Environmental Monitoring Plan

2014

Auckland Council

Te Kaunihera o Tāmaki Makaurau

Table of contents

Research, Investigations and Monitoring Unit

Auckland Council

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Executive summary

Auckland has a unique and diverse natural environment that supports a wide variety of valuable terrestrial, freshwater and marine biodiversity. However, as a result of human settlement and increasing population, Auckland's land cover and land use has been severely modified from its once predominantly evergreen forest. Changes include the clearing or conversion of native forest to provide suitable sites for a place to live, crop rotation, pasture, and storage; while wetlands were drained to create more agricultural land. These changes have resulted in increased pressures on Auckland's natural environment including the introduction of exotic plants, birds and mammals which drove many species to local extinction or made them increasingly rare.

Increasing population growth means that hunman activity encroaches on Auckland's most fertile, versatile and non-renewable land and soil resources which could ultimately risk the city's capacity to be a self-sufficient food producing region. Land cover and land use changes have also released large amounts of sediment and nutrients that are discharged into freshwater, estuary and coastal water bodies. These sediment and nutrient discharges are detrimental to some freshwater and marine flora and fauna species.

Despite the enormous modifications that have resulted from human settlement in Auckland, the importance of monitoring and protecting the natural environment has never been more urgent. The region's population is forecast to increase to 2.5 million people by 2040 which will place additional pressures on our region's natural resources and the capacity to accommodate future growth. The value of the provisioning, cultural and regulating ecosystem services the natural environment provides for our society will become even more significant in the future and we have a moral duty to ensure that future generations are not deprived of these natural values.

The Research, Investigations and Monitoring Unit (RIMU) leads the evidence gathering functions of the Auckland Council to monitor the state of the environment (SOE). It is also RIMU's responsibility to provide sound evidence for policy development and implementation. The purpose of this report is to provide an overview of what, why, when and how RIMU monitors environmental quality and quantity. The overview will be presented by the following environmental science disciplines:

- Land and soil
- Terrestrial biodiversity
- Freshwater (including wetlands)
- Marine
- Air

For additional detail and information, individual monitoring plans exist for each of these five disciplines in separate technical reports as listed in section 7. The focus of this report is to explain and integrate Auckland Council's various existing environmental monitoring programmes.

1 Introduction

Auckland has a unique and diverse natural environment that supports a wide variety of valuable terrestrial and marine biodiversity. Early settlers were first attracted to Auckland because of its forests, rivers, coastline and sea which provided a wide variety of food, while the warm climate and fertile soils were excellent for horticulture. The once evergreen forest that covered Auckland was cleared by Maori to provide suitable sites for dwellings, crop rotation and storage. European settlement began in the 1830s which resulted in further conversion of native forest to pasture, while wetlands were drained to create more agricultural land. The establishment of settlements across Auckland drove many species into local extinction or they became increasingly rare. This was due to the modification and destruction of habitat, the introduction of exotic plants and birds, hunting, and predation by the arrival of new mammal species. The changes in Auckland's land cover and land use since human settlement has also released large amounts of sediment and nutrients, which has been mobilized and released into receiving freshwater, estuary and coastal water bodies.

Despite the enormous modifications that have resulted from human settlement in Auckland, the importance of monitoring and managing the natural environment has never been more imperative. Auckland's population is forecast to increase up to 2.5 million by 2040 which will ultimately put additional pressures on our region's natural resources to accommodate future growth (Figure 1). The value of the provisioning, cultural and regulating ecosystem services the natural environment provides for our society will become even more significant in the future and we have a moral duty to ensure that future generations are not deprived of these natural values.

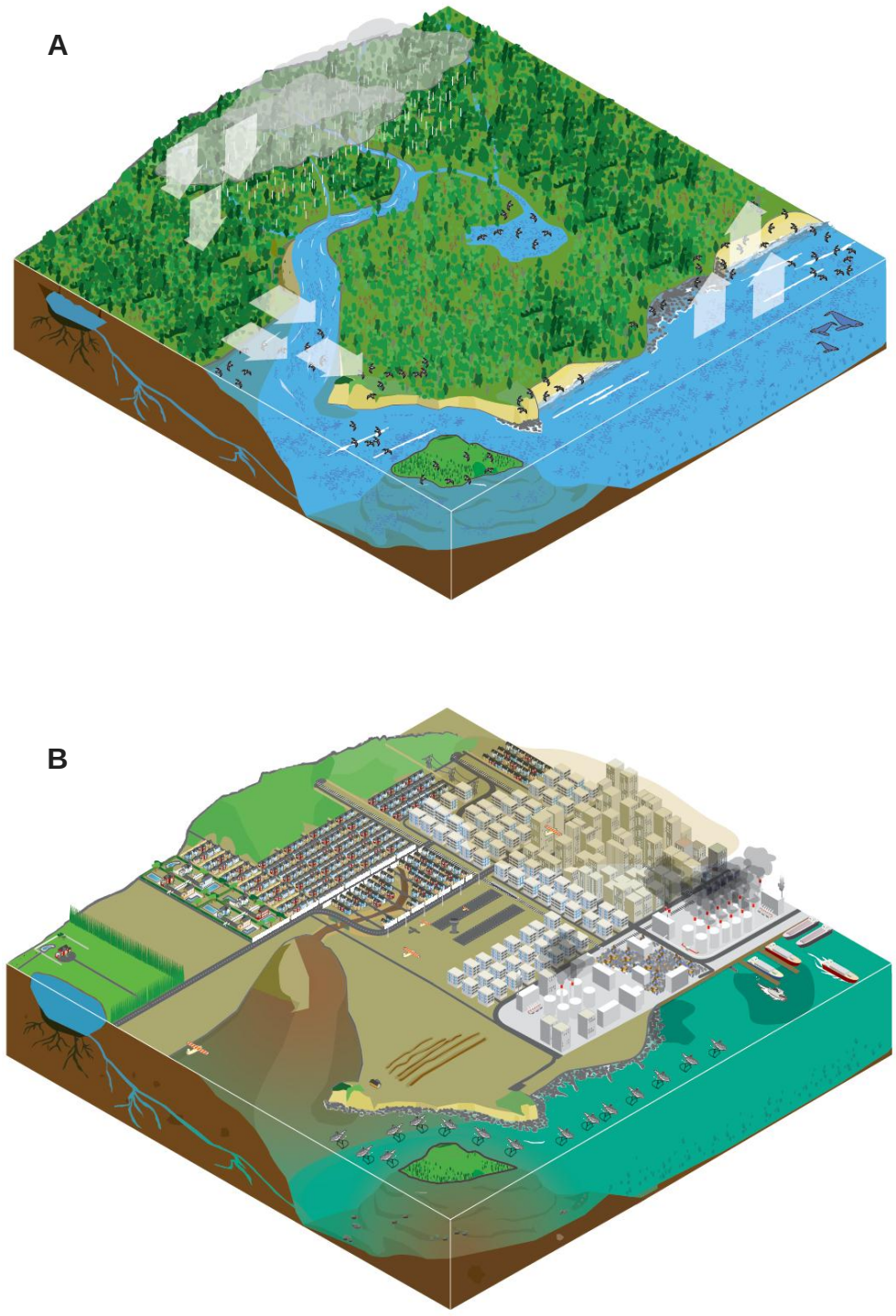

Figure 1. Illustration of how the environment interacts before (A) and after (B) human intervention.

1.1 The Auckland Council Research, Investigations and Monitoring Unit

The Research, Investigations and Monitoring Unit (RIMU) leads the evidence gathering functions of the Auckland Council to monitor the state of the environment (SOE). It is also RIMU's responsibility to provide sound evidence for policy development and implementation – from issue identification, to development of response options and subsequent evaluation of effectiveness. The foundation of the evidence base is the broad data obtained through systematic, comprehensive and long-term monitoring programmes established across the four domains: social, economic, cultural and environmental. For the purpose of this plan, the focus is on integrating the various existing environmental monitoring programmes of the Auckland Council.

1.2 What is monitoring?

Monitoring is a systematic process that involves the planned and repeated collection of data, its analysis, interpretation and reporting. Monitoring provides evidence to inform council of appropriate management actions, assess the effectiveness of those actions and identify emerging issues (Figure 2). It is not possible or cost effective to monitor everything. A monitoring plan assists with prioritising what is most important to monitor and what will provide the most relevant information.

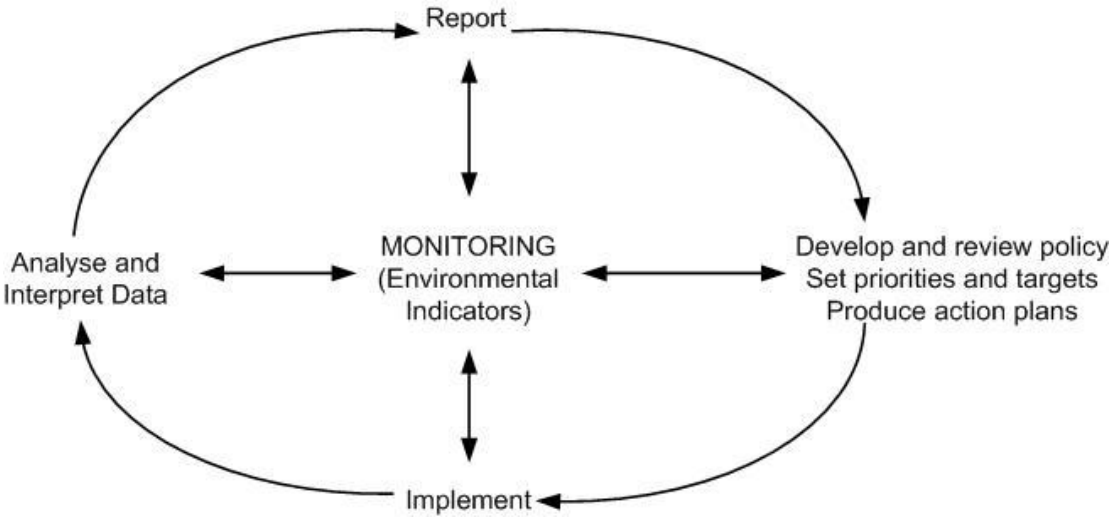

Figure 2. Schematic illustration of the monitoring framework.

1.3 Why do we monitor?

From a local government perspective the need to monitor arises from:

- Legislative duties (mainly the Resource Management Act 1991 (RMA) S.35)
- Policy and plan requirements
- Good resource management and business practice (performance, accountability)

Section 35 of the RMA specifies the duty to gather information, monitor and keep records and to take appropriate action when monitoring indicates that this is necessary. The Resource Management Amendment Act 2003 requires local authorities to:

- Monitor the state of the whole or any part of the environment
- Monitor the efficiency and effectiveness of policies, rules or other methods in its policy statement or plan
- Monitor the exercising of any functions, powers, or duties delegated or transferred by it

- Take appropriate action when monitoring indicates that action is necessary
- Prepare a report at least every five years on the results of section 35(b) policy and plan effectiveness monitoring.

Monitoring is also required under the Local Government Act 2002, specifically to assess:

- progress towards community outcomes
- how the council's activities contribute to achieving community outcomes
- levels of service.

