Annual science review
2017–2018

British Geological Survey
Expert | Impartial | Innovative
Dear colleagues,

This was a very significant year for the BGS as it was one in which we started the process of redefining our governance, strategy and future business model.

The process was initiated with the Natural Environment Research Council (NERC) agreeing that the science the BGS does is largely undertaken through a public-facing science role, and thus different to the research-led science of a research council. Nonetheless it was recognised that the BGS and the NERC would continue to benefit from working closely with each other.

A decision was taken to create a BGS Board that would be responsible for much of the governance of the BGS. The Board started work in April 2018 with Sir Keith O’Nions as its chair. A selection process was undertaken to select the full BGS Board and I am very pleased to say that we have an excellent, diverse and international group as the founding members of the Board. The terms of reference for the Board have been agreed with NERC-UKRI and allow for a significant amount of autonomy for the BGS in its management going forward.

In parallel with the creation of the BGS Board, the research base in UK Government, UK Research and Innovation (UKRI), was created as the legal entity responsible for research in the UK; the BGS will thus report to UKRI legally in the coming year.

As you will see in this report, the BGS undertakes applied geoscience research with a focus on solutions to problems in the natural environment, both globally and in the UK. This is an increasingly important requirement as we need to resource future generations and to ensure a healthy and safe living environment.

As a result of international development funding now being available directly in the research base, Official Development Assistance (ODA) activities are now possible at the BGS and we are able to work directly with international partners on research and development. This, coupled with research funding from the Global Challenges Research Fund, has allowed us to develop three platforms:

- sustainable development focused around health, water and agriculture in East Africa
- sustainable urban development in South-east Asia, with a focus on the use of the subsurface in urban development
- natural hazard risk and response to disaster relief, with pilot areas in St Lucia and Trinidad and Tobago

In the UK, the shift from 3D to real-time observation is moving apace with the UK Geoenergy Observatories project. The BGS will operate two subsurface observatories aimed at defining the possibilities of using the subsurface for a number of energy solutions as we move forward in the decarbonisation of the UK. This world-leading infrastructure investment of £31 million is linked to operating and development investment of £7.5 million from the BGS and associated research and innovation investments from UKRI and other partners.

Our staff numbers increased from 632 to 640 this year, marking a growth for the first time in a decade. Our funding of £62.6 million — including £10.3 million capital and £6.5 million of International Ocean Discovery Programme funding (IODP) — resulted in us being able to make significant investments for the future.

As I hope you will see from my summary and the Annual science review, the BGS is at a critical crossroads with an exciting future. We are developing a refreshed science strategy ready for publication in early 2019.
Contents

Foreword 2
Introduction 4
International 6
National 14
Inside the BGS 22
Introduction

As a world-leading, global geological survey, we have an extensive programme of geoscience research, survey and monitoring, data management and dissemination. This helps us to focus on public-good science and to understand and predict the geological processes that matter to people’s lives.

Increasingly, our work is being carried out internationally and is directed towards issues such as helping developing countries realise sustainable benefits from their natural resources.

Most recently we have been using geoscience to help provide solutions to the major challenges recognised in the UN Sustainable Development Goals (SDGs), which are critical to underpinning global economic development. Many of these challenges, including food and water security, urbanisation, energy poverty, resilience to natural hazards and climate change, span the interface between the Earth and human systems.

We are working collaboratively with countries on the Development Assistance Committee (DAC) list of Official Development Assistance (ODA) recipients and our 2017–2020 ODA programme builds upon our recent and ongoing research on groundwater, soils, minerals, energy, urban planning, environmental modelling and geohazards.

We still focus on geoscience issues that affect the lives of UK citizens. To effectively deliver regional services and expertise, we have a number of offices located throughout the UK. This allows us to meet the specific demands of each region, including those of the devolved governments, and enables us to deliver the key elements of our science strategy and further our provision of public-good science activities. These all have a direct, positive impact on every aspect of UK society.

#BGS4GlobalGood
We have an extensive international programme of geoscience research, survey and monitoring, data management and dissemination. Much of the work that we do is directed towards development issues such as helping developing countries realise sustainable benefits from their natural resources. We do this by improving access to water, food and energy, helping communities deal with natural hazards, understanding global environmental change, and aiding the development of sustainable cities.

### Food and water security

#### Hidden crisis in sub-Saharan Africa

Over the last three years, we have been leading a £2 million international research consortium grant project called ‘A Hidden Crisis’ across three African countries, with university research partners and WaterAid country programmes. The aim of Hidden Crisis is to better understand the causes of poor functionality of groundwater supplies in Ethiopia, Malawi and Uganda.

Hand-pumped borehole supplies are the main type of rural water supply within Africa, but high rates of failure and poor performance of the supplies have been persistent problems over recent decades. Results from the first main survey phase of the project indicate that, at any one time, around 70 to 80 per cent of supplies provide some water, but only one third reliably provide sufficient water of good quality year round. The causes behind this are multifaceted, and do not simply relate to a badly built pump or a change in climate; they are the result of wide set of inter-related issues such as how water points are sited to ensure they make best use of local hydrogeological conditions; how communities inter-relate with technology, and, ultimately, how rural water supplies are commissioned. The project is now working with WaterAid and the ministries to identify key
research-into-use pathways, so that the research findings can feed into and inform improved future water supply practices and policy on multiple scales.

