GeoNet Annual Report

Financial year 2023-24

Mount Inframenta Station, South of Hokitika

Recognising our partners

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HIKINA WHAKATUTUKI

Natural Hazards Commission
Toka Tū Ake

Toitū Te Whenua
Land Information New Zealand

National Emergency Management Agency
Te Rākau Whakamarumaru

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Introduction

GeoNet: A Critical Science Programme for Aotearoa New Zealand

For over two decades, the GeoNet programme has delivered Aotearoa New Zealand's geohazard monitoring services. What began in 2001 with just 102 land-based sensors has grown into a world-class system with a network of more than 9,100 pieces of equipment across 700+ locations.

GeoNet has become an integral part of how Aotearoa New Zealand monitors, understands, and responds to natural hazards, providing open-access data for researchers, real-time information for decision makers and emergency responders, and vital public information.

The 2023-24 year was a time of both achievement and forward planning. We delivered a full programme of work, ensuring Aotearoa New Zealand's geohazard monitoring remained robust and responsive.

Our 24/7 operations continued to provide real-time monitoring, and scientific expertise to support decision-makers and communities through geohazard events. We also reached a major milestone with the completion of the GeoNet 10-Year Strategy 2024–2034, developed to guide the long-term evolution of the programme.

Mount Ngauruhoe from Te Onetapu

GeoNet: A Critical Science Programme for Aotearoa New Zealand

However, as we look ahead, the landscape for GeoNet is changing. While we planned for a future of continued investment and innovation, the reality of the government funding now allocated means that resources for geohazard monitoring will decline significantly over the coming years.

The expectation that user-pays models will offset this reduction presents challenges, and, without additional funding, the scope of GeoNet services will need to be reduced. This will impact our ability to sustain the full breadth of monitoring, infrastructure maintenance, and scientific advice that Aotearoa New Zealand relies on.

Despite these uncertainties, 2023-24 was a year of success, demonstrating the strength of the GeoNet programme and the dedication of the team and partners in delivering critical services for Aotearoa New Zealand.

This report aims to present a summary of the highlights and challenges from the year, including performance of contracted deliverables and finances. It will also present a summary of the future for the programme.

Mount Taranaki from German Hill GNSS Station

Key Events in 2023-24

Event Monitoring & Response
Throughout the year, the GeoNet programme continued to support Aotearoa New Zealand in its role in monitoring and responding to geohazard events, ensuring timely information was available to decision-makers and the public.

Earthquake Monitoring
- 20,486 earthquakes were centred in, and around, New Zealand.
- The largest event was a magnitude 6.0 earthquake 45km north of Geraldine on 20 September, with over 13,000 felt reports submitted.
- The most widely felt earthquake was a deep magnitude 5.2 event south-west of Whanganui on 11 August, generating over 20,000 felt reports via our website and app.
- A Canterbury earthquake sequence in June highlighted the ongoing aftershock activity from the 2010-2011 sequence.

Volcanic Monitoring
- Whakaari/White Island: A new eruptive episode in May–June 2024 followed five years of relative calm. By mid-year, the crater lake had disappeared due to evaporation, and new vents had formed. Steam, gas, and ash plumes were visible from the mainland, prompting increased monitoring and analysis.
- Mt Ruapehu: The crater lake went through multiple heating and cooling cycles, and a small earthquake sequence was recorded beneath the volcano in November 2023. This triggered additional monitoring and analysis activity, including ongoing communication with key stakeholders

Tsunami & Landslide Hazard Monitoring
- Our contribution to the operation and analysis of data from New Zealand's DART tsunami buoy network helped ensure this valuable data input was available to feed into critical early warning capabilities.
- GNS Science, with support from the GeoNet programme worked closely with emergency managers to assess potential landslide risks following heavy rainfall events, particularly in regions still recovering from Cyclone Gabrielle.

Infrastructure & Network Maintenance
Maintaining and upgrading the monitoring network is essential to ensuring reliable data collection and hazard detection.
- 121 field trips were completed, covering over 300 monitoring stations for maintenance, repairs, or upgrades.
- Satellite and instrumentation renewals and upgrades strengthened data reliability.
- Our data archive surpassed 330TB, accessible through Amazon Web Services, supporting thousands of researchers and users worldwide.

Public Engagement & Data Accessibility
GeoNet's public engagement and open data continue to play a crucial role in how New Zealanders interact with geohazard information.
- The GeoNet app has now been installed on over 261,821 devices, ensuring instant access to earthquake and volcano alerts.
- Our Communications Duty Officers responded to 37 earthquakes of significant interest, providing rapid public updates.

Organisational Milestones
- The National Geohazards Monitoring Centre (NGMC) celebrated its fifth anniversary in December 2023, marking five years of 24/7 real-time geohazard monitoring.
- The GeoNet 10-Year Strategy 2024–2034 was finalised, alongside a draft 5-Year Rolling Business Plan to guide its implementation.

Looking Ahead

Navigating Funding Changes

While 2023-24 was a year of strong performance, the coming years will bring new challenges. The funding allocation received for GeoNet services over the next four years declines significantly, with an expectation that user-pays models will address the shortfall. However, under current fiscal conditions, achieving this level of user pays funding is uncertain.

This will impact the ability of the programme to sustain the full scope of geohazard monitoring and scientific services. Over time, reductions in funding will:

- Limit infrastructure maintenance and upgrades, leading to gradual degradation of monitoring networks.
- Reduce real-time hazard monitoring capacity, potentially affecting the speed and accuracy of earthquake, volcano, tsunami, and landslide detection.
- Impact the progamme's ability to provide 24/7 geohazard response, including real-time monitoring and scientific advice to important decision makers.
- Risk the availability of open data and science communication, which is widely used by researchers, media, and the public.

Despite these challenges, GeoNet remains committed to delivering the best possible geohazard monitoring and research within available resources alongside our partners.