Information from monitoring activities is also an important tool for education and advocacy.

Monitoring may also be required by law for specific issues or parts of the region, for example;

- The Waitakere Ranges Heritage Area Act 2008 mandates five-yearly reporting on a wide range of environmental indicators within its boundaries
- The Biosecurity Act 1993 requires council to prepare a Regional Pest Management Strategy based on quantitative evaluation of the impacts of weeds and pests on the region's natural environment
- Implementing the National Policy Statement on Freshwater Management requires extensive environmental data on freshwater bodies and their capacity to absorb change

1.4 Auckland Council environmental monitoring

The key objective of environmental monitoring carried out by the Auckland Council is to provide robust empirically derived evidence for decision making. A number of key principles are employed to ensure that the data collected is of maximum value, is robust and fit for purpose and carried out in the most cost effective manner.

Objectives: The objectives must be stated clearly at the outset as these determine the nature of the sampling and data analyses that follow.

Regional cover: State of the environment monitoring programmes should provide broad spatial coverage of the Auckland region. However, RIMU also carries out other targeted sub-regional monitoring on an issue-by-issue basis.

Representativeness: State of the environment monitoring should be representative of the wide range of environmental conditions (e.g. native, rural, urban) or types (e.g. soil) within the region. Sub-regional programmes are representative of their specific areas of interest.

Length of data record: Without long-term data, short-term natural variability can mask chronic or cumulative impacts, often until critical levels are reached. Long-term data sets enable us to examine long-term cycles related to decadal scale climatic patterns such as the El Niño Southern Oscillation (ENSO). These long-term data sets will be invaluable as we examine the potential for climate change effects.

Statistical design and analysis: The careful design of any programme is key to the analyses that can be carried out and the ability to make inferences from the data. It is critical that the design and potential statistical analyses be considered at the initiation of the monitoring programme to ensure adequate data is collected.

1.5 State of the environment monitoring

State of the environment monitoring provides information on resource condition and pressures exerted on that resource.

State of the environment monitoring involves monitoring key indicators to determine:

- The environmental baseline – quality and quantity
- Sudden changes or gradual trends away from that baseline (issue identification)
- Possible cause and effect (for investigation)
- The success and effectiveness (performance) of resource management
- Policy

State of the environment monitoring provides a stock-take of, and baseline data on, the status (quality and quantity) of environmental resources at representative locations around the region, against which future cause-effect or impact studies could be conducted.

Monitoring this through time allows identification of long-term trends, cyclic temporal variability and spatial variability. This understanding of systems allows us to detect changes which may indicate there is an issue which requires further investigation or an improvement in resource condition. The longer the dataset the greater our ability to distinguish between trends of change associated with human sources of stress and those caused by natural processes.

State of the environment monitoring includes both baseline and event based monitoring programmes. Baseline programmes are spatially representative (regionally,

habitat, receiving environment) and sampled consistently through time. They are designed to detect generalised status and trends, not to determine cause and effect.

Event based programmes are episodic in nature (although sampling may still be carried out long-term) and dependant on a particular trigger event. They are designed to capture information on fluctuations in the environment such as the delivery of stormwater contaminants or sediment associated with storm events.

1.6 Effectiveness monitoring

The monitoring and reporting framework is circular (Figure 2) and the outcomes of responses (changes in policies or behaviours) can be assessed by monitoring changes in environmental condition.

Evaluating the effectiveness of policy and plans, involves integrating and reporting the appropriate information gathered under state of the environment monitoring programmes. In some cases, issue specific information will be gathered to determine the effectiveness of a particular plan. For example, the effects of a zoning change in a particular location might involve specifically monitoring sediment delivery in relation to land use changes.

In other cases the issue will be more broadly based and a more extensive information source is required. For example, many of our monitoring programmes gather information on the effects of sediment delivered to aquatic environments. The information from these programmes can be integrated and reported together to provide a regional picture on how our policy and plans in general are addressing the issue of sedimentation in aquatic environments, it does not necessarily relate changes to any specific policy or plan.

The key to reporting on the effectiveness of policy and plans is to establish defined measurable objectives around the implementation of the proposed policy and plan, and to establish at the onset how these will be monitored.

1.7 The importance of data consistency, integrity and quality

A critical component of environmental monitoring and reporting is information management. All of our environmental datasets are important for the Auckland region. In addition, many of the Auckland Council's monitoring datasets are nationally (and potentially internationally) significant for their longevity, consistency, and quality. Rigorous sampling and analysis protocols must be maintained to ensure that the results obtained from the monitoring

programmes are consistent through time, and that the information provided is statistically robust. Both are essential requirements for the analysis of long-term datasets.

Maintaining the consistency and high quality of the programmes is vital to ensuring that Auckland Council:

- Can detect gradual, long-term changes in environmental quality. This is particularly important for detecting the cumulative effects of large scale stressors whose effects become apparent on decadal timeframes e.g. climate change, sedimentation and stormwater runoff.
- Has robust environmental information available to technically support resource management decisions and submissions.
- Safeguards its reputation for providing a robust technical basis for policy, regulatory and non-statutory decisions. The Auckland Council is nationally recognized as a leader in this area.
- Fulfils a moral obligation to carry out its monitoring and investigations to the same high standards imposed on major consent applicants and consent holders.
- Has the ability to leverage research and investigations targeting Auckland issues is maintained through the in-kind provision of quality, long-term environmental datasets.
- Continues its national leadership in environmental monitoring and its research continues to be recognized through the degree of influence it has with regional and national agencies.

A key criterion in the design of each monitoring programme is that each programme requires the ability to quantify differences among sites and detect statistically significant temporal trends against a background of seasonal and other natural variation. Sampling interruptions or irregular sampling intervals compromise the ability to detect temporal trends.

1.8 Auckland Council data management

For sound decisions based on empirical evidence, data reliability must be quality assured; data management and information systems are therefore critical foundations of any monitoring programme. Data is of good quality when it is deemed to have integrity relative to completeness, consistency, timeliness and accuracy.

Data management principles of the Research, Investigations and Monitoring unit (RIMU) include:

- Ensuring that all data management processes are efficient, consistent and effective in obtaining quality data;

- Data is collected to specified quality standards that ensure good quality data and fit for appropriate use;
- Data is managed within secure well-structured databases that facilitate a platform for dataset interoperability (consolidating data from different data sources and integrating operational database systems);
- Data is accessible to customers through various media in an efficient and timely manner. For example, this involves embracing real time data collection and using technology to manage data efficiently through to the web environment.
- Embracing innovation, evolving technology and best practice ensures that RIMU is kept abreast in order to meet new challenges.
- Data management performance is measured and benchmarked using key indicators.

To maximise the value of monitoring, the data must be of high quality, well managed and freely available. To ensure data management standards RIMU maintains ISO9001:2008 which provides the guiding operational framework for our science and monitoring programmes. Secure data storage is required to maintain the integrity of long-term datasets. Within RIMU, data, security and accessibility are assured through:

- Contractual requirements for service providers to deliver data on standardised templates.
- The centralisation of environmental data management and database development within the Environmental Monitoring team.
- Development of web tools which allows the public to directly query Auckland Council databases.
- Annual audits under the ISO9000 accreditation for data collection and management procedures.

1.9 Project documentation

Information on monitoring activities carried out by the council is held in a number of related documents explained further below.

This *Environmental monitoring plan 2014* sets out the resource monitoring programmes currently being undertaken by the council and integrates these across resource classes in terms of data management, reporting and review.

For each resource class (e.g. air, land, freshwater, marine), there is a *Monitoring plan* which outlines the individual programmes and their development, carried out for that resource class (briefly summarised in this *Environmental monitoring plan 2014*).

For each monitoring programme (e.g. marine ecology) there is a detailed *Project summary* document, which contains the details on how each programme is carried out.

For each monitoring programme there is also a *Service level agreement* document which specifies the operational delivery of services related to data collection and management for each project and includes key performance measures.

Protocols for carrying out the field component of monitoring are detailed in the *Protocol* document, for example site co-ordinates and instrument calibration.

1.10 Reporting

Reporting of information must be targeted to the information needs of the relevant user, which will vary along a continuum across the organisation and externally. For example, scientists may require very detailed data intensive information (even raw data) in order to carry out their analyses and these reports will be required to go through a peer review process. At the other end of the scale the public require less data intensive information but more interpretation and simplified communication of the results and what they mean. Policy makers may also require less data intensive information and more interpretation and it is vital that the information conveyed to them relates to the policies they are considering or issues that require addressing are clearly identified.

There are several levels of detail at which data collected through Auckland Council monitoring programmes can be reported which are listed below:

- Raw data
- Technical reports
- Report cards
- Five-yearly *State of the environment* reports
- Journal manuscripts
- Conference abstracts
- Ad hoc data or reporting requests

1.11 Programme reviews

Even when monitoring programmes are established following rigorous principles, it is important to continue to review the programmes to ensure those high standards are maintained and the programmes remain relevant in the face of changing environmental and political objectives. A review process also provides the opportunity to implement improvements and efficiencies.

Monitoring programmes are reviewed approximately every five years to:

- Review and provide recommendations on the overall design of the programme.
- Assess the technical proficiency of all personnel involved in the monitoring programme (internal and external).
- Check that the standard of work is sufficient to assure the quality of results.
- Audit data quality and data management.
- Audit analytical procedures.
- Review data reporting.
- Assess the findings of the programme and consider whether the programme is continuing to provide key information, which supports the Auckland Council's resource management functions.

1.12 What do we monitor?

The RIMU Environmental Science team monitors environmental quality and quantity across five resource classes

- Land and soil
- Terrestrial biodiversity (including wetlands)
- Freshwater
- Marine
- Air

The monitoring activities under each of these programmes are outlined in the following chapters 2-6.

2 Land and soil monitoring

2.1 Context and background

The land and soil in the Auckland region are important and valuable resources. They support the growing population by providing food, a place to live and work, and recreational and tourism opportunities. Some soil and landform combinations also have cultural and/ or historical significance to different groups of people.

The Auckland region consists of a wide range of landforms, land cover and associated land uses, all of which combine to generate the soil properties at a specific location. Soil is the fine loose biologically active layer of the earth's crust that supports plant life and billions of tiny insects, worms, bacteria and other micro-organisms. It can range in depth from a few centimetres to many meters. Soil forms into many different types, depending on the parent material and the environment that it has come from. It takes thousands of years for soil to form, and for all practical purposes, it is a non-renewable resource that must be well managed.

It is important to determine and understand the dynamics of land use change over time and its subsequent effects on the quality and quantity of land and soil resources. Use of the land and soil, and changes in land use and intensification, has a wide range of short and long-term implications for the environment. For example, urban expansion resulting from the increasing population in the Auckland region is putting the land and soil resource under pressure. In addition the discharges generated by land use patterns have wider implications for freshwater and marine receiving environments.

