the average annual flow was near the long-term mean, except for 2011. So although it may have seemed as if the weather has been out of the ordinary, the data does not indicate any long-term trends.

JAN 2011 – THE LARGEST RECENT FLOOD

As figure 2 shows, flood measurements over the last five years have been less extreme than similar periods in the past 25 years. The largest recent flood was recorded in January 2011, coinciding with extreme rainfall. This flood exceeded the 25-year return period[2] in the rivers Papakura, Hoteo, Mangawheau and Ōtara and the 10-year return period in a few other rivers in the region.

LOW FLOW DAYS

Over the past 25 years, Auckland's streams and rivers have had an average of 14 days each year of low flow (below the MALF). However, there is great variability from year to year and river to river (see figure 3).

During the dry hot summer of 2012/13, all rivers in the region had very low flows for extended periods. On average the flow fell below MALF for 26 consecutive days.

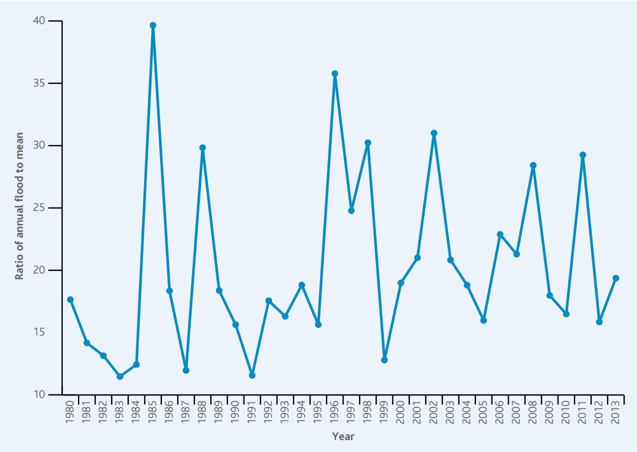


FIGURE 2: The magnitude of the annual flood events compared with the mean annual flow of Auckland's rivers (averaged over all sites). The larger the value, the more extreme the flood event.

HOW HAVE THINGS CHANGED?

Climate change predictions for Auckland indicate that the magnitude of extreme flood events may increase in the future[3]. But as yet our monitoring data has not revealed such a trend.

The climate change predictions also indicate an increase in droughts in the future. Our data shows quite a high variability in the number of Low Flow Days, but again no clear trend.

However, it is important not to get complacent. To see the type of long-term trends predicted by climate change models, in a system as variable as river flow, you need a dataset much longer than 25 years. We need to keep on monitoring river flow across Auckland. The more data we have, the more we will be able to predict and prepare for the future – floods or droughts.

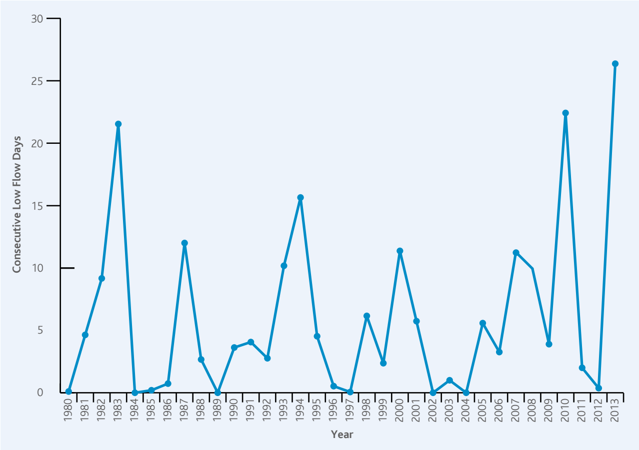


FIGURE 3: Number of consecutive Low Flow Days (days below MALF) in Auckland's rivers over the past 25 years.

References:
1. Proposed Auckland Unitary Plan, Appendix 5.2 River and stream minimum flow and availability.
2. An annual return period is a statistical estimate of the likelihood of a given flood occurring in any one year. For example, if the return period of a flood event is 25 years, it means there is a 1/25, or 4%, chance that a flood event of this size occurs in any given year.
3. Ministry for the Environment: Climate change predictions for the Auckland region. mfe.govt.nz/climate-change/how-climate-change-affects-nz/how-might-climate-change-affect-my-region/auckland

WATER CONSUMPTION INDICATOR

CONSERVING WATER AS AUCKLAND GROWS

We need clean drinking water to survive

What if one day our taps ran dry? Water is essential to life. Monitoring has shown that per capita water consumption is decreasing in Auckland. But water resources are limited and demand is forecast to increase dramatically with population increase. We need to continue using water in a highly efficient manner to avoid running out in the future.

WHY DO WE MONITOR WATER CONSUMPTION?

Supplying Auckland's population with a secure supply of fresh water is one of the Auckland Council's most important jobs. Watercare Services Ltd, the council-controlled water service provider, delivers around 326 million litres of drinking water per day. Auckland's per capita water consumption is already one of the lowest in New Zealand.

However, the population is continuously increasing and therefore so is the total water demand. We will need to be innovative and efficient with water use to meet the demands.

WHAT IS THIS INDICATOR?

Gross per capita consumption is the total amount of water supplied by Watercare Services Ltd divided by the total number of people using it. It comprises household water supply as well as supply to the industrial, commercial and institutional sectors.

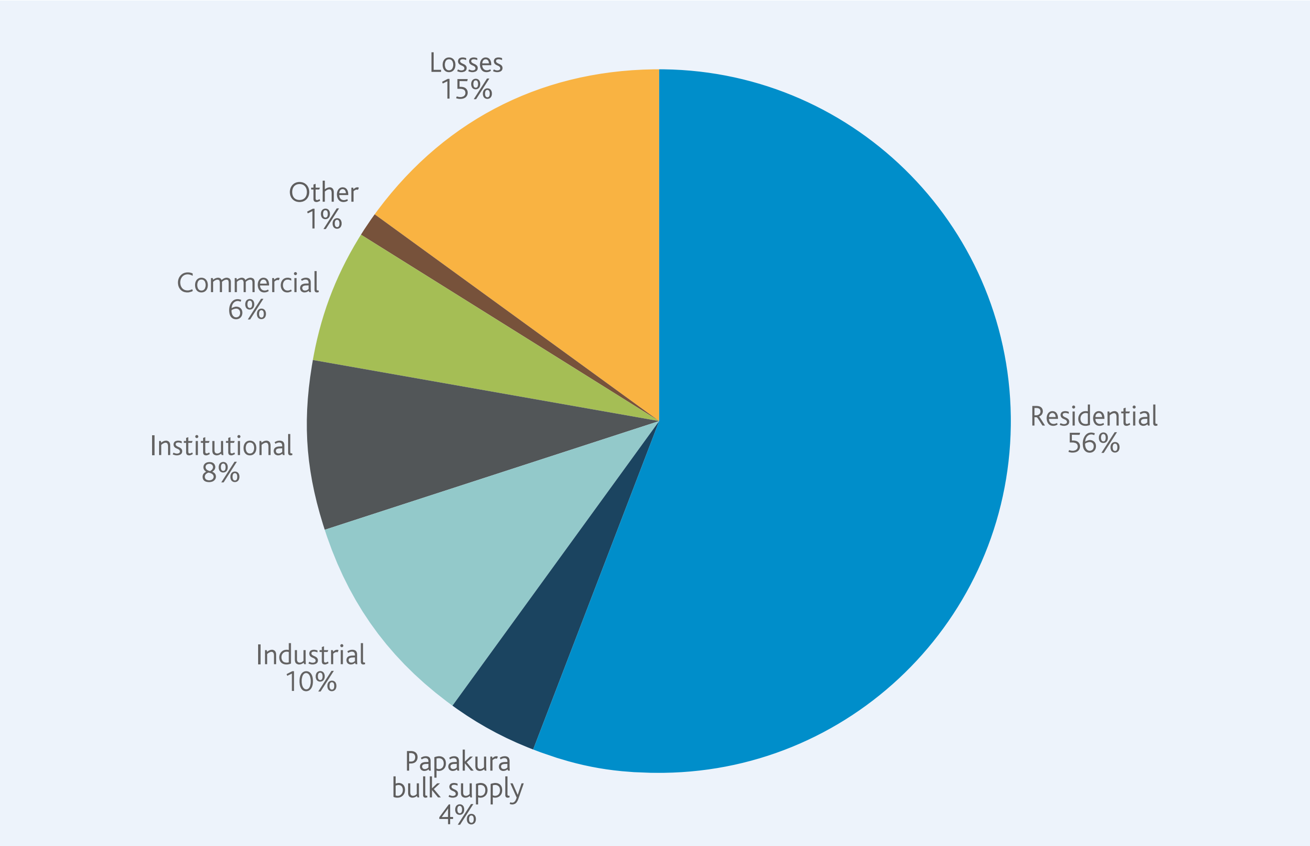


FIGURE 1: Percentage of water use per sector[1].

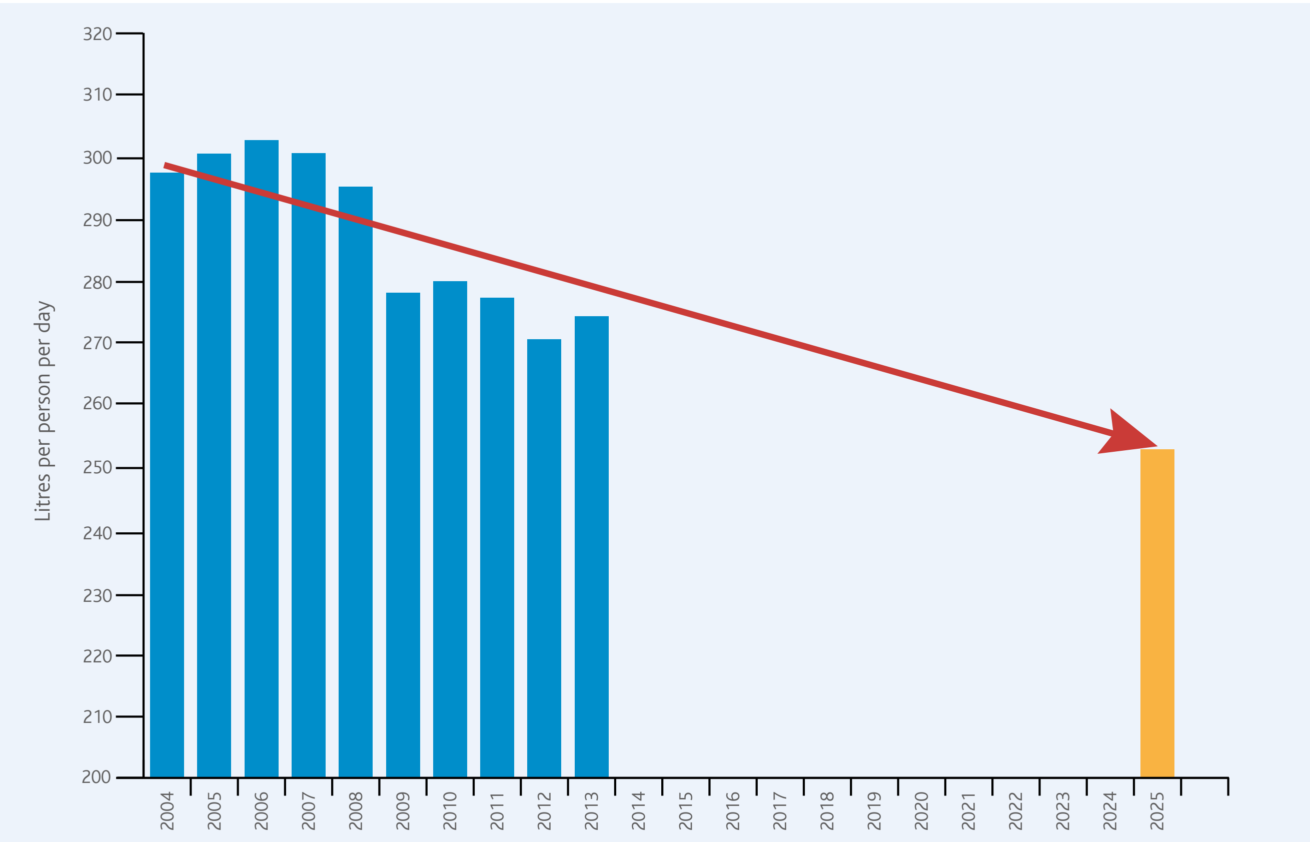


FIGURE 2: Gross per capita water consumption, 2004-2013, and target in 2025[1].

References:
1. Source: Auckland Regional Water Demand Management Plan 2013-2016. Watercare 2013.

WHAT HAVE WE FOUND?

In 2013, gross per capita water consumption was **274 litres per person per day**. Most of the water supply is for residential use (figure 1). There are also considerable amounts supplied to the industrial, institutional and commercial sectors. Losses add up to about 15% of the water provided. Losses include leakages in the water supply network, as well as non-billable water (e.g. for fire fighting or operational flushing), unauthorised consumption and inaccurate meter readings.

> Reduce gross per capita water consumption from 2004 levels by 15% by 2025.
>
> THE AUCKLAND PLAN - CHAPTER 7

HOW HAVE THINGS CHANGED?

Figure 2 shows the trend of water use over the past decade. In 2004, gross per capita water consumption was 298 litres per person per day. After a slight increase in the following years, consumption now shows a decreasing trend and was below the annual target in the last five years (figure 2). We need to continue increasing efficiency in our water use to keep up this trend and reach the target of 253 L/p/d in the year 2025. For a comparison of our water consumption with other cities see the case study, liveable cities.

HOW MUCH WATER DO WE USE IN OUR HOMES?

Water used in homes represents about 56% of the water supplied by Watercare Services Ltd. What do we use it for?

A study by the Building Research Association of New Zealand in 2008[3] revealed the major water use in households was for showers, followed by washing machines and toilets (figure 3). Toilets used on average 6.7L per flush, with some toilets using up to 12L per flush. There is a great potential for water savings if we upgraded our toilets to more efficient standards. Modern designs might reduce the water consumption to as little as 2.3L per flush. Washing machines also have great water-saving potential. The average water use per load was 122L, with some machines using up to 190L. The most efficient models use only 60L per load. Upgrading the water appliances in our homes could save several billion litres of water per year and help achieve the water consumption target. Watch out for the WELS rating (water efficiency labelling scheme) when buying new appliances (**waterefficiency.govt.nz**).

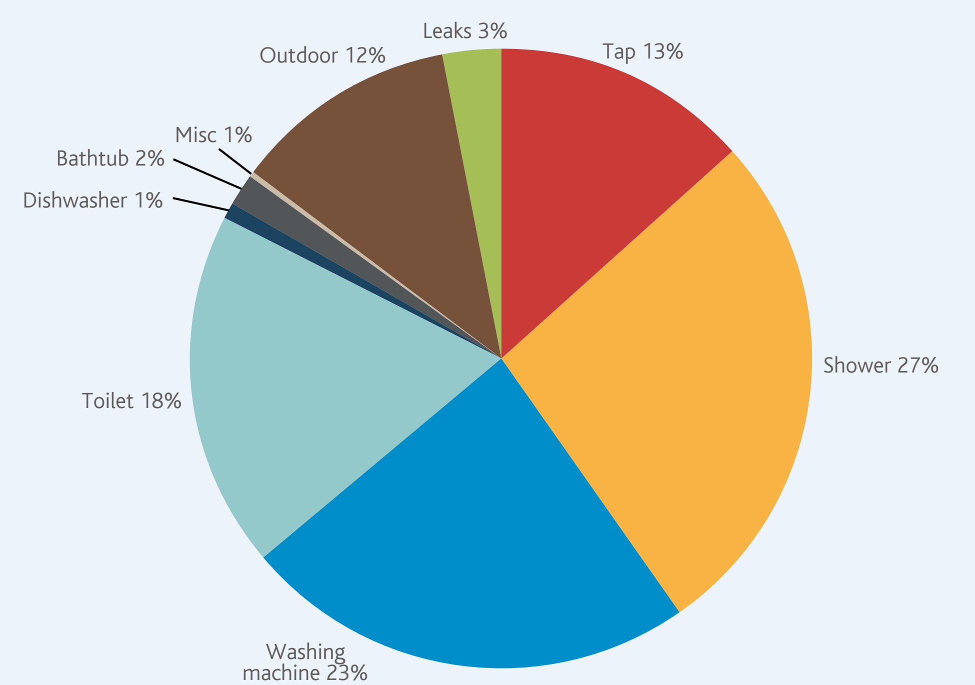
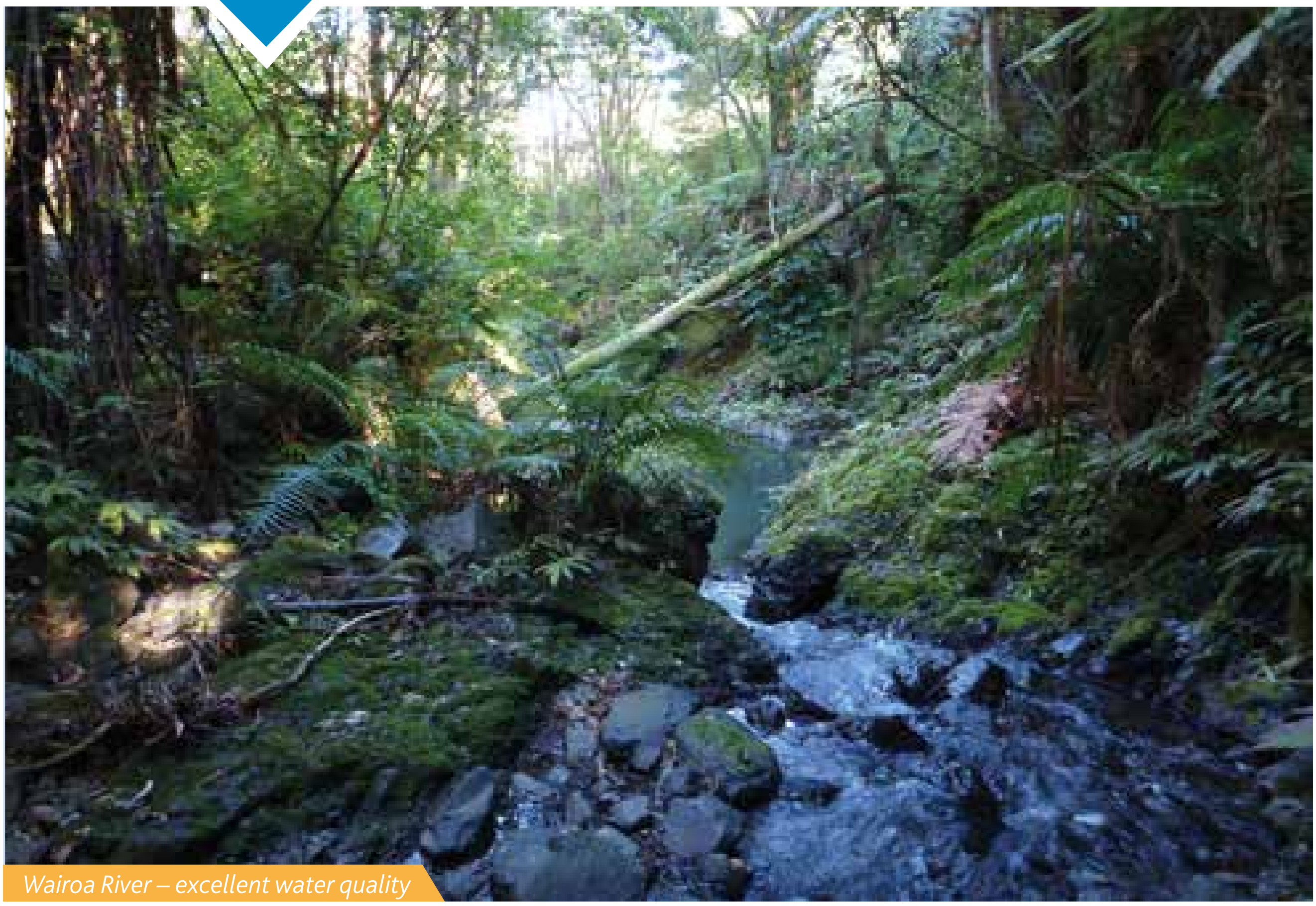


FIGURE 3: Residential water use.

References:
3 Heinrich, M. (2008): Water Use in Auckland Households. Building Research Association of New Zealand.

FRESHWATER QUALITY INDICATOR

OUR STREAMS AND RIVERS NEED HELP



Wairoa River – excellent water quality

Urban Stream Syndrome, weeds growing in our lakes and nitrate in our groundwater are the big issues revealed by our freshwater monitoring programme. We are collaborating with groups in Auckland Council, community members and researchers to work out the most effective ways to solve these problems.

WHY DO WE MONITOR FRESHWATER QUALITY?

Water quality affects everybody. We all care about water quality in some way, whether for its natural beauty, its recreational value, as a source of healthy drinking water or for its significant Māori cultural value (Māuri, a life-giving principle; mana, spiritual power and authority).

Over the last 20 years declining freshwater quality in New Zealand has become a big and widely publicised issue. Auckland Council's objective is to maintain or improve water quality in the region and prevent any further degradation. Our comprehensive water quality monitoring programme allows us to track and evaluate the success of the council's freshwater policies and initiatives.

It also provides a solid foundation and direction for restoration efforts by enabling us to:

- identify waterways under particular threat
- identify trends of improving or declining water quality
- point to the most effective and efficient restoration methods.

> Ensure no loss in the area of significant landscape, natural character and natural features
>
> THE AUCKLAND PLAN - CHAPTER 7

WHAT IS THIS INDICATOR?

This indicator gives an overall score of the health of different waterways. A healthy freshwater ecosystem is a complex web of animals, plants and chemicals. To assess the overall quality of a waterway we combine a range of physical, chemical and biological measurements such as:

- **Temperature** – when streams are exposed to the sun or run through concrete channels they can heat up, and many fish, invertebrates and other bugs no longer survive in the water.
- **Suspended solids** – particles of soil or other solids suspended in the water can reduce clarity and make the water appear dirty.
- **Nutrients** – nitrogen and phosphorus in particular can encourage the growth of algae and weeds in water.
- **Other contaminants** – a wide range of contaminants enter Auckland's waterways, particularly during and after rain. They are often linked to the land use and management in the surrounding catchment. For example, high concentrations of zinc and copper can be associated with heavily urbanised areas (galvanised roofs) and roads with large traffic volumes.

We then compare our water quality results with a range of guidelines including the Australia New Zealand Environment and Conservation Council (ANZECC) guidelines for environmental health, the World Health Organisation (WHO) standards for human recreation and drinking water, and the attribute states and national bottom lines as set out in the National Policy Statement for Freshwater Management (NPS-FM), 2014.

HOW DO WE MONITOR FRESHWATER QUALITY?

The council operates a series of long-term freshwater monitoring programmes covering rivers and streams, lakes and groundwater. Formal monitoring has been in place for more than 25 years. Over this time we have expanded to include more sites.

Rivers: The river monitoring programme is the largest network, with 36 sites across the region. The sites are geographically representative and cover a spectrum of water quality states from poor through to very high.

Lakes: The lake monitoring programme monitors water quality in the region's five largest lakes (Pupuke, Kuwakatai, Ototoa, Tomarata, and Wainamu). Water quality monitoring is undertaken in these lakes every two months.

Groundwater: A range of sedimentary and volcanic aquifer systems in the Auckland region store a significant groundwater resource. This groundwater is important for geothermal use, domestic and stock water supply and irrigation, as well as providing essential baseflow to Auckland's streams. Groundwater quality data is collected quarterly from nine sites region-wide, selected primarily on the extent of groundwater use and intensive land use in the surrounding area.

WHAT HAVE WE FOUND?

Water quality varies widely across Auckland's rivers and streams. On the whole the pattern tends to be:

Excellent: catchments dominated by native forest.

Good-fair: catchments dominated by exotic forest and/or rural land use. Poor water quality in rural catchments is generally characterised by high nutrient levels and sediment.

Poor: catchments dominated by urban land use.

Our monitoring programme has alerted us to three particular issues, which we are investigating further.

ALERT 1: URBAN STREAM SYNDROME

Many of Auckland's urban streams are in a poor state of health and suffer from 'Urban Stream Syndrome'. This is a result of the many pollutant sources in urban environments, i.e. urban development, roads and vehicle use, industry waste, and stormwater and wastewater overflows. Addressing these multiple and interacting stressors to improve water quality is a very real challenge.

A typical urban stream

The council's priority is to restore these waterways and/or prevent further pollution through careful strategic planning and targeted, specific pollutant management. For example, we encourage consideration of water sensitive design for new developments to reduce sediment and contaminant runoff.

We are collaborating across council groups and with external researchers to develop monitoring and evaluation plans at the design stage of stream restoration projects. This allows us to monitor specific and measurable objectives against baseline levels, and to scientifically evaluate the relative success of the restoration.

