GeoNet Annual Report

Financial year 2022-23

GNS SCIENCE
TE PŪ AO

GeoNet

Contents

This document has been produced as part of the reporting suite under the GeoNet Programme Head Operating Agreement between GNS and our funding partners.

The contents of this report are intended to raise awareness of the work undertaken and increase understanding of how financial allocations are made across the GeoNet Programme.

Please refer to the GNS Annual Report for the corporate documents that fulfil the annual reporting responsibilities under the Crown Research Institutes Act 1992 for the year ended 30 June 2023.

The GNS Science Annual Report is available online at www.gns.cri.nz

Ngā mihi maiohia
Thank you

GeoNet's vision is to be a trusted public good service, highly valued for its widely-used open data and readily accessible information and tools to make New Zealand a safer and more resilient place to live.

Thank you to our funders, supporters, and to all who've worked on the programme to bring this vision into reality.

Introducing **GeoNet**

Just 22 years ago, GeoNet launched with 102 land-based sensors, gathering data to help New Zealand monitor its geohazards. Fast forward to 2023 and we've become known as a 'public good service' which has captured the hearts and minds of New Zealanders. Through major geohazard events like the Christchurch and Kaikōura earthquakes and the Whakaari eruption, as well as in quieter times, GeoNet has supported New Zealanders by sharing data, information, advice, and offering people reassurance.

Over time, New Zealand's capacity and capability to monitor, measure, and respond to geohazard events has improved greatly. Our resources span physical and virtual assets, including a 24/7 monitoring centre keeping eyes on the outputs from more than 9,100 items of equipment in over 700 locations across Aotearoa, each supported by a raft of technology that serves to relay the data being collected. But, most importantly, at the heart of GeoNet is a team of skilled people, supported by dedicated funders and collaborators. Our people care for the core infrastructure that makes geohazard, geological, and positioning data freely and openly available to others. GeoNet is truly part of a collaborative system to make New Zealand a safer and more resilient place to live.

Partners

The GeoNet programme is a collaboration between GNS Science Te Pū Ao (GNS), Toka Tū Ake EQC (EQC), Toitū Te Whenua, Land Information NZ (LINZ), Hīkina Whakatutuki Ministry of Business Innovation and Employment (MBIE), and the National Emergency Management Agency Te Rākau Whakamarumaru (NEMA).

2022-23

Reflections

The beginning of the 2022-23 financial year marked a milestone for GeoNet. After three years of anticipation the Head Operating Agreement was signed, marking a shift in maturity of the programme. The parties that have always enabled the programme have agreed to jointly contract for the delivery of GeoNet products and services.

Over the year, significant progress has been made to enhance our capabilities and operational practices. Execution of our ambitious Annual Integrated Work Plan included the expansion of some services and enhancements to others, markedly reducing risks within our sensor infrastructure network. New products have been developed, our platform is more secure, our website is better and our data is more open and available than ever before.

Operational practices, such as our reporting suite, have also evolved. Our Strategic Review was completed, and we're encouraged to see our partnerships across the ecosystem evolve and strengthen as we work together to plan the next decade for GeoNet, through the collaborative development of our Strategic Plan.

Of course, there were also the responses of the day. The year saw the first 'all peril' response effort in December 2022, when earthquake events occurred at Taupō Volcano, triggering an underwater landslide and subsequent tsunami.

Landslides and weather-related event responses kept the teams busy. Between hundreds of landslides in Nelson in August 2022, the extreme and tragic weather events over Auckland Anniversary Weekend in January and Cyclone Gabrielle in February, GeoNet has been there. Our teams have worked tirelessly to provide robust infrastructure, surge-stable networks and platforms, secure, reliable and high quality data, and deliver evidence-based information and advice to support emergency managers and other decision makers to be equipped for the national response.

Together, we have played our part in helping to make New Zealand a safer and more resilient place to live. Securing sustainable funding is fundamental to the ongoing provision of GeoNet products and services.

Our year **at a glance**

23 Geohazard
Event activations
Up, down and around the country

Delivered on budget
$26,169,333
Funding contributions from Toka Tū Ake EQC, MBIE, LINZ and MetService, and hosted by GNS Science **p. 25**

Future planning
Strategic review
Development and delivery **p. 22**

New product development
Shaking Layers
Cross-programme, cross-disciplinary collaboration **p. 17**

Custodians of data
140TB and growing
Open and accessible for users through AWS **p. 7**

2022-23 **Event activations**

Offshore activity near the
Kermadec region & Loyalty Islands
Multiple activations following earthquake events

Auckland Anniversary
Floods and Cyclone Gabrielle
Case studies
Cyclone Resilience **p. 11**
Rainfall induced landslides **p. 23**

Alert level change
Mt Ruapehu
Lowered from L2 to L1 in July 2022

Enhanced monitoring and 5.7 magnitude quake
Taupō volcano
Case studies
Taupo stirring? **p. 14**
Iwi relationship/collaboration **p. 20**

6.0 magnitude quake
North-west of Kāpiti Coast
1.82 million website views on 15th Feb alone **p. 7**

Multiple landslide responses
Tahunanui, Nelson
GNSS installation collaborations **p. 13**

Ongoing activation period for
Whakaari
L2 following the 2022 eruption, remaining throughout the year

Almost 1000 earthquakes located over a week
Kawerau swarm
Beyond business as usual **p. 13**

20,000+ felt reports
Pōrangahau events
Two quakes in April 2022

Canterbury
Widely felt 4.7 magnitude earthquake in March 2022

Our reporting **Approach**

Our reporting approach reflects the broad and holistic nature of our impact. As part of the evolution of our reporting, future reports will start to focus more on the impacts and outcomes enabled by GeoNet. We look forward to this increased focus. This year's annual report for the 2022-23 period links to the impact areas set through the GNS Statement of Corporate Intent for the same year.

As a programme of work within GNS Science and its Natural Hazards and Risks Theme, the report covers our contribution to the research priority areas of our Theme: Understanding Geohazards Processes; Stewardship of National Capability; Trusted Science Advice; Knowledge Exchange; Building Community Resilience; Natural Hazard Risk Management System Improvement, and our financial and risk management performance.

