British Geological Survey

Year 1 progress report for the International Geoscience R&D programme

NERC NC International

Open Report OR/23/045

BRITISH GEOLOGICAL SURVEY

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Keywords

International Geoscience; BGS National Capability; Monitoring, Evaluation and Learning.

Bibliographical reference

WATTS, M, UPTON, K, MCKENZIE, A, MITCHELL, C, SARGEANT, S.2023. Year 1 progress report for the International Geoscience R&D programme. *British Geological Survey Open Report*, OR/23/045. 38pp.

Keyworth, Nottingham British Geological Survey 2023

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Executive Summary

Purpose of this report

This report provides a progress review of Year 1 of the NERC National Capability (NC) funded BGS International Geoscience Research and Development (IGRD R&D) programme. The IGRD programme has a total value of £11.929M and runs from 2022-26.

The IGRD Programme

The intended impact of BGS' IGRD programme (see Section 1) is to facilitate the sustainable use and secure supply of Earth's natural resources and increased community resilience to natural and anthropogenic hazards. The programme's multifaceted pathways to impact are outlined in a Theory of Change (ToC) (see Appendix 1), which defines how the programme aims to transition from a series of outputs, through to outcomes and, ultimately, the long-term impact that the programme seeks to contribute towards. This ToC provides the basis for a logical framework (Logframe) against which progress is monitored and evaluated (see Section 4 and Appendix 3).

Progress and outcomes in Year 1:

As would be expected, Year 1 of the four-year programme has largely focussed on building the partnerships and scientific understanding that will provide the foundation for outcomes and impact to develop over the duration of the programme and beyond.

1. Significant progress has been made towards **developing the research evidence base** through overseas fieldwork campaigns with programme partners, data collection and analysis, and 37 research publications.
2. **Key partnerships have been established or expanded** – reflected by 80 engagement activities in the first year with partners and stakeholders across the programme, several extended training and knowledge exchange visits of partners to BGS, and four Memorandum of Understanding between BGS and overseas institutions. Successful funding pathways for partnerships have also been secured in the first year with the Department of Mineral and Geoscience Malaysia (JMG), the National Geophysical Research Institute (NGRI) in India, and two funded PhD studentships researching geohazards and risk in Indonesia and Zambia. Section 2 of the report provides more detail on these aspects.
3. **Outcome pathways centred around nine thematic hubs** are starting to develop. Section 3 of the report expands on the activities and outcome pathways being taken forward within these themes. The risks and priorities for Year 2 are discussed in Section 5.

Year 1 of the programme has provided opportunity for cross-programme exchange and learning through RIC and programme-wide workshops, in addition to more focussed research and thematic discussions. This will provide the basis for deeper exchange through subsequent years as the research and partnerships become more established.

1 Aims and objectives of the IGRD Programme

The IGRD programme is funded from the NERC NC International initiative from 2022-2026 at £11.929M. The programme aims to facilitate the sustainable use and secure supply of Earth's natural resources and increase community resilience to natural and anthropogenic hazards by addressing three global environmental challenges: (1) adaptation and resilience to natural hazards; (2) sustainable and secure resources for the future; and (3) sustainable land management and climate change adaptation.

To respond and deliver solutions to these challenges, the programme is organised into three corresponding Research and Innovation Challenges (RICs), each with clearly defined objectives:

- RIC 1 Living in multi-hazard environments: Geoscience data, information and knowledge are used to improve the detection and forecasting of hazards, and multi-hazard interactions, to support disaster risk management (DRM);

- RIC 2 Resources for the future: Geoscience data, information and knowledge are used to determine how global demand for resources (water, food, energy, minerals) can be met with minimal environmental and social impact, while addressing the energy transition to net-zero;

- RIC 3 Sustainable land management and climate change adaptation: Geoscience data, information and knowledge are used to provide solutions to counter the negative impacts of land use change and urban development and help communities adapt to climate change.

Each of the RICs comprise several projects, each with their own research questions, novel research methodologies and geographical focus, which will contribute to the objectives outlined above. Projects have been co-designed with partners in the most appropriate country for that challenge to generate outcomes for local practitioners while also providing the basis for translation to global impact where appropriate. Several projects explicitly build on previous initiatives delivered during BGS' precursor 'Geoscience for Sustainable Futures' (GSF) NC programme, which ran from 2018 to 2022. GSF had an explicit focus on Official Development Assistance (ODA), whereas IGRD seeks to deliver research for global public good outcomes.

Recognising the inherent synergies and overlaps across the three RICs, mechanisms are in place to facilitate cross-programme exchange and learning through a team of experienced Co-Investigators. This team has expertise in particular geographical settings or areas of science that cross-cut the RICs described above.

Pathways towards achieving the aims and objectives described above are outlined in a programme Theory of Change (ToC) - see Figure 1 and Appendix 1. The ToC defines how the programme intends to transition from delivering a series of outputs, to a series of outcomes, whereby programme outputs are used by partners and external stakeholders to inform decision making and practice, whether at a sub-national, national or international level. These outcomes are one of many prerequisites for achieving the desired impact and will be the primary focus for evaluating success of the programme, recognising that impact is likely only measurable over

much longer timescales and is dependent on a wider array of interventions (political, socio-economic, environmental etc) than can be delivered by BGS. The chance of achieving lasting impact will be maximised by activities designed to translate findings and outcomes to a wider audience, building on our links to international initiatives, overseas governments, supported by key links to UK Government, e.g. Foreign, Commonwealth & Development Office (FCDO) and Department for Business & Trade (DBT); global financial initiatives, e.g. World Bank and Bill & Melinda Gates Foundation; and long-standing involvement in multi-lateral organisations, e.g. Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP), Food and Agriculture Organization of the United Nations (FAO-UN), and the African Ministers' Council on Water (AMCOW).

Over 160 BGS staff contributed, to varying degrees, in the first year of the IGRD programme, spanning the full breadth of BGS capability. It was designed in consultation with staff and the BGS senior leadership team with activities that complement and support the BGS strategy. A leadership team manages the finances, staff resourcing and project activities within three Research and Innovation Challenges (RICs). A small group of Co-Investigators assists the management team in identifying where there are synergies between projects and in identifying the most effective ways to achieve outcomes in the wider geoscience community.

Monitoring, Evaluation and Learning (MEL) is a continuous process (explained further in Appendix 2), guided by the ToC. The ToC forms the basis for a Logframe (see Appendix 3), which defines a series of indicators against which qualitative and quantitative evidence is collected. This is used to measure progress, highlight successes, identify areas for improvement, and guide year-on-year resourcing. In Year 1, a workshop in January 2023, preceding business review and planning in February 2023 (see Appendix 4) provided a review of emerging success, outcomes and challenges – enabling these to be built upon in Year 2 project plans.