ALERT 2: HORNWORT IN LAKES

The growth of the aquatic weed hornwort is a major issue facing Auckland's lakes. Hornwort is an invasive weed that threatens biodiversity, water quality, utility and recreation. It grows up to 10 metres tall, blocks water intakes and out-competes desirable native aquatic vegetation. The council is investigating options to eradicate hornwort, including manual removal, introduction of grass carp or selective herbicides.


Hornwort in an Auckland lake

SPOTLIGHT

OAKLEY CREEK FLOOD PROTECTION AND STREAM RESTORATION

Work is due to begin on restoring a 1.5km stretch of Oakley Creek in 2016. This is an unprecedented opportunity to collect baseline monitoring data before restoration starts and, after it is complete, to track and evaluate the effectiveness of the project.

ALERT 3: HIGH NITRATE CONCENTRATIONS IN GROUNDWATER

An important issue for Auckland's groundwater is the high nitrate concentrations in the south Auckland volcanic aquifers, which exceed drinking water and environmental standards. This groundwater emerges at various springs in the Franklin area, introducing high nitrate concentrations to Franklin's streams. We are involved in research projects to better characterise nitrogen cycling in soils and waterways in Franklin. This will enable science-based management to reduce the nitrate concentrations and the associated environmental and health risks.

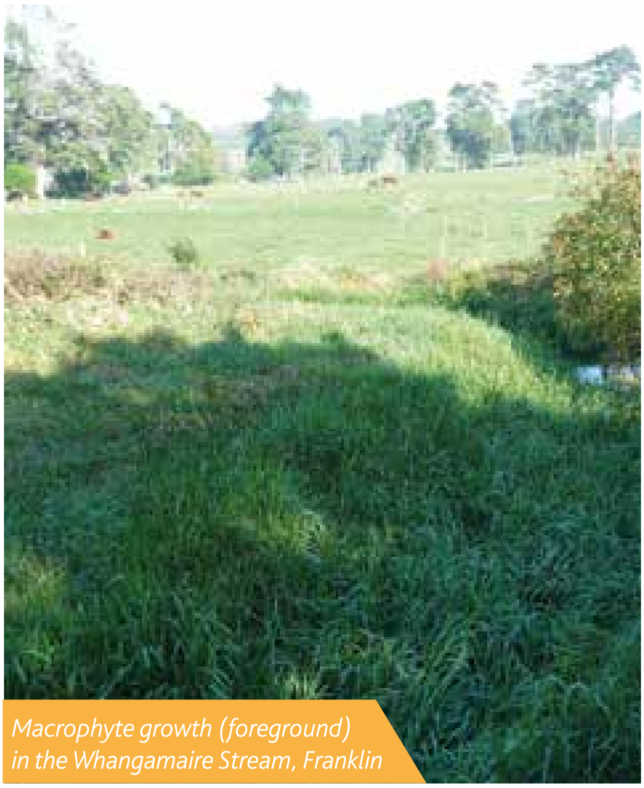

Macrophyte growth (foreground) in the Whangamaire Stream, Franklin

FIGURE 1 River water quality sites and their water quality class, indicated by colour.

FRESHWATER ECOLOGY INDICATOR

URBAN STREAM ECOLOGY IN A POOR STATE

Sampling the Wairoa River

Streams are diverse living systems and provide vital habitat for many living organisms. Ecology, biodiversity, nutrient cycling, flow and habitat are all vital functions for a healthy ecological system. Of the sites we monitor for stream ecology, 46% are in a good or excellent state, and 54% are in a degraded or poor state. The streams in a poor state are dominated by urban catchments.

WHY DO WE MONITOR FRESHWATER ECOLOGY?

The state of the stream ecology is a good indicator of overall water quality and stream health. In a healthy stream there is usually a diverse community of plants, invertebrates and fish. By contrast, unhealthy streams are often dominated by tolerant populations of invertebrates and fish with little diversity and sometimes low overall numbers.

These living communities of plants and animals can give a more holistic picture of the water quality and health of a river than physical indicators such as temperature or chemistry alone.

WHAT IS THIS INDICATOR?

Auckland Council monitors freshwater ecology in about 100 rivers across the region, ranging from pristine to highly polluted. This data, along with water quality and hydrological assessment data, is used to develop a numerical score called the Stream Ecological Valuation (SEV). The SEV score is a snapshot of a river's health at a particular site.

The SEV incorporates several measurements.

- **Hydraulic function:** This is a measure of the stream's ability to flow naturally, and its hydraulic connectivity upstream and downstream. This is done using flow gauges which collect flow data as often as every 15 minutes.
- **Nutrient cycling:** We measure the inputs and transformations of nutrients and contaminants in streams. Water samples are collected and analysed for physical and chemical parameters.
- **Habitat:** Plants and animals require a healthy and diverse physical environment to thrive (e.g. rocky substrate, woody debris). Using detailed observations, we monitor the type, diversity and suitability of habitats within the stream and in the stream bank riparian margin.
- **Biodiversity:** A diverse range of ecology in and around a stream indicates it is healthy enough to support a wide range of life. We collect samples, count fish and invertebrate species and take detailed site observations to measure stream biodiversity.

WHAT HAVE WE FOUND?

SEVs across the Auckland region vary widely. In general, the pattern tends to be:

Excellent in catchments dominated by native forest. With little to no human influence, the streams have natural flow regimes, few additional nutrient inputs and a range of habitats to support diverse biological communities.

Good-Fair in catchments dominated by exotic forest and/or rural land use. Changing land use and management has affected the ecological state of these streams. Generally there is less shade and riparian habitat and increased nutrient inputs than at streams in native bush catchments.

Poor in catchments dominated by urban land use. Most urban streams are affected by inputs of metals, other contaminants and sediment. Also, many urban streams have been channelised and concreted as part of historical stormwater overflow solutions, and piped underground as a result of urban developments. There is little opportunity for ecological communities to develop in these concrete-lined channels and pipes, which explains the low ecological value in these urban streams.

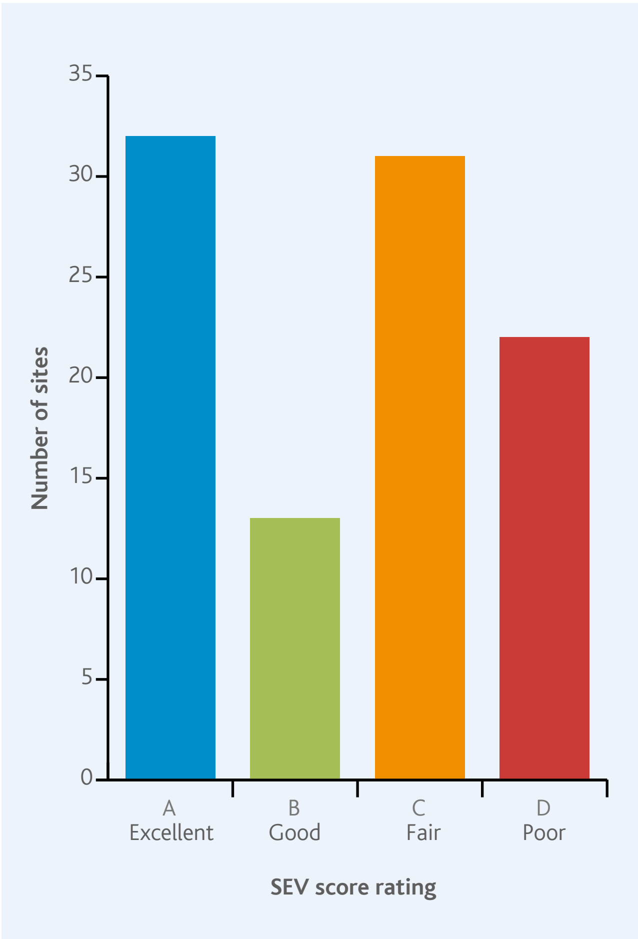
> "Rivers and streams in Auckland with high natural character and high ecological values are protected"
>
> PROPOSED AUCKLAND UNITARY PLAN

Mt Auckland Stream has one of the highest ecological values in the region

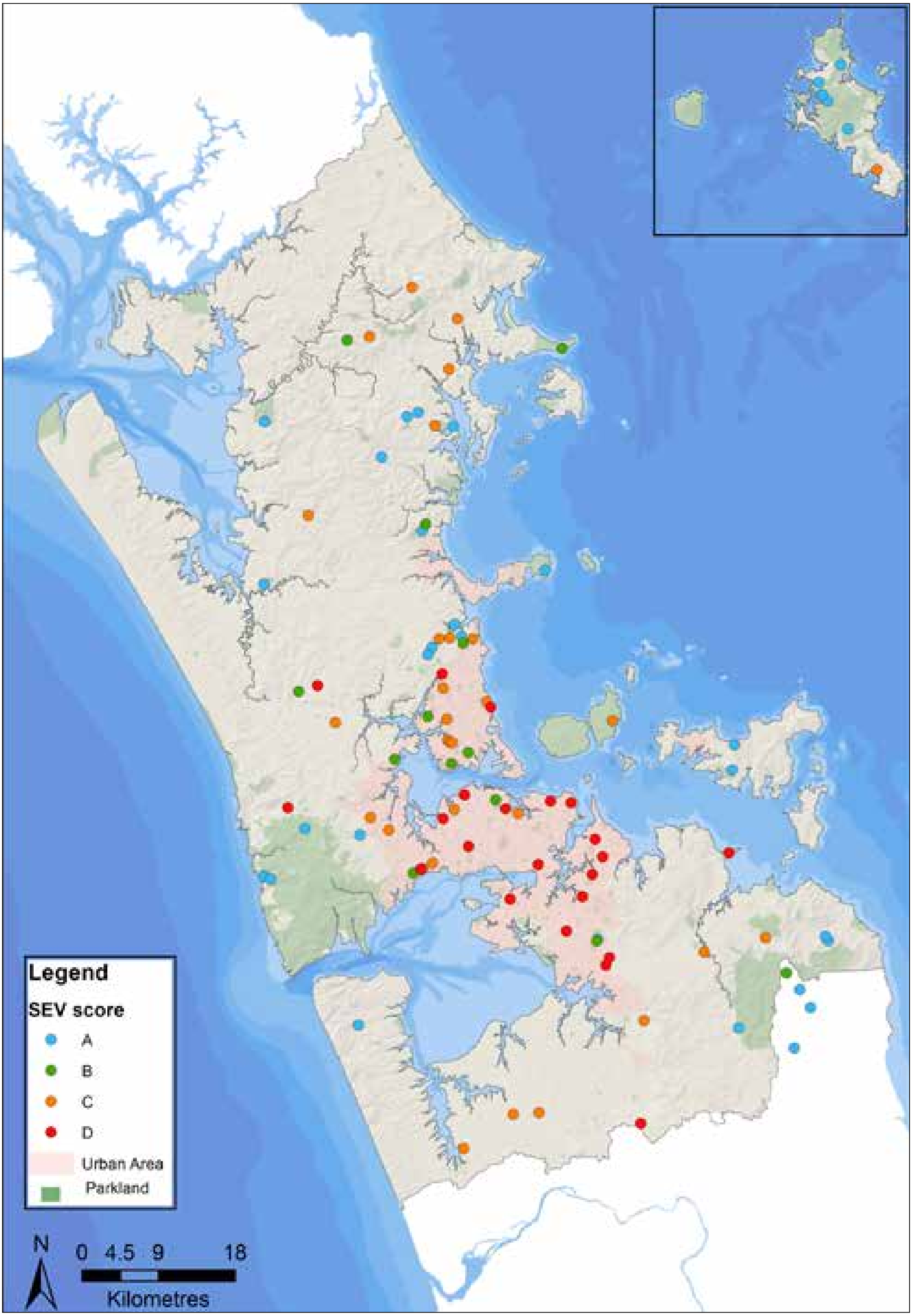

Caddisfly larvae


Banded kōkopu


Kōura, found in Mt Auckland stream



Number of sites in the Stream Ecology programme that fall into each SEV score category



Freshwater Ecology sites with their SEV scores indicated by colour.

CASE STUDY: RESTORATION OF WATER

BRINGING OUR DEGRADED RIVERS AND STREAMS BACK TO LIFE

Te Muri waterfall

We value the health and quality of Auckland's freshwater for many reasons including spiritual and cultural connections, diverse ecology, natural beauty and for recreation. However, over the years the use and development of land and resources has degraded these environments, with the loss or contamination of water, and damage to habitats, wildlife and whole ecosystems.

Different types of land use can have big impacts on the quality and health of rivers and streams. In urban areas, the discharge of contaminants lower water quality. Land development and earthworks can result in the large release of sediment, which not only impairs freshwater quality, but flows into estuarine environments. There it can smother wildlife and its habitats, as well as introduce contaminants.

In rural areas, farming releases nutrients from the soil and into waterways, which increases plant and algae growth in streams and potentially reduces dissolved oxygen.

Erosion of rural soils also contributes sediment to rivers and streams. Options for restoration include:

- planting riparian areas
- fencing stream margins
- reverting piped or channelised streams back to their natural form and character (daylighting)
- eliminating direct contaminant sources
- managing land to reduce indirect contaminant sources.

There are more than 130 community groups dedicated to stream restoration in the Auckland region. This represents more than 2200 volunteers giving their own time – an incredible achievement in community action.

Restoring water quality in a stream is a challenging task, requiring much planning and strategy, hard work and perseverance. Restoration also requires a good understanding of the stream system as a whole, which monitoring data helps to provide. Key findings from examples of restoration in New Zealand and around the world include[1].

- **Objectives are key** – Defining clear, measurable objectives is important for keeping to the overall goals and giving project direction. Objectives also help to identify the most appropriate restorative methods.
- **Results take time** – Responses in water quality to restoration efforts can take a long time. In most cases, degradation is the result of many years of land use and contaminant inputs, and restoration can take just as long, or even longer. In this time, efforts can understandably tire and funds can disappear before the full benefits are seen.
- **Scale is important** – Most of us like to start on a section of our local stream. However, if the focus area for restoration efforts is too small, it's not likely to enhance the overall ecosystem. Taking a strategic, large-scale approach, as opposed to a series of small unconnected approaches, is more likely to result in observable water quality improvements.
- **Strategy before action** – A common challenge with stream restoration is resisting the urge to 'just do something' or 'get started'. Taking extra time at the beginning to plan strategically, agree on objectives and set clear and measureable goals can result in more successful outcomes for water quality.
- **Did it work?** Evaluation and monitoring during and after the restoration process is the only way to determine whether the objectives were achieved and ecosystem quality improved. Evaluation is also crucial for learning where improvements can be made next time.

LUCAS CREEK RESTORATION PROJECT

Lucas Creek is a good example of a typical restoration project in Auckland. This project realigned part of the Lucas Creek channel to provide flood protection, and enhanced access and social amenity near the creek by building pathways and a playground, and landscaping with native plants. Riparian planting and daylighting also enhanced the environment.

Water quality and ecological monitoring occurred before and after completion of the restoration project. The results exemplify the lag time in response to restoration, particularly with the macroinvertebrate community index (MCI) scores. Unfortunately, these scores have continued to decline since the restoration (figure 2).

FIGURE 1: 1 Lucas Creek before and after restoration.

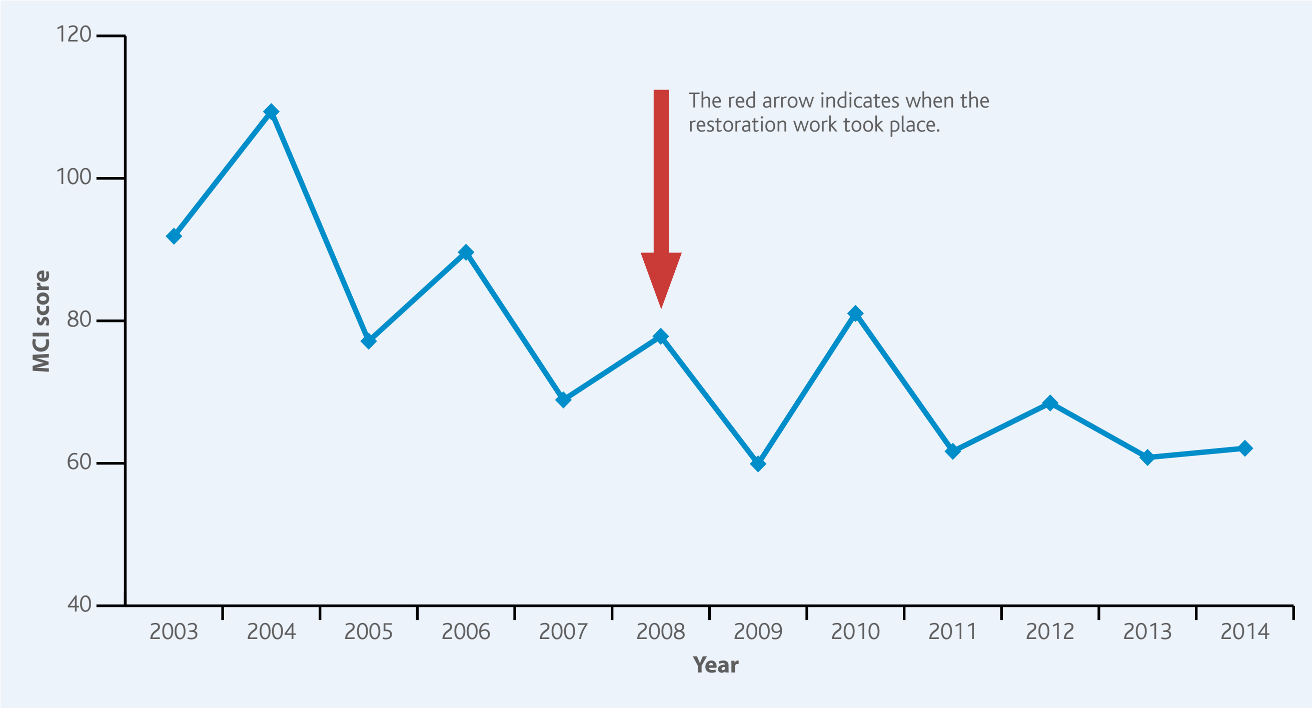


FIGURE 2: Lucas Creek MCI results, 2003-2014.

This continued ecological decline at Lucas Creek does not necessarily indicate unsuccessful restoration, as there are many potential reasons for it. It may be that the ecology is responding more slowly to restoration efforts, due to the nature of biological cycles and the need for habitat improvements to be established and sustained first.

Continued monitoring of the ecological health at this site will determine if the decline is due to a lag effect in more diverse invertebrate communities returning to the site, or whether other factors are influencing the ecology and water quality. While we wait to see ecological improvements, there have been other benefits of the restoration including more social and recreation use. This shows the multiple outcomes of restoration efforts (figure 1).

The Lucas Creek example also demonstrates the value of long-term datasets in setting baselines and context for measuring water quality improvements. Auckland Council has a wide monitoring network that provides a large-scale view of water quality across the region. This helps us prioritise tasks, identify issues, and plan and monitor restoration work.

TE MURI FARM: LOCAL LABORATORY FOR FRESHWATER RESTORATION

We are carrying out a restoration research project on a working sheep and beef farm in the Te Muri Regional Park. This is an exciting opportunity to measure the environmental and economic outcomes of sustainable land management on farms. The project is at a 35ha sub-catchment of the Te Muri Stream.

Over the past year we have collected baseline data to measure the water quality and ecology in the stream. Different sustainable farming practices are being applied by the park staff from June 2015. For example, different fencing regimes and pasture and livestock management will be implemented. We will continue to monitor water quality and ecology to capture the short, medium and long-term effects of the changes. The outcome will provide a wealth of region-specific knowledge that we can apply to restoration programmes across Auckland.

Te Muri Farm, Pūhoi Estuary

Reference:
1. USEPA, 2000. Principles for the Ecological Restoration of Aquatic Resources. EPA841-F-00-003. Office of Water (4501F), United States Environmental Protection Agency, Washington, DC. 4 pp.

BATHING BEACH WATER QUALITY INDICATOR

COUNCIL SAFESWIM PROGRAMME – TELLING YOU WHEN IT'S SAFE TO SWIM

Muriwai Beach

Auckland Council's Safeswim monitoring programme is designed to provide regular assessments of water quality at popular beaches, lakes and lagoons, so we can safely swim in these waters. We have also developed a beach quality forecast model, providing a three-day forecast of bacteria concentrations so you can plan in advance. This will be available soon on the Safeswim website.

Kohimarama Beach

WHY DO WE MONITOR BATHING BEACH WATER QUALITY?

The answer is simple – so you can swim safely. Auckland has many great places to swim, surf and play. But if the water is contaminated with bacteria from human or animal faeces, you risk catching salmonella, campylobacter, giardia, a respiratory illness or an ear or skin infection. Faeces contamination can find its way into your favourite swimming spot in a number of ways – wastewater overflows, stormwater discharges, old or faulty septic systems, pets, livestock or wildlife. One faeces contains about 100 billion bacteria. Many of these are pathogenic bacteria or viruses. So it pays to know if it's in the water you swim in.

> Protect coastal areas, particularly those with high values including (...) recreational importance.
>
> THE AUCKLAND PLAN - DIRECTIVE 7.12

WHAT IS THIS INDICATOR?

To detect the presence of faecal contamination we use an 'indicator bacteria' – one which we know will be present in contaminated water and can be used as a measure of overall contamination. We use Escherichia coli (E.coli) for freshwater and enterococci for marine environments. Concentrations of the indicator bacteria are then compared with Ministry for the Environment (MfE) guidelines to determine if swimming spots are safe.

MINISTRY FOR THE ENVIRONMENT GUIDELINES FOR WATER SAFETY

MfE guidelines tell us that water is safe when samples have:

- Less than 140 enterococci per 100ml for marine water.
- Less than 260 E.coli per 100ml for fresh water.

We publish the most up-to-date results for each monitored site on the Safeswim section of the Auckland Council website (**aucklandcouncil.govt.nz/safeswim**). They can also be found at the Land, Air, Water, Aotearoa website (**lawa.org.nz/explore-data/auckland-region/coastal/**).

GRADING BEACHES

This indicator also includes an overall grade for each beach, which has been calculated using test results from the past three years. The grade (from A to D) relates to the number of times water contamination at that site has gone above the safe limit (figure 1).

A = very low risk of becoming sick and it is safe to swim almost all of the time.

B = low risk of becoming sick and it is safe to swim most of the time.

C = moderate risk of becoming sick and it is safe sometimes during dry weather.

D = high risk of becoming sick and caution is advised.

HOW DO WE MONITOR BATHING BEACH WATER QUALITY?

Tests for faecal contamination are carried out in summer, from November to March. Water samples are collected from 68 popular swimming spots across the region every week.

If concentrations are above the safe level in our first weekly test, we immediately take another sample to confirm the result. If high concentrations are confirmed, we erect warning signs advising against swimming and shellfish gathering and continue daily testing. Signs stay in place until our daily testing shows concentrations have dropped to safe levels.

WHAT HAVE WE FOUND?

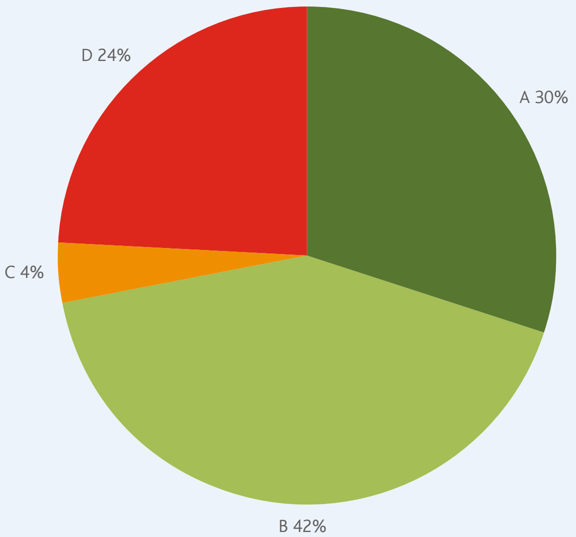
- 72% of swimming sites – grade A or B
- 28% of swimming sites – grade C or D

In other words, most monitored sites are suitable for swimming most of the time.

CAUTION ADVISED FOR SWIMMING SPOTS WITH GRADES C OR D

Sites graded as C or D are in the Manukau Harbour, Waitematā Harbour, East Coast Bays and the lagoons near the west coast beaches (figure 1). Caution is advised while swimming at these sites as the risk of contracting a water-related illness is higher than at sites graded A or B. Sites graded C or D are influenced by bacteria found in the surrounding catchments. The council is undertaking research to determine these sources and how to best reduce bacteria affecting our favourite swimming sites.

HOW DO AUCKLAND'S BEACHES GRADE?



Waiake Beach

EXCITING NEW FORECASTING SERVICE

We are developing a new forecast model to provide the public with three-day forecasts of bacteria concentrations – so you can plan your swimming trips in advance. The model is currently for seven popular city beaches (St Heliers, Kohimaramara, Mission Bay, Ōkahu Bay, Herne Bay, Home Bay and Pt Chevalier). We would like to make it available for all swimming spots across the region.