**Agricultural productivity in sub-Saharan Africa**

It is essential to improve the productivity of agriculture in sub-Saharan Africa while protecting land and water resources. There is evidence that reduced tillage and returning crop residues to the soil diversity can make cropping more resilient in the face of climate change. This is known as conservation agriculture (CA). Our understanding of the soil under CA is limited, which makes it hard to predict when and where CA will be successful.

‘CEPHaS’, funded by UKRI's GCRF programme, is a joint project between UK institutions — the BGS, the University of Nottingham, Rothamsted Research and Liverpool School of Tropical Medicine — the University of Zambia, the University of Zimbabwe and Lilongwe University of Agriculture and Natural Resources (Malawi) to strengthen our shared capacity to study the behaviour of water in soil, crop and groundwater systems. We are using modern methods in soil physics, geophysics and hydrogeology to examine soil and groundwater under CA experiments, and so develop our capacity as a network to answer questions about these systems on behalf of farmers, their advisors and policymakers.

**Global patterns of nitrate storage in the unsaturated zone**

Our hydrogeologists have quantified the amount of nitrate stored in the unsaturated zone at the global scale for the first time. Water moves slowly through the unsaturated zone and so a large store of nitrate can accumulate if this water contains nitrate derived from surface sources such as fertiliser. Release of this store can affect groundwater quality for decades, which could have a negative impact on public health. It can also continue to be released for a long time after changes in farming practice that reduce nitrate leaching.

By linking mathematical models of nitrate leaching and unsaturated groundwater flow, we calculated that 1.8 billion tonnes of inorganic nitrogen are stored in unsaturated rocks, up to twice the amount stored in soils. The most nitrate is stored in North America, China and Europe, where water tables are deep and there is an extensive history of agricultural fertiliser use. The distribution of unsaturated-zone nitrate storage can give policymakers and decision makers a first global indication of where this store may be significant and where delays in improvements in groundwater quality can be expected.

This research has had a significant socio-economic impact through media coverage, resulting in increased public awareness of groundwater pollution, as well as...
supporting the UK Government’s Environmental Audit Committee inquiry on nitrate.

**Upscape project**
In October, our scientists, together with partners from the Indian Institute of Science and the Ashoka Trust for Research in Ecology and the Environment working on the Upscape project, were joined in the field by the UK Deputy High Commissioner of Bangalore, Dominic McAllister, and his senior advisor on science and innovation, Sunil Kumar.

The Newton–Bhabha (NERC and Ministry of Earth Sciences, India)-funded project is investigating ways to represent the many local water processes within the hydrological models at a river basin scale (‘upscaling’), using the Cauvery River in southern India as a test case. We are using these models to help us understand the cumulative impact of small-scale interventions, such as check dams and groundwater pumping, on the hydrology of this increasingly water-stressed region. The fieldwork involved gathering data to investigate how connected groundwater within the gneiss aquifer is over a range of scales. Various activities were undertaken during the field campaign, including geological field observations, sampling for groundwater chemistry and residence-time indicators (CFCs and $\text{SF}_6$), geophysics and borehole dilution tests.

**Energy and mineral resources**

**EURARE project**
We were project partners in the European Commission FP7-funded EURARE project for the ‘Development of a sustainable exploitation scheme for Europe’s rare earth ore deposits’. This project came to an end in December 2017, following five years of intense research on the rare earth elements (REEs) across Europe. Partners in the project included seven geological surveys, four universities, four mining companies and one aluminium producer, two technology providers, two engineering companies, and three REE end users, thus encompassing the entire value chain of the REE.

The EURARE project included work packages on geological resources, mining and beneficiation, extraction and separation of the REEs, and regulation. We contributed to the geological understanding of REE resources across Europe, and managed the dissemination of the outcomes of the project, including the project website.

Our research within the project included study of REE deposits...
in Turkey and Romania, as well as leading an overview of REE resources across Europe.

Selected important achievements include advances in the beneficiation of rare-earth-bearing minerals (e.g. eudialyte) and selective extraction of REEs from red muds using ionic liquids. Innovative REE separation techniques using ionic liquids and nanotechnologies were developed, and the development of the electro-winning of high-purity REE metal to produce didymium was a major success.

**GEMex: understanding geothermal resources in Mexico**

Mexico is committed to societal improvement and energy reform, and has goals of a 30 per cent reduction in greenhouse gas emissions by the end of the decade, plus 50 per cent of electricity being generated from clean energy sources (including nuclear) by 2050. The active volcanic geology of Mexico results in many geothermal systems and these can be used as renewable sources of power. Whilst many systems can be exploited using ‘conventional’ technologies, some present specific difficulties, especially those related to super-hot conditions (>350°C) and high-temperature engineered geothermal systems. There are shared European and Mexican interests in understanding these systems, resulting in the €20 million GEMex project, which is undertaking detailed studies of the Los Humeros and Acoculco geothermal systems. This allows European and Mexican researchers to work together to address the challenges in understanding such ‘unconventional’ geothermal resources, which will help future clean energy production in Mexico and in Europe.