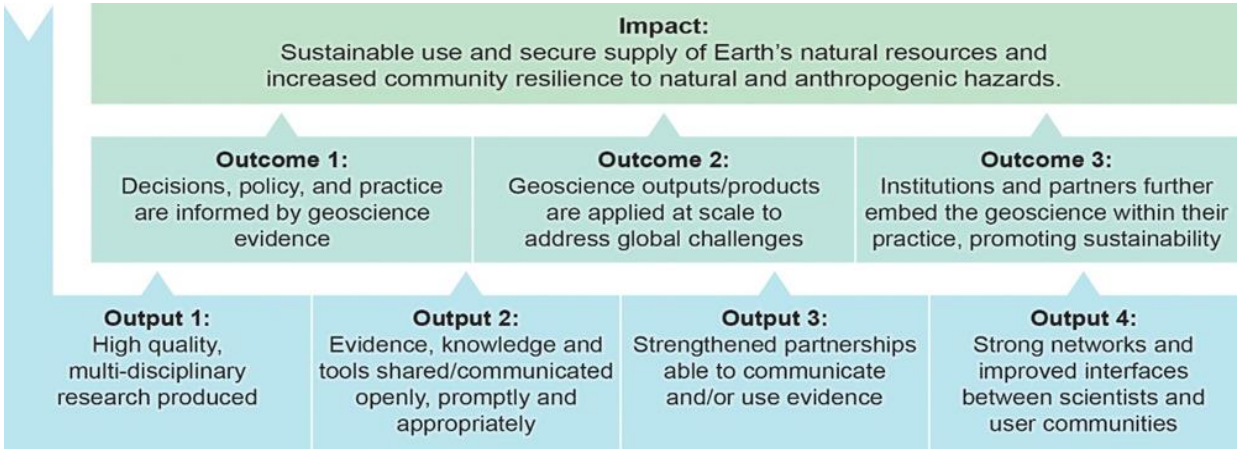


Figure 1 IGRD Theory of Change.

2 Year 1 highlights

Across the programme, the focus during Year 1 has largely been at the output level.

During the first year, significant progress has been made towards **developing the research evidence base** through:

- Fieldwork –field campaigns and in-field training with collaborators;
- Data collection and analysis;
- Publications – 37 academic and non-academic outputs were produced during Year 1.

Significant focus has been on **establishing or expanding key partnerships**:

- 80 partner and stakeholder activities were undertaken during Year 1;
- Zambian and Kenyan researchers made extended visits to BGS to undertake training and analysis;
- 4 new MoUs were signed during the first year.

Identification of potential **funding pathways for partnerships** has also been successful:

- IGRD supported two partners – Department of Mineral and Geoscience Malaysia (JMG) and National Geophysical Research Institute (NGRI) in India – to secure significant funding for aligned research;
- Two funded PhD studentships were secured in Year 1 working on research aligned to geohazards and risk in Indonesia and mine waste in Zambia.

This builds the foundation for project- and programme-level pathways to impact, some of which are already progressing towards **tangible outcomes**. For example, building on partnerships and research under the GSF NC programme, IGRD research informed two major global-level policy documents on groundwater by the World Bank and UN-Water, and two key partners leveraged additional funding with support from IGRD, increasing their capacity to undertake aligned research and activities.

Through Year 1, as projects have become more established, focus has also shifted at the programme level to **understanding synergies and building links** across projects and RICs. Examples are provided in the thematic narratives below, which will be developed further during Year 2, and summarised in Appendix 5.

3 Emerging Thematic Narratives

While the programme is managed as a series of projects and activities within the three RICs, each of which is focussed on specific science questions and distinct geographies, several thematic hubs are starting to emerge, around which multiple projects coalesce. These hubs provide a useful framework for developing narratives, or stories of change, which describe how the programme is progressing towards outcomes and impact in response to the global challenges described above.

3.1 RIC 1: NOVEL DETECTION AND FORECASTING OF HAZARDS

This hub centres around developing new methods that are useful for understanding hazards in a way that will be helpful for decision making, and BGS becoming a key player in wider discussions about the use of Machine Learning (ML) and Artificial Intelligence (AI) in understanding geohazards and their management. The hub consists of three AI/ML-focused

projects using large datasets (earthquake forecasting, creating landslide inventories and quantifying urban subsidence using satellite data) and one that is more grounded in field observations to understand landslide trigger thresholds in tropical residual soils.

At the end of Year 1, the core partnerships for this hub are in place and the projects are developing tools/approaches to tackle specific hazards (quantifying urban subsidence rates, developing ML forecast models for earthquakes, developing landslide inventories and understanding landslide trigger thresholds for tropical soils). Some of the AI/ML work is revealing challenges for BGS around developing processes for using cloud-based services and what the projects learn during the IGRD Programme will change the way BGS access data in future. Links with key stakeholders like UNESCO, NASA and USGS will extend the projects' reach and progress is also being made at the national level where agreements with agencies such as the Geological Survey of India are being developed. This paves the way for connecting with new initiatives such as the Landslide Early Warning Centre for India.

3.2 RIC 1: UNDERSTANDING AND MANAGING MULTI-HAZARD INTERACTIONS

This hub centres around decision-making for disaster risk management being informed by our research in Indonesia, the Philippines and the UK Overseas Territories (UKOTs). In Year 1, the projects have concentrated on building trusted relationships with key stakeholders both in the focus areas (e.g. the Resilience Development Initiative in Indonesia and the Philippine Institute of Volcanology and Seismology) and in the UK (e.g. FCDO). This has included setting up necessary inter-organisational agreements. Building networks has been central to the project in Indonesia (e.g. a landslide working group has been set up that involves a wide range of stakeholders and facilitates increased information sharing). The Indonesia project has also been pivotal in facilitating connections between their Indonesian partners and other IGRD projects that help to extend the geographic reach of the individual projects. In Year 1, understanding stakeholder needs and information gaps in each location has been crucial to developing areas of joint research in coming years. All of these activities will prepare the projects to start fieldwork and other activities in collaboration with partners in Year 2 (e.g. deploying instrumentation and developing hazard scenarios with partners in the UKOTs). Initial discussions about how to extend the multi-hazard governance research in the Philippines to include anthropogenic hazards such as the failure of mine tailings dams (see RIC 2) have also started in Year 1.

3.3 RIC 1: MAKING GEOSCIENCE USEFUL, USABLE AND USED

Useful and usable scientific information that can support decision making for a wide range of stakeholders is fundamental to implementation of the Sendai Framework for Disaster Risk Reduction, and success for this hub focuses on improving the integration of science in decision making for disaster risk management. In common with the other RIC 1 hubs, significant effort in Year 1 has gone into building relationships with key stakeholders (e.g. FCDO and various institutes and organisations in Malawi) that will underpin this hub's research. Partner-focused activities run by the disaster self-recovery project have included a workshop in Malawi with local geoscientists and representatives from humanitarian organisations such as CARE Malawi to discuss how geoscience could support WASH (water, sanitation and hygiene) and shelter activities. Multi-institutional events have brought key stakeholders together to discuss how reporting from volcano observatories could provide information on the impacts of volcanic activity that could be useful for disaster management. Getting commitment from DG-ECHO to

support the aims of this project was a significant milestone. All of these activities set the scene for undertaking joint research with partners in Year 2.

3.4 RIC 2: STRATEGIES FOR SUSTAINABLE MINING AND RAW MATERIAL SUPPLY

This fourth hub is focussed on geoscience informed decision making for resource development that helps to secure the continued supply of raw materials, particularly for the energy transition to net zero, and ensure minimal environmental and social impact.

The mineral waste research project is focused on nickel laterite mining in the Philippines and copper-cobalt mining waste in Zambia as part of the drive to ensure sustainable mining of critical mineral resources. In the Philippines, UAV drone flights have enabled development of a digital terrain model of the Tailings Storage Facility (TSF) and a geophysical monitoring observatory has been established. Characterisation has been carried out on the tailings material to determine geotechnical, mineralogical and bioaccessibility properties. Geochemical analysis of the laterite is planned to determine the distribution of Platinum Group Elements (PGEs). In Zambia, a PhD research project has been initiated with the Copperbelt University (CBU) involving dust sampling of the 'Black Mountain' copper-cobalt waste site in Kitwe with the intention to carry out lung bioaccessibility testing. Success for this research would be the sustainable management and economic development of mineral waste resources.

The sand mining research project carried out a successful visit to Kuala Lumpur, Malaysia. Meetings with scientists, activists and the local mining industry were hosted by the JMG (the Malaysian geological survey) and the UK Science Innovation Network officer based at the British High Commission in Kuala Lumpur. Good practice sand mining illustrations have been developed to show how geoscience data and information can be used for monitoring and management of sand resources. Success for this research would be geoscience informed resource management and policy enabling a secure and sustainable supply of construction sand.