WHAT CAN YOU DO TO KEEP YOURSELF SAFE?

- Take appropriate precautions, including obeying signs against swimming, and not swimming 48 hours after heavy rain.
- Avoid high-risk areas such as stormwater outfalls and stream mouths.
- Seek the most up-to-date results for each monitored site via the Safeswim section of the Auckland Council website (**aucklandcouncil.govt.nz/safeswim**).
- If the water doesn't look nice or smell nice, don't swim in it.

Ōrākei Midwinter Splash

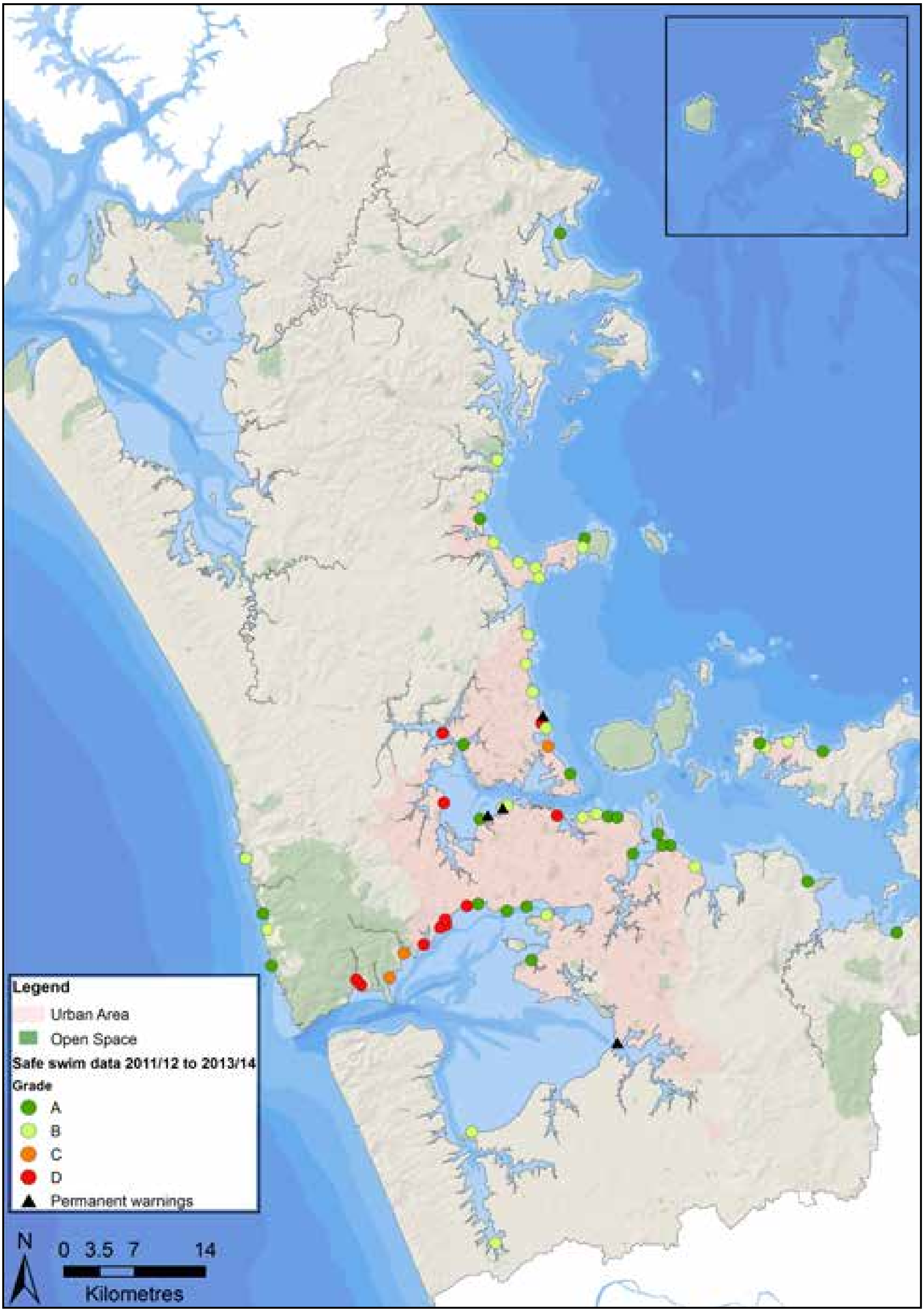


FIGURE 1: This map shows monitored swimming sites in the Auckland region. The colour of the dots indicates the grade of each site calculated from data collected over the last three summer seasons (2011-2014).

MARINE WATER QUALITY INDICATOR

THE SEAS ARE SHOWING SOME IMPROVEMENT

View of Hauraki Gulf waters and Rangitoto

Although Auckland's marine water quality is good in some areas, our activities on land have affected our ocean playground. The quality of harbour and coastal waters near the city and in some rural areas is poor.

WHY DO WE MONITOR MARINE WATER QUALITY?

Healthy coastal waters are not only important for obvious reasons like recreation and fishing. Auckland's marine environment provides us with countless ecological assets that often go unnoticed. To name a few, the sea provides a food source and is a taonga for Māori, absorbs greenhouse gases from the atmosphere and regulates nutrients, retains sediment and provides habitat structure for marine organisms. Monitoring water quality allows us to determine the health of our coastal waters.

WHAT IS THIS INDICATOR?

To monitor the health and ecological functioning of our marine waters, we measure a comprehensive range of 17 parameters including nutrients, turbidity (murkiness or cloudiness), salinity (salt content) and pH (acidity or alkalinity). We grade monitoring sites according to a Water Quality Index (WQI), which was developed by the Canadian Council of Ministers of the Environment in 2001 and adapted by Auckland Council. The index combines parameters to give an overall water quality grade of excellent, good, fair, or poor, calculated from the past three years of data (figure 1).

To analyse trends in water quality over the past decade, we used sediment, total oxidised nitrogen (TON) and total phosphorus (TP) as measures of ecosystem health and ecological functioning.

These parameters are good indicators of the health of our marine waters. Suspended sediments can come from rural land use in the surrounding areas and the re-suspension of sediment that is already part of the sea bed. Too much sediment can bury shellfish and cause the water to be murky, preventing light from getting to plants depending on it. TON and TP come mostly from overuse of fertilisers from farming and wastewater discharges. The increase in nutrients encourages the growth of phytoplankton and seaweed and can cause algae blooms that can alter our ecosystems.

HOW DO WE MONITOR MARINE WATER QUALITY?

Marine water quality is collected at 36 sites across the region (7 Kaipara, 6 East Coast, 2 Tāmaki Estuary, 2 Tāmaki Strait, 11 Waitematā and 8 Manukau sites). The monitoring programme has been running for almost 30 years at some sites. It was first established in Manukau Harbour in 1987. At most other sites, sampling started in the early 1990s, with additional sites established in 2009 (most Kaipara sites) and the most recent site added in 2012 (Waiuku town basin-Manukau Harbour).

> "Protect coastal areas, particularly those with high values (...) from the impacts of use and development, and enhance degraded areas"
>
> THE AUCKLAND PLAN - DIRECTIVE 7.12

For most sites we use helicopters to collect monthly samples of surface waters (top 1m) for analysis. This method enables us to cover a broad spread of sites in a short time, without being constrained by tides. Additional sites in the Upper Waitematā Harbour are sampled by boat, and Tāmaki Estuary sites are sampled from land. Some parameters are measured on site using a hand-held water quality probe. Others are analysed in the lab using a water sample collected from the surface. Maintaining a consistent sampling time relative to the tidal cycle avoids introducing daily fluctuations into the dataset and improves our chances of detecting long-term trends.

HOW DO AUCKLAND'S MARINE WATERS GRADE?

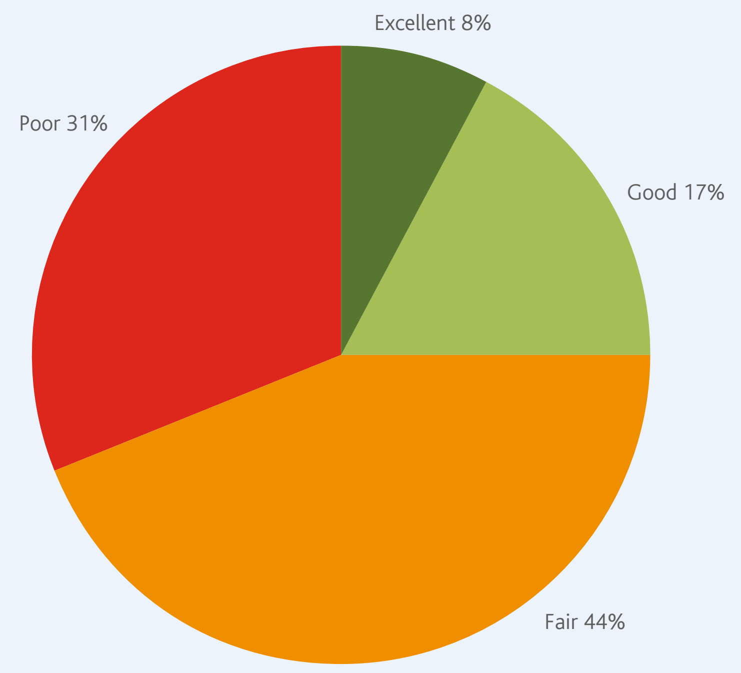


FIGURE 1: Percentage of marine water quality sites graded from poor to excellent. 36 sites are monitored and have been grouped according to their grade.

WHAT HAVE WE FOUND?

Using the WQI we found that 31% of sites have poor water quality, 44% have fair water quality, 17% have good water quality and 8% are classified as excellent (figure 1). Most poor sites are in our harbours, influenced by discharges from urban or rural areas.

Hand-held probe (EXO2 YSI)

HOW HAVE THINGS CHANGED?

An analysis of data collected over the past 10 years (January 2004 to December 2013) from all sites across the Auckland region has revealed that most of the parameters are stable with only small increases or decreases.

However, a stable condition does not equate to a tick of health. Auckland has some chronic and serious marine health issues that require action to improve the health of our marine ecosystems.

AUCKLAND OVERALL

Suspended sediment, TON and TP are representative of ecosystem health and ecological functioning. Their concentrations have remained relatively stable over the last decade, yet high concentrations are still present today (figures 2 and 3).

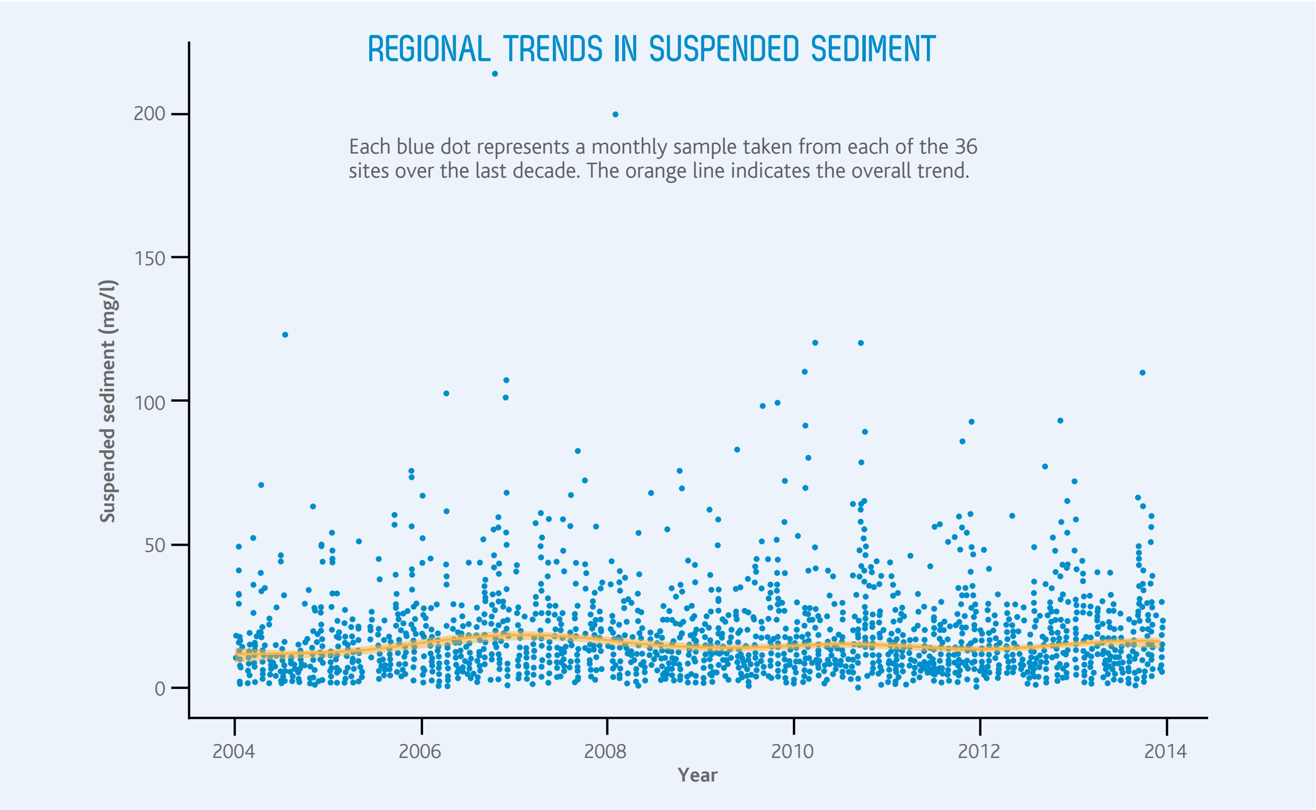


FIGURE 2: Regional trends in suspended sediment, 2004-2013.

VARIATIONS IN DIFFERENT AREAS OF AUCKLAND

At a broad level (harbours, estuaries and east coast) we have observed both increases and decreases in a range of parameters. Figures 4 and 5 illustrate the trends of suspended sediment and TON across six different areas, and TP follows a similar trend as TON.

East coast sites have consistently low suspended sediment concentrations, as do Tāmaki Estuary and Tāmaki Strait sites (although only a shorter dataset is recorded). Manukau, Kaipara and Waitematā harbours have consistently higher concentrations, which have increased the muddiness and affected the ecology of these harbours (see the Marine Ecology and Marine Sediment Contaminants indicators).

Statistically significant decreases have been seen in the Kaipara, while at all other locations we have recorded small incremental increases and decreases. A decrease in suspended sediment levels in the Kaipara has occurred at four of the seven sites. However, the present levels are still high and similar to the Manukau Harbour.

The Manukau Harbour has shown a small increase in suspended sediment. Most of this has been observed at the Weymouth sampling site, which has been increasing by ~6% per year.

Similar trends (with a couple of exceptions) were observed for TON and TP. Manukau Harbour consistently shows the highest levels of oxidised nitrogen of all the harbours over the past decade. Both Waitematā and Tāmaki Estuary sites also show elevated concentrations. The other areas have lower concentrations with significant decreasing trends observed at east coast sites, Tāmaki Strait sites and Kaipara Harbour. Total phosphorus shows statistically significant reductions in all areas, except Tāmaki Strait.

Despite these improvements in some of the variables, 75% of sites monitored are either poor (31%) or fair (44%). This highlights the need to be aware of our actions on land and how these affect our seas.

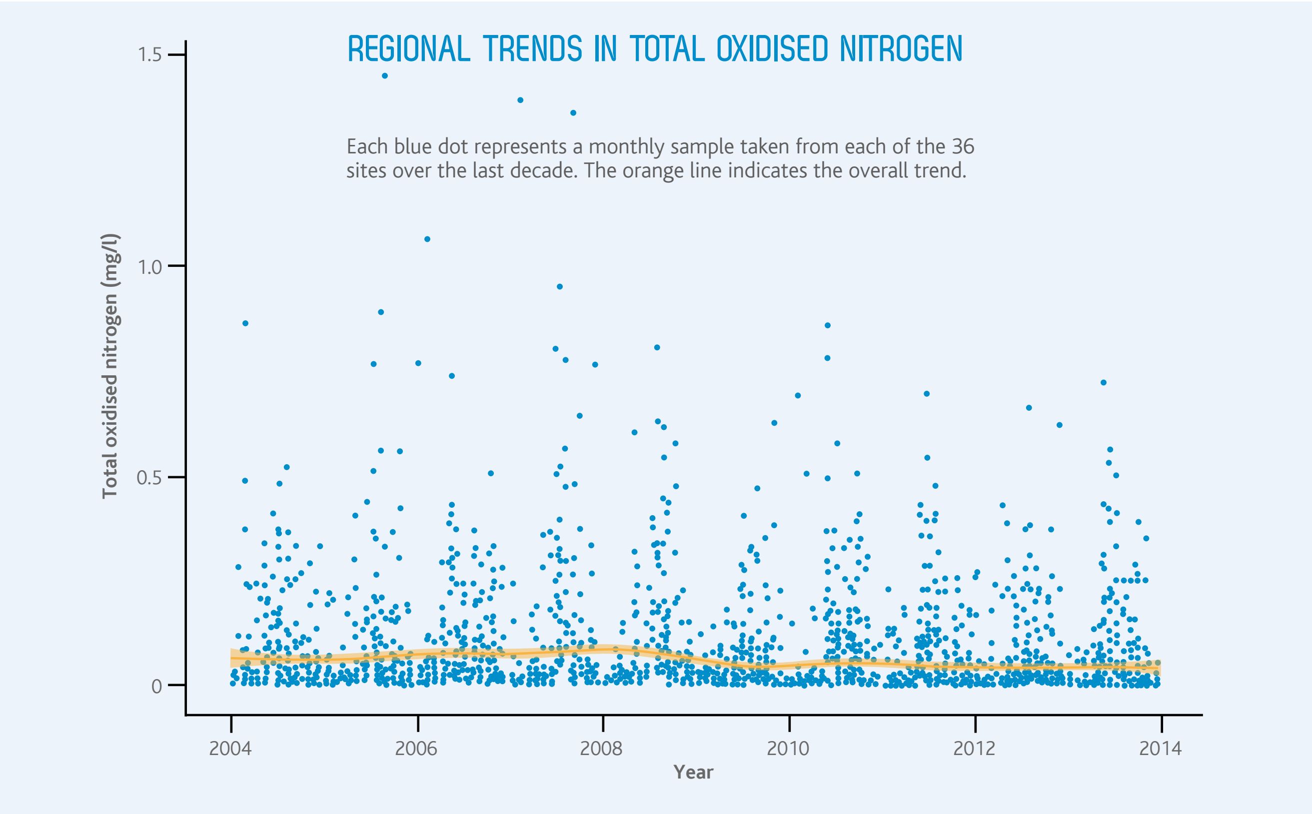


FIGURE 3: Regional trends in total oxidised nitrogen in 36 sites, 2004-2013.

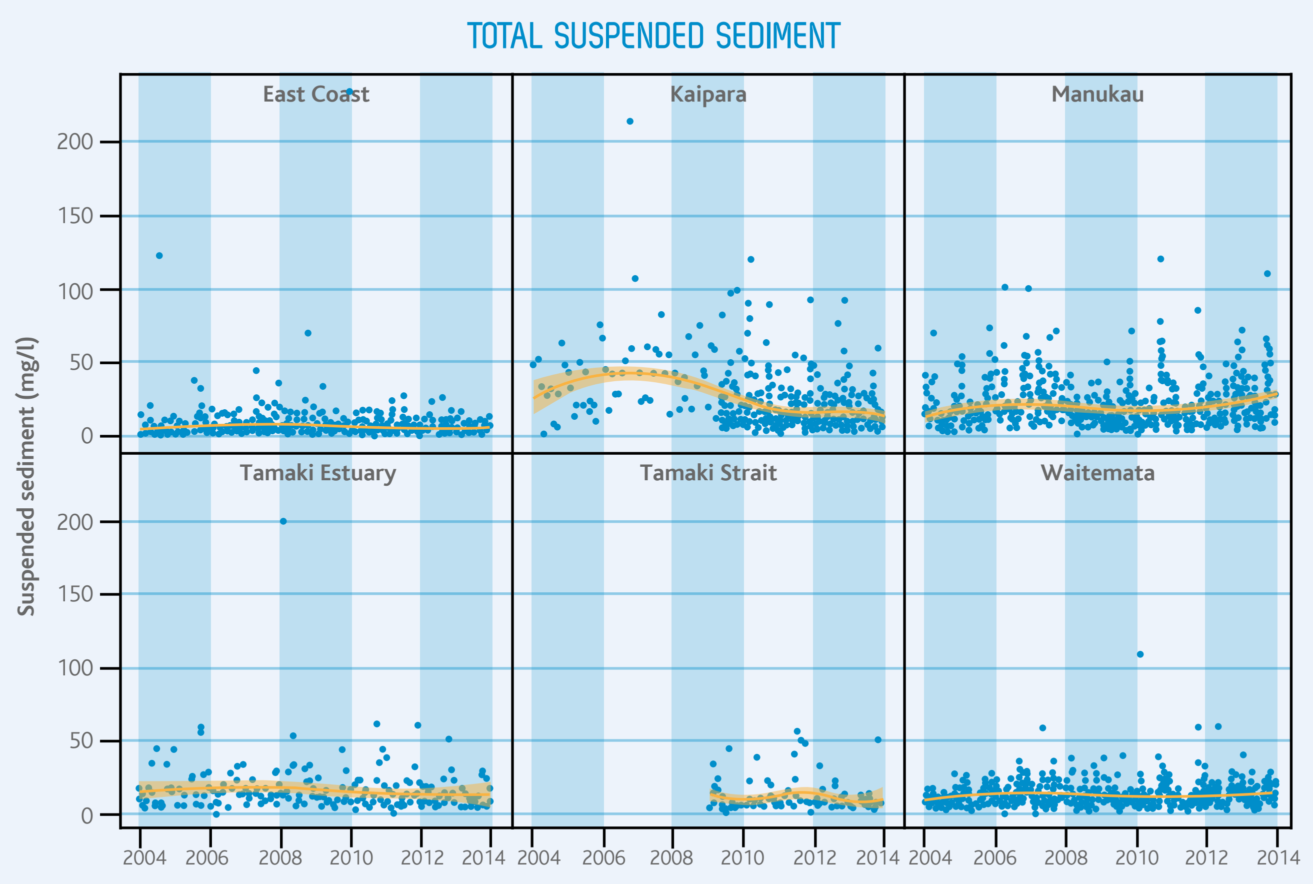


FIGURE 4: Trends in suspended sediment levels at different areas, 2004-2013. Each blue dot represents a monthly sample taken from sites within each harbour over the last decade. The orange line indicates the overall trend.

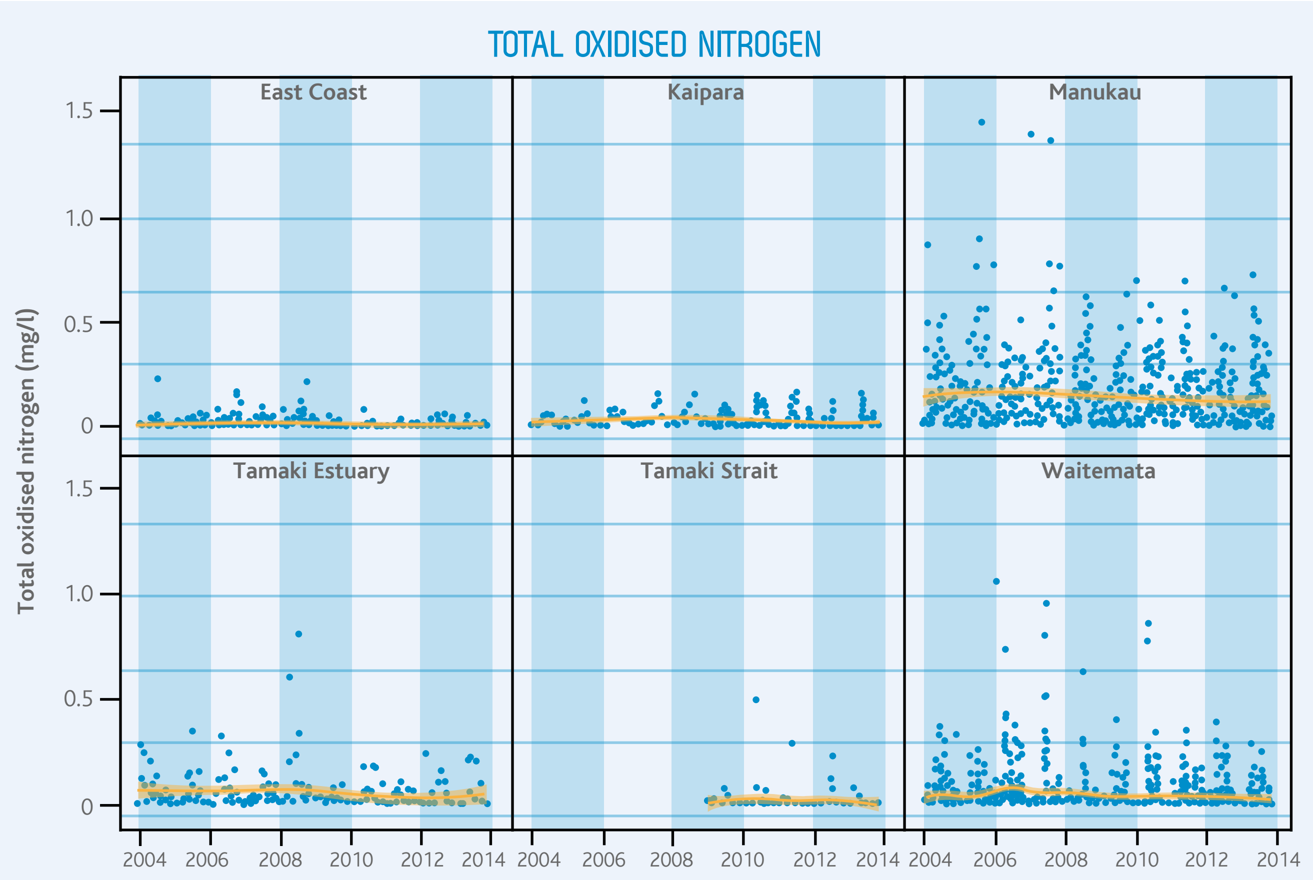


FIGURE 5: Area-level trends in total oxidised nitrogen, 2004-2013. Each blue dot represents a monthly sample taken from sites within each harbour over the last decade. The orange line indicates the overall trend.

