

STATEMENT OF CORPORATE INTENT

JULY 2016–JUNE 2021

Mai i te rangi, ki te nuku o te whenua,
ka puta te ira tangata i te po,
i te whaiāo, ki te ao mārama.
Ko Te Pū Ao mātou.

From the sky and the land,
came people from the night,
from the old world, to the world of light.
We are GNS Science.



UPCOMING MILESTONES

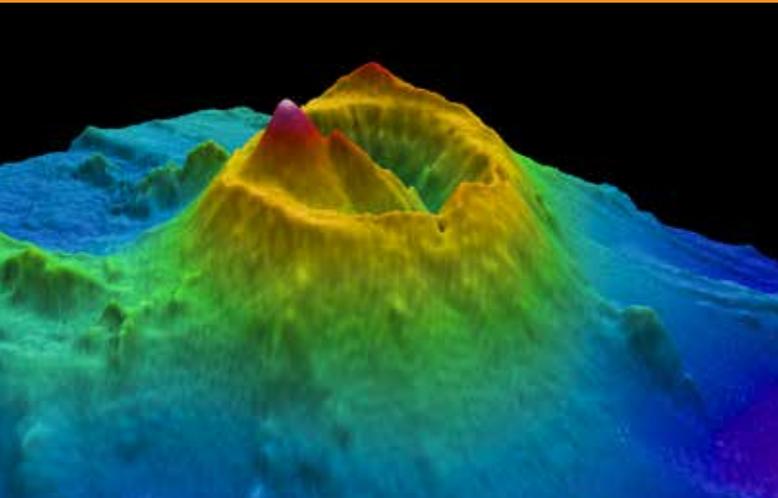
NEW DIGITAL PETROLEUM PROSPECTIVITY ATLAS

The first instalment of new map-based, digital geological data products will help to pinpoint oil and gas prospective areas in New Zealand's offshore territory. The 'atlas' will present the current geological understanding of the 18 mostly-offshore petroleum basins, for the first time in one place, in a standardised ARC GIS format. Included will be factors such as sediment thickness, and the distribution of potential source, reservoir and seal rocks. The main users will be companies seeking new opportunities in New Zealand, companies already here, and government agencies that administer permits.

NEW MAP FOR TONGARIRO NATIONAL PARK

GNS Science has plans to publish a new flagship geological map of the Tongariro National Park by December this year. New Zealand's oldest national park, Tongariro, is the most popular, with over a million visitors a year. The large colourful map, the first of its type for this area, will cover an area of 2000 square kilometres of the central plateau, with Ruapehu, Tongariro, and Ngāuruhoe volcanoes as prominent features. With a companion book supported by digital data in various forms, it will be well used by the tourism and hazard management sectors, as well as the public.

JULY 2016–JUNE 2017



PROBING SUBMARINE VOLCANOES

In late 2016, two major back-to-back German-New Zealand research voyages are scheduled to the Kermadec arc to investigate submarine volcanoes, seafloor mineral deposits, and the biology of this unique region. Lasting 11 weeks, the voyages will take place on the recently-built German research vessel *Sonne*. The first will use a remotely-operated vehicle to probe four hydrothermally-active submarine volcanoes. The second will investigate the tectonic history of the Kermadec arc to provide a better context for the modern-day geology and volcanism in this region.



NOVEL SOFTWARE TO QUANTIFY INFRASTRUCTURE LOSSES

GNS Science and partner organisations, Market Economics and Resilient Organisations, are completing development of a modelling toolkit that quantifies the economic implications of infrastructure failure from both natural hazards and infrastructure-only events. It also evaluates mitigation measures, recovery options, and policies to deal with such events. The Measuring the Economics of Resilient Infrastructure Tool (MERIT) boasts novel features that make it unique amongst this class of software. Users will include central and local government agencies and lifeline utilities looking to quantify resilience options.



BOOST FOR GEOTHERMAL ENERGY

An international consortium led by GNS Science is building new modelling software that will accelerate the development of geothermal resources worldwide. The powerful, open-source software will be particularly useful for New Zealand's geothermal industry, making geothermal development more efficient and more productive. It directly addresses two big challenges for the industry – improving the efficiency of existing fields, and developing reliable assessments of new geothermal resources. This contribution will help to meet New Zealand's target of generating 90% of our electricity from renewable sources by 2025.



BETTER DETECTION OF VOLCANIC UNREST

By 2018, we will be well advanced with development of remote and automated methods for monitoring the North Island's active volcanoes. Our GeoNet project will employ a range of sensing devices and drones for early and reliable detection of volcanic unrest. A greater flow of data from fumaroles and crater lakes, in particular, will enable faster and more-robust detection of volcanic unrest and the development of short-term forecasts and automated detection of eruptions. We will adopt a 'beta approach' with all new data being publicly available during the development phase.

JULY 2017–JUNE 2018



REVEALING OUR STORMY PAST TO INFORM OUR FUTURE

GNS Science is working with national and international partners to extend our knowledge of the potential impact of global climate change on the Southern Hemisphere mid-latitudes. Comprehensive knowledge of the drivers that influence New Zealand's climate is limited by the short duration of the instrumental records. This is being addressed via high-resolution climatic archives that span millennia. Through our sediment and ice coring programmes, we will provide detailed environmental observations from Antarctica and New Zealand that will help to reduce uncertainties in the climate models used for predicting future change.



PROBING THE HIKURANGI SUBDUCTION ZONE

In 2018, GNS Science will lead International Ocean Discovery Program (IODP) legs to drill the seafloor 50km east of Gisborne, using the US drilling ship *Joides Resolution*. This world-first initiative is aimed at understanding the mechanisms of slow-slip earthquakes. During 2018, we will also acquire 3D seismic reflection data as a prerequisite to proposed riser drilling, by the Japanese drillship *Chikyu*, of the slow-slipping Pacific Plate subduction thrust. As well as gaining a better understanding of plate-boundary earthquake behaviour, it is hoped the research will open the door to early warning of damaging earthquakes and tsunami.

GNS SCIENCE PROFILE

Institute of Geological and Nuclear Sciences Limited Trading as GNS Science

Head Office 1 Fairway Drive, Avalon, Lower Hutt 5010

Other Locations National Isotope Centre, 30 Gracefield Road, Lower Hutt 5010
Dunedin Research Centre, 764 Cumberland Street, Dunedin 9016
Wairakei Research Centre, 114 Karetoto Road, RD4, Taupō 3384

Postal Address PO Box 30368, Lower Hutt 5040

Web Address www.gns.cri.nz

Ownership Crown-owned entity, established under the Crown Research Institutes Act 1992

Board Chairman, Dr Nicola Crauford
Deputy Chairman, Hon Ken Shirley
Director, Mr Chris Bush
Director, Ms Sarah Haydon
Director, Ms Belinda Vernon
Director, Prof Steve Weaver

Executive Management Chief Executive, Dr Neal Wai Poi (acting)
Corporate Services Director and Chief Financial Officer, Mr Graham Clarke
Environment and Materials Division Director, Dr Chris Daughney
Geological Resources Division Director, Dr Kevin Faure
Natural Hazards Division Director, Dr Gill Jolly
External Relations and Commercialisation Director, Dr Neal Wai Poi

CONTENTS

Upcoming Milestones.....	2
Delivering On Our Vision	6
Statement Of Core Purpose	8
Operating Environment	10
Our Contribution To Government Priorities	14
Sector Priorities	16
National Science Challenges	22
Natural Hazards Research Platform.....	24
Te Whakatinanatanga O Te Tirohanga Mātauranga	26
Implementing Vision Mātauranga.....	28
Organisational Initiatives.....	30
Our Research	32
Horizon Scanning	66
Performance Monitoring.....	68
Financial Forecasting	70
Accounting & Business Policies	73



DELIVERING ON OUR VISION

Crown Research Institutes (CRIs) matter to New Zealand. Their importance is increasing as science plays an ever more-critical role in the nation's economic development. Research, and the other services provided by GNS Science, help address New Zealand's most pressing issues of achieving economic growth by making the tradable sector more productive, improving the sustainable use of natural resources, and managing exposure to risks that could otherwise destabilise society, the environment and the economy.

Earth is a mass of six billion trillion tonnes, held together by gravity and heated internally by radioactivity and externally by solar radiation. Gravity and heat drive plate tectonics, and the processes that generate and store energy, minerals, and water. These underpin wealth and life, and create the fertile regions that sustain our industries and people. Plate tectonics also creates the volcanoes, earthquakes, tsunamis, and landslides that threaten the industries and people that they sustain. We will meet New Zealand's need to discover and understand these Earth processes and materials, facilitating the application of this research in

accordance with the CRI Act, through our technology transfer (commercial consultancy and services) to achieve **Our Vision of a Cleaner, Safer, More Prosperous New Zealand.**

This Statement of Corporate Intent contains milestones for the period July 2016 to June 2021. Aligned with the Government's National Statement of Science Investment (NSSI), we will invest our resources to deliver excellent science and profound impact which, in line with our Vision, addresses the six Outcome Statements identified in our Statement of Core Purpose (SCP).

Our research, across four Core Science Areas and 12 Themes, is supported by a mix of funding from the Crown (core and contestable), EQC (support for GeoNet), and domestic and international clients (technology transfer).

Following on from 150 years of service to New Zealand, GNS Science will continue its evolution as a national science provider. In setting our direction for future research and development, we see opportunities to sharpen our focus, grow our partnerships and capability, improve our internal corporate culture, and enhance our national and international reputation.



To bring benefit to New Zealand, we must first understand how and why the world is changing, pro-actively respond and adapt to those changes in ways that are tailored to the nation's needs, and make the best decisions we can using the resources available to us.

In the 2016-2017 financial year, we expect MBIE Strategic Funding to provide around 33% of our total revenue, with the remainder coming from contestable (29%), EQC (14%), and technology transfer (24%) sources. We remain optimistic that the current downturn in consultancy

activity within New Zealand will reverse, and that our recent success in securing MBIE and Royal Society of New Zealand (Marsden) research contracts will continue, allowing us to deliver on the research described herein, and the array of impacts and benefits they promise.



Dr Nicola Crauford,
Chairman



Dr Neal Wai Poi,
Acting Chief Executive

STATEMENT OF CORE PURPOSE

GNS Science's purpose is to undertake research that:

- drives innovation and economic growth in New Zealand's geologically-based energy and minerals industries;
- develops industrial and environmental applications of nuclear science;
- increases New Zealand's resilience to natural hazards; and
- enhances understanding of geological and earth-system processes.

GNS Science will fulfil its Purpose through the provision of research and transfer of technology and knowledge in partnership with key stakeholders, including industry, government and Māori, to:

- OS1:** Increase resource security and economic benefit from the development and diversification of New Zealand's oil, gas, geothermal energy and minerals industries
- OS2:** Increase New Zealand's resilience to natural hazards and reduce risk from earthquakes, volcanoes, landslides and tsunamis
- OS3:** Improve the sustainable management of and increase economic returns from groundwater resources
- OS4:** Create value for New Zealand industry through the use of isotope and ion beam technologies
- OS5:** Increase understanding of the geology and past climates of New Zealand, the Ross Dependency and Antarctica
- OS6:** Enhance the geotechnical engineering that underpins New Zealand's transport and energy infrastructure

To achieve these Outcome Statements (OS), GNS Science is the lead Crown Research Institute in:

- » geothermal energy, oil, gas, gas hydrates (including carbon sequestration)
- » mineral and geobiological resources
- » geological hazards, risk mitigation and societal impacts of natural hazards
- » earth-system processes and landscape evolution
- » groundwater processes and quality
- » the geological component of global environmental processes and climate change
- » application of nuclear technology and isotope science and ion beam technology



GNS Science will work with other research providers and end-users to contribute to the development of:

- » high-value manufacturing
- » freshwater management
- » hazards management
- » ocean floor exploration
- » climate change adaptation and mitigation
- » Antarctica

GNS Science will:

- » operate in accordance with a Statement of Corporate Intent and business plan that describes how GNS Science will deliver against this Statement of Core Purpose, and describes what the shareholders will receive for their investment
- » meet its obligations as a Crown Company and remain financially viable, delivering an appropriate rate of return on equity
- » develop strong, long-term partnerships with key stakeholders, including industry, government and Māori, and work with them to set research priorities that are well linked to the needs and potential of its end-users

- » maintain a balance of research that both provides for the near-term requirements of its sectors and demonstrates vision for their longer-term benefit
- » transfer technology and knowledge from domestic and international sources to key New Zealand stakeholders, including industry, government and Māori
- » develop collaborative relationships with other CRIs, universities and other research institutions (within New Zealand and internationally) to form the best teams to deliver its Core Purpose
- » provide advice on matters of its expertise to the Crown
- » represent New Zealand’s interests on behalf of the Crown through contribution to science diplomacy, international scientific issues and/or bodies as required
- » seek advice from scientific and user advisory panels to help ensure the quality and relevance of its research
- » establish policies, practices and culture that optimise talent recruitment and retention

- » enable the innovation potential of Māori knowledge, resources and people
- » maintain its databases, collections and infrastructure and manage the scientific and research data it generates in a sustainable manner, providing appropriate access and maximising the reusability of data sets
- » seek shareholder consent for significant activity beyond its scope of operation

OPERATING ENVIRONMENT

In setting our investment priorities as laid out in this SCI, we take guidance from the NSSI 2015–2025, and the refreshed Towards 2025 Business Growth Agenda (BGA). We will meet the shareholders' expectation that investment in science be relevant to stakeholder needs, and contribute to New Zealand's economic, social, cultural, and environmental well-being. Emerging opportunities and challenges for New Zealand's use of its natural capital will increasingly demand the application of research carried out by GNS Science. Important is the increasing role of Māori in the management and economic use of geological resources, and the mitigation of natural hazards.

Evolution of the New Zealand science system, in particular the impacts of the National Science Challenges, changes in the operation of MBIE contestable funds, and enhanced expectations around the use of MBIE Strategic Funding, are factors in the constrained fiscal environment in which we will operate over the next five years.

Although Treasury has forecast positive economic growth over the next five years, we expect the spending of central and local government, and our New Zealand commercial clients, to be constrained. Low oil prices and flat domestic electricity demand persist, and this, together with a tailing-off of Canterbury earthquakes recovery work, is having a direct impact on our ability to earn New Zealand technology transfer revenue.

Countering this, we expect some modest revenue growth from the National Science Challenges as well as continued incremental growth from international technology transfer. Overseas contracts tend to be larger in size and longer term than domestic contracts, but timing is uncertain and there are additional risks involved in operating in foreign jurisdictions. We have a process for mitigating these risks, or declining to participate, as appropriate. This increased focus on the offshore allows us to continue the work started in 2015–2016 with the Government to Government (G2G) initiative for new offshore clients, and promotion of New Zealand Crown-funded intellectual property (IP) and expertise.

We have budgeted accordingly, with a forecast of modest revenue growth from \$83.2 million in 2016–2017 to \$87.5 million in 2019–2020.

Expenditure will remain under tight control throughout this period.

In setting our priorities, we consider the research and service needs of the main sectors we serve, and key Government strategies, to deliver maximum impact and, ultimately, outcome benefits for the nation. Maintaining our strong tradition of collaboration and stakeholder engagement will ensure that we tackle only the highest priority research. The research needs of Government, industry, and community partners are determined by various means. These include advice from our Strategic Science and User Advisory Panel, the Natural Hazards Research Platform (NHRP) Strategic and Technical advisory groups, programme-specific advisory groups, and sector-based strategic groups, e.g., Straterra, PEPANZ, the Land and Water Forum, and the



New Zealand Geothermal Association. We also obtain input to our research plans via regular engagement with government organisations and clients, such as EQC and Contact Energy, and through outreach.

We maintain cutting-edge research through regular participation at international conferences and membership of major international forums, such as the Global Earthquake Model (GEM), International Ocean Discovery Program (IODP) and the Intergovernmental Panel on Climate Change (IPCC). These interfaces also help to ensure that we collaborate widely with the national and international research community to form 'best teams' to provide comprehensive and effective science solutions.

On page 30 we outline strategies for building deeper relationships and collaborations with key stakeholders such as EQC, so as to secure longer-term funding streams. We are also seeking to open up new sources of revenue such as commercialisation of IP via engagement with Callaghan Innovation-initiated technology incubators.

Our Vision of a **Cleaner, Safer, More Prosperous New Zealand** translates into three Core Science Areas (CSAs), underpinned by a fourth. Twelve Themes describe the research undertaken across the CSAs, and these relate to 33 Impact Statements (see pages 37 to 65). Collectively, these encompass our full research capability, and underline our ability to deliver on our six SCP Outcome Statements (OS).

CSA1: Science for a Cleaner NZ

– providing critical information for more-effective management of climate and sea-level change, groundwater, air quality and land use [relates to OS3 and OS5]

CSA2: Science for a Safer NZ

– enhancing the nation's ability to understand, mitigate and communicate the effects of earthquakes, volcanic eruptions, tsunami, and landslides [OS2 and OS6]

CSA3: Science for a More Prosperous NZ – developing new knowledge and tools to enhance resource security and optimise the discovery and sustainable use of our geothermal energy, petroleum and mineral resources, and developing high-value materials and processes for industry [OS1 and OS4]

CSA4: Underpinning Geoscience Knowledge – assembling and managing comprehensive geoscience data, information and collections to underpin applied research, strategy and policy development, and decision making [OS1 to OS5]

CORE SCIENCE AREAS

THEMES

IMPACTS

SCIENCE FOR A CLEANER NZ

Past, Present & Future Climates

1. More-robust model predictions
2. Enhanced mitigation and adaptation strategies
3. Increased international research leverage

Air, Water & Land

4. Improved water management
5. Improved land-use policies
6. Greater societal empowerment
7. Improved air quality regulations

SCIENCE FOR A SAFER NZ

Hazard Monitoring

8. Effective response to hazard events
9. Timely response to hazard events
10. Meeting society's information needs

Understanding Hazards

11. Better mitigation planning
12. Enhanced global research presence

Assessing Risk

13. Enhanced risk analysis
14. Enhanced National Seismic Hazard Model

Societal & Economic Resilience

15. Better-informed policy development
16. Enhanced recovery from hazard events
17. Improved infrastructure design

SCIENCE FOR A MORE PROSPEROUS NZ

Renewable Geothermal Energy

18. Enhanced efficiency
19. Increased foreign earnings
20. Greater socio-economic benefits

Petroleum Resources

21. Increased exploration investment
22. Wealth and energy stability
23. Improved resource management

Mineral Resources

24. Enhanced offshore mineral prospectivity
25. Increased onshore exploration investment

New Materials & Processes

26. More efficient energy production and use
27. New high-value products and services for export

UNDERPINNING GEOSCIENCE KNOWLEDGE

Zealandia Revealed

28. Better asset management
29. Sustainable resource decision making
30. Better-informed strategies for disaster mitigation
31. Better understanding of megathrust risk

Geoscience Information

32. Advanced learnings
33. Informed risk management

Relative Investment



>\$4M

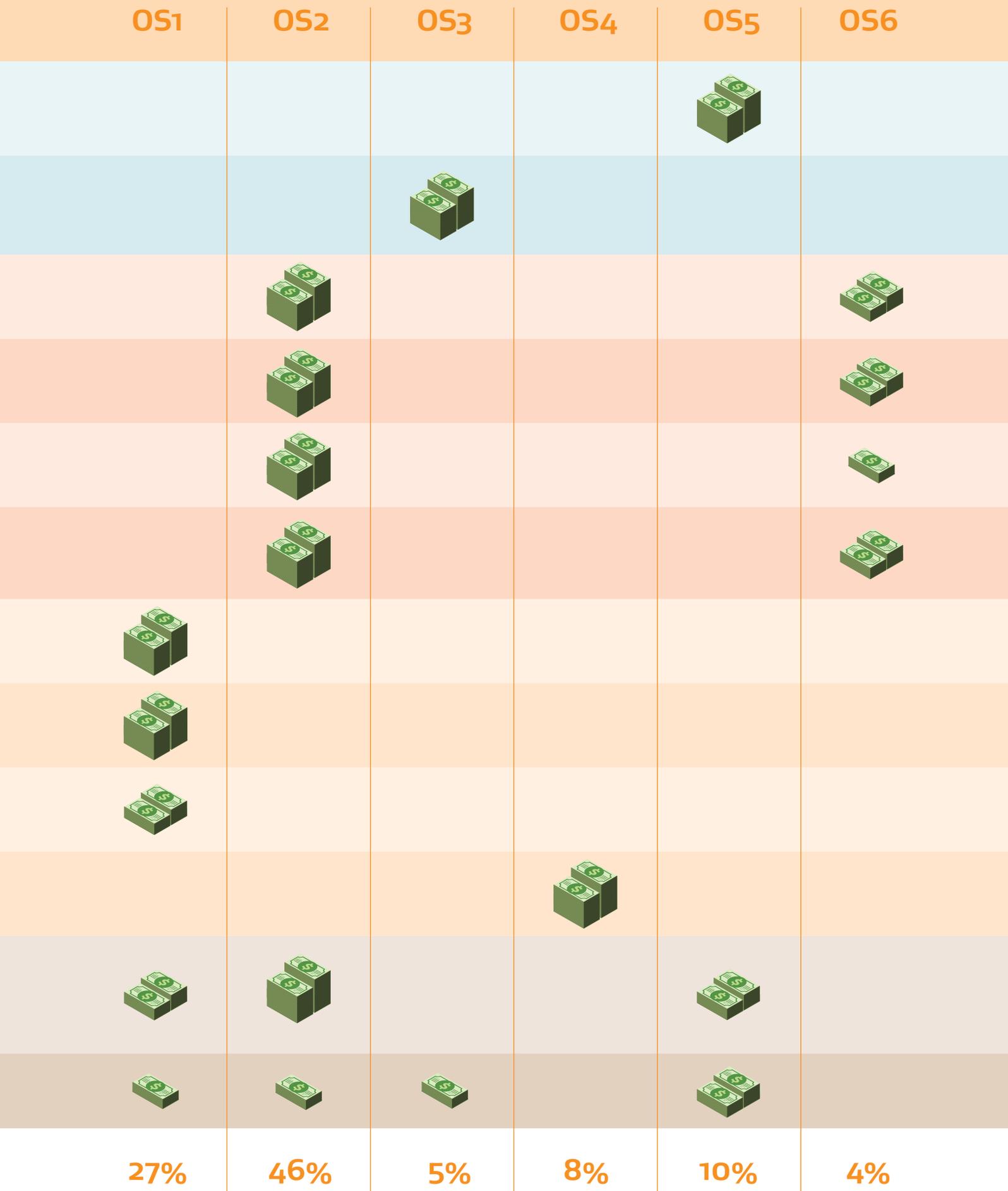


\$0.5-\$4M



<\$500K

SCP OUTCOME STATEMENTS



OUR CONTRIBUTION TO GOVERNMENT PRIORITIES

The NSSI confirms the dual importance of science excellence—peer-reviewed research of international quality, and impact—strong line of sight via end-users to eventual benefits for individuals, businesses or society.