The African graphite research project carried out several visits to Zambia in 2022 with the establishment of a research team that comprised the Copperbelt University (CBU) and the Geological Survey Department (GSD). Awareness of graphite resources in Zambia increased, including Hon. Paul Chansa Kabuswe MP, Minister of Mines & Mineral Development in Zambia. Success for this research would be an increased understanding of graphite resources in Africa, active reconnaissance programmes by geological surveys, and mineral promotion leading to junior mining companies exploring for graphite in Africa.

The Lithium Triangle research project has established good contacts in Argentina, Bolivia and Chile with the assistance of the UK embassies. The BGS presence in the region enabled by the IGRD project helped to secure Science Innovation Network (SIN) funding to develop a road map for sustainable and responsible development of salars in the region. This has the potential to lead to a much larger SIN funding opportunity. Success for this research would see the removal of obstacles to decarbonisation, increased understanding Salar systems, how people relate to them socio-economically and to enable responsible evidence-based decisions.

3.5 RIC 2: ENERGY RESOURCE EVIDENCE FOR TRANSITION TO NET ZERO

The second RIC 2 hub examines the way geoscience is harnessed to help develop the potential of the subsurface, particularly for geothermal energy and Carbon Capture, Utilisation & Storage (CCUS), for the energy transition to net zero.

The superhot geothermal research project has developed a rock physics model that aims to identify geothermal 'sweet spots' by combining different geophysical techniques that is aimed to encourage investment in geothermal energy development. Case study focused on the Aluto Volcano area in central Ethiopia, which is the site of the Aluto–Langano Geothermal Power Station. The African Geothermal resource data research project contributed data to the Geothermal Atlas for Africa, presented work at ARGeo-C9, leading African Geothermal Conference in Djibouti (November 2022) and built relationship with leading private/ public geothermal institutions in Kenya (GDC, KenGen, and Geothermal Energy Training and Research Institute). Success for the geothermal research would be to de-risk geothermal drilling and giving investors a greater degree of certainty for hitting good geothermal yields.

The Indian CCUS research project focused on engagement with researchers in India, where CCUS research programmes are developing rapidly. BGS is well placed to be a part of this, building on past engagement. Decarbonisation initiatives in India offer a big prize due to the size of the Indian economy; also, other countries look towards India as an exemplar for economic development. Research has included sequestration trials with basalt from the Deccan Traps and characterisation of CCUS potential of reservoir rocks in an Indian oilfield area. Success for this research would be the establishment of an active, capable research programme to enable development of CCS in India based on good science.

3.6 RIC 2: UNLOCKING THE POTENTIAL OF GROUNDWATER IN SUB-SAHARAN AFRICA

This hub aims to provide the necessary partnerships, geoscience understanding, and hydrogeological evidence for groundwater to contribute to improved water and food security for rural communities in sub-Saharan Africa (SSA).

This hub is centred around three areas of research: (1) improving our understanding of basement aquifer typologies across SSA and their potential to support sustainable groundwater abstraction, alongside an understanding of key groundwater quality challenges; (2) identifying the key hydrogeological, social and engineering controls on the functionality of rural water points; (3) working with the solar pumping community to ensure that groundwater knowledge and information informs the anticipated shift to solar-powered groundwater abstraction in SSA.

The basement aquifer typology work was a key factor in BGS' success in winning additional funding from UNICEF, with whom we have a long-standing partnership, to carry out groundwater resource assessments in Southern and Eastern Africa. The basement typologies being developed by IGRD are informing national / sub-national scale assessments to identify suitable areas for drilling, using a methodology that is likely to be applied by UNICEF in other regions of SSA in the coming years. This work is also feeding into ongoing discussions with BGR, who are keen to partner with BGS to develop a business case to the German government on groundwater and food security in SSA. The work on waterpoint functionality has been widely cited by the Waterloo Foundation-funded Stop the Rot campaign – aimed at reducing issues of handpump corrosion and failure – resulting in BGS being invited to act in an advisory capacity to this continental-scale initiative, enabled by IGRD.

At a global scale, the portfolio of work in this project fed into several global-level policy documents and media stories centred around World Water Day 2022 and the UN-Water Summit in 2022. This included a World Bank report on the economics of groundwater (The hidden wealth of nations) and a UNESCO report on the UN-Water Summit on Groundwater 2022, the messages from which were conveyed to the UN 2023 Water Conference in New York.

3.7 RIC 3: INFORMING WATER MANAGEMENT PRACTICES TO PROTECT WATER QUALITY

The aim of this theme is to provide water resource managers in South Asia with improved process understanding that can guide decision making towards improved water quality.

Programme work in South Asia is mainly focussed on groundwater salinity in the Indo-Gangetic basin, which can be either geogenic or exacerbated by irrigation practices. With potentially contested transboundary aquifers clear attribution of salinity sources is important for the future management of water resources in the basin. The international dimensions of data access are key to project success and much of the work in the first year of the project has been focussed on developing understanding of data availability, and appropriate data management procedures with partners in India and Pakistan. By identifying suitable partners significant quantities of observational data have been obtained and were validated. A secondary focus for the project is understanding how intensively exploited aquifers respond to different stresses. Work in Southern India is examining how surface and groundwater interact in urban areas, and how effective are management interventions in improving groundwater recharge; in Northern India we will look at how aquifers and society respond to extreme over-exploitation. The first year's work was focussed on developing partnerships, and a highlight was aligning significant grant funding for an Indian partner to the project's objectives.

3.8 RIC 3: GEOSCIENCE SOLUTIONS FOR SUSTAINABLE LAND MANAGEMENT

Understanding the influence of soil geochemistry on food production and nutritional security is an essential component of policy support for agriculture (e.g. liming and fertiliser rates) and public heath (e.g. identifying regions at risk of micronutrient deficiencies). National spatial soil data often remains outside interoperable, easily used visualisation/data platforms. This project builds on our agriculture-nutrition-public health partnerships in SSA to capitalise on geostatistical and field experimental approaches. This experience is investigating the trade-offs between soil and mineral use for nutritious food production compared to other land-uses, via alignment with research funded by the Bill & Melinda Gates Foundation funded project Geonutrition and MAPS (https://micronutrient.support/). Geochemistry and health research will deliver Global Public Good via digital open-access tools (Western Kenya Soil Geochemistry 2022 (arcgis.com)) to visualise spatial data and support user querying functionality (e.g. statistical models, tracers). The research has supported the study of geospatial incidence on non-communicable diseases (e.g. cancer, micronutrient deficiency), initially in Kenya and Malawi with IARC-WHO (McCormack et al. 2016). A resulting model will identify where intervention strategies may be most appropriate to efficiently increase agricultural productivity. An additional outcome will include a spatial location map of geological resources with the Geological Surveys in Kenya and Malawi to underpin advice for agricultural intervention strategies by the Ministry of Agriculture: in Malawi, this will focus on potassium to build on prior Malawian team research and respond to current difficulty in accessing global potassium supplies.