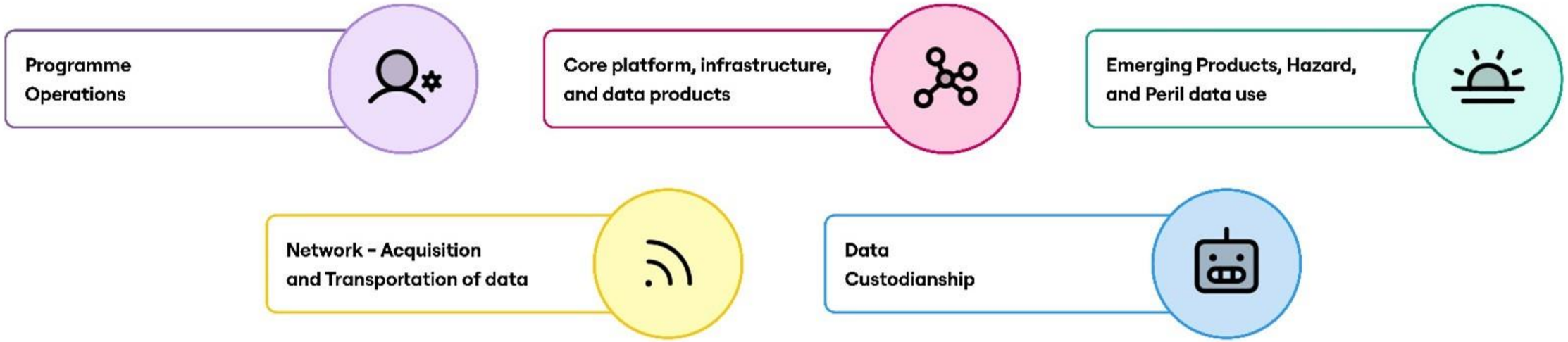
Mount Ngauruhoe from nearby GNSS Station

National Geohazards Monitoring Centre, GNS Avalon

Our Reporting Approach

This annual report is structured in alignment with the Draft GeoNet Five-Year Rolling Business Plan. This plan divides the GeoNet program of work into five cross-functional delivery areas of the programme:

- Programme Operations
- Network – Acquisition and Transportation of Data
- Core platform, infrastructure, and data products
- Data Custodianship
- Emerging Products, Hazard and Peril data use



Programme Operations

The GeoNet Programme Operations roadmap outlines the activities that we do to produce a science-led, user-focused, sustainably funded programme, benefiting Aotearoa New Zealand. It sets the groundwork for smooth operations, ensuring that priorities and decisions are transparent and clear. This includes explaining the value of our work in a way that is easy for everyone—ourselves, our users, and our stakeholders (Hunga Whaipānga) to understand, and that helps build pride and recognition for our people and partners.

The roadmap also focuses on managing and maintaining trust in the GNS Science, GeoNet and funding stakeholder brands, helping educate people on New Zealand's land and geohazards, all while supporting others to make a positive impact within the science value chain.

Highlights and Outcomes

Programme Operations:

- In March 2024, the *GeoNet 10 Year Strategy 2024 – 2034* was finalised and approved. This is our first 10-year strategy and is guided by the outcomes of the 2022 GeoNet Strategic Review. We had planned toward three sequential future states, Sustain, Evolve & Strengthen, and Transform. They were progressive by design, with blended boundaries between each state. They were set up to support GeoNet to build the capability, resources, and partnerships it needs to achieve the ambitious possible futures it envisions. The reality of the government funding now allocated means that resources for GeoNet will decline over the coming years, and much of the ambition articulated in the strategy will need to be tempered.

- In May 2024, we completed a draft of our first Five-Year Rolling Business Plan. This is the document that outlines the implementation steps of the GeoNet 10 Year Strategy 2024-2034. The roadmaps that make up this plan present key initiatives and milestones against timelines. The roadmaps demonstrate how we have planned to achieve our strategic direction set out the future states in the 10-Year Strategy. This forward planning provides GeoNet and its partners an understanding and indication of planned investment in the medium term.

- During the 2023-24 year we worked with our stakeholders to complete a significant programme of work including a business case for sustainable funding. As a result, a multi-year funding allocation was secured for GeoNet and the National Seismic Hazard Model (NSHM) in the Government Budget 2024.

- An independent review of 24/7 services was completed and presented to the GeoNet Advisory Panel in March 2024. This review assessed the performance and operational challenges of the GeoNet 24/7 real-time geohazard monitoring service and made recommendations to inform the evolution of 24/7 real-time geohazard monitoring, including what is needed to align the National Geohazard Monitoring Centre (NGMC), GNS Incident Management System (IMS) and National Emergency Management Agency's (NEMA) 24/7 Monitoring, Alerting and Reporting Centre (MAR).

Highlights and Outcomes (cont.)

Programme Operations:

- We hosted the April 2024 Southwest Pacific SeisComP Regional User Group (SCRUG) in Wellington. For three days, we were joined in person and online by over 50 colleagues from across New Zealand, Australia, Tonga, Fiji, and other neighbouring nations to talk about SeisComP (the earthquake location software that we all use). The attendees received first-hand information on new product development and upcoming software releases from GEMPA, the developers of SeisComP and shared their experiences from the earthquake and hazard monitoring front line. This was the fifth meeting of this regional user group. SCRUG is a great opportunity for technical specialists and seismologists to dive into the inner workings of SeisComP and share their experiences, leading ultimately to improvements in GeoNet data and products.

- We received endorsement from the GeoNet Steering Group to formally include support for geomagnetic (GeoMag) data services in the Product & Services Catalogue. GeoMag is one of the key datasets for monitoring Space Weather, a potential global and regional hazard. Operational support and activities around geomagnetic data and infrastructure have been intermingled within GeoNet programme delivery since its inception. This endorsement allows us to integrate existing work that requires infrastructure and capability provisioned for GeoNet delivery into the GeoNet Integrated Work Plan.

- Geomagnetic data was added to our website displaying real-time data from our two magnetometers located north-west of Christchurch, through a new dashboard. This tool helps us monitor Space Weather events arriving in New Zealand. Using the dashboard, we can identify the onset of a geomagnetic storm, how it evolves and when it ends.

- We continued to bring science to our stakeholders, colleagues and collaborators, end users, and the public through:
    - Attendance at conferences in New Zealand and overseas, such as GeoScience NZ
    - Visits and talks to school children (both on-site at GNS Science and at schools where we have equipment installed);
    - Displays at high school career days
    - Participation in public events such as the Te Papa Little Scientist Expo in April and the Climate Change Wananga in Whakatane in June.

Looking Ahead

Programme Operations

While a multi-year allocation has been secured for GeoNet, the funding is reducing to a lower-level baseline and has come with a clear directive from Treasury and MBIE to preserve core services and infrastructure and consider appropriate funding sources for non-core services such as the National Geohazards Monitoring Centre service. This is a direct reflection the foundational principles that underpinned the Budget Bid options.

These principles are:

- Data, as fundamental to everything GeoNet does, remains a public good, open and freely available.
- Core functions and infrastructure must come first. Due to their role in producing and providing fundamental data, investment in the sensor network and IT platform cannot be decoupled and requires an appropriate level of resilience.
- GeoNet data, products, and services need to reflect appropriate quality, resilience, and capability for different use cases, from fundamental research to peril-specific monitoring and response to maintaining the New Zealand geodetic datum.
- Planning for transitions, including decommissioning and when to automate, is intentional, funded, and balanced.
- Experts will always be needed, and development of both scientific and technical expertise has a long lead time with high dependencies on the science ecosystem. Tailored, expert advice cannot be automated.
- The Programme will be delivered in a way that is financially sustainable, fully recovering its costs plus a margin, where financial contributions from users are explored and include necessary uplift of core functions and infrastructure.