NSSI Goals	Our Actions
A better-performing science system that is larger, more agile and more responsive, investing effectively for long-term impact on our health, economy, environment and society	<p>We will focus our activities to deliver on our Vision of a <i>Cleaner, Safer, More Prosperous New Zealand</i>, and apportion our resources appropriately.</p> <p>We will balance our activities to achieve immediate benefit and longer-term impact: c. 38% of revenue will be directed towards application and leverage of proven ideas (Horizon 1; time to impact 1–2 years); c. 50% towards development of emerging ideas (Horizon 2; time to impact 3–5 years); and c. 12% towards generation of new ideas (Horizon 3; time to impact 6–15 years). This revenue will be derived from an appropriate mix of core, contestable, and technology transfer projects (see bar graph, page 32).</p> <p>We will annually review and, where necessary, redirect our research to ensure responsiveness to New Zealand’s changing needs, with stakeholder input obtained via close alignment of our research activities with our commercial contracts. We will support innovation and agility by annually directing c. 9% of our MBIE Strategic Funding towards short-term (1–2 year) strategic development initiatives.</p>
Growth in Business Expenditure on R&D to well above 1% of GDP, driving a thriving independent research sector that is a major pillar of the New Zealand science system	We will transfer our scientific expertise to end-users, thereby assisting them to undertake in-house R&D. This technology transfer will occur through our commercial contracts with businesses, government agencies and foreign companies, joint research programmes with businesses, our partnership with the University of Auckland <i>Product Accelerator</i> , and our memberships of <i>KiwiNet</i> and <i>Return on Science</i> .
Reduced complexity and increased transparency in the public science system	We will ensure that our research outputs are accessible, and comply with the Open Government Information and Data Programme. All of our Nationally Significant Databases, along with several other key datasets, are already publicly accessible through web interfaces.



NSSI Goals	Our Actions
<p>Continuous improvement in New Zealand’s international standing as a high-quality R&D destination, resulting in the attraction, development and retention of talented scientists, and direct investment by multinational organisations</p>	<p>We will continue to demonstrate our, and New Zealand’s, high standing in the global scientific community through participation in high-profile international collaborations such as the Roosevelt Island Climate Evolution and Thwaites Glacier projects (see page 36), and IODP drilling of our submarine territories (see page 62). Confirmation has been received (May 2016) that the research ship <i>Joides Resolution</i> will undertake five back-to-back drilling legs, each of about two months duration, starting in August 2017. These will be focused on the Hikurangi megathrust, Brothers submarine hydrothermal system, Tasman Sea tectonic history, gas hydrates, and Ross Sea climate evolution. Cumulatively, these represent an investment of c. \$80 million in New Zealand science (c. \$20 for every dollar invested by New Zealand in the research).</p> <p>We will attract, develop and retain talented scientists by improving our remuneration system, updating our career path framework, and implementing a Future Leaders Programme (see page 30).</p> <p>We will actively work to maintain our reputation for science excellence, as reflected in our consistently top performance in Marsden bidding and delivery, and in international science quality and impact indicators, such as the ‘Nature Index’.</p>
<p>Comprehensive evaluation and monitoring of performance, underpinned by easily available, reliable data on the science system, to measure our progress towards these goals</p>	<p>We will enhance our own performance evaluation and monitoring by implementing our improved systems for integrated administration and reporting, document management, research reporting, and stakeholder engagement (see page 31).</p>

The BGA recognises that the future of New Zealand’s export-based economy is increasingly reliant on development of the manufacturing sector. That sector requires a clean natural environment, resilience to natural hazards, and secure access to energy and mineral resources. GNS Science

is thus positioned to support all six key inputs to the BGA to grow competitive businesses, particularly ‘natural resources’, ‘infrastructure’, and ‘innovation’. Research into New Zealand’s abundant geological resources, namely oil, natural gas, geothermal energy, and minerals,

aims to improve the country’s resource management system, build growth from more efficient land and resource use, and realise greater value from our freshwater resources.



SECTOR PRIORITIES

GNS Science's dual geoscience and industrial research focus means that we have needed to develop and maintain close relationships with a large number of end-user groups across a diverse range of stakeholder sectors. Engagement has taken place through technology transfer contracts, secondments, and joint projects, with many of our commercial clients also being the targeted end-users for our core and contestable research programmes. This has ensured that we have an excellent understanding of their research strategies and needs.

SCIENCE FOR A CLEANER NZ

Fresh water, clean air and sustainable environmental practice are vital to our social, cultural and economic well-being (cf. OS3). Those charged with managing the quality of water and air (principally the regional councils, territorial authorities, and Ministry for the Environment) require high quality, independent analysis on which to base their decisions. Climate change mitigation and adaptation have also become critically important global and regional environmental issues, requiring sound strategy and policy development (cf. OS5).

Much of the scientific advice currently offered on climate change is underscored by numerical modelling, which seeks to quantify impacts based exclusively on instrumental (historical) records. Such models fail to account for the evidence contained in ice and sediment archives extending back into geological time. These offer the only avenue to observe and examine Earth's longer-term environmental and biological variability. They also allow us to determine the rate and magnitude of the change that can occur beyond the relatively stable historical period monitored by instruments. Data gleaned from geological archives has, uniquely, shown that mean

sea level can vary by more than a few millimetres and mean surface temperature by as much as 6°C, in response to changes in atmospheric CO₂ concentration. Our internationally acclaimed **paleoclimate** research is, therefore, critical to refining and validating predictive climate change models. It provides essential observation-based data to identify the types and scale of change to which we will need to adapt in the future (see also page 36).



There are about 200 mapped aquifers in New Zealand. **Groundwater** supplies 35% of the water used domestically, and more than 80% of agricultural needs, especially in dry periods. Regional authorities have a statutory responsibility to maintain this water supply, and lean heavily on the data provided through active monitoring networks and aquifer case studies. At the national scale, 110 groundwater sites are monitored quarterly as part of the National Groundwater Monitoring Programme (NGMP), with each sample analysed for 25 parameters for long-term trends in water quality. The data provide a national baseline perspective on groundwater quality that differentiates between natural and human-induced change, and feeds into models and tools used to improve New Zealand freshwater management (free software for interpreting trends in groundwater quality is now used in 74 countries following its release in 2007). The Ministry for the Environment compiles a national report card on groundwater quality and quantity, which relies on NGMP data. Regional councils seek

advice and review on the operation of their regional groundwater monitoring networks, and changes in water chemistry related to land use, to allow them to work out the most effective management strategies to ensure sustainability. There is an identified need for information on the source, flow paths and transit times of water and key contaminants through groundwater systems, and identification of recharge areas, flow paths, mixing of ground and surface waters, seawater intrusion, and aquifer structure. For this, we employ a range of chemical and isotopic tracing and dating techniques. These can also contribute directly to environmental management (cf. OS3) by, for example, determining the sources of nutrients that contribute to toxic algae growth in rivers, or variations in the geochemistry of soils, with their attendant health or agricultural implications (see also page 38).

Urban **air pollution** is thought to be responsible for about 2300 premature deaths in New Zealand annually, as well as \$8.4 billion in health costs and lost productivity. Reducing particulate matter levels in the air will thus deliver major health benefits for local communities as well as the national economy, in terms of reduced respiratory disease. Using ion beam technology (IBT), particles trapped on air filters can be chemically analysed, and the relative contribution of different air pollution sources determined, such as vehicle emissions, domestic heating, industrial sources, sea salt, and wind-blown soil. Councils use the results to develop air-pollution mitigation measures and to track the effectiveness of these measures. IBT is also used to develop new materials or sensors, which are sought by New Zealand's manufacturing firms focused on environmental management (see also page 38).



SCIENCE FOR A SAFER NZ

New Zealand's location on an active plate boundary means that nature's forces can change our world dramatically at any time. As our population and cities grow, we become more at risk. Major geological hazard events have had, and continue to have, a significant impact on New Zealand's economy and social well-being. The total cost of the Canterbury earthquakes is likely to be at least \$25 billion. After the Boxing Day and Japanese tsunami, the Ministry of Civil Defence & Emergency Management (MCDEM) now rates tsunami alongside earthquakes in the 'potentially most dangerous' category. Volcanic eruptions are equally important, and the threat under our largest urban area, Auckland, is significant. The frequent eruptions from Tongariro are individually costly, causing disruption to air transport, agriculture and forestry over a wide area of the central North Island. The more we learn about such events, the better prepared we are to deal with them (cf. OS2).

New Zealand is one of many countries that this year (2016) signed up to a new global agreement on disaster risk reduction that will guide actions to reduce risk from natural disasters over the next 15 years. The Sendai Framework is a non-binding agreement that outlines seven targets and four priorities for action to prevent new and reduce existing disaster risks. Science is embedded throughout the Framework and there is strong recognition of the need for enhanced understanding of disaster risk and risk-informed decision making, especially at government level. The Framework aims to achieve: *A substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries.* The key stakeholders charged with delivering on the Sendai Framework – MCDEM, EQC and regional CDEM and lifelines groups – will require research information to inform the development of a national strategy for disaster risk reduction and resilience to support the Government's obligations. There is a need to reduce the economic and social costs of natural hazards through a robust evidence-base for determining priorities for action

across the full range of disaster-risk management options. These will involve land-use planning, engineering standards, emergency response planning, and risk transfer through insurance. Important research input will include improved understanding of the processes that cause earthquakes, tsunami, volcanic eruptions and landslides, and estimation of the size, frequency and potential impacts of each of these geological hazards.

High demand from civil defence agencies, the commercial sector and the public for the data it generates amply demonstrates the important role GeoNet plays in this country. Over the past 15 years, GeoNet has become a household name, and an international exemplar of how to monitor geological hazards and provide timely information to the people who need it. New Zealanders can now see where an earthquake occurs and the magnitude of the shaking in their neighbourhood within seconds on their mobile devices. Continuing and increased support from its sponsor, EQC, will ensure that GeoNet continues to enhance its delivery and range of services (see also pages 30 and 42).



Determining the rupture history of **earthquakes** on the Alpine Fault (the South Island's largest source of earthquake hazard) and the Hikurangi subduction zone (the North Island's biggest risk), is key to understanding where and when future earthquakes will occur, and what their impacts are likely to be. Modelling the likelihood of future seismic activity and the effects of ground shaking is important information for the development of hazard mitigation strategies. Earthquake engineering research feeds into structural design standards, enabling structures to be built to withstand earthquake shaking for a given location, leading to a safer built environment and faster recovery in the event of a natural disaster.

Propagation models showing how **tsunami** travel across the Pacific Ocean and impact on our coast help authorities to prepare coastal communities. When a large sub-seafloor earthquake occurs in the Pacific, the best matching model is quickly found to obtain a first approximation of what the likely impacts will be in New Zealand. This is communicated to MCDEM and other agencies, as every minute of advance warning can make a difference in terms of public safety. As fresh information comes to hand

on the size, location, depth and style of an earthquake, the model can be refined to give updated information on the arrival time and likely effects. Given our long coastline, increasing the sophistication of such models becomes ever more important as our coastal communities grow in size and become more at risk.

New Zealand has ten **volcanoes** that are considered active, and they present a wide range of potential hazards. Tāupo Volcano is the world's most dangerous volcano in terms of the size of the eruptions it has produced historically, so the threat must be taken very seriously. There is permanent surveillance operating at the active volcanoes to detect early signs of volcanic unrest. Research focused on sub-surface processes and plumbing systems, and on the impacts of eruptions on infrastructure and people, is necessary for the development of eruption scenarios for emergency management and risk assessment models.

Unstable geological conditions, heavy rain, earthquakes, and human-induced landscape changes can trigger **landslides**. Expertise in geomorphology and engineering geology enables strategies for reducing the impacts of slope failures and landslides to be developed. As well, there is a need to identify and quantify landslides and their triggers, design safer slopes, assess risk, monitor unstable slopes, understand landslide movement mechanisms, and consider social impacts.

Loss modelling helps to quantify the impact of natural disasters on infrastructure and people, providing quantitative estimates of likely damage, loss of assets, and casualties, critical for risk management, hazard planning, and insurance assessment. Disaster risk reduction and resilience can only be achieved through understanding how society interacts with natural hazards and disasters. It is important to understand what contributes to effective land-use planning for natural hazards, how agencies and the public understand and respond to threats, and the attributes of an effective recovery (see also page 48).



SCIENCE FOR A MORE PROSPEROUS NZ

New Zealand is relatively well endowed with natural energy and mineral resources, which collectively are important contributors to the wealth and energy security we expect as a first-world nation. The knowledge base and intellectual capacity within the resource sector is critical to support the Government's overarching goal, espoused in the New Zealand Energy Strategy 2011-2021, to grow our economy to deliver greater prosperity, security and opportunities for all New Zealanders (cf. OS1 and OS4).

Renewable geothermal energy is a critical component of New Zealand's electricity generating capacity at around 16%; behind hydro, and well ahead of wind. Geothermal energy is reliable, clean and cost-effective and provides a consistent energy flow day and night, in any season and in any weather. Research is essential to maintaining the viability of the industry, and increasing investor/developer confidence by reducing technical risks of exploration. For example, field and laboratory investigations shed light on rock permeability and sub-surface fluid

flow pathways, making successful drilling targets more-likely to be successful. Finding new ways to modify the internal surfaces of geothermal pipes to prevent the build-up of minerals increases operational efficiencies at power plants. Investigation of hotter and deeper geothermal resources (3–5 km deep) is the key to opening up future, more sustainable resources. The abundance of high-temperature geothermal resources in the central North Island means geothermal is the lowest-cost electricity generation option to build and operate. With well-targeted research, geothermal energy is on course to help New Zealand achieve its goal of having 90% of our electricity supply generated by renewables by 2025 (see also page 54).

Local oil and gas (**petroleum**) production contributes between \$2 billion and \$3 billion per annum, directly and indirectly, to New Zealand's economy. This includes about \$300 million in company tax from exploration and production companies and almost \$400 million in royalties and energy resource levies from oil and gas production. At \$1.42 billion pa, petroleum is one of New Zealand's top commodity exports by value. Oil is a

commodity with high intrinsic value and locally-produced oil helps to offset oil imports. Natural gas will continue to be an important base-load and peak-load fuel (and replacement for coal) for electricity generation as the world transitions to a low-carbon economy, and an important feedstock. *Methanex NZ*, one of the world's largest producers of methanol, uses natural gas to manufacture methanol, itself a major chemical feedstock and an increasingly important, clean transport fuel. *Ballance Agri-nutrients* also uses natural gas to manufacture ammonia and then urea for use domestically as farm fertiliser and feedstock. Increased methanol production and floating Liquefied Natural Gas (LNG) technology provide key export avenues for any significant future gas discovery.

New Zealand is lucky to have a natural endowment of petroleum, but the full extent of this resource is far from known. Petroleum exploration is a global venture and New Zealand has to compete with other jurisdictions to attract investment. The perception of New Zealand basins as gas-prone theoretically helps our status as an exploration destination. Whilst there is consensus that our 18 sedimentary



basins contain the ingredients for world-class petroleum fields, their geology is complex and recent wells have been unsuccessful in finding new reserves. The geoscientific search for drilling targets is increasingly sophisticated, and there is still much to learn about the habitat, occurrence and movement of petroleum in our sedimentary basins. A key role for publicly-funded research is in establishing the geoscientific basis for understanding, defining and predicting the oil and gas potential in our sedimentary basins. This research is essential in helping to attract exploration investment and building industry critical mass, to improve the likelihood of petroleum discoveries within New Zealand's jurisdiction. Investigation of unconventional energy resources such as gas hydrates (methane-rich icy deposits beneath the seafloor) off the North Island's east coast also presents an opportunity. New Zealand has some of the most extensive and highly concentrated deposits of hydrates in the world; the potential size of this resource is enormous, even if only a fraction of it can be commercially recovered (see also page 54).

Mineral exploration and discovery remains a fledgling industry in New Zealand, especially in our Exclusive Economic Zone (EEZ) and extended continental shelf (ECS). Onshore minerals, including aggregate for roads and construction, limestone for agriculture, and gold, silver, iron sands, clay and zeolite for export, have a combined production value of \$2 billion pa. Seafloor deposits, yet to be commercially extracted, include phosphorite, iron sands, and metal-rich accumulations (massive sulphides) associated with sea-floor hydrothermal vents. There is a need to discover the geological processes of mineralisation and use this to identify the extent and grade of mineral resources both onshore and offshore. This is crucial for appraising and managing these resources, and for mining with minimal environmental impact. Digital map products are also required to promote knowledge and understanding of mineral accumulations and their host regions. Massive sulphide deposits occur along a chain of about 80 submarine volcanoes between New Zealand and Tonga, an area seen as a new frontier in mineral exploration, and also of high environmental value. Since the mid-1990s, these have been systematically

explored and mapped, with the research shedding light on their size and economic potential. Such data are critical for making informed decisions on whether these seafloor deposits could, or indeed should, be harvested (see also page 56).

Niche capability in **isotope and ion beam technologies** (cf. OS4) has the capacity to create value for New Zealand industries, building competitive export commodities from the primary sector. An example is the use of isotope methods to authenticate the source of high-value food or beverage products such as mānuka honey and orange juice, to check they are 'true to label' and meet export criteria. Ion beam techniques can also be used to develop new materials with characteristics such as increased hardness and wear resistance, hydrophobicity, or magnetic properties. The New Zealand manufacturing sector makes use of such new materials in, for example, high-value products for harvesting waste heat, improving the energy efficiency of heating and cooling processes, and developing new sensors and sensor systems (see also page 58).



NATIONAL SCIENCE CHALLENGES

Appreciating the important role that they play in underpinning the Government's socio-economic agenda, we are an active partner in seven of the eleven National Science Challenges (NSCs). We host *Resilience to Nature's Challenges* due to our wide knowledge of natural hazards and their societal risks and impacts.

Our understanding of soil degradation, groundwater and geomicrobiological systems are germane to *Our Land & Water* and *New Zealand's Biological Heritage*. Our ion-beam capability in materials and atmospheric science will add value to *Science for Technological Innovation* and *Building Better Homes, Towns and Cities*. *Sustainable Seas* and *Deep South* will also benefit from our knowledge of seabed and sub-seafloor geology, and from our carbon-cycle research and analysis of past climate, which can enhance predictive models of future climate.

Resilience to Nature's Challenges NSC

Resilience to Nature's Challenges, Kia manawaroa – Ngā Ākina o Te Ao Tūroa, launched in June 2015, has a research programme aimed at improving New Zealand's preparation, response and adaptation to a range of geological and weather hazards. Departing from traditional single-risk models, the '*Resilience*' NSC is focused on building broad-spectrum resilience for our unique rural, urban and Māori communities to multi-hazards,

including weather and rural fire, exacerbated by climate change. There is a special emphasis on extreme-risk communities, such as vulnerable coastal margins. The overarching mission of the *Resilience* NSC is to: *Partner with multiple stakeholders to generate new co-created research solutions to inform how New Zealand builds a transformative pathway toward natural hazard resilience.*

The *Resilience* NSC formal partnership includes six universities — Auckland, Canterbury, Lincoln, Massey, Otago and Victoria — three CRIs — GNS Science, NIWA and Scion — and two private research organisations — BRANZ and Opus. The initial research programme includes over 80 scientists from these and another 10 organisations, notably Landcare Research, University of Waikato, Market Economics and Resilient Organisations. The team is a true multi-skilled mix of physical science, Māori, engineering, social science, economics, and business and enterprise researchers. The science work programme consists

of four 'Priority Laboratories': *Vision Mātauranga; Rural Resilience (including fire); Urban Resilience; and Living on the Edge*. These are underpinned by six 'Toolbox Programmes': *Resilient Governance; Infrastructure; Economically Resilient New Zealand; Resilience Culture; Hazards; and Resilience Trajectories*.

The *Resilience* NSC, initially, has a 10-year lifespan with \$19.6 million in Government funding for its first four years. It will develop new science-backed approaches to resilience, and fast track their implementation. The planned research will extend beyond defensive and adaptive approaches to make New Zealand a safer place to live and a more attractive, lower risk investment opportunity. By active partnering with stakeholders, the co-investment into resilience-building initiatives is expected to far outweigh the Government research investment and generate more enduring co-created science solutions.



The *Resilience* NSC will be an important vehicle to build the next generation of researchers in natural hazard resilience, with over 20 doctoral students included in its first phase.

As host of the *Resilience* NSC, GNS Science has responsibility for financial management and coordination of the partnership to deliver on the *Resilience* NSC mission against a series of outcome-based key performance indicators. This is supported by a full formal partnership agreement. A Challenge Manager has been appointed to support the Director, and a Governance Group of experienced senior independent members will drive the strategic direction.

July 2016 will herald the first full year of *Resilience* NSC operations, with all research planning completed, and sub-contracting underway for the research programmes. Planned developments over the coming year include:

- » A symposium held to present highlights of science programmes to stakeholders, at which several key international thought leaders and innovators will participate in the mapping of resilient futures thinking in a New Zealand context;
- » A contestable funding round involving \$1.8 million, some of which will be directed at encouraging new players and emerging researchers to join the *Resilience* NSC;
- » Development of a plan for integrating the Natural Hazards Research Platform with the *Resilience* NSC (by 2019); this will involve a joint effort by the management teams, the Governance Group, and the related strategic and technical advisory groups, research partners and stakeholders;
- » Quarterly meetings of the Governance Group to oversee the work programmes and management of the *Resilience* NSC (with reporting to the GNS Science Board); and
- » Monthly meetings of the science leaders for each of the 10 programmes to ensure the research continues to be aligned and integrated.



NATURAL HAZARDS RESEARCH PLATFORM

GNS Science is host of the Natural Hazards Research Platform, a consortium of Government-funded science providers dedicated to increasing New Zealand's resilience to natural hazards. Established in October 2009, the Platform brings together integrated hazard and risk expertise from GNS Science, NIWA, University of Canterbury, University of Auckland, Massey University, and Opus. A number of other universities, consultancies, and international partners are also involved as sub-contractors or through aligned research programmes.

The Platform is charged with providing the best science advice possible in the national interest, and research aligns with the strategies of Government agencies responsible for reduction, readiness, response and recovery. The aim of the Platform is to contribute directly to improved economic, infrastructural and societal resilience to natural hazards in New Zealand. The science capability supported by the Platform is available to assist decision-makers during significant hazard events.





