

BUILDING ON GEOLOGICAL MODELS – THE VISION OF AN ENVIRONMENTAL MODELLING PLATFORM

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1. INTRODUCTION AND BACKGROUND

Geological Survey Organisations (GSOs) were originally founded to produce an inventory of the earth's resources to inform governments and support construction and primary industries. Therefore, their initial emphasis was on finding construction material, metalliferous minerals and hydrocarbons. Throughout the 20th century the focus shifted towards aggregates, water and more recently to environmental concerns such as waste, reuse of post-industrial contaminated land, climate change and biodiversity.

Although the external drivers for their existence have changed, the fundamental purpose has not, and this is unlikely to change in the future. Price (1992) summarises the mission of a GSO to “maintain the national geoscience knowledgebase” in order to “ensure the availability of the geoscience information and expertise to promote the wise use of the nation's natural resources and the safety, health and well being of its people” However as many countries move towards knowledge and service driven economies faced with global environmental challenges, GSOs of the 21st century will have to continue to evolve, adapt and in particular change the ways they operate. This is especially true against a background of rapidly advancing geospatial technology.

The GSO's agenda must be to confirm themselves as the natural custodians of the subsurface, not focussed on one particular industry or science area, but assisting governments, industry and the general public to manage the subsurface in an integrated, holistic and sustainable manner. They must then engage with other organisation to link the understanding of the subsurface with the wider environment, to understand the interaction of the subsurface with the atmosphere, biosphere and hydrosphere (see Figure 1) Last but not least they have a duty to make their knowledge and information accessible and understandable to the people on behalf of whom the governments act and to whom they are accountable.

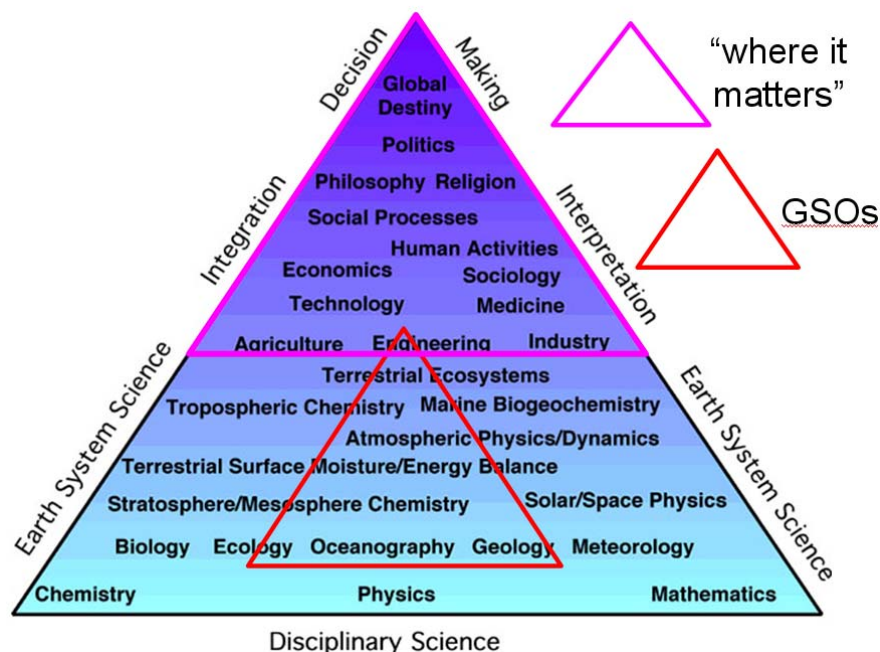


Figure 1 The footprint of GSOs in Whole Earth System Science, modified from Ruzek (2009)

Taking the British Geological Survey (BGS) as an example, this paper will outline the next stage in the evolution of a GSO, which will see the opening up of their information and the transdisciplinary integration of their geological, groundwater and other geoscience models within the wider “modelling” community including the social and economic disciplines. A main part of this mission is the development and deployment of an open Environmental Modelling Platform (EMP) providing ready access to data and knowledge as well as geospatial, conceptual and numerical models through a subsurface management system akin to Geographic Information Systems in use today.

The urgency of this task as well as the size of the cultural and technical challenges that need to be accomplished demand the close co-operation of GSOs amongst themselves as well as strong collaboration with partners in science, industry and government.

2. THE ENVIRONMENTAL CHALLENGES AHEAD

Reports by Stern (2006) and the IPCC (2007) have identified the need for urgent action to tackle the causes of climatic and environmental change. Importantly, they emphasise the need to plan for the mitigation of their impacts, and the importance of preparing society to adapt to the consequences of these changes.