Understanding
GeoHazard processes

GeoNet collects data. It's at the core of all we do.

It's through this data and the infrastructure that underpins it that GeoNet contributes to the growing scientific understanding of geohazard processes. Our data supports monitoring and real-time understanding of geohazard events; it is a foundation for research that grows our collective understanding of our land and geohazards. Data users have access to a range of data types which are transported, stored, and distributed for anyone to use.

The beauty of the data we provide is that it transcends geographical, institutional, sectorial, and expertise boundaries. To meet the needs of our diverse user base we tailor our data collection to suit the phenomena we're measuring and observing, and to meet the needs of users. We're always working on ways to improve and adapt, and to align with our users and the best available science.

Custodianship of the data, which is used and trusted by many across New Zealand and across the world, is no small feat. The systemic impacts of the decisions we make in GeoNet ripple widely and thus decisions are made carefully and deliberately.

It's because of our robust and considered stewardship of our data, and the infrastructure it depends on, that users can rely on us. Open and free access to data enables others to build knowledge and generate innovations that increase our understanding of the complex physical processes that generate natural hazards and change New Zealand's landscape.

Our role in increasing the understanding of New Zealand's land and geological hazards is through the provision of data at the early stage of the science value chain. Our contribution is then built on by others within GNS and our many partners. Key programme outcomes include:

- **Research impact:** GeoNet data is more available than ever, enabling users throughout the world to utilise our quality data-sets. Research adds to the science knowledge pool, and in return leads to the provision of robust science advice.
- **Economic resilience:** Users, from public and private sectors, generate value from our data through innovation beyond the scope of GeoNet's mandate. Models grounded in GeoNet data underpin the building code and global reinsurers are able to independently validate New Zealand hazard and risk so the country can purchase a high level of reinsurance. The New Zealand geodetic reference datum enables all location-based services, supporting agriculture, infrastructure, and basic navigation.

2022-23

Highlights & outcomes

- **More accessible than ever before.** This year, our entire archive became available to download. We were the first organisation in Aotearoa New Zealand to release research datasets on the Registry of Open Data on Amazon Web Service. Our datasets are faster to download and more available openly to researchers, learning institutions, and the public globally.
- **Digital Object Identifiers are live.** We have made it easier for researchers to acknowledge and cite when they reference GeoNet datasets. DOIs (Digital Object Identifiers) have been allocated to our most popular GNSS, landslide, seismic, tsunami, and volcano datasets and metadata. DOIs identify objects persistently, allowing our data to be uniquely identified and accessed reliably by researchers and other users.
- **Educational content for data users.** In June 2022 we began publishing our new monthly Data Blogs covering topics that delve deeper into technical information for our data users. We have had great feedback, with users describing them as valuable and telling us to 'keep up the good work'.
- **Stewarding our data.** We developed a GeoNet Data Strategy for 2024-2028 to support development and improvement of how we manage our data so it's fit for the future. We've had active consultation of the draft and look forward to publishing the strategy in 2024.
- **Monitoring Slow Slip Events.** Slow slip events or 'silent' earthquakes are a consistent phenomenon of the Hikurangi subduction zone and typically last for weeks to months. Multiple slow slip events under the North Island were detected and carefully watched throughout this year, including slow slip events under the Manawatū and Kāpiti and more recently beneath the Hawkes Bay. GeoNet data has been critical to detecting and building scientific understanding of these events.

Busiest day of FY22-23

1.82 million

website views

61,000

felt reports

6.0 magnitude

North-west of Kāpiti Coast

15 Feb 23

29,343

Earthquakes detected

in FY22-23

140TB+

of data archived

growing by ~13TB a year

3.91 million

Users across our mobile apps and website

Case study
Data blogs

Data Blogs were first released in June 2022, with the goal of bringing some technical insight and learning into data-related storytelling - so far with great success! The monthly blogs cover the range of data GeoNet has, sometimes focusing on specific datasets, like our Volcano Alert Level dataset, and other times broadening out to discuss more general data-related information, such as rates of recording/sampling or collecting data and why they might vary for different data types. We've written nine blogs since they first started up last year and are looking forward to continuing to explore our data in this way.

Looking
ahead

We're focused on maturing our datasets and data stewardship practices. This will contribute to the usability of our data by researchers and other users.

We are also investing in the future, through exploring new technology with other science programmes and the broader research and innovation sector. Currently, we're working across GNS to trial new technology with FibreSense, a company using fibre cable networks to monitor and detect seismic activity. As said by Dr Richard Kellett (FibreSense trial project manager), "The type of technology offered by FiberSense has been evolving rapidly over the last five years and it is part of our long-term plan to undertake an evaluation of distributed fibre optic sensing".

GNS has a reputation as an organisation at the global forefront of research into all aspects of seismic activity. GeoNet is proud to contribute through the targeted investment into strategic development initiatives, such as the FibreSense trial currently underway.

Stewardship
of national capability

At the core of GeoNet are data and data infrastructure, which are a foundational part of the science value chain. Since 2001 when GeoNet was founded, the sensor networks have expanded from 102 instruments to over 9100 instruments and supporting equipment. These span across more than 700 sites.

On top of the instrumentation network, there is also an extensive platform of virtual infrastructure. The platform ensures data is pulled into GeoNet's systems, processed, and stored in ways accessible to a wide range of users. There's a virtuous circle where science advice flows both from and back into GeoNet. Changes made to our systems and infrastructure are informed by advancements in science and technology. In the same way, improvements to our systems and infrastructure inform science and technology.

Custodianship of New Zealand data is crucial. Real-time streams of Global Navigation Satellite System (GNSS) data underpin all location-based services in New Zealand; seismic, volcanic, and tsunami data in real- and near-real time ensure experts have what they need when they need it to be able to understand geohazards, and monitor and be ready to respond to them. GeoNet has to be ready, and therefore it is always 'on' - making sure data is flowing and our systems are able to handle the load when the going gets tough and demand for information is high.