The programmes of research are underpinned by aligned MBIE Strategic Funding at GNS Science (see pages 44–49) and NIWA, and by six long-term (2015–2019) research programmes led by the non-CRI partners, covering a range of hazard and engineering topics. These projects and the lead organisations are:

- » Climate Change Impacts on Weather-related Hazards (University of Auckland);
- » Tools and Knowledge to Improve New Zealand’s Long-term Resilience to Wind Storms (Opus);
- » Volcanic Risk: From Hazards to Impacts (Massey University);
- » Building Quake and People – A Serious Game Platform for Informing Life-Saving Strategies (University of Auckland);
- » Research-informed Advancements in Guidelines and Standards of Engineering Practice for Natural Hazards (University of Canterbury); and

- » Building to Recover: Quantifying and Predicting the Role of the Built Environment in Social and Economic Recovery (Opus).

In addition, the Platform has 13 projects under contract via its contestable process (2015–2017) covering a range of hazard, engineering, and economics topics. These projects and the lead organisations are:

- » Paradigm of Alpine Fault Paleoseismicity (GNS Science)
- » Shaken and Stirred: Okataina Caldera (GNS Science)
- » Unknown Faults Under Cities (GNS Science)
- » Modelling Earthquake Engineering Seismic Parameters (GNS Science)
- » Southern Lakes Tsunami Hazard (NIWA)
- » High-water Red-alert Calendar (NIWA)
- » Offshore Marlborough Faults (NIWA)

- » Faster Flood Forecast (NIWA)
- » National Volcano Hazard Model (Massey University)
- » Large-scale PDC Hazard Impact Simulations (Massey University)
- » Coupled Soil-Foundation-Structure Systems Earthquake Response (University of Auckland)
- » Seismic Hazard of Kekerengu Fault (Victoria University of Wellington)
- » Disaster Risk Full Cost Accounting (Resilient Organisations)

The next contestable research funding round will be conducted in early 2017, for research to be undertaken through to 2019.

TE WHAKATINA- NATANGA O TE TIROHANGA MĀTAURANGA

E manawanui ana a GNS Science ki te whakawhanake i ngā kōtuinga Māori kia tautohu ai i ngā whāinga ā-iwi, ā, kia mahi ngātahi ai māua kia whakatutuki i aua awhero.

He rautaki umanga māori tā GNS Science, ā, ko te tikanga kia whangaia ai ngā kōtuinga a mātou ko ngā rūnanga Māori, ko ngā pakihī Māori, ko ngā tiakitanga Māori hoki. Ko te whakaaro kei te pūtake o Te Rautaki Umanga Māori (TRUM) ki te “whakapuāwai i te whakawhanake Māori.” Ko te tirohanga rautaki kia whakapakari ai i ā mātou whakahaerenga, kia whakatinana hoki ai i ngā kōtuinga Māori.

E miramira ana tēnei rautaki i te whakahirahiratanga o te whāngai i tā mātou whakawhanaunga ki Ngāi Māori. Mā te taunaki i ngā whāinga ā-ōhanga, ā-pāpori, ā-tikanga, ā-kaitiaki o te iwi Māori, ka whakawhanake i tā māua nei kōtuinga pakihī.

Ka whakawhanake i te tā māua ko Ngāi Māori kōtuinga pakihī, mā;

1. Te whakamana i tō māua ko Ngāi Māori whakawhanaungatanga, mā te tohatoha hoki i ngā kōrero kia mārama ai te katoa
2. Te whakapakari i ngā whakahaerenga, i ngā tikanga hoki kia tū māia i roto i tō mātou mahi, kia tautoko pai ai i Ngāi Māori
3. Te whakamōhio atu ki Ngāi Māori mā ko wai mātou, he aha hoki ā tātou nei mahi hei tautoko i a rātou
4. Te whakapakari i ō mātou kaimahi, i tō mātou mātanga i te ao Māori
5. Te tohatoha i ō mātou mātauranga hei tautoko i te whakawhanake Māori.

Kei te aro whakamua Te Rautaki Umanga Māori, ā, e tīaroaro ana ki te tirohanga mātauranga, ki ngā wero pūtaiao ā-motu, ki te rautaki ōhanga Māori, ki ngā whakakaupapa Māori, ki tā mātou rautaki whakahaere ā-motu. Ka mahi ngātahi ā mātou kaimahi rātou ko Ngāi Māori kia whakatinanatia ai ngā whāinga Māori.

I te wā nei, mā te pūtea tirohanga mātauranga a te MBIE, ka whakahaeretia ētehi whakatakanga e mātou ko Ngāti Kahungunu, ko Whakarewarewa, ko Ngāti Rangiwewehi hoki (tirohia te wāhanga whā hei whakakikokiko i ēnei kōrero). Mā ēnei whakatakanga ka whakawhanake haere i te rangapū o māua ko Ngāi Māori kia whaihua.



Ko te pāhekoheko i ngā iwi Māori kei te marae

E whakahaere ana māua ko Ngāti Kahungunu i tētehi whakatakanga kia whakatewhatewha ai i ngā hononga o te mātauranga pūtaiao ā-nuku ki tō te mātauranga ā-iwi. Mā te pūtea matua, ka whakaako ā-tinana i ngā mātauranga pūtaiao e hāngai ana ki te hinu urutapu, ki te hōpara kapuni, ki te whakarerekē āhuarangi, ki ngā mōrearea ā-taiao hoki. (Kua whakamihi mai tētahi kaumatua o Ngāti Kahungunu, a Aki Paipa, “I a mātou e tiroiro haere ana i tō mātou nei whenua, ko tā ngā kaimahi o GNS mahi kia whakamārama ia i nekehanga ā-taiao o mua nei, o āiane hoki. Ki tōku nei whakaaro, rawe ana tō rātou whakawhānui i tō mātou tirohanga i te ao pūtaiao.” Mā te pūtea tirohanga mātauranga ka taea e mātou te tohatoha tēnei whakatakanga ki iwi kē hei ngā tau e rua kei te heke mai.

Ko te rangahau ngātahi i te parahanga ā-hau

E whai mārama ana a GNS Science mātou ko te papakāinga o Whakarewarewa ki Rotorua, ko Ngāti Rangiwewehi ki Ngongotaha i ngā take parahanga ā-hau, inarā, kei ngā huarahi matua. Mai i te mutunga o te tau rua mano, tekau mā whā whakamātau ai mātou i te hau kei Te Mātāpuna o Papatūānuku (GNS Science House). E hono ana tēnei whakatakanga ki ā mātou kaupapa matua, ki te tirohanga mātauranga hoki. Ko te tikanga ka mahi ngātahi ai a GNS Science māua ko te Whakarewarewa Village Charitable Trust kia kōtuitui ai i ngā mātauranga pūtaiao ki te mātauranga ā-iwi e hāngai ana ki te hau e pupuhi mai ana i Te Rotorua nui a Kahumatamomoe.

E rua ngā wā ia wiki, ka arohaehae ngā tātari ā-hau i te hau kia whakamōhio ai i ngā parahanga, ā, nō hea hoki aua pūmotu. Ko ngā hua kua puta mai ko te kohikohinga i ngā mātauranga Māori e hāngai ana ki tēnei takiwā, otirā ko ngā nekehanga a Rūaumoko, ā, ko ngā hononga ki tā te mātauranga pūtaiao. Ka taea e te katoa te kite i taua tātari ā-hau kei te whare o GNS ki te papakāinga o Te Whakarewarewa, ā, ki tā tō mātou whakaaro ko te tikanga o tēnei mahi kia whai wā ai mātou ki te whakawhānuitia tā tātou nei tirohanga pūtaiao i tēnei tāonga, a Te Whakarewarewa.



IMPLEMENTING VISION MĀTAURANGA

GNS Science is committed to developing partnerships with Māori to identify iwi aspirations and to work jointly towards realising them.

Beginning in 2016–2017, GNS Science will implement a Māori strategy (Te Rautaki Umanga Māori - TRUM), which seeks to encompass a range of relationships with various Māori organisations including iwi, businesses and trusts. The overarching vision for TRUM is ‘Unlocking the GNS Science potential to accelerate Māori development’, which is as much about unlocking our own potential as it is about deepening our key existing relationships with Māori.

We will achieve this through:

1. Mana-enhancing relationships and the sharing of information (manākitanga)
2. Strengthening of our internal processes (Tikanga) and policies to improve our service delivery, research and responsiveness to Māori
3. Being more visible to Māori, Māori knowing who we are and what we do, and by promoting science (and GNS Science) into Māori communities
4. Strengthening our people (whakapakari tāngata) and professionalism in the te ao Māori space
5. Ensuring the technologies that GNS Science is aware of are available to support Māori development

TRUM is forward looking and aligns with Vision Mātauranga, the National Science Challenges, the Māori Economic Strategy, iwi planning, and our own organisational strategy. Our staff work closely with Māori trusts, iwi, and businesses, to help realise Māori aspirations and test innovation.

Currently, a number of MBIE-funded Vision Mātauranga Capability Fund (VMCF) projects are underway, in conjunction with Ngāti Kahungunu, Whakarewarewa, and Ngāti Rangiwewehi. These and other projects in the pipeline (see pages 36 and 38) will build on the understandings from past successful projects. They seek to forge even closer, productive relationships that effectively meld our scientific know-how to that of iwi to achieve mutually beneficial outcomes.



Marae-based iwi engagement

GNS Science and Hawke's Bay iwi, Ngāti Kahungunu, are undertaking a programme to explore the connections between Earth science and mātauranga-a-iwi (traditional knowledge). Through a MBIE Strategic Funded pilot programme, a hands-on approach was identified as being a very effective way of demystifying the science behind topics, such as oil and gas exploration, climate change, and natural hazards. Ngāti Kahungunu elder Aki Paipa has praised GNS Science staff for their 'down-to-earth approach': "When we did the practical part of the pilot workshops we went out into the field, and they explained things that we could relate to ... the different features of the land, what's happening to the whenua, and what had happened in the past. I thought they did a really good job of helping lay people to get a glimpse of the scientific world." The new VMCF project will allow this initiative to be extended to other regions.

Partnership in tracking air pollution

GNS Science is working with Whakarewarewa Village in Rotorua and Ngāti Rangiwewehi at Ngongotaha to better understand air pollution issues, particularly on high-pollution days. Air at Whakarewarewa has been sampled at Te Mātāpuna o Papatūānuku (GNS Science House) since late 2014. The VMCF project links to other MBIE Strategic Funded initiatives in which GNS Science and Whakarewarewa Village Charitable Trust work together to demonstrate a framework for integrating scientific data and mātauranga-a-iwi to better understand the air quality in Rotorua. Twice weekly, special air filters are analysed for 30 different chemical elements, shedding light on where air pollutants are coming from.

The project has mutual benefits, providing insights into Māori understanding of earth and physical sciences, corroborating historical volcanic events, extending Māori appreciation of Earth science, and identifying new research opportunities. This air pollution

sampler is on permanent display at the GNS Science House at Whakarewarewa Village and is viewed daily by tourists and other visitors. We see this as an excellent opportunity to work with a community that is concerned about their environment, as well as contributing to maintaining the cultural importance of the Whakarewarewa Village.

ORGANISATIONAL INITIATIVES

Our Vision focuses on core priorities for New Zealand, for the next five years.

Sustaining a high performance culture

GNS Science is committed to building an organisation of talented, diverse and capable leaders and staff. We want a workplace environment in which our people feel empowered, valued and supported. We will achieve this by focusing on four key strategies: 1. Developing our people; 2. Driving performance excellence; 3. Creating an engaged workforce; and 4. Developing effective systems and processes.

Activities in 2016–2017 aimed at addressing these include:

- » Continuing to use Workforce and Succession Planning to assess capability and capacity gaps, to build a strong talent pipeline to meet future needs
- » Developing leadership capability at all levels in the organisation, leading to a 'Future Leaders Programme'
- » Developing initiatives to promote, celebrate and recognise excellence
- » Working with managers and staff to improve levels of engagement
- » Enhancing systems and processes linked to performance management to ensure they are easy to understand, transparent and have clear links to strategy and priorities

Enhancing external relations and collaboration

By creating value through close engagement, and linking our business with our stakeholders, we will see greater awareness and appreciation of our science by all New Zealanders. We will incorporate more outreach activities into our research, building on our success with MBIE-funded *Unlocking Curious Minds* projects. Positive outcomes include being widely respected by stakeholders as a trusted advisor and the first port of call for solving their problems, and being regarded as an innovative company.

EQC recently approved a five-year renewal of funding for GeoNet. The funding has increased to \$11.6 million in 2016, with further increases to \$13.2 million by 2021. A formal review of the governance arrangement of GeoNet and signing of the new evergreen contract is scheduled for 2016–2017. Therefore, we will be able to maintain our excellent stewardship of the GeoNet project. We will use the additional investment to continue to move GeoNet forward through streamlining our current operations and updating our monitoring network. Work will start on our longer-term goal to accurately and automatically detect eruptions at New Zealand's most active volcanoes (see page 42). This includes development of forecasting tools that assist decision-making once

an eruptive sequence is under way. We will investigate the feasibility of a 24/7 geological hazard monitoring centre for New Zealand in collaboration with EQC, MCDEM and other stakeholders. One benefit of such a centre would be to reduce the time taken to provide critical information to stakeholders on natural hazard events.

Through participation in Centres of Research Excellence ('MacDiarmid Institute' and 'QuakeCore'), University of Auckland's Product Accelerator, the National Science Challenges and the Natural Hazard Research Platform, we will make further progress in removing barriers to science and technology partnerships.

Maintaining research funding

We will maintain research funding at a level that fully supports our SCP. We will continue to make effective use of core and contestable funding aligned with stakeholder funding to address issues of national importance. Coupled with further streamlining of the ONCE system for greater efficiency (see below), this will ensure a robust and enduring skill-base to underpin our technology transfer capability. A stage-gate process aimed at enhancing research proposal quality, and reducing administration costs was trialled in 2015–2016 and will be improved and more fully implemented in 2016–2017.



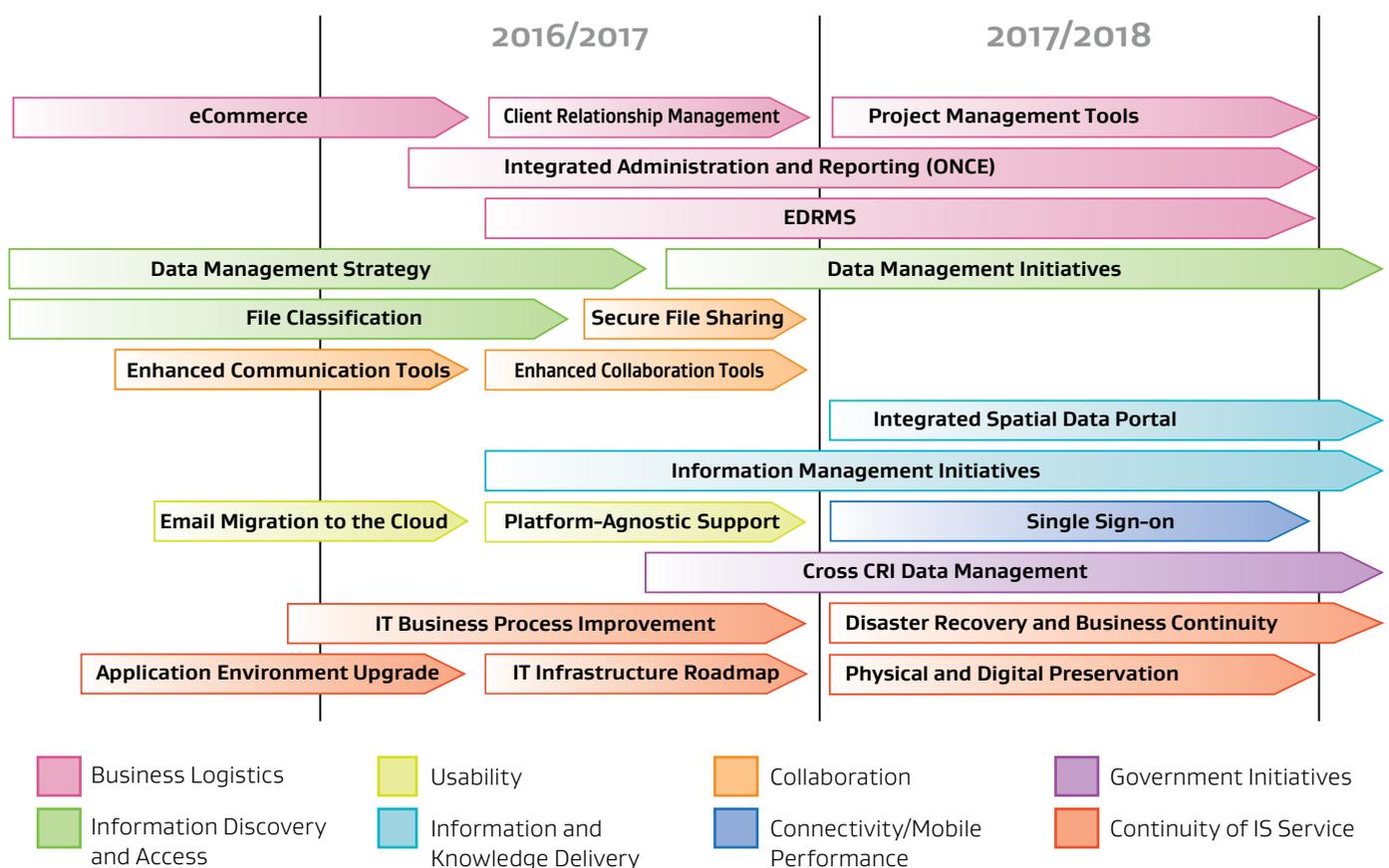
Enhancing information services

Our goal is to streamline operational practices to increase efficiency through high-performance, robust systems that are usable, connected and interoperable. Targets for 2016–2017 include:

- » Development of a business case for an Electronic Document and Records Management System (EDRMS)

- » Expansion of a move to Microsoft Office 365 for email, and Skype for Business for meeting rooms
- » Continued development of functionality of ONCE, our research project management and reporting system, including interfacing with external collaborators
- » Utilisation of in-house and/or external cloud solutions to enable data and information to be efficiently and securely shared with collaborators

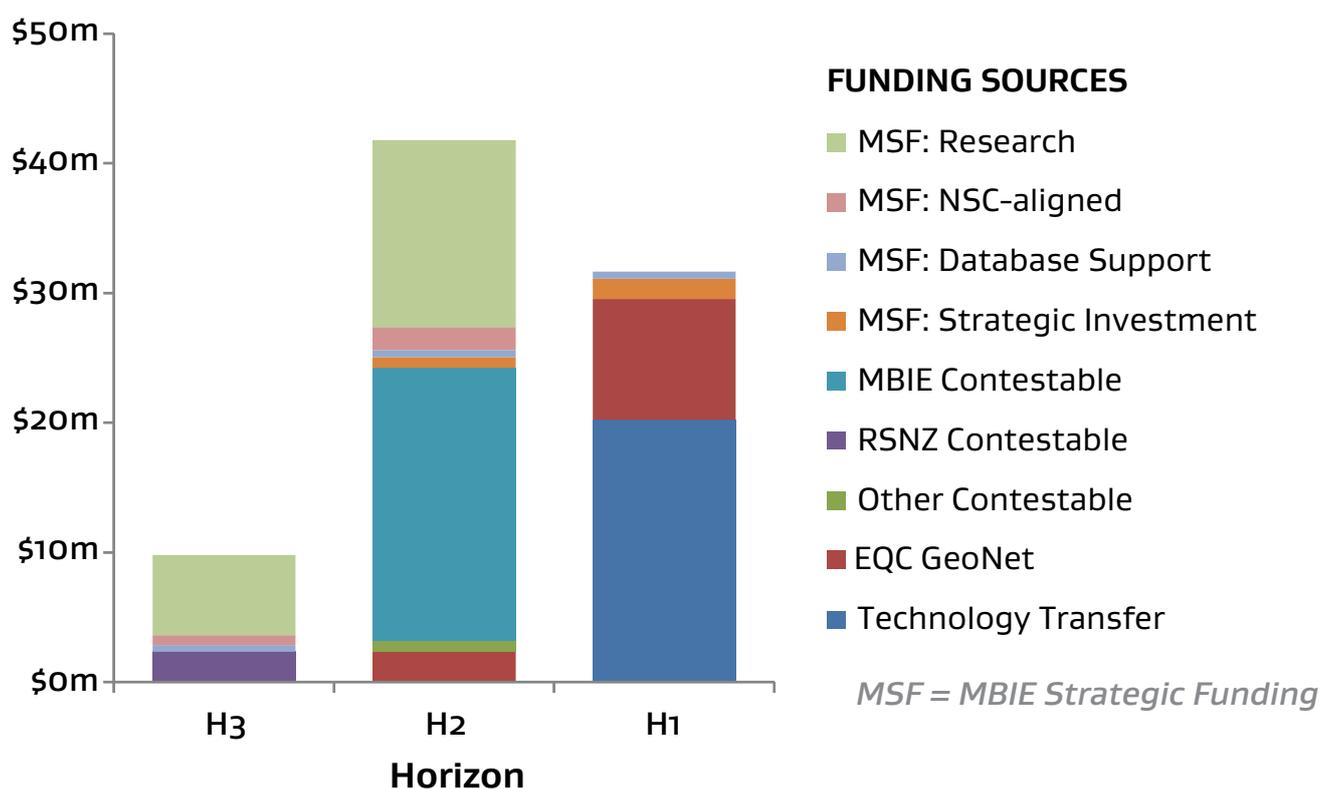
- » Development of a technology roadmap to guide our IT hardware and service procurement decisions, enabling us to achieve improved scalability, efficiency and availability of information services in the medium and long term



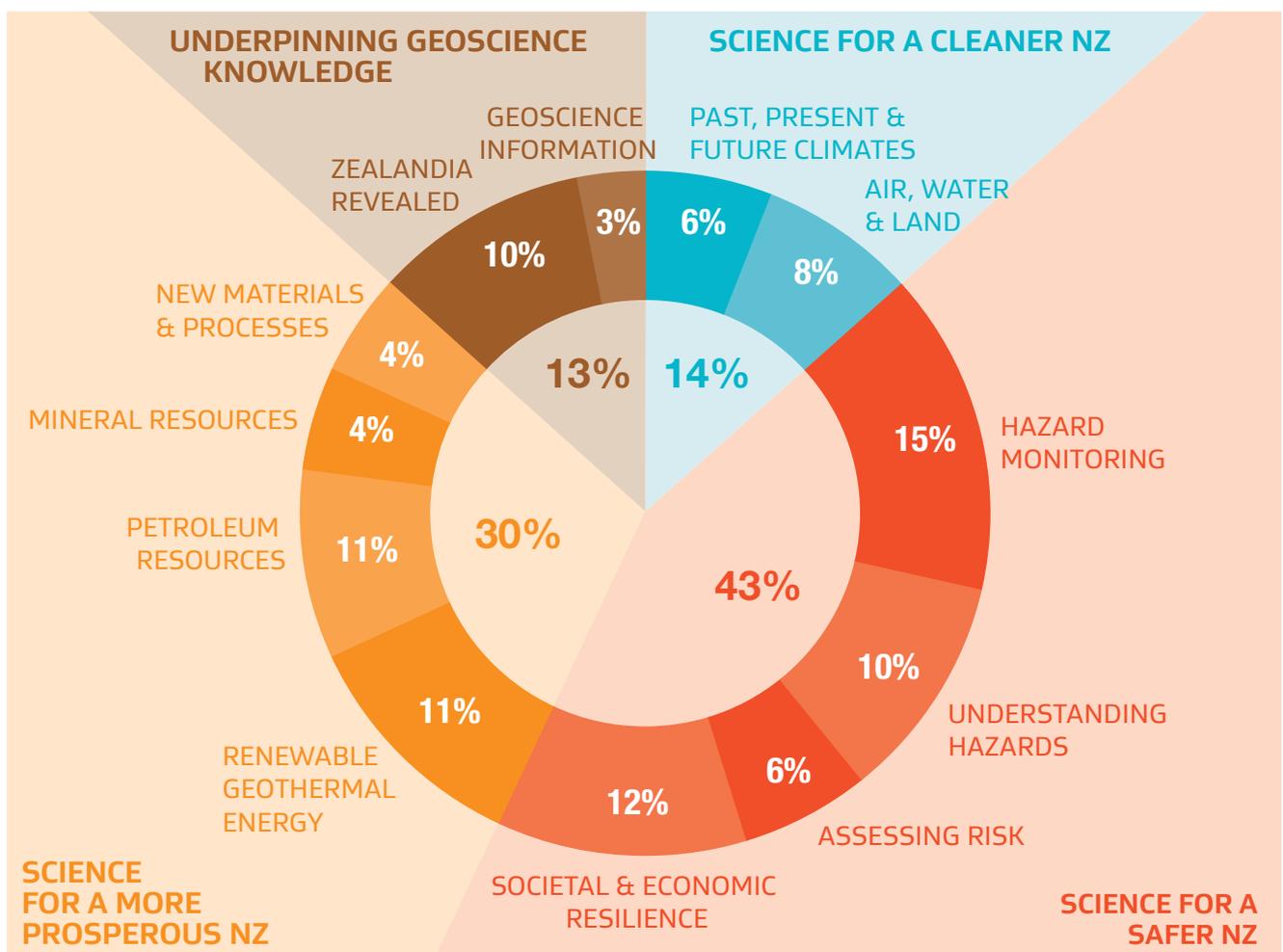
OUR RESEARCH

Over the next five years, GNS Science will undertake a wide range of research designed to deliver on our SCP.