Our staff are contributing to GEMex in four specific areas:

- monitoring surface gases and waters to track fluid movement and locate fracture zones that reach the surface
- using unmanned aerial vehicle (UAV)-based thermal imaging to identify warm areas where hot fluids reach the surface
- detailed examination of deeply eroded, equivalent ancient systems where analogous
processes to those ongoing in the subsurface can be studied.

- Laboratory experiments to understand how fluid–rock reactions alter fluid-flow properties of the geothermal reservoir.

Urbanisation

Resilient Asian cities: Varanasi, a sense of place

Shortlisted as one of India’s 100 Smart Cities, Varanasi, one of the oldest continually inhabited cities in the world with profound cultural and religious significance, is earmarked for development. Such an ancient city requires sensitivity and, combined with outdated infrastructure, water contamination, flooding, and the sustainability of groundwater resources, presents an opportunity to demonstrate how geoscience can underpin the UN SDGs.

The project combines research on the local geomorphology to characterise sediment supply and river migration over the last 20,000 years to develop an understanding of the aquifer systems below Varanasi. In 2017, the team completed a city-scale borehole drilling programme and supported two PhD students in analysing the river sediment history and water chemistry, and delivered possibly the first 3D model of the geology beneath an Indian city. Ongoing studies in 2018 will tackle issues of clean sanitation and water and involve drilling three deep (>200 m) monitoring water wells to provide time-series (4D) data on aquifer connectivity and the impact of seasonal recharge from the River Ganga.

Climate change

DeepCHALLA project and climate change in equatorial Africa

DeepCHALLA is an international project funded (in the UK) by NERC and the International Continental Scientific Drilling Programme (ICDP). A consortium of scientists drilled over 214 m of sediment from Lake Challa (dating back to around 250,000 years) to understand climate change in equatorial East Africa. The region (three degrees south of the equator, on the eastern flank of Mount Kilimanjaro and directly on the border of Tanzania and Kenya) is subject to two rainy seasons a year, but the length in between these seasons has changed over thousands of years as the Earth changes its orbit of the Sun, and has led to periods of aridity and
drought. In particular, around 110,000–160,000 years ago, it is believed that megadroughts that lasted thousands of years at a time led to the dispersal of our hominin ancestors out of Africa and caused vegetation changes, leading to the high biodiversity of the region today.

This year, UK scientists (including BGS scientists) have been involved in providing novel dating techniques and isotope data from diatoms found in the lake sediments, to determine changes to the hydrological climate and nutrient cycling.

**IODP Expedition 381 — Corinth active rift development**

In October 2017, a team of scientists, drillers and staff from the European Consortium for Ocean Research Drilling Science Operator (ECORD-ESO) took part in International Ocean Drilling Programme (IODP) Expedition 381 to drill the Corinth Rift, Greece. BGS staff were integral in both phases, providing project management, operations management and drilling supervision (offshore), data management, and outreach expertise throughout.

The rift is a unique laboratory situated in one of the most seismically active areas in Europe. The closed drainage system and high sedimentation rates make the main rift an ideal location to examine the relationship between rift development and faulting, and how the landscape responds to those forcing factors. The team used a specialised geotechnical vessel, the *DV Fugro Synergy*, to obtain 1.6 km (500 cores) of material with a recovery rate of 86 per cent. The team cored in three different locations, up to a depth of 750 m below the seabed. Work is now ongoing to fully investigate the records contained within the cores. Other objectives from this highly successful expedition include palaeoclimate reconstruction and analysis of how the landscape responds to both tectonic and climatic forcing.

**IMMeRSS**

In May 2017, our scientists took part in the Interagency Mission for Methane Research at Seafloor Seeps (IMMeRSS) cruise aboard the *RV Hugh R Sharp*. The IMMeRSS cruise was led by the United States Geological Survey and was sponsored by the National Oceanic and Atmospheric Administration and the US Department of Energy. The expedition targeted methane seeps offshore Delaware, Maryland and Virginia at water depths between 400–1500 m. Water-column imaging using multibeam and split-beam techniques was used to survey the locations of known methane plumes, as well as to detect new seeps. A major focus of the expedition was the collection of methane-derived authigenic carbonate samples, which we will analyse to constrain the timing of methane emissions.

Sampling was carried out over the course of five dives using the remotely-operated vehicle
**Global Explorer.** Video footage collected during the dives will be used to track the spatial distribution of bacterial mats and chemosynthetic mussels, which use methane and/or hydrogen sulphide to fuel their metabolism, to reveal the location of recent methane seepage. The resulting data will provide insight into methane sources, gas hydrate reservoir dynamics, and the driving forces of methane emissions.

**ORCHESTRA: Ocean regulation of Climate through Heat and carbon Sequestration and Transport**

We are a major partner in a scientific programme called ORCHESTRA, which has been running for nearly two years. The project aims to improve our ability to understand and predict the role of the Southern Ocean currents to modulate global climate. Our contribution to this research is to analyse the oxygen and carbon isotope composition of waters from the world’s oceans over a five-year period. The carbon data will be used to investigate where carbon is either absorbed by the ocean or expelled into the atmosphere. This is particularly important as the oceans regulate atmospheric carbon dioxide (CO$_2$). The oxygen will help us to track currents and understand where fresh water enters the oceans.