The impact of land degradation from poor land management has consequences for food quality and productivity. Initial investigation has been undertaken in the Lake Victoria basin in Kenya via aligned funding from the Royal Society, academic, research institute and community/regulatory partnerships to encompass agriculture, industry and urban changes that influence land-to-lake dynamics, with global relevance for settings experiencing rapid

deforestation for conversion to agricultural use. Field experiments are determining specific rates of soil erosion using tracers across differing land-uses to inform intervention strategies to improve soil lifespan. Source apportionment analyses at catchment scale for land-to-lake transfers of soil/sediment will connect the agricultural and fisheries sectors and their decision makers to develop holistic management practices e.g. working with nature in land and aquatic environments. A resulting model for land-to-lake dynamics in the Winam Gulf of Lake Victoria will be used to demonstrate a catchment scale approach to inform sustainable land/aquatic management. Our ambition is to explore the extension of this approach to a diverse range of environments, while continuing the development of tools to make the data and learning widely accessible to regional stakeholders. A second area of focus is measuring the effectiveness of conservation agriculture, building on the work of the CEPHAS project in Malawi and Zimbabwe and the Terrafirma project, increasing monitoring of groundwater to provide robust evidence of which interventions are successful, or not. Conservation agriculture is largely employed to improve water retention via rainfall by reducing run-off, retain nutrients and reduce acidification of soils. It will be explored as one of the mitigation methods to maintain soil lifespan.

3.9 RIC 3: GEOSCIENCE TO INFORM URBAN PLANNING

A significant element of the previous GFS programme was focussed on geoscience in Asian cities, and this has remained the main region of focus within the current IGRD research programme in relation to urban planning. CCOP (a multilateral organisation representing Southeast Asian geological surveys) are a key partner in this work and share our goal of promoting urban geoscience so that it is routinely applied by urban planners to optimize the use of the sub-surface and minimize exposure of population and infrastructure to geohazards. Working with CCOP and KIGAM (the Korean Geological Survey) the IGRD programme in Year 1 has run several? regional workshops on urban geoscience strengthening outcome pathways. Cooperation with CCOP and with the CCOP Research Centre in Urban Geology is a key to wide dissemination of specific research carried out by the IGRD programme, for instance the development of urban geoscience typologies.

Funding secured by JMG (the Malaysian Geological Survey), a key partner in our IGRD urban programme portfolio, will deliver a programme of geological investigation (circa £0.5 million/annum) in the Kuala Lumpur area. This will form an exemplar for other regional cities, building on the co-development of digital tools and training in field mapping skills initiated under the previous GSF programme. Landslides are a significant geohazard in Kuala Lumpur, often affecting critical infrastructure such as roads and power lines. We forged links with university partners in Malaysia (Universiti Tenaga Nasional) who have an active programme in Microbial Induced Calcite Precipitation that complements work that BGS is carrying out in the laboratory. Linking with the JMG mapping and work in RIC 1 on detecting and forecasting landslide hazards should lead to opportunities for early field testing of MICP as a way to reduce landslide risk where extensive civil engineering based mitigations would be impractical.

Urban water quality is a multi-dimensional issue, affecting cities and populations in diverse ways depending on geology, climate and the history of infrastructure development and industry in an area. Our projects aim to understand the relative importance of these factors. Initial progress has been made understanding the resilience of shallow water points used by low-income urban families in Harare using eDNA, and continuing investigation of industrial legacy contaminants in Hanoi. This work will link into the urban typologies concept to inform planners of risks and priorities.

Several of the other themes are likely to influence outcomes in the Urban theme – these include, but are not limited to, work on landslides which are a key urban hazard in Malaysia and on subsidence in Hanoi (RIC 1, Detection and forecasting of hazards), work on groundwater surface water interaction in Bangalore and blue green infrastructure assessment tools in Mexico (RIC 3 – Informing water management practices to protect soil and water quality).

In both the Philippines and Mexico workshops were held with project partners and other stakeholders with, in addition to technical project discussions, a strong emphasis on network development and identifying pathways to extend activities and fund partners. This led to DOST (Philippines science funding body) adopting the IGRD programme as a basis for a funding call, and creation of a consortium of partners including Mexico, Canada and South Africa to bid for expansion of the socio-hydrological project. The ultimate aim of these projects is to put tools into the hands of non-specialist stakeholders that allow actionable decisions on water management to be made.

4 Logframe Report

4.1 IMPACT

In responding to the global challenges described above (see Section 1), the long-term impact that the IGRD programme aims to contribute towards is:

Sustainable use and secure supply of Earth's natural resources and increased community resilience to natural and anthropogenic hazards in: (1) the urbanising world; (2) resource rich emerging economies; and (3) communities on the climate change frontline.

This impact spans across BGS' capabilities within the geosciences, reflected in the range of projects and tasks within the programme, and across a broad spectrum of beneficiaries, reflected in the range of partners involved in the research. Narratives towards achieving the intended impact, where the IGRD programme is playing a significant role in effecting change, are developing in several key thematic areas, as described in Section 3 above. Progress towards impact will be monitored as part of the ongoing MEL process, however, evaluation will primarily be at the outcome level, recognising that impact is likely to happen over much longer timescales due to a wider array of interventions (political, socio-economic, environmental etc).

4.2 OUTCOMES

The IGRD programme is working towards three key outcomes that focus on the uptake and use of IGRD research by various stakeholders, providing multiple pathways towards achieving the impact described above. Further description of these outcomes within the context of the three RICs is provided in the ToC (Appendix 1). Within each outcome, progress is being monitored against a series of indicators, as outlined below. Detailed evidence for each indicator can be found in the full Logframe document.

Outcome	Indicator	Number delivered Year 1

O1. Decisions, policy and practice are informed by geoscience	O1.1. Number of citations of IGRD research (papers / datasets / tools / reports) within policy or practice documents	0
	O1.2. Number of media reports (written articles, TV, radio) mentioning IGRD research	7
	O1.3. Number of stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue influenced by IGRD research	0
	O1.3a. Number of *developing* stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue influenced by IGRD research	5 (5)*
O2. Geoscience research is applied at scale to address global challenges	O2.1. Number of citations of IGRD research (papers / datasets / tools / reports) within policy or practice documents *beyond project localities*	3
	O2.2. Number of academic citations	n/a**
	O2.3. Number of stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue *beyond project localities influenced* by IGRD research	0
	O2.3a. Number of *developing* stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue *beyond project localities* influenced by IGRD research	9 (4)
O3. Institutions and partners further embed the geoscience within their practice, promoting sustainability	O3.1. Number of partners who report a change in their capacity (e.g. stronger networks/additional funding success/position of responsibility/ research outputs)	n/a***
	O3.2. Number of instances of participation (by partners) in relevant stakeholder meetings / forums	1
	O3.3. Number of stories of change to the capacity or working practices of institutions and partners as a result of IGRD research	3
	O3.3a. Number of *developing* stories of change to the capacity or working practices of institutions and partners as a result of IGRD research	6 (2)

*a(*b*): a is the number of *developing* stories of change with clear pathways to outcome/impact; b is the number of *potential developing* stories of change where the pathway to impact is less clear; ** not monitored in Year 1; *** not monitored in Year 1; data will be collected for this indicator in Year 2 through a partner survey

Highlights at the outcome level at the end of Year 1, some of which build on work from the GSF programme, include:

- Several media stories around water security, with a particular focus on groundwater and Africa, largely stemming from research outputs from the GSF programme and due to groundwater being the key focus of World Water Day in 2022;
- National media attention in 'The Hindu' for fieldwork to understand landslide trigger thresholds in Kerala;
- IGRD/GSF research used in two major global-level policy documents on groundwater: a World Bank report on the economics of groundwater and a UNESCO report on the UN-Water Summit on groundwater in 2022;
- IGRD research on urban geosciences cited in the CCOP annual report for 2022;
- Two stories of change to partners' capacity, where IGRD (building on GSF) helped secure additional funding for partners – JMG in Malaysia, to undertake an Urban Geoscience programme in Kuala Lumpa, and NGRI in India, to undertake a project on CCUS;
- One story of change to partner's capacity where training provided under IGRD to CARE International has been used in a separate project for USAID.