A key piece of work moving forward is to continually examine and improve delivery of the GeoNet work programme. With the establishment of the new Service Delivery team, there is an opportunity to align this work to enhance project and programme delivery.

There has been significant change in operating context since the current governance and reporting arrangements for GeoNet were established in 2019. This includes changes in ongoing funding commitments and stakeholder understanding and confidence in management and delivery of GeoNet. A Reporting & Assurance review will examine the responsibilities of the funding stakeholders and make recommendations on an efficient approach to oversight of GeoNet, ensuring the funding stakeholders are assured and able to deliver to their responsibilities.

Network – Acquisition & Transportation of Data

The Network – Acquisition and Transportation of Data roadmap focuses on the acquisition of field data, including the sensor networks, and the physical and virtual networking infrastructure required for data transportation and telemetry. These activities are key parts of the core infrastructure supporting the delivery of GeoNet and are the first steps in gathering and making the best possible use of data. Delivering this roadmap will allow GeoNet to keep up with advancements in science and technology and ensure that the data collection and processing systems are built on strong, resilient, secure foundations with coverage across New Zealand. Our network needs to be strong enough to withstand the increasing risks posed by both climate and geohazard events.

The roadmap ensures that the needs of our Hunga Whaipānga and our other users are met and that our land and geohazard data is fit-for-purpose for research, geospatial, and geohazard monitoring and response.

27 MAY 2025

Ngauruhoe Outer Rim Fumarole

Highlights and Outcomes

Network: Acquisition & Transportation of Data

- Two key projects to support science-backed recommendations for network development and expansion were completed this financial year; a GNS SSIF Strategic Development Project (SDP) *Science-case for GeoNet Expansion* and the New Zealand Volcano Early Warning System (NZVEWS). The SDP was a collaborative effort across GNS and beyond, including GeoNet, to develop a documented, prioritised set of science-backed recommendations for how GeoNet seismic and geodetic sensor networks could be expanded and why. NZVEWS used a well-documented, global method adapted to New Zealand to provide risk-based recommendations for instrumentation and monitoring requirements for Aotearoa volcanoes. There was extremely strong support from participants for expansion of the GeoNet sensor network, particularly in the South Island Plate Boundary zone (Marlborough-Alpine Fault-Puysegur Trench), and to fill gaps in the geodetic network and seismic coverage in the North Island along the Hikurangi subduction zone and the western North Island. In terms of volcano monitoring, the Auckland region, Taranaki, and several other active volcanoes in New Zealand were highlighted as needing improved monitoring capability. Analysis done by the project teams to understand the impact of these recommendations directly informed network changes this year; specifically, new stations along the Alpine Fault, new and refurbished stations in Auckland, and planned new stations around Taranaki.

- Our Remote Infrastructure team of skilled technicians were kept busy through the year with 121 Field trips to over 300 of our stations. These field trips included VSAT (Very Small Aperture Terminal) satellite equipment renewals, instrumentation repair and upgrades, and new station installations.

- The Structural Instrumentation Network monitors the effects of earthquakes on building structures. In 2023-24 we upgraded three stations in the network (one in Hawkes Bay and two in Christchurch). There are nineteen stations located in representative built structures (e.g., commercial type buildings, residential housing and bridges) across some of the main urban centres of Aotearoa New Zealand. The goal of this network is to provide high-quality research data that supports building standards, design codes, and fragility functions. This data helps improve design and construction standards to meet public expectations. These stations consist of a set of instruments installed in strategic locations throughout a building. The equipment used at these stations varies and we are gradually upgrading them to the same standard as our wider network.

Highlights and Outcomes (cont.)

Network: Acquisition & Transportation of Data

- As part of our efforts to increase our resilience and continually expand our capabilities, we completed a renewal and upgrade programme of 56 National Seismograph Network (NSN) stations to replace aged and obsolete VSAT (Very Small Aperture Terminal) satellite assets and added VSAT communications at three new locations. This is our most resilient and reliable network, and it uses VSAT as a primary communication path to transfer data, landing data offshore to improve resilience. We also use cellular, low bandwidth satellite (BGAN) and terrestrial radio links as part of our communications resilience. As part of the VSAT renewal, efforts were made to establish or upgrade redundant communications at every station wherever possible – this increased resilience at thirteen of our NSN locations.
- We carried out a work programme to densify our sensor networks to meet our coverage design objectives. In 2023-24 we upgraded and installed seismic equipment at 27 locations, this included upgrading and enhancing three NSN stations, establishing one new NSN station, and upgrading fifteen Strong Motion and eight Broadband stations. These stations were located mostly across the western and lower North Island, Taupo Volcanic Zone, and the upper South Island, aligning with the priority areas identified in the SDP and NZVEWS initiatives. We also installed a new web camera at Te Kaha for monitoring of Whakaari White Island during the recent eruptive activity beginning in May 2024.

Case Study

National Seismograph Network Densification – Ensuring sufficient coverage of our most resilient sensor network

The New Zealand National Seismograph Network (NSN) is our backbone network of high-grade, high-uptime ground velocity and acceleration sensors. The NSN has a nominal spacing of 100 km across the Aotearoa New Zealand mainland and includes one station each on the Chatham Islands and Raoul Island.

In 2023/24 we upgraded three existing stations and established a new station in the Wairarapa region to cover gaps in our network coverage.

Through network review and planning we identify areas that would benefit from increased coverage. Before we go into the field, we review the geology, topography and land parcels to identify potential locations that meet our requirements.

We meet with several landowners and install temporary equipment at a few locations to find out which locations will give us the best data and weigh this information against the ease of install and other requirements such as sky view (for optimal satellite connectivity and solar panel efficiency). Once we have selected a preferred location, we work through agreements with landowners before our remote infrastructure team install the equipment.

Our remote infrastructure team is experienced at installing and maintaining equipment in all sorts of interesting locations around the country. Our new NSN station in the Southern Wairarapa region improves our network density and monitoring capability.

New Wairarapa National Seismic Network Station

Looking Ahead

Network: Acquisition & Transportation of Data

- The Web Camera Network is a collection of webcams used (presently) to monitor Aotearoa New Zealand's volcanoes. There are ten cameras: nine on mainland North Island and one on offshore Raoul Island. These cameras are crucial for volcanic activity assessments and eruption detection. We have undertaken a review to investigate the suitability of the cameras used in the network and whether they align with the requirements of the Volcano Monitoring Group. Future upgrades and replacements in the coming financial year will include increasing coverage, camera resolution, frame rate and thermal imaging capacity.

- We will continue to enhance our network within the constraints of our funding. Work began in 2023-24 on several seismic and GNSS stations which we plan to commission in 2024-25. These stations are located on the South Island's West Coast, in Auckland, and in Taranaki and will increase our coverage across the Alpine Fault and New Zealand's volcanoes; two priority areas identified in the SDP & NZVEWS.