R&D investment 2016–2017



Underpinning research in regional geology, tectonics, biostratigraphy and materials science (H3; c. 12%), provides the essential fundamental understandings for applied research in environment, resource and manufacturing sectors (H2; c. 50%). In combination, these generate the knowhow capability to provide effective technology transfer (H1; c. 38%). Our research investment is deployed across the four Core Science Areas and 12 underlying Themes.



Translating the Themes (outer ring, above) to the appropriate SCP Outcome Statements (see page 13) reveals that the greatest amount of effort is directed towards OS2 – natural hazard risk and resilience, OS1 – wealth from resources, and OS5 – geology and past climates, with a lesser, but still significant, amount of effort directed to the other three outcomes (OS3 – groundwater quality; OS4 – value for New Zealand industry; OS6 – enhanced geotechnical engineering).

In the detailed explanation of our research that follows (see pages 34–65), we address four questions to each of the 12 Themes:

- » To whom are we aiming our research findings, i.e., who are the targeted end-users and other key stakeholders that will take up our research results and put them to good use?

- » What research are we doing, i.e., what medium- to near-term research initiatives are we undertaking over the next 1–5 years, and where does the funding come from?
- » What impact(s), and ultimate outcome(s), do we expect to achieve?
- » How will we measure success?



SCIENCE FOR A CLEANER NZ

Our role is to enhance the nation's ability to understand and responsibly manage changes in climate, sea level, air quality, water quality, and land use.

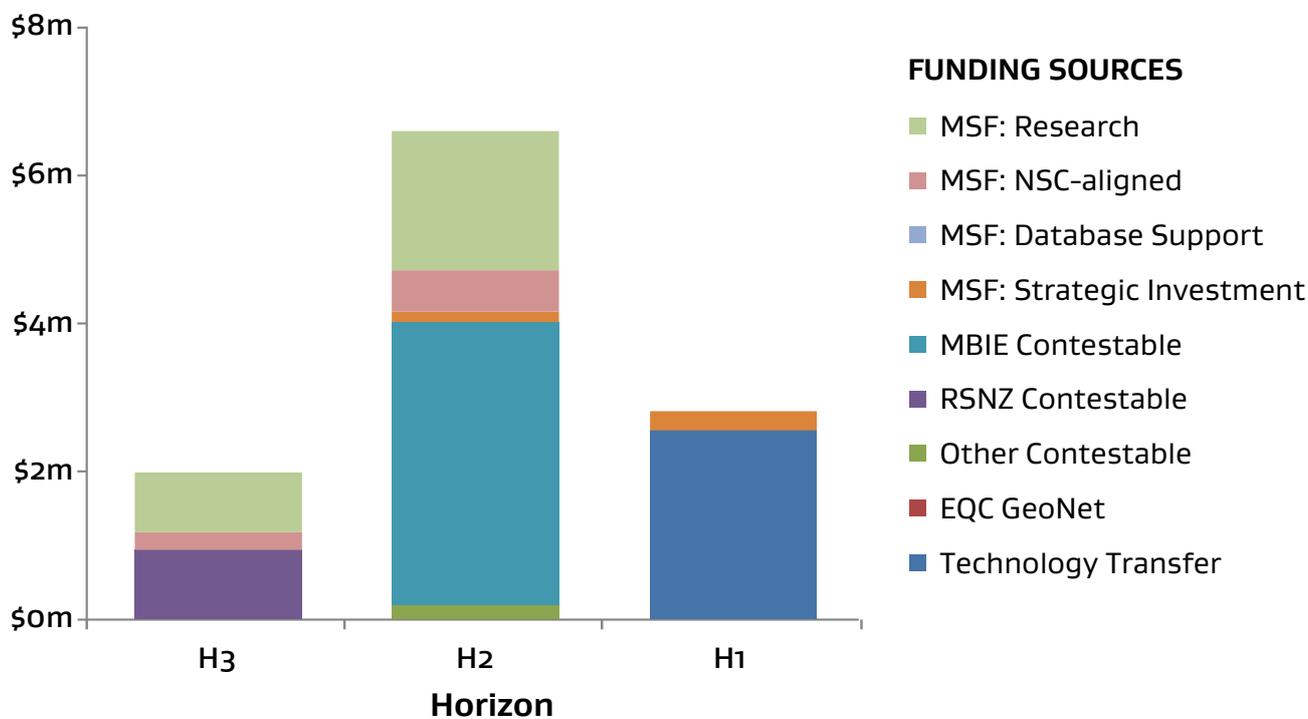
We contribute to improved environmental assessment by developing better networks for real-time monitoring and effective mechanisms for dissemination to, and engagement with, the public, iwi and other stakeholders. The desired outcome for New Zealand is achievement of kaitiakitanga (environmental stewardship), leading to social, cultural, health and economic benefits. To achieve this we seek to understand ancient and modern environmental systems and processes and to determine the impacts of human activity and changing climate.

We will partner with Government, regional authorities, iwi, industries, universities and the public to empower environmental stewardship. We will improve the accuracy, reliability and coverage of environmental monitoring networks and paleo-environment proxies. We will provide authoritative, unbiased data and advice to support the development of informed policies, plans and strategies for environmental stewardship and climate change mitigation.

The research investment of \$11.4 million pa is made up of 34% core, 44% contestable, and 22% technology transfer. Allocated MBIE Strategic Funding is unchanged from 2015–2016. The research is undertaken within two Themes; Past, Present & Future Climates (43% of total investment) and Air, Water & Land (57%).



R&D investment 2016–2017



The research is dominantly H2, related to characterising our air, land and water environment. H1 research relates to supporting the land and water sectors, while H3 relates to obtaining a basic understanding of the drivers and impacts of climate change via paleoclimate and carbon cycle research.

PAST, PRESENT & FUTURE CLIMATES

Science outlook

Our research on past climate and environments is essential for improving predictions of the rate, scale and magnitude of future climate change, and assessing the likely impacts of these changes on New Zealand and New Zealanders (see page 16). Knowledge of past environmental changes is also key to understanding the evolution of Zealandia (the largely-submerged New Zealand continent), the origins of its biota and the nature and distribution of its geological resources.

We will continue to contribute to international efforts to understand how climate has changed in the past and how these changes have affected the wider SW Pacific region, from Antarctica to the tropics. For example, the Roosevelt Island Climate Evolution (RICE) project is a New Zealand-led research collaboration involving 26 nations, which aims to determine the stability of the Ross Ice Shelf in a warming world. This will improve estimates of contributions of the West Antarctic Ice Sheet to future sea level rise. RICE has attracted c. \$5 million in overseas investment and has allowed New Zealand to take the lead on the planned 15-nation Thwaites Glacier ice core drilling project in West Antarctica. This highly leveraged international research supports New Zealand's efforts to be a good global citizen in understanding and mitigating the impacts of climate change and resultant environmental degradation (see page 3).

Our focus on previous episodes of major climate shifts and intervals of warmer than present climate is aimed at quantifying ice-sheet contribution to sea level rise, and informing longer-term (centuries to millennia) adaptation and mitigation strategies. We seek paleoenvironmental evidence that extends the understanding of Earth system behaviour beyond the short instrumental record, to times of global temperature and atmospheric CO₂ concentrations relevant to those projected for the next several decades. This is essential

to any assessment of the impacts of climate change on New Zealand's environment, society, and prosperity. A quantitative understanding of the source and fate of key greenhouse gases is also critical to this assessment.

Targeted end-users

Through our 'Te Kura Whenua' initiative (see pages 27 and 29), we have learned that the long-term perspective gleaned from geological archives is of great value to iwi for whom kaitiakitanga spans multiple generations into the future. Paleoclimate-validated predictive models and associated climate impact information are targeted at international bodies such as the IPCC and the World Economic Forum (WEF), which provide advice to Government, but also to national regulators and policy developers such as government ministries (Climate Change Impacts; Conservation; Environment; Foreign Affairs and Trade; Health; Primary Industries), regional councils and territorial authorities. In developing ever more sophisticated and robust models and evidence-based advice, an effective interface with other researchers becomes a key element in the science value chain. To facilitate the critically-important research on ice-sheet evolution, Antarctica New Zealand and the New Zealand Antarctic Research Institute (NZARI) are key stakeholders. As an important spin-off, petroleum explorers and other geoscientists rely on the baseline information we provide on Zealandia's climate and environmental history, including on-going improvements to the New Zealand Geological Timescale.

Near to medium-term research initiatives

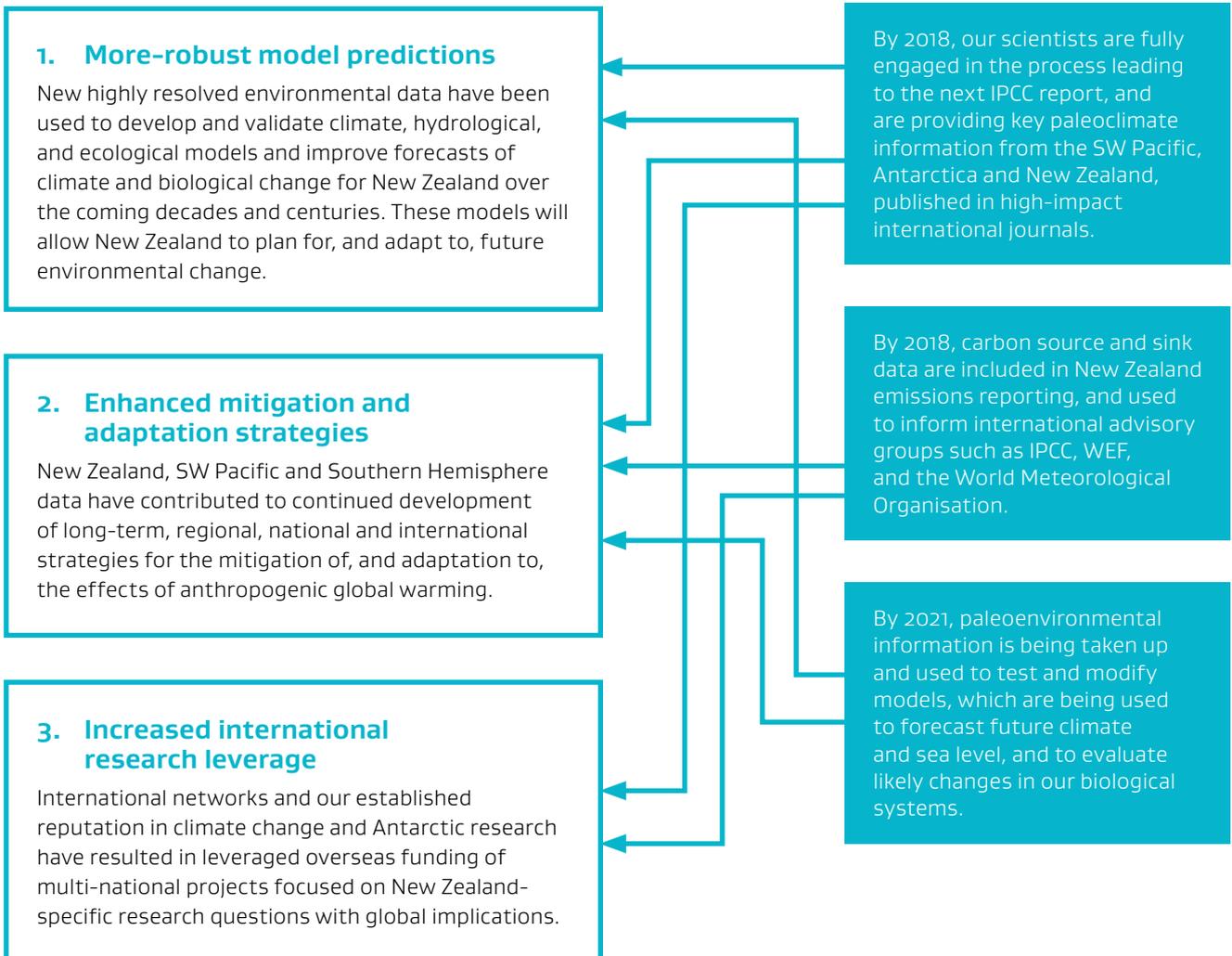
Advance understanding of the regional impacts of global change at a range of spatial and temporal scales, by:

- » reconstructing pre-instrumental climate records for the past 100,000 years from high-resolution geological archives to improve our knowledge of Southern Hemisphere climate drivers and test model reliability;
- » assessing the responses and dynamics of carbon stocks and flows in the biosphere, atmosphere and ocean system relevant to New Zealand during recent, contemporary and future timeframes using radiocarbon and related measurements;
- » constraining the timing and magnitude of abrupt shifts and transitions in climate over the past 150,000 years, evaluating the effect of these events on New Zealand's terrestrial and oceanic environment and biota;
- » reconstructing the scale and magnitude of past environmental change in the SW Pacific that occurred in response to extreme global climatic events under atmospheric CO₂ concentrations that were similar to those projected for the coming centuries;
- » determining how the climatic and environmental history of Zealandia has influenced the quality, quantity and distribution of its geological resources; and
- » refining and developing isotopic methods for dating climate archives and deriving climate proxies.

In collaboration with Victoria, Otago, and Canterbury universities and NIWA, examine the effects of climate warming on Antarctica's ice sheets by using observation-based reconstructions and model-based simulations of Antarctic ice sheet and Southern Hemisphere climate-ocean

IMPACTS

MEASURES OF SUCCESS



dynamics; simulate future response to climate change using models that have been validated against prehistoric data to improve sea level rise projections.

In conjunction with Ngāti Kahungunu, identify synergies between paleoclimate and paleoenvironmental research goals and aspirations of iwi groups in relation to kaitiakitanga and responsible development of natural resources.

Characterise the response of Southern Ocean dynamics to climate change, via atmospheric radiocarbon, to determine how the Southern Ocean carbon sink is evolving.

Resolve changes in South Island precipitation under the varying influence of tropical and polar forcing over the past 17,000 years.

Determine past Antarctic ice sheet characteristics and stability deduced from lava-ice interactions at Mason Spur, Mount Morning volcano, and McMurdo Sound, during mid-Late Miocene climatic warmth.

AIR, WATER & LAND

Science outlook

To help address the 'supply of fresh water' issue (see page 17), which continues to be the major environmental and resource issue internationally, we undertake a range of groundwater-related research. We address the need to fully understand the structural characteristics of, and the fluxes of water into, out of, and through New Zealand aquifers, and improve our ability to predict the response of New Zealand aquifers to pressures such as climate change and land-use intensification. There is also a need to better understand contaminant transfers between air, land and water, and the resulting environmental impacts. We see environmental stewardship as a collective responsibility. Improved engagement and knowledge exchange mechanisms that give the public and Māori a more active role will improve awareness of environmental risks and help provide tools for decision makers to address multi-faceted issues.

We also will make a contribution to the increasingly damaging problem of air pollution in New Zealand (see page 17) by applying our unique (to New Zealand) ion beam technology to determining the origins of particulate matter, and by creating smart environmental sensors.

Targeted end-users

Principal users of our air, water and land research are the regulators, regional and territorial authorities and government ministries and agencies (Conservation; Environment; Foreign Affairs and Trade; Health; Land Information; Primary Industries), and agricultural industries (forestry; horticulture; farming; and viticulture), and iwi/Māori (e.g., Whakarewarewa Trust; Ngāti Rangiwewehi). Community groups, teachers, researchers, and international organisations, particularly the International Atomic Energy Agency Regional Cooperative Agreement (IAEA-RCA), are also important end-users.

Near to medium-term research initiatives

Provide new knowledge on the physical and chemical characteristics of New Zealand's land and water systems and their response to future pressures, to support policy development and improved management, by:

- » undertaking systematic, nationwide collection of groundwater samples and analysing them for key water quality parameters (chemistry, age, nutrients, and microbial biodiversity);
- » determining the hydrogeological and structural characteristics of New Zealand's aquifer systems;
- » developing fit-for-purpose chemical/isotopic tools for determining the dynamics of hydrologic systems;
- » applying tracers for biogeochemical processes defining the source, fate and transport of nitrogen, carbon, and other pollutants; and
- » determining how human activities, climate change, and other pressures affect our groundwater resources, land and water systems, and associated ecosystems.

Determine the physical and chemical hydrology of near-surface groundwater and hydrothermal aquifers, and rock properties, to understand shallow thermal conditions across New Zealand, and their susceptibility to subsidence and salination.

Merge existing and new tracer data with available numerical modelling software to develop tracer-validated numerical models for selected New Zealand catchments.

In collaboration with European institutes (Deltares, Royal Haskoning and University of Salzburg), identify, develop, apply, validate, and optimise a suite of novel methods for accurate, rapid, and cost-effective characterisation and mapping of New Zealand's aquifers.

Develop, test and validate methods for simplifying large-scale groundwater models so that they can run quickly without introducing biases or inaccuracies.

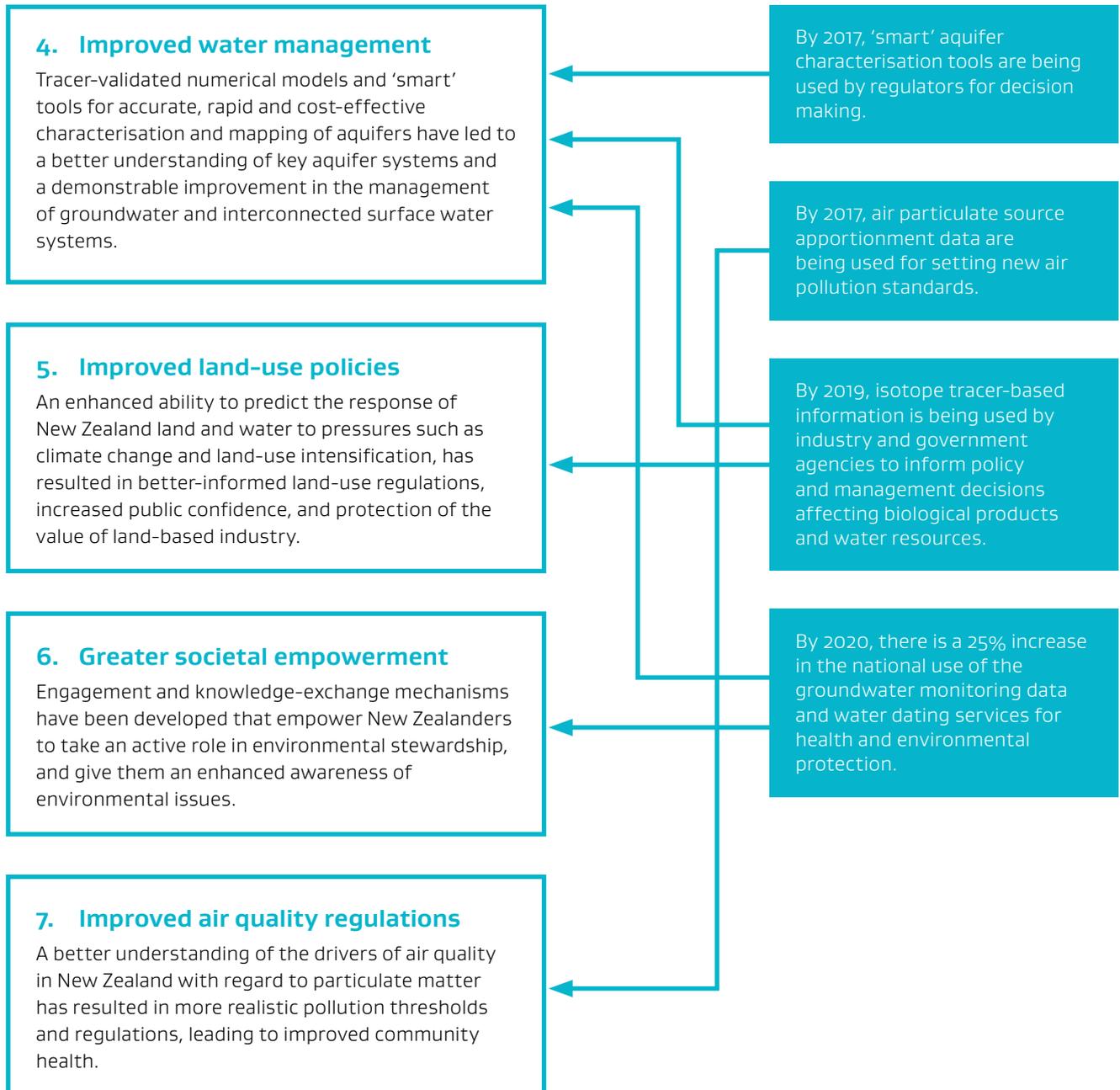
Understand the impacts of development in the Awahou groundwater catchment to ensure the health and wellbeing of the Ngāti Rangiwewehi people, and in so doing, develop a better understanding of the planning/policy frameworks for freshwater management and appreciate the positive contribution mātauranga can make.