These outcomes help raise awareness of and influence the discourse around the challenges being addressed by the IGRD programme among various audiences, from the general public through to global financial institutions. The additional funding and capacity achieved by partners for continuing related work helps to further embed geoscience practice in key institutions addressing similar global challenges.

4.3 OUTPUTS

The IGRD programme is working towards four key outputs that build the foundation for achieving outcomes and impact, from the scientific evidence base to the partnerships needed to translate that evidence for uptake to effect change. Further description of these outputs is provided in the ToC (Appendix 1). Within each output, progress is being monitored against a series of indicators, as outlined below. Detailed evidence for each indicator can be found in the full Logframe document.

Output	Indicator	Number delivered
P1. High quality, multi-disciplinary research is produced by the IGRD programme	P1.1. Number of academic publications	9
	P1.2. Number of products and tools	2
P2. Dissemination of research	P2.1. Number of non-academic outputs (e.g. policy briefs, webpages, blogs)	1

	P2.2. Number of presentations at conferences / workshops	25
P3. Strengthened partnerships able to communicate and/or use evidence	P3.1. Number of collaborations and partners	tbc
	P3.2. Number of co-produced outputs and activities (including training and capacity building activities)	34
P4. Strong networks and improved interfaces between scientists and user communities	P4.1. Number of external stakeholder workshops and networks engaged with	46

As is evident in the table above, a considerable effort has gone into partnership and network building during Year 1. There were 34 outputs or activities co-produced with partners, the majority of which were in-person partnership meetings and training activities held in-country. Furthermore, there were 46 examples of stakeholder engagement through various forums, including bilateral meetings with government departments and industry, multi-stakeholder roundtables and workshops, engagement with professional forums and advisory groups, and school engagement activities. Production and dissemination of academic outputs was also a primary focus in Year 1, including publication of a preliminary landslide inventory following the major earthquake in Turkey/Syria in February 2023.

5 Forward Look: Risks & Priorities

Potential risks going forward:

- Projects working in silos and not maximising opportunity for cross-project or cross-RIC learning;
- Fragmented stakeholder engagement or missed opportunities for collective engagement;
- Lack of staff capacity to respond to new opportunities.

Priorities for 2023/24:

- Focus Co-I resources on stakeholder engagement, and, where appropriate, horizon scanning activity for upcoming policy initiatives at UK, national, and international scale alongside identifying potential funding initiatives (23/24 Q2);
- Apply Co-I expertise to review the activities, pathways to impact, and scale of each project's research and identify opportunities for knowledge and skills transfer between projects, regionally and between settings, e.g. technology transfer / AI (23/24 Q3)
- RIC leaders continue to develop thematic narratives to support progress towards impact and continue to identify synergies and opportunities for cross-project exchange (review 23/24 at end Q2)
- Map out interconnectivity across programme
- Work towards a staff and partner survey for the mid-point review to understand successes and areas for improvement (end 23/24)
- Identify specific milestones for indicators in the Logframe

6 Summary

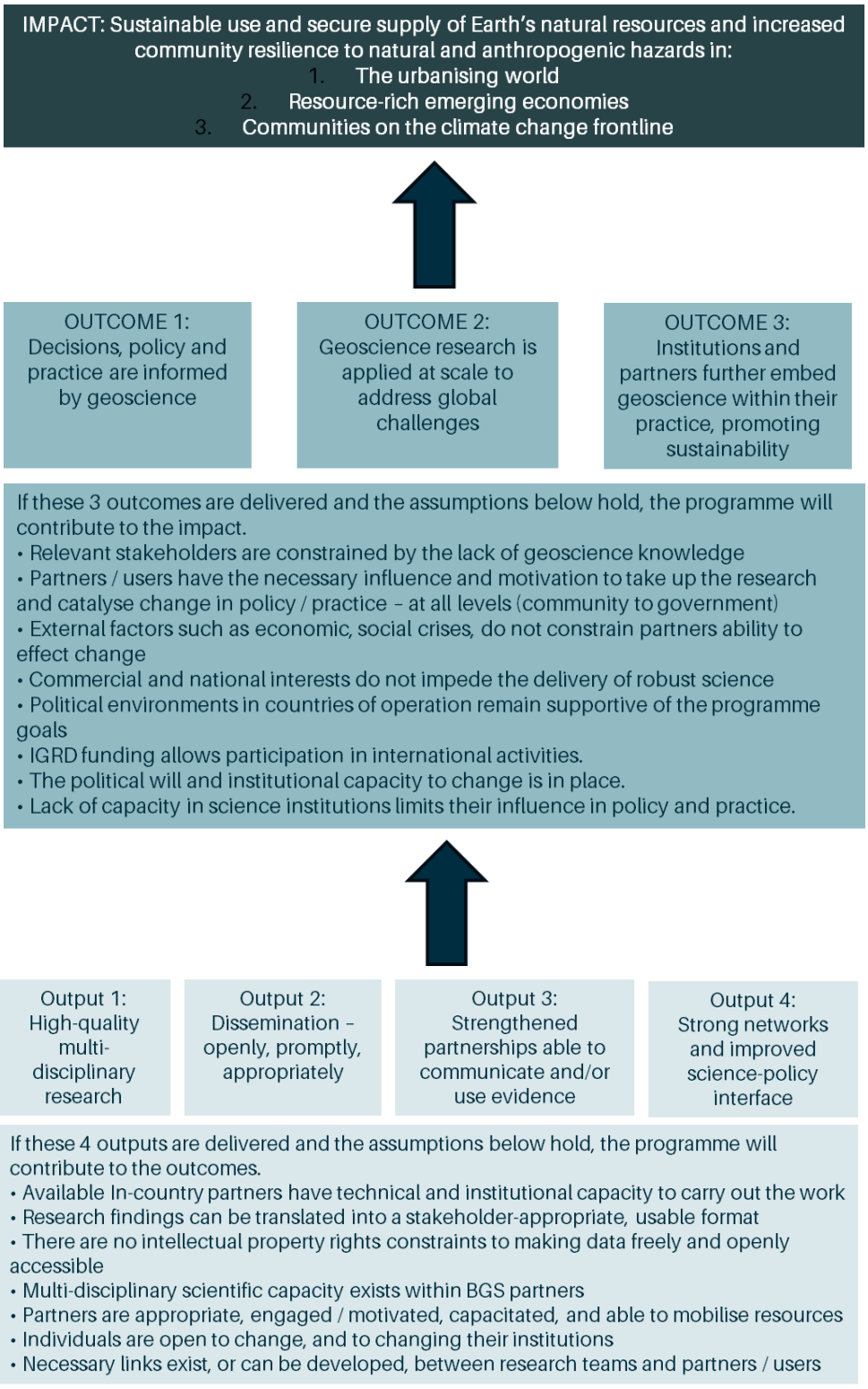
Considerable progress was made in Year 1 as shown by the metrics captured. A key point in Year 1 was the programme workshop in January, described in Appendix 4, which confirmed that all project activities had gained momentum in developing their stakeholder partnerships to the required level to enable meaningful research to be undertaken. Developing the required impact pathways for intended outcomes and realisation of global public good is recognised as a key planning priority for Year 2, and the programme-wide awareness on the need to be focussed on impact pathways was encouraging, as was recognition of the need for evidence to develop narratives to explain project successes to a broad audience that may include non-specialists. The workshop also highlighted the positive perception across the BGS IGRD community in giving opportunities to work in teams across the challenge areas. There was also great appreciation for the programme role in acting as an incubator to develop opportunities for early career staff to manage projects, developing their experience and track record, and creating greater diversity of leadership for BGS.

Appendix 1 Theory of Change

The purpose of this document is to lay out the pathways that link the outputs that the IGRD programme will deliver through to the long-term change that the programme seeks to contribute towards. It was compiled in a series of discussions with the leadership team of IGRD, and external consultants, during 2022.