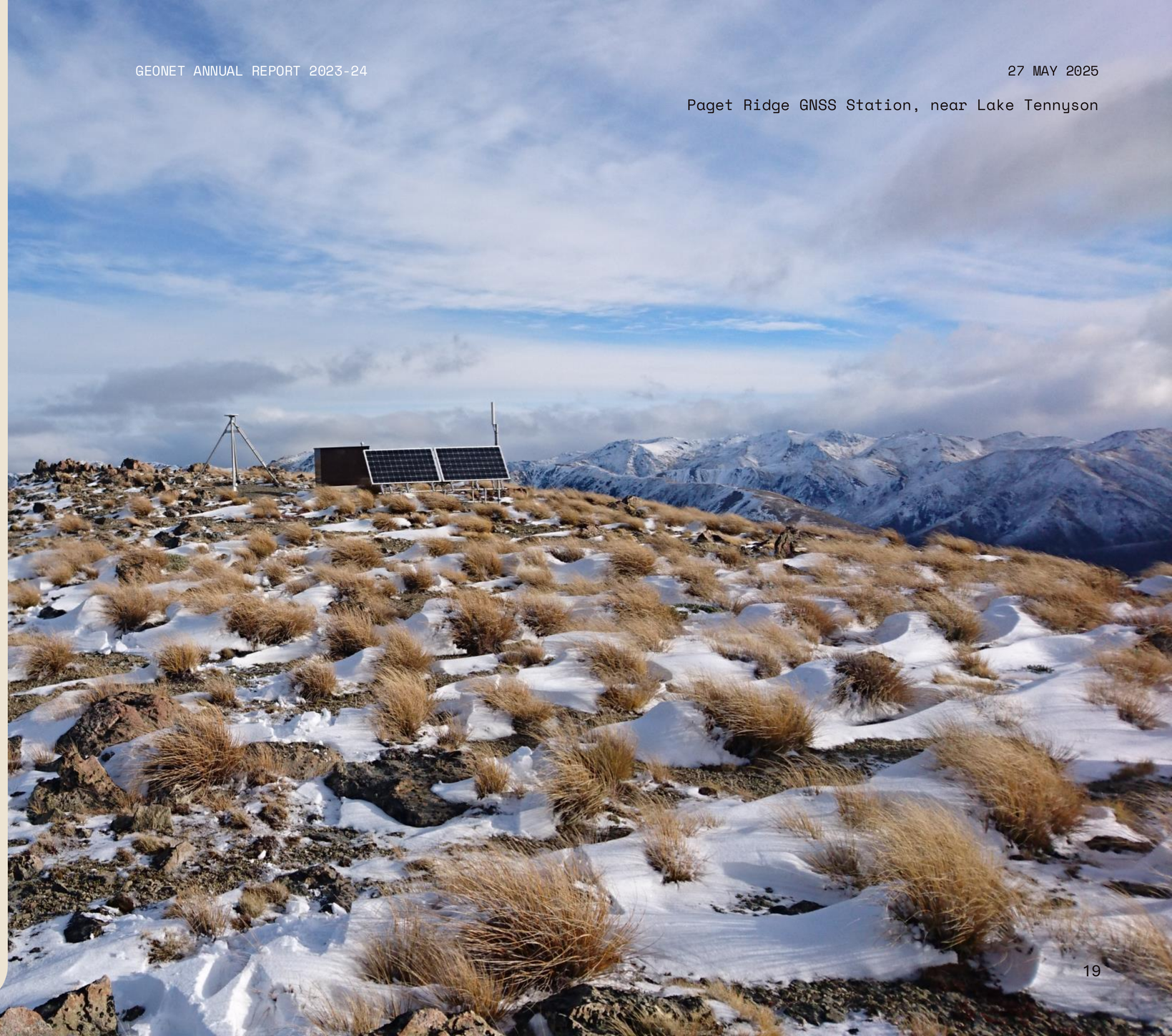
- We plan to install two downhole multi strong motion sensor arrays in Wellington. Installing these arrays in urban areas at risk of high ground shaking significantly enhances our ability to assess ground shaking in a large earthquake. A borehole array gives us 3D characterisation of the ground shaking, in addition to the 2D effects provided by surface strong motion sensors. Detailed site understanding at key locations underpins improved ground motion modelling across that network, especially where liquefaction may occur. This was a priority enhancement identified in the SDP workshop.

- Under contract from Land Information New Zealand (LINZ), in 2024-25 GNS will install 10 new GNSS stations, located at existing tide gauges. The data from these stations is primarily used to offset tectonic movement in tide gauge data and provide a better understanding of the rate and impact of sea level rise. The ongoing operation for these stations will be contracted under the GeoNet Head Operating Agreement and the stations will be adopted into the GeoNet network.

Core Platform, Infrastructure, and Data Products

The Core Platform, Infrastructure and Data Products roadmap covers the core infrastructure that enables us to collect, process, store, and share data. This infrastructure is crucial to ensure that GeoNet data is fit-for-purpose, useful, usable, and used. This roadmap also includes other technology needs that add extra value to the data and data products but sits within core platform infrastructure. This roadmap will keep our systems up to date with advances in science and technology, and ensure they remain secure and sustainable so that GeoNet data can continue to improve our understanding of New Zealand's land and geohazards.

Our systems will be able to safely and securely integrate new networks or technologies, like DART (Deep-ocean Reporting and Assessment of Tsunamis) into our operations. Delivering on this roadmap helps to ensure the data infrastructure and systems will remain strong, trusted and resilient, providing a reliable foundation for users.



27 MAY 2025

Paget Ridge GNSS Station, near Lake Tennyson

Highlights and Outcomes

Core Platform, Infrastructure, and Data Products

- Over the past decade, Global Navigation Satellite System (GNSS) saw a huge increase in satellite constellations and observables that can be collected, archived and utilized for precisely determining the position of GNSS ground receivers. New GNSS equipment capabilities, data standards and software have been introduced. Our GNSS data collection systems needed to leverage those new capabilities and tools to be able to align with best practices and maximise the investment done on the remote sensor network from 2020 onward. The data collection system has been re-factored to eliminate the risk of using deprecated software and system incompatible with recent field equipment's firmware versions. The raw data collection, translation to RINEX (Receiver Independent EXchange format) and quality assurance have been migrated to use new software and tools, and data available to end users now contain all available GNSS observables. This work has unblocked future evolutions of the GNSS network and in 2025, all GeoNet capable stations will be enabled to record all available GNSS systems. The initiative also included the addition of station specific metadata headers in the 1s GNSS RINEX data products, to facilitate downstream processing of LINZ customers.