2.2 Auckland's land and soil resources

The land in the Auckland region is diverse. The west coast is dominated by huge dunes that form the peninsulas at Awhitu and South Kaipara Head: much of this sandy land contains brown soils, and is unstable and prone to erosion. In the north, the land consists of layers of sandstone and mudstone (the Waitemata formation). This area is dominated by highly weathered clayey soils on rolling and hilly slopes, with some steeper slopes that are unstable and prone to erosion. The Waitakere Ranges in the west were formed by lava from volcanic eruptions and are covered mostly in native forest. The low undulating land of the Auckland isthmus is scattered with numerous small volcanic cones consisting of volcanic ash and lava. The volcanic eruptions covered a wide area and resulted in well-structured and productive granular

soils in the west and south. Alluvium (older volcanic material deposited by water) is found south of the Manukau Harbour. To the east the soils are a mixture of brown soils from alluvium, and clayey soils from Waitemata formation. The Hunua Ranges in the south-east are characterised by steep slopes formed by greywacke and argillite. The central Franklin District is covered by airfall volcanic ash from local basaltic volcanoes and from much older rhyolitic eruptions from the central North Island volcanoes, producing well-structured and productive granular soils. The soils in Franklin, and particularly in and around west Pukekohe, are some of New Zealand's most productive soil types that have been continuously producing vegetables for over 100 years on some properties.

Due to the diverse landforms, geology, soil types (natural environmental variation) and many land use types and land management practices (anthropogenic impacts) it is not feasible to monitor all of the land and soil resources and land uses at all locations. The land monitoring programme measures the quantity and quality of the land and soil resource and the effects of land use. It uses a stratified approach to monitoring which enables representation across the region for most programmes. Some programmes (soil quality) are specific to rural land as different rural land uses have different characteristics and different resource requirements to urban areas. Other monitoring programmes look at the effects of urban land use and the boundary between urban and rural and these are also location specific.

2.3 State of the environment monitoring

This section will provide a brief overview of the land and soil monitoring programmes that Auckland Council undertakes.

The overall aim of the land monitoring programmes is to describe the quantity and quality of the region's land and soil resources, and to assess the effects of land use pressures on them. The state of the environment land and soil monitoring programme covers four key modules that are discussed in Table 1:

Table 1. A brief outline of each programme.

Module	Sub-module	Baseline
1. Land pressures	a. Land cover	Regionally representative
	b. Land use	Regionally representative
	c. Soil loss to urbanisation	Regionally representative
	d. Extent of impervious surfaces	Location specific
	e. Rural fragmentation	Location specific
2. Land stability and disturbance (quantity)		Regionally representative
3. Soil quality and trace elements		Regionally representative
4. Sediment quantity		Regionally representative

2.3.1 Land pressures

An important determinant in the extent of environmental pressure on land is the way in which it is used (e.g. contrasting sediment yields from native forest vs. high production pasture on the same landform). Land uses have diverse characteristics and resource requirements and can change the quality and the quantity of natural resources. The land pressures module of the programme focuses on land use and population growth (both urban and rural).

a. Land cover

Land cover (vegetation or natural elements covering the ground) monitoring can identify critical causes of change or provide an early warning system for habitats being degraded. Land cover has been mapped nationally but at a scale where the data can be used at the regional level (the minimum mapping unit was 1ha). The Land Cover Database (LCDB) is a digital thematic map. The land cover classes mapped for the Auckland region are categorised at a high level (exotic vegetation, horticulture, native vegetation, pastoral, urban and other). These classes are used by many other programmes as a means of stratification in their programme design.

b. Land use change

Detection and reporting of land use change, particularly for areas undergoing rapid land use change or facing critical natural resource management issues is very important. It is critical in evaluating and monitoring trends in natural resource condition. The Auckland Council does not maintain a formal or systematic monitoring system of land use pressures. However, it subscribes to a number of key external databases including the Land Cover Database (LCDB), Agribase™, Statistics New Zealand census and Agricultural Production Survey. These collect data using different methods and at different temporal scales and dates and therefore, are not always comparable. Nevertheless, these databases and other data sources allow the council to investigate particular pressures when required and have sufficient spatial coverage.

c. Soil loss to urbanisation

The type of land use, changes in land use and intensification all have a wide range of short and long-term implications for the environment. The conflict between continued agricultural production and urban expansion resulting from the increasing population in the Auckland region is putting the soil resource under pressure. The productive potential of the soil is being lost or reduced by increased development and non-economic rural residential blocks at the urban fringes. Monitoring soil loss to urbanisation uses spatial analysis to determine the amount of soil loss at defined intervals where urban boundary information has been compiled. Using this method the conversion of elite and prime land to development can also be quantified.

d. Extent of impervious surfaces

Auckland's urban streams have typically undergone substantial modifications to accommodate development and convey flood flows, which have significantly altered ecosystem function. Urbanisation increases the amount of surface area impervious to natural infiltration through the soil profile. Surfaces can be man-made (roads, parking lots, roofs) or natural (compacted soil or gravel). Such surfaces modify the surface hydrology, altering the flows and can change the physical and chemical properties of surface water. The measurement of impervious surfaces is central to benchmarking and subsequently evaluating the urban stream management framework.

e. Rural fragmentation

Rural or land fragmentation is the ongoing subdivision of rural land that leads to increasingly smaller land parcels. It occurs when large land parcels used for agriculture are subdivided into small and more intensive production units,

hobby farms or lifestyle blocks primarily for residential use. Rural fragmentation increases settlement density and also excludes land uses such as pastoral farming that for practical or economic reasons require large land parcels. Rural fragmentation can be measured using land parcels of different sizes, e.g. 0-0.5ha, 0.5-1ha..... >8ha, and to determine the number, proportion (per cent) and area of land (ha) occupied by each across the region.

2.3.2 Land stability and disturbance

Soil erosion is a natural process by which soil is gradually eroded by water or wind from the earth's surface, and then replaced in the soil forming process. It is important to understand the stability of the land resource, so that it continues to be available for urban use, farming, forestry and conservation across the Auckland region. Measuring the stability of the land gives us an understanding of its natural stability, and the amount of unstable land and land that has been affected by natural erosion processes.

2.3.3 Soil quality

Soil quality is often referred to as the capacity of a soil to sustain biological production, maintain environmental quality, and promote plant and animal health. Soil quality is monitored to provide data about the effects of primary land uses on long-term soil quality. It tracks trends over time by collecting and analysing samples from sites that represent the dominant land-use types and soil types, to characterise their chemical, physical and biological attributes.

Land use types include dairy farming, drystock farming (sheep, cattle and deer), exotic (pine) forestry, outdoor vegetable cropping and horticulture. Long-term indigenous bush sites were also selected for the determination of background soil quality. The soil quality programme has recently been extended to include urban parks to determine soil quality within an urban setting.

The sites sampled for soil quality parameters are also sampled for a suite of trace elements. Trace elements occur naturally in soils, mainly as a result of the natural weathering of rocks and minerals. These natural levels are often referred to as 'background concentrations' and can vary depending on the soil type, geology and climate.

Trace elements can also be added to the soil as the result of urban, agricultural and horticultural land use activities (e.g. vehicle emissions, fertilisers and pesticide applications). Soils on land used for production can have different trace element concentrations than natural background conditions. Trace elements can reach levels that exceed guidelines for human

and animal health and may restrict the future use of the soil resource and have the potential to contaminant receiving environments. The location of both soil quality and sediment monitored sites are illustrated in Figure 3

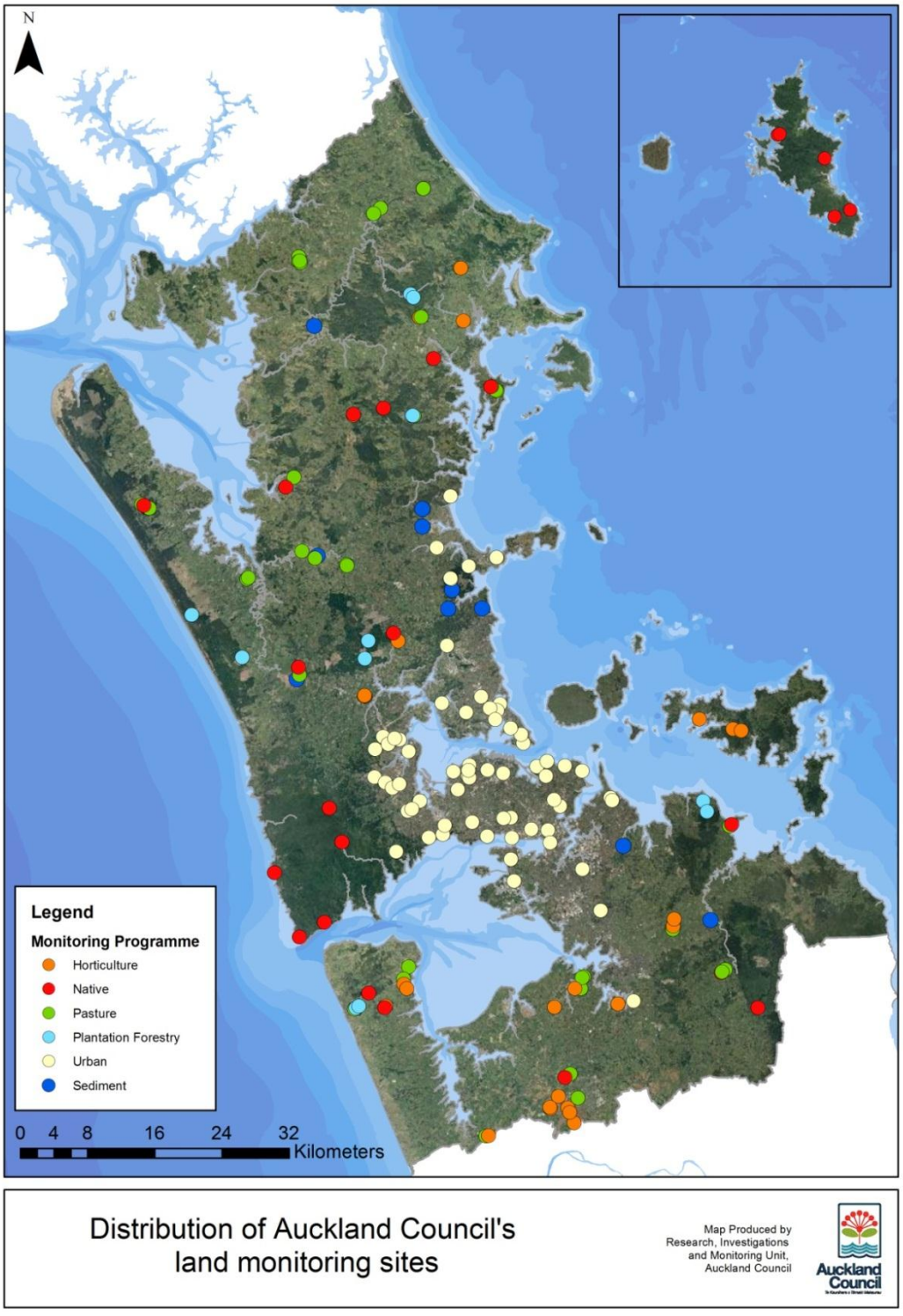

Figure 3. Distribution of Auckland Council's soil quality and sediment monitoring sites.