Identify, in collaboration with Te Papa, the unique geochemical fingerprints of paru (black mud) from different locations used by Māori to dye flax fibre for weaving, and so allow ancient and unprovenanced taonga to be reconnected with their original owners.

Develop new knowledge on outdoor and indoor air quality and environmental management via source apportionment of air particulate matter, and sensor development.

IMPACTS

MEASURES OF SUCCESS





SCIENCE FOR A SAFER NZ

Our role is to develop and support the nation's ability to understand, communicate and mitigate the impacts of earthquakes, landslides, volcanic eruptions and tsunamis, and to help us become more resilient to these geological hazards.

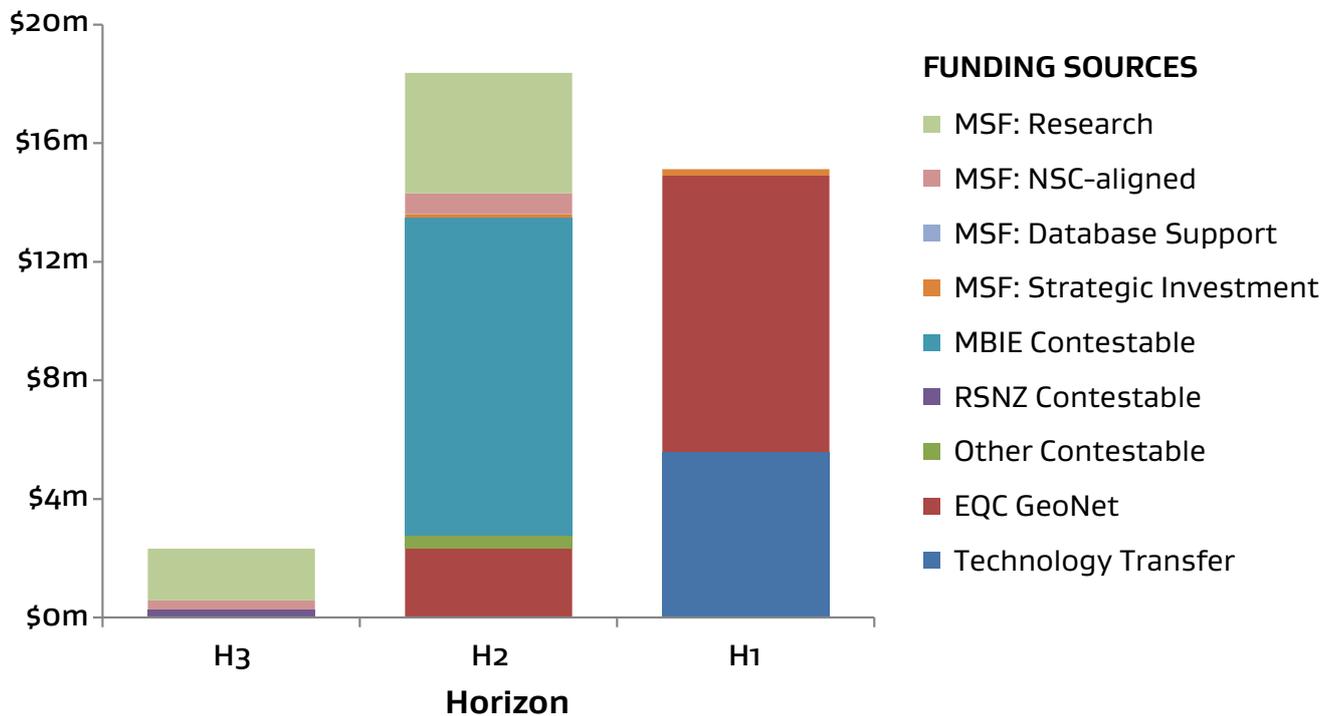
The desired outcomes for New Zealand are reduced economic, environmental and social impacts of natural hazards on communities and infrastructure and, ultimately, the nation. To achieve this we will undertake research to better understand natural hazards and community exposure, and support risk mitigation and community resilience. We will partner with researchers, stakeholders and communities in national and international programmes for disaster risk reduction that yields safeguards from the impact of natural hazard events. And we will provide authoritative and independent information and advice to support risk mitigation, community resilience and informed decision-making in response to and in preparation for natural hazard events.

A significant proportion (32%) of the \$35.8 million pa operational investment comes from EQC support for GeoNet. Of the remaining investment, 20% is core, 32% contestable and 16% technology transfer. The MBIE Strategic Funding profile is the same as that of 2015–2016, with \$1 million pa currently aligned to the *Resilience* NSC.

36% of the total investment is associated with Theme 1: Hazard Monitoring (GeoNet), 24% with Theme 2: Understanding Hazards, 13% with Theme 3: Assessing Risk, and 27% with Theme 4: Societal and Economic Resilience.



R&D investment 2016–2017



The research is dominantly H2, relating to hazard assessment and mitigation, with a significant amount of H1, delivering immediate geohazard advice to key stakeholders (mainly via GeoNet). Although relatively small, there is over \$2 million pa of H3 research, relating to a fundamental understanding of geohazards and their future predictability.

HAZARD MONITORING

Science outlook

Recognising its pivotal role in supporting natural hazard research in all its forms, we will continue to enhance the services of GeoNet in line with a measured strategy of development agreed with EQC. GeoNet is well equipped to continue at the leading edge of delivery of hazards information to everyone in New Zealand, when and where they want it. We seek to deliver better real-time forecasts for all geological perils and their impacts, so the public can be better prepared for impending events, and know how to respond when an adverse event does happen (see page 3). Our goal is a comprehensive 24/7 warning capability for all perils, enhanced communication of hazard and risk through media channels and comprehensive response planning for all future events in New Zealand and the SW Pacific. Land Information New Zealand (LINZ) funding of the national geodetic framework and tsunami gauge network is an important complement to this activity.

Targeted end-users

The key targets for geohazard monitoring delivery and outputs are government ministries and agencies (including MCDEM; Department of Conservation (DoC); EQC; lifelines groups; LINZ; regional CDEM groups; regional councils; and territorial authorities), as well as the media and the public.

Near to medium-term research initiatives

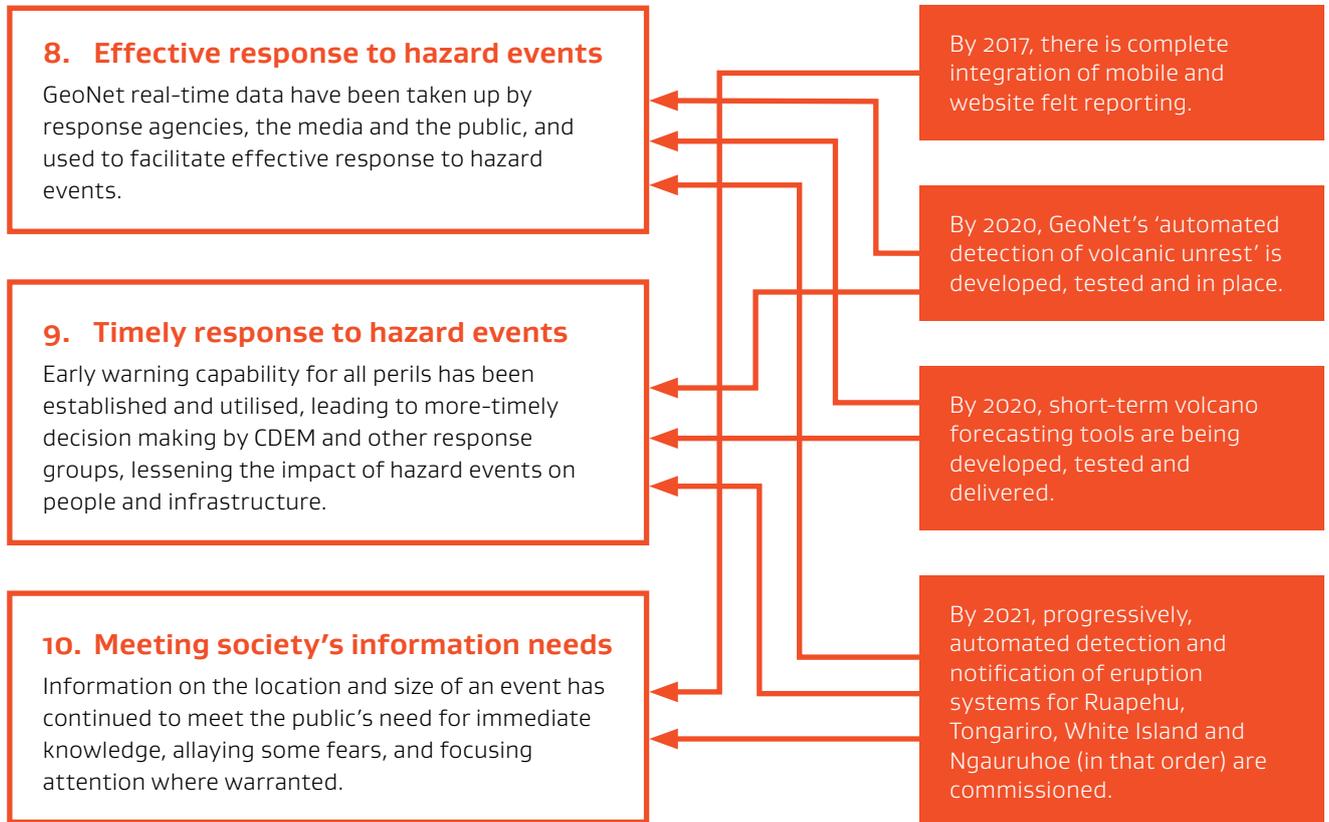
Improve the scope and value of our hazard monitoring service, by:

- » applying *GeoNet Rapid* to volcano monitoring, to create a fast, open and threat-based capability, reducing response time and improving information quality;
- » expanding citizen initiatives, such as felt reporting through apps and social media, in collaboration with the *Resilience* NSC, and offering education in Big Data techniques; and
- » continuing to improve GeoNet's ability to deliver data and event information such as warnings and advice.



IMPACTS

MEASURES OF SUCCESS



UNDERSTANDING HAZARDS

Science outlook

Critical to a resilient society is the ability to understand and mitigate the risk from the range of hazards we encounter. Thus, we look to provide government, community leaders and the public with sound information on which to base decisions on priorities for action, and methods to reduce risk. We seek understanding of geological processes and the hazards they pose to society, as the first step to quantifying risk. Through discovery of new insights into when, where, why and how a volcano erupts, an earthquake strikes, landslides occur, or a tsunami is triggered, we build models to compare risks between different perils. In this context, we are actively ensuring that New Zealand is well-positioned as an international hazards laboratory, and there is integrated hazards research leading to comparative risk across all hazards. We seek an improved physical understanding of natural-hazard processes and their consequences, and identification of potential events of national significance and the development of end-to-end research projects.

Targeted end-users

Target recipients of basic information and interpretation of hazard cause and effect include: government ministries and other agencies (e.g., Canterbury Earthquake Recovery Agency (CERA); DoC; EQC; MCDem; Met Service; NZAID; Ministry for the Environment (MfE); MBIE Building System Performance; New Zealand Transport Agency (NZTA); regional councils; CDEM and lifeline groups; territorial authorities); insurance providers and underwriters; infrastructure providers; consultants (e.g., BECA; DamWatch; Transpower; Vector); iwi/Māori; the public; and researchers from universities and other institutions (including those involved in collaborative research and outreach—*Resilience to Nature's Challenges, Deep South, New Zealand's Biological Heritage,*

Sustainable Seas, and Our Land and Water NSCs; QuakeCoRE; DEVORA; It's Our Fault; and East Coast LAB).

Near to medium-term research initiatives

Advance understanding of earthquakes, and the mitigation of their risks, by:

- » using active fault data to quantify the rate at which faults with high slip rate, high hazard, and/or poor characterisation move;
- » quantifying earthquake predictability, and development of enhanced earthquake forecasting models;
- » establishing a better understanding of the earthquake seismic cycle, (stress build-up and release, fault interactions);
- » developing refined models of the earthquake rupture process;
- » improving the estimation of earthquake motions for engineering and risk applications; and
- » quantifying space-time variability in strong ground motion.

Use high-frequency scattering methodology and aftershock data to isolate and understand complex wave-propagation effects in the near surface, and their impact during the largest earthquakes.

Probe the Hikurangi subduction zone using full-waveform inversion to better understand the controls on mega-thrust slip behaviour.

Use waveform modelling to capture broadband characteristics of ground motions in the lower North Island from interface earthquake scenarios.

Use airborne LiDAR, lake sedimentation, and on-fault paleoseismic data to measure fault displacements and provide a more-reliable forecast of the next great Alpine Fault earthquake.

Advance understanding of active volcanism to improve response times and mitigate risk, by:

- » determining the frequency, size and style of volcanic eruption through an analysis of eruption deposits, volumes and their age;
- » analysing eruption ash, pyroclastic flows, lava flows, ballistic deposits, and lahar and debris flows to determine their potential impacts on communities;
- » providing advice and evidence-based mitigation tools for reducing disruption and loss in a crisis; and
- » investigating subsurface magmatic conditions using geophysical, geochemical and geodetic surveys.

Examine the effects of earthquakes or magmatic intrusions on the plumbing system of Okataina Caldera, and determine the likelihood of eruption triggering.

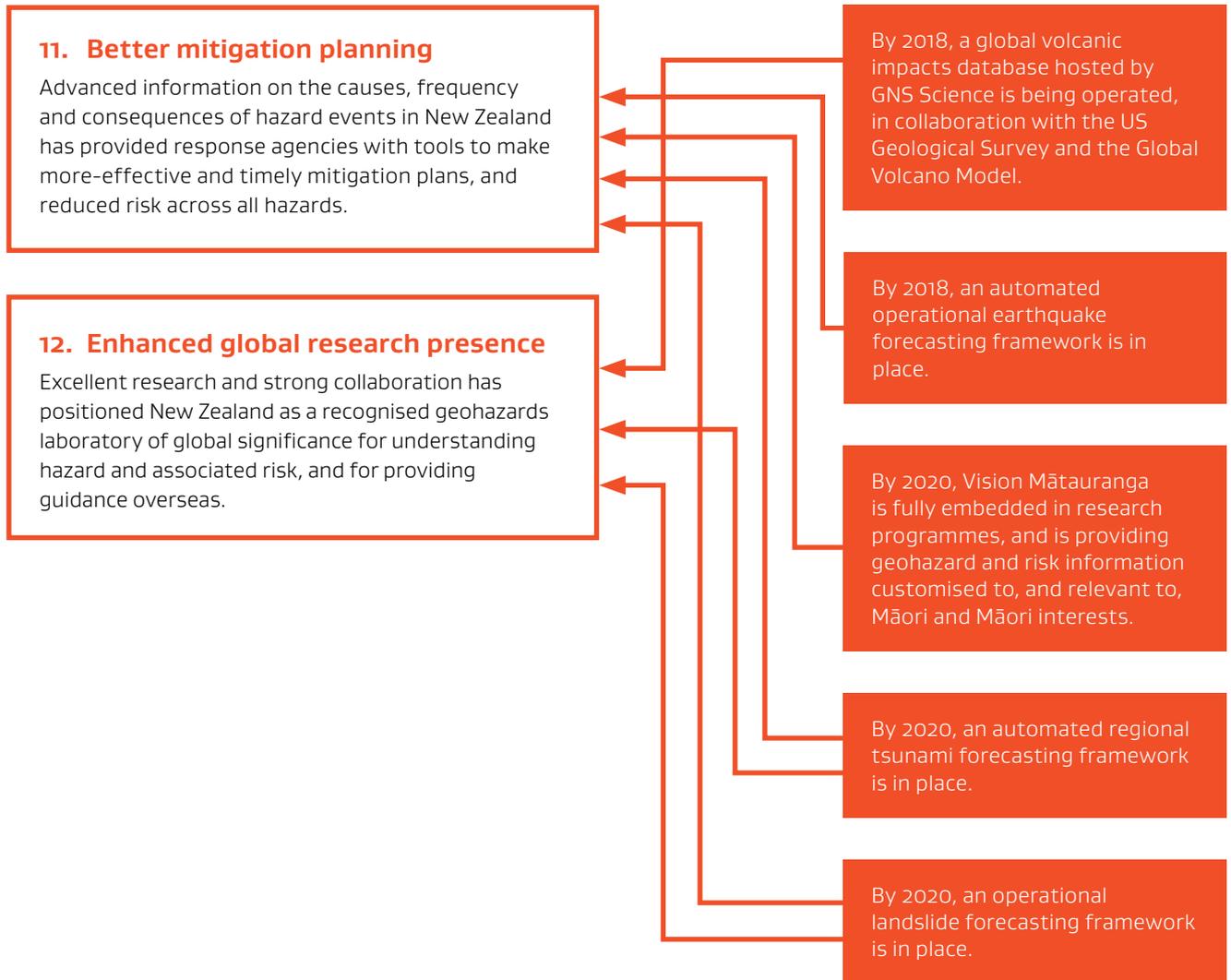
Determine the sources of tsunami and the processes of propagation and inundation, and make better estimates of tsunami hazard in a quantitative frequency-magnitude framework to support tsunami forecasting capability.

Advance understanding of landslide hazards, and the mitigation of their risks, by:

- » determining the geomechanical properties of soils and rocks and how they influence the causes and mechanisms of landslide development through time;
- » recording, monitoring and modelling landslide processes in time and space, including landslide initiation, run-out mechanisms, and their impacts on society; and
- » characterising the spatial distributions of landslide occurrences from rain, earthquakes and other triggers, and their role in landscape evolution.

IMPACTS

MEASURES OF SUCCESS



ASSESSING RISK

Science outlook

Risk can be treated by a range of mitigation methods—avoid, transfer, reduce, or accept. Our research underpins decisions about which treatment option is the most optimal: Do we avoid a lahar by not building in potential pathways for future events? Can we transfer the risk by insurance and, if so, how can insurers better assess the premium we should pay? Can we strengthen our buildings in areas of high earthquake activity, thus lowering the likelihood of business interruption. Or do we have the discussion with our communities that we are comfortable to accept a certain level of risk from a low probability, high-impact event such as a Tohoku-size tsunami, so long as we build in safeguards such as good evacuation planning?

Our RiskScape research makes us uniquely placed to inform national conversations on natural hazards risk. We are developing multi-hazard risk models, engaging with decision makers to guide the most

effective methods for risk mitigation and improving our knowledge of how best to communicate risk to all New Zealanders. Key to this is establishing enduring partnerships with government agencies to ensure seamless and sustained delivery of quality risk advice, using our expertise to develop strong risk management across government and the private sector.

Targeted end-users

Information on risk assessment is targeted at government ministries and agencies (including CERA; DoC; EQC; LINZ; MCDem; NZAID; MBIE Building System Performance; NZTA; Local Government Risk Agency; regional councils, CDEM and lifeline groups; and territorial authorities), as well as insurance and infrastructure providers, business and iwi/Māori.

Near to medium-term research initiatives

Develop the RiskScape regional risk assessment tool, to increase the resilience of communities through effective management of natural hazard risk, by informing risk-based land-use planning, informed emergency responses, and appropriate investment in mitigation and risk transfer mechanisms.

Improve the reliability and applicability of the National Seismic Hazard Model (NSHM).

Generate a new NSHM for Dunedin based on the tectonic structure and rates of crustal deformation in and around Dunedin City.



IMPACTS

13. Enhanced risk analysis

Enduring partnerships with insurance and other companies have ensured uptake of accurate and timely risk evaluations, and widespread use of RiskScape as an effective tool to assist geohazard risk-reduction activities, resulting in more resilient New Zealand communities and businesses.

14. Enhanced National Seismic Hazard Model

An improved National Seismic Hazard Model has been used to underpin development of RiskScape, as the basis of refined earthquake risk assessment, and the setting of building standards.

MEASURES OF SUCCESS

By 2019, RiskScape is being used by 50% of regional and territorial authorities and three key Government stakeholders.

By 2020, GNS Science is recognised as the custodian of national hazard models for all perils.

By 2020, an improved National Seismic Hazard Model is the basis for all earthquake risk modelling in New Zealand.



SOCIETAL & ECONOMIC RESILIENCE

Science outlook

As host and partner to the *Resilience to Nature's Challenges* NSC, and building on the success of the Natural Hazards Research Platform, we will sustain momentum around social and economic resilience research. We will play a leading role in helping the Government fulfil its obligations to the *Sendai Framework for Disaster Risk Reduction* and contributing to the development of a national strategy for disaster risk reduction and resilience (see page 18). We will undertake research aimed at understanding the social, economic and cultural factors that enhance community resilience, and develop economic models for quantifying the economic impacts of disasters (loss modelling).

Targeted end-users

Evidence-based resilience advice is aimed primarily at government ministries and agencies (including the Accident Compensation Commission (ACC), CERA; EQC; MCDEM; NZAID; MfE; Ministry of Health; Ministry of Social Development; regional councils, CDEM and lifeline groups; and territorial authorities), as well as iwi/Māori, business and the public.

Near to medium-term research initiatives

Advance understanding of the social, economic and cultural factors that enhance community resilience to natural disasters, by:

- » improving ways to create effective plans and policies that address natural hazards;
- » creating practical strategies for developing community resilience to disasters; and
- » developing advice mechanisms for effectively responding to, and recovering from, disasters, including how to respond to warnings.

Improve methods for achieving acceptable levels of functionality of the built-environment in cities after a disaster by:

- » assessing integrated hazard impacts on the built-environment;
- » identifying information needs in recovery planning; and
- » exploring alternative strategies to assist in short, medium, and long-term recovery from hazard events.