Although predictive modelling of atmospheric and marine systems is key to test the understanding of the causes of climate change, the most direct impacts of any change (whether human or natural in cause) will be felt onshore. Earth sciences will play a major role in adapting to these impacts and responding to challenges including:

- The ability of to provide clean and affordable drinking water and water for industrial use from ground or surface water
- Managing the risks of flooding from the sea, rivers, rainfall run-off and groundwater
- The safe disposal, containment and potential re-use of anthropogenic waste products
- Prediction of ground conditions for major infrastructure projects (transport, housing, utilities)
- The mitigation of physical hazard such as landslides, subsidence, earthquakes and tsunamis
- The conservation of land to maintain food production as well as protecting biodiversity
- The sustainable management of ground sourced heating and cooling

These challenges can only be met if solutions are based on sound scientific evidence. Although we have knowledge and understanding of many individual processes in the natural sciences it is clear that a single science discipline working in isolation is not able to answer these questions or understand their inter-relationships. For example, models of the carbon cycle largely ignore the presence of deep terrestrial carbon and hydrological models rarely deal with groundwater in an adequate way.

3. THE BGS STRATEGY

In its current 5 year strategy (British Geological Survey, 2009) the BGS recognises the need to share its data, models and knowledge with the wider science community in order to contribute adequately to resolving the questions set out above. Furthermore, the strategy document states that ‘BGS will develop a more holistic focus on modelling and the prediction of environmental change and its impacts’; effectively moving the survey’s primary activities from mapping and archiving increasingly towards modelling and forecasting to support decision making (see Fig. 2).

The scientific and organisational challenges to deliver this mission are detailed as follows:

1. acquire, interpret and enhance the UK geoscience knowledge base and make it accessible and interoperable
2. improve the communication of geoscience knowledge so that it can better support policy and decision-making by government and society
3. enhance external partnerships to improve the quality, reach and impact of our science
4. apply a whole-systems approach to our science and improve understanding of the nature and sustainable use of natural resources and the potential impact of hazards
5. understand, quantify and predict the response of the Earth’s ‘zone of human interaction’ to future environmental change
6. increase the economic impact and relevance of our work

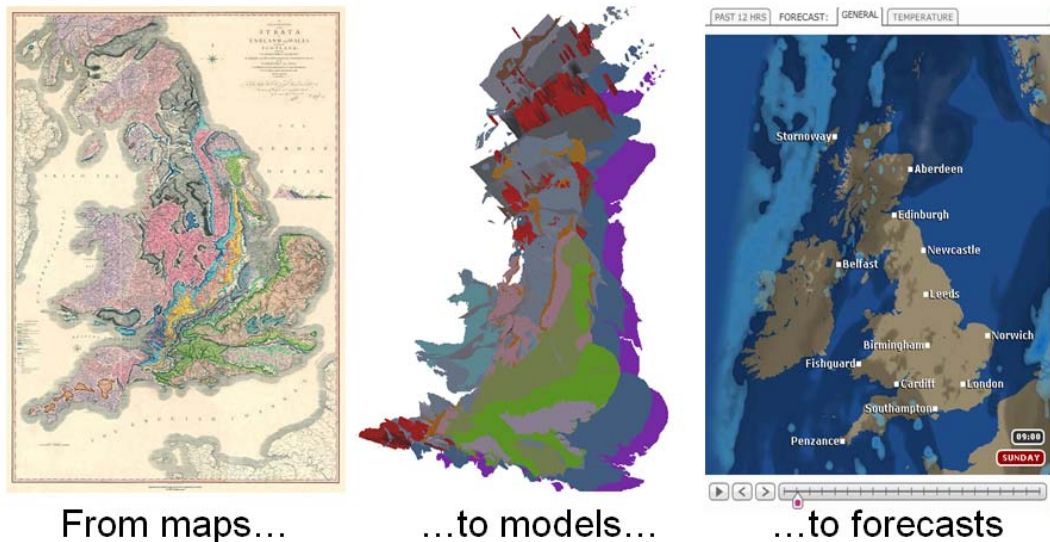


Figure 2 The evolution of a Geological Survey Organisation, including a screenshot of the BBC's weather forecast, © BBC (2009)

A corner stone in delivering the BGS strategy is the development of an open Environmental Modelling Platform (EMP) to provide a data architecture and applications environment that supports the generation and coupling of spatial and process models.