MARINE ECOLOGY INDICATOR

LIFE ON MUD AND SANDFLATS – NOT ALL IT COULD BE

Weiti River

Crabs, shellfish, worms, bacteria and a host of other plants and animals are the unsung heroes of our coastlines. From their homes in and on mud and sand flats they do a vast amount of unseen work. They clean the water, lock contaminants up in the sediment, and provide food and habitats for other animals like fish and birds and us. But this monitoring programme has shown that most of Auckland's estuaries and harbours have sites where ecology is affected, areas far from the urban centre.

WHY DO WE MONITOR MARINE ECOLOGY?

By monitoring the numbers and types of animals found in intertidal mud and sandflats we get a sensitive measure of how healthy these ecosystems are. Unlike birds or water, they don't move around much so they make good representatives of the local conditions. The data we collect gives us insights into the possible sources of impact.

WHAT IS THIS INDICATOR?

This indicator reports on how healthy the intertidal ecology of the mud and sand flats of our harbours and estuaries is (ecology is singular). The indicator is made up of two components:

- The Benthic Health Indicator (Mud and Metals) is a reporting tool for classifying intertidal sites based on the number of animals present and their responses to both heavy metal contamination from stormwater (BHMmetals) and to sediment mud content (BHMmud).
- The Traits Based Indicator looks at the types of functions that the animals perform. For example, burrowing crabs turn over sediment and bury contaminants, and filter-feeding shellfish clean the water. This indicator counts the numbers of species performing each of seven essential functions. This tells us not only how healthy the ecosystem is and how well it is functioning, but also how resilient the system is to change and impact.

These measures are added together to score sites from one to five, with one being healthy and five being unhealthy with low resilience. The traits based indicator is a new development since the 2009 State of the Auckland Region report which provides us with more understanding of how well an ecosystem is working and enables us to compare this across the region.

The Auckland Plan has a target of reducing the overall yield of suspended sediment to priority marine receiving environments from 2012 levels by 15% by 2040 (The Auckland Plan - Chapter 7). This indicator will give us a good measure of how the ecological communities are responding to increased or decreased muddiness over time.

HOW DO WE MONITOR MARINE ECOLOGY?

We have monitoring sites in Auckland's four main harbours (Kaipara, Manukau, Waitematā and Mahurangi) as well as eight smaller east coast estuaries. We take cores of sediment at each site, sieve them, then identify, measure and count the animals that are revealed. We use the results to calculate both the benthic and traits-based indicators.

WHAT HAVE WE FOUND?

IMPACT OF URBANISATION

A quick glance at the scores over a map of Auckland clearly shows the historical impact of the urbanisation. Most sites near the older urban centres scored as unhealthy (scores of four to five), particularly within the Waitematā Harbour and Tāmaki Estuaries. Two sites in Shoal Bay in the Waitematā are no longer monitored as they have become too muddy from sediment runoff to provide a good ongoing measure of ecological health.

MANUKAU AND KAIPARA HARBOURS RELATIVELY HEALTHY

Thanks to frequent tidal flushing, the intertidal sand flats of the wider Manukau and Kaipara Harbours are relatively healthy; however, the tidal creeks and arms are muddy due to sediment washed off the land. Some areas such as Māngere and Pāthurehure inlets were rated unhealthy due to additional contamination from current and historical discharges.

UNHEALTHY SITES IN MOST HARBOURS AND ESTUARIES

While some sites were scored as very healthy or healthy, all harbour and estuary locations contained sites that were scored as only moderately healthy and most had sites scored as unhealthy. This includes sites further away from urban Auckland, showing the influence of rural land use in also generating sediment.

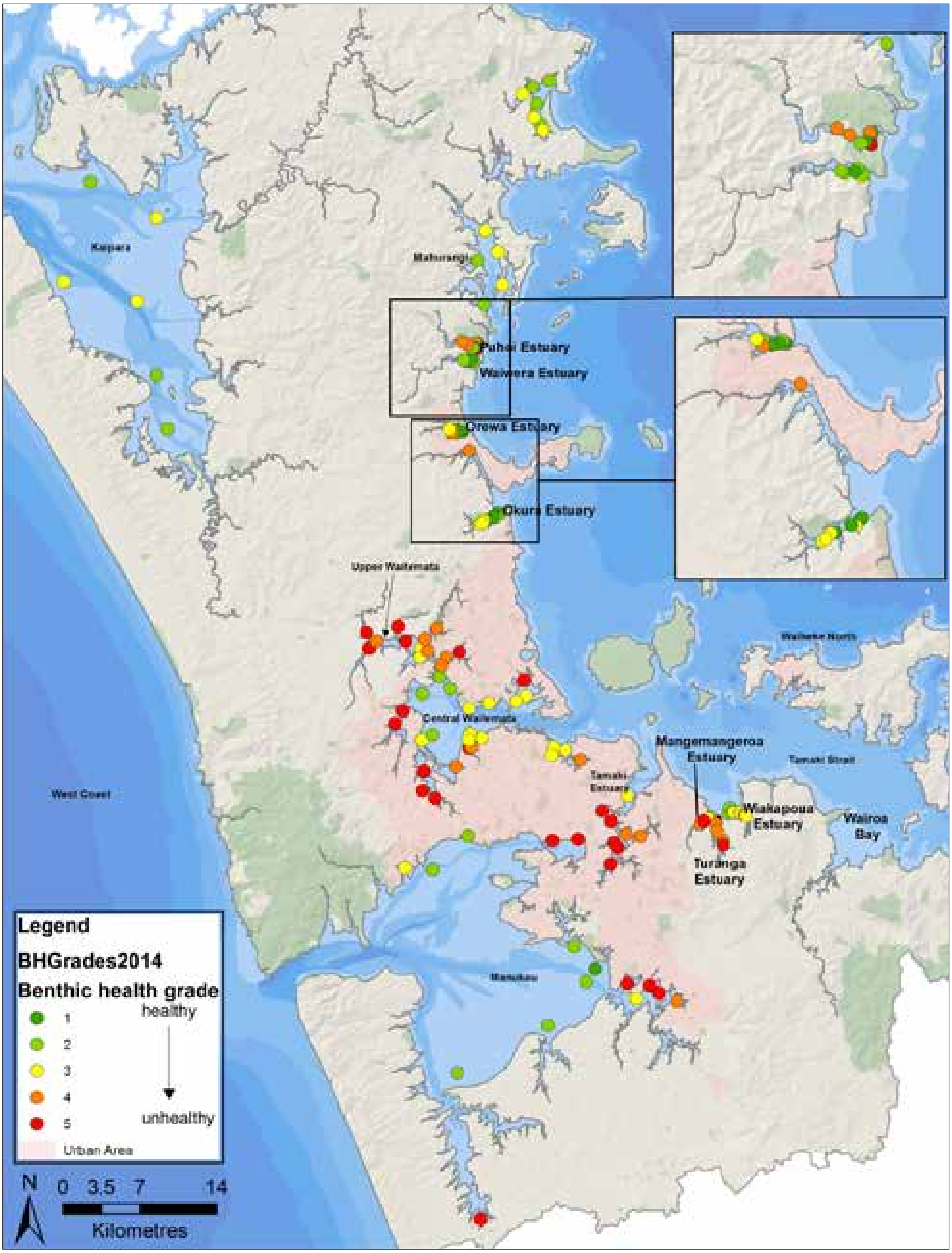


FIGURE 1: Marine ecology health grades for sites around Auckland based on types of animals in the sediment. Grades are the latest available from 2012-2014 and combine outputs from benthic health scores for responses to mud or metal contamination and also from the Traits Based Indicator (TBI) – a score based on the ecological function of the community.

Whangateau Harbour

HOW HAVE THINGS CHANGED?

There is a lot of variation across the region in how things are changing and we don't have long enough datasets to use the benthic health indicator consistently across the region yet. However, we do have consistent long-term monitoring of individual species across all our harbours and estuaries that have been selected as good representatives of what is changing and why. These are reported in detail in the technical reports for each harbour and the eight estuaries. In general, as described in the 2009 State of the Auckland Region Report, the spatial patterns in the health of the benthic ecology are largely a reflection of historical changes in land use. For the most part, the abundance of different species in the most modified harbours now only shows small fluctuations.

While the ecology has been relatively stable over the last couple of years in Mahurangi Harbour, declining trends in ecology related to sediment first detected in 1994 are still evident. Of most concern is that five intertidal species considered sensitive to increased sediment, including cockles and wedge shells, have continued to decline in abundance[1].

All of the monitored east coast estuaries now also show trends that are consistent with increased sedimentation, although these changes are relatively subtle, with not all species that might be expected to respond to sediment showing change[2]. Okura, Ōrewa and Pūhoi are exhibiting the most ongoing change, consistent with increased sedimentation. Mangemangeroa and Waikōpua have the lowest number of trends consistent with sedimentation.

References:
1. Halliday, J., Edhouse, S., Lohrer, D., Thrush, S., Cummings, V. (2013): Mahurangi Estuary Ecological Monitoring Programme: Report on Data Collected from July 1994 to January 2013. Prepared by NIWA for Auckland Council. Auckland Council Technical Report 2013/038.
2. Hewitt, J.E., Lohrer, A.M., Cartner, K. (2014): East Coast Estuarine Monitoring Programme: report on data collected 2000 to October 2013 Prepared by NIWA for Auckland Council. Auckland Council Technical Report 2015/010.

MARINE SEDIMENT CONTAMINANTS INDICATOR

HEAVY METALS IN OUR ESTUARIES

Sediment contaminants

Copper from vehicle brake pads and antifouling paint on boats, plus zinc from vehicle tyres and unpainted metal roofs are some of the worst culprits contaminating Auckland's harbours and estuaries. Thankfully most of our coasts away from urban areas remain relatively free of heavy metal contaminants, but care is needed to keep them in check.

WHY DO WE MEASURE MARINE CONTAMINANTS?

Do you ever wonder what happens to the metals, oils and paints that come off our cars and boats or from industrial processes and spills? Or how about the chemicals used to grow our food on farms? Despite efforts to treat our stormwater and wastewater, many of these contaminants still enter our waterways, attaching to fine sediments which settle and accumulate in sheltered coastal areas, such as estuaries and harbours. These contaminants can be toxic to the organisms that live on and in the sediments (see marine ecology indicator on page 169).

This monitoring programme enables us to assess the risk posed to marine life by contaminants of human origin. It also helps us track our progress in reducing contaminant inputs to our harbours and estuaries.

WHAT IS THIS INDICATOR?

We monitor contaminants in our harbours and estuaries that pose the greatest risk to aquatic life and are indicators of other contaminants. These are:

- Metals – zinc, copper, lead, mercury and arsenic. These metals are widely used in building materials, paints, automobiles and industry.
- PAHs (polycyclic aromatic hydrocarbons), which are by-products of burning fuels; for example, combustion engines in cars.

We compare concentrations with Auckland Council's Environmental Response Criteria (ERC) and classify them according to a traffic light system:[1]

- Green indicates low levels of contaminants
- Amber indicates moderately elevated levels
- Red indicates relatively high levels.

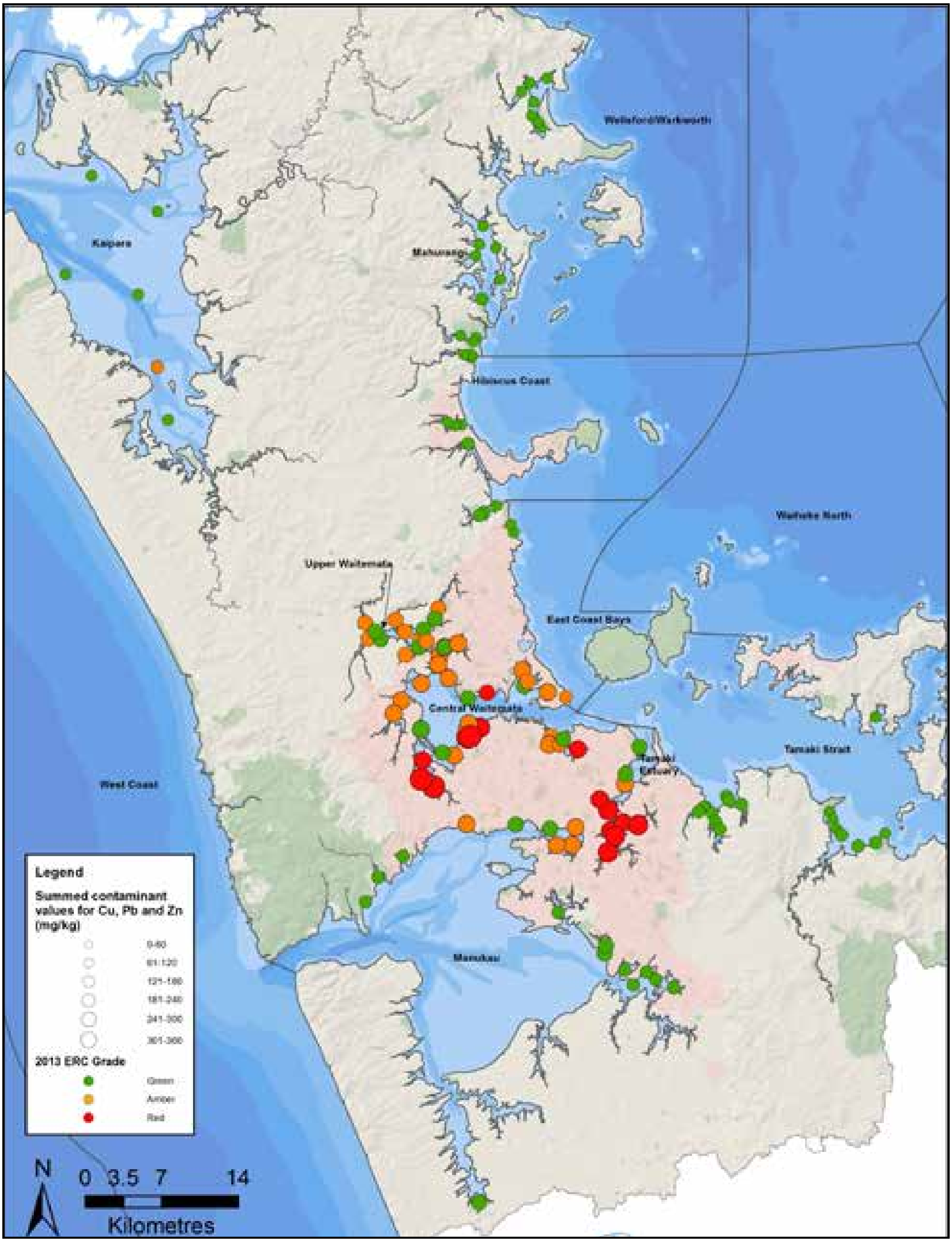


FIGURE 1: Site locations and contaminant status for Auckland Council's regional sediment contaminant monitoring programme (RSCMP) (data to 2013). Copper, lead and zinc values have been added together to provide combined contaminant values.

HOW DO WE MONITOR CONTAMINANTS IN MARINE SEDIMENTS?

Since 1998 we have sampled over 125 intertidal sites (see figure 1). Sampling is carried out every two to five years, with more highly contaminated sites monitored more frequently than cleaner sites.

The sediments are mixed both by animals in the sediment and by physical processes such as wind and waves. So to get an integrated mixture of recently deposited and older material, we take samples from the top two centimetres of the sediment[2].

WHAT HAVE WE FOUND?

The good news is that most of the sites measured are still in the green (figure 2). These tend to be in less developed and rural areas, which have fewer inputs from urban stormwater. Contaminant levels for the 125 sites we sampled between 2009 and 2013 were:

- 62% – Low
- 26% – Moderately elevated
- 12% – High.

However, the spatial distribution of sites in figure 1 and the bar chart in figure 3 show there are several hot spots of high contamination across the region. These tend to be muddy estuaries and sheltered tidal creeks receiving runoff from older, intensively urbanised or industrialised catchments. The worst affected marine reporting areas (used in our annual State of Auckland report cards) are central Waitematā Harbour and Tāmaki Estuary.

CONTAMINANT STATUS AT MONITORED SITES FOR THE AUCKLAND REGION

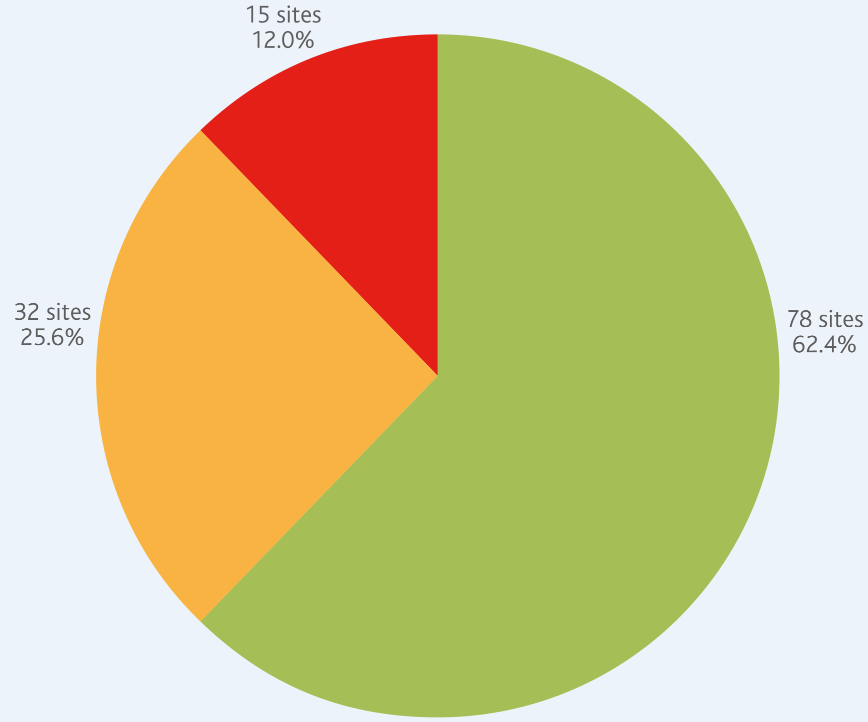


FIGURE 2: Number and percentage of sites with contaminant concentrations in the green, amber and red ranges for all contaminants combined. Latest data from 125 sites sampled between 2009 and 2013.

HOW HAVE THINGS CHANGED?

The good news is that contaminant source control, stormwater treatment and improved industrial practices are working.

It takes a long time for changes on land to be detected in the sediment on the shore. Twenty years after lead was removed from petrol we are finally seeing a decrease in concentrations of lead in marine sediments (figure 4). This goes to show that controlling contaminants at their source does work.

We have also seen a decline in concentrations of copper and lead in highly affected areas such as the Whau Inlet since the late 1990s when this monitoring programme began. This may be a result of measures to improve stormwater treatment practices and a slow recovery from a legacy of industrial pollution.

Zinc, which has had slightly more increases than decreases, is the most concerning heavy metal in the region. In particular we observed increases in zinc concentrations in Tāmaki Estuary. Some of the likely origins of zinc include vehicle tyres and unpainted metal roofing.[3]

While there may be some decreases, contaminant concentrations in many areas are still above levels that are harmful to aquatic life. We must continue our focus on removing contaminants at their source and improving stormwater treatment. This will help affected areas to recover and newly developed areas to avoid suffering the same fate as the estuaries in our older developed catchments.

CONTAMINANT STATUS AT MONITORED SITES GROUPED BY CATCHMENT OR COASTAL AREA

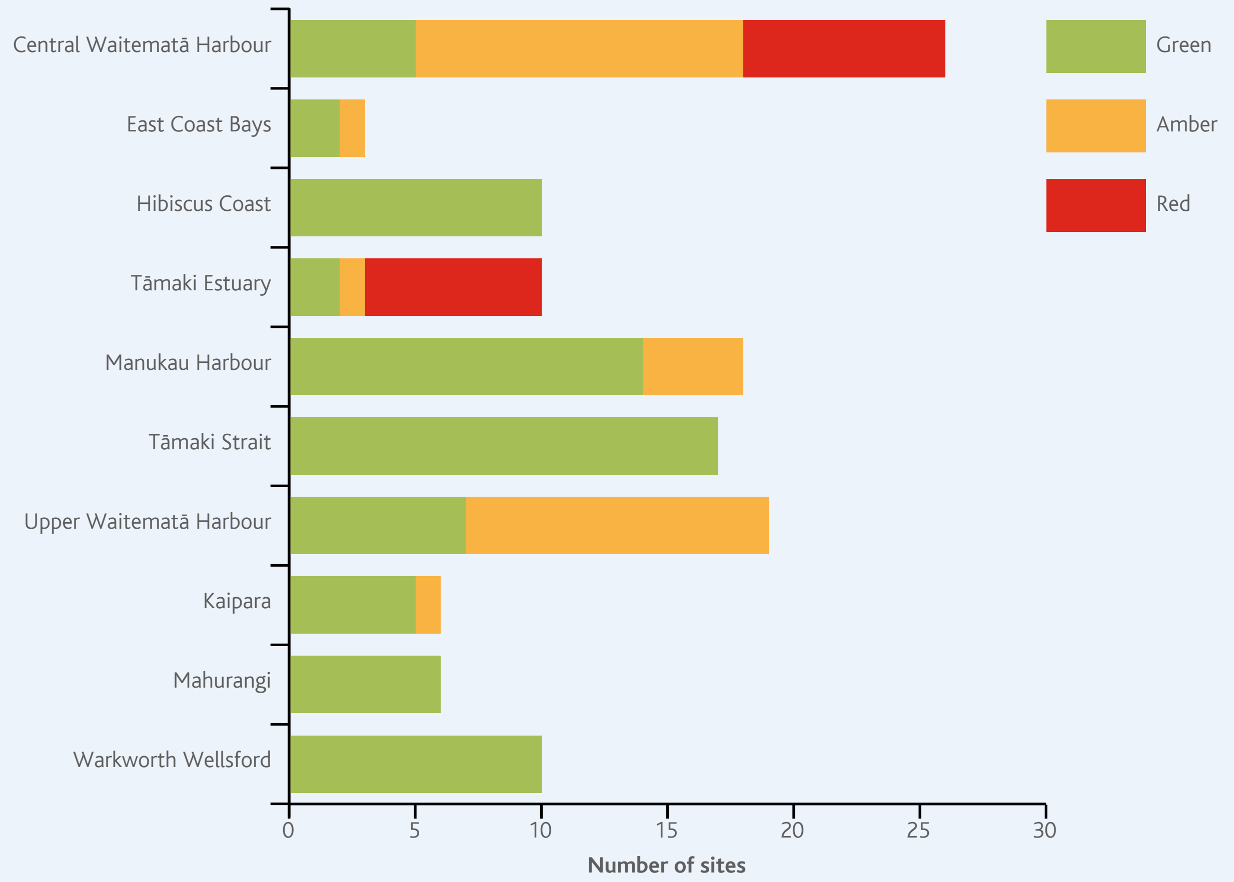


FIGURE 3: Number of sites grouped by catchment or coastal area (Marine Reporting Area) with contaminant concentrations in the ERC green, amber and red ranges for all contaminants combined. Latest data from 125 sites sampled between 2009 and 2013.