2.3.4 Sediment quantity

Sediment loss to receiving water bodies is of concern and the council needs to understand and monitor the movement of sediment through the waterways, quantify the amount of sediment coming off the land, and identify where sediment is from, and where it is going.

A key requirement of state of the environment reporting is to provide a region wide picture. Since it is not practical to monitor sediment loads continuously in all streams around the region, a sampling programme has been designed that is regionally representative and stratified by geology and land cover. Ten sediment monitoring sites have been selected that are representative of the region's dominant geology and land use, the latter known to be major sediment generating determinants.

For trend monitoring, council needs to distinguish climate-driven change in sediment yield from that associated with land use activities. This requires information from reference catchments that retain a stable land use.

To conclude, soil is a non-renewable resource which provides Aucklanders with a multitude of benefits and it is imperative that the monitoring described above is conducted to safeguard the life supporting capacity of the land and soil resource.

For further information about the land monitoring programme please refer to Auckland Council technical report, *Land and soil monitoring programme 2013*, TR2013/019.

3 Terrestrial biodiversity monitoring

3.1 Context and background

Biodiversity is a composite term used to embrace the variety of types, forms, spatial arrangements, processes, and interactions of biological systems at all scales and levels of organization. It is widely accepted that many components of biodiversity are being lost rapidly at global scales, with significant impacts on natural systems and the well-being of human societies. Primary causes of the current biodiversity crisis are the destruction, fragmentation, and deterioration of ecosystems, invasive species, pollution, overharvesting, and increasingly, climate change. The resulting decline in ecological integrity warrants concern. In addition to its intrinsic value, indigenous biodiversity is essential to the provision of ecosystem services such as climate regulation, biofiltration of water, erosion control and sediment retention, pollination, recreation, and resource use.

Increasingly, land management agencies are developing regional and national monitoring programmes to more closely inventory, monitor, and report on biodiversity. Such programmes are deemed essential for biodiversity management, which depends on understanding the roles, value and importance of biodiversity; its condition; the pressures on it; changes resulting from pressures; and the appropriateness, effectiveness of policy, and management responses.

3.2 Auckland's terrestrial biodiversity

The Auckland region has a total land area of almost 5000km², and is bounded by the Waikato region in the south and the Northland region in the north. The region has a diverse range of lowland landform types including extensive estuarine areas, coastal promontories, isthmuses, consolidated sands, uplifted and dissected hill country, volcanic hills, lowland hills and islands. The overriding characteristic of the region is its coastal setting and strong maritime influence. The region encompasses the Auckland isthmus – where east and west coasts are <1500m apart - and over 50 offshore islands. Catchments are small and there are few large lakes. Wetlands are common in the lowland parts of the region, but are now generally much reduced in extent. The Auckland isthmus also had an abundance of swamps and small lakes formed by the blockage of drainage patterns by lava flows from volcanic activity, most of which have now been drained. Lakes and swamps were also formed by shifting coastal sands and dune formation processes and there were extensive areas of tidal mudflats in estuaries.

Pre-human land cover in the region is estimated to have been 93 per cent forest (largely podocarp-broadleaf forest with localised kauri and coastal broadleaf), with the balance of the land area in open water, wetlands, dunelands, and shrublands. However, natural ecosystems of the region have been highly modified by human settlement through large scale clearance of forest and scrub, residential and road development, reclamation of bays, draining of wetlands, culverting of streams, quarrying of volcanic cones, and the introduction of alien plants.

The most extensive remaining native vegetation consists of modified forest. In total, 27 per cent of indigenous landcover remains in the Auckland region, with some ecosystems now below 10 per cent of their original extent, e.g., kauri forests (9%), wetlands (4%), coastal forests (3%), and mainland lava forests (0.5%). Many of these threatened ecosystems are on private land. Moreover, the region has 326 plants (43% of the total regional flora) classified as nationally or regionally threatened, including 35 now considered regionally extinct, and seven that are only found in the region. Auckland also has 20 per cent (49) of New Zealand's threatened vertebrate fauna.

Auckland's extensive and diverse terrestrial environments, and the biodiversity they support, remain at risk from a variety of sources. These include development pressures (which are common in such a fast growing region), the ongoing negative impact of pest plants and animals, and the impact of pollution and natural hazards. The terrestrial biodiversity monitoring programme measures coarse scale changes in biodiversity in key landscapes and across the region. This information can then be used to track Auckland Council's progress towards a wide range of different targets. For example, success in achieving Auckland Plan targets, assessing policy effectiveness, and ensuring the best possible return from resources committed to biodiversity protection and enhancement.

3.3 State of the environment monitoring

The terrestrial biodiversity monitoring programme was first implemented in 2009 (coinciding with the SOE reporting cycle). The main objectives of this programme are:

- To quantify the state of indigenous terrestrial biodiversity and monitor changes in pattern and processes through time
- To identify key threats to indigenous biodiversity
- To assess and improve the effectiveness and efficiencies of biodiversity-related management and policy development

- To contribute to public understanding of issues, status, trends, and management
- To identify and remedy information gaps
- To fulfil statutory monitoring and reporting requirements (e.g. SOE monitoring, Auckland Plan monitoring, monitoring the effectiveness in achieving Unitary Plan objectives, Waitakere Ranges Heritage Area Act 2008).

The terrestrial biodiversity monitoring programme was designed to focus on indigenous forest and shrublands, wetlands, and dune ecosystems systems across the Auckland region, however saline wetlands and dunelands are yet to be established and thus there are two main programmes at present: Forest/shrublands and freshwater wetlands. The specific details of these programmes are covered in the Terrestrial Biodiversity Monitoring Plan (in preparation) with a brief outline provided below.

3.3.1 Forest and shrubland monitoring

The forest/shrubland programme monitors biodiversity in forest and scrub ecosystems. The spatial coverage of the terrestrial biodiversity monitoring programme was designed to accommodate differences in reporting requirements and scales of interest. It uses a tiered or nested approach that extends from surveillance monitoring across the region to targeted monitoring at key ecological restoration initiatives or ecosystems, or of specific taxa (Table 2). The forest/shrublands and freshwater wetlands monitoring programmes have recently completed their first 5-year cycle and hence the first baseline measures for these environments are complete, with remeasures underway.

Approximately 400 forest/shrubland plots and ~250 freshwater wetland plots, distributed across the Auckland region, were sampled over this first 5-year cycle (Figure 4).

This procedure is based on establishing sample plots using existing methodologies used by other agencies (e.g. DOC national inventory and monitoring, LUCAS plots, Greater Wellington Regional Council biodiversity monitoring programme). These include creating a standard 20m x 20m vegetation plot where a variety of vegetation measures are collected for all plant age classes/types (seedlings, saplings, trees, vines) and for indigenous and weed species.

Pest and bird monitoring is also carried at each plot using chew cards and 10-minute bird count methods, respectively. In addition, forest condition and various site data (e.g. photography, GPS coordinates, slope, aspect, drainage, soil, ground cover, evidence of historical use such as mining or forestry, etc) are also collected at each site. These descriptors help put the various ecological data collected

into context and are used when conducting analyses on the programme's output data. Monitoring is stratified into tiers in order to meet the varying demands on the programme (Table 2).

- The Tier I programme established ~220 indigenous forest and shrubland plots across the region, and integrates directly with the National LUCAS programme (MfE) and any other existing non-LUCAS plots which are suitably compatible with the site and plot methodology of this programme.
- Approximately 30 Tier II plots were established in the three largest intact indigenous forest blocks in the region in the Waitakere Ranges Heritage Area, the Hunua forest tract, and Great Barrier Island. A further ~30 Tier II plots were established to monitor the effectiveness of weed and pest management work by Landcare groups at Tapora, South Kaipara and Awhitu.
- An additional ~120 plots were established in six 'Key Ecological Restoration Initiative' areas spread throughout the region (Tier III). These six areas are Ark in the Park (Waitakere Ranges), Kokako Management Area (Hunua Ranges), Glenfern (Port Fitzroy, Great Barrier), Windy Hill (Tryphena, Great Barrier), Shakespear Regional Park, and Tawharanui Regional Park.
- Tier IV includes research and monitoring of specific sites, species or species assemblages, and encompasses a number of existing monitoring programmes across the region as well as new programmes where adaptive research and monitoring needs arise (e.g. Kauri dieback monitoring in the Waitakere Ranges).

Table 2. Terrestrial biodiversity monitoring programme as structured by tiers in relation to focus, reporting requirements, data collection, and monitoring cycle

Tier	Focus	Reporting requirements	Data collection	Broad indicators	Monitoring cycle
I	**Regional:** (e.g., entire region, comparisons between public versus private lands; islands versus mainland)	State of the environment reporting and policy effectiveness, e.g., National Biodiversity Strategy (NBS), Regional Policy Statement (RPS), and Auckland Regional Pest Management Strategy (ARPMS)	Database and information analyses (e.g., Landcover Database LCDB) and field monitoring	Legislation and policy, indigenous landcover, threatened species, indigenous plants and birds, weeds, mammalian pests, climate change and variability, community input and awareness	5-10 yearly
II	**Key regional forest and wetland assets:** including Hunua Ranges and Foothills (reference site), Waitakere Ranges Heritage Area, Great Barrier Island, Kaitoke Swamp, Bethell's/Te Henga wetland, and Whatipu wetland	Policy effectiveness: Regional Policy Statement (RPS) and Waitakere Ranges Heritage Area Act	Database and information analyses (e.g. Landcover Database LCDB) and field monitoring	Legislation and policy, indigenous landcover, threatened species, indigenous plants and birds, weeds, mammalian pests	5-10 yearly
III	**Key Ecological Management and Restoration Initiatives**, e.g. Kokako Management Area (Hunua Ranges); ARK (Waitakere Ranges), Tawharanui Regional Park), Waiatarua wetland, Shakespeare Regional Park, Glenfern and Windy Hill	Management/Restoration plans (Performance / Result monitoring and Biodiversity outcome monitoring)	Predominately field monitoring	Indigenous landcover, vascular plants, weeds, mammalian pests, indigenous birds, invertebrates, reptiles	Various, as required
IV	**Additional programmes:** e.g., specific inventory, survey, and monitoring programmes e.g., Kauri Dieback; Hochstetter frog monitoring in the Waitakeres and Hunuas ; regional reptile monitoring programmes	Policy effectiveness and performance/result monitoring and biodiversity outcome	Predominately field monitoring	Variable (programme specific)	Variable