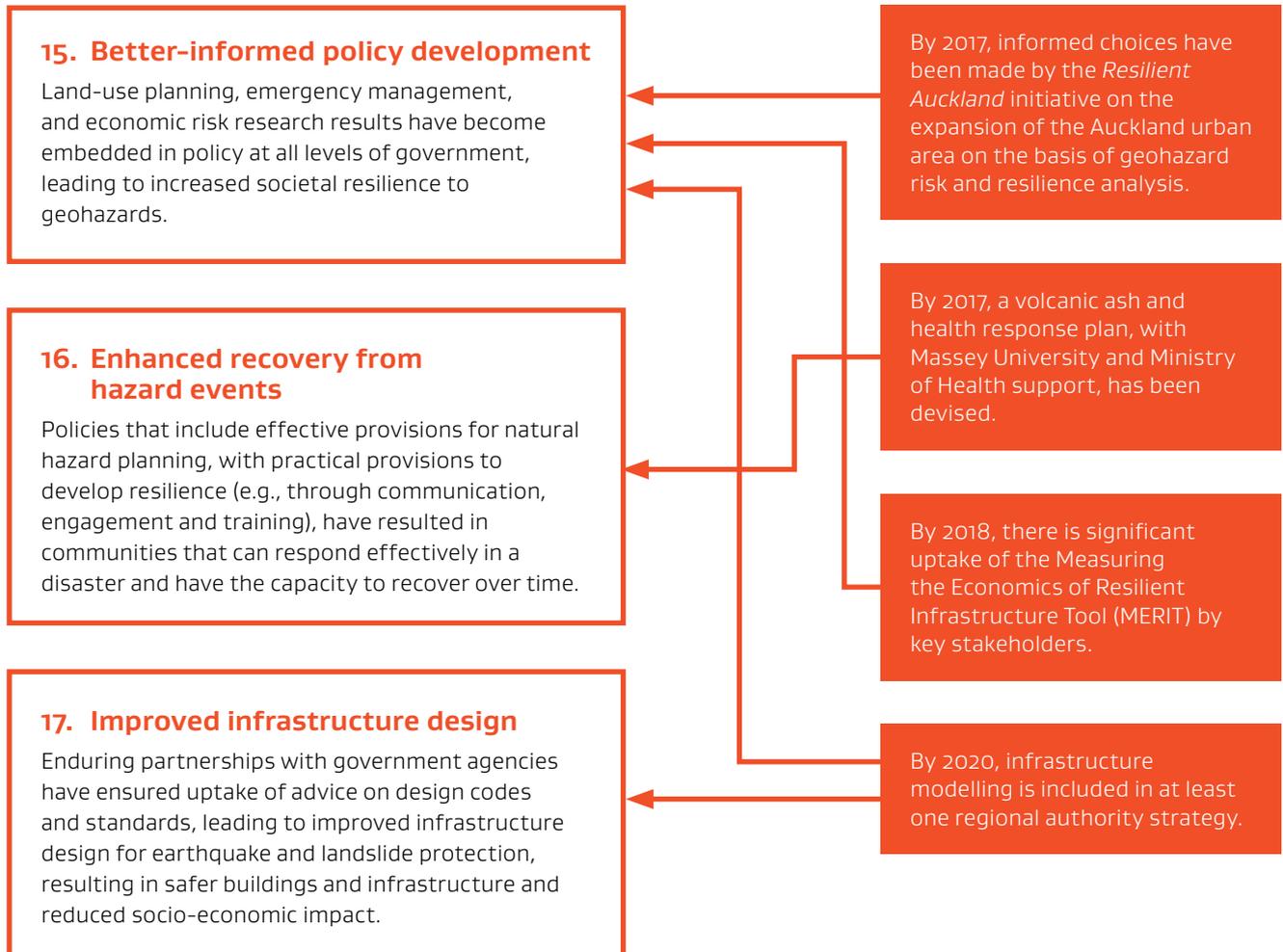
Develop a Measuring the Economics of Resilient Infrastructure Tool (MERIT) (see page 2) to quantify the likely short, medium and long-term (up to 20 years) economic implications of potential infrastructure failures, covering both natural hazard and infrastructure-only events.

Improve infrastructural resilience through better knowledge of the behaviour of anthropogenic slopes, and developing efficient strategies for robust remediation approaches.



IMPACTS

MEASURES OF SUCCESS





SCIENCE FOR A MORE PROSPEROUS NZ

Our role is to provide the nation with tools to enhance resource security, energy stability and sustainable development of its geothermal energy, petroleum, and mineral resources and to develop new high-value materials and processes for industry.

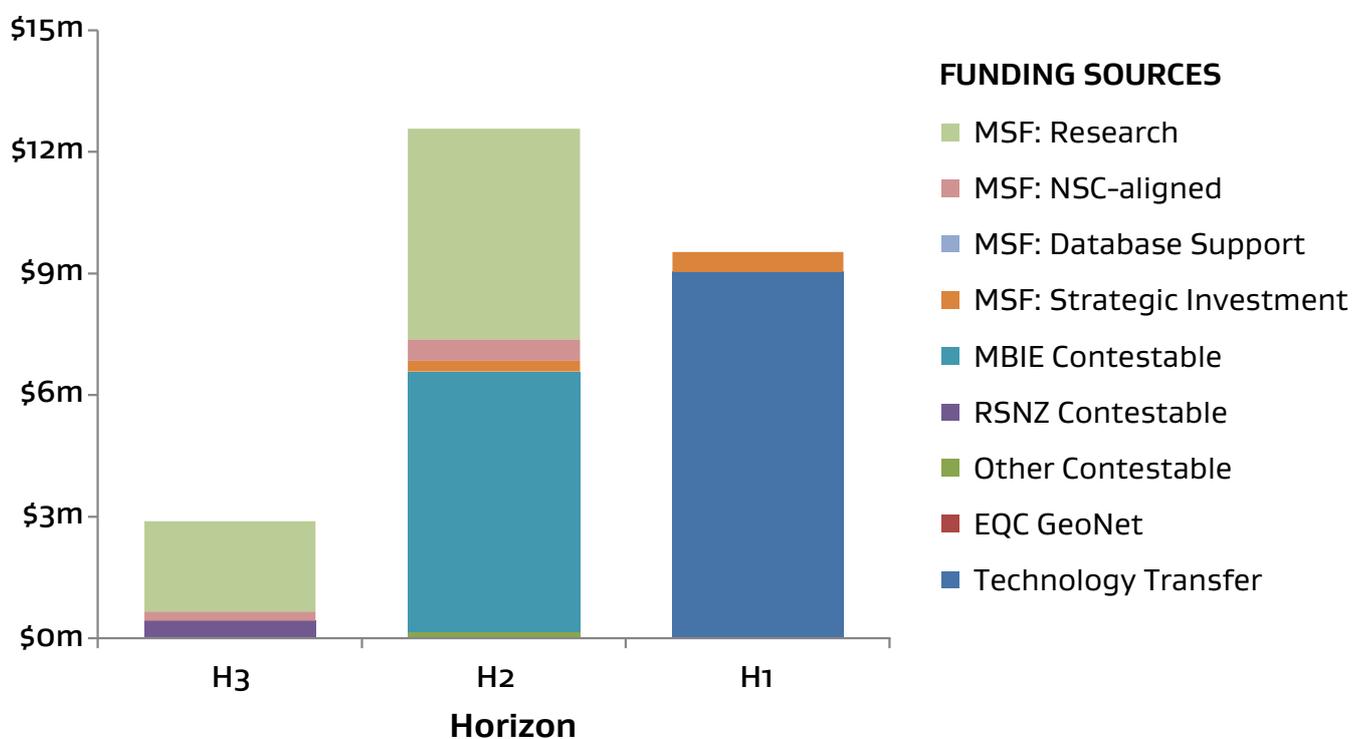
The desired outcomes for New Zealand include sustainable and environmentally responsible use of our energy and mineral resources, and creation or enhancement of high-value industries that generate national wealth. To achieve this we will delineate and quantify New Zealand's natural energy and mineral resources, and assist the discovery of new minerals and processes.

We will collaborate with universities, government agencies and industry to provide leadership in understanding and promoting energy and mineral resource potential, and with high-value industries to promote uptake of new technologies. And we will apply our knowledge to provide independent and respected advice to inform debate on resource development, and on opportunities in minerals, energy and high-value industries.

The research investment of \$25.0 million pa comes from core (36%), contestable (28%), and technology transfer (36%). The MBIE Strategic Funding profile is similar to that of 2015–2016, except that alignment to the *Sustainable Seas* NSC has been significantly reduced, in line with its newly established scope and mission statement. 37% of the investment supports the Petroleum Resources Theme, 38% Renewable Geothermal Energy, 12% Mineral Resources, and 13% New Materials & Processes.



R&D investment 2016–2017



The research is dominantly H2, relating to characterising our known geothermal, petroleum and mineral resources, and H1, supporting the existing extraction industries; H3 relates to assessing offshore gas hydrate and seafloor massive sulphide deposits, and investigating innovative ways to improve energy efficiency.

RENEWABLE GEOTHERMAL ENERGY

Science outlook

In recognition of the critical contribution of geothermal to our energy security, we will continue to make a major contribution to supporting the viability of the industry. Thus, our research addresses a range of barriers to profitability, including the maintenance of permeability and fluid flow, discovery of new fields, corrosion, scaling, and environmental degradation.

Two challenges facing the industry are improving the efficiency of existing field management operations, and developing reliable assessments of new geothermal resources. We will address these by developing a new generation of geothermal numerical modelling software to support decision making around efficient and sustainable use (see page 3). The aim is to combine specialist models to create a geothermal 'supermodel', utilising expertise and data from regional councils and geothermal development companies in New Zealand, Japan and the Philippines, and from US, Australian, Swiss, Icelandic and Italian collaborators. Improved simulations of individual geothermal systems will offer regional councils the ability to assess the future impact on neighbouring systems, and give geothermal operators an unprecedented ability to assess deep-energy sources in the central North Island for future geothermal development.

Targeted end-users

The principal stakeholders that use our research results are geothermal companies, such as Contact Energy, Mighty River Power, Ngāti Tuwharetoa Geothermal Assets, Tauhara North No.2 Trust, Tikitere Trust and, internationally, Chevron, EDC, Origin Energy and Pertamina. Geotechnical companies, including AECOM, BECA, HADES Systems, MB Century and Tiger, are also important end-users, as are direct-use industries in the heat pump, horticulture, manufacturing and processing, and tourism areas. Economic and environmental regulators, such as NZ Petroleum & Minerals, the Energy Efficiency and Conservation Authority (EECA), the Environmental Protection Agency (EPA), and regional councils/territorial authorities (principally Bay of Plenty, Northland and Waikato) depend on research results to set policy. Finally, economic development agencies such as Enterprise Great Lake Taupō, Grow Rotorua, Ministry of Foreign Affairs and Trade, New Zealand Trade and Enterprise and Te Puni Kōkiri use results to develop strategy and for trade promotion.

Near to medium-term research initiatives

Characterise New Zealand's geothermal resources and their time-space evolution, by:

- » defining the geology of our geothermal systems;
- » determining the relationships between back-arc rifting and geothermal activity;
- » determining the controls on water flow from reservoir structure, stress and rheology;
- » identifying heat sources and areas of possible deep-seated permeability and fluid flow;
- » experimentally simulating fluid-rock interactions deep within geothermal systems; and
- » creating reservoir and combined fluid flow-rock mechanics models, at various scales.

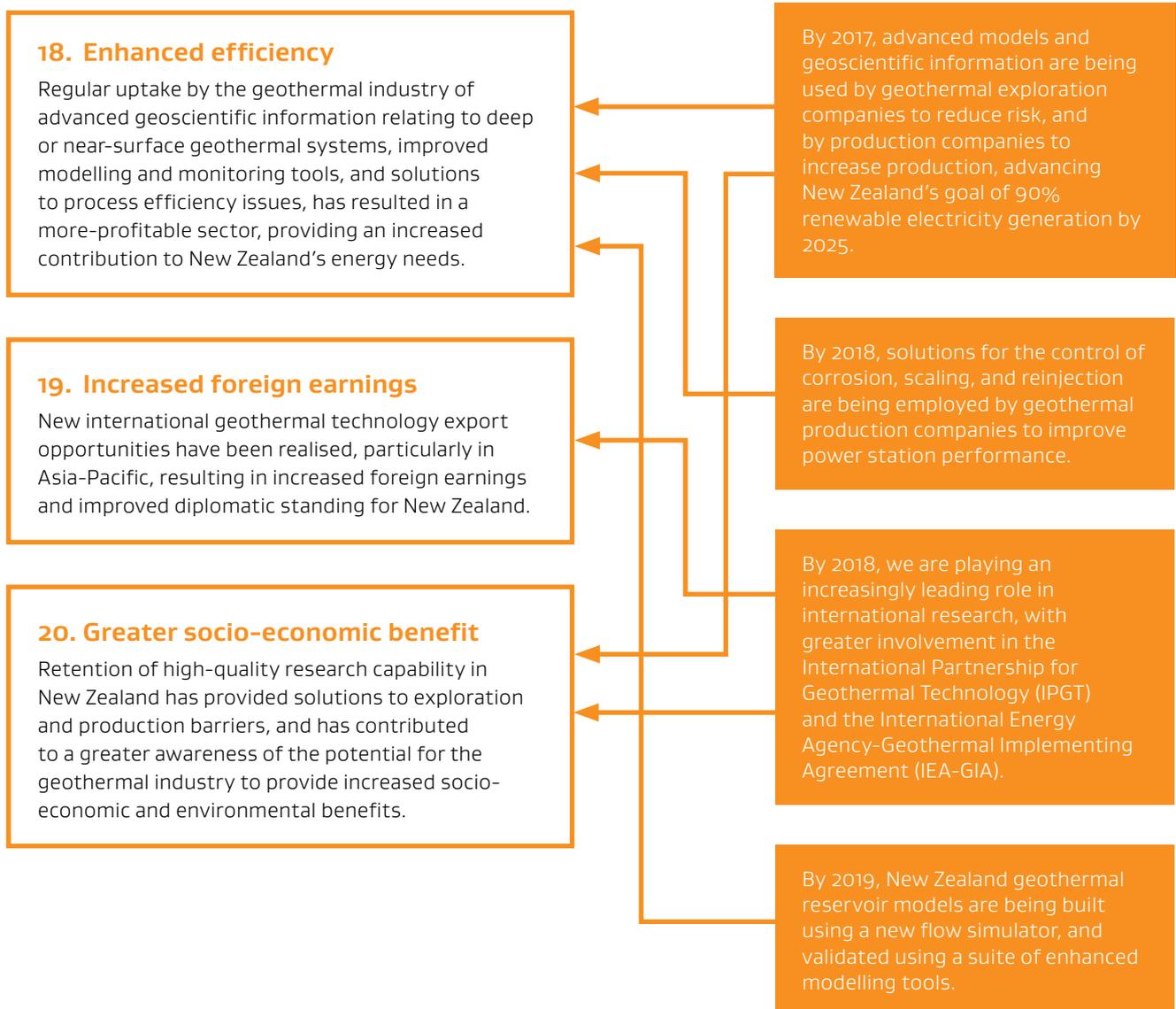
Support the sustainable utilisation of our geothermal resources, by:

- » monitoring changes in our geothermal ecosystems;
- » seeking solutions to scaling and corrosion problems, and the safe disposal of fluids;
- » developing new mineral extraction technologies; and
- » informing improved socio-economic policy and management frameworks.

In conjunction with The University of Auckland, develop the next generation of integrated geophysical, chemical and flow-simulation modelling tools to more-reliably model production effects on geothermal fields.

IMPACTS

MEASURES OF SUCCESS



PETROLEUM RESOURCES

Science outlook

As the principal provider of petroleum geoscience research in New Zealand, we cover a wide range of specialist disciplines, with expertise and local knowledge rarely found within the companies exploring here. Our research seeks to address the question of where the next commercial discovery might occur, by qualifying and quantifying critical parameters of our petroleum systems and providing fit-for-purpose data and knowledge to the global exploration industry. This helps reduce technical uncertainty and aids investment decision making. Our focus is on critical aspects of petroleum source, reservoir, seal, trap and charge, where gaps in knowledge impede exploration efficiency, whilst providing technical overviews of frontier regions. Expanded data sets of geochemical and petrophysical properties for petroleum sources, reservoir rocks, and fluids will drive new interpretations of our petroleum systems. A nationally significant compendium of maps, the Petroleum Prospectivity Atlas, will depict current knowledge of petroleum potential of our offshore basins, helping to inform the Government and industry on the relative merits of areas for exploration permitting (see page 2).

Research began in 2015–16, with new domestic and overseas collaborators, into understanding petroleum source rocks, fluids, and plumbing systems in our established and frontier basins, and into modern depositional analogues of ancient reservoir systems. With the current low oil price, companies are likely to concentrate on exploring the proven oil-producing region of Taranaki. 2016–2017 will see the completion of a seismic mapping project in the offshore Taranaki Basin, providing a benchmark for evaluating and refining exploration planning for years to come. High-resolution fluid-flow models in known petroleum fields in Taranaki will form an empirical basis for predicting petroleum charge scenarios for as-yet undiscovered

petroleum accumulation there, and elsewhere in New Zealand's EEZ. This diversified approach will ultimately help to improve regional exploration play concepts and drilling target delineation.

Targeted end-users

Our mix of fundamental and applied research is tailored explicitly to our primary end-users. The main recipients of our petroleum research outputs are NZ Petroleum & Minerals which uses them to develop strategy around permitting, and to promote New Zealand to foreign investors. We undertake research for nearly every petroleum company exploring here, and have partnerships with several multi-client seismic companies, adding value to their speculative acquisition products. Our Petroleum Basin Explorer web portal provides open access to geoscientific data and information.

Near to medium-term research initiatives

Advance baseline knowledge and interpretation of the structure, stratigraphy, depositional processes and fluid-rock geochemistry of New Zealand's sedimentary basins, to substantiate predictive models of petroleum prospectivity, by:

- » developing a new reference volume, comprising maps and derivative 3D models that illustrate the evolution of the Taranaki Basin structure and stratigraphy through geological time;
- » undertaking multi-disciplinary studies of key stratigraphic intervals;
- » developing multi-dimensional models and visualisation tools that illustrate petroleum-system dynamics throughout the Taranaki Basin; and
- » providing geoscientific data as an improved technical basis for evaluating the petroleum prospectivity of the 17 known frontier basins.

Produce a new generation of digital maps and metadata of potential subsurface petroleum habitats in New Zealand's EEZ, to aid exploration targeting.

Develop new insights into oil and gas occurrences in New Zealand's established and frontier basins, through integrated studies of source rocks, fluids, and subsurface migration systems, enhancing prospectivity and the efficacy of future drilling, by:

- » determining the types, volumes, and properties of petroleum source rocks;
- » geochemically analysing oils, condensates, and gases to provide new information on source rocks, migration pathways, and controls on the distribution of oil versus gas;
- » modelling how petroleum fluids move through strata over geological time; and
- » promoting informed dialogue between the public, iwi, and the private sector on the environmental, social, economic and cultural issues around petroleum exploration.

In collaboration with NIWA, University of Otago, University of Auckland and GEOMAR, assess New Zealand's gas hydrates on the Hikurangi margin, by:

- » determining distribution and style of formation;
- » determining how the hydrate responds to, and influences, faulting, fluid flow, methane seepage, seafloor habitats, and submarine slope failure, providing a baseline for environmental impact assessment; and
- » assessing critical parameters for production modelling of the hydrate reservoirs.

IMPACTS

MEASURES OF SUCCESS

21. Increased exploration investment

Enhanced knowledge of prospectivity has led to greater confidence within the global petroleum sector that New Zealand is an attractive destination for oil and gas exploration and extraction, leading to a steady uptake of exploration permits.

By 2019, there is increased uptake and use by the Government and the petroleum sector, of research results, including the Petroleum Prospectivity Atlas and various petroleum systems databases.

22. Wealth and energy stability

Knowledge gains have resulted in new commercial oil and gas discoveries, leading to increased oil exports, and gas exports in the form of methanol and/or LNG. In addition, the scale and quality of New Zealand's hydrate resource is well enough known to encourage assessment drilling by exploration companies, leading to a potential new energy source and export commodity.

By 2020, at least one new exploration company entrant is taking up acreage in New Zealand, with one or more wells drilled in our frontier basins.

23. Improved resource management

Knowledge of the prospectivity of petroleum resources within New Zealand's EEZ has been used by the Government to prioritise research investment and to award and monitor exploration permits. Informed debate has resulted in greater public consideration of the risks, consequences and potential benefits of petroleum exploration and production.

By 2025, interest in New Zealand's gas hydrates by exploration companies is leading to an exploratory drilling programme.

MINERAL RESOURCES

Science outlook

Although the minerals industry in New Zealand is small by some international standards, it still makes a significant contribution (c. 1%) to New Zealand's GDP, with precious metal production, particularly gold, at record levels currently. Our research is aimed at maintaining this, and attracting new exploration investment. To achieve this, we will provide the Government and industry with information on mineral prospectivity, and knowledge of mineralisation styles, to better identify exploration targets and to de-risk exploration and extraction operations. Key to this is the acquisition and interpretation of new geological, geophysical and geochemical mineral exploration data, and delivery in appropriate product formats.

Targeted end-users

The principal users of mineral data and interpretations are NZ Petroleum & Minerals, and mineral exploration and production companies, such as OceanaGold, Newcrest, Evolution Mining, Blue-Pacific Minerals and Nautilus Minerals. Regional councils, particularly Otago, Waikato, West Coast and Northland, and iwi/Māori, such as Te Rūnanga O Ngāi Tahu and Te Arawa use mineral data to inform environmental and/or economic development strategies and policies. Consultants, such as Kenex and Opus also require basic mineral data to undertake their contracted work.

Near to medium-term research initiatives

Determine the origin and distribution of onshore mineral deposits, and their geological and economic context, to enhance their prospectivity and our ability to locate them, by:

- » undertaking mineral deposit and ore paragenesis studies;
- » developing innovative geoscientific methods for mineral exploration; and
- » undertaking regional and national resource assessments.

In collaboration with US and German researchers, characterise seafloor massive sulphide deposits along the Kermadec arc, improving exploration methods, and providing appropriate policy advice, by:

- » determining the size, extent, and heat flow of active seafloor hydrothermal systems;
- » conducting high-resolution electromagnetic and autonomous underwater vehicle (AUV) surveys to map detailed bathymetry, determine magnetic signature, and locate mineralised vents;
- » conducting remotely-operated vehicle (ROV) surveys to surgically-sample selected hydrothermal systems for vent fluids, minerals and rocks for genesis studies;
- » delineating the 3rd dimension of ore deposits by shallow drilling; and
- » developing a holistic model for the formation of copper-gold mineralisation.