- In GeoNet Programme delivery, a Tiny Team is a small cross-functional team working together on a project or initiative, often in a highly agile or focused environment. Tiny Teams are really just Scrum Product Teams, but we like the name! We have been using Tiny Teams for around eighteen months now. There are two teams, Roma and Lazio. Roma has focussed on GNSS items such as daily processing and modernisation of the data and format, while Lazio has had a slightly more varied work plan including our timeseries API enhancements, GeoMag data services, FELT reports, volcano and tsunami dashboard, and the cross-programme Shaking Layers project. These two teams have greatly improved the accuracy of work planning with very predictable outcomes and excellent forward planning visibility.

Highlights and Outcomes (cont.)

Core Platform, Infrastructure, and Data Products

- SeisComP is the software that sits at the heart of our earthquake location system. Staying on top of updates and version changes for this software is crucial to our ability to keep up with earthquake location capability. Timely upgrades help us make sure we are not introducing unnecessary risk and additional technical debt. Despite an early hiccup in October 2023, we were able to complete an overdue upgrade of SeisComP from version three to version four in November. This paves the way for quicker shifts to even newer versions. Significant progress has been made towards the current latest version (version six).

- The Tilde API was developed to become the new access mechanism for time series data, replacing older and increasingly outdated mechanisms such as FITS (field time series database) and creating a more fit-for-purpose data access solution. This year, the Tilde API has undergone significant enhancements, including the addition of new datasets and advanced tools. A notable improvement is the Data Exploration Tool, which allows users to compare up to five data streams simultaneously and provides the ability to bookmark and save visualizations via URL links. As part of our modernization efforts, the FITS database system is being deprecated, with its datasets migrated to the Tilde API. These datasets include manually collected volcano data, GNSS daily position solutions, ScanDOAS data (continuous gas emission detectors for volcano monitoring), including Whakaari/White Island (formerly mini-DOAS), and Inferno Crater Lake data.

Looking Ahead

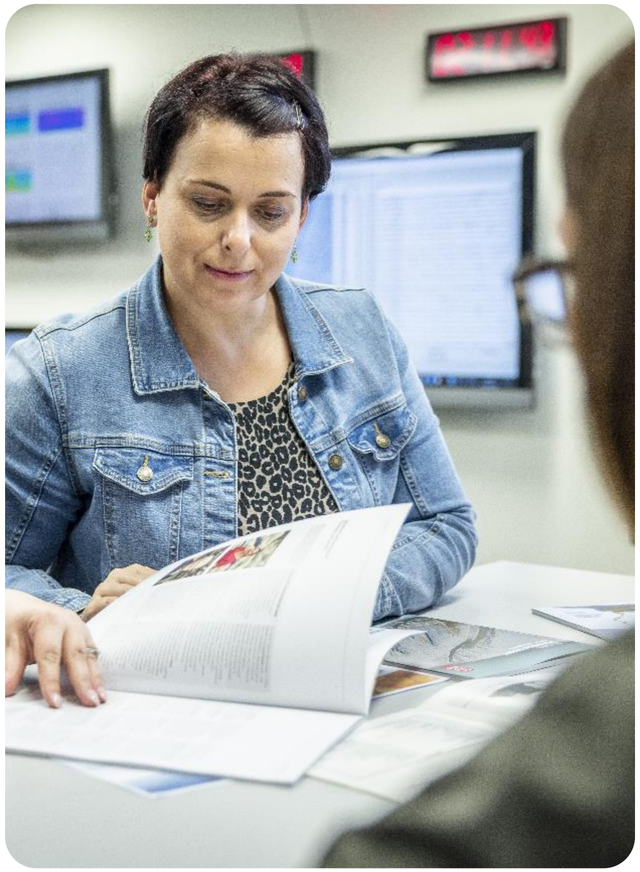
Core Platform, Infrastructure and Data Products

- Following the successful upgrade to SeisComP version four this year, we plan to upgrade to version six (the current latest version) in July 2024. This will allow us to clear technical debt in this area and pave the way for our earthquake location system rearchitecture project.

- FITS is a data access mechanism for GNSS, volcano data, and more, but it is old and increasingly insecure. The development of the Tilde API in the past several years was a key step towards enabling the deprecation of this access mechanism. Work to shift FITS datasets into Tilde will finish this year so that we can officially deprecate the FITS access mechanism. FITS will be turned off by June 2025.

- We will be working to future proof our earthquake location system by ensuring the system design meets current and future needs.

- We are redesigning the GeoNet website to make it easier for users to access and use. Our goal is to improve accessibility, usability, and dissemination of data and information to support science advice and informed decision-making for natural hazard and disaster management. We aim to help researchers and professionals to efficiently access and utilize GeoNet data to drive research and innovation. We also want to increase public awareness and engagement with GNS' hazard monitoring services and encourage public education through promoting community preparedness and safety with links to NEMA and NHC.



Data Custodianship

Data is at the heart of GeoNet delivery, and how well it can be used depends on good data management practices.
The goal of this roadmap is to make GeoNet data FAIR - findable, accessible, interoperable, and reusable - for all users. This is key to ensuring GeoNet outputs are fit-for-purpose, useful, usable, and used.
By following this Roadmap, several key benefits will be achieved. GeoNet data will be trusted and reliable, providing a strong foundation for users. Our systems will keep up with new technologies to ensure our data remains open and FAIR. GeoNet datasets will be easy to find and useful for data science and scientific modelling. Additionally, the data will help improve our understanding of New Zealand's land and geohazards, which is crucial for research, long-term advice, real-time applications, and informed decision-making.

View up the Haast River from above Clarke Bluff

Highlights and Outcomes

Data Custodianship

- FAIR (which stands for Findable, Accessible, Interoperable, and Reusable) is the globally recognised, widely-used acronym of underpinning principles and guidelines that we have adopted and apply to our data products. FAIR principles work towards ensuring data is well-curated and value can be realised. There are numerous different FAIR scoring tools that help assess different aspects of FAIRness for a given dataset. There is a need of continuous improvement, and work has been done on many of our datasets following results of the FAIR assessment done in 2021. Highlights include improvements in FAIRness for the acoustic waveform archive, structural array data, and historic volcanic activity (to name a few) data products have been developed with FAIR principles in mind, notably shaking layers and automatic volcanic time series. We are planning to undergo a full FAIR re-assessment next financial year.

- Back in 2020, the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) agreed to establish and host a Global Geodetic Centre of Excellence (UN-GGCE). The UN-GGCE officially launched in 2023. GNS Science, represented by Elisabetta D'Anastasio, is represented as part of the UN-GGCE International Advisory Committee that met for the second time in Bonn during March 2024. GeoNet plays a key role in the global geodesy supply chain in New Zealand and New Zealand's connection to the Global Geodetic Reference Frame (GGRF), specifically through the PositioNZ network and our free, open data. Our close partnership with LINZ is also crucial to this – together we help to ensure New Zealand has the observatories, data, analytical centres, and geodetic products that enable us to stay connected – nationally and globally.