The BGS has established a portfolio of test bed projects including the Thames Basin and Glasgow and Clyde Basin cross-cutting projects to support the development of the EMP. Each of these projects will provide the EMP with real-world data and models together with the key environmental questions affecting each region (see Campbell, 2007; Ford 2008). The aim of the EMP is to facilitate the transdisciplinary integration of this information with socio-economic and wider environmental models to generate predictive responses to these questions. The test bed projects will establish proof of concept for the EMP, and lead to the development of generic and extensible methodologies and systems to deploy the EMP throughout the BGS and make it operational across its territory.

3. THE ENVIRONMENTAL MODELLING PLATFORM

GSOs increasingly employ advances in Information Technology to better visualise and understand natural systems. Instead of 2 dimensional paper maps and reports, many GSOs now produce 3 dimensional geological framework models and groundwater flow models as their standard output (see Figure 3). Additionally, standard routines are emerging to link geological data to groundwater models (Kessler 2007, Hughes 2008)), but still these models are only aimed at solving one specific part of the earth's system, e.g. the flow of groundwater to an abstraction borehole or the availability of water for irrigation. Although the outputs are often impressive in terms of accuracy and visualisation, they are inherently limited in the extent to which they can be used to simulate the response to feedbacks from other models of the earth system, in particular the impact of human actions.

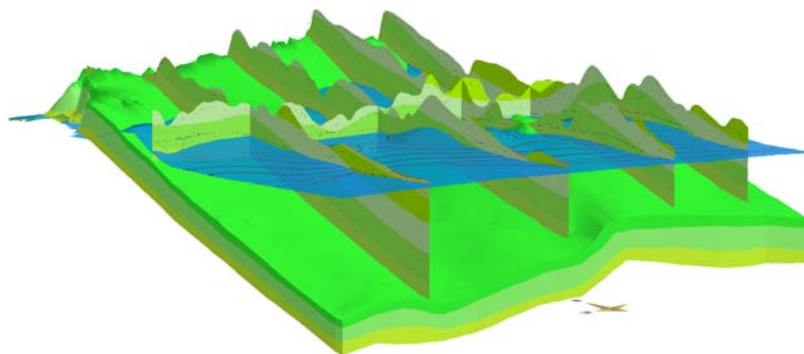


Figure 3 Integrated geological and groundwater models in an area around Brighton, UK (from Hadlow et al 2008)

At the heart of the EMP stands the vision to provide the data standards and applications seamlessly to link data models concepts and numerical simulations concerned with the surface and subsurface (see Figure 4). Furthermore these geoscience models also need to link to socio-economic models such as population growth, urban growth scenarios or commodity prices.

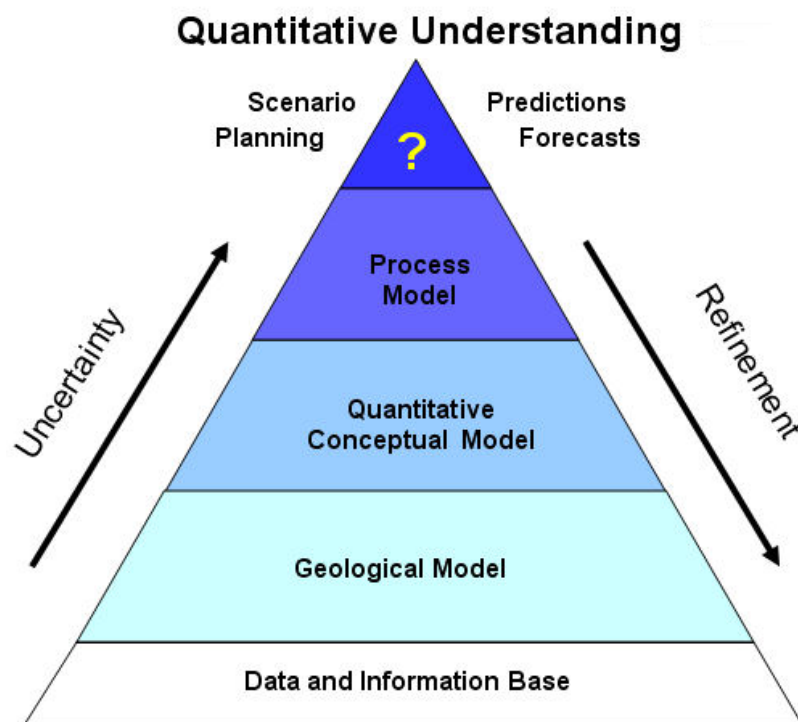


Figure 4 Schematic diagram showing the interrelationships between models and data (modified from Sharp et al 2002)

Problems with linking models arise where data from models from one discipline are incompatible with the other either in terms of the data format or the scientific concepts and language. The Geological and Hydroscience communities have begun to develop common languages and software standards to overcome these barriers. Two examples of initiatives that are beginning to change the way we interact between science disciplines are OpenMI (Open Model Integration Environment) and GeoSciML (Geoscience Mark-up Language). OpenMI provides a standard interface, which allows models to exchange data with each other and databases on a time step by time step basis as they run. It thus facilitates the modelling of process interactions. The models may come from different developers, represent processes from different domains, be based on different concepts and have different spatial and temporal resolutions (OpenMI 2009). GeoSciML aims to agree a common conceptual data model on the nature and structure of the geoscience information, to which data held in individual databases can be mapped and consequently transferred between applications and users (GeoSciML 2009).