In collaboration with Otago, Waikato and Auckland universities, develop regional to deposit-scale exploration models to aid the discovery of new world-class gold-silver deposits in New Zealand and better-target resources in known deposits, by:

- » determining geological and structural controls on the localisation of volcanic, intrusive, and orogenic ores;
- » characterising the geochemical and geophysical footprints of volcanic, intrusive, and orogenic ores and determining geochemical and mineralogical vectors to mineralisation; and
- » validating ore-deposit models.

IMPACTS

24. Enhanced offshore mineral prospectivity

Understanding of our offshore mineral potential has been sufficient to create renewed interest in exploring the EEZ and ECS by international companies outside of the proposed Kermadec Sanctuary.

25. Increased onshore exploration investment

The provision of enhanced models and targets for exploration has enabled better-focused and more-efficient exploration, resulting in increased Government revenues and flow-on wealth creation.

MEASURES OF SUCCESS

By 2019, new exploration and deposit models, resource assessments, and digital map products are widely used by industry for risk analysis.

By 2020, at least one new mineral exploration permit is taken up in the EEZ, or soon after the release of new prospectivity information.



NEW MATERIALS & PROCESSES

Science outlook

Taking advantage of our niche in ion beam technology, we are undertaking research in advanced materials, with applications in the development of sensor devices and systems, and functional surfaces. Both areas have rapidly expanding global markets that are already worth billions of dollars. We are able to modify precisely the near-surface region of metallic and other substrates, to alter surface properties, or to enhance performance in sensor applications. We are working closely with several New Zealand manufacturers to develop and prototype the devices needed for energy savings, as well as security systems, food processing, medical applications, and other markets. We will develop new materials and technologies for storage and efficient use of energy and energy networks (see also

page 67), and seek ways to achieve resilience of energy infrastructure to natural hazards. This will include development of new materials for improved energy efficiency in industrial processes (including direct use of geothermal energy), new devices to harvest waste heat, and storage devices customised to local conditions. We will continue our efforts to discover extremophile strains suitable for industrial use (see also page 67), and develop and apply isotopic methods for food authentication.

Targeted end-users

In addition to high-value manufacturers, such as Gallagher Group and Page MacRae, the main users of our research findings include engineering consultants, such as HEPA, and technology incubators, such as WNT Ventures, Astrolab and Powerhouse.

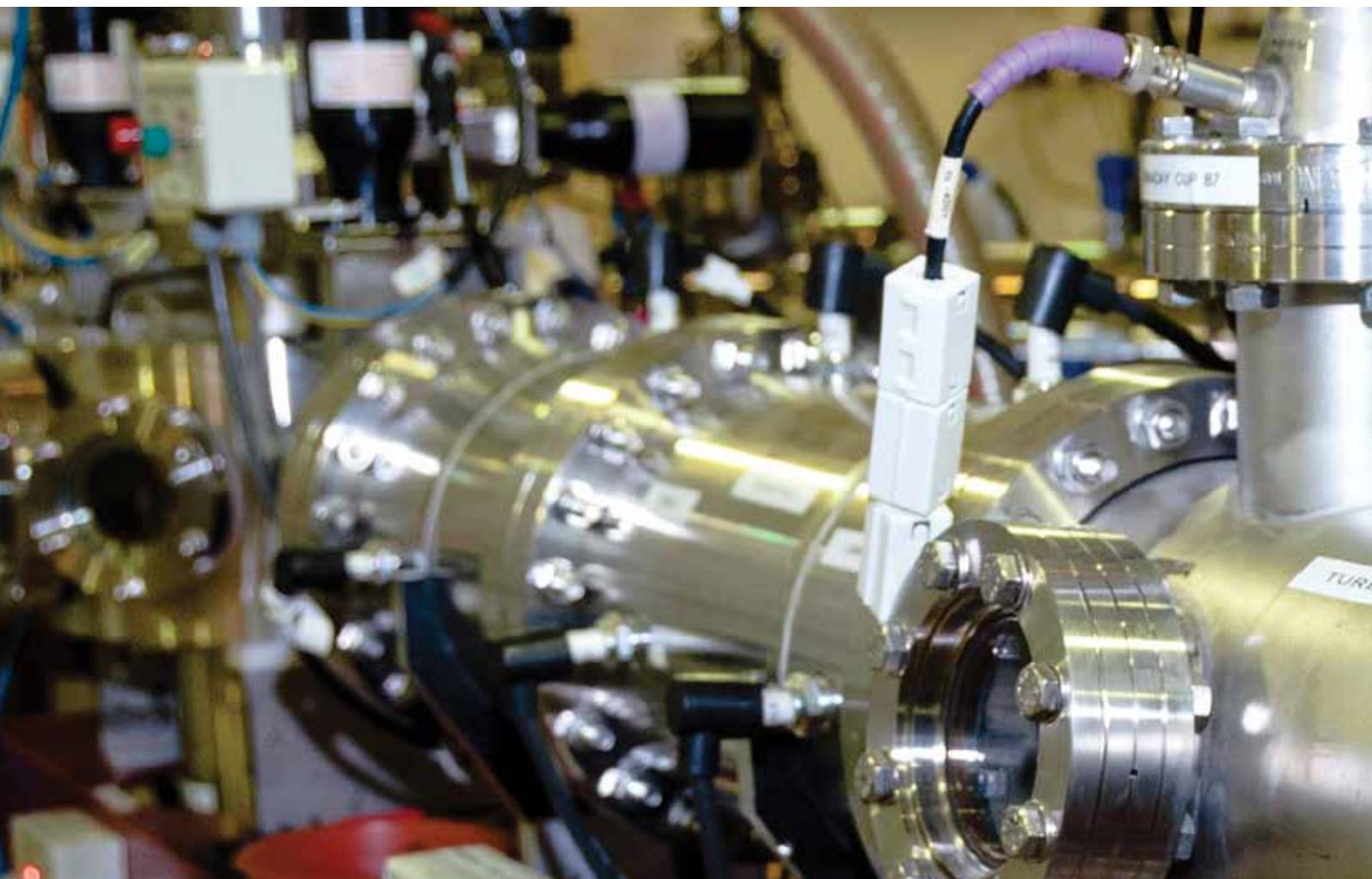
Near to medium-term research initiatives

Undertake fundamental new materials and sensor research for high-value manufacturing applications, to develop proofs of concept as precursors to more-specific product and process applications.

Investigate how to increase the efficiency of thermo-electric power generators by nano-structuring and electronic doping, so that the technology can be used to increase energy conversion efficiencies and reduce greenhouse gas emissions.

Undertake targeted screening of strains in our extremophiles culture collection for industry-relevant bioactive compounds and enzymes.

Develop isotopic methods for authentication of high-value biological products.



IMPACTS

MEASURES OF SUCCESS

26. More-efficient energy production and use

New technological innovations for renewable energy resource use have been developed by New Zealand companies, leading to more energy-efficient primary and manufacturing industries and products.

27. New high-value products and services for export

Our innovative ion beam and isotope technologies have been developed into potential new applications, resulting in wealth creation.

By 2020, R&D created by GNS Science is taken up and used by at least one primary or manufacturing industry.



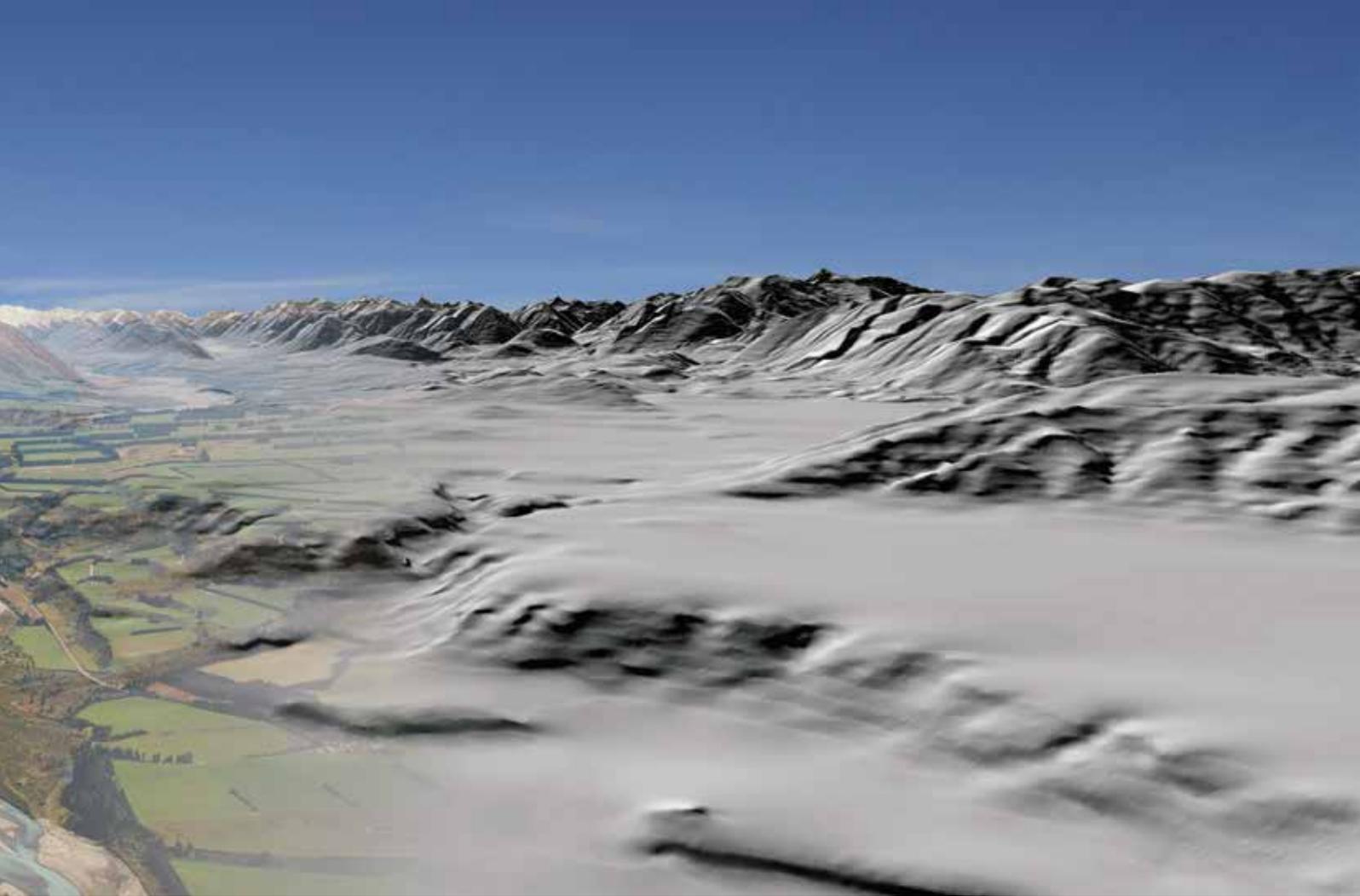


UNDERPINNING GEOSCIENCE KNOWLEDGE

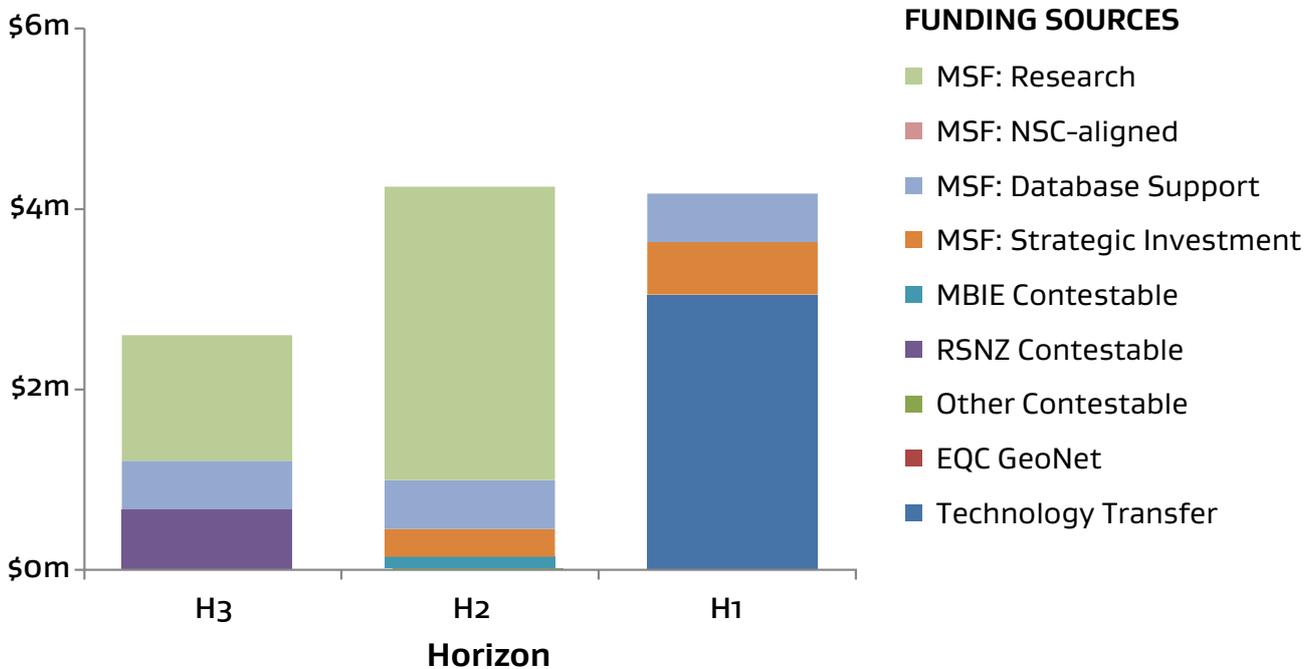
Our role is to expand understanding of Earth science in New Zealand and to ensure that geoscientific data, information and collections are acquired, managed, and made available to end-users now and in the future, thus providing a comprehensive and accessible knowledge base to support policy and decision making by Government, communities and industry.

To achieve this we will continue to explore and map the geological history, structure and processes of Zealandia. We will cooperate with creators, users and stewards of geoscience data and collections to ensure security and accessibility now and into the future. We will use geoscience information, high performance computing, data analysis and new technologies to facilitate innovation that serves local, regional and national needs. And we will promote, educate and build public and stakeholder awareness of our geology, associated geoscience information and its potential benefits for the nation.

The research investment of \$11.0 million pa comes mainly from core (65%), with most of the remainder from technology transfer (28%) and contestable (7%). The MBIE Strategic Funding profile is similar to that of 2015–2016, except that alignment to the *Sustainable Seas* NSC has been significantly reduced, in line with its newly established scope and mission. 67% of the research investment is directed towards the Zealandia Revealed Theme; of the balance, 15% (c. \$1.6 million pa) supports database maintenance and enhancement.



R&D investment 2016–2017



The research is semi-equally H1, relating to use of acquired geoscience to solve current problems and H2, relating to database development and the refinement of pre-existing knowledge (mapping); H3 relates to data acquisition and the development of fundamental understandings of the geological makeup of Zealandia.

ZEALANDIA REVEALED

Science outlook

As an island nation with one of the largest marine jurisdictions in the world (95% of its total EEZ; c. 6 million km²), New Zealand has continental-scale marine resources, with attendant responsibilities and opportunities. Building on research begun in the 1960s, we will continue to survey the seabed and study the underlying geology of this vast offshore area, a task that is large by any measure. Our focus will be on collecting and interpreting geophysical and geological data in the Tasman and Campbell frontiers, NE and SE of New Zealand, respectively, and the submarine volcanoes of the Kermadec arc (see page 2). The aim is to acquire information on the tectono-stratigraphic history of Zealandia, its hazard potential, and its prospects for geological resources.

Such maritime research requires sophisticated and expensive infrastructure, which is being made available through collaboration with overseas marine research organisations, such as the International Ocean Discovery Program (IODP), one of the largest earth science organisations in the world. IODP has committed, over the next two years, to drilling the Hikurangi margin to investigate, for the first time, the physical controls on subduction earthquakes, including slow moving (days to months) plate-boundary slip events (see page 3). Four other sites within New Zealand's EEZ and the Ross Dependency will also be drilled.

Knowledge of the offshore geology and tectonics of Zealandia, thus acquired, will be integrated with new and extant onshore knowledge to provide underpinning support for research aimed at assessing geological hazards and resources, and climate change.

Targeted end-users

Because of the fundamental nature of this Theme – determining and mapping regional tectonics, geological composition and structure – the main end-users of the research are other researchers, who apply the knowledge in the geohazard resilience, environmental science, natural resource, and earth-system processes spaces. Downstream end-users include regional councils, territorial authorities, government ministries (e.g., DoC; MfE; MBIE), government agencies (e.g., EQC, LINZ), geological resource exploration companies, geohazard risk mitigation (infrastructure and insurance) companies, geotechnical consultancies, iwi/Māori and the public.

Near to medium-term research initiatives

Determine the underlying geological structure, and model the tectonic evolution of Zealandia and the SW Pacific, by:

- » synthesising long and short-term active crustal deformation, including rates of horizontal and vertical motion, strain, and stress;
- » analysing Hikurangi margin subduction and fore-arc processes, and Alpine Fault continental collision processes; and
- » determining feedback between tectonics and landscape evolution.

Determine the crustal structure, tectonic history, resource potential and natural hazards of offshore Zealandia, using gravity, magnetic and seismic data.

Advance IODP drilling proposals for Hikurangi, Brothers and Tasman Frontier to scheduling, collect samples and seismic reflection data from proposed sites, and install observatory equipment to monitor near-surface deformation and seismicity.

Determine the tectono-stratigraphic evolution, paleogeography, and sediment dispersal pathways within Cretaceous-Cenozoic successions of our offshore sedimentary basins (the Zealandia Megasequence).

Acquire and collate information on the distribution, composition and origin of geological units of New Zealand and its territories, by:

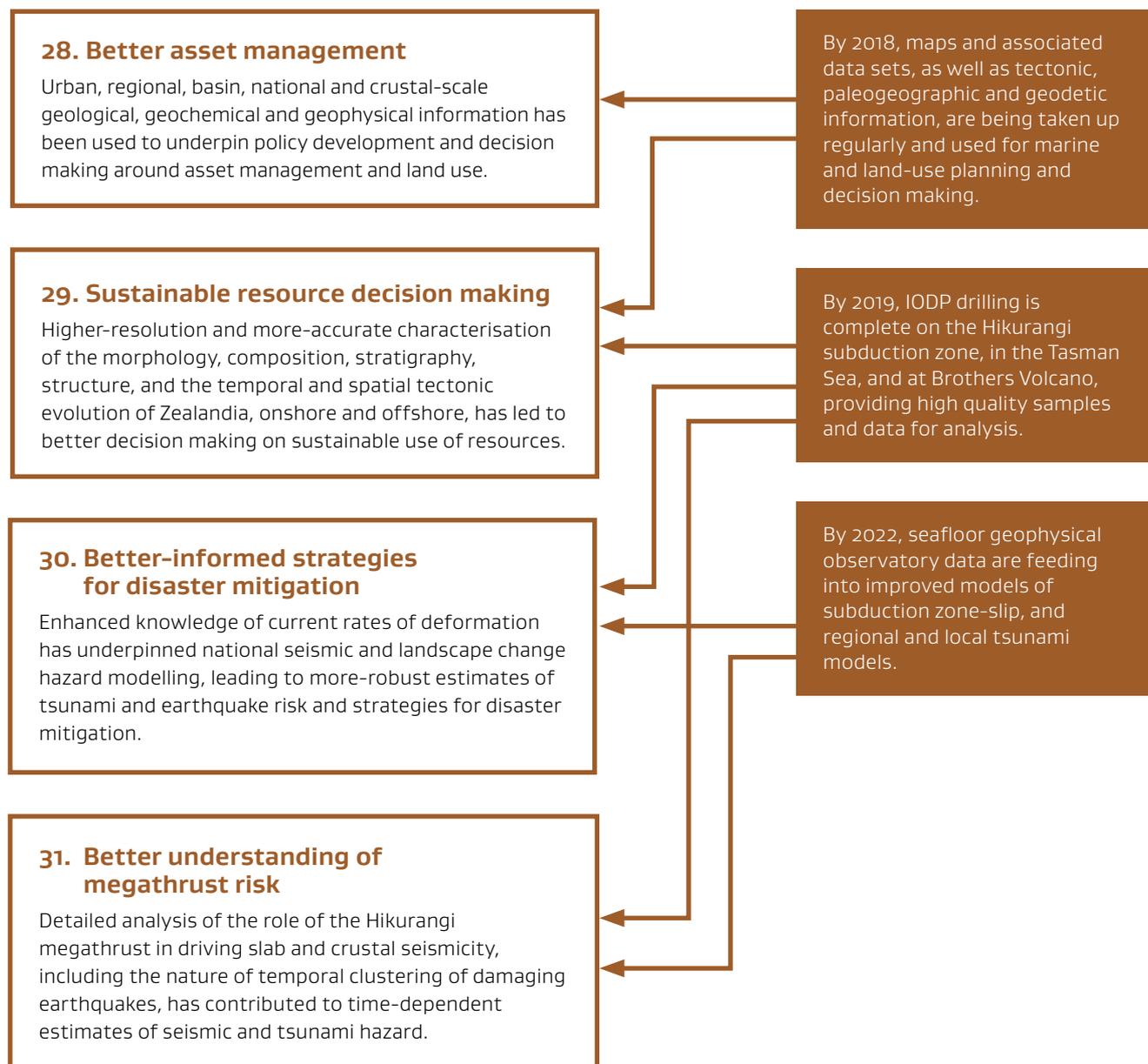
- » mapping urban areas (prioritised by population growth, data availability, and land stability), with surface and subsurface data compiled into 2D and 3D digital geological maps;
- » mapping areas of proven and potential geological resource, offshore territories and regions of other geological significance;
- » determining the composition, structure, thermal history and tectonic evolution of the crystalline and meta-sedimentary basement of Zealandia; and
- » mapping surface features using remote-sensing techniques.

Determine whether the zone of active deformation associated with oblique plate collision increases between Canterbury and Otago, reflecting the southern edge of the underlying Hikurangi Plateau.

Use seismic mapping to identify physical changes across a cycle of slow-slip deformation in the northern Hikurangi subduction zone, to determine if this rapidly increases stress on nearby faults.