References:

1. Traffic light system outlined in the Blueprint for monitoring urban receiving environments (see Technical Publication 168 ARC, 2004) and ANZECC guidelines). Check out report TR2012/041 for further information on these guidelines.
2. Sampling is carried out using protocols detailed in the monitoring blueprint document (see Technical Publication 168, ARC 2004). Protocols for the analysis of contaminants are summarised in Auckland Council's technical report TR2012/041.
3. Kennedy, P. and Sutherland, S. (2008): Urban Sources of Copper, Lead and Zinc. Prepared by Golder Associates for Auckland Regional Council. Auckland Regional Council Technical Report 2008/023.
4. TR2012/033: Gadd, J. and Cameron, M. (2012): Antifouling biocides in marinas: Measurement of copper concentrations and comparison to model predictions for eight Auckland sites.

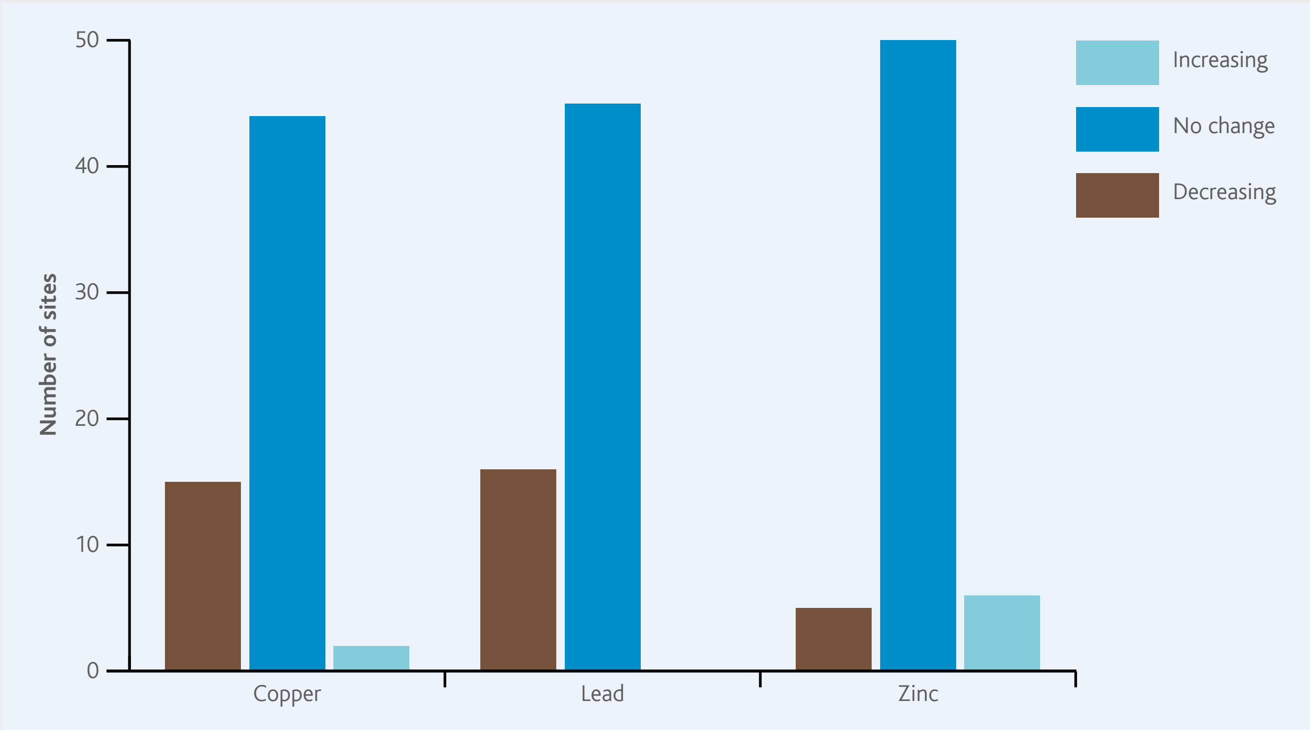


FIGURE 4: Trends in total recoverable metals from 61 sites. Increasing and decreasing trends were statistically significant (at $p<0.05$) with a rate of change >1% of the Threshold Effects Levels (TEL) per year. The TEL is the boundary between the green and amber values. 'No change' means trends were not statistically significant ($p>0.05$) or the rate of change was <1% of the TEL per year.

ANTIFOULING PAINT – A LIKELY CAUSE OF COPPER CONTAMINATION

Did you know that since the 1988 ban of tin-based antifouling paint products on recreational vessels in New Zealand, copper is now found in almost all antifouling paints we use here? Auckland Council's scientist Marcus Cameron has been working with the National Institute of Water and Atmospheric Research (NIWA) to investigate the use of antifouling paints on boats as a source of copper in the marine environment.

This research[4] found that copper levels in the water inside eight Auckland marinas are high enough to threaten marine life, and the total amount of copper being discharged from these marinas each year weighs about the same as an Asian elephant (3100 kg/year). This is roughly double the amount predicted from stormwater for the entire Waitematā Harbour catchment and could be threatening marine life outside marinas as well. Leaching of antifouling paints from vessel hulls is also the major source of copper in marina waters, rather than inputs from stormwater or hardstand activities (boat painting/cleaning).

To reduce the amount of copper from antifouling paints, boat owners can use low or non-copper antifouling products, and maintain their boat at a facility with treatment of hardstand runoff. For more information visit the EPA page on **antifouling paints** and visit the **NZ marina operators association**. The council is also working with marina operators to improve discharges from marina hardstand areas.

This is just one example of how seemingly insignificant contributions from a number of sources can add up to a serious impact. The brake pads in your car are another example. Particles of copper rub off the pads when we brake, falling onto the road where they are picked up by the rain, washed into stormwater pipes and eventually end up in the ocean.

Knowing the sources of contaminants can help us take steps to reduce or remove these sources, just like lead was removed from fuel in 1996.

MARINE MUDDINESS INDICATOR

OUR MUDDY ESTUARIES

Okura Estuary

The clear waters and sandy bottoms of many of our estuaries are being lost to increasing amounts of fine sediments that muddy the waters and smother sea life – what happens on land is affecting our seas.

WHY DO WE MEASURE MARINE MUDDINESS?

When wading through Auckland's estuarine waters, you might notice the feeling of soft slippery mud squeezing up between your toes. These same fine sediments have a large impact on ecosystem health and the survival of marine life. They block feeding and breathing structures of animals, change the living conditions and chemistry of the sediment, and block light for plants. More mud can lead to more mangroves. Built-up mud can also affect the depth and navigation of tidal channels or marina areas. The mud that does not settle is carried out into the coastal environment nearby.

WHAT IS THIS INDICATOR?

This indicator measures the amount of mud in our estuaries. Mud is defined by its grain size and is composed of very fine particles less than 63 μm across – that's about the thickness of a human hair.

For this indicator we determine the grain size distribution of sediment samples from across the region, dividing them into proportions of gravel, sand, fine sand and mud.

TARGETS

Both local and central[1] governments are seeking to make reductions to sediment loads (the amount arriving) and sediment accumulation (the amount that stays on the coast) with the aim of reducing further impact and degradation of coastal areas.

The Auckland Plan sets a target to: "Reduce the overall yield of suspended sediment to priority marine receiving environments from 2012 levels by 15% by 2040." (The Auckland Plan - Chapter 7).

WHERE DOES MARINE MUD COME FROM?

Over the last 170 years of European modification of the surrounding land, the amount of sediment runoff and mud being deposited in our estuaries has increased from an accumulation rate of less than 1mm per year to up to 20mm per year, averaging 3.8mm per year[2] in some east coast locations. Fine sediment loosened on the land is washed by the rain into streams, rivers and pipes and collects in the coastal environment. Typical origins of sediment include:

- Erosion of unfenced streambanks
- Runoff from ploughing fields
- Forestry and pasture
- Erosion of hills without trees
- Earthworks and urban development
- Natural erosion.

HOW DO WE MEASURE MARINE MUD[3]?

Gathering data for this monitoring programme is messy work. We wade through the mud to collect samples from the top layers of the sediments from intertidal flats. Each sample is put through a series of sieves, filter papers or laser analysis machines to measure the size and weight classes of all the grains.

Sampling sites are chosen to represent the different types of environments in each estuary (for example sheltered areas in the upper estuary and exposed areas near the harbour entrance) and a range of geographic locations throughout the region.

In some harbours we have been monitoring sediments in this way since the 1980s. For example Manukau has been going since 1987 whereas the Kaipara Harbour monitoring began in 2009.

WHAT HAVE WE FOUND?

Our harbours and estuaries are in general very muddy, particularly in the upper reaches and more sheltered areas. For example, sailing up to Riverhead is best done at high tide to avoid the narrow tidal channel lined on either side by soft tidal mud flats.

Figure 1 shows muddiness levels across the region. Sheltered upper estuary settling zones, such as in the Upper Waitematā Harbour and Pāhurehure Inlet, often have the highest mud levels. Some sites, such as those shown in the Kaipara Harbour are less muddy as they are more exposed and sediment gets moved around by waves and tide and is less likely to deposit. Higher levels of mud can have detrimental effects on ecological health and function, with declines broadly occurring around 10%, 25% and 60% muddiness. However, these numbers are just a guide, as different benthic communities can respond to the same level of muddiness in different ways. That said, the latter muddiness thresholds of 25% and 60% should be avoided, especially 60%. As these latter thresholds are breached, ecosystem resilience is likely to become compromised and restoration potential more unlikely[5,6].

References:
1. Swales, A. et al. (2008): Technical Publication Number TR 2009/079.
2. NZ Coastal Policy Statement.
3. Background and methodology are outlined in sediment sections of the following Auckland Council technical reports: TR2014/039 Marine sediment contaminant monitoring: 2013 data report. TR2013/027 Manukau Harbour ecological monitoring programme: report on data collected up until February 2013.
4. Lohrer, D. and Rodil, I. F. (2011): Suitability of a New Functional Traits Index as a State of the Environment Indicator. Prepared by NIWA for Auckland Council, Auckland Council technical report 2011/004.
5. Hewitt, J. E. and Ellis, J. (2010): Assessment of the benthic health model. Prepared by NIWA for Auckland Regional Council, Auckland Regional Council technical report TR2010/034.
6. Thrush, S. F., Hewitt, J. E., Cummings, V., Ellis, J. I., Hatton, C., Lohrer, A. and Norkko, A. (2004): Muddy waters: elevating sediment input to coastal and estuarine habitats. Frontiers in Ecology and the Environment, 2 (6), 299-306.

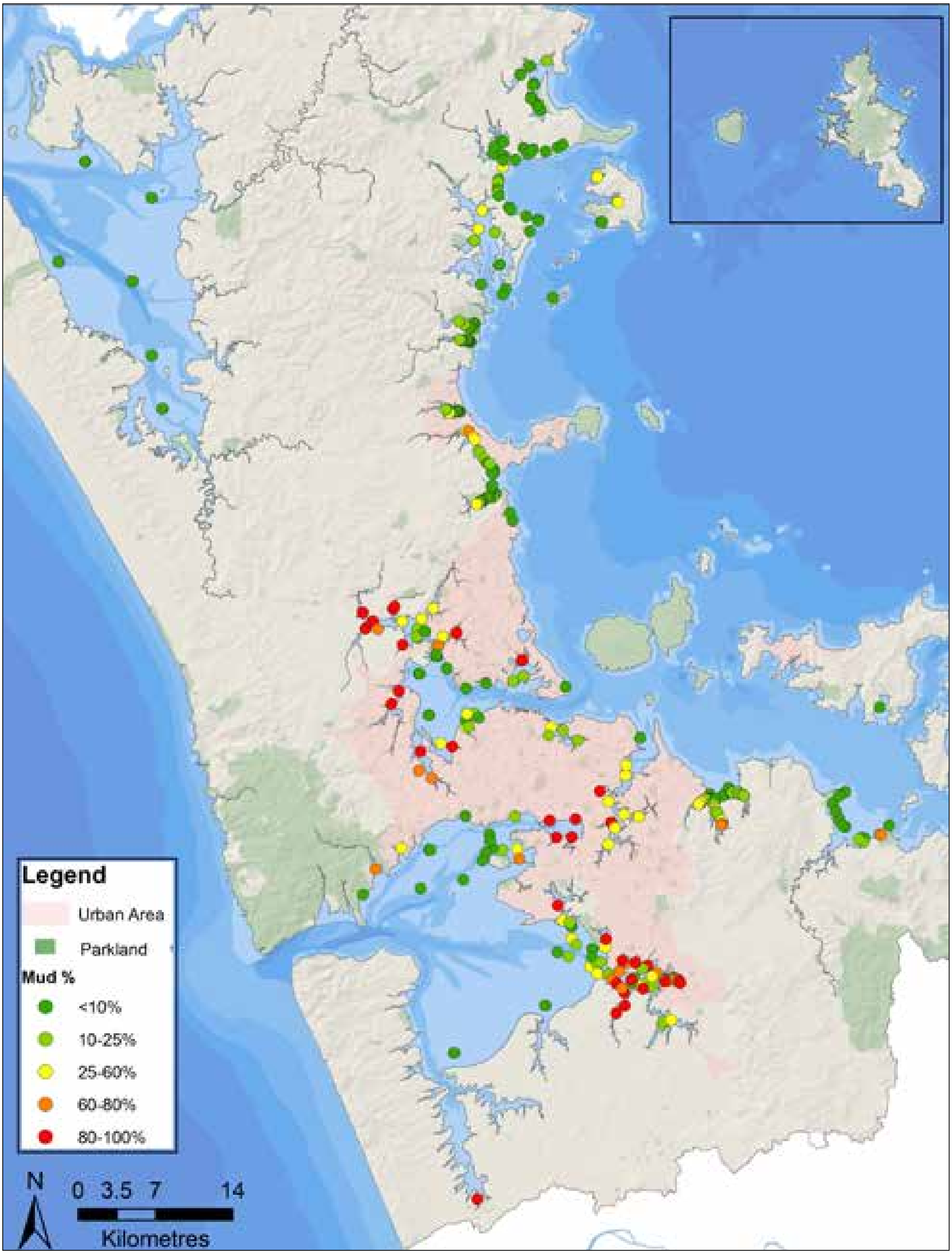


FIGURE 1: Muddiness at sites around the Auckland region shown as percentage mud. Sites with mud (<63 μm) content greater than 25% (yellow to red) are the most detrimental to ecological health (see the marine ecology indicator).

CASE STUDY: MARINE HABITATS

WHAT LIES BENEATH? NEW TECHNIQUES FOR MAPPING OUR BLUE BACKYARD

Kawau Bay – Spionid tube mat carpets the sea floor and surrounds a sponge (Chondropsis kirkii). Shell hash in the sediment is visible in the foreground. Photo: S. F. Thrush.

Diverse and healthy marine habitats not only support marine species but provide food and clean water for humans. Auckland's marine area is vast and it can be difficult to sample underwater. We will never know all the mysteries that are out there, but every day we are advancing our knowledge and understanding, along with our ways of sampling large areas and predicting where important habitats are.

In the coastal waters all around Auckland, countless armies of plants and animals are busy cleaning up after us and producing food for us. Crabs take contaminated sediment from the sea floor and bury it, shellfish filter the water and absorb toxins, plants and animals absorb carbon from the atmosphere, and tiny plants and animals balance the water chemistry so other plants and animals can flourish and feed the fish we eat. And yet many of the communities providing these silent benefits are threatened by our activities. They are sensitive to even small changes in their environment. Sediment from land is sweeping into estuaries and harbours, smothering many inhabitants. Contaminants washing in from city streets are accumulating in the sediment in our estuaries and harbours.

WHERE DOES MARINE LIFE LIVE?

Just like humans, marine animals require different habitats and resources during their lives – places to find food, to meet mates, to raise young, to grow old. Maintaining a diverse marine ecosystem with a range of habitats is the best way to provide for all of these needs.

Biogenic habitats, which are structures created by other plants and animals, are particularly important habitats to consider. A famous example is the Great Barrier Reef in Australia, which supports an incredible abundance of sea life. While Auckland does not have a 'Great Barrier Reef' it does have horse mussel beds, tubeworm mounds, kelp forests, mangrove forests, green-lipped mussel beds, seagrass, sponge gardens and much more, which all provide important habitats for other plants and animals.

Intertidal seagrass bed with cockle siphons visible

Intertidal rockpool fringed with encrusting algae and Neptune's necklace (Hormosira banksii)

WE NEED TO KNOW MORE ABOUT MARINE HABITATS

We know that to maintain marine biodiversity it is important to maintain habitat diversity and connectivity, that is, a lot of different habitats connected within an area so that marine life can move between them.

But knowing where these important habitats are is more difficult. There is so much we do not know about the underwater world. Why? Because we cannot easily see beneath the surface. Large information gaps exist in New Zealand about where habitats are and what species are associated with them. In many places we do not even know how deep the water is.

Auckland Council has been working on improving knowledge of the region's habitats with a monitoring programme designed to describe habitats and ecological communities in intertidal (parts of the coast exposed when the tide goes out) and shallow sub-tidal areas (water up to about 20m deep).

HABITAT SURVEYS – THE FOUNDATION OF MARINE MAPPING

Accurate mapping of the marine environment is a challenging and expensive task. But by using a combination of fieldwork and new technology, we are starting to get a better picture of what lies beneath Auckland's watery backyard.

Fieldwork is the foundation and reference point for all marine mapping, where scientists go out and observe what is happening. They start by identifying a selection of representative sites. They take core samples of sediment and, back in the lab, sieve the samples to reveal the animals living in them. The scientists also observe, count and record organisms living on the surface. We monitor subtidal areas (below the surface) using a mix of samples collected by divers, underwater video and sonar mapping (using sound pulses, like a dolphin does, to learn about the contours of the sea floor).

The council has been conducting habitat surveys like this since 2004. So far Kaipara Harbour, Kawau Bay, Tāmaki Strait, Wairoa Estuary and Whangateau Harbour have been surveyed and results are available in technical reports.

Satellite image of Waiheke Island coast

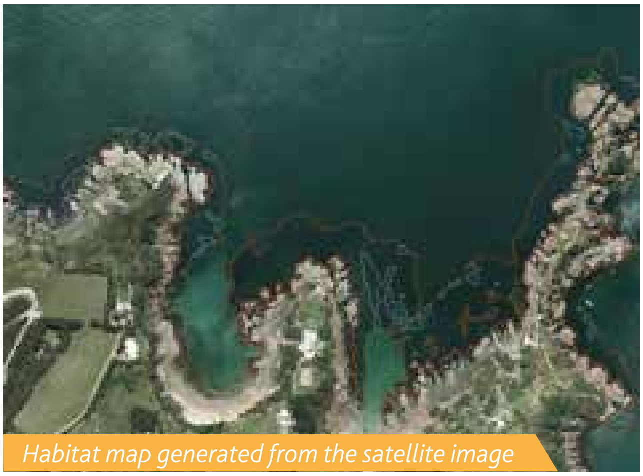
USING TECHNOLOGY TO EXPAND OUR KNOWLEDGE

Although direct sampling of habitats gives us the best and most detailed information, it is very expensive. This is where new technology comes in. Working with GIS company EcoGIS, we have developed an approach using satellite images to create habitat maps of large-scale areas.

Analysis of satellite imagery is being used to identify both physical (intertidal and subtidal reef, sand and mud) and biological habitats (kelp forest, urchin barrens, mixed algae and turfing algae) on rocky reefs in the Hauraki Gulf.

The imagery is captured by a satellite the size of a four-wheel drive car, with an image resolution of 1.84m (this means from space you can 'see' objects that are 1.84m in diameter). Light spectrum analysis doubles the capability of most other satellites, enabling us to see deeper underwater and differentiate types of vegetation.

This has enabled mapping of underwater reefs and their habitats for 2000km of Auckland's east coast to a depth of 15-18m. The analysis of the satellite imagery is checked by overlaying aerial photographs to make sure the habitats and their boundaries are real and make sense. In some cases this has been further validated by physical 'ground truthing' (going out and checking what is there) or using existing data from surveys.



Habitat map generated from the satellite image

So far we have produced maps of intertidal and shallow subtidal reefs for most of the Hauraki Gulf. From the maps the total area of these reefs can be estimated, along with the gulf's total area of kelp forest and urchin barrens. These habitat areas can now be used to calculate reef productivity, helping us understand the role of reefs in supporting the gulf's marine ecosystem.

These maps and data layers will enable better planning for the use of the gulf and help us track both large and small-scale changes in marine habitats. So far we have applied the imaging technique to the Hauraki Gulf; next we would like to expand it to the rest of Auckland.

USING WHAT WE KNOW TO MAKE PREDICTIONS

Even with new technologies, we cannot sample everywhere. However, we can use what we know about how the environment works, and the types of conditions that plants and animals like, to make predictions about where things may occur.

The council has been working with NIWA (Hamilton) to map ecosystem activity in the Hauraki Gulf including biogenic habitat formation[1]. These maps use the relationship between physical variables, such as sediment grain size and plants and animals, to predict where these biogenic habitats might be. This predictive process has been tested against areas with data from our monitoring.

From the maps, high biogenic habitat occurred on the northerly tip of the Coromandel, the easterly tip of Whangaparaoa, the east of Waiheke Island and in the westerly lee of Great Mercury and Little Barrier islands. Locations such as Kawau Island, Goat Island and Little Barrier stood out for shallow productive reef patches.

Mapping more of Auckland's underwater habitats will help us identify important areas to protect for biodiversity and ecosystem services. It will also provide more certainty for people wanting to use the marine environment, as important areas to consider will be more clearly identified.

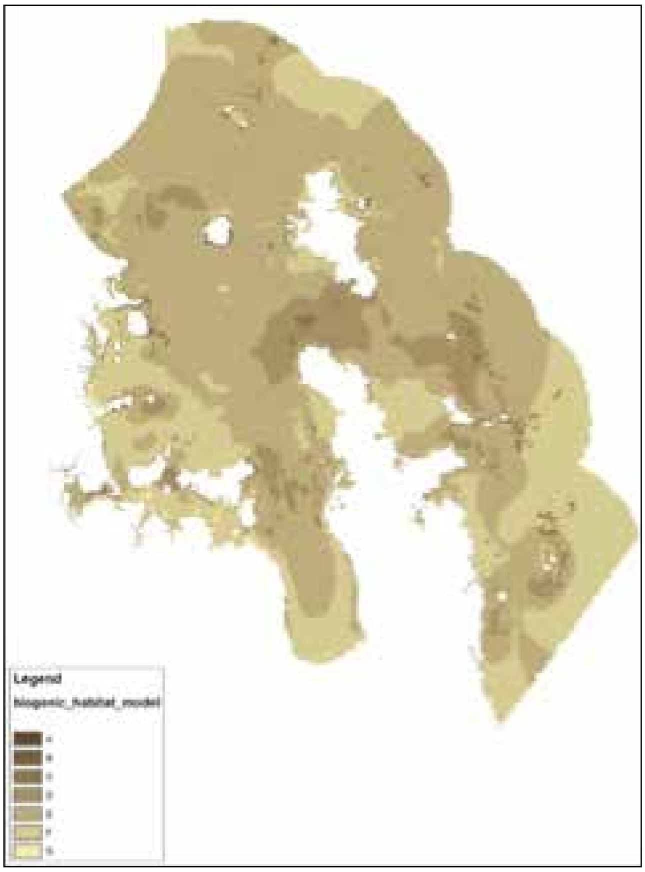


FIGURE 1: Map showing the levels of biogenic habitat (predicted) where A is the greatest and G the lowest[1].

MONITORING REVEALS BIODIVERSITY HOTSPOTS

The Kaipara is a unique harbour and the largest in New Zealand. The southern Kaipara's high diversity of habitats includes extensive fringing mangroves and salt marshes, seagrass meadows and patches, sandy and muddy intertidal and shallow subtidal flats, deep high-flow channels, and rocky reefs and cliffs.[1] Many areas of the southern Kaipara display high species diversity and a number of animals living in the harbour are large and long-lived.

The harbour also has a number of species commonly associated with pristine environments, such as sponges, ascidians (sea squirts), bryozoans, hydroids, echinoderms (e.g. starfish and kina) and pipis. Some Kaipara Harbour habitats are unique to the region. In particular, a colony of diverse tube-building worms was found in the shallow subtidal area of the main harbour. Subtidal seagrass is also comparatively rare in New Zealand.

Kawau Bay was also found to be an area of high habitat diversity, with communities varying from large plants on reefs to dense beds of sediment-dwelling species[3]. The soft-sediment subtidal areas, in particular, are highly diverse. For a relatively small estuary, Whangateau has a wide range of intertidal and subtidal habitats[4].

The dominant fauna observed in Kaipara and Kawau Bay contribute to nutrient cycling and productivity, sediment stability and water clarity, provide refuge and food for fish, and provide food and recreational value for people.

References:
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IN SUMMARY
TE KĀPUINGA

The health of Auckland's fresh and marine waters is essential to life as we know it. Around 75% of the region is water, so it is an integral part of Auckland's identity and well-being.

Auckland Council's water indicators tell a complex story. The quality of our fresh and marine waters varies widely. There are pristine locations where rivers have clean water and are surrounded by native bush, and where marine waters are clear and blue. Water quality is excellent at these locations and supports healthy ecological communities. However, at severely degraded locations, rivers are affected by water runoff from urban areas and have little to no surrounding bush or in-stream habitat, while our sheltered estuaries are degraded by sediment and contaminants from the surrounding catchments.