This year we have analysed over 2000 samples as well as preparing staff for participating in three major transects of the world’s oceans: along the 24° south parallel between Rio de Janeiro and Cape Town; a transect between the Falklands and Cape Town via the Weddell Sea, and a transect across the Drake Passage.

**Resilience to natural hazards**

**METEOR: Modelling Exposure Through Earth Observation Routines—Nepal and Tanzania**

We are leading an international project using earth observation (EO) satellite imagery to help increase resilience to natural hazards in ODA countries. The escalating impacts of natural hazards are caused mostly by increasing exposure of populations...
and assets. It is estimated that the world will see the construction of one billion new dwellings by 2050 and this growth may lead to rapid increase in risk.

A major challenge when making disaster risk management (DRM) decisions in ODA counties is poor understanding of the distribution and character of exposure. METEOR makes a step-change by developing rigorous and open routines and standards to allow quantitative assessment of exposure, leading to better-informed DRM decisions. It also provides country-scale flood, landslide and earthquake hazard maps, investigating their interactions and how they impact on exposure. We are also making exposure data openly available for the other 47 least-developed ODA countries.

METEOR is funded by the UK Space Agency and is focused in Nepal and Tanzania, where we are working in close collaboration with the Nepal Society for Earthquake Technology (NSET) and the Disaster Management Department (DMD) of the Prime Minister’s Office in Tanzania.

**Landslides in Sierra Leone**

In August 2017, heavy rain affected the capital city of Sierra Leone, Freetown, and triggered a catastrophic landslide that travelled 6 km through the city to the sea. A national emergency was declared, more than 3000 people were left homeless, hundreds of buildings were buried or completely destroyed and over 1000 fatalities were recorded. We were contacted by the United Nations Institute for Training and Research (UNITAR) and their Operational Satellite Applications Programme (UNOSAT) to provide support and geohazard advice during the emergency situation. The UN Charter on Space and Major Disaster was activated on behalf of the Food and Agricultural Organisation (FAO) Sierra Leone Office to acquire satellite imagery to help understand the situation.

With funding from the Global Geological Risk platform of our ODA programme, we were able to respond quickly to use the satellite data to map the main landslide area and any buildings that were potentially affected, and to identify two additional landslides in the hills above Freetown. We provided advice to UNOPS on the residual landslide hazard, working closely with Arup and World Bank. Our map was made widely available to ensure open access by a range of government and humanitarian agencies. It was presented by the FAO to the coordination meeting of the Office for National Security and to the president of Sierra Leone, and we contributed to the World Bank Disaster and Loss Assessment (DaLA). Following a site visit, analyses of rock and soil samples at the BGS helped to characterise the landslide processes and inform long-term decision making.
Although we are a global geological survey, we continue to work with new technology and data to understand and predict the geological processes that matter to people’s lives and livelihoods here in the UK. Through new understanding and existing research capability, we strive to address the current challenges that face society including using our natural resources responsibly, managing environmental change, and increasing our resilience to environmental hazards.

**UK Geoenergy Observatories**

The UK Geoenergy Observatories project will establish new centres for world-leading research into the subsurface environment. The knowledge they generate will contribute to the responsible development of new energy technologies both in the UK and internationally. The project, commissioned by NERC, follows the Government’s 2014 announcement that it would allocate £31 million to us to create and operate world-class, subsurface-energy research test centres.

Over the last year we have focused on developing the detailed technical plans for the boreholes, science equipment and telemetry that we will deliver at the two field sites in the Clyde Gateway area in Glasgow and Ince Marshes in Cheshire. In addition to the technical plans, we have also developed planning applications for the sites. The planning application for the Clyde Gateway site was submitted in April 2018, and we aim to submit the planning application and environmental impact assessment for the Cheshire site during late summer/autumn 2018.

A key aspect of the UK Geoenergy Observatories team’s work has involved engagement events in the local areas around the two proposed field sites, as well as with the wider science community. Our aim is to have
the field sites operational by the end of the project in mid-2020.

**Groundwater watch list: emerging contaminants**

There is growing concern globally about the occurrence of organic contaminants in the environment, including pharmaceuticals and personal care products. This concern extends to groundwater, which is a critical water resource in Europe and its protection is a priority for the European Commission (EC) and European Union (EU) member states. The difficulty is that for many substances little is known about their toxicity and how they are transformed when they enter the environment. To address European concerns, the EC amended the Groundwater Directive to require member states to work together to establish a ‘groundwater watch list’ of emerging contaminants.

The objective of the list is to gather further monitoring data on selected priority contaminants for which there is currently inadequate information at the European level. We have been supporting UK Government (Defra) as members of the EC’s groundwater watch list working group. This group is finalising a procedure for defining the watch list and this will be submitted to the EC for approval in 2018. If accepted it will contribute to the revisions of the Water Framework Directive, scheduled for 2019.

**Developing new data products**

Our hazard and resilience modelling team (GeoAnalytics & Modelling) have been researching and developing a suite of new data products. The work has culminated this year in the release of three new datasets: coastal vulnerability, GeoSure debris flow susceptibility, and GeoSure shrink–swell 3D London. The data is GB-focused, however, the next steps could be to apply the methods globally, contributing to the UN SDGs such as climate change, innovation and hazard resilience.