GeoNet is instrumental in ensuring the capability to gather, integrate, and deliver science advice is ready when New Zealand needs it. The tools and services that GeoNet supports are an important contribution to GNS' rapid geohazard response capability. Key programme outcomes include:

- **Engineered for resilience:** Infrastructure and services, like our sensor networks, the National Geohazards Monitoring Centre, and the GeoNet website, deliver reliable and rapid information when demand surges and uncertainty is high.
- **Forward-thinking:** We collectively make deliberate decisions with the awareness that the impact of our choices will endure well beyond our individual contributions to the GeoNet programme.
- **Power in diversity:** We foster and harness diverse expertise - from scientists to technologists, engineers to designers and data managers - to ensure our systems, products, and services are fit-for-purpose, functional, and ready to gather, integrate, and share the right data and information.

2022-23

Highlights & outcomes

- **Mitigated sensor network risk.** From a data acquisition perspective, this year was focused on mitigating significant risk across our sensor networks by replacing ageing assets. We are pleased that most networks are back to a healthy state and that we can shift back towards normal maintenance.
- **Robust reputation.** We learned from former GNS Natural Hazards and Risks Theme Lead Gill Jolly that the Head of Data Journalism at the New Zealand Herald used GeoNet's web engineering as a model for the NZ Herald's own web resilience. GeoNet's ability to "just keep trucking through surges" made it their gold standard!
- **GeoNet website updates.** Website navigation was updated to support data being easier to find and navigate. These updates also make it easier for us to add new data products in future and include the release of our new data access mechanism Tilde, the time series API.
- **Even more open and reliable data.** GeoNet joined the AWS Open Data Program - enabling us to eliminate unexpected costs associated with users downloading large datasets, while providing end-users with free and open access to our entire archive.
- **Testing 1,2,3.** In September 2022, we ticked off a major outstanding item in our testing schedule. We shut down our data collection systems at Avalon (Lower Hutt) for one hour to test the resilience of our system should the connection between Avalon and our other data centre at Kapua (Hamilton) be broken. The outcomes of this test were positive, with data recovering in about 5 minutes and no issues reported by the National Geohazards Monitoring Centre (NGMC).
- **Bringing back auto-publish.** When COVID-19 was at its peak, we brought back the automatic publication of earthquakes to the GeoNet website and mobile app. Autopublising was enacted to support the resilience of the NGMC should COVID affect too many staff, ensuring earthquake information would still go to the public as fast as possible. Preliminary earthquake solutions are published automatically and then our geohazard analysts refine solutions to 'best quality' (confirming location, depth, etc.). This year, we decided that despite some of the complexities of autopublishing, it was a worthwhile technical feature to continue as a way to increase GeoNet resilience more generally.

Northland array

15 new sites installed on behalf of RCET, our partners investigating new methods of Rapid Characterisation of Earthquakes and Tsunamis. This Endevour project aims to expediate tsunami warnings and focus recovery efforts.

Regional seismic network

assets within expected life
was 81.2% now 88.6%

7.39%

Risk now estimated at medium and ahead of target

> **"To have this data freely available on AWS will drive research globally, especially in areas like machine learning, and help us to better prepare for natural disasters."**
>
> Dr Natalie Balfour
> Toka Tū Ake EQC Manager Research

Case study
Cyclone resilience

Cyclone Gabrielle was a huge test for GeoNet's resilience.The cyclone caused wide scale disruption to electricity and communications services across the upper North Island. This created a network jeopardy situation for inter-region fibre connectivity.

Our sensor network is designed for resilience. One way this is achieved is through the intentional tiering of our sensor station network; designing the system to prioritise connection to critical data feeds and managing others to continue to collect data when connectivity is lost.

During the extreme weather caused by Cyclone Gabrielle, there was damage to our network. Critically though, connectivity with the Tier 1 networks, and some other sites that had been fitted with satellite communications, remained operational throughout. This is testament to the resilience investments and careful management of the system. There was a brief satellite communications outage during the same period, though coincidental as it was caused by an electrical storm in Sydney.

While our communication with those Tier 1 sites with satellite communications was maintained, other sites were not so lucky. Tier 2 and 3 regional seismic and geodetic network sites lost communications, along with some specific Tier 1 tsunami and PositioNZ geodetic network sites. Interventions for Tier 1 sites that were affected were prioritised in the aftermath, weighing up the cost to intervene with the impact on network capability. We have further work to do to explore the capability of all of our Tier 1 networks and re-examine their resilience measures.

During the event, we were notified by Research Education Advanced Network New Zealand (REANNZ) of a jeopardy situation for their network. Our two data centres were at risk of being cut off. REANNZ is GNS' internet provider who specialises in high availability, low latency networks for data movement and sharing. Regular communication with them was integral to how we managed the impacts of the situation. Together, we considered emergency alternatives and prepared to execute our Disaster Recovery Plan. Fortunately though, it wasn't required. The REANNZ network was reinstated and we didn't need to execute our Disaster Recovery Plan.

Looking
ahead

2023-24 will see progress towards the enhancement and expansion of our sensor networks, both at sea and on land. At sea, we're expanding our tsunami detection capabilities through the full integration of the DART (Deep-Ocean Assessment and Reporting of Tsunami) network of ocean sensors into GeoNet, in collaboration with NEMA, MFAT and NIWA.

On land, we're undergoing planning to enhance our 10 sensor networks. A more complete distribution of sensors across the country is needed to provide additional data to support our understanding of geohazards. For example, our greatest vulnerabilities such as the Alpine Fault and our high risk volcanoes (Taranaki and Auckland) are sparsely instrumented. The choice of enhancements has been guided by our expert partners, to ensure new sensors provide the most valuable data to help us understand our greatest risks better.

Trusted
Science advice

GNS does Science Advice in spades. GeoNet is an integral part of that.

Data is a fundamental input to science advice provided by GNS and others. Science advice is evidence-based knowledge and understanding, supported by experience, and expert judgement, analysis, and insight, which is used to inform effective and timely decision making for public good.