Auckland's degraded marine and freshwaters reflect historic and current contamination from urbanisation, industrial activities and rural land use. Some places continue to decline in quality due to the ongoing impacts of three major land-derived inputs: sediments, nutrients and contaminants (such as metals).

But it's not all bad; we are also seeing some improvements. For example, our monitoring data shows Auckland's water consumption per capita is decreasing and in some marine locations the metal load is also reducing. However, Auckland's population is forecast to increase substantially, which will put further pressures on water quality and resources, and the plants and animals that rely on or live in the water.

FRESHWATER

Our freshwater monitoring programme reinforces that urban water quality is a result of historic and current activities in the urban environment. It is challenging to directly link urban freshwater contaminants to one source, as many potential sources, large and small, come together to negatively impact on our streams. These sources are from urban development, industrial activities including discharges, vehicle use, and stormwater and wastewater systems. Rural land-use activities, such as using fertiliser and allowing grazing cattle access to streams, result in elevated nutrients, sediment and E. coli in some rural streams and groundwater systems.

MARINE

Historically, our harbours, estuaries and open coastal areas supported healthy and diverse marine habitats, communities and species that contributed to clean water, food resources, biodiversity and a host of other ecosystem benefits. Today, the clear waters and sandy bottoms of many of our estuaries and harbours are being lost to increasing amounts of fine sediments that muddy our waters and smother sea life. Inputs of nutrients and contaminants are also adding to this degrading effect.

Marine water quality is good in some areas, but activities on land have affected our coastal playground. Some harbour and coastal waters near the city and in some rural areas have poor water quality due to high sediment and nutrient loads, and are showing continued decline for some measurements. Most of our water quality issues are urban related, but some are linked to rural land use. Despite these results, most of Auckland's monitored swimming beaches have low faecal contamination and are safe for swimming most of the time. However, some beaches are severely affected during heavy rain, when increased stormwater runoff and wastewater overflows discharge into our harbours.

Contaminants such as copper from brake pads, antifouling paint on boats, zinc from tyres, E. coli from sewer overflows, sediment from development sites and nutrients from fertilisers are just some of the culprits contaminating Auckland's rivers, harbours and estuaries. While many of the sites monitored for heavy metals have relatively low levels, they tend to be in less developed and rural areas, with fewer inputs from urban stormwater. The contamination hotspots tend to be muddy estuaries and sheltered tidal creeks that receive runoff from older, intensively urbanised or industrialised catchments. The worst-affected areas are the central Waitematā Harbour and Tāmaki Estuary.

While there may be some decreases, contaminant concentrations in many areas are still above levels harmful to aquatic life. So we need to keep focusing on removing contaminants at source and improving stormwater treatment. These areas can then recover and newly developed areas can avoid the same fate as estuaries in our older developed catchments.

We still have pristine marine and freshwater environments, although mostly located away from urbanised areas and relatively free of human influence. We must continue to value and protect these precious resources. Our freshwater and marine indicators clearly show the connections between these environments and the land – our activities on land have flow-on effects for our marine and freshwaters.

Data from our monitoring programmes provides a good measurement of the health of Auckland's water resources. Maintaining this evidence base into the future is important for tracking how our water resources are responding to the myriad of threats, as well as evaluating the effectiveness of policies and actions aimed at protecting our environment.

WHAT CAN YOU DO TO HELP? ME PĒHEA TŌ ĀWHINA MAI?

Using water in your homes more efficiently helps reduce the pressure on natural water resources. For example:

- Use more water-efficient appliances (upgraded designs for toilets, efficient washing machines and showers). Check out WELS – water efficiency labelling scheme (**waterefficiency.govt.nz**).
- Capture rain for irrigation.
- Reduce leaks in your water supply system.
- Check out: Be Waterwise. **watercare.co.nz/community/Be%20Waterwise/Pages/Be%20Waterwise.aspx**

- Did you know that stormwater drains flow directly into streams and the sea? It's important not to let litter or pollutants enter stormwater drains. For example, wash your car on the grass rather than on the street (**See the AC urban stream care page**) and dispose of old paints and fuels correctly (**See the AC hazardous waste page** and see the **AC waste minimization for business page**). To report pollution, contact our pollution response team.
  AC Pollution page link.
- Soil and sediment can dirty our waterways, smother aquatic life and often carries contaminants. Use best practice on work sites, especially minimising soil and sediment loss (**AC Earthworks page**).
- Using water sensitive design when landscaping, building or renovating can reduce flooding and prevent contaminants entering our waterways. Examples include using green roofs, permeable pavers, raingardens and raintanks, and reducing exposed copper and zinc in roofing and architectural products.
- Use low-copper or non-copper antifouling paints on your boat and maintain it at a facility with runoff treatment (See the EPA page on using **antifouling paints** See the **NZ Marina operators page**).
- **Auckland Low Carbon Action Plan** outlines ways of mitigating greenhouse gas emissions and limiting climate change including sea level rise.
  Play your part by making simple sustainable choices such as using public transport and using energy efficiently in your home.
- Help stop litter reaching the sea by trying to reduce the amount of waste you produce. Recycle wherever possible. Avoid items with a lot of packaging and shop with reusable carry bags rather than plastic bags. Composting is a great way to reuse organic waste in your garden.
- Ensure your rubbish doesn't end up in the sea when you are fishing, including fishing line, nets, hooks and sinkers.
- Vehicles are a major source of trace element contaminants. You can improve air quality and our marine and freshwaters by using cars less, car-pooling, taking public transport, walking and cycling.
- Rural management for waterways:
  - Fencing streams to exclude cattle and sheep prevents their waste directly entering the water, reducing the amount of E. coli and nutrients. It also prevents animals treading on stream banks, which can cause erosion and release sediment into the water.
  - Using nutrient budgets to match fertiliser use to crop needs can be an effective way of cutting back on fertiliser, nutrient leaching and nutrient leaching and runoff to waterways. If plants can take up most of the available nutrients from the soil, there are fewer nutrients vulnerable to loss. For more advice on land management practice, contact the council's **Land and Water Advisors.**
- Join an environmental group such as **sustainable** coastlines, check out **ecoevents.org.nz** or sign up to one of Auckland Council's **environmental programmes** such as Wai Care, Enviroschools or community planting days. Waicare is a water quality monitoring, education and action programme for community groups, individuals, businesses and schools. To contact your local Waicare representative, visit **waicare.org.nz/ContactUs**.

CASE STUDY: LIVEABLE CITIES

HOW WE COMPARE WITH THE MOST LIVEABLE CITIES

Auckland's CBD on the edge of the sparkling Waitematā Harbour

Auckland's goal is to become the world's most liveable city. In 2014 it was ranked 10th in the Economist Intelligence Unit's Liveability Ranking. In this case study we compare Auckland with the three top-ranked cities: Melbourne, Vienna and Vancouver.

WHAT IS LIVEABILITY AND HOW DO WE MEASURE IT?

According to a prominent expert, liveability has been defined as "the sum of all things that make life enjoyable, comfortable and meaningful including physical, psychological, economic, aesthetic and recreational benefits"[1].

Although it is difficult to measure such intangible qualities, it is not hard to see how fundamental the environment is to liveability. The environment is the place we live in, the air we breathe, the water we swim in and drink, the parks we play in, the food we eat and so much more.

Despite the importance of the environment, neither of the two most popular international liveability indices takes account of its current state in their calculations. The Economist Intelligence Unit's Liveability Ranking and the Mercer Quality of Living Survey consider factors such as stability, safety, healthcare, culture, education and infrastructure. In terms of the environment they consider the climate and the risk of natural disasters but not the current state of air quality, ecosystem health or other such indicators in this report.

A more environment-focused international index is the Green City Index (developed by the Economist Intelligence Unit and sponsored by Siemens) which covers air quality, CO_2 emissions, water and sanitation, waste management, land use, energy, transport, buildings and environmental governance. This index ranks cities based on their performance in terms of policies, technologies and outcomes, but it also does not directly reflect the state of the natural environment. A report of the Green City Index for Auckland has not been published yet.

Given the importance of our environment directly and indirectly in achieving the goal of being the world's most liveable city, how does Auckland's environment compare with those of other most liveable cities? We have done our best to find out, comparing the state of the environment in the top-ranked cities with Auckland's.

> "A city where all people can enjoy a high quality of life and improved standards of living, a city which is attractive to mobile people, firms, and investors, and a place where environmental and social standards are respected."
>
> THE AUCKLAND PLAN - SECTION B

HOW WE COMPARED THE CITIES

To date, there are no globally accepted standard indicators to compare the state of the environment in different cities. Every city monitors its own set of indicators in different ways and reports them using different scales. Because of this, we have only been able to compare a few of the indicators from our monitoring data. In addition we have included some general environmental indicators such as waste recycling and public transport use to give a more complete picture. Where possible we also looked at the extent of environmental monitoring programmes in the different cities.

DISCLAIMER

The data we have presented only provides a snapshot of some environmental attributes in the different cities. It does not constitute a comprehensive assessment. Where we couldn't find primary data we used processed data (e.g. published in reports), which may have introduced some errors. For example, we could not always verify if the data we found was related to the city boundary or the metropolitan area. We could not always find data from the same year for all cities. In cases where no comparable quantitative data was available, we describe the environmental conditions in the different cities qualitatively.

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4. World Health Organisation (2014): Burden of Disease from household air pollution for 2012.
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INTRODUCING THREE OF THE WORLD'S MOST LIVEABLE CITIES

MELBOURNE

Australia's fastest growing city, Melbourne is home to four million people. The Melbourne metropolitan area has the highest population of the compared cities. The city of Melbourne is recognised worldwide for its support for green building. It received the C40 & Siemens City Climate Leadership Award in 2013 for its Sustainable Buildings Program, and in 2014 for its Urban Landscapes Climate Adaptation Program.

VIENNA

Vienna, Austria's capital, has a population of 2.4 million in its metropolitan area. It's ranked fourth overall in the European Green City Index, scoring particularly well in the categories for water and renewable energy. Vienna calls itself a model environmental city based on the comprehensive use of public transport and fast access to inner-city green spaces.[2]

VANCOUVER

The Vancouver metropolitan area is the most populous area in western Canada with around 2.3 million people. It ranked second overall in the US and Canada Green City Index, particularly due to low CO_2 and air pollutant emissions. Vancouver aims to be the greenest city in the world by 2020.[3]

THE WORLD'S MOST LIVEABLE CITIES

Liveable cities

MELBOURNE	VIENNA	VANCOUVER
Population (metro): 4.0 million Population density (city): 1532/km^2 Average low temperature: 10.2°C Average high temperature: 20.1°C Average annual rainfall: 647mm	Population (metro): 2.4 million Population density (city): 4258/km^2 Average low temperature: 8.3°C Average high temperature: 15.3°C Average annual rainfall: 548mm	Population (metro): 2.3 million Population density (city): 5249/km^2 Average low temperature: 6.8°C Average high temperature: 13.9°C Average annual rainfall: 1153mm

AUCKLAND		
Population (metro): 1.5 million Population density (city): 1300/km^2	Average low temperature: 11.3°C Average high temperature: 19°C	Average annual rainfall: 1311mm

AIR

Globally, air pollution is responsible for 7 million premature deaths.[4] Because of this, many cities keep a close eye on pollutants such as PM_{10} (airborne particles smaller than 10 micrometres) and $PM_{2.5}$ (airborne particles smaller than 2.5 micrometres). Standard measurement techniques are used worldwide, making these results easy to compare.

For PM_{10} we're doing well compared with the other cities, with only Vancouver recording a lower annual average. For $PM_{2.5}$ our annual average is slightly above Melbourne and Vancouver. $PM_{2.5}$ is particularly important as the tiny particles can lodge deep in people's lungs and cause health problems.

For more information on Auckland's PM_{10} and $PM_{2.5}$ monitoring programmes see pages 42-49.

MELBOURNE	VIENNA	VANCOUVER
Number of Sites 10 (PM_{10})/2 ($PM_{2.5}$)	**Number of Sites** 13	**Number of Sites** 18
National air quality standards PM_{10} Annual average: no value set 24-hour average: 50µg/m³ (five exceedances per year are permissible) $PM_{2.5}$ Annual average: 8µg/m³ 24-hour average: 25µg/m³	**National air quality standards** PM_{10} Annual average: 40µg/m³ 24-hour average: 50µg/m³ (25 exceedances per year are permissible) $PM_{2.5}$ Annual average: 26.43µg/m³ 24-hour average: no value set	**Metro Vancouver air quality objectives** PM_{10} Annual average: no value set 24-hour average: 50µg/m³ $PM_{2.5}$ Annual average: 8µg/m³ 24-hour average: 25µg/m³
Air Quality 2013[5] Annual average concentrations were below the WHO guideline and national standards. The 24-hour PM_{10} standard was exceeded on 11 days. The 24-hour $PM_{2.5}$ standard was exceeded on one day.	**Air Quality 2013**[6] Annual average concentrations were above the WHO guideline, but below national standards. Eight sites exceeded the national 24-hour PM_{10} standard on more than 25 days.	**Air Quality 2013**[7] Annual average concentrations were below the WHO guideline and national standards. One site exceeded Vancouver's annual $PM_{2.5}$ objective. The 24-hour $PM_{2.5}$ objective was exceeded on seven days.

AUCKLAND
Number of sites: 12
Auckland Ambient Air Quality Standards (AAAQS): PM_{10}: Annual average: 20µg/m³ 24-hour average: 50µg/m³ (one exceedance per year is permissible) $PM_{2.5}$: Annual average: 10µg/m³ 24-hour average: 25µg/m³
Air Quality 2013: Annual average concentrations were below the WHO guideline and AAAQS standards. The Auckland Urban Airshed breached the 24-hour PM_{10} standard in 2013. Two exceedances were recorded at Khyber Pass Road, and one at Pakuranga. In 2014 no exceedances of this standard were recorded. The 24-hour $PM_{2.5}$ standard was also breached in 2013 with one exceedance recorded at Penrose. The Auckland Rural Airshed breached the 24-hour $PM_{2.5}$ in 2013. One exceedance was recorded at Patumahoe.

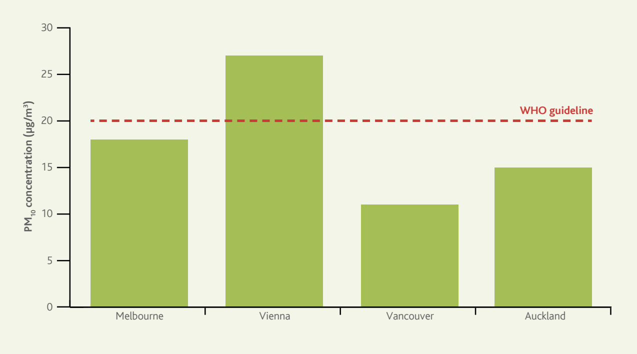

FIGURE 2: Annual average PM_{10} concentrations in the different cities[8] compared with World Health Organisation (WHO) guideline.

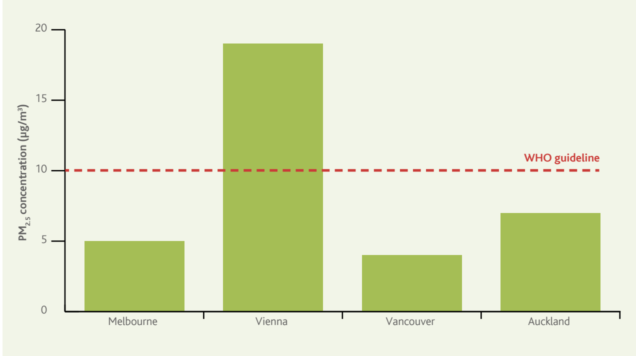

FIGURE 3: Annual average $PM_{2.5}$ concentrations in the different cities[8] compared with World Health Organisation (WHO) guideline.

BATHING WATERS

Auckland, Vancouver and Melbourne are coastal cities with popular beaches. They all monitor popular swimming spots weekly during the summer months (four-five months) to advise if there are any risks to human health and safety. Vienna is the odd one out. It has no beaches, but it does have several bathing areas at rivers and lakes. Some of these sites are sampled fortnightly during the bathing season, as part of a European Union (EU) monitoring programme, with other sites sampled three times per season.

To determine if a site is safe to swim at, each city has pre-determined recreational guidelines. As you will see below, different cities use different indicator bacteria. They also have different safe levels, which is the concentration above which further testing is done and warnings are made. Each of the four cities publishes its results on a website for the public to access.

Auckland monitors the highest number of beaches, and at most of them it is safe to swim. The number of samples below the safe level is in the same range as for the other cities. The high number of monitoring sites reflects the number of great swimming beaches in Auckland and the importance of the Safeswim programme.

For more information on Auckland's Bathing Beach Monitoring Programme see pages 160-163.

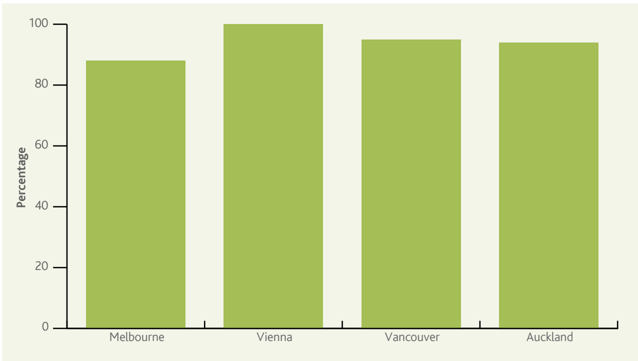

FIGURE 5: Percentage of bathing water samples that adhered to the guidelines.

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MELBOURNE	VIENNA	VANCOUVER
Number of Sites: 36	**Number of Sites:** 28 EU sites: 17 Other sites: 11	**Number of Sites:** 27 (within metro Vancouver)
Indicator Bacteria Enterococci Safe level: <400 organisms/100mL	**Indicator Bacteria** Enterococci Safe level: <400 organisms/100mL *Escherichia coli* Safe level: <1000 organisms/100mL	**Indicator Bacteria** *Escherichia coli* Safe level: <200 organisms/100mL
Grading System Not found	**Grading System:** Vienna assigns a grade to each site at the time of monitoring – either excellent, good or poor	**Grading System** Not found
Overall Water Quality Very good	**Overall Water Quality** Very good	**Overall Water Quality** Very good
Recent Results: 2013/14[9] 88% of samples below safe level	**Recent Results:** 2014[10] 100% of samples below safe level	**Recent Results:** 2014[11] 95% of samples below safe level

AUCKLAND
Number of Sites: 68
Indicator Bacteria 1: Enterococci Safe level: <140 organisms/100mL **Indicator Bacteria 2:** *Escherichia coli* Safe level: <260 organisms/100mL
Grading System: Auckland calculates a grade (A-D) for the site, which is based on the previous three years of data
Overall Water Quality: Very Good
Recent Results: 2013/14: 94% of samples below safe level

RIVERS

Rivers are an important feature of all the cities. The Yarra River in Melbourne, the Danube River in Vienna and the Fraser River in Vancouver shape the cityscapes. All cities monitor river water quality regularly but all use different reporting systems and spatial scales, which makes it difficult to compare.

Auckland has a wider range of river water quality compared with other cities, with a notable portion of rivers with excellent quality, but also a considerable share of rivers with poor water quality, particularly in urban areas.

For more information on Auckland's River Monitoring Programmes see pages 149-159.

MELBOURNE	VIENNA	VANCOUVER
Largest river: Yarra	**Largest river:** Danube	**Largest river:** Fraser
Number of Sites: >100	**Number of Sites:** 9	**Number of Sites:** 22 (British Columbia)
Monitoring Frequency: monthly	**Monitoring Frequency:** monthly	**Monitoring Frequency:** monthly
Reporting Organisation Victoria Catchment Management Authorities	**Reporting Organisation** Water Information System for Austria	**Reporting Organisation** Environment Canada
Reporting System Water Quality Index, which takes into account physical and chemical parameters.	**Reporting System** The European Water Framework Directive's classification scheme based on the river's ecological status.	**Reporting System** Freshwater Quality Indicator, which takes into account physical and chemical parameters.
Water Quality: Overall: Fair to Good [12]	**Water Quality:** Overall: Good[13]	**Water Quality:** Overall: Fair to Good [14]
Good water quality is seen in the upper Yarra catchment, where the river flows through protected forests. As it flows through into the more rural and urbanised areas, the water quality decreases, from rural and stormwater runoff pollutants.	The Danube has a good ecological status within the administrative boundaries of Vienna. One smaller tributary in Vienna has a fair ecological status.	Most rivers are rated 'good', only a few rivers are rated 'poor' or 'excellent'. Rivers in the most densely populated areas of British Columbia have lower water quality due to the greater pressures on aquatic health.

AUCKLAND
Largest River: Hoteo.
Number of Sites: 36.
Monitoring Frequency: Monthly.
Reporting Organisation: Auckland Council.
Reporting System: Water Quality Index based on a range of physical, chemical and biological variables.
Water Quality: Overall: Fair to Good.
Water quality is excellent in catchments dominated by native forest, good to fair in catchments dominated by exotic forest and/or rural land use, and poor in catchments dominated by urban land use.

GROUNDWATER

All the cities monitor their groundwater levels and groundwater quality. However, there are great differences in the number of wells each city monitors. One of the major groundwater issues for Auckland is nitrate contamination, and that's why we focus on this contaminant in our comparison.

Nitrate contamination is a widespread problem worldwide and for all of the cities compared here. Sources of nitrate concentrations include agricultural fertilisers and septic tanks.

For more information on Auckland's Freshwater Quality Programmes see pages 149-152.

MELBOURNE	VIENNA	VANCOUVER
Number of wells Several hundred.	**Number of wells** About 1200; 45 sampled for water quality.	**Number of wells** 145 in British Columbia; 9 in Vancouver metropolitan area sampled for water quality.
Groundwater quality Across Australia, nitrate contamination is widespread and a large number of bores in the Melbourne area show elevated nitrate levels [15].	**Groundwater quality** About half of the sampled wells show nitrate levels above drinking water standards[16].	**Groundwater quality** Nitrate concentrations above drinking water standards occur in several areas in the Fraser Valley[17].

AUCKLAND
Number of wells: About 80; 9 sampled for water quality.
Groundwater quality: Nitrate concentrations above drinking water and environmental standards occur in the South Auckland volcanic aquifers.

MARINE WATER

Worldwide, the quality of marine waters is in decline. Most cities near the sea monitor marine water quality regularly, but all use different methods, parameters and grading systems, which makes it difficult to compare.

MELBOURNE	VIENNA	VANCOUVER
Number of sites: 8	Vienna does not have marine waters!	Vancouver samples faecal coliforms and biotoxins as part of a shellfish programme; however, no water quality data could be found.
Sampling frequency Monthly		
Number of parameters analysed: 15		
Reporting system: Scores are calculated based on the level of attainment of the relevant indicators against the environmental water quality objectives in the State Environment Protection Policy (Waters of Victoria) and its Schedule F6 (Waters of Port Phillip Bay). The scores are calculated on both marine (8 sites) and freshwater (102) sites.		
Water quality: Good[18] For the year July 2012-June 2013, the entrance to Port Phillip Bay was included in the 13% of sites rated very good, and the Port Phillip Bay sites are part of the 20% of good sites.		

AUCKLAND
Number of sites: 36.
Sampling frequency: monthly.
Number of parameters analysed: 17.
Reporting system We calculate a Water Quality Index (WQI), which was adopted from the Canadian Council of Ministers of the Environment 2001 and takes the previous three years of data into account.
Water quality: Fair The most recent WQI calculated from 2010-13 indicates that the water quality at 8% of sites is excellent, 17% good, 44% fair and 31% poor.

For more information on Auckland's Marine Water Quality Programmes see page 164-168.

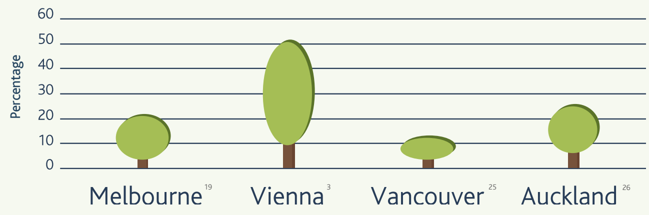
GREEN SPACE

Urban forests and green spaces are critical to human health and quality of life within cities. They offer a place for biodiversity and recreational activity, as well as a place of refuge and solace. Green spaces also have the ability to reduce the heat island effect of cities. Almost all the world's most liveable cities monitor their area of green spaces and have policies to preserve and expand it.

In Auckland, roughly 25% of the urban area consists of green spaces and the remaining 75% is impervious built-up area. But this only refers to the urban centre – in greater Auckland, our coastal fringe of pohutukawa, the Waitākere and Hunua Ranges, remnant bush patches and many parks contribute to a wealth of vegetation that provides a huge range of benefits and values to Aucklanders. The value of green space will increase as the population of urban Auckland grows.