The coastal vulnerability dataset indicates multihazards and interdependencies within the coastal zone of Great Britain. We have a diverse coastline of over 11 000 miles and multiple vulnerabilities to erosion, flooding and cliff degradation to name a few. By understanding the geology and geomorphology of these environments, better planning and resilience can be achieved.

The GeoSure debris flow landslide dataset provides information on the potential to form a debris flow. It is based on a combination of geological, hydrogeological and topographical data and is designed for users specifically interested in this type of landslide phenomenon. Debris flows typically occur in upland areas with steep terrain and rock 'debris' that accumulates on
slopes and are often triggered by heavy or prolonged rainfall.

The GeoSure shrink–swell 3D dataset is a regional hazard susceptibility map that identifies areas of potential shrink–swell hazard, in 3D space, at intervals down to 20 m in the London and Thames valley area.

Swelling clays can change volume due to variation in moisture, which can cause ground movements that may affect foundations, pipes or services and can affect anyone involved in the construction of large structures (deep foundations, basements), infrastructure networks (road or rail) or utility companies. The 3D properties of these materials can be used to identify potential problems at surface, in the shallow subsurface or deeper underground (e.g. tunnels).

The new HEX grids are open-data versions of our primary datasets (GeoSure and mining hazard). They utilise new methods of visualisation to convey the regional and national extents of these hazards across Great Britain.

Knowledge exchange and commercialisation
Our GeoAnalytics & Modelling team won Team of the Year at the PraxisUnico Impact Awards 2017. This award recognises excellence in knowledge exchange and commercialisation across the university and research institute sector.

The award was in recognition of the directorate's consistent excellence in adding value to the vast datasets held by the BGS, in addition to building relationships and overcoming challenges. The award recognises the hard work and dedication of our staff to support the UK innovation agenda, thereby encouraging economic growth and improving societal health and wellbeing. The data models and products produced help users make decisions that enable responsible stewardship of the Earth aligned to the SDGs covering topics such as engineering, energy, geohazards, hydrogeology, contamination and agro-geology.

The installation of magnetometers under power lines to measure currents from space weather impacts.
In May 2017, the geomagnetism team kicked off a major new project called 'Space Weather Impacts on Ground-based Systems' (SWIGS). We are leading this £3 million, four-year, NERC-funded consortium of ten institutes.

Space weather describes the conditions in near-Earth space and in the Earth's upper atmosphere, mostly relating to activity on the Sun. Extreme space weather events can be damaging to technology such as satellites, power grids, communication systems, aircraft and railways. The SWIGS project aims to create radical improvements in the understanding and forecasting of space weather impacts on ground-based technological infrastructure through a more thorough understanding of combined solid-earth and space physics processes. Together with project partners, we will develop our understanding of how space weather and geomagnetic activity drives electric fields in the Earth and quantify the impacts of these on the UK power grid, as well as on pipeline and rail networks.

We have begun installing new monitoring equipment to provide more data so that we can better quantify the risk from space weather and validate our computer models of surface electric fields. We are also developing capability to model the impact on pipelines for the first time in the UK.

The installation of magnetometers under power lines to measure currents from space weather impacts.

Exploring rock pools at the Giant's Causeway. ©Tourism Northern Ireland.

**SWIGS: Space Weather Impacts on Ground-based Systems**

Since the creation of UNESCO’s Global Geoparks in 2015, our staff have been instrumental in their development and maintenance throughout the UK. There are currently seven UNESCO Global Geoparks in the UK, each of which has been designated based on their internationally important geological heritage, in addition to their ability to manage this heritage for sustainable tourism, education and conservation. Each geopark also has a role to play in raising awareness of the sustainable use of natural resources, geological hazards and climate change and we work with all the geoparks in the UK to achieve this both nationally and globally.
The UK UNESCO Global Geoparks each make a significant contribution to the local economy through tourism and make a significant positive social and educational impact, augmented by their strong commitment to local community involvement. We also support new UNESCO Global Geoparks in the UK and advise and mentor such areas through the UK National Commission for UNESCO and the UK Committee for UNESCO Global Geoparks. Given our expertise, we also provide advice and guidance to UNESCO Global Geoparks around the world and assist in their establishment and accreditation, with work being carried out this year in Japan, South Korea, mainland China and Hong Kong.

England

Hyporheic zone monitoring in the Skerne catchment

By studying the hyporheic zone (the region beneath and alongside the stream bed where groundwater and surface water mix) we are helping the Environment Agency (EA) to better understand the connectivity between groundwater and surface water, as well as groundwater flow mechanisms, within the Skerne catchment. The research is needed to better protect both groundwater resources and surface water ecosystems.

The River Skerne, in the south-east of County Durham, is underlain by the Wear Magnesian Limestone groundwater body. This groundwater body is classified as being ‘at risk’ from an eastwards-moving plume of mine water, related to the recovery of groundwater levels in the Coal Measures within the Durham coalfield since cessation of mine dewatering in the 1980s. It is estimated that the sulphate-rich plume could reach a number of strategic public water supplies in less than 40 years. The risk posed to the river water quality by sulphate-rich groundwater entering the Skerne is also unknown.