GeoNet provides data and information that underpins the fundamental science of many other programmes and agencies. Their work enables the development of further knowledge and understanding, giving rise to models and tools that enable science advice. But science advice doesn't just flow outward from GNS and GeoNet, it's also how we ensure our networks are designed properly, our data is of known quality, and our outputs relevant for users.

During a response there is an intense demand for data and information. GeoNet acts as the custodian of much of GNS' rapid response capability, including the NGMC and the on-call duty teams. This expertise spans from geohazard-specific advisors to communications and GeoNet application support specialists. We also facilitate the coming together of expert panels and monitoring groups that rapidly integrate expert knowledge to provide advice.

These services are core capabilities in GNS' ability to deliver advice on New Zealand geohazards, especially when advice is needed quickly and uncertainty is high.

The information and advice we provide is gathered from a variety of automated and expert-driven science tools. Tools are developed in collaboration with a wide range of people and programmes. GeoNet supports Expert Panels, who together generate bespoke advice through their collective understanding, tooling and analysis. Emergency managers and many others have come to depend on GeoNet data and science advice, and want more products, services, and interpretation from it. We work hard to provide information and advice in ways that are inclusive and transparent, and meet the needs of the dynamic range of people who rely upon them.

The mutually beneficial cycle between providing evidence-based advice and the collection and processing of the evidence - the data - to inform better and more developed advice is never ending. We strive to work with our users to understand their needs so we can improve our products. Our users' research and advice informs how we collect data and information. And, our data and information underpins the research that then generates advice. Key programme outcomes include:

- **Data available and accessible:** Our data is open, free and in a format people can use, when they need it, to grow the collective knowledge that informs science advice.
- **Advice that's appropriate and useful:** Our users, from the everyday public to partners like Civil Defence and Emergency Management (CDEM) groups and NEMA, are connected to the right information for their needs and equipped to make decisions about hazards that may pose a risk to life and/or infrastructure.

2022-23

Highlights & outcomes

- **Firsts for Taupō volcano.** Taupō volcano had its first ever shift to Volcano Alert Level 1. The Volcano Monitoring Group determined that 'minor volcanic unrest' best characterised the earthquakes and ground deformation they were observing at Taupō. The November 2022 M5.7 earthquake that became a focal point of the unrest was the first activation of all four peril - earthquake, landslide, tsunami, and volcano - expertises at the same time.
- **Beyond business as usual.** During the Kawerau earthquake swarm in March 2023, the NGMC located an earthquake, on average, every two minutes in the first hour of the event. This was the beginning of what turned out to be one of our most active swarms, in terms of earthquakes larger than magnitude 3, to date. We produced numerous posts, comments, articles, and interviews to help those impacted understand the science of what was going on beneath the ground.
- **GeoNet needs science advice too.** A GNS Scientific Development Project focused on what the science community wants to see from GeoNet's networks to help answer the big questions it has now and on its horizon. GeoNet also funded the NZ Volcano Early Warning System (NZVEWS) project which provided an update of the volcano monitoring network needs and recommendations. Both of these projects are key inputs into our multi-year sensor network enhancement planning.
- **CASCADE.** GNS' Communication and Assessment of geohazard risk for Science Advice programme seeks to support continual improvement to science advice in support of Aotearoa's risk managers. This work enables us to use insights from social science to make science advice more accessible for different audiences.
- **Multimedia advice.** To support education and advice about Ruapehu and Taupō volcano's unrest, GNS took a new tactic to help build engagement and understanding about the volcanoes. Expertise and decision-making from the Volcano Monitoring Group - our group of volcano experts who regularly analyse, review, and advise on the behaviour of all New Zealand volcanoes - provided the foundation to develop videos and updates that went beyond the more technical Volcanic Activity Bulletins, as well as working closely with local iwi and councils.

Cross-collab

Nelson City Council needed our help to track landslides after major flooding. We installed 2 GNSS sensors to collect data, and used this data to support them and contribute to wider scientific understanding.

1,800+

Earthquakes located under Taupō volcano in late 2022 & public observation reports submitted following the lake Taupō earthquake.

41

35

Active on-call specialists trained or in training across seismic, volcano, communications, landslide and app-support specialties.

776

Email queries from the public and data users to info@geonet.co.nz

Case study
Taupō stirring?

In September 2022, the Volcano Alert Level (VAL) at Taupō volcano was increased to level 1, for the first time ever. Signs of unrest had been under close observation since May 2022. Ongoing earthquakes and ground deformation led the Volcano Monitoring Group to determine that activity at Taupō was best characterised as 'minor unrest' (VAL1).

When the Taupō region was shaken by a strong M5.7 earthquake under the lake in November 2022, this was deemed consistent with minor unrest, but it led to another first: the activation of all four perils - earthquake, landslide, tsunami, and volcano - at the same time.

The event occurred under Lake Taupō, generating a small tsunami, possibly compounded by an underwater landslide, and strong shaking triggered more than 30 landslides. To support understanding of this event, further geodetic and seismic sensors were rapidly installed, and work undertaken with local iwi to enable installation of a tsunami gauge in the lake.

Social scientists have evaluated the science advice GNS provided during the event activation. They've demonstrated that the wraparound communications and scenarios packages were well-received and widely valuable, including across central government. Media and public responses in Aotearoa to the alert level rise were well informed and matched to the levels of increased risk. This was largely attributable to the widely co-produced science and communication material in the lead up to and during the unrest.

This was an enormous effort, both cross peril, but also in the collaborative work with the Tūwharetoa Māori Trust Board, to provide timely and appropriate advice and to understand this unusual event. Along with many others, GeoNet data, its rapid advice services, and its trusted voice played its part.

Looking
ahead

IInitiated by GeoNet and led by the Natural Hazards and Risks Theme, GNS has embarked on a journey to understand its operating model for the development and delivery of science advice. This work will help define ways of working and help clearly outline the roles and responsibilities of different science programmes across GNS, including GeoNet.

In the medium term, the work to stand up and clarify our support for more formalised science advice and monitoring functions for each peril will continue. A key goal for the peril groups is to be a strong science voice within GeoNet, drawing on science expertise to help advise GeoNet on where it needs to go with regards to data and tools to best support each peril's needs.