For more information on Auckland's Land Ecosystem Monitoring Programmes see pages 76-100.

URBAN GREEN SPACE AS PERCENTAGE OF TOTAL AREA



MELBOURNE	VIENNA	VANCOUVER
Green space policy Melbourne's Urban Forest Strategy[19] is part of a wider initiative by all major Australian cities to increase their urban forest cover and green spaces. Melbourne's strategy sets the specific target of increasing forest canopy cover from its current level of 22% to 40% by 2040, with additional targets to ensure the urban forest comprises diverse and healthy trees.	**Green space policy** The Vienna council has a programme of planting new trees throughout the city. It also offers financial and technical support for green development approaches that incorporate natural spaces such as green walls and roofs.	**Green space policy** Vancouver's plan of becoming the greenest city in the world by 2020 includes targets to increase the green space. This will ensure that every person lives within a five-minute walk of a park, greenway or other green space by 2020, and150,000 additional trees are planted in the city between 2010 and 2020. Currently about 92% of city residents live within a five-minute walk of a park or green space[3].

AUCKLAND
Green space policy: Auckland Council's Parks and Open Spaces Strategic Action Plan (2013) sets out what needs to happen to the park and open space network over the next 10 years to achieve the aims of the Auckland Plan. However, open space not owned by the council makes up a big part of this network, so the Department of Conservation, schools and rural landowners all have key roles in protecting and managing it.

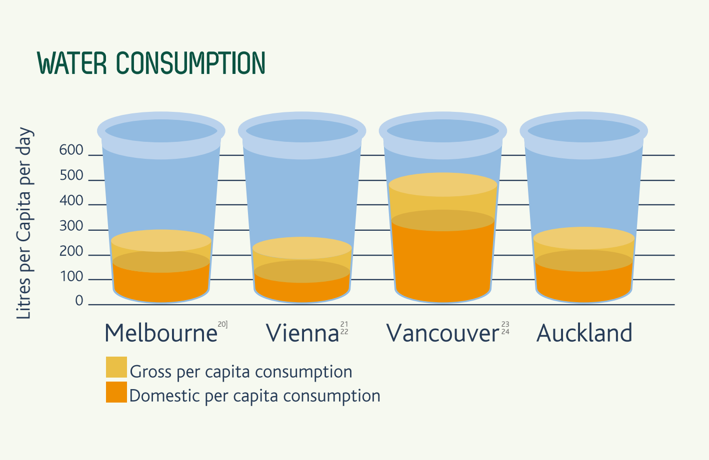
Reference:
3. Greenest City 2020 Action Plan. City of Vancouver, 2012.

WATER CONSUMPTION

All the cities have programmes to encourage efficient water use and monitor the water consumption using water meters.

Auckland's per capita water consumption is one of the lowest in New Zealand and is much lower than in Vancouver. However, we consume more water than people in Melbourne and Vienna. Vienna has the lowest water consumption of all the cities. When looking at what the water is used for, the greatest difference between Vienna's households and Auckland's lies in the washing machines: 15L per person per day are used for washing clothes in Vienna, whereas in Auckland we use 42L per person per day.

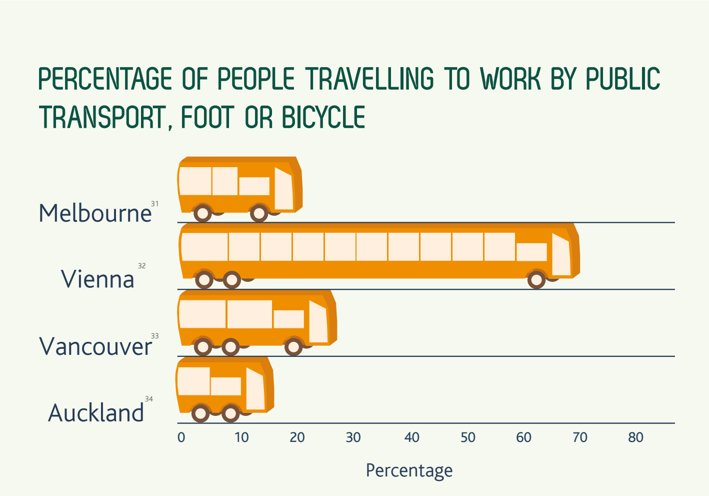
For more information on Auckland's water consumption see pages 146-148.



PUBLIC TRANSPORT

Public transport inherently benefits the environment because it reduces the number of vehicles on the roads. This reduces harmful emissions to the air and contaminants such as copper and zinc flowing to our waterways. It also helps to reduce energy consumption and greenhouse gases.

Public transport is a key component of many liveability indices, but also has many benefits for the environment. Auckland has the lowest percentage of people travelling to work by public transport, foot or bicycle.



WASTE RECYCLING

Recycling of waste is good for the environment in many ways. It saves energy, because manufacturing products from raw materials requires more energy than using recycled materials. It reduces pollution and preserves natural resources. It also saves space that would otherwise be used for waste disposal on landfills.

Of the cities compared, only Vancouver had a higher rate of recycling than Auckland.

CONCLUSION

Our monitoring programmes have allowed us to make some broad comparisons with other cities and show that Auckland's performance is broadly in line with the three most liveable cities. Good air quality, clean waters and lots of green space rank Auckland relatively highly in the environmental indicators we selected. Like every other city, Auckland has its challenges too. In particular, we need to work on our marine and urban water quality, and public transport.

A number of projects are already underway to address these challenges and our Environmental Strategic Action Plan will guide the way. For example, the City Rail Link will considerably enhance public transport. Stream restoration projects (see page 157) and the Central Interceptor will improve the water quality of Auckland's rivers and coastal waters. With the Zero Waste philosophy implemented in the Auckland Waste Management and Minimisation Plan, the amount of waste sent to landfills will be minimised.

As we move forward with our goal of becoming the world's most liveable city, continued environmental monitoring will ensure we track our progress in relation to our most valuable natural assets.

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CASE STUDY: AUCKLAND'S HISTORIC HERITAGE – TE TĀMAKI O NEHERĀ

OUR HISTORIC HERITAGE – THE LINK TO OUR PAST

NGĀ WAIHOTANGA IHO – HE HONONGA KI TE AO O NEHE

Wenderholm Regional Park

Auckland has a rich and diverse heritage. It embraces all the historic places and areas significant to us because they are associated with our ancestors, our cultures and our past. And it improves our quality of life by adding to our sense of place. It is a legacy to protect for current and future generations to enjoy.

Our unique heritage includes the Auckland War Memorial Museum/Tāmaki Paenga Hira, Fort Takapuna and the extensive archaeological landscapes of Āwhitu Peninsula. It encompasses the Auckland isthmus volcanic cones, the Ōtuataua stonefields and the Franklin volcanic fields. It includes post-war architecture such as the Group Architect houses, infrastructure and engineering feats such as the Grafton Bridge, and our Victorian and Edwardian buildings. As well as archaeological and maritime sites, and historic buildings and structures, it comprises gardens and plantings, cemeteries and burial places, historic and cultural landscape areas, and places of significance to Māori, including wāhi tapu, urupā and places of traditional importance. We value them as outstanding features in the Auckland landscape, and appreciate both their natural and human elements.

Aucklanders are passionate about historic heritage; a 2011 survey of a cross-section of the Auckland population showed 88% of respondents believed it was important to protect them, 78% had visited a historic heritage site in the last six months, and 54% thought historic heritage was not well understood in their area[1]. We as Aucklanders need to improve the understanding of Auckland's heritage values, keep this passion alive and ensure everyone has the opportunity to appreciate and enjoy their heritage.

WHY IS THIS HERITAGE IMPORTANT TO US?

Auckland's history is unique and distinctive to our place in the world. Our historic places are physical reminders connecting the past with the present. They help to form individual and collective identities and contribute to our sense of history and place. They offer educational and recreational value and are important to our social, economic, environmental and cultural well-being. Our historic heritage is a product of past human activity that cannot be replicated or replaced.

This heritage is vulnerable to physical changes resulting from both human and natural processes. Changes in physical form can reduce or take away from the specific qualities that make our historic heritage valuable. For example, urban infill and redevelopment can lead to more intensive use of built heritage (buildings and structures) and the loss of their natural surroundings, such as trees. Preserving the heritage value of a building might not be prioritised when compared with redeveloping a site for maximum economic gain.

With Auckland's rising population, rural land is being developed for residential and commercial use. As housing and related infrastructure such as stormwater and sewerage are developed, pressure is placed on fragile and already diminished archaeological and Māori heritage areas. Coastal land is particularly popular for subdivision and development; it also has a high concentration of archaeological sites from early Māori occupation as well as later European activities.

Natural processes such as coastal erosion are becoming an increasing threat. Heritage sites along the coastal margins are also at risk of damage or destruction from storms and rising sea levels as a result of climate change.

WHAT IS THE STATE OF OUR HISTORIC HERITAGE?

OUR PRIORITIES:

- Understand, value and share our heritage
- Invest in our heritage
- Empower collective stewardship of our heritage.

The Auckland Plan – Chapter 4

We keep an eye on our heritage using three main tools. These are the Cultural Heritage Inventory (CHI), the New Zealand Heritage List and Auckland Council's heritage schedules.

CULTURAL HERITAGE INVENTORY

The CHI is Auckland Council's key repository of historic heritage information. Developed and maintained by the council, it is a melting pot of information that receives regular updates from the New Zealand Archaeological Association, Heritage New Zealand Pouhere Taonga, Department of Conservation, heritage consultants, Ministry for the Environment, University of Auckland's anthropology department, historical societies, iwi authorities and other resources including books and journals.

The past decade has seen a steady increase in the number of items recorded in the CHI, mainly due to an increase in archaeological sites. At the end of May 2015, the CHI database held a record of 16,730 heritage sites within the council area. This total consisted of:

Artefact, Pūhoi Cottage. Photo: Rachel Ford

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CULTURAL HERITAGE INVENTORY SITE RECORDS AS AT THE END OF MAY 2015

10,304	ARCHAEOLOGICAL SITES
3402	HISTORIC BUILDINGS AND STRUCTURES
1136	BOTANICAL HERITAGE SITES (TREES AND PLANTS WITH HISTORICAL OR CULTURAL ASSOCIATIONS)
730	SITES WITH HISTORIC MARITIME ASSOCIATIONS
581	REPORTED HISTORIC SITES (REFERRED TO IN BOOKS OR MARKED ON MAPS)
507	HAYWARD AND DIAMOND SITES (EITHER PRE-EUROPEAN OR EUROPEAN ARCHAEOLOGICAL OR HISTORICAL SITES IN THE WAITĀKERE RANGES)
70	MAORI HERITAGE AREAS

HOW ARE HERITAGE SITES DISTRIBUTED IN AUCKLAND?

Three main patterns are worth noting. Firstly, a large number of sites line Auckland's coastline. Most of these are archaeological sites where Māori lived before European settlement. The coast has always been popular, from the early Māori and European settlers to today when it is in high demand for subdivision and development. Because of this, the coastal environment has been assessed as a high priority area for heritage surveys, resulting in more data for the coastline than other locations.

Secondly, there is a greater concentration of heritage sites in Auckland's high-density urban areas, namely the Auckland isthmus, North Shore and Manukau. This is because many buildings and groups of buildings are recognised for their heritage value and strong development pressure has led to new sites being identified through the planning process. For example, resource consent applications require a heritage assessment identifying the heritage values associated with a site earmarked for development.

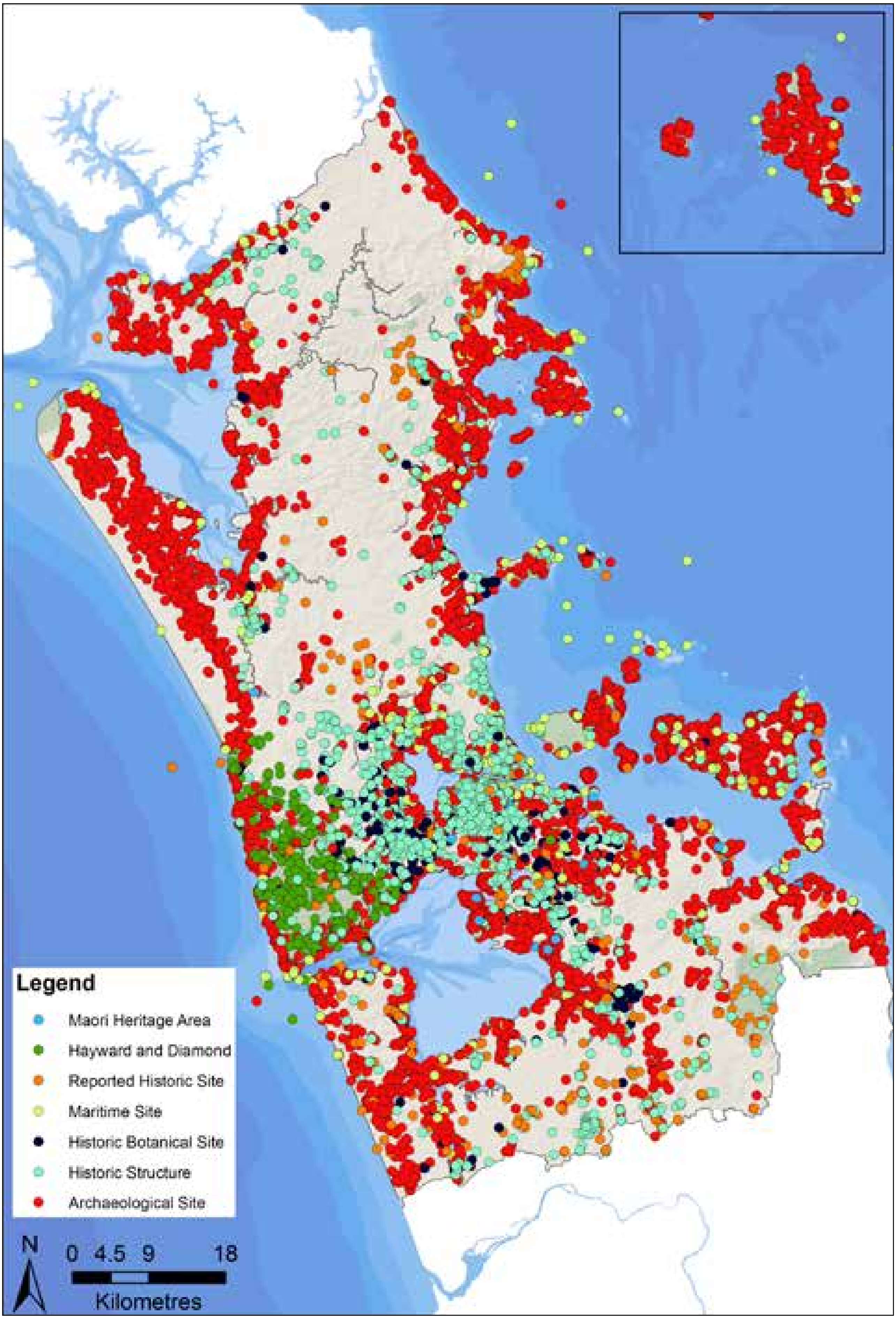


FIGURE 1: Distribution of heritage sites recorded in the CHI database across the Auckland Council area.

Thirdly, large areas have little or no recorded heritage sites, particularly in the north and south. This does not necessarily mean there are no heritage sites in these areas, rather it points to a lack of systematic surveys to identify them.

Although the CHI has important information, there are two key issues. The data is not based on a comprehensive survey of the Auckland Council area and there is a lack of systematic monitoring of known, inventoried items.

NEW ZEALAND HERITAGE LIST/ RĀRANGI KŌRERO

Heritage New Zealand Pouhere Taonga identifies New Zealand's significant and valued historical and cultural heritage places and records them on 'the List'. The List is the only national statutory record of our rich, significant and diverse heritage places. It is important because it informs and notifies owners, the public, community organisations, government agencies and local authorities about significant heritage places. It is also a source of information about historic places and areas, wāhi tūpuna, wāhi tapu and wāhi tapu areas for the purposes of the Resource Management Act 1991 (RMA).

Historic areas are groups of related historic places, such as a geographical area with a number of properties or sites, a heritage precinct or a historical and cultural area. Wāhi tūpuna are places important to Māori for ancestral significance and associated cultural and traditional values. Wāhi tapu are places sacred to Māori in the traditional, spiritual, religious, ritual or mythological sense, such as maunga tapu, urupā, funerary sites and puna wai. Wāhi tapu areas contain one or more wāhi tapu.

The past six years have seen a steady increase in the number of Auckland items on the List, with 52 added since 2008. Table 1 shows there were 546 listed items in the Auckland Council area at the end of May 2015. These account for close to 10% of the 5718 items listed nationally.

LOCAL BOARD	BROAD AREA	HISTORIC PLACE	HISTORIC AREA	WĀHI TAPU	WĀHI TAPU AREA	TOTAL
Rodney, Hibiscus and Bays, Devonport-Takapuna, Kaipātiki, Upper Harbour	**NORTH**	**80**	**0**	**1**	**2**	**83**
Waitākere Ranges, Henderson-Massey, Whau	WEST	**9**	**0**	**0**	**0**	**9**
Great Barrier, Waiheke, Ōrākei, Waitematā, Puketāpapa, Maungakiekie-Tāmaki, Albert-Eden	**CENTRAL**	**374**	**10**	**2**	**2**	**388**
Franklin, Māngere-Ōtāhuhu, Manurewa, Ōtara-Papatoetoe, Papakura, Howick	**SOUTH**	**64**	**1**	**1**	**0**	**66**
Total		**527**	**11**	**4**	**4**	**546**

TABLE 1: Number and type of New Zealand Heritage Pouhere Taonga listed for the Auckland Council area in May 2015.

Nearly three-quarters of these are in central Auckland, across seven local boards and including Waiheke and Great Barrier islands (figure 2). Historic places dominate the List, accounting for 96% (527) of all Auckland items. Historic areas make up another 2% (11), with four wāhi tapu sites and four wāhi tapu areas making up the rest.

This distribution shows the dominance of built heritage on the List, most of which comprises buildings, structures (including wharves and stone walls) and objects such as memorials. Recognition of Māori heritage, in the form of wāhi tapu sites and wāhi tapu areas, and the group value of heritage buildings, sites and places are significantly under-represented.

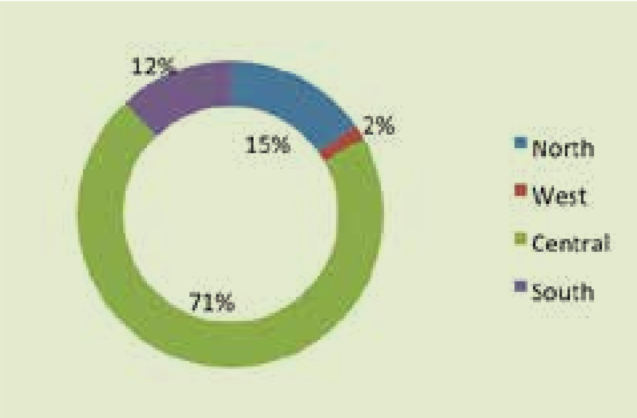


FIGURE 2: Proportion of New Zealand Heritage List items by broad Auckland Council area (defined by local boards as shown on table 1).

The Heritage New Zealand Pouhere Taonga Act 2014 requires historic places to be assigned a rating. Category I applies to "places of special or outstanding historical or cultural heritage significance or value" and Category II applies to "places of historical or cultural heritage significance or value". Figure 3 shows that most historic places on the List in the Auckland Council area have Category II status (372) and just under a third have Category I status (156).

FIGURE 3: New Zealand Heritage List items in the Auckland Council area by category.

Both the CHI and the New Zealand Heritage List provide us with useful information, but it is our statutory responsibility as Auckland Council to protect our historic heritage.

HOW DO WE PROTECT OUR HISTORIC HERITAGE?

Scheduling historic heritage places and areas as well as Māori cultural heritage sites and places provides protection and management of these heritage values within the planning framework. This is the key statutory process that ensures our historic heritage is protected and conserved for us to benefit from and enjoy today, as well as for future generations.

The Proposed Auckland Unitary Plan (PAUP) has a number of overlays and schedules protecting our heritage. Based on the latest monitoring, the total number of scheduled historic heritage and Māori cultural heritage sites, places and areas is 6329, an increase from 2012 of 3639. The total of 6329 is made up of:

- 2152 significant historic heritage places
- 19 significant historic heritage areas
- 61 sites and places of significance to mana whenua
- 3600 sites and places of value to mana whenua.

There is also a schedule of 2642 notable trees under natural heritage. This is the key protection for trees after the RMA changes removed general tree protection. All these numbers are from the PAUP notified 30 September 2013 (updated 27 February 2015) and subject to change as the plan goes through the hearings process.

The PAUP objectives are to identify and protect Auckland's significant historic heritage places, and ensure they are used appropriately and their owners and the community are encouraged to protect and conserve them. The objectives also seek to protect and enhance both the tangible and intangible values of scheduled sites and places of significance and value to mana whenua. Identifying historic heritage places takes a wide range of values into consideration. This includes historical, social and mana whenua value, potential to provide knowledge, technological value, notable physical attributes and aesthetic value, as well as context.

Identifying values of mana whenua cultural heritage to be scheduled includes criteria such as the mauri (life force and life-supporting capacity) and mana (integrity) of the place or resource holding special significance, being a venue or repository for mana whenua cultural and spiritual values, or having special amenity, architectural or educational significance to mana whenua.

HOW DO WE MONITOR OUR HISTORIC HERITAGE?

Essentially, we do not systematically monitor our historic heritage. There is no regional monitoring programme providing information on the changing state of our heritage items or on the effectiveness of the council's responses. The state of Auckland's heritage environment remains poorly understood because data sources contain little information about condition, and there is no periodic, regular monitoring. However, we are taking steps towards monitoring our heritage, in the Waitākere Ranges Heritage Area.

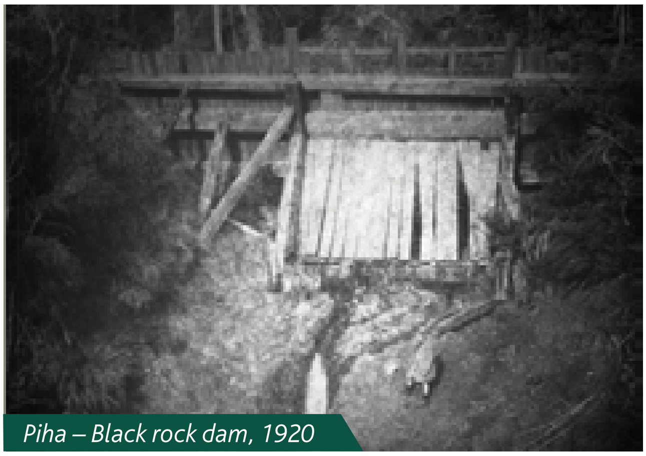
INTRODUCING THE WAITĀKERE RANGES HERITAGE AREA

Spanning 27,700ha of public and private land, the Waitākere Ranges Heritage Area (WRHA) lies between metropolitan Auckland and the coast of the Tasman Sea to the west, the Manukau Harbour coastline to the south and the Waitākere Valley to the north.

It is characterised by its outstanding landscape and beauty, unique native forests, wetland, streams, lakes and dunes, as well as its ecological diversity and wildlife. The area is associated with artistic and spiritual values, has excellent recreational opportunities, and is an attractive living environment and a significant source of public water supply. It also has many European heritage sites, and sites of significance to tangata whenua.

The Waitākere Ranges Heritage Area Act 2008 recognises the national, regional and local significance of the area and promotes its protection and enhancement so that everyone can enjoy all that it has to offer, now and in the future. It aims to preserve the unique character and natural and cultural heritage of the local areas and communities making up the Waitākere Ranges, their foothills and coasts. This includes the Waitākere Ranges Regional Park, which covers 60 per cent of the area.

Whatipū – Wharf, c. 1910



Piha – Black rock dam, 1920

Huia – Manuaku Timber Co Mill, 1888-1922

To ensure the Act's objectives are met, it provides for statutory management, monitoring and reporting of the area's unique natural and cultural heritage resources. The WRHA heritage dataset encompasses a large and diverse range of prehistoric Māori and European settlement and occupation sites, in a heavily vegetated and rugged landscape.

There are 1324 historic heritage sites in the WRHA recorded in the council's CHI. Of this total, built heritage and pre-European site categories are almost equally represented, and about half the historic heritage in the WRHA has some form of regulatory protection under the RMA or Heritage New Zealand Pouhere Taonga Act 2014. However, most of the site data is poorly located, under-reported and more than 40 years out of date.

This lack of timely information is an obstacle to achieving the objectives of the Act. So a recommended staged strategy of short, medium and long-term survey and monitoring projects is getting underway to assess and maintain the condition and value of historic heritage in the WRHA. It aims to ensure relevant information is available to inform decision-making and provide for long-term sustainable management of historic heritage.