Geophysical tomography

Our geophysical tomography team has successfully completed phases 1 and 2 of an Innovate UK Small Business Research Initiative (SBRI) research and development project, developing innovative solutions to improve non-destructive evaluation (NDE) and material testing capabilities for the British armed forces. The project, which was funded by the Ministry of Defence (MoD) and coordinated by Defence Equipment & Support (DE&S), has evaluated the potential of our capacitive resistivity imaging...
(CRI) technology for military NDE applications.

CRI is a technique used for imaging beneath engineered surfaces in the built environment as well as on dry or frozen ground. It has been used successfully to detect abandoned mine shafts, but it also has great potential for the rapid mapping of soils and permafrost or the non-destructive testing of roads and engineered structures. CRI was developed for geoscience research and this work therefore provides an opportunity for technology transfer from an established field to new applications.

We have developed prototype instrumentation and data interpretation techniques for CRI for nearly 20 years, and we are widely recognised as world leaders in the field. The technique offers unique information that is complementary to other NDE methods.

The SBRI project has developed, tested and validated a new hand-held prototype CRI system with novel NDE capability. The inspection of submarine stealth materials, which are used in coatings that help make submarines less detectable, where conventional NDE techniques have limitations, has been identified as an ideal application for CRI, where the technique holds great promise for providing novel capability to the MoD. We have developed a collaborative relationship with a major UK defence technology company in order to bring CRI technology to market.

Scotland

Clyde soil and water atlas

Our Clyde Urban Superproject (CUSP) was a multidisciplinary catchment-based project that aimed to characterise the geoenvironment of the Clyde basin to aid sustainable planning and development in and around Scotland's major conurbation. One of the key themes of CUSP was to understand the chemical quality of soil and water resources in the region. To address this, our geochemical baseline survey of the environment (G-BASE) carried out extensive field programmes to collect topsoil (0–20 cm) and stream water samples in rural and urban environments across the catchment of the River Clyde.

The results of multiple phases of survey, representing over ten years of work, have been recently launched in two milestone geochemical atlases for the area. These not only show the distribution of key nutrients such as potassium, phosphorus and selenium that are essential for agriculture, but also the impact of the urban environment and past industrial heritage on soil and water quality. This is particularly the case for metal pollutants such as lead and chromium that require ongoing management in the region.

The datasets provide an invaluable statement on the chemical quality of vulnerable soil and water resources for catchment management, urban
planning and environmental protection in this important region of Scotland.

**Scotland’s tsunamis**
The Storegga tsunami that struck the North Atlantic 8200 years ago was from a submarine mega-landslide off Norway. On Shetland the tsunami reached up to 20 m above sea level. Up until recently, this was the only known major tsunami to strike Scotland and based on this, the hazard and risk from these events was considered very small. However, recent work on Shetland now challenges this understanding, because younger tsunamis, dated at 5000 and 1500 years ago, have been found. These tsunamis reached elevations of up to 13 m, so if they happened today, they would be a major hazard.

Evidence for the tsunamis is based on sand deposited as they flooded the land and our scientists have been working onland to map where these are found as part of the NERC-funded Landslide-Tsunami project. We also need to better understand what caused the tsunamis. Earthquakes are the most common cause of tsunamis, but on Shetland earthquakes are too small, so the cause must be a submarine landslide, just like Storegga but much closer.

On present evidence these younger tsunamis only seem to have struck Shetland, so in August 2017, our survey boat, *RSS White Ribbon*, surveyed offshore from where the tsunamis were recorded. Submarine landslides are hard to identify on the data recorded, and no convincing evidence for local landslides was found so there is still uncertainty on where the landslides may be, but the search continues. Our research feeds directly in to the risk and resilience group in the Scottish Government, which is considering adding tsunamis to the risk register.

**Wales**

**Cardiff Urban Geo-Observatory**
Working with our partners at Cardiff Council and the Cardiff Harbour Authority, we have established a city-scale ‘geo-observatory’. The aim of the Cardiff Urban Geo-Observatory is to monitor the underground, providing data that can support the sustainable development and regulation of heat recovery from shallow urban aquifers.

The backbone of the observatory is a network of 60 boreholes instrumented with temperature sensors. Operational for four years, over two million temperature measurements have been made, making this the foremost observatory of its kind in the UK. Work is progressing on an open-access data portal, and
it is hoped that the data, via this site, will be used by developers, planners, regulators, policymakers and others who have an interest in the subsurface.

With partners, we installed a fully operational open-loop ground-source heat system into a local nursery school, which continues to operate successfully. Instrumented with various sensors, data are telemetered directly to key staff via email and text message, allowing a rapid response should operational or regulatory targets be exceeded.

Moving forwards we hope that the Cardiff Urban Geo-Observatory will be an exemplar, and we intend to share knowledge with 14 other pilot cites across Europe, all of whom are investigating how best to manage heat from shallow urban aquifers as part of the GeoERA-MUSE project.

**Bridgend mine water heating scheme**

BGS Wales was involved with a Cardiff University-led feasibility study to assess the potential for heat recovery from abandoned coal mine workings in the village of Caerau, in the Llynfi valley. As one of Wales’s most deprived wards, the project attracted Welsh Government and European Union funding to support the search for a sustainable, low-carbon heating solution.