The theory of change is illustrated in a diagram overleaf, followed by a narrative description. The structure of the change pathways outlined in this document has also been used as the basis for a separate log frame. The log frame gives more details of how these changes will be measured. It shows indicators of change, as well as milestones and targets against which progress can be tracked.

The programme is sub-divided into three research settings, namely: living in multi-hazard environments; resources for the future; and sustainable land management and climate change adaptation.


IMPACT: Sustainable use and secure supply of Earth's natural resources and increased community resilience to natural and anthropogenic hazards in:
1. The urbanising world
2. Resource-rich emerging economies
3. Communities on the climate change frontline
OUTCOME 1: Decisions, policy and practice are informed by geoscience
OUTCOME 2: Geoscience research is applied at scale to address global challenges
OUTCOME 3: Institutions and partners further embed geoscience within their practice, promoting sustainability
If these 3 outcomes are delivered and the assumptions below hold, the programme will contribute to the impact.
• Relevant stakeholders are constrained by the lack of geoscience knowledge
• Partners / users have the necessary influence and motivation to take up the research and catalyse change in policy / practice – at all levels (community to government)
• External factors such as economic, social crises, do not constrain partners ability to effect change
• Commercial and national interests do not impede the delivery of robust science
• Political environments in countries of operation remain supportive of the programme goals
• IGRD funding allows participation in international activities.
• The political will and institutional capacity to change is in place.
• Lack of capacity in science institutions limits their influence in policy and practice.
Output 1: High-quality multi-disciplinary research
Output 2: Dissemination – openly, promptly, appropriately
Output 3: Strengthened partnerships able to communicate and/or use evidence
Output 4: Strong networks and improved science-policy interface
If these 4 outputs are delivered and the assumptions below hold, the programme will contribute to the outcomes.
• Available In-country partners have technical and institutional capacity to carry out the work
• Research findings can be translated into a stakeholder-appropriate, usable format
• There are no intellectual property rights constraints to making data freely and openly accessible
• Multi-disciplinary scientific capacity exists within BGS partners
• Partners are appropriate, engaged / motivated, capacitated, and able to mobilise resources
• Individuals are open to change, and to changing their institutions
• Necessary links exist, or can be developed, between research teams and partners / users

The impact that the programme seeks is the secure supply and sustainable use of the Earth's natural resources and increased community resilience to natural and anthropogenic hazards. The focus of the programme will be in three particular environments: i) the urbanising world; ii) resource rich emerging economies; and iii) communities on the climate change frontline. In order to achieve this long-term goal, there needs to be sustained action taken by many partners, together with a range of actors in the external environment. The external environment also needs to be conducive to such an impact. For example, economic and social crises do not constrain the partners ability to effect change. It is also important that partners and users of the products of this programme have the necessary influence and motivation to take up the research and catalyse changes in policy and practice at all levels, from community to government. It is assumed that the relevant stakeholders are currently constrained by the lack of geoscience knowledge.

One of the pathways towards this impact relates to **decisions, policy and practice which are informed by geoscience evidence** (Outcome 1). The programme and project partners, together with a range of external actors, articulate a voice of responsible advocacy through representative bodies and the leverage that they command through their networks of influence. This outcome will be developed by each of the RICs across the three key settings, as follows:

For Research and Innovation Challenges (RIC) 1 this relates to Disaster Risk Management (DRM) and/ or resilience-related decisions. The objective is that urban planners and infrastructure managers are informed by robust landslide hazard and risk analyses and by new evidence of subsidence rates. Responding organisations are able to act in a timely manner during earthquake sequences. DRM decisions taken by authorities and community decision makers are informed by new hazard analyses and scenarios. Geoscience knowledge and expertise supports people recovering after disasters in multi-hazard environments to become more resilient.

RIC 2 relates to sustainable natural resource supply decisions. In this case the objective is that decision makers in the public sector (including government ministries, resource licencing authorities and environmental agencies) and the private sector (including mining, power, and water supply companies) are using geoscience-based best practice to ensure sustainable development and use of natural resources. Informed policies and plans are put in place that assist the energy transition to net zero (including development of geothermal, solar pumping, carbon capture and storage and critical raw materials) and address environmental, social and governance issues including mine tailings safety and utilisation, groundwater utilisation, sand extraction and Li-brine mining.

RIC 3 relates to land and water use and climate change adaptation decisions. The objective is that farmers, local authorities and/ or national agencies (in Zambia and India) will adopt working with nature approaches to soil and groundwater conservation. Government agencies (in Canada, and Mexico) will use social and hydrological tools to assess the resilience of marginalised communities and optimise blue-green infrastructure solutions. Impacts of climate change on future soil and water resource will be quantified and incorporated into national resource plans and planning mechanisms (in Kenya, Philippines).

The second objective at the outcome level is that **geoscience outputs and products are applied at scale to address global challenges.** Providing global leadership and influence,

alliances that share environmental and scientific ambitions meet the scientific challenges of the complexity and scale that require an international response.

For RIC 1, DRM and resilience stakeholders with a global presence (e.g., UNDRR, UN Global Shelter and WASH clusters) are informed by RIC 1 outputs. Landslide forecasting in tropical regions is informed by landslide trigger threshold workflow developed for India. Inventory maps for landslide-prone regions produced by the 'landslide tracker' tool are in use. The process for making subsidence forecasts is applied to rapidly expanding cities in different geological settings around the world. For example, the understanding of how multi-hazards interact with policy in the Philippines is applied elsewhere; approaches to integrating geoscience in DRM decisions in the UK Overseas Territories (UKOT) is transferred to other island settings. RIC1 will provide international leadership and influence through supporting the implementation of the Sendai Framework for Disaster Risk Reduction by developing mechanisms for reporting against its targets.

For RIC 2, the objective is that research outputs inform and influence natural resource stakeholders across the world. RIC2 research enables the application of: Ni-laterite waste monitoring to international mine sites and emerging areas such as landfill mining; the better understanding and best practice for sand mining to other areas of the world where active sedimentary environments are mined; new understanding from the Lithium triangle to other environmentally sensitive mining districts especially in arid areas where mining could exacerbate water scarcity; the knowledge gained through the CO_2 storage research in India to the Indian subcontinent and Southeast Asia; and the superhot geothermal research to volcanic settings worldwide.

For RIC 3 this will mean the development of digital platforms for data delivery on soils and geosciences, the African Groundwater Literature Archive and the African Groundwater Atlas. African policy makers in the water sector give increased attention to the groundwater sector influenced by bodies such as the African Ministers' Council on Water (AMCOW) and the APA Groundwater Programme. Geological Surveys in SE Asia prioritise urban geoscience issues, influenced by bodies such as the Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP) and the Research Centre on Urban Geology (RCUG). Tools developed for social and hydrological resilience, climate change impact, predicting future groundwater abstraction and urban typologies are adopted outside partner countries.

The third outcome on the path to impact has the objective that **institutions and partners further embed the geoscience within their practice, promoting sustainability**. This will vary across partners and partner types. It will include the ability to undertake research but also to network and connect the supply of evidence with the demand for it. The capacity of researchers and intermediaries will strengthen research uptake approaches.

RIC 1: Partners (in India) have capacity to carry out landslide trigger threshold modelling. Partners have increased 3D visualisation and modelling capacity that supports communication with people exposed to hazards in the Philippines. There is raised awareness among geoscience partners of what information is needed for making DRM decisions. Decision makers in the UKOTs are aware of geohazards and the need for monitoring in the UKOTs. Humanitarian partners understand the role of water supply in

recovery, and how geoscience can support their decision making. They design and implement strategies accordingly.