Knowledge **Exchange**

Over the last 22 years, GeoNet has become a household name. People reach for their phones and the GeoNet app when the earth moves. They trust GeoNet to provide reassurance through delivering real-time data, and rapid information and advice when they need it most.

GeoNet's success in distributing data, information and knowledge is the result of longstanding collaborations between scientists, technologists, communication specialists, and emergency responders throughout the public and private sectors. Our whakapapa is one of collaboration. Cross disciplinary and cross organisation work sits at the heart of knowledge exchange.

Within GNS and with its partner agencies, GeoNet works to support collaborative efforts to build understanding of geohazards. Together, we are knowledge brokers for the hazard and risk management system - in times of response and in calmer times of readiness and recovery. We do this through our work with the public and our work with each other.

Regular news stories and our responsive and informative social media presence help bring science to the public in an accessible way. Attendance at and sponsorship of events like conferences and science fairs and more technical workshops enable us to meet with our colleagues and collaborators, stakeholders and users, and the public.

Behind the scenes, we have robust and resilient infrastructure and services that ensure we can share our data and information. GeoNet data is always free and open, and our technical users can access it in a range of ways for their own uses at any time. We are there to support, with user guides and FAQs, and are ready to answer queries and learn ways to make our services better.

Our near real-time data and rapid products and services enable us to get scientific information and advice to emergency managers and the public in times of response. Our website and mobile applications can handle huge surges in demand, so we can be there for people to access the information they need, when they need it.

We help New Zealanders through exchanging data and information. Knowledge and understanding help people increase their confidence and gain peace of mind. Building understanding helps people become better equipped to make decisions and reduces the likelihood they would lose their lives or be injured in natural disasters. Key programme outcomes include:

- **Collaborative delivery:** Partnerships are strong. We develop system-based solutions that leverage organisational strengths, lift up our partners, and deliver value for New Zealand.
- **Impactful engagement:** We grow engagement in GeoNet and our partners' work, to enhance people's awareness and commitment to preparing for and responding to geological hazards and risks in New Zealand.

2022-23
Highlights & outcomes

- **Future-proofing.** The GeoNet Strategic Review was undertaken and delivered, and the development of the 10-year Strategic Plan is well underway. Though development of the plan is still in flight, input through workshops and interviews with a range of stakeholders was undertaken during FY 22-23. This consultation included a reference panel made up of the Strategic Review panel and additional experts from across GNS and New Zealand and key partners such as Toka Tū Ake EQC, LINZ, MBIE, and NEMA.
- **Flagship cross-programme collaboration.** At the end of the financial year, Shaking Layers was transitioning into a new phase of the project, with engagement with geospatial experts across GNS and New Zealand underway. Shaking Layers is a new mapping tool, developed in collaboration between the Rapid Characterisation of Earthquakes and Tsunami Endeavour programme (RCET) and GeoNet. The tool was presented at several conferences throughout the year, and has been touted as a prime example of how to do user-focused co-development.
- **The Head Operating Agreement.** We're maturing how we exchange information within the programme. Following on from executing the new operating agreement, a new suite of reporting has been developed and iterated upon. This work better brings together our contracting partners, improving their ability to make informed decisions for GeoNet.
- **Forecasting together.** From 10-16 February 2023, twice-daily rainfall-induced landslide forecasts were provided to key emergency management stakeholders to support the response to Cyclone Gabrielle. This work was tightly coupled with work from NIWA and MetService, who provided the rainfall inputs for the forecasts and hindcasts, respectively. This marked the wide scale operational debut of this forecasting tool.
- **Tilde, the new data access tool.** The new Tilde Time Series API was officially released in November 2022, and is on its way to becoming our 'one stop shop' for access to GeoNet time series data with sample rates of 1 second or longer. Keep an eye out for further updates to Tilde in the coming year.

Taupō M5.7 Earthquake and Aftershocks

animation

helping people to understand our hazards

views
3000+

> "Even though most are quite weak, that's still a lot of aftershocks!"
>
> YouTube commenter

145
social media posts published

245,654
Social media followers

72,000
People viewed our Kawerau earthquake swarm story

100+ entries

To the 'draw your own volcano' competition at the sixth Emergency Services Expo took place at Te Papa, in Wellington in April 2023.

Case study
Shaking it up

Over the last two years, a team involving more than 50 people has been working on how we view earthquake shaking. The Shaking Layers project has been one of our most complex projects, and one of our best examples of cross-programme, cross-discipline collaboration. Co-developed with the Rapid Characterisation of Earthquake and Tsunami Endeavour programme, this project began in 2021 with a goal of releasing shaking layers maps on the GeoNet website in a user-endorsed way. It includes mechanisms to enable experts to revise and improve the maps as further data and information becomes available.

Collaborators included people throughout GNS, together with external experts and users. The project was guided by a Science Advisory Panel and an End User Advisory Panel. These panels helped ensure the most appropriate and up-to-date science was being incorporated into the automated tool and to ensure the outputs of the tool were fit-for-purpose for the myriad of end users. Technical staff - from the science lead to the development lead, software architect, and user experience designer - were embedded in the leadership team. Their mandate was to ensure all voices were clear and the right balance between science, tech, and end users was struck.

As of June 2023, Shaking Layers was preparing for a September 2023 release on the GeoNet website. User engagement was underway, marking a shift into a new project phase that would take development towards integration with Geographic Information System (GIS) mapping systems used by GNS, emergency managers, councils, and many others across New Zealand.

Looking
ahead

This coming year, the next phase of the Shaking Layers project is to build more seamless integration with GIS capabilities. This work will be a huge benefit for Shaking Layers and the interoperability of shake maps, and will unlock this capability for other tools that rely on map output, such as earthquake- and rainfall-induced landslide forecasts.

Our Communications, Education, and Outreach services are preparing for a revamp. We're working closely with communications, social science, and leaders in geoscience engagement from across GNS and outside of it to make this service more focused and impactful.

Building
Community resilience

GeoNet's imperative is to improve our collective understanding of New Zealand's land, geohazards and their impacts, to help communities become more resilient.