Following the end of coal mining in south Wales, dewatering operations stopped and water flooded back into the mine workings. It is this water that is being targeted to be used for heat recovery, with the hope that the coalfields can once again provide heat to the communities of Wales.

To measure the heat potential of the mine waters, a borehole was drilled to 230 m depth, intercepting the flooded workings. The measured geothermal gradient exceeded the national average, producing temperatures of about 20°C at 200 m depth, making the mine waters an attractive prospect for heat recovery.

**Northern Ireland**

**Planning and policy development for the Northern Ireland Government**

Our staff at the Geological Survey of Northern Ireland (GSNI) have provided scientific evidence and advice to support the Northern Ireland Department of Infrastructure (Dol) policy...
development on amending the permitted development rights for drilling boreholes for minerals, petroleum and monitoring activities. The evidence and support provided by GSNI helped to improve the DoI’s understanding of the operation and impact of existing permitted development rights and provided up-to-date information on their social, environmental and economic impacts.

Since the restructuring of local government in Northern Ireland in 2015, all of the 11 council areas are responsible for developing a local development plan (LDP) that creates a clear vision as to how each council area should develop. These framework documents support economic and social needs in each area in line with regional strategies and policies, whilst providing for the delivery of sustainable development. GSNI staff have been contributing to this process and helping to shape the LDPs by providing advice and guidance on various economic and environmental issues that are relevant to each council area, including mineral development, groundwater resources and abandoned mine risks. This has been done through the Northern Ireland Department for the Economy, within which the GSNI sits.

New mine risk maps for Northern Ireland
GSNI manages and monitors Northern Ireland’s abandoned mines on behalf of the Department for the Economy (DfE), which owns over 2400 mine workings. In 2017, GSNI started a project to carry out an assessment of the east Tyrone coalfields to inform the DfE of the risk posed by historic mines in the area.

The towns of Dungannon and Coalisland have a 300-year history of coal and fireclay mining and, due to their age, many of the mine records are incomplete or absent. The area contains a high number of mine workings over a small area due to the heavily faulted nature of the underlying bedrock. Using GSNI databases, historic geological field slips, borehole records, mine plans, historical archives and literature, a desktop study was conducted to ascertain the scale of mining and identify areas of high risk. Over 600 known mine shafts were identified, and, using the locations of outcrop and shallow coal seams, GSNI has helped to delimit areas of possible mining activity.

The depths of workings, together with shaft location and proximity to overlying structures and infrastructure, has resulted in
GSNI developing new mining risk maps. These will be used to prioritise further investigative work, enable close monitoring of high-risk areas, and plan for any necessary remedial works that may be required. Apart from informing DfE of the risk associated with the abandoned mines, the new information will be incorporated into the land-use planning process to assist the planning authorities in minimising any risk to new development.

**GSNI 70th anniversary**

In 2017, GSNI celebrated 70 years of public service after opening its first office in Belfast in 1947. The milestone occasion was highlighted during a number of events throughout the year showcasing how GSNI scientists have made a positive impact on Northern Ireland’s economy, infrastructure, environment, tourism, education and health.

All of the events organised were designed to be complementary and with a particular emphasis on the positive partnerships that GSNI has developed over our 70 years of public service. It is these partnerships that have helped GSNI to achieve such a high level of success in a diverse range of sectors.

GSNI has at its heart the need to carry out scientific research for the public good of Northern Ireland. There is still a large focus on providing impartial and independent geoscientific advice for the benefit of the economy, but societal challenges mean that the nature of this work has evolved. GSNI now also has a role to play in contributing to the green economy by searching for alternative energy sources, providing information that helps to monitor the natural environment, contributing to the acquisition of data that helps safeguard both human and animal health, and helping to develop sustainable tourism resources. A lot has changed in 70 years, but this ‘small but perfectly formed’ geological survey continues to develop and adapt to the needs of the citizens of Northern Ireland and will do so for many years to come.
Inside the BGS

The 2017–18 year started with a review of some areas within the overall science structure to ensure it remains fit for purpose and that we are able to continue to successfully deliver the science programmes in the longer term. This resulted in the geology and regional geophysics (GRG) and the land, soil and coast (LSC) directorates being disbanded, with affected staff being reassigned to other directorates to enable a better match of resources to science priorities and bringing activities closer to our partners, users and markets.

Equally, new regional specialist teams known as ‘regional hubs’ were created to provide an enhanced regional response to some strategic geological questions in key areas. Whilst this restructuring process did cause some disruption, staff were generally very positive about the change and demonstrated real commitment and flexibility in working through some of the uncertainty to make the change effective.

In addition to this, 2017–18 was also characterised by the preparations for change in respect of the impending transfer of all BGS staff into UKRI employment ready for the planned transfer date of 1 April 2018.

Other 2017–18 HR highlights

**Recruitment of the BGS Board**

During the last quarter of the 2017–18 year, the BGS was pleased to appoint Sir Keith O’Nions as the BGS Board Chair. Sir Keith subsequently appointed other members of the Board and the first BGS Board meeting was held on 27 April 2018.