RIC 2: Partners and stakeholders have the knowledge and capacity to make natural resource decisions based on geoscience data and information. RIC2 research will enable the: multiscale observation of tailings storage facilities to mitigate the risks of failure and enable sustainable mining to recover critical raw materials; the improvement of sand and lithium mining practices; the development of CO_2 storage in India and beyond; the potential of groundwater in sub-Saharan Africa to be unlocked to help achieve water and food security; the provision of geoscientific data and geoscientific knowledge needed for geothermal resource development.

RIC 3**:** Support to AMCOW and BGS representation on the RCUG board and scientific steering committee will ensure that these partners integrate the latest research on groundwater and urban geoscience, respectively, into central government planning and action. Partners in academic sectors in Africa and Central America will have the capacity to support and extend the deployment of tools developed by IGRD projects in the long-term, and will demonstrate a capacity to win grants and access funding to support fieldwork and studentships.

Feeding into those outcomes are the outputs, the deliverables of the programme. The paragraph below describes these. In order for these outputs to contribute to the three outcomes listed above requires several enabling factors .These are listed below:

- Available in-country partners have the technical and institutional capacity to carry out the work and there is multidisciplinary scientific capacity in place. The partners are appropriate, engaged, motivated, capacitated, and able to mobilise resources.
- The necessary links exist, or can be developed, between research teams and partners, and users.
- The individuals involved in the programme are open to change and to changing their institutions.
- The research findings can be translated into a stakeholder appropriate, usable format and there are no intellectual property rights constraints to making that data freely and openly accessible.

There are four classes of outputs. The first is that **high quality, multi-disciplinary research is produced**. That is, responsible research that adheres to the ‘fair’ principles, that data should be findable, accessible, interoperable, and reusable. This research will be cross-disciplinary.

The second output is that **evidence, knowledge, and tools are shared and communicated openly, promptly and appropriately**. This will ensure that data, information, and knowledge will be openly available and easily accessible to a global audience, that it will be informed by a range of stakeholders to ensure that it is useful, usable and used.

The third output is **strengthened partnerships able to communicate and or use evidence**. These partnerships will be ethical and equitable, ensuring that there is relevance and informed consent.

The fourth output relates to **strong networks and improved interfaces between scientists and user communities**.

Appendix 2 MEL Strategy

MEL PRIORITIES

Monitoring, Evaluation and Learning (MEL) is a key pillar of programme implementation. The purpose of MEL is to increase the likelihood of the programme achieving its intended outcomes and impact, while maintaining key values of efficiency, integrity, equity, preventing harm (safeguarding), inclusivity and openness. Information gathered via monitoring is primarily for the purpose of enabling reflection and programme adjustments towards increased impact.

Official reporting requirements are through the UKRI ResearchFish platform, on an annual basis, but the programme will also prepare an annual report to highlight key achievements, progress and learning. This will help to inform the next corporate-level evaluation by NERC, which is likely to take place in 2026.

The reporting is guided by an IGRD Logframe reporting template. This is used to document the key outcome stories under each of the 3 outcomes. The template also collates aggregated data on the outputs and outcomes.

USERS

The primary users of the data are within BGS. The project leads and partners can share the information and reflect on progress, updating the workplan and budget to improve performance. The RIC leads can look across projects in that portfolio to share good practice and lessons, and to see patterns of change, or identify blockages. The programme lead can use the data and analyses to reprioritise projects or areas of work, to understand where there might be synergies or gaps and to pull together all the work done and benefits gained from the implementation of the whole programme.

DATA COLLECTION

There is data collection from each project at the output level using a 2-strand approach.

Information on the research outputs and engagement activities is uploaded to NORA with corresponding datasets uploaded to the National Geoscience Data Centre (NGDC). Engagement activities (including meetings, conferences, blogs, training, workshops, panel discussion, outreach events, media activity) are recorded on a separate form(s). Projects report on outputs as they happen, throughout the year– with data compiled for input to the Logframe in February/March of each year

The information from these sources can then inform ResearchFish.

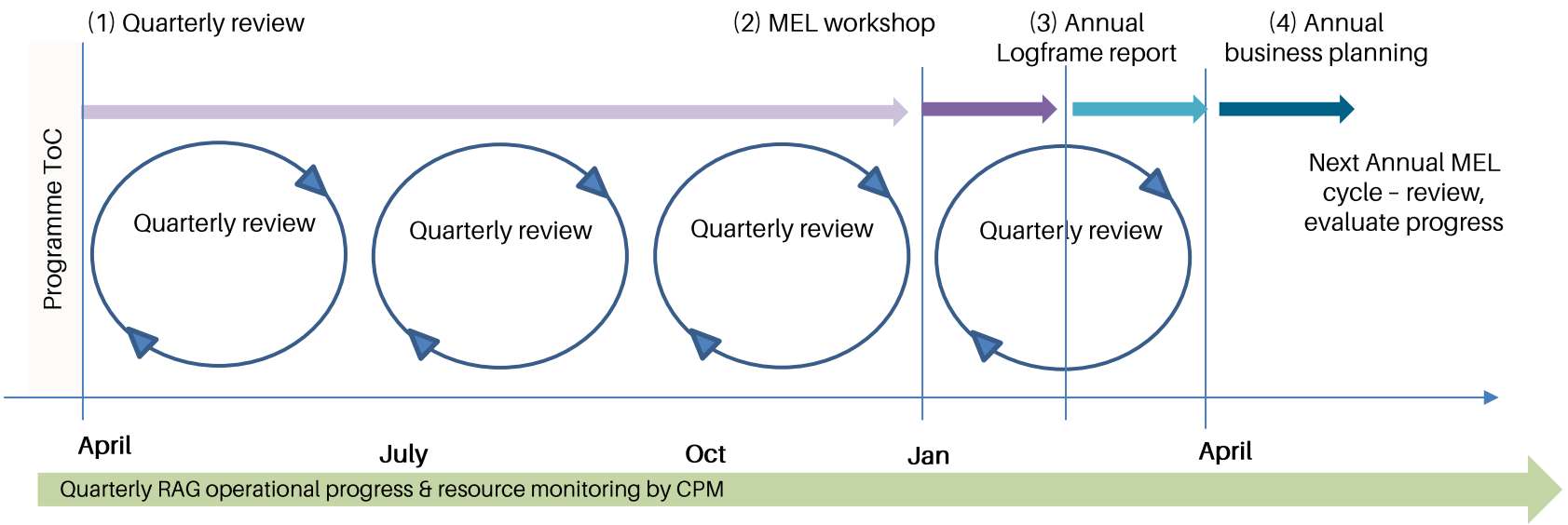
Information at the outcome level is gathered primarily in the regular (quarterly) discussions with the RIC lead. These discussions review outputs that have been reported, linking back through the project impact pathway towards the outcomes. Impact stories collected in this way are recorded in the Logframe. So, for example, if a project reports several engagement events, the RIC lead will probe to elicit further information on the consequences of those engagements, in terms of policies or practices that have been influenced. RIC leads will use a reporting template to guide their discussions and gather relevant information for the Logframe. Outcome data will be compiled for input to the Logframe in February/March.

The annual report will be completed in March/April.

The MEL process is supported by one or more workshops throughout the year. These provide opportunity for cross-project and cross-RIC exchange, allow progress towards outcome and impact to be discussed and evaluated at a programme level, and promote discussion of future priorities.