A key way to ensure the work we do is useful, usable, and used is to integrate social science methods and learnings into our products and communication. Social science builds user perspectives into the way we develop our services and provide trusted science advice. This helps those receiving science advice to apply it to ground their decisions.

Well communicated science advice is a key to community resilience. It supports decision-making across the civil defence emergency management framework - the 4 R's - reduction, readiness, recovery, and response. Our communities are more resilient when the decisions made by engineers, infrastructure operators, insurers and reinsurers, emergency managers, councils, and the public, are grounded in robust science.

GeoNet supports GNS by gathering, integrating, and delivering science advice to New Zealanders, leveraging and amplifying the expertise of our research delivery and impact partners. GeoNet is always 'on' with data and information flowing through its systems and ready to handle the intense demand that comes with response and recovery.

GeoNet is ready to share - embedding social science best practices to ensure our advice is fit-for-purpose. This way, we help people to better understand the land and geohazards we live with, and direct them to the right places for further information on protective action. Key programme outcomes:

- **User-driven design.** Our products are designed and iterated on with users at the fore, integrating social science best practices to ensure they are fit-for-purpose, useful, usable, and used.
- **Coordinated communication.** We are aligned with key partners wherever practicable in order to connect people to the right information and amplify each others' messages.

2022-23

Highlights & outcomes

- **Users front and centre.** A key pillar of the Shaking Layers project was the regular consultation with an End User Advisory Panel - a group of diverse technical users spanning engineers, emergency managers, insurers, and lifelines providers - and the public. Information gained from consistent engagement guided the product design from the get go - setting a new standard for engagement and collaboration with users.
- **Teaming up across the Tasman.** Sparked by the revival of the Regional SeisComP (our earthquake locating system) User Group workshop, we, along with some of our other GNS colleagues, were able to spend some additional time with Geoscience Australia and the Australian Bureau of Meteorology. Together, we had our first face-to-face opportunity in a while to discuss common challenges, share ideas, and kick off working groups on topics like information and data sharing in the South Pacific.
- **Resilient communities, resilient researchers.** A return to in-person conferences and workshops allowed us to reconnect with colleagues across NZ and the world. The GeoSciences New Zealand conference and QuakeCore were as popular as ever, and New Zealand hosted the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) Scientific Assembly in Rotorua at which we had a significant presence. The RSCUG was restarted after a several-year hiatus, hosted by Geoscience Australia (GA) in Canberra. Being able to share and discuss ideas from across our communities - from infrastructure to data to science - and work together is so important to the resilience of our people, work, and systems.

GeoHazard event activations **23**

Quarter 3 (January - March 2023) saw the most event response activations, with 12 activation events occurring.

Developing

Shaking Layers

over

1000 public participants

contributed to our 2022 earthquake survey

10 different end-user groups represented on the

End-User Advisory Panel

GeoNet representatives attended a range of conferences working groups, both in-person and online

GeoSciences New Zealand | International Association of Volcanology & Chemistry of the Earth's Interior Scientific Assembly | Regional SeisComP User Group | GeoScience Australia & Australian Bureau of Meteorology | QuakeCore

Case study

Volcano - iwi relationship/collaboration

In 2022, for the first time ever, GNS Science raised the Volcanic Alert Level (VAL) at Taupō Volcano from VAL0 (no volcanic unrest) to VAL1 (minor volcanic unrest). Monitoring and keeping locals informed during the unrest period provided opportunities to strengthen our relationships with the local community and iwi. A significant increase in felt earthquakes served as a regular reminder for locals about the volcanic activity at play beneath the lake. The largest – a M5.7 on 30 November 2022 – was widely felt and resulted in two small tsunami. Clear communication was essential to keep decision makers informed, and to manage local interest. We produced and shared a series of videos featuring our volcano experts providing updates on activity over the unrest period. These were positively received by both stakeholders and local communities.

We worked closely with our partners at Taupō District Council and Tūwharetoa Māori Trust Board to ensure updates and public safety messages were being heard by the people who needed them. “It was crucial for us to work closely with the Tūwharetoa Māori Trust Board, the landowner of Lake Taupō,” explains GNS Science Volcanology Team Leader, Nico Fournier. “Regular hui were organised not only to ensure that the Trust Board had the information they needed to make informed decisions, but also that we worked hand in hand towards improving the level of volcano monitoring at Taupō volcano, with the installation of further instrumentations around the lake.” Taupō volcano was reduced to VAL 0 in May 2023, but the unrest could start up again at any time. We continue to provide public education on volcanic hazards, and work with local Civil Defence Emergency Management and iwi to ensure they are up to date on any activity.

Looking **ahead**

As a programme, we remain committed to fostering our partnerships with other programmes, organisations and communities to maximise the collective impact of a New Zealand well prepared for geohazard events. Building stronger relationships with our research, delivery and impact partners will be an important focus for us as we continue to support improvements to New Zealand’s resilience.

In recent years, social science has worked closely with GeoNet to develop products and our long term programme plans. We are looking to use the knowledge gained through the experience of developing the new Shaking Layers tool to embed social science in our product and service design processes. By strengthening this capability, we feel confident that GeoNet will evolve to meet the needs of our users in engaging and useful ways.

Natural hazard risk management
System improvement

GeoNet functions in a rapidly evolving operating environment.

Our future must adapt to the impacts of climate change, national science system reforms, legislative change, rapid new developments in technology and science, and an uncertain funding future, both for GeoNet and the science programmes it is underpinned by.

The future operating challenges and increasing demand for data and services weave a web of uncertainty that needs to be carefully considered and managed even as New Zealand's exposure to risk from natural hazards increases.

At the beginning of the year, the independent strategic review of GeoNet was released. This put forward ambitious possibilities of how GeoNet could evolve. To set the strategic direction of the programme and guide decision making, we have begun the development of a 10 Year Strategic Plan. Over the course of the year, we've worked with a range of stakeholders to ensure GeoNet is well positioned to play its role in supporting New Zealand to become more resilient to natural hazards. This work has highlighted the need for a collective and joined up approach across the science value chain. For GeoNet to succeed into the future, deep engagement with our delivery and impact partners is critical.