**Workforce establishment**

A total of 53 the new staff joined BGS in 2017–18, however, despite this, the BGS headcount did not increase to the planned level of 609 full-time equivalent (FTE) (approximately 672 headcount) in 2017–18. This was due to a higher level of leavers than anticipated (25 resignations in total) plus delays in recruiting into approved posts.

An estimated forecast for the headcount in 2018–19 is 621 FTE (approximately 684 headcount).
This is based on recruiting into the planned posts carried over from 2017–18 as well as a small number of anticipated new posts in 2018–19. Following this, it is expected that headcount will stabilise, although this is subject to any changes arising from a refresh of the science strategy planned for later in 2018–19.

Implementation of the BGS apprenticeship strategy
The BGS made great progress in implementing its apprentice strategy and taking account of the government public sector apprenticeship target. We had nine apprentice new starters against a target of ten.

Re-accreditation of the Investors in People (IiP) Award
The BGS underwent a re-accreditation assessment against a new IiP standard and was proud to achieve a Silver Level award.

Provision of an enhanced leadership development offering
The BGS made further progress in aligning its development activities to better support talent management and succession planning. A 'development interventions grid' and a 'talent conversations guide' were published to provide support and guidance in identifying the right development tools to support an individual’s career development.

Simplification of line-management arrangements
A review of line-management arrangements was carried out across the BGS, aimed at achieving an improved flow of communication through the organisation and improved targeting of development in people management, as well as to improving the management of change. This resulted in a reduction in the number of managers and a move towards three layers of management.

Improved HR analytics
Through the development of local databases and tracking systems, improvements have been made in the provision of management information to monitor people-management processes. This has enabled a more detailed review of recruitment activities, which has highlighted positive progress in 2017 compared to 2016 relating to an increase in the proportion of women applying for BGS roles, being shortlisted and offered appointments. Similarly an increased disclosure rate relating to individuals declaring their ethnicity is showing an increase in the proportion of black, Asian and minority ethnic (BAME) staff.

Looking forward, key areas of focus in 2018–19 will be to continue to review people practices to ensure the creation of a fair and inclusive working environment as well as working with managers to help align staff structures with the science and business strategy, ensuring all BGS colleagues are supported in their roles enabling them to deliver to their full potential.

Estates
The last year has once again been a busy one for the Estates team as we continue to work with both the Executive and senior management to ensure that the BGS estate continues to provide facilities in line with the developing science that the organisation undertakes.

We continue to operate out of the following sites:
- Keyworth, Nottingham (HQ)
- Lyell Centre, Edinburgh
- Cardiff
- Belfast
- London
- Wallingford
- Hartland
- Herstmonceux
- Eskdalemuir
- East Kilbride
During 2017–18, the Estates team completed project works in excess of £2 million. The works were all designed to improve safety, security, compliance or building integrity and included the following tasks.

**Keyworth**
- installation of lightning protection
- roof works to the Library, PPFPL, gatehouse and HV/LV switch room
- fire safety upgrades to detection and doors to ensure compliance with current regulation
- replacement CCTV
- replacement door access system
- flooding and sewage sump pump works

**Eskdalemuir**
- re-wiring of listed building
- upgrades to security and access control systems
- refurbishment of listed building
- demolition of redundant non-listed building

**Hartland**
- works to remove and replace asbestos floor tiles

Our business assurance team achieved successful transition to both the new ISO9001 and ISO14001 standards, ensuring that the organisation is able to continue providing assurances regarding both quality and its commitment to the environment.

The team also put in place many of the systems required in order to allow the BGS to apply for certification under the new ISO45001 standard. The standard was ratified on 12 March 2018 and the BGS completed its initial audit shortly thereafter. If achieved, the BGS would be the first organisation in UKRI to do so.

Looking forward, the organisation will remain challenged as there is a need for significant investment in the portfolio over the next twenty years, much of this at the Keyworth site. Estates will continue to work with the Executive to look at the required development of the Keyworth site, particularly in relation to the laboratory facilities and the National Geological Repository, which is now nearing capacity. The Estates team will, in the meantime, continue to ensure the BGS portfolio remains well managed, compliant, safe and fit for purpose.

**Finance**

The financial year was a successful one; we brought in external funding of £18.9 million and generated a surplus of £900,000, which we have carried forward. During 2017–18, we received £22.45 million from NERC to fund our public science role and as a contribution towards infrastructure.

The NERC allocation, taken together with the competitively won NERC funding (£4.4 million), accounted for approximately 51 per cent of the non-capital funding (including IODP funding of £6.5 million). There has started to be a redirection of the funding from NERC towards major initiatives such as the UK Geoenergy Observatories project and ODA.

We earned approximately 49 per cent (£25.4 million) of non-capital budget from external sources. Research commissioned by customers through externally funded projects accounted for £14.6 million in addition to the IODP programme. Externally won projects enhanced the science programme through funding, ideas, data and review and made a vital contribution towards infrastructure. In 2017–18 this income included revenue from various sources including £4.7 million from Government departments, £8.3 million from foreign, public and private sectors and £1.6 million from European funding. There was also £4.3 million from non-project sources, primarily royalties and licence fees (£3 million).

NERC also provided capital funding of £10.3 million including £6.3 million towards the UK Geoenergy Observatories. The Department for Business, Energy & Industrial Strategy (BEIS) provided ring-fenced funding for this project.