- In July 2023 we completed our first draft of the GeoNet Data Strategy 2023-27. This strategy is a supporting document of our 10 Year Strategic Plan. The goal of the GeoNet Data Strategy in the next 3 years is to make GeoNet data more adaptable and trustable. A new feature of the strategy is the identification of three categories of data:
    - GeoNet Core Data (data that is created directly though delivery of GeoNet and GNS has Stewardship and Custodianship responsibilities for)
    - GeoNet Adopted Data (data that GNS adopts and becomes Custodian for)
    - Supporting Data (data created by others and used by GNS to derive the other data categories).

Case Study

Data Custodianship – modernising GNSS operations

To support the monitoring of earthquakes, volcanoes, landslides, and slow slip events, GeoNet operates a continuous GNSS (Global Navigation Satellite System) network. Data from the GNSS stations is routinely collected, processed, distributed, and used by many scientists in New Zealand and around the world.

In June 2024, we finished a long and challenging project, migrating to the cloud the software used to process raw GNSS data and obtain ground deformation time series data. Until 2024, the processing system for this data was hosted on premise in the GNS Avalon office. This was a key step in a much longer process to shift services to the cloud, begun in 2018.

We use a software called Gamit/Globk to process raw GNSS data and capture how much the stations deform in response to tectonic processes. Researchers, and interested members of the public, can use these outputs to detect slow slip events in the Hikurangi margin or to capture ground deformation after significant earthquakes or during volcanic unrest.
It's been a long journey. By combining the cross-disciplinary knowledge of geodesists, software developers, and DevOps engineers, we have been able to wrangle Gamit/Globk and architect a system that can work effectively in the cloud. The new process was launched in production on 25 June 2024.

Looking Ahead

Data Custodianship

- A benchmark seismic dataset for NZ to train machine learning and artificial intelligence models will be developed using manually reviewed GeoNet earthquake catalogue events from 2013-2024 and associated picks and waveform data. This dataset includes over 900,000 events. This dataset will be updated annually and will be released in 2024. This work will be presented at Geoscience NZ at a presentation entitled "Benchmark Seismic Dataset for AI", by Pasan Herath.

- Building on efforts from this year, we are working hard to build tighter, closer relationships with other global data centres and repositories, such as EarthScope (USA) and EPOS (Europe) and others. While GeoNet is a relatively small-scale programme internationally, we've been invited to participate in and present at various international meetings (both online and in person), including participating in EPOS Days in 2025, this brings together global data centres to present on core services, new services, technical challenges and opportunities, and to build coordination and collaboration opportunities. One such collaboration opportunity has resulted in a paper in submission about seismic data usage, and the value of FDSN and DOIs, with GNS co-authors. We continue to contribute to international organisations that provide access to free and open data and products such as the International Federation of Digital Seismograph Networks (FDSN) and the International GNSS Service (IGS).

- Continuing to focus on FAIR and FAIR assessments will always be a key part of our work. We will rescore FAIRness of all GeoNet managed datasets in FY24-25, and progress will be presented at the 2024 GeoScience New Zealand conference in Dunedin in November. We will be able to compare this to the 2021 assessment and highlight what initiatives can improve FAIRness of GeoNet data. We will continue to incrementally improve GeoNet data FAIRness using the principles and scoring tool as a fundamental guideline.

- We've been working closely with our Landslide Science Advice & Monitoring Group to support consolidation, quality assurance, and improvements to GNS' landslide database. Significant chunks of the landslide database come from GeoNet-funded response efforts, as well as government-funded emergency responses, commercial work, and other research programmes. The database underpins landslide forecasting (from earthquakes and rainfall), which we have been partnering with various Endeavour programmes to operationalise. Work this year is expected to be a huge step forward in the landslide database availability and accessibility. Where previous years efforts were primarily about consolidation, this year, we're funding efforts to pull it all together into a usable system where users can view the data.

Emerging Products, Hazard and Peril Data Use

GeoNet is developing new products and services that make it easier to use its data. This roadmap helps us contribute to the science community, enabling others to create meaningful results.

One of the main benefits of this roadmap is the opportunity to build strong partnerships with our research, delivery, and impact partners. These collaborations lead to products that improve our understanding of New Zealand's land and geohazards.

GeoNet products and services help expand our understanding of New Zealand's land and geohazards for research, long-term advice, real-time applications, and decision-making.

View of Fox Glacier from Rapanui Bluffs Station

Highlights and Outcomes

Emerging Products, Hazard and Peril Data Use

- The 2022 GeoNet strategic review identified several potential future products and partnership opportunities to expand on main strategic themes of the GeoNet programme. One of these is fibre-optic cables, a technology that is now investigated by several international seismological data centres to enhance seismic monitoring capabilities. In 2023-24 GeoNet funding supported a science pilot project that enabled the collaboration of GNS scientists with a commercial fibre optic sensing company. The company provided data from a 49km fibre-optic loop around Wellington harbour and gave GNS access to internationally renowned experts through a series of workshop and tutorials. These workshops allowed a GNS group of geophysicists, data scientists and data management specialists to learn this novel technology and how to manipulate Distributed Acoustic Sensing (DAS) processed data.
- This year, we stood up Science Advice and Monitoring Groups for all four perils, including the development of an initial Terms of Reference. These groups were stood up to be an explicit contribution from GeoNet to the development of peril advice tools and practices, and to enable another science advice pathway into GeoNet. Their input significantly guided the development of the draft Five-Year Business Plan.
- The volcano dashboard, a pioneering tool of its kind, was developed to ensure the availability of critical volcanic data during periods of heightened activity and eruptive episodes. Its core maintenance was transitioned from the volcano team to the teams maintaining the infrastructure supporting GeoNet, enhancing its long-term sustainability and operational efficiency. This initiative is a key step in integrating experimental science tools into a supported environment, ensuring reliability and resilience during geohazard events when system demand increases. We have established a pipeline that enables scientists and developers to create dashboards using their own data sources and visualizations, which can then be deployed on a robust, supported platform. This approach ensures broader access to these tools, benefiting a wide range of users.

Highlights and Outcomes (cont.)

Emerging Products, Hazard and Peril Data Use

- GNS eScience Solutions Platform (GeSSP) is GeoNet funded sandbox/development area for science tools that went live in June 2024. GeSSP is a supported, reliable, computing platform for science applications. It provides a cost effective and easy deployment and a tier that is resilient for important applications. Design patterns and technology in GeSSP mean that applications are easier to support and manage, more secure and cloud friendly. GeoNet funding has been supporting the development of GeSSP because it is an enabler for research and monitoring activities in GNS that contribute to the delivery of GeoNet and help realise the value of GeoNet data.