IMPACTS

MEASURES OF SUCCESS



GEOSCIENCE INFORMATION

Science outlook

We will maintain our long-term role as the national provider of trusted geoscience knowledge by enhancing nationally important geoscience and geospatial databases and collections of which we have custodianship. By realising the full value of these to the nation, the research community and ourselves, we seek to enhance productivity of basic and applied research through efficient use of data, models and knowledge. As part of the process, we will merge offshore and onshore geoscience data into seamless and publicly accessible packages, update and deliver hard copy and digital geological maps and information, implement global standards, and adopt emerging technologies for enhanced data delivery.

Targeted end-users

Ready access to geoscience information is needed by a wide range of stakeholders involved in research or decision making. This includes: researchers involved in programmes such as QuakeCoRE, DEVORA, It's Our Fault, East Coast LAB, and the National Science Challenges; officials in government ministries, regional councils, territorial authorities or other agencies; scientists and technical officers within the resource, infrastructure, environmental, and civil defence sectors; iwi/Māori; and the public.

Near to medium-term science initiatives

Enhance the content and/or accessibility of Nationally Significant Databases and Collections:

- » Earthquake Information Database
- » Fossil Record File
- » Geomagnetic Database
- » National Groundwater Monitoring Programme database
- » National Paleontology Collection and associated databases
- » National Petrology Reference Collection and PETLAB
- » Regional Geological Map Archive and Data File
- » Volcano Database

Enhance the content and/or accessibility of other nationally important databases:

- » Geological Resource Map of New Zealand
- » Landslide Database of New Zealand
- » Marine and terrestrial geophysical survey databases
- » New Zealand Active Faults Database
- » Petroleum Basin Explorer and associated databases
- » Strong Motion Database



HORIZON SCANNING



A 9% component of our MBIE Strategic Funding (c. \$2.4 million pa), named the Strategic Development Fund (SDF), is allocated contestably on a two-year cycle to investigate the potential of innovative research ideas. Such ideas may require 'pilot' testing for research or commercial potential before they can be considered for contestable, core or commercial support.

Examples of projects currently underway, to be completed by June 2017.

Exploratory roadmaps:

- » Designing and building cost effective, easily deployable, sensitive and selective new environmental sensors. Making sensor-derived interpretations accessible to, understandable by, and useful for, end-users, allowing them to add to and interact with sensor-derived interpretations.
- » Integrating disaster risk reduction and resilience programmes to help New Zealand better understand disaster risk, strengthen governance to manage disaster risk, invest in disaster risk reduction for resilience, and enhance disaster preparedness for effective response.
- » In concert with other national research partners, setting a path for New Zealand's sustainable energy future that provides energy security, protects our environment, and creates wealth.
- » Investigating in detail the geological history, hazards and resources of New Zealand's EEZ, the submerged and largely unknown part that makes up more than 95% of the country's area.



Targeted projects:

- » Develop a pilot, non-stick coating system capable of modifying surfaces, to demonstrate ion beam technology on a semi-commercial scale.
- » Develop an automated Operational Earthquake Forecasting framework that will continually forecast earthquake probabilities for all of New Zealand, and which seeks to address identified issues related to data and models currently in use.
- » Explore the ability of extremophilic bacteria to capture methane and carbon dioxide emissions and convert them into valuable products.
- » Determine the causes of chemical element variation in soils of southern New Zealand, to provide baselines for agriculture, health, environment and resource discovery applications.
- » Build geodetic capability in New Zealand, to better measure and understand tectonic deformation and sea level rise.
- » Improve regional relative sea level rise projections for Hawke's Bay and evaluating the impact of these changes on our natural coastal environment, groundwater systems, and hazards (liquefaction) risk.

PERFORMANCE MONITORING

The overall performance of GNS Science is monitored via the set of Key Performance Indicators (KPIs) in the table below. These include two GNS Science-specific indicators, and eight CRI generic indicators, upon which we will report. Other information, of a commercial-in-confidence nature, is included in the Quarterly Reports to our shareholders. These KPIs are complementary to the 37 Measures of Success linked to the Research Initiatives and Impacts detailed on pages 34 to 65.

2016–2017 deliverables (in addition to the Upcoming Milestones on pages 2 and 3 and the Horizon Scanning projects on page 66) are:

- » Air particulate source apportionment data used for setting new air pollution standards.
- » ‘Smart’ aquifer characterisation tools used by regulators.
- » Mobile and website felt reporting integration completed.
- » Choices on the expansion of the Auckland urban area made on the basis of geohazard risk and resilience analysis.
- » Increased uptake of research results in land-use and emergency management plans, policies and strategies.
- » Volcanic ash and health response plan devised.
- » Advanced models and geoscientific information used by geothermal exploration companies to reduce risk, and by production companies to increase production.
- » Publicly-accessible databases and collections regularly interrogated by research, government and commercial sector end-users, with data and samples making a significant contribution to analysis, decision making and risk reduction.

Indicator	Measure	Forecast 2016	Budget 2017	Outlook 2018	Outlook 2019
GNS Science Specific		Year ending 30 June			
High performance culture	Workplace injuries, causing missed work days, per million work hours	<5	<5	<5	<5
	Staff proud to work for GNS Science (biennial climate survey)	86%	N/A	90%	N/A



Indicator	Measure	Year ending 30 June	Forecast 2016	Budget 2017	Outlook 2018	Outlook 2019
CRI Generic						
End-user collaboration	Revenue per FTE from commercial sources (\$000)		92	84	88	93
Research collaboration	Papers with New Zealand co-authorship only		15%	15%	15%	15%
	Papers with international co-authorship only		42%	42%	42%	42%
	Papers with New Zealand and international co-authorship		37%	37%	37%	37%
	Papers co-authored		93%	93%	93%	93%
Technology transfer	Commercial reports per scientist FTE		1.0	1.0	1.0	1.0
Science quality	Impact of scientific publications (weighted citation index) ¹		2.9	3.0	3.0	3.0
Financial indicator	Revenue per FTE (\$k)		228	219	222	225
Stakeholder engagement ²	Surveyed end-users who have confidence that GNS Science considers their sector's priorities when setting its research priorities		N/A	>70%	N/A	>70%
	Surveyed end-users who have confidence that GNS Science has the ability to assemble 'best' research teams		N/A	>85%	N/A	>85%
	Surveyed end-users who have adopted knowledge from GNS Science in the past three years		N/A	>90%	N/A	>90%

¹Mean 2-year impact factor for SCImago-assessed journals, weighted by the number of GNS Science publications

²Based on the results of a biennial MBIE-commissioned Colmar Brunton Survey (>50 respondents)

FINANCIAL FORECASTING

In recent years, GNS Science has delivered steady profit and cash flows while continuing to invest in its scientific equipment, IT infrastructure and facilities. Our long-term aim is to achieve an annual return on average Shareholders' equity of 8%. In the short-term, there are factors affecting specific areas of the business that result in a lower return on average Shareholders' equity of 6.8% for the 2016-2017 financial year and 7.4% for 2017-2018. This is in line with the forecast in last year's SCI.

We have assumed only marginal changes to GNS Science's operating environment in developing our financial projections. MBIE Strategic Funding is assumed to remain flat throughout the planning period. Revenue from EQC to maintain and operate the GeoNet network is at levels agreed with EQC. Our management of *Resilience to Nature's Challenges* NSC will have a full year of operation in 2016-2017 with an increase in revenue and costs to research sub-contractors.

The plan reflects modest revenue growth and continuing tight control on operating costs. The budgeted Group revenue for 2016-2017 is \$83.2 million with total costs of \$80.3 million, creating an operating surplus (EBIT) of \$2.9 million. GNS Science expects to deliver steady operating cash flows with an EBITDA of \$8.9 million.

The capital plan includes the on-going investment in scientific equipment to support our research activities and to secure new revenue streams. Our rolling IT upgrade and our building and facility refurbishment programmes will continue. No significant investments are envisaged

for 2016-2017, although planning has commenced on renovating one of our buildings at Wairakei; this will likely commence in 2017-2018. Our capital programme will continue to be funded through existing resources and operating cash flows.

A dividend payment of \$250,000 has been forecast in those years where the company is carrying no bank debt.

Risks

There is forecasting uncertainty associated with our revenue budgets:

- » The change in the MBIE contestable funding system may reduce our ability to secure revenues to replace expiring contracts in what is likely to be an increasingly competitive process. We only have a small amount at risk in 2016-2017 but the amount increases significantly through the planning period.
- » The achievement of our technology transfer revenue targets is subject to the market and the economic climate, which have been increasingly volatile over recent years.

- » Outcomes of the MBIE Strategic Funding Review could positively or negatively affect our revenues beyond 2016-2017.

GNS Science's budgeting has been realistic and we have established achievable targets. We believe that upside opportunity offsets any downside risk. We also have the resources to address adverse trading conditions should they occur, without recourse to the shareholders for financial support. We will actively monitor and respond to any risks that emerge.

Deployment of MBIE Strategic Funding

GNS Science receives \$27.1 million of Strategic Funding from MBIE each year and invests it in basic and applied research, science capability, national and international collaboration and science infrastructure (specifically, Nationally Significant Collections and Databases). MBIE Strategic Funding has enabled us to build, with confidence and speed, science capability in areas of national need.



Without MBIE Strategic Funding, developing and maintaining capability would be a slow and uncertain process through contestable bidding. Our science users will also benefit from being able to align their funding with our MBIE Strategic Funding and hence boost practical outcomes.

MBIE Strategic Funding allocation at a CSA and Theme level has remained relatively constant since its introduction, except for the c. 9% SDF component, which is refreshed every two years. At a programme level, there has, and will continue to be, core investment adjustments made on the basis of changing sector priorities and shifts in international science. Such changes are implemented by the Executive with Board approval.

Commercial value

Section 16(3) of the CRI Act requires the Company to furnish an estimate of the current commercial value of the Crown's investment. We use net asset value as a proxy for the commercial value of the Group. The net asset position as shown in accordance with the company's accounting policies for 30 June 2015 was \$30.5 million.

Dividend policy

Our dividend policy is that funds surplus to the Company's investment and operating requirements, as determined by the principles outlined below, will be distributed to the shareholders. In determining surplus funds, consideration will be given to:

- » Providing for capital investment requirements (including equity investments) without recourse to the Crown for equity injections to the Company;

- » Opportunities for internal development expenditure;
- » The Company's working-capital requirements (including subsidiaries and businesses in which equity is held);
- » The short, medium, and long-term financial viability of the Company, including its ability to repay debt and the level of revenue in advance;
- » Risks of meeting our financial targets; and
- » The obligations of the Directors under the Companies Act 1993 and other statutes.

The Board will detail, in a submission to shareholding Ministers, within two months of the end of each financial year:

- » The amount of dividend (if any) recommended to be distributed to the shareholders; and
- » The percentage of tax-paid profit that the dividend represents.

Compensation

Where the Crown wishes us to undertake activities or assume obligations that will result in a reduction of our profit or net worth, the Board will seek compensation sufficient to allow the Company's position to be restored. No compensation is currently being sought from the Crown.

Government Outcome Area	Research (\$k)	NSC Aligned (\$k)	Database Support (\$k)	Total (\$k)
Biological Industries	152.5	0	0	152.5
Energy and Minerals	8,417.5	0	48	8465.5
Hazards and Infrastructure	10,131.0	1,000	353	11,484.0
Environment	2,722.0	1,300	1,213	5,235.0
High-value Manufacturing	869.0	250	0	1,119.0
Capability Enhancement	659.0	0	0	659.0
Total	22,951.0	2,550	1,614	27,115.0

Group Ratios and Statistics

Year ending 30 June	Forecast 2016	Budget 2017	Outlook 2018	Outlook 2019	Outlook 2020	Outlook 2021
Revenue (\$000)	84,047	83,236	84,558	85,940	87,522	89,271
Revenue growth	10%	-1%	2%	2%	2%	2%
Operating results (\$000)						
Operating expenses and depreciation	81,997	80,336	81,176	81,938	83,185	84,603
EBITDA	7,830	8,880	9,462	10,182	10,637	11,118
EBIT	2,050	2,900	3,382	4,002	4,337	4,668
Profit before tax	2,270	3,100	3,582	4,202	4,537	4,868
Profit after tax	1,634	2,232	2,579	3,025	3,267	3,505
EBITDA per FTE	21	23	25	27	28	29
Total assets	54,430	54,978	56,609	58,693	62,028	65,608
Total equity	31,929	33,911	36,240	39,015	42,032	45,287
Capital expenditure	7,000	7,000	7,300	7,300	7,300	7,300
Liquidity						
Quick ratio	1.51	1.39	1.41	1.43	1.59	1.78
Profitability						
Return on equity	5.2%	6.8%	7.4%	8.0%	8.1%	8.0%
Operating margin	9.3%	10.7%	11.2%	11.8%	12.2%	12.5%
Return on capital employed	5.9%	7.9%	8.7%	9.6%	9.7%	9.7%
Operational risk						
Profit volatility	10.9%	10.5%	10.1%	11.5%	10.5%	8.0%
Forecasting risk	-0.4%	-1.8%				
Growth/Investment						
Capital renewal	121%	117%	120%	118%	116%	113%
Dividend (\$000)	250	250	250	250	250	250
Financial strength						
Equity ratio	59%	62%	64%	66%	68%	69%
Cash and short term deposits (\$000)	6,881	5,744	5,839	5,996	7,720	9,836

ACCOUNTING & BUSINESS POLICIES

The Institute of Geological and Nuclear Sciences Limited is established under the Crown Research Institutes Act 1992 and the Companies Act 1993. Its subsidiary companies are established under the Companies Act 1993. The financial statements have been prepared in accordance with the Crown Research Institutes Act 1992, the Public Finance Act 1989, the Companies Act 1993, the Crown Entities Act 2004 and the Financial Reporting Act 1993.

Consolidated financial statements for the Group comprising the Institute of Geological and Nuclear Sciences Limited (the Company) and its subsidiaries are presented.

The principal activities of the Company are to undertake geoscience and nuclear science research, development and technology transfer, predominantly in New Zealand.

The financial statements have been prepared in accordance with New Zealand generally accepted accounting practice. They comply with New Zealand equivalents to International Financial Reporting Standards and other applicable Financial Reporting Standards, as appropriate for profit-oriented entities. The financial statements also comply with International Financial Reporting Standards.

The financial statements of the Group have been prepared on an historical cost basis, except that derivative financial instruments are measured at their fair value.

The financial statements are presented in New Zealand dollars, which is the Group's functional currency. All values are rounded to the nearest thousand.

Subsidiaries are those entities controlled by the Company. Control is achieved where the Company has the power to govern the financial and operating policies of an entity to obtain benefits from its activities.

The financial statements of subsidiaries are included in the consolidated financial statements using the purchase method of consolidation. The effects of intra-group transactions are eliminated in the consolidated financial statements.

A joint arrangement is an arrangement whereby the Company or its subsidiaries have joint control over an entity. Joint control is the contractually agreed sharing of control of an arrangement, which exists only when decisions about the relevant activities of that entity require the unanimous consent of the parties sharing control. A

joint arrangement is either a joint operation or a joint venture. For a joint operation the Group recognises its share of assets, liabilities, revenues and expenses on a line-by-line basis using the proportionate method. For a joint venture the Group recognises its interest in a joint venture as an investment and accounts for that investment using the equity method.

In applying the accounting policies, there is the requirement for judgements, estimates and assumptions to be made about the carrying amounts of some assets and liabilities. The estimates and assumptions are based on historical experience and other relevant factors. Actual results may differ from these estimates.

Further detail in respect of the accounting policies for the Group is set out in the GNS Science Annual Report for the year ended 30 June 2015. No significant changes in accounting policies are envisaged between the above policies and the budget and forecast information included in that document.

Shareholder consent for significant transactions

The Board will obtain prior written consent for any transaction or series of transactions involving full or partial acquisition, disposal or modification of property (buildings, land and capital equipment) and other assets with a value equivalent to or greater than \$10 million or 20% of the Company's total assets (prior to the transaction), whichever is the lesser.

The Board will obtain prior written consent of shareholding Ministers for any transaction or series of transactions with a value equivalent to or greater than \$5 million or 30% of the Company's total assets (prior to the transaction) involving:

- » acquisition, disposal or modification of an interest in a joint venture or partnership, or similar association;
- » acquisition or disposal, in full or in part, of shares or interests in a subsidiary, external company or business unit;
- » transactions that affect the Company's ownership of a subsidiary or a subsidiary's ownership of another entity; and
- » other transactions that fall outside the scope of the definition of the Company's core business or that may have a material effect on the Company's science capabilities.

Investments in capital assets

We will invest in capital equipment and facilities that will enhance our ability to develop our business and provide an appropriate rate of return on the investment. Return on investment will be monitored to provide a basis for future investment decisions.

Procurement of services

We will continue to assess the procurement of services, facilities and resources that may be shared among the Crown Research Institutes and other related organisations. This assessment will involve working with the other CRIs to identify any duplications of effort where cost savings, efficiencies, or quality improvements may be achievable.

Databases and collections

The Company has policies on the management of its data and collections, which comply with applicable legislation, including the Official Information Act 1982, the Commerce Act 1983, the Crown Research Institutes Act 1992, and the Privacy Act 1993.

We will make our scientific datasets and collections publicly available using a suitable Creative Commons license, except: 1. when data or collections were obtained or created for a third party. In this circumstance we will maintain any agreed confidentiality or restriction on use until the data or collection has entered the public domain; or 2. when Creative Commons licence terms are not appropriate, for example, where access fees are necessary to sustain our business by giving us a return on investment from our own resources.

Whenever possible we will adopt international, national, or industry standards applicable to the data. When this is not possible, we develop organisational standards.

We allocate a portion of our MBIE Strategic Funding for maintaining our databases and collections, and facilitating their wider use.

We will not dispose of, without the prior permission of the shareholders, any of the Nationally Significant Databases and Collections for which we have responsibility; nor will we dispose of any other database or collection we consider to be of national significance without first discussing this with the shareholders (see listings on page 64).

Regard will be held to the Crown Research Institutes Act 1992 and the Public Records Act 2005 when disposing of any database or collection. We will advise shareholders of any dispute regarding the terms of access and use of any Nationally Significant Database or Collection. The Company will make all reasonable attempts to settle the dispute with the disputing party. We will refer the matter to shareholders in the absence of any agreement within 30 days of notification of a dispute. Any decision by the shareholders will be binding on the Company.

Image credits

FRONT/BACK COVER:

Aoraki Mount Cook and Lake Pukaki at sunset, *Lloyd Homer*

UPCOMING MILESTONES (pages 2–3):

Oil Rig at Sunset, *Shell Todd Oil Services*

Eastern flank of Ruapehu between Wahianoa and Whangaehu valleys, *Dougal Townsend*

3D Image of Brothers volcano, *Cornel de Ronde and WHOI*

3D Software blueprint projection of Cathedral Square, *AXO Anchor*

Nga Awa Purua Geothermal Power Station, Wairakei, *Mighty River Power/Tauhara North No. 2 Trust*

Ruapehu erupting, *Lloyd Homer*

Icicles in Antarctica, *Rebecca Roper-Gee, Antarctica New Zealand*

Ocean view, Canterbury from JOIDES Resolution, *Martin Crundwell*

DELIVERING ON OUR VISION (pages 6–7)

Winter sunset Mount Ruapehu, *Paul Grimwood*

STATEMENT OF CORE PURPOSE (pages 8–9)

Milford Sound, *Graham Hancox*

OPERATING ENVIRONMENT (pages 10–13)

Sunset at Lion Rock, Castlepoint Beach, Wairarapa, *Margaret Low*

OUR CONTRIBUTION TO GOVERNMENT PRIORITIES (pages 14–15)

The Beehive, Parliament House, Wellington, *Image provided by MBIE*

SECTOR PRIORITIES (pages 16–21)

Gisborne, *Max Lawton - unsplash.com*

Benmore Dam, *Public Domain Access*

Symmetry in Energy, Ngatamariki Geothermal Power Station, Taupō, *Chris Sisarich - nzstory.govt.nz*

NATIONAL SCIENCE CHALLENGES (pages 22–23)

Flooding at the Hororata River following the Darfield Earthquake, *Dougal Townsend*

NATURAL HAZARDS RESEARCH PLATFORM (pages 24–25)

Crater on White Island (Whakaari) Volcano, Bay of Plenty, *Lloyd Homer*

TE WHAKATINANATANGA O TE TIROHANGA MĀTAURANGA (pages 26–27)

Meeting House, Waitangi, *Unknown*

IMPLEMENTING VISION MĀTAURANGA (pages 28–29)

Meeting House, Waitangi, *Unknown*

ORGANISATIONAL INITIATIVES (pages 30–31)

Seascape and sunset, Charleston, West Coast, *Lloyd Homer*

OUR RESEARCH (pages 32–65)

Laboratory equipment at National Isotope Centre, *Margaret Low*

Inside the ice core tent, Antarctica, *Nancy Bertler*

Mount Ruapehu volcano in eruption, June 1996, *Lloyd Homer*

Setting up laser scanner to document damage to Christchurch Basilica, *Margaret Low*

House teetering after a landslide, Maungaraki, Wellington, *Lloyd Homer*

Collapse of Pohangina River Bridge following extensive flooding, *Graham Hancox*

Christchurch earthquake damage clearance, *Margaret Low*

GNS Science scientists with oil company representatives on the North Taranaki Coast, *Peter King*

Marble like mineral deposits, *Unknown*

Ion Beam laboratory, National Isotope Centre, *Margaret Low*

Canterbury plains and Southern Alps blend into 3D topographic data, *GNS Science*

Mapped rock terrain, photo composite, *GNS Science*

HORIZON SCANNING (pages 66–67)

GPS measurement equipment on the top of the Southern Alps, *Aline Peltier*

PERFORMANCE MONITORING (pages 68–69)

Cliffs and lagoon at Castlepoint, Wairarapa, *Lloyd Homer*

FINANCIAL FORECASTING (pages 70–71)

Waiau Falls, Coramandel, *Lloyd Homer*

ACCOUNTING & BUSINESS POLICIES (page 73)

Money, *Public Access - negativespace.co*

Principal Location

GNS Science
1 Fairway Drive, Avalon
Lower Hutt 5010
PO Box 30368
Lower Hutt 5040
New Zealand
T +64-4-570 1444
F +64-4-570 4600

Other Locations

National Isotope Centre
30 Gracefield Road
Lower Hutt 5010
PO Box 31312
Lower Hutt 5040
New Zealand
T +64-4-570 1444
F +64-4-570 4657

Dunedin Research Centre
764 Cumberland Street
Dunedin 9016
Private Bag 1930
Dunedin 9054
New Zealand
T +64-3-477 4050
F +64-3-477 5232

Wairakei Research Centre
114 Karetoto Road
Wairakei 3377
Private Bag 2000
Taupo 3352
New Zealand
T +64-7-374 8211
F +64-7-374 8199