Alongside our operating environment, our products need to adapt too.

With our collective deep expertise in hazard and risk science (GNS, including GeoNet), we are navigating a path of designing science services that best enable the people in New Zealand to live and prosper alongside our natural hazards.

A recent joint initiative is the Rainfall-induced Landslide modelling tool (RIL). Co-funded through GeoNet and Strategic Science Investment Fund (SSIF) RIL is a GeoNet product developed by research scientists. It is used to forecast landsliding caused by rainfall in advance of, during, and following rain events. GeoNet data is also one of the inputs for RiskScape, a collaborative GNS-NIWA programme, which focuses on exposure to geohazard events and modelling loss and impact.

We need to rapidly evolve our products, the supporting services that underpin them, and the operating environment required to deliver them. It's only through a collective and systems-based approach that GeoNet can thrive. We are proud of the part that GeoNet plays in contributing to the wider system. Key outcomes include:

- **Systems innovation:** Improving the ways we address complex problems, within the GeoNet Programme, GNS Science, and more broadly in the Science, Research and Innovation Sector.
- **Collaborative product development.** Work collaboratively to support development of impact-based tooling, from development through to standard operational use.

2022-23

Highlights & outcomes

- **Impactful collaboration.** In the GNS response to cyclone gabrielle, GeoNet benefitted from landslide expertise. Not only through teaming up with NIWA and MetService to provide rainfall-induced landslide forecasts, but the team also came together with the RiskScape programme to forecast impact on landslide-affected residential areas and state highways, providing emergency managers with more detailed and actionable information.
- **Review and plan, plan and review.** The Strategic Review released in October 2022 set a direction and articulated a bright future for GeoNet. The 10-year Strategic Plan will help signal that path forward. Work and advice from those involved in the Strategic Review flowed into the extensive consultation on the Strategic Plan. Engagement and development of the plan has illuminated, more clearly than ever, the interdependencies of GeoNet and other programmes in the delivery of science advice for the benefit of New Zealand.
- **Public good service.** The Te Ara Paerangi white paper published in December 2022 sets out a vision for the future of the public Research, Science, and Innovation sector. This vision illustrated a need for public good services and infrastructure, which support the research system and New Zealand's resilience. In the list of possible examples, GeoNet was the only service to get called out by name!
- **Future funding.** Te Ara Paerangi signalled the Government's commitment to create a sustained funding mechanism for GeoNet.

2022

Strategic review

grounded in stakeholder and scientific insights.

10 diverse, expert panel members

22 stakeholder interviews

30 presentations on perspectives that included iwi Māori, emergency mgmt users, physicial, data & social sciencences & engineering

> "To remain relevant, GeoNet cannot lapse into some sort of steady state."
>
> GeoNet Strategic Review 2022

Te Ara Paerangi

Policy direction 4.4

"Introduce, where appropriate new funding approaches to support the wider goals of the reform, such as stable long-term funding for public good science services."

Case study

Rainfall induced landslides

In January and February 2023, the upper North Island was hit hard by significant rainfall. The severe weather resulted in unprecedented flooding and slips across the region and on the 14th February, New Zealand declared a national state of emergency.

These events quickly met the criteria for our landslide experts to activate to support the response, providing them an opportunity to use their rainfall-induced landslide (RIL) tool on a larger scale than ever before. The RIL tool creates a geodatabase with the RIL probabilities for the latest rain forecasts, allowing key stakeholders to make decisions about where to evacuate or to send additional resources.

In collaboration with NIWA, who provided the rainfall forecasts, we released RIL forecasts twice-daily from 10-16 February. With the RiskScape programme we were able to trial more tailored impact forecasts that focused on the effects of RIL on landslide-affected residential areas and state highways. We also worked closely with MetService to produce hindcasts. These were produced using actual rainfall data.

GeoNet also took to the skies, conducting significant field reconnaissance to identify the extent of landslides (ultimately used to help validate the forecasts and hindcasts), identify potentially hazardous areas, and determine where more detailed satellite imagery was needed. The data from this reconnaissance was made available to emergency managers and stakeholders immediately following.

Further field reconnaissance work and the subsequent deep collaborations across the sector - through universities and councils and more - was crucial to accurately capturing the extent of landslides across the region from these severe weather events. These events make up one part of an extensive landslide database that is the foundation of all of our landslide forecasting tools, and are therefore critical to training, development, and validation of these forecast models in future!

Looking

ahead

The challenge for 2023-24 is to attain the necessary, sustained funding and support to allow for the continuation of GeoNet's work into the future. In recent years, demand for our products and services has grown significantly. This trend is expected to continue into the future as the impacts of climate change, such as more extreme weather events, increase. We are actively working with our government partners to mature our funding and contracting arrangements to ensure GeoNet has a secure future.

Sustained funding will enable us to advance our capabilities, keep pace with technological and scientific advancements, keep our data open and enhance our resilience. Increased understanding of geohazards helps reduce the costs and loss of life suffered from natural disasters.

Creating value through **financial & risk management**

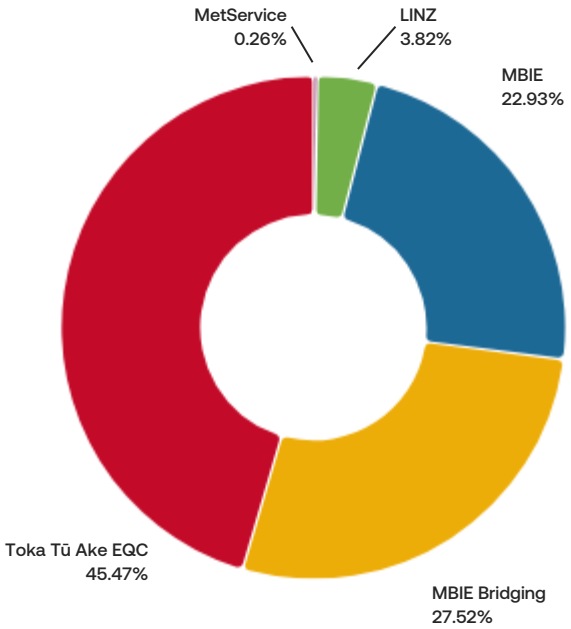
2022-23 By the **Numbers**

GeoNet delivered on budget and within its funding envelope for FY 2022-23. Alongside sustaining operations we supported: developments in products and services (Shaking Layers); additional open data access through AWS; bringing more of a social science lens to the way science advice is delivered and the operation of the Rapid Characterisation of Earthquakes and Tsunami Northland array of seismic equipment. The capital budget allowed for continued mitigation of asset related risk. Vacancies across the programme meant that GeoNet could support response activity at Tāupo, Cyclone Gabrielle and other weather events.