An additional hurdle that needs to be overcome is that the fragmentation of institutions responsible for the monitoring and protection of the environment, and in particular the subsurface, combined with impediments due to copyright restrictions and ownership of data, have together made the strategic and integrated management of the subsurface a virtual impossibility.

4. The need for a Subsurface Management System

As discussed, the subsurface is used intensively for a variety of purposes. Historically, human interaction with the subsurface has been limited to the exploitation of resources on which construction and industry depend, such as metals, industrial minerals, building materials and groundwater. Traditional thematic geological maps and GIS systems suited the need of these individual themes. However, economic development driven by population growth has placed greater demands on the subsurface, including the need to accommodate utilities and telecommunications infrastructure: vital elements of the emerging information economies. Competition for available space will continue to increase in response to the demand for geothermal energy, the need for storage of waste (including CO₂) and ongoing construction of road, rail and sewerage infrastructure. The subsurface is an integral part of the economic system, and its increasingly complex use suggests that a more coordinated

approach to its regulation and management is essential, and should be coupled with that of the surface. To provide a basis for the sustainable management of the subsurface, a 3D and 4D understanding of the ground, its existing subsurface installations, land use history and suitability for future use is critical

Current practice in the management of the subsurface is far from this ideal. Most subsurface interventions are preceded by feasibility studies, predictive modelling or investigations intended to mitigate risks or predict the impacts of the work. However, the complex interactions between the anthropogenic structures and natural processes mean that a holistic impact assessment is often not achievable. A fundamental pre-condition for integrated spatial, volumetric and temporal planning in the subsurface is knowledge of the distribution of existing infrastructure in the context of the geological succession and its properties. Increasingly, this information is expressed in three dimensional geological framework models which allow the full complexity of the subsurface to be analysed and predictions made concerning the movement of liquids, gases and heat and their interaction with buried infrastructure and any planned intervention in the subsurface.

Key to the delivery of the results from the EMP to planners, regulators and other decision makers is to make the results visible in the context of the real world. There is an identifiable need for a comprehensive 4 dimensional subsurface management system forming the basis for spatial, volumetric and temporal decision making in the subsurface in the same way as today's GIS systems are used for spatial planning, insurance risk assessment or emergency planning. It is vital that this system is not developed in isolation from real end-users and also that the system is able to deal with the wide variety of subsurface models that exist in the GSOs across the world. Systems that fulfil parts of this strategy are emerging at several GSOs and examples from the Geological Survey of the Netherlands and the British Geological Survey are shown in Figures 5 and 6. The former shows the dissemination of subsurface data and models via the TNO DinoLOKET website, the second shows the integrated visualisation of tunnels and buildings with the geological model.