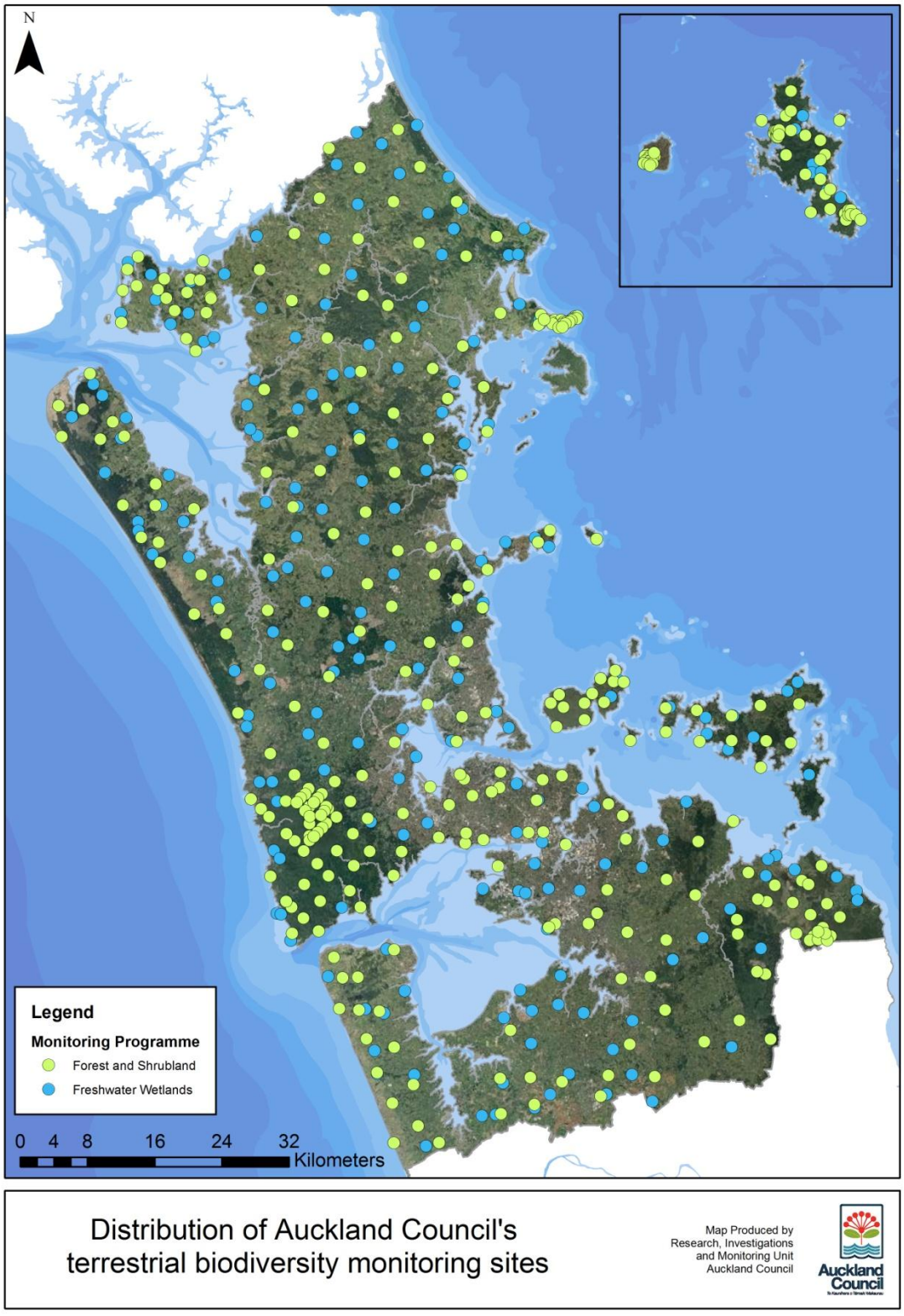

Figure 4. Terrestrial biodiversity monitoring programme plot network across the Auckland region.

3.3.2 Freshwater wetland monitoring

The freshwater wetland programme is designed using a similar landscape approach as the forest/shrubland programme. Around 120 wetland plots (Figure 3) used for regional reporting requirements are uniformly distributed across the Auckland region (i.e. Tier I plots). An additional ~60 plots were planned for particular areas of interest where large and important wetland systems present (i.e. Tier II plots) at Kaitoke swamp, Bethell's/Te Henga wetland, and the Whatipu wetland complex. A further ~70 plots were established to track changes in 'Key Ecological Restoration Initiatives' (i.e. Tier III plots) at Waiatarua, Kohuora Park, Awhitu Regional Park, Onepoto Basin, and other sites.

The wetland monitoring methods are based on national standards using a plot design which includes a standard 15m x 15m vegetation plot as well as a 10m x 10m and a 2m x 2m plot nested within the single plot. This has been done so that data collected at various spatial scales can be tested so as to identify the most efficient methods to monitor wetlands. A large number of data are collected at each plot including vegetation measures (both indigenous and weed species), soil and foliage samples (for laboratory analyses), site metrics (GPS coordinates, aspects, etc), and wetland condition measures. Bird monitoring is conducted at each plot using the same 10-minute bird count methods as the forest/shrubland programme and additional playback bird monitoring to detect the key wetland bird species: fernbird, spotless crake and banded rail.

4 Freshwater monitoring

4.1 Context and background

A basic feature of the earth is an abundance of water, which extends over 71 per cent of its surface. While estimates vary slightly, less than three per cent of this global water resource is freshwater, and less than one per cent is in a readily available form, that is, in the atmosphere, rivers, lakes or groundwater. Hence, the high value of this available freshwater resource is in a stark contrast to its small size.

Plentiful rainfall across the Auckland region sustains a wide variety of freshwater environments, including rivers and lakes on the surface and groundwater. However, ensuring a secure supply of freshwater, while maintaining the health of freshwater ecosystems, becomes ever more challenging as the population grows. Of critical importance to the management of freshwater is an understanding of the quantity and quality of the region's freshwater resources.

To understand the quantity and quality of the region's freshwater resource it is necessary to monitor all stages of the freshwater cycle. Hence the Auckland Council monitors the quantity of water falling as precipitation, and the quantity and quality of water in rivers, lakes and groundwater.

It is impossible for us to monitor every characteristic of every freshwater environment. Therefore, the monitoring sites are selected to be regionally representative; that is, they cover both the range of natural environment variation (for example, size, altitude and geology) and the range of anthropogenic impacts (from catchments of pristine native bush to fully urbanised – this is known as the "disturbance gradient").

4.2 Auckland's freshwater environment

4.2.1 Rivers

The Auckland region has an estimated 16,500km of permanently flowing rivers. As no mainland location in the region is greater than 20km from the coast, the catchment areas of each river are relatively small. Consequently, most rivers are first and second order, meaning they are relatively small and most are less than a few metres wide.

The majority (63%) of rivers within the Auckland region drain non-forested rural catchments (pastoral farming, horticulture and rural residential), followed by native forest catchments (21%), with exotic forest and urban catchments accounting for eight per cent each.

4.2.2 Lakes

There are 72 natural and artificial lakes greater than one hectare in size in the Auckland region. These range in size from small farm ponds to the largest water supply reservoir behind the Mangatangi Dam in the Hunua Ranges. On a national scale, the lakes are small and shallow; with large deep lakes absent from the region.

Lakes can be classified according to how they were formed. Natural lakes in the Auckland region are mainly dune lakes, although one, lake Pupuke, has a volcanic origin. Dune lakes have a common feature of a barrier of sand that has blocked stream valleys to form a dammed valley lake, for example lakes Ototoa and Wainamu. Artificial water supply reservoirs are found in flooded valleys behind artificial dams in the Waitakere and Hunua Ranges.

4.2.3 Groundwater

The Auckland region has many aquifers, which are important for municipal water supply, irrigation and stock drinking water. Groundwater is also important for sustaining surface waters during periods of low rainfall.

Broadly, there are two types of aquifer: confined and unconfined. Confined aquifers are overlain by impermeable material, which restricts the flow of water into the aquifer from the surface. As a result, confined aquifers tend to be protected from contamination from overlying land use activities. Unconfined aquifers are in direct contact to the surface and consist of permeable material that allows the vertical flow of water, and any associated contaminants. As a result, unconfined aquifers are susceptible to pollution from overlying land use activities.

4.3 State of the environment monitoring

The overall aim of the Auckland Council's freshwater monitoring programme is to describe the quantity and quality of the region's freshwater resources, and to assess the effects of environmental stressors upon them. To meet this aim, the monitoring is carried out under two concurrent work streams. The quantity work stream measures the volume of the region's freshwater resources. The quality work stream measures the condition of the region's freshwater resource using a combination of structural and functional measures of their physical, chemical and biological characteristics.

The inclusion of sites in the monitoring programmes has occurred, and continues to occur, for a variety of reasons. Sites have been included, inter alia, to monitor the important freshwater resources in the region, the effectiveness of plans and policies, and in response to specific issues (development and water allocation being the most common). Recent efforts have focused on organising these sites into a strategic, regionally representative monitoring programme, while retaining the ability to add new monitoring locations in response to emerging or changing issues.

The freshwater monitoring programmes are briefly summarised below and in Table 3 and the spatial distribution of the freshwater monitoring sites are illustrated in Figure 5.

Table 3. Summary of freshwater monitoring programmes.

Programme	No. of sites	Longest record	Record commencing in					
			60s	70s	80s	90s	2000s	2010s
Quantity								
Rainfall (auto)	25	Whenuapai (1945)	0	4	3	12	5	0
Rainfall (manual)	11	Albert Park (1872)	0	4	3	4	0	0
River flow	31	Waitangi (1966)	2	8	6	10	6	0
Lake level	7	Several sites (2005)	0	0	0	0	5	0
Groundwater (auto)	8	Waiwera (1976)	0	1	3	4	1	0
Groundwater (manual)	67	Glenbrook (1970)	0	7	18	33	11	0
Quality								
River WQ	34	Opanuku & Wairoa (1977)	0	4	6	12	9	3
River ecology	90	Several sites (1999)	0	0	0	19	47	24
Lake WQ	7	Pupuke (1966)	1	0	6	0	0	0
Lake ecology	29	Several sites (2001)	0	0	0	0	29	0
Groundwater WQ	27	Wilcox (1990)	0	0	0	27	0	0

4.4 Freshwater quantity

The quantity work stream assesses the volume of water at all stages of the freshwater cycle at a range of regionally representative sites.

4.4.1 Rainfall

Fundamentally, rainfall is the source of the region's freshwater resource. Therefore, it is crucial to understand its spatial and temporal variation. While, Auckland's temperate climate produces an abundance of rainfall, spatial and temporal patterns can lead to shortages in particular areas at particular times.

The network currently consists of 36 rainfall monitoring sites. Of these sites, 25 are fully automated and 11 are manual. The length of data record for these sites varies

considerably. The oldest manual site is Albert Park and dates from 1872, whereas the oldest automated site is Whenuapai (1945). Other than these two exceptional sites, the majority of the data records commence between 1977 and 1997, providing a long-term record of rainfall in the region.

4.4.2 Rivers

The river levels monitored at selected sites across the region and is converted to river flow using a site-specific water level – discharge relation. This data allows us to determine seasonal and long-term trends in river flows, predict the extent of flooding and impacts of droughts and provides supporting data for the river quality and sediment monitoring programmes. The data from some of these monitoring sites is also used to inform water allocation limits.

The network currently consists of 31 river level monitoring sites. This network of sites is fully automated with real time data reported to the AC website and the length of data record for these sites varies considerably.

4.4.3 Lakes

Lake levels monitored at selected lakes across the region are converted to lake volume using a site-specific water level – volume relation. This monitoring aims to determine seasonal and long-term trends in lake level. This information will provide high quality information on lake volume and residence time, which are important measures of lake hydrodynamics and recognised as key drivers of lake processes.