We have completed the first step in this process, organising all the available data relating to the heritage resources of the WRHA and prioritising sites for survey upgrade and monitoring. These include the archaeological, Māori and European sites scheduled in the operative and unitary plan, as well as at-risk sites on council and public land in coastal environments prone to erosion.

We are preparing data packs so that survey and assessment fieldwork can go ahead in the summer of 2015/2016. This work is an important and exciting step towards implementing monitoring programmes tailored to our historic heritage. It will provide us with more information on the condition of our historic heritage sites, how they are faring over time and the effectiveness of our protection.

Karekare – Watchman dacite dome and crater and boarding house, 1943

WHAT CONCLUSIONS CAN WE DRAW?

Our awareness of the amount and nature of historic heritage in the Auckland Council area is improving. The numbers of heritage items recorded in the CHI and the New Zealand Heritage List have increased steadily over the past 10 years, as have the council's scheduled items.

The amount of land in the council area surveyed for historic heritage is an important consideration when assessing our overall effectiveness in heritage management; if we are unaware of heritage items, we cannot manage and protect them. There has been a slow but steady increase in the amount of land systematically surveyed and assessed for heritage sites and items.

Despite positive trends for historic heritage, it is hard to establish a clear picture of the overall condition of historic heritage or the success of heritage provisions, due to an overall lack of research and monitoring. Few conclusions can therefore be drawn about whether historic heritage as a whole is being protected over time. However, since the *2009 State of the Auckland Region* Report, work has been done with local hapu and iwi, and we have more representation of sites and places of significance and value to mana whenua.

WHAT CAN YOU DO? ME PĒHEA TŌ ĀWHINA MAI

Greater community promotion, support and involvement is key to protecting and conserving places of significance, and we all have a role to play.

If you want to get involved, you can nominate a place or tree to be included in the schedules, lend a hand to a survey, apply for funding or ask for help with a project. Experience heritage by visiting our featured sites, using our walk maps or taking part in the annual Auckland Heritage Festival. Visit the heritage page on the council website for more information on discovering, experiencing and protecting these assets.

The Auckland Plan includes some specific targets, including assessing all of Auckland for historic heritage value by 2040 and increasing the number of scheduled items. We are working with people and communities to achieve this as mutual protectors of our region's heritage.

CONCLUSION
TE OTINGA

The natural environment and historic heritage are key components of Auckland's liveability, and both will be placed under pressure by the region's projected population growth. Taking stock of the state of our physical environment and understanding the pressures on it can inform policy development and council operations. This 2015 State of the Environment report is the first by Auckland Council. It highlights current and potential environmental issues, recent changes and long-term trends. It also provides a baseline and firm platform for considering the challenges of a growing Auckland.

CHANGING AUCKLAND

Auckland's population increased by 110,000 between 2006 and 2013. It will continue to increase; Statistics New Zealand's population projections suggest Auckland's population could reach 2.01 million by 2033, an increase of 517,000 people over the next 20 years (medium series projections). This growth will be driven by a mix of natural increase and migration.

The region experienced land use changes between 2008 and 2012, in rural areas. Since 1998 the area of land in parcels of less than four hectares has increased by 60%.

Changes in Auckland's rural areas are planned for the future. The Proposed Auckland Unitary Plan indicates how the urban area might expand over the next 30 years into the Future Urban Zone (FUZ), an area bounded by the Rural Urban Boundary (RUB). The FUZ covers just over 10,800 hectares, an area that could accommodate 90,000 dwellings and provide employment for 57,000 people.

IN SUMMARY

AIR

Poor air quality has broad health impacts, some serious. Sensitive groups, such as children and the elderly, are especially susceptible. Poor air quality also affects the way the city looks. In winter, calm weather conditions cause pollutants to stay close to the ground, especially in the evenings when people are using their fireplaces. Emissions from vehicles and fireplaces can also cause an unsightly brown haze to form, especially around the Central Business District (CBD).

There are three key sources of air pollution in Auckland: transport, domestic heating and industry. Vehicles of all types emit a range of pollutants, including tiny particles called $PM_{2.5}$ and PM_{10} (particulate matter). Vehicle emissions (especially diesels) also contribute nitrogen oxides (NOx), including nitric oxide (NO). Nitric oxide reacts in the atmosphere to form nitrogen dioxide (NO_2), which can cause an unpleasant brown haze and affects our health. Shipping also has an impact, contributing mainly particulate matter, NOx and sulphur dioxide (SO_2) to the air. In winter, the major source of air pollution is emissions from domestic fires. Industry also emits pollutants, most of these coming from combustion processes.

The key findings are:

- In general Auckland's air quality is good, with pollutants generally below guidelines, standards and targets. However, from time to time these are still breached.
- The number of exceedances for PM_{10} has decreased from 17 days in 2005 to zero in 2014.

- Concentrations of PM_{10} in urban Auckland have significantly decreased due to source management programmes, cleaner fuels, lower vehicle emissions and declining use of solid fuels for home heating. However, in certain areas we are still in danger of breaching air quality standards.
- Concentrations of NO_2 at all of the worst sites are decreasing due to the improved efficiency of diesel engines. Decreasing levels of NO_2 in Queen Street are also due to diverting traffic away from these areas. The worst locations are Newmarket and the CBD where concentrations still occasionally exceed air quality standards and guidelines.

LAND

Auckland has a diverse range of ecosystems and landforms. It boasts an impressive variety of habitats, from dunelands and wetlands in lowland and coastal areas to extensive tracts of native forest on the rugged hills of the Waitākere and Hunua ranges, and on Aotea (Great Barrier) and Hauturu (Little Barrier) islands. The soils include some of the best agricultural resources in the country.

There are over 20,000 plant and animal species in the region, including arguably the rarest bird (New Zealand fairy tern/tara-iti), a remnant population of kōkako in the Hunuas, and the world's heaviest parrot (kākāpō) and insect (wētā punga or giant weta) on Hauturu. There is also a variety of reptiles, amphibians and New Zealand's only native mammals (bats). Although Auckland covers only 2% of New Zealand's total land mass, it is home to a high number of threatened species, including about a fifth of threatened terrestrial vertebrates and plants.

The land section of this report presents results from the first regionally comprehensive baseline measure of the health of the dominant land ecosystems.

The key findings are:

- At a large scale, Auckland's landcover has remained the same over the last decade, with little change in the balance of farmland versus native forest and scrub versus exotic forestry.
- On a finer scale, some areas are experiencing more dramatic changes, particularly on the city margins where urban growth is replacing high production pasture.
- Biodiversity values are higher in the larger forests, such as in the Waitākere and Hunua ranges, and also on Hauraki Gulf islands where native habitat remains and control efforts mean there are no pest animals, or lower numbers of them.
- Diversity of native plants and birds is reduced in mainland areas modified by farming and urban growth.
- Larger native forest tracts are resistant to invasion and have fewer weeds. Urban and rural forest patches are more exposed and show much higher infestation levels.
- Biosecurity management can be effective in keeping down the populations of mice, rats and possums. This is exemplified by the great work being done in places like Ark in the Park (Waitākere Ranges), Glenfern and Windy Hill (on Aotea/Great Barrier Island) and by the high biodiversity values of pest-free islands such as Hauturu (Little Barrier).
- The 2009 State of the Auckland Region report identified the relatively large proportion of threatened species living in the region. Auckland Council's biodiversity team has since put in place a prioritisation protocol and is currently managing 38 species, up from 14. Additional species are also managed within the parks network by council staff and through community initiatives.
- While elements of Auckland's soil quality are good, too much phosphorus fertiliser is being applied and soils are compacted, which impacts the quality of the soil and also increases the likelihood of surface runoff. Ultimately, this sediment and nutrient runoff can be carried through our streams or directly to the sea.
- Auckland has moderate levels of soil pollution when compared with native bush. In rural Auckland levels of cadmium (largely from phosphorus fertilisers) and copper (copper-based fungicides) are highest, and in urban Auckland nickel, lead and zinc are higher.

WATER

Auckland's spectacular twin coastlines are lined with beaches and estuaries, three large harbours (including Kaipara, one of the largest in the southern hemisphere) and the islands of the Hauraki Gulf. In total these cover 11,117km² of ocean and 1800km of coastline. The region also boasts 16,500km of permanently flowing rivers, 72 natural and artificial lakes, and many aquifers.

The key findings are:

- Freshwater quality and ecology is rated excellent in catchments dominated by native forest, good to fair in catchments dominated by exotic forest and/or rural land use, and poor in catchments dominated by urban land use.
- Poor water quality in rural catchments is generally due to high nutrient levels and sediment.
- Many of Auckland's urban streams are in a very poor state of health as a result of the many pollutant sources in urban environments.

- The council's Safeswim monitoring programme regularly assesses water quality for swimming at popular beaches, lakes and lagoons. Of the monitored sites, 72% were graded as A or B (very low or low risk of people becoming sick) and 28% as C or D (moderate to high risk of becoming sick). Most of the monitored sites are suitable for swimming most of the time.
- Most of the poor marine water quality sites are in harbours, influenced by discharges from urban or rural areas. Of 36 sites monitored for marine environment water quality, 31% are poor, 44% are fair, 17% are good and 8% are classified as excellent. Across the whole region, most of the monitored parameters are stable over time.
- Auckland's harbours and estuaries are in general very muddy, particularly in the upper reaches and more sheltered areas, and those near older urban catchments.
- Contaminants in marine sediments tend to be low in less developed and rural areas, with fewer inputs from urban stormwater. Hotspots of contamination tend to be in muddy estuaries and sheltered tidal creeks receiving runoff from older, intensively urbanised or industrialised catchments. The worst-affected areas are central Waitematā Harbour and Tāmaki Estuary.
- Twenty years after lead was removed from petrol we are seeing a decrease in concentrations in the freshwater and marine sites we monitor. We have also seen a decline in concentrations of copper in some marine locations, likely due to improved control of sediment and stormwater. Zinc remains the most concerning heavy metal contaminant.
- Fine sediment and associated stormwater contaminants are affecting the ecology of Auckland's harbours and estuaries. Most sites near older urban centres have locations with unhealthy ecology, particularly within the Waitematā Harbour and Tāmaki Estuary.
- While many sites have good or excellent ecological health, all harbours and estuaries had at least one site with moderate or poor ecological health, even those further from Auckland's urban centre as the city's ecological footprint expands.

Artefact 2, Pūhoi Cottage. Photo: Rachel Ford

HISTORIC HERITAGE

Auckland has a rich and diverse historic heritage. It embraces all the historic places and areas significant to us because they are associated with our ancestors, cultures and past.

- Our awareness of the extent and nature of historic heritage in the Auckland Council area is improving. The number of heritage items recorded in the council's Cultural Heritage Inventory and the Heritage New Zealand List has increased steadily over the past 10 years, as have the council's scheduled items.
- There has been a slow but steady increase in the amount of land systematically surveyed and assessed for heritage sites and items.

CLIMATE

Auckland's climate shapes our natural environment and the ways we use it. The council monitors several climatic variables that inform its strategy and operations. For example, conserving our use of freshwater resources and managing flooding and stormwater drainage requires us to understand rain's natural variability and to know the depths, durations and frequencies of rainfall events over several decades.

The key findings are:

- Rainfall is highly variable over time across the region. The Waitākere Ranges receive the most rain (1500-2300mm/year) and Waiheke Island the least (700-1700mm/year). Auckland averages seven to eight days with significant rainfall per year.
- The largest significant rainfall in the last five years was on 29 January 2011 when we measured 210mm of rainfall in one day at Mt Tamahunga (Warkworth).
- There is no consistent trend in rainfall. Days with significant rainfall and dry spells occur across Auckland, with large variability from year to year and for longer time scales.
- Long-term measurements in Auckland Harbour by Ports of Auckland Ltd show a clear trend of rising sea level of 1.5mm/year over more than 100 years. These rising sea levels are in line with local and global averages.
- The annual average air temperature at Onehunga (longest dataset) is 15.6°C. The average sea surface temperature over the last 20 years was 17.11°C. Stream monitoring shows that urban streams are warmer than forest streams.

Tūī

IN CONCLUSION

The state of our environment is a function of many social, cultural and economic factors; population growth and the demands people place on our environment are key drivers. Auckland's population increased by 110,000 between 2006 and 2013. The current population is 1,526,900 (as at June 2014) and projections suggest the region will be home to over 2 million people by 2033 in a medium growth scenario.

The environmental effects of this growth will depend on a number of factors: economic and technological factors will shape the effect of industrial practices on air quality; social values will drive the rates and types of resource consumption such as drinking water; the location of housing and workplaces, and the ways people move between them, will influence a range of variables including air and freshwater quality. The latter example particularly highlights the importance of land use and infrastructure in determining the state of our environment, now and in the future. The Unitary Plan will therefore play an important role in setting a land use framework that considers growth and environmental issues.

Safeguarding Auckland's environmental assets requires addressing both legacy issues and the future challenges presented by a growing city. This 2015 report shows a clear link between transport and land use pressures and environmental outcomes. Along with the challenges of a growing city there are many opportunities to improve environmental outcomes. The 'natural systems for urban design' case study (see page 125) highlights the multiple benefits of using new design and technological advances.

It also shows that while the effects from development might be mitigated with the best possible earthworks and stormwater treatment, the effects of land use outside of the development area also have an effect, reinforcing the need to consider historical and current inputs as well as the wider surrounding environment. Source control of contaminants is showing results in the environment, such as the removal of lead and lowering of benzene content in petrol. The results take time to manifest in the environment, but source control efforts are worth the long-term investment.

Maintaining the health of Auckland's environment is not only critical for intrinsic environmental or conservation reasons, but because of the myriad of benefits derived from a healthy functioning ecosystem. It underpins our economy, health and culture. Sustaining and improving the quality of our environment requires us to consider the capacity of the environment to continue to absorb disturbances such as increasing sediment and contaminant loads, associated with increased development. Monitoring data forms an important component of modelling and predicting this capacity and in setting standards and limits to ensure that environmental effects are understood and managed.

Further, confronted with a changing Auckland and wider global climate change it is critical to maintain resilience. A resilient environment is one that is able to cope with change and environmental disturbances. We cannot predict all environmental responses to change, and we need to ensure that we include a buffer in environmental management. The healthier the environment, with a diverse range of habitats and species, the more resilient it is likely to be.

View of Auckland

As well as changing population and land use for Auckland, the environment itself is not static. It responds both to human influence and to natural climatic and biological variation and the overarching pressure of climate change. Understanding change in relation to natural and anthropogenic drivers is key to making informed decisions. State of the Environment monitoring is an important road map for Auckland's decision making; it can tell us where we have been and how we got to where we are, and provide guidance for where we go in the future. For monitoring to be successful it must be consistent, regular, and representative of regional differences in both environmental type and anthropogenic pressures, and to occur long term so that natural environmental cycles (e.g. El Niño and La Niña) can be distinguished from changes due to management decisions and personal choices.

While we have seen reductions in contaminants like lead through source control, people produce, consume and use a myriad of other chemicals and synthetic compounds in their everyday lives. There is potential for these to accumulate in the environment, potentially causing adverse ecological or human health effects. These emerging contaminants include such things as hormone system disruptors from some plastics, nanoparticles, pharmaceuticals and personal care products. As the population expands these emerging contaminants may become more important to monitor, and to consider their management.

There have been mixed results since the *State of the Auckland Region* report in 2009, with some regional improvements in air quality and good progress where terrestrial biodiversity is being intensively managed. However, in marine and freshwater there remains the slow decline in environmental health reported in 2009 due to sediment and contaminants, and the footprint of urban Auckland is expanding.

The big changes in environmental pressure will come in the near future as we face increasing population growth and urban intensification and expansion. One of the big challenges is how we consider environmental outcomes in the decisions we make both as an organisation and as individuals.

We also need to consider how we turn these challenges into opportunities for enhanced environmental and economic outcomes, working with the environment rather than against it to benefit Aucklanders today and into the future.

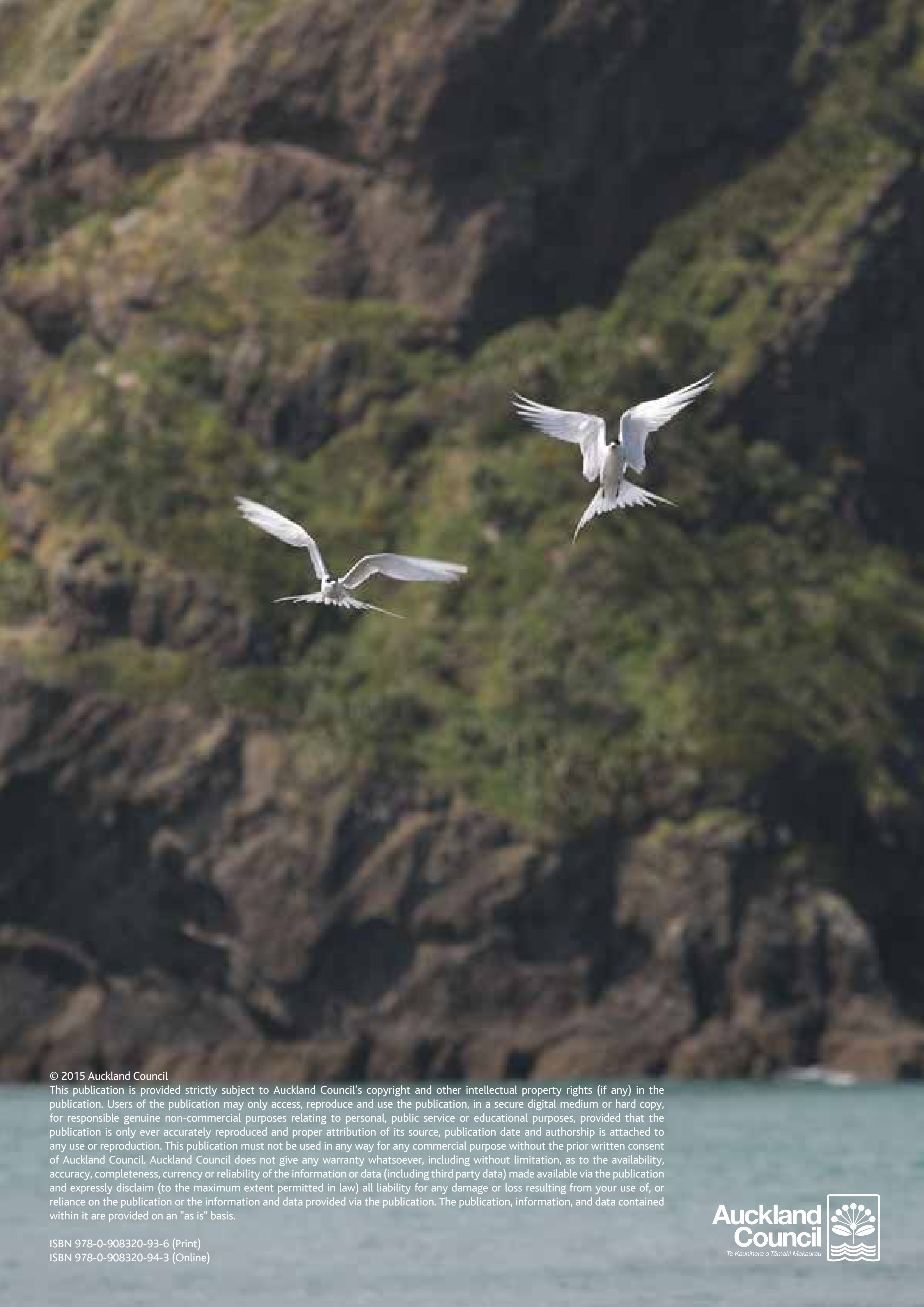
GLOSSARY
PAPA KUPU

WORDS	DESCRIPTION
Abiotic	A process or product characterised by the absence of living organisms.
Agronomic	Describes the science of soil management and the production of field crops.
Biodiversity	Diversity among and within plant and animal species in the environment.
Biosecurity	Procedures or measures designed to reduce the risk of transmission of harmful biological or biochemical diseases, pests or substances to protect the environment and population.
Biotic	A process or product characterised by the action of living organisms.
Carbon sequestration	The trapping and isolation of carbon in a natural or artificial storage area.
Carcinogen/carcinogenic	Any substance or agent that can cause cancer. Carcinogens alter the genetic structure of cells so that they multiply continuously and become malignant.
Central Interceptor	A new wastewater tunnel proposed by Watercare to run between Western Springs and the Mangere wastewater treatment plant. The tunnel will be about 13km long and will lie 22-110m below the ground. It will connect to the existing trunk sewer network and divert flows and overflows into the tunnel.
Climate adaptation	The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. [IPCC AR5]
Cultural ecosystem services	The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.
Ecological neighbourhoods	Sub-sections of the land area of the Auckland Region with similar ecological features (i.e. they have similar plants, animals, landforms and underlying geology).
Ecosystem	A system or group of interconnected elements, formed by the interaction of a community or organisms within their environment.
Ecosystem services	The important benefits for people that arise from healthily functioning ecosystems.
Endemic	Belonging exclusively or confined to a particular place.
Estuary	An arm or inlet of the sea at the lower end of a river.
Estuarine	Formed or found in an estuary.
Fugitive (non-energy)	Refers to products, such as refrigerants, which emit greenhouse gases (GHG), during non-energy related activities, such as refrigeration and air conditioning.
Heat island effect	The effect caused by urban areas often being hotter than the surrounding natural landscape because the large areas of sealed surfaces absorb and emit large quantities of heat, creating a warming effect.
Indicator	Measurements of physical, chemical or biological aspects of the environment, that can be used to indicate the state of that environment.

GLOSSARY
PAPA KUPU

WORDS	DESCRIPTION
Indigenous	Originating in and characteristic of a particular region or country.
Interdecadal	A period of time spanning more than one decade.
Landcover	Describes the physical material at the surface of the earth. Land covers include pasture, asphalt, trees, bare soil, water etc.
Metropolitan Urban Limits	A regional boundary of an urbanised area used as a guide to zoning and land use decisions. Legislating for metropolitan urban limits is one way of managing the challenges posed by urban growth and encroachment of cities upon agricultural and rural land. Now termed the 'Rural Urban Boundary' (RUB) in the Proposed Auckland Unitary Plan.
Microbial	A process facilitated by microorganisms, which are microscopic living organisms (single celled or multicellular). Microorganisms include bacteria and archaea, most protozoa and some fungi, algae and animals.
Microbial biomass	The total mass of the living component of microorganisms in an environment.
Ocean acidification	A decrease in the pH of seawater (increase in acidity) due to increased levels of carbon dioxide (CO_2).
Opacity	The characteristic of being impervious to light or lacking light transparency.
Particulate matter (PM)	A mixture of solid particles and liquid droplets suspended in the air.
$PM_{10}/PM_{2.5}$	Particles less than or equal to 10 and 2.5 micrometres in diameter, respectively. PM_{10} particles are small enough to be inhaled into the lungs, potentially causing health problems.
Precipitation	Water released from clouds that fall to the Earth's surface in the form of rain, sleet, snow, or hail.
Riparian	Refers to the interface or margin between land and a river or stream.
Stationary energy	Energy, including fuel and electricity, used at stationary locations (e.g. in residential, commercial and industrial buildings).
Terrestrial	Relates to land as distinct from water.
Terrestrial vertebrate fauna	Land-dwelling animals that have vertebrae or back bones.
Turbidity	The cloudiness or haziness of water caused by large numbers of tiny suspended particles.
Urban Planning that Sustains Waterbodies	A research programme led by NIWA and Cawthron aimed at helping local government to plan the development of New Zealand's cities and settlements in a way which protects and enhances the services and values associated with urban water bodies. The research is part of the multi-disciplinary 'Resilient Urban Futures' project, which is investigating how we can develop cities that are vibrant, resilient, liveable and internationally competitive.

ACRONYMS	DESCRIPTION
AAAQS	Auckland Ambient Air Quality standards
ARTM	Auckland Regional Transport Model
DAQI	Daily Air Quality Index
DOC	Department of Conservation
DSS	Decision Support System
ERC	Environmental Response Criteria
GHG	Greenhouse gas
LCDB	Land Cover Database
IBA	Important Bird Area
MfE	Ministry for the Environment
MoT	Ministry of Transport
MUL	Metropolitan Urban Limit
NIWA	National Institute of Water and Atmospheric Research
NOx	Collective term for nitrogen oxides
NZTA	New Zealand Transport Agency
PAHs	Polycyclic aromatic hydrocarbons
PAUP	Proposed Auckland Unitary Plan
RSCMP	Regional Sediment Contaminant Monitoring Programme
RUB	Rural Urban Boundary
TBMP	Terrestrial Biodiversity Monitoring Programme
TEL	Threshold effects level
UPSW	Urban Planning that Sustains Waterbodies
USEPA	United States Environmental Protection Agency
VOCs	Volatile organic compounds
WHO	World Health Organisation
WQI	Water Quality Index
WSD	Water Sensitive Design



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