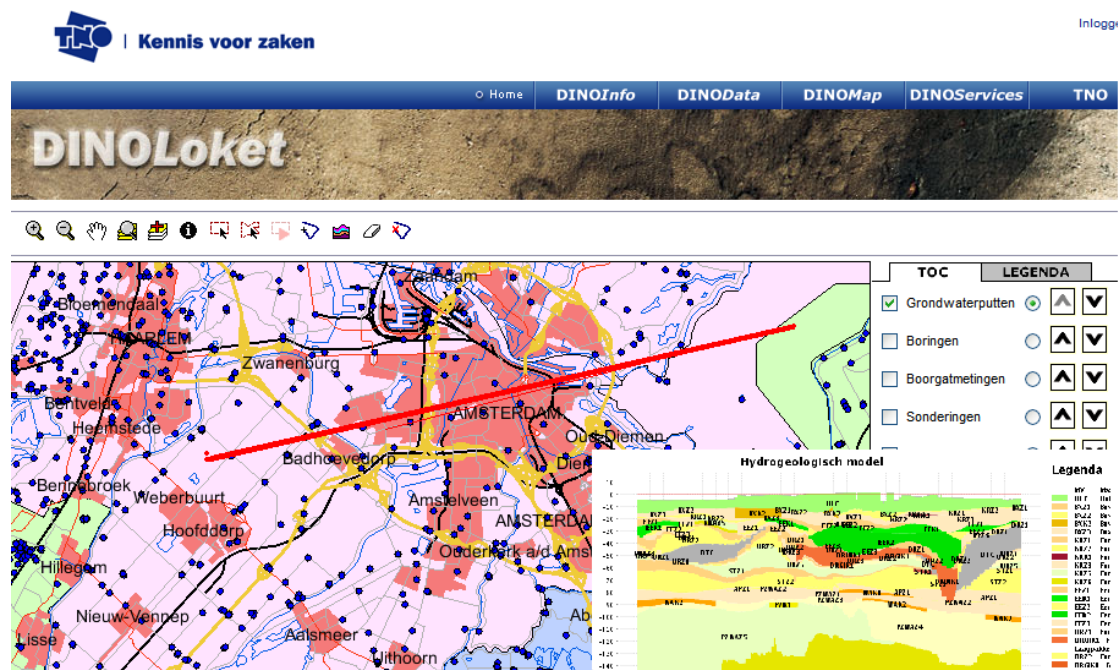


Figure 5 A hydrogeological section through Amsterdam, Netherlands, using the TNO's DINOLOKET web service, TNO (2009)

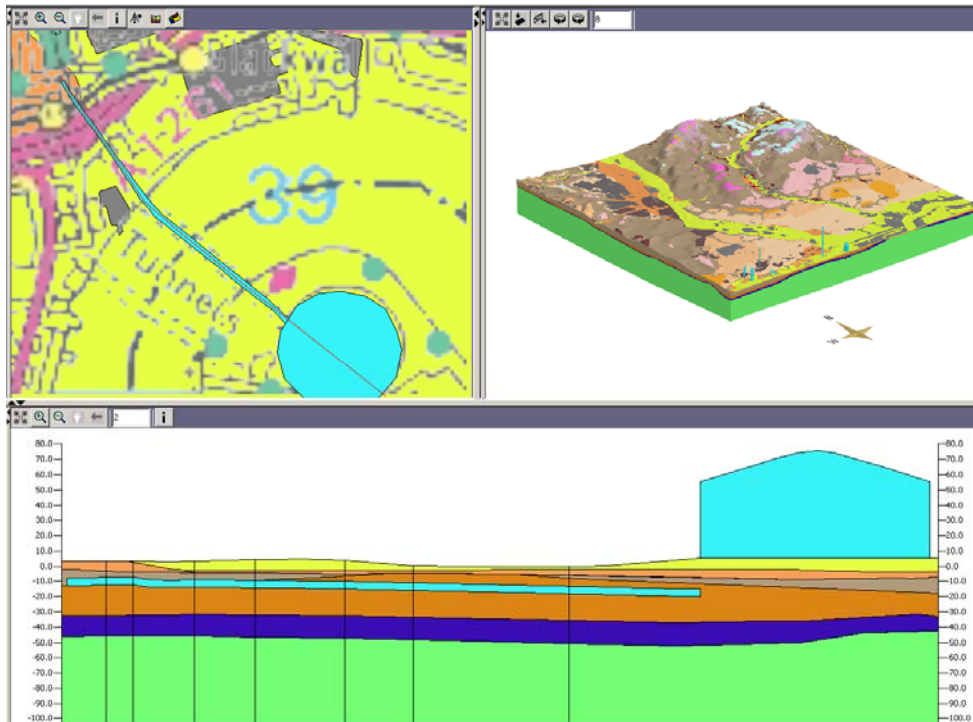


Figure 6. A map and cross-sectional view of the Blackwall Tunnel and Millenium Dome, London displayed in the Subsurface Viewer (Terrington et al, 2009)

5. Conclusions

Attributed geological and groundwater models are means to an end, not an end in themselves. They are more parts of a jigsaw of data and models needed by decision makers to respond to the pressing human and environmental questions in today's changing world. Geological Survey Organisations, as the custodians of strategic Earth Science knowledge and information, have to rise to the challenge and leave their traditional comfort zone to interact with the wider science and user community to link up their data and knowledge with others and provide the outcomes in a form that can be used readily by decision makers.

Most importantly, the need for international cooperation between GSOs is crucial whether it is through workshops, joint projects or collaborations using the Internet. As Jackson (2009 this edition) indicates the geology may be different in each corner of the world, but the global challenges we face as well as the core functions of GSOs are the same in Bangladesh as in the Netherlands. Only if we engage with each other and align our knowledge and resources can we create the momentum needed to build the Environmental Modelling Platform.

As Price (1992) concludes in his paper on the future role of GSOs: "The potential role for national geological surveys is very large, the actual future role will depend ... on the leadership displayed by national geological surveys both individually and collectively."

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