The network currently consists of seven lake level monitoring sites. This monitoring programme is a relatively recent addition to the quantity work stream, with all sites installed in 2005, and therefore the data record is relatively short.

4.4.4 Groundwater

Groundwater level is monitored at selected sites across the region. This monitoring allows us to determine long-term trends in groundwater levels, providing evidence of the sustainability of water allocation limits.

The network currently consists of 78 groundwater level monitoring sites. Of these sites, nine are fully automated and 69 are manual. The majority of records commence between 1977 and 1997, providing a long-term record of groundwater level for the region.

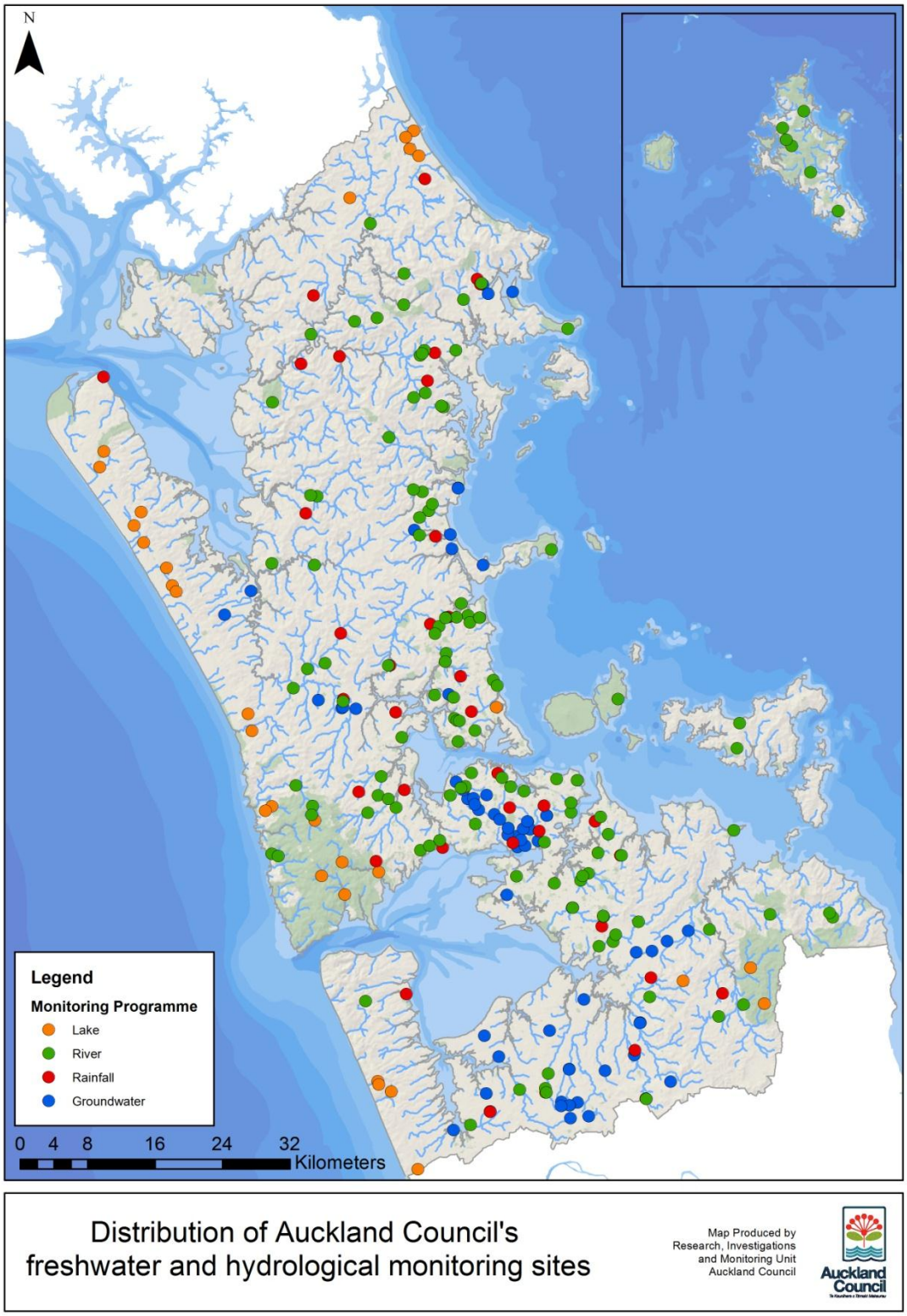

Figure 5. Distribution of Auckland Council's freshwater quality and quantity monitoring sites.

4.5 Freshwater quality

The quality work stream assesses the quality of the region's freshwater resources at a range of regionally representative sites, using a combination of structural and functional measures of their physical, chemical and biological characteristics.

4.5.1 Rivers

The Auckland Council operates two river quality monitoring programmes.

The **Water Quality Programme** monitors the physical, chemical and microbiological properties of rivers at 34 sites. This monitoring provides information on the temperature, amounts of nutrients, oxygen, sediment and other pollutants in the sampled rivers. The results enable us to assess the life-supporting capacity of the river (how suitable it is for supporting plant and animal life) and the microbiological quality of the river (how suitable it is for recreational use and for stock to drink).

The **Ecological Quality Programme** monitors the biological communities and habitat of the rivers at 90 sites. This monitoring provides information on the invertebrate and fish communities, together with an assessment of the habitat quality of the sampled rivers. The type and number of invertebrates and fish found at a site, together with the quality of the habitat, is used to indicate the ecological quality of the river.

These two monitoring programmes are regionally representative. This means that they monitor all sizes and types of rivers, and also cover the range of different catchment land cover types found across the region. This allows us to extrapolate the results to infer the likely water and ecological quality of rivers that we do not sample.

4.5.2 Lakes

The Auckland Council operates two lake quality monitoring programmes.

The **Water Quality Programme** monitors the physical, chemical and microbiological properties of seven lakes. This monitoring provides information on the temperature, amounts of nutrients, oxygen, sediment and other pollutants in the sampled lakes. The results enable us to assess the life-supporting capacity of the lake (how suitable it is for supporting plant and animal life) and the microbiological (bacteria and algae) quality of the lake (how suitable it is for recreational use).

This programme commenced in 1988, although there are intermittent water quality records for Lake Pupuke dating from 1966. The seven lakes were selected for monitoring because they are the largest natural lakes in the region. The lakes are sampled six times each year at intervals selected to capture to the important seasonal variations in lake systems.

The **Ecological Quality Programme** monitors the biological communities of selected lakes using two sub-programmes;

- Rotifers are part of the zooplankton community found in lakes. They are sampled at the seven lakes in the lake water quality monitoring programme. The type and number of rotifers are used to provide an indication of the ecological health of the lake. The rotifer sub programme has been operating since 2001.
- Macrophytes or aquatic submerged plants. These are surveyed at 29 lakes within the Auckland region. The type and amount of submerged plants are used to provide an indication of the ecological health of the lake. The first regional lake survey using this methodology was carried out in 2008, although previous lake-specific assessments had been carried out on a case by case basis.

4.5.3 Groundwater

The Auckland Council operates a water quality programme for groundwater.

The groundwater quality programme monitors the physical, chemical and microbiological properties of groundwater in aquifers that are of high importance for water supply. This monitoring provides information on the temperature, amounts of nutrients, oxygen, sediment and other pollutants in the sampled groundwater. The results enable us to assess the life-supporting capacity of the groundwater (for supporting plant and animal life when discharged as baseflow to rivers) and how suitable it is for drinking water supply.

The programme began in 1998 and the current network consists of 27 sample locations (groundwater bores or springs) from eight of the region's most important aquifers. Sampling is carried out quarterly at eight main locations and the remaining sites are monitored irregularly over longer periods to track whether any changes are occurring require investigation.

5 Marine monitoring

5.1 Context and background

Auckland's marine environment is highly complex and ecologically valuable for the range of habitats available that support a diverse range of species. The Auckland marine environment also provides a range of ecosystem services and functions (e.g. climate change mitigation, biodiversity and tourism) of great significance to the region. The region's coastal marine area is very large and highly variable, with two vastly different coast lines, a strong exposure gradient from the inner to outer Hauraki Gulf, three large harbours (including Kaipara Harbour, the largest harbour in New Zealand and often reported as the largest in the Southern Hemisphere), as well as many estuaries and embayments. The complexity of Auckland's marine environment makes it very difficult to generalise across the region so a comprehensive monitoring programme is required that covers the range of habitats and exposure gradients present.

Programmes like water and sediment quality and coastal profiles take a regional approach, but the marine ecology programme is structured into harbours, estuaries and reefs to reflect the inherent differences in these environments. This is a fundamental difference to the regional approach of air, land and freshwater monitoring.

The marine environment is extremely variable and, in order to try and determine whether changes in species or habitats are due to human-induced activities, natural processes or climatic variation, we need to understand this natural variability. Therefore, monitoring programmes use a consistent, long-term monitoring method with an appropriate frequency, so that natural biological and climatic variations can be differentiated from anthropogenic (human) impact.

5.2 Marine monitoring programmes

Marine state of the environment monitoring comprises both baseline and event based monitoring programmes, both of which also encompass the ability to investigate specific issues. More detailed outlines of the programmes can be found in the *Marine monitoring plan,* TR2013/025 and in individual programme histories.

Marine monitoring is carried out through five key programmes:

- Coastal Water Quality
- Sediment Contaminants
- Shellfish Contaminants
- Marine Ecology (Harbours, Estuaries and Reefs and Broad Scale Habitats)

- Coastal Profiles

Together these monitoring programmes provide consistent, long-term information on the environmental quality of Auckland's marine environment. The data from these programmes provides a large amount of information that is used to inform our marine management decisions and policies and enables us to assess the effectiveness of those actions. The spatial coverage of the marine monitoring programme is shown in Figure 6 and a brief explanation of the SOE, issue specific and event based monitoring programmes is provided below.