Our funding **Sources**

GeoNet is a collaboration. Our cross-agency funding partners all contribute to the success programme.

In FY22-23 $26,169,333 was contributed for both operating and capital expenditure.

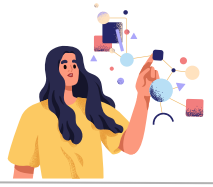


Where the **money went**

For every $100 our partners contributed in the 2022-23 financial year, we allocated our spending (both operating and capital) across:

$2.89
Geohazard Specialist Advisors
Our experts who jump into action when an event occurs

$16.98
Sensor network investment
Maintaining & improving our network of sensor equipment.



$6.72
GeoNet programme operations
Behind the scenes work, like financial management, planning & reporting

$1.16
Communications & outreach
Connecting with our users, like researchers & the people of Aotearoa

$3.98
Monitoring in event response
Those extra activities following an event, like supporting the Cyclone Gabrielle response

$35.74
Core operations
The work on our infrastructure that gets all the parts of GeoNet working together

$25.82
Monitoring our hazards
Running our 24/7 monitoring centre, plus science to track our 'four perils'

$6.71
Development initiatives
Improving GeoNet through applying current science into new products & enhancing our ways of working

Risk management
& internal control

Our success as a public good service depends on our ability to develop and maintain the right products, services and supporting infrastructure for our many user groups. The GNS risk management approach is designed to identify and assess risks as early as possible and take appropriate measures to seize opportunities and protect the value of the business, within agreed tolerance levels. For GeoNet it's about managing risks that pose a threat to GeoNet's future, and to strengthen our ability to create sustainable long-term value.

The following overview reflects the key risks that we believe are most relevant to the delivery of our programme. This overview is not exhaustive as there may be risks not yet known to us or which are currently not deemed to be material.

Details	Description	Response
Issue; Finance: Failure to secure perpetual funding	Due to funding shortfalls and annual funding allocations, the GeoNet Programme is unable to confidently plan and build sustained capability (people, process and technology).	Bridging funding was granted for FY22-23 by Central Government (administered through MBIE). Funding for FY23-24 has also been secured. A bid for perpetual funding is being prepared, together with associated strategic and business planning, with the objective of sustained funding being allocated from FY24-25.
Risk; Health & Safety: Failure to protect field workers from remote and hazardous environments	If we do not adequately plan and provide for the safety of our workers in remote and hazardous environments then serious personal harm could result.	We operate under GNS' Health and Safety policies and procedures and maintain a highly competent workforce to operate in these environments. This is achieved through robust recruitment practices, specialised competency training, fostering a caring and safety conscious culture and conducting frequent safety checks and audits. Alongside these activities, site individual activities have risk management processes in place, which include intentions, communications and tracking protocols for staff out on the field.
Risk; Operational: Failure to deliver timely geohazard monitoring, information, and advice during a natural disaster response	If we are unable to provide effective geohazard monitoring, and timely information and advice during a natural disaster, emergency managers and other decision makers will not have the advice they need to help protect lives and assets. Our operations and reputation are substantially dependent on our ability to maintain 24/7 services, including in remote locations. This service needs to be maintained during geohazard events which may cause widespread disruption to physical infrastructure and digital internet infrastructure that GeoNet sits within. Unforeseen disruptions could affect our service to users and cause loss of, or delays, in GeoNet's critical network systems, our data, and our dissemination channels. Any permanent or temporary loss of critical systems could result in reputational damage, source code destruction, loss of data quality and/or completeness, and reduced ability or inability to provide services in a disaster. Any permanent or temporary impediment to meet our expected targets or committed service levels for relevant products and services, inhibits our ability to gather, integrate, and share advice during a natural disaster. Timely, data-based advice is essential for sound decision making by the government and the public in times of emergency. If sufficient data and expected services are affected or unavailable it could further adversely impact the ability of wider GNS and others to provide advice. Material disruption to provide this could result in loss of life.	GeoNet infrastructure, both virtual and physical, is engineered to a high level of resilience with redundant geographically separated sensors and processing. A key strategy is diversity of vendors and technology for communications, as this tends to be disrupted during a natural disaster. Another strategy is the intentional tiering of our sensor station network; designing the system to prioritise connection to critical data feeds which are hardened, and managing others to 'go off' when connectivity is strained. We structurally deploy and maintain information security governance, controls, processes, and tools in our engineering, operations, products, and services using a risk-based approach. We consistently improve, tighten and invest in our cyber-defence and resilience capabilities, including our commitment to training for our staff to keep pace with evolving threats facing our network. We continually invest in site reliability engineering best practices to further improve the resilience of our network and platform technology. We invest in best practice asset management, including proactive maintenance, repair, and enhancements to our physical asset network. We see opportunities in the future to enhance our resilience through consultation with expert user groups. We have business continuity and disaster recovery planning in place for critical systems and continuity of services, designed for various possible eventualities. However, we are unable to plan for every possible disaster or incident. GeoNet is still dependent on a single internet provider (REANNZ) to route data in from the sensor network and is vulnerable to some large events such as a widespread NZ internet disruption, a full AWS Sydney region failure and a major Wellington region disaster. Work is ongoing to ensure that GeoNet has the right balance of resilience and cost for the future. We continue to build resilience into our on-call duty teams and expert panels through increasing the pool trained experts and continuous improvement to operational practices.