- GeoNet is one of many geomagnetic teams across the globe that measure and monitor the Earth's magnetic field and how it is being impacted by space weather events. Through a collaboration with the Solar Tsunamis Endeavour Programme (led by University of Otago and funded through MBIE), real-time data from our two magnetometers located north-west of Christchurch is now available on our website, through a Geomagnetic Dashboard. This tool helps us monitor space weather events arriving in New Zealand. We can identify the onset of a geomagnetic storm, how it evolves and when it ends. GeoNet's developers and operational teams worked hard to get this vital dashboard ready to provide data to Transpower in time for the sunspot cluster that produced the 10-11 May 2024 solar storm. This data helps the Transpower control room operators to verify how their power transmission system is impacted by a geomagnetic storm.

- GeoNet's remote volcano monitoring stations are equipped with cameras capable of both incremental imaging and live video streaming. In 2023-24, we upgraded these systems to enhance performance and reliability, enabling synchronised live video from multiple sources. These upgrades allowed us to rapidly deploy an internal-only proof-of-concept solution to stream live video from the volcano webcams to volcanologists and the National Geohazard Monitoring Centre (NGMC) during the Whakaari eruption and volcanic unrest in May and June 2024. This deployment was important for continued monitoring of Whakaari during this time as it provided the only source of continuous data about the island and provided a key opportunity to explore and test new technology.

Case Study

Emerging Products, Hazard and Peril Data Use

After years in the making, Shaking Layers arrived on the GeoNet website in September 2023, followed by the GeoNet app in November 2023.

The Shaking Layers maps illustrate the intensity of ground shaking caused by an earthquake of magnitude 3.5 and greater in different parts of New Zealand.

Now when you feel an earthquake, not only can you check the Felt reports – as we all do to see if the shaking we felt was real, imagined or a particularly gusty wind rocking the walls – but also get a measure of ground shaking based on data from ground motion sensors.

Teams from across GNS and GeoNet came together to pool their expertise to make Shaking Layers, from science, project management and user experience design to IT, web development, database management and more.

GNS Project Leader Tatiana Goded said she was grateful to everyone involved in getting Shaking Layers to its public launch.

"*It has been an amazing project to work on because no matter the challenge, everyone was willing to step up or step in without being asked to keep the project on track.*

In those rattling moments after an earthquake, I think New Zealanders will really value a tool designed specifically for them that offers new insights on the shaking they felt."

The Shaking Layers model combines recorded data from strong motion stations with ground motion models to produce spatial estimates of ground shaking for peak ground acceleration and velocity, modified Mercalli intensity scale and spectral acceleration.

Looking Ahead

Emerging Products, Hazard and Peril Data Use

- Landslide forecasting is hugely important for response and recovery to landsliding events and insurance/reinsurance. In partnership with the Earthquake Induced Landslide Dynamics (EILD) Endeavour (2019-24) and now the Sliding Lands Endeavour (2024-29), GeoNet has supported the operationalisation of both the earthquake- and rainfall-induced landslide forecasting tools. This type of partnership is valuable to enabling the long-term operational uptake of science developed through Endeavour programmes. The past several years have focused on the development of the forecast model code and manual operation, while this year will be looking to further automatic triggering and publication of forecast data to ArcGIS Online (AGOL) and selected forecast data on the GeoNet website.
- The Science Advice and Monitoring Groups were set up to help manage GeoNet's contribution to monitoring and advice tools and processes and support a pathway for science advice at an operational level. As we look to mature the groups and their function, we will be working on folding them into annual planning as part of our monitoring function and build on the progress we made with five-year planning. As we do this, we aim to be able to better plan for and report on these aspects of the GeoNet workplan, particularly as the funding landscape continues to change.
- The GNS eScience Solutions Platform (GeSSP) has been a big investment from GeoNet over the past several years to create a more stable and supported environment for the development of science tools. Building on successes from the last financial year, we hope to partner more closely with GNS' Information Systems & Technology department to sustain and amplify the existing use cases for the GeSSP.

Looking Ahead (cont.)

Emerging Products, Hazard and Peril Data Use

- Tsunami Experts Panel (TEP), Geohazards Analysts (GHA), and Seismology Duty Officers (SDO) need to quickly gain situational awareness of an unfolding tsunami event to create effective response products. GeoNet is developing the Tsunami Dashboard as an operational science response tool for these groups that provides fast, reliable, and centralized access to essential tsunami data visualisations, enabling more concise and informed assessments in real time. Unlike the current array of disparate tools currently in use, our product will offer a single, integrated platform to streamline tsunami data visualization and decision-making. It also includes working with the Rapid Characterisation of Earthquake and Tsunami Endeavour (2020-25) to ensure specific outputs and visualisations from their tools are available through this mechanism.
- As agreed in the Government Budget 2024 construct process, FY25 funding reductions are going to most significantly impact GeoNet's monitoring function. To better understand and mitigate the impacts of these funding changes, we plan to set up a Monitoring Mitigation and Continuity Project. This will determine how we adjust and rescope our monitoring services, including the NGMC, the duty teams, and the expert panels to best continue to deliver accurate and timely science advice.
- Since being formally adopted into GeoNet scope in September 2023, geomagnetic data has been gaining additional traction. Following the successful release of the dashboard privately to Transpower in May 2024, we plan to release the dashboard publicly on the website in the first quarter of 2024-25 to help other users visualise geomagnetic data.