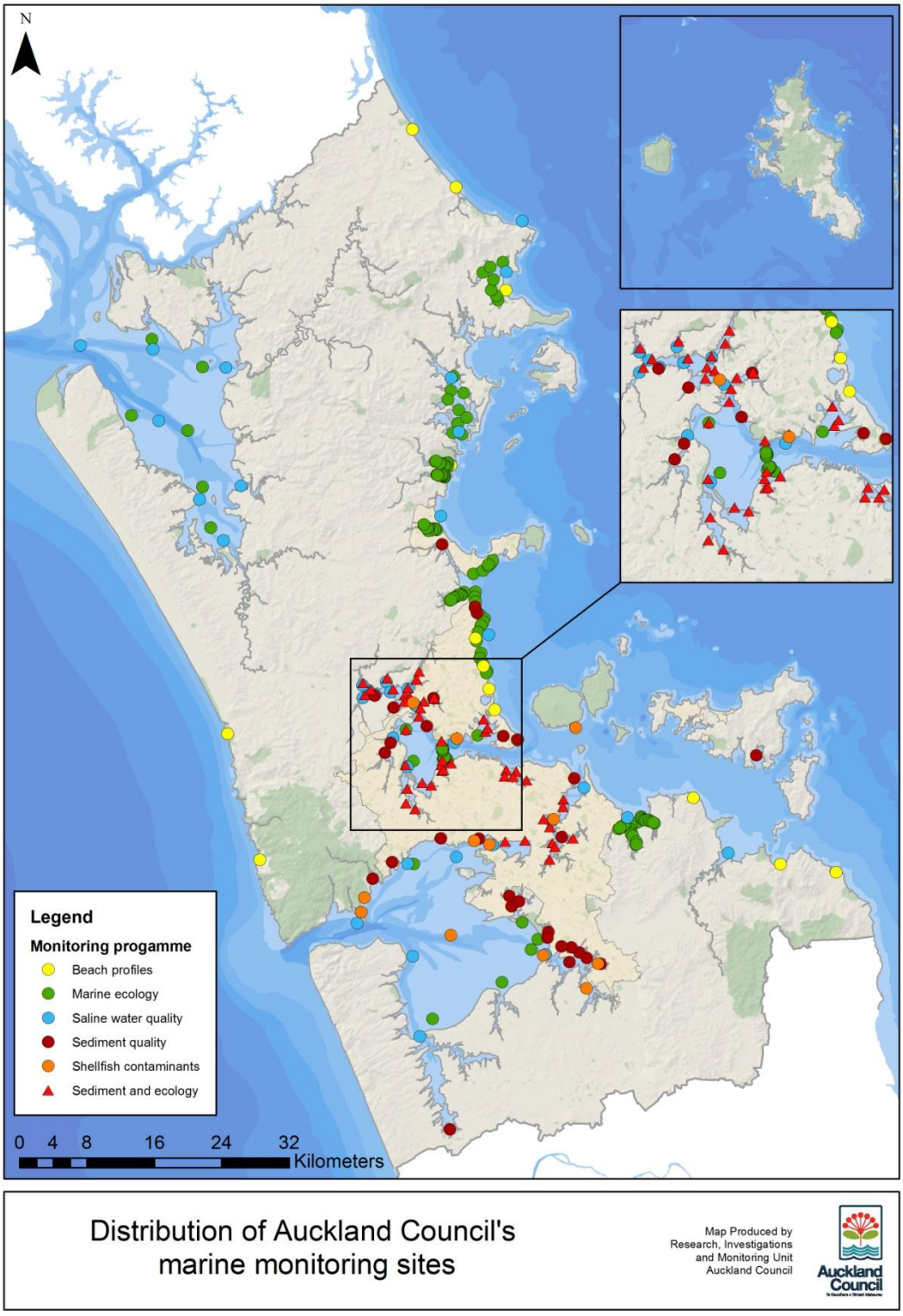

Figure 6. Distribution of Auckland Council's marine monitoring sites.

5.3 State of the environment monitoring

5.3.1 Coastal water quality

This programme monitors contaminants associated with erosion, nutrients and biological wastes (organic material and faecal contaminants) in the water column and provides regionally representative baseline monitoring.

A standard set of parameters are used as indicators of sediment, nutrients and biological contaminants. In addition, a number of environmental parameters (such as temperature) are measured to provide information on ambient coastal water conditions or because they effect the toxicity of contaminants such as ammonia.

5.3.2 Sediment contaminant monitoring

The sediment contaminant monitoring programme assesses the spatial distribution and temporal trends in key chemical contaminants in near-shore sediments across the region's urban estuaries, harbours and beaches.

Many contaminants attach to particulate material which settles out of the water column and accumulates in depositional zones. These contaminants can be toxic to the organisms that live on and in the sediments. The sediment contaminant monitoring programme combines regionally representative baseline sites as well as additional regional discharge sites subject to stormwater inputs, increasing the spatial coverage of the baseline programme and the programme's ability to report on stormwater outcomes.

5.3.3 Shellfish contaminant monitoring

Direct measurement of chemical contaminants in the water column can be unreliable because concentrations are commonly below analytical detection limits, and they vary widely due to water movement and the patchy nature of inputs. However, plants and animals can accumulate contaminants over time, even when ambient levels in the water column are relatively low. The tissues of sedentary, filter-feeding shellfish therefore provide an integrated measure of ambient chemical contaminant levels in the water column.

The shellfish contaminant monitoring programme uses contaminant levels in mussels and oysters to provide an indirect measure of ambient seawater quality. The programme was primarily established to track the level of urban contaminants, but reference sites included in the programme also provide information from areas beyond the urban fringe. Samples are also analysed for some contaminants, such as persistent pesticides, which may originate from agricultural areas.

5.3.4 Marine ecology

The abundance and composition of benthic organisms found in coastal ecosystems provides a sensitive measure of ecosystem condition or health. Organisms in these

communities form a significant component of our regional biodiversity and also provide an important food source for birds, fish, and people.

This programme follows a tiered network design which is being progressively implemented. The tiered design aims to provide both spatial and temporal information on the condition of marine ecology.

5.3.5 Benthic health programme

The benthic health programme provides a means to assess soft sediment ecological health on a regional basis. It involves monitoring a combination of ecology and sediment contaminants across the region and uses information from both the marine ecology and sediment contaminant monitoring programmes.

5.3.6 Coastal profile monitoring

This programme monitors long-term changes in the landward position of the beach, changes in the volume of sand stored within the beach, changes in beach width, and the overall change for each beach. The programme provides information on beach dynamics, coastal hazards and changes that can potentially be linked to changes in climatic patterns.

5.4 Issue specific monitoring

As well as providing regionally representative coverage of temporal change, monitoring carried out at number of locations is designed to answer additional questions related to specific issues. These issue specific programmes may be spatially specific or temporally intensive in specific locations, or may measure a selected suite of parameters additional to those monitored in the core monitoring programme. A brief summary of issue specific monitoring is discussed below:

5.4.1 Upper Waitemata Harbour

In November 2005, a long-term monitoring programme was established in the Upper Waitemata Harbour to monitor the ecological status of benthic macrofauna in habitats that have the potential to be affected by development of the surrounding catchments. The core monitoring is aligned to the marine ecology programme and contributes to regional coverage. In addition, concurrent sampling of sediment characteristics and chemical contaminants is also carried out to correlate macrofaunal information with the effects of catchment development.

5.4.2 Estuaries

In addition to providing information on the state of marine ecology in east coast estuaries, the estuaries monitoring programme was established to address particular questions arising from proposed changes in land use. The objective of the estuaries monitoring programme is to determine whether land disturbance associated with varying degrees of urbanisation or land use intensification in the surrounding

catchment causes ecologically damaging sedimentation to intertidal soft-sediment macrofauna in the estuary. The information also allows verification of modelling and environmental risk predictions used to underpin development-planning decisions.

5.4.3 Long Bay

Monitoring was initiated to determine whether the adverse effects of urban “green-field” development on coastal and freshwater environments were more than minor. Changes in the health of marine communities on subtidal reefs are monitored. Several control sites are also included in the programme to ensure that any changes detected can be attributed to land based activity rather than natural processes. These control sites form the basis of the reefs SOE monitoring programme. In addition to ecological monitoring, sedimentation is also measured using sediment traps and per cent cover of sediment on the reef. This allows us to link changes in the ecology to changes in sedimentation levels resulting from land use change in the surrounding catchments.

5.4.4 Stormwater

Stormwater and its effects are a key issue for the Auckland region. This programme incorporates spatially intense sampling within the sediment contaminant and benthic health programmes in urban areas affected by stormwater. Based on this information we can assess the level of stormwater contaminants in marine receiving environments and the ecological health of benthic communities in relation to those stormwater contaminants.

5.5 Event monitoring

Currently event based monitoring is only carried out as part of one programme, the estuaries monitoring programme. Event based sampling is under development for the coastal water quality monitoring programme. If the estuarine event based sampling proves useful it may be progressively added to the marine ecology programme following the establishment of sediment monitoring in adjoining catchments.

6 Air quality monitoring

6.1 Context and background

Auckland Council is responsible for the management of air quality in the Auckland region. In order to support this, the council runs an air quality monitoring programme to identify pollutant levels, trends and sources in the region. The monitoring programme also enables council to assess the cumulative effects and potential impacts these pollutants have on health and the environment. Information obtained from the monitoring programme is used to support the development of policies, plans and rules in order to reduce air pollution.

Compared to many other international cities, Auckland has relatively clean air. However, Auckland's urban setting means that emissions from transport, domestic fires (the use of solid fuels such as wood and coal) and industry combine to add pressure upon the environment and degrade air quality, particularly during winter. This mixture of gases and particles can affect human health and well-being.

There are three main sources of air pollution in Auckland. Emissions from transport are the primary source of air pollution throughout the year (especially motor vehicles). Emissions from domestic fires are the highest source during the winter months of June, July and August. Industrial discharges also contribute to Auckland's air pollution, however industry has been heavily regulated over the past decade so emissions contribute to a much lesser extent than domestic fires and transport, and generally have a local rather than regional effect. These sources produce different pollutants, some of which are dangerous and hazardous to human health.

The Auckland region is home to over 1.5 million people, which accounts for one third of New Zealand's population, and it is projected to grow to up to 2.5 million by 2040. This high growth affects transport use (increasing car ownership, and more vehicles trips and of longer distances) and the domestic sector (causing an increase in the number of domestic fire appliances discharging emissions into the air). Aside from transport and domestic sources, industrial and rural activities such as outdoor burning also contribute to Auckland's emissions.

The most common pollutants in the region from these sources are similar to those found everywhere else in the world including:

- Particulates smaller than 10 micrometres (PM_{10}), 2.5 micrometres ($PM_{2.5}$) and one micrometre (PM_1) in diameter
- Nitrogen dioxide (NO_2)
- Carbon monoxide (CO)
- Ozone (O_3)
- Sulphur dioxide (SO_2)

- Volatile organic compounds (VOCs)
- Benzene (C_6H_6)
- 1,3 butadiene (C_4H_6)
- Lead (Pb).

Exceedances of relevant standards in the Auckland region for $PM_{2.5}$, PM_{10}, NO_2 and CO have occurred in the past due to traffic, domestic fires, road works, construction activities, outdoor burning, or from special events such as fireworks displays.

Pollutants cause adverse effects on health, making asthma, lung and heart conditions worse. The worst air pollutants are the particulates PM_{10}, $PM_{2.5}$ and PM_1 as they are made up of a mixture of different chemical substances (e.g. polyaromatic hydrocarbons) and heavy metals (e.g. chromium, copper, or nickel) depending upon the season, weather conditions and sources producing them, and can stay suspended in the air for up to 40 days. It is for these reasons that particulates are considered a surrogate for health effects and associated costs from air pollution. Every year, air pollution causes more than 300 premature deaths, and results in increased numbers of reduced activity days and hospital visits, and higher usage of medications. It is estimated that the social cost from air pollution in Auckland is $1.07 billion per year.

6.2 Air quality monitoring programmes

Auckland Council's air quality monitoring programme consists of a combination of continuous monitoring, gravimetric particulate monitoring, meteorological monitoring, survey-type monitoring, passive monitoring, a visibility programme and special projects that include source apportionment studies. Each of these is described in the following sections. The spatial distribution of monitoring sites is illustrated in Figure 7.