TIMELINE

IGRD Annual MEL Cycle



(1) Quarterly review cycle:

- RIC leads discuss progress along pathways to impact with project leads
- Logframe reporting template supports discussions
- RIC leads discuss with MEL lead to inform Logframe reporting

Outputs reporting:

- Ongoing by PLs via NORA and engagement activities form
- Annual metrics into Logframe (February)

(2) MEL workshop:

- Involves all Project leads and CoIs
- Review and assimilate progress over the year in emerging outcomes, constraints and opportunities

Focus workshop: MEL lead, RIC leads and CoIs:

- Synthesise key outcomes narrative
- Identify where outcomes / pathways could be amplified – these are followed through into business planning

(3) Logframe report

- Completed by MEL lead with input from RIC leads

(4) Business planning:

- Led by PI, CPM and RIC leads

Appendix 3 Logical Framework

IMPACT				
Sustainable use and secure supply of Earth's natural resources and increased community resilience to natural and anthropogenic hazards in: i) The urbanising world; ii) Resource rich emerging economies; and iii) Communities on the climate change frontline.				
OUTCOMES				
		Year 1		
Outcome	Indicator	Number delivered	Milestone	Progress against Milestone
O1. Decisions, policy and practice are informed by geoscience	O1.1. Number of citations of IGRD research (papers / datasets / tools / reports) within policy or practice documents	0	n/a	n/a
	O1.2. Number of media reports (written articles, TV, radio) mentioning IGRD research	7	n/a	n/a
	O1.3. Number of stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue influenced by IGRD research	0	n/a	n/a
	O1.3a. Number of *developing* stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue influenced by IGRD research	5 (*5*)	n/a	n/a

O2. Geoscience research is applied at scale to address global challenges	O2.1. Number of citations of IGRD research (papers / datasets / tools / reports) within policy or practice documents *beyond project localities*	3	n/a	n/a
	O2.2. Number of academic citations	n/a	n/a	n/a
	O2.3. Number of stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue *beyond project localities* influenced by IGRD research	0	n/a	n/a
	O2.3a. Number of *developing* stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue *beyond project localities* influenced by IGRD research	9 (4)	n/a	n/a
O3. Institutions and partners further embed the geoscience within their practice, promoting sustainability	O3.1. Number of partners who report a change in their capacity (e.g. stronger networks/additional funding success/position of responsibility/ research outputs)	n/a	n/a	n/a
	O3.2. Number of instances of participation (by partners) in relevant stakeholder meetings / forums	1	n/a	n/a
	O3.3. Number of stories of change to the capacity or working practices of institutions and partners as a result of IGRD research	3	n/a	n/a

	O3.3a. Number of *developing* stories of change to the capacity or working practices of institutions and partners as a result of IGRD research	6 (2)	n/a	n/a
OUTPUTS				
		Year 1		
Output	Indicator	Number delivered	Milestone	Progress against Milestone
P1. High quality, multi-disciplinary research is produced by the IGRD programme	P1.1. Number of academic publications	9	n/a	n/a
	P1.2. Number of products and tools	2	n/a	n/a
P2. Dissemination of research	P2.1. Number of non-academic outputs (e.g. policy briefs, webpages, blogs)	1	n/a	n/a
	P2.2. Number of presentations at conferences / workshops	25	n/a	n/a
P3. Strengthened partnerships able to communicate and/or use evidence	P3.1. Number of collaborations and partners	tbc	n/a	n/a
	P3.2. Number of co-produced outputs and activities (including training and capacity building activities)	34	n/a	n/a

P4. Strong networks and improved interfaces between scientists and user communities	P4.1. Number of external stakeholder workshops and networks engaged with	46	n/a	n/a

Appendix 4 January 2022 Workshop Report

A workshop was held on January 11th 2023 across the IGRD programme aimed at sharing l project progress, development of stakeholder networks and subsequent pathway to impact, early highlights from the research and potential problems encountered. The workshop was undertaken in two parts, firstly with discussions between project leaders within each of the RICs, sharing their experience and best practice in developing pathways to impact and working with stakeholders. This proved a valuable opportunity for the more experienced project leaders, and projects at a more advanced stage, to share lessons learned with the less experienced project leaders. In the second part of the workshop all interested BGS staff were invited to a programme information sharing exercise, with a series of two-minute nano-presentations from every project activity and subsequent discussion. Each project was required to present three points: their aim and objectives, their partners and stakeholders, and highlights from the research and partnership development to date. The nano-presentations were organised into the RICs for clarity, as shown below, but in many cases began to present the opportunities for wider cross programme collaboration between projects. Importantly this workshop started to formalise connections for the wider BGS staff complement beyond the project leaders with activities across the programme. It should be noted that many staff work across multiple projects.

RIC 1: Susanne Sargeant (Chair)

1.Philippines multi-hazards – Annie Winson

2.Earthquake forecasting using AI – Margarita Segou

3.Geohazards and risks in Indonesia – Ekbal Hussain

4.Landslide Trigger thresholds – Nikhil Nedumpallile-Vasu

5.Landslide Mapping with EO data – Alessandro Novellino

6.Subsidence in developing urban centres – Luke Bateson

7.Global Reporting of multi-hazards and impact – Melanie Duncan

8.UKOTs multi-hazards – Charlotte Vye-Brown

9.Self-recovery after disasters – Susanne Sargeant

RIC 2: Clive Mitchell (Chair)

10. Mineral mine waste: whole system approach – Jon Chambers, Alicja Lacinska, Elliott Hamilton (3 nano's)

11. Sand and sustainability – Tom Bide

12. Improving SEA of Li-brine mining – Jon Ford

13. Water and Food security in Africa – Alan MacDonald

14. Enabling clean growth in India through CO2 storage – John Williams

15. African geoscience data for improved geothermal assessment – Darren Jones

16. Superhot geothermal – Brian Baptie

17. Graphite in Africa: Carbon for decarbonisation – Clive Mitchell

RIC 3: Andy McKenzie (Chair)

18. Land use and environmental geochemistry – Michael Watts and Louise Ander (Olivier Humphrey, 2 nano's)

19. Blue green infrastructure, coastal resilience and landslide mitigation – Andrew Barkwith, Olivier Kuras, Marcus Dobbs (5 nano's)

20. Groundwater futures – Andy McKenzie, Jon Mackay, Kirsty Upton, Bentje Brauns (4 nano's)

21. Groundwater in South East Asia – Alan MacDonald, Daren Gooddy (2 nano's)

22. Urban Geosciences – Marcus Dobbs, Chris Vane, Dan Lapworth, Nikki Smith (4 nano's)

23. Mapping digital tools across the IGRD programme for impactful outputs – Kay Smith

Appendix 5 Thematic Synergies

	Multihazard Detection & Forecasting	Multihazard Management	Water Security	Urban Resilience	Sustainable Resources	Decarbonisation	Sustainable Land Management	Useful, useable, used
RIC1								
Philippines multi-hazards		x						x
Earthquake forecasting using AI	x							x
Self-recovery after disasters		x	x				x	x
Geohazards and risk in Indonesia		x						x
Landslide trigger thresholds	x							x
Landslide mapping using Earth Observation	x							x
Subsidence in developing urban centres	x			x				x
Global reporting of multi-hazards and impact		x						x
Geoscience for sustainable living in the UK Overseas Territories		x	x					x
RIC2								
Mineral mine waste: whole system approach (multiple tasks)	x				x			x
Sand and sustainability					x			x
Improving SEA of Li-brine mining from Lithium Triangle of South America					x			x
Food and water security Africa (multiple tasks)			x					x
Enabling clean growth India through CO2 storage						x		x

African geoscience data for improved geothermal assessment						x		x
Identifying superhot geothermal zones using geophysical methods						x		x
RIC3								
Land use and environmental geochemistry (multiple tasks)							x	x
Blue green infrastructure (multiple tasks)	x		x	x			x	x
Groundwater Futures (multiple tasks)			x				x	x
Groundwater in SE Asia (multiple tasks)			x					x
Urban Geosciences (multiple tasks)			x	x				x