Appendices

Risk Management & Finance

Mt Vexation Station

Helicopter flying over native bush near Reefton

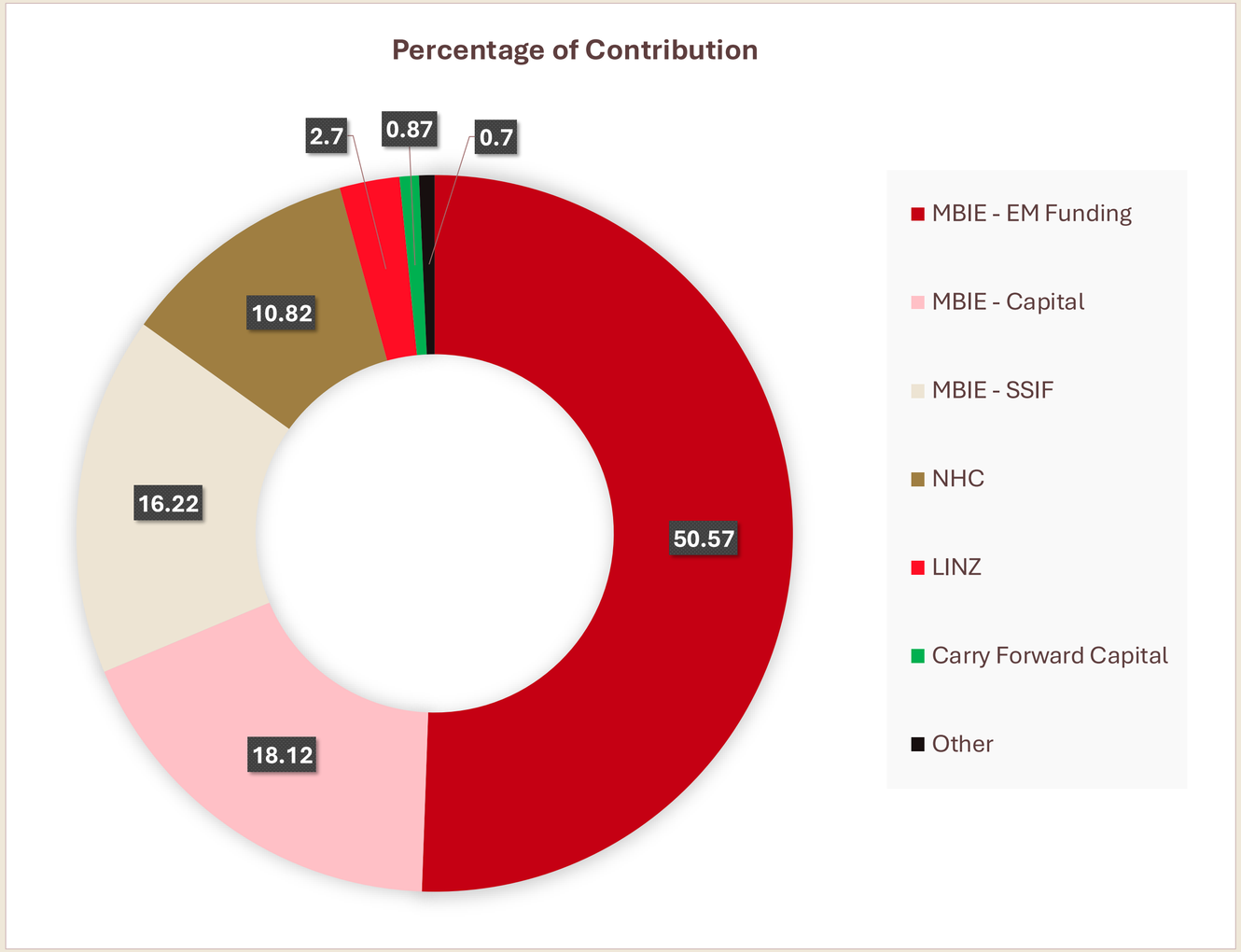
Risk Management

GeoNet programme risks are identified, assessed and treated using the GNS Science risk management framework. The status of risks identified is reported through various internal and external governance groups throughout the year. The biggest risk to the delivery of GeoNet products and services is that the funding announced in Budget 24 for the programme is not at a level where GeoNet can operate sustainably. GNS Science is working with its funding stakeholders to use the prioritisation framework from the budget bid to guide programme changes.

Limestone outcrops, Castle Hill Basin, Canterbury

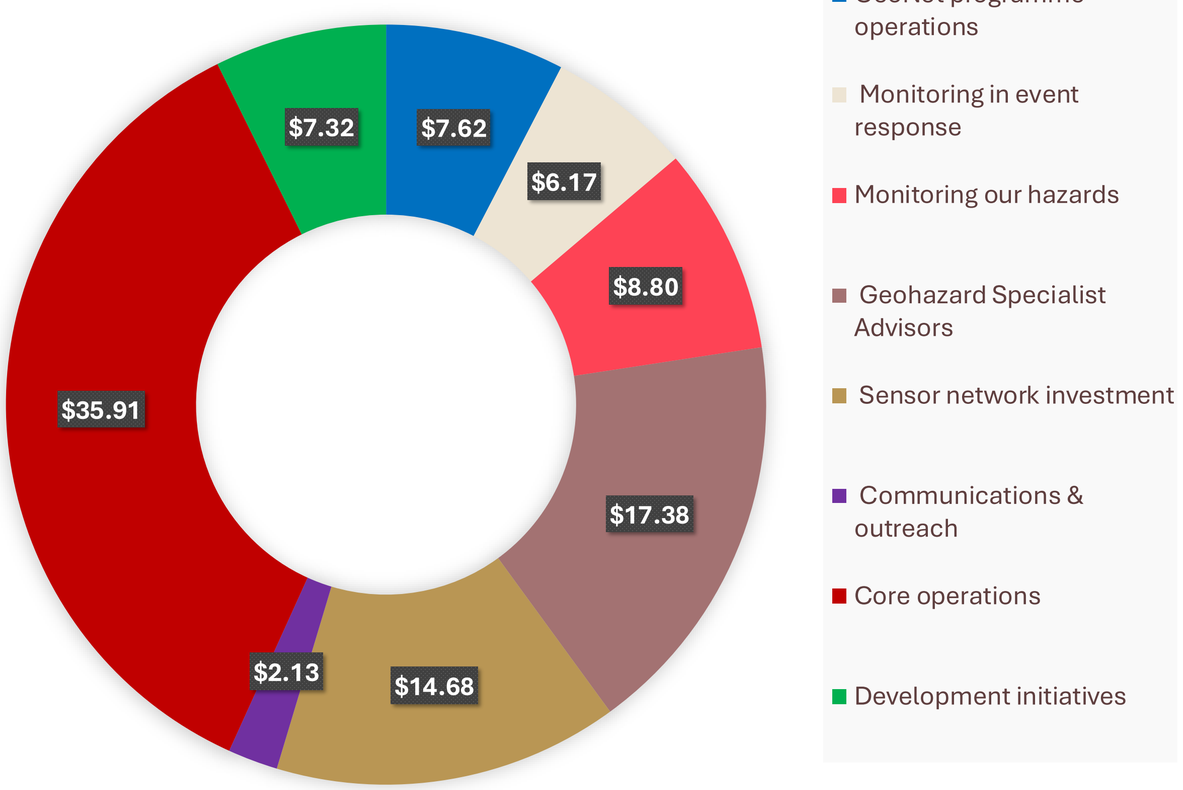
Finance

GeoNet is a collaboration. Our cross-agency funding partners all contribute to the success of the programme. In FY2023-24 $36,980,252 was contributed for both operating and capital expenditure.



Finance

For every $100 our partners contributed, we allocated our spending (both operating and capital) across:



GeoNet programme operations

Behind the scenes work, like financial management, planning and reporting.

Monitoring in event response

Extra activities following an event like the Whakaari/White Island eruptive episode and continued risk assessment following Cyclone Gabrielle.

Monitoring our hazards

Running our 24/7 monitoring centre, plus science to track our ‘four perils’.

Geohazard Specialist Advisors

Our experts who move into action when an event occurs.

Sensor network investment

Maintaining & improving our network of sensor equipment. Managing asset renewals.

Communications & outreach

Connecting with our users, like researchers & the people of Aotearoa.

Core operations

The work on our infrastructure that gets all the parts of GeoNet working together.

Development initiatives

Improving GeoNet through applying current science into new products & enhancing our ways of working.

GeoNet Annual Report
2023/2024

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