6.2.1 Continuous ambient air quality monitoring programme

Continuous monitoring methods provide continuous records for each pollutant and can operate over extended periods (for weeks, months or years). Auckland Council has used continuous sampling methods for more than 10 years. After the national environmental standards for air quality were introduced in 2005, the Ministry for the Environment issued mandatory regulatory continuous monitoring methods (in accordance with Australia/New Zealand standards, and US Environment Protection Agency standards). These regulatory methods have a high degree of measurement precision but are the most expensive type of monitoring as they need a high standard of site and instrument management to obtain good quality data.

The Auckland Council monitor several pollutants at 14 sites around the Auckland region (13 permanent sites and one mobile site) as part of Auckland's continuous ambient air quality monitoring programme. The sites range in their scope and represent a variety of sources and exposures (from suburban residential areas to peak traffic areas). Most monitoring sites in the region are influenced by multiple

sources. Some sites are set up to monitor a single pollutant while others measure a suite of pollutants all on a continuous basis.

6.2.2 Gravimetric monitoring programme

The gravimetric particulate monitoring method involves a known volume of air being passed through a filter that is weighed pre and post sampling for a determined length of time (usually 24 hours). Both gravimetric and continuous methods have been used by Auckland Council to monitor particulates for many years. Auckland Council uses gravimetric particulate monitoring methods to collect filters which are analysed in a laboratory for particulates, airborne lead and other studies. Results from the analysed filter samples provide Auckland Council with an indication of localised air pollution sources across the region.

6.2.3 Passive monitoring programme

Auckland Council currently has three passive monitoring projects underway which include:

- VOC passive sampling
- BTEX passive sampling

6.2.4 Meteorological monitoring programme

Weather conditions can significantly influence the concentrations of air pollutants. It is therefore essential to monitor meteorological conditions along with ambient air pollutants at air quality monitoring sites to better understand pollutant sources, short-term pollution events, chemical reactions, trends in data and why exceedances of guidelines and standards have occurred.

Meteorological monitoring is co-located at all permanent and mobile sites along with the ambient air quality monitoring (with the exception of the Queen Street and Whangaparaoa permanent sites). The following meteorological parameters are measured at most sites:

- wind speed,
- wind direction,
- ambient temperature,
- relative humidity,
- solar radiation and
- rainfall.

6.2.5 GRIMM particulate monitoring programme

GRIMM samplers are light scattering instruments used to estimate particle numbers and mass, but have mostly been used to monitor dust in the workplace. The method is suited towards undertaking low-level survey work. The instruments that use light scattering techniques can measure particles smaller than $PM_{2.5}$. The GRIMM sampler is the only instrument available to Auckland Council that can measure these finer particles. The Auckland Council therefore uses the GRIMM sampler to identify mass concentrations of PM_{10}, $PM_{2.5}$ and PM_1, and count particle numbers which are used to ascertain trends in particulates in Auckland's air.

6.2.6 Industrial monitoring

Data collected from the air quality monitoring programme is used by Auckland Council regulatory officers to process air discharge consents. There are approximately 270 regulated industrial sites across Auckland that requires resource consent. Almost 200 of these sites are required to undertake some form of air quality monitoring for the application process (as part of an assessment of environmental effects) and/or as part of their resource consent conditions (undertaken by other independent organisations). In addition to this, some sites (depending upon the activity) have to also undertake stack and odour testing.

6.2.7 Transport projects

There are numerous air quality monitoring projects conducted by other government organisations in addition to Auckland Council's programme:

- NZ Transport Agency's (NZTA) NO_2 passive sampling network located near roads in order to capture the impact of road transport on air quality.
- NZTA's project monitoring before, during and after construction of major state highway projects (the State Highway 20 Waterview Connection project and the Victoria Park Tunnel project are both examples of these).
- Auckland Transport's project monitoring (formerly conducted by Auckland City Council) before, during and after construction on major roads in the region. The Central Connector project (formerly the Auckland Central Transit Connector) is an example of this.

Air quality monitoring data from these projects provide additional information on the state of air quality in Auckland.

6.2.8 Visibility camera network

Auckland Council operates visibility cameras which capture half hourly images of the city's skyline. The images captured by these cameras are used to monitor the development of brown haze and assess the number of brown haze days in a year for reporting under the Auckland Plan and for the *State of the environment* report.

There are three cameras located across Auckland at the following sites:

- Como Street in Takapuna
- Arataki Visitors Centre in the Waitakere Ranges
- Central Park on Great South Road in Penrose.

6.2.9 Special projects

Measuring the mass concentrations of particulate matter does not provide enough information on the contributing sources. The chemical composition and size of particulates can provide valuable details about the sources of these particles. In addition to routine monitoring activities, specialised monitoring projects are also undertaken by Auckland Council to help determine sources and pollutants that could pose a potential issue for air quality, and identify areas for further or future monitoring. Filter analyses and source apportionment techniques provide a means to determine the contribution of particles from various sources. These methods also assist the council in assessing localised air pollution sources, developing policy, and research and monitoring strategies.

6.2.10 Laboratory analysis programme

This programme involves the laboratory analysis of particulate matter collected on filters by the gravimetric monitoring programme using various techniques including the following analyses:

- Elemental analysis
- Ion analysis
- Black carbon analysis
- Organic and elemental carbon analysis.

6.2.11 Source apportionment programme

This programme involves the apportionment of sources from particulate matter collected on filters under the gravimetric monitoring programme using the source apportionment methods. Source apportionment is a type of receptor modelling which provides a way to quantify the contribution of sources on particulate matter. This is conducted by collecting filter samples of particulate matter at monitoring sites (using gravimetric particulate monitoring methods) and then analysed using statistical methods (such as the principle component analysis and positive matrix factorisation) for the identification of sources.

The programmes described above provides for comprehensive air quality monitoring for the Auckland region.

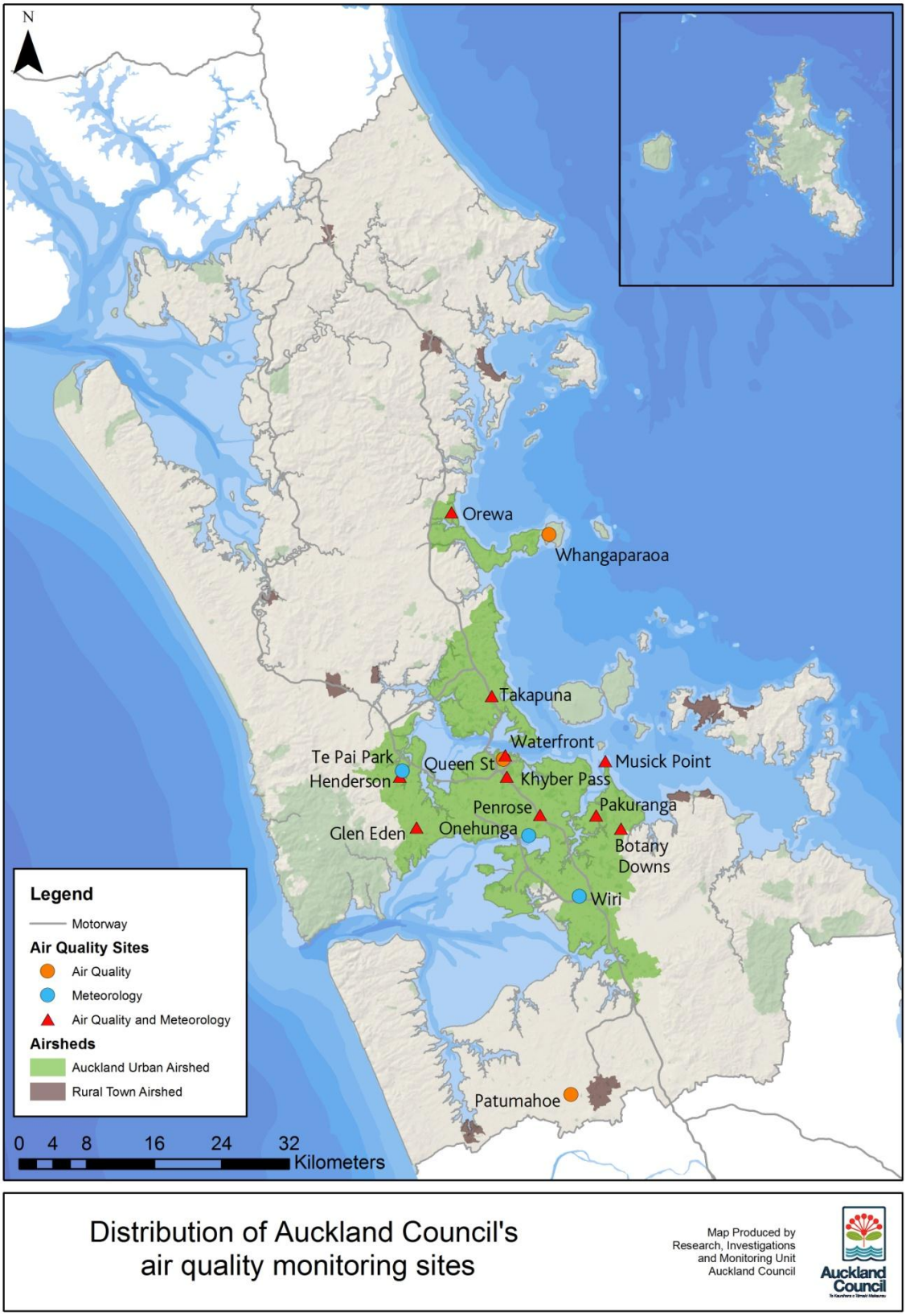

Figure 7. Map showing the 13 permanent sites and one mobile site in Auckland's airsheds.

7 Summary

Auckland Council's Research, Investigations and Monitoring Unit (RIMU) monitors a wide range of parameters across the five environmental resource classes, land and soil, terrestrial biodiversity, freshwater, marine, and air. All data are collected to high quality standards and are made freely available to scientists, policy makers and the public. Regular reports ensure the dissemination of knowledge gained from analyses of the monitoring data.

The data obtained from the monitoring programmes in the framework of this *Environmental monitoring plan 2014* provide valuable information on the state of the environment and any changes or trends. This creates knowledge about the drivers and responses of environmental change and helps evaluate the effectiveness of policies and plans. Considering the forecast population increase in Auckland and the modifications of the environment resulting from human settlement, monitoring and managing the natural environment remains important.

It is important to have a broad understanding of the linkages across the various environmental disciplines because changes occurring in one field can either directly or indirectly impact on the other and vice versa.

There is an integral link between what happens on land, what flows down streams and what ends up in the sea and human activity introduces an additional dimension to these interactions (Figure 1). Considering the enormous modifications that have resulted from human settlement in Auckland, the population continues to increase therefore monitoring and managing the natural environment remains important.

More information on the individual monitoring programmes can be found in the following documents:

- *Air quality monitoring plan* (in preparation)
- *Freshwater monitoring plan* (in preparation)
- *Land and soil monitoring plan,* TR2013/019
- *Marine monitoring plan,* TR2013/025
- *Terrestrial biodiversity monitoring plan* (in preparation)

Find out more: phone 09 301 0101
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Auckland Council
Te Kaunihera o Tāmaki Makaurau