Grounds for success

If you had to name the vital conditions for Olympic success, geological expertise probably wouldn't be near the top of the list. But the London games couldn't have happened without it. Kate Royse and colleagues from the British Geological Survey (BGS) explain why.

The 500-acre Olympic Park sits in the Lower Lea Valley in London's East End. Construction work has had to overcome problems like high groundwater levels, compressible soils – which threaten foundations and underground constructions – and contamination from pollutants like oil, petrol, tar, arsenic and lead, which pose serious risks to water supplies and ultimately human health if left untreated.

In fact, all the major development projects that have been carried out in the run-up to the 2012 Olympics have involved construction on ground that engineers class as 'difficult'.

The Institution of Civil Engineers estimates that about half of all cost and time overruns on civil engineering projects are caused by 'unforeseen ground conditions'. This is partly because too little is understood of 3D geology – of the ground's physical, mechanical and chemical properties, and the processes acting on it.

Traditionally, geological information has been displayed in two dimensions – as maps supported by cross-sections. Digital advances have allowed the routine use of Geographic Information Systems (GIS), which let us display and query an unlimited range of spatial data. In this project, we have used 3D-modelling software to produce high-resolution geological models of the shallow subsurface.

The 3D models then had geotechnical and hydrogeological data added. They could then be used to predict not only the type of rocks and how they vary both vertically and laterally, but also the variation in their engineering properties – such as rock strength, shrink-swell characteristics and compressibility – and hydrological characteristics like how easily water passes through the ground. Finally, we combined our high-resolution 3D geological models with spatial data within a GIS in order to develop 'intelligent' map layers and systems that support planners by clarifying the consequences of different choices.

Below are just three examples of how all our work can help developers.

3D models of the shallow subsurface

Modelling the shallow subsurface can help predict potentially difficult engineering ground conditions by assessing the thickness, geometry and distribution of different types of rock (geological units). A full assessment of ground conditions using available borehole or trial pit data can be used to help understand the nature of the ground before development starts.

Each unit can be characterised in terms of the kinds of rock it contains and the layers it is made up of, as well as being attributed with a variety of information about properties such as strength, permeability and compressibility. 3D models in urban areas, such as the Lower Lea Valley, include information on the thickness and distribution of artificial ground – places where humans have changed the ground level, often by adding new material from elsewhere, and where there's consequently now a higher risk of contamination and instability than elsewhere. This can be linked to the history of how the land has been used, letting us fully understand changes in the ground surface as a result of human activity.

We can then use the 3D model to estimate the thickness of these deposits, giving the developer an indication of the cost of remedial measures at the beginning of the planning process. It can also help plan the ground-investigation phase which will ultimately result in significant savings of time and resources, as difficult ground conditions can be anticipated and planned for.

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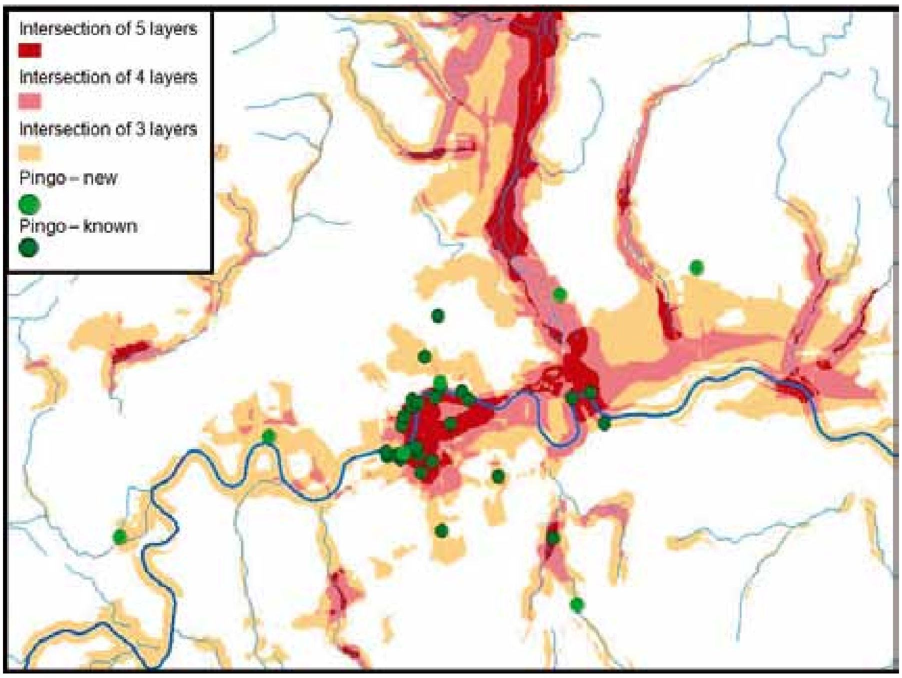
Screening for potential groundwater hazards

Each period of industrial development has left its own contamination in urban areas. Regulators and planners need to know where these contaminants are, and assess the risk of them being be released into ground and surface waters by redevelopment. Contaminated areas are generally identified first through a detailed desk study and then by focused field investigation, which can be time-consuming and expensive.

With this in mind, BGS developed an initial screening tool to help the planning community gauge potential contamination risks more quickly and effectively. The prototype for developing this tool was the Olympic Park site.

Our tool uses GIS layers that have been integrated with the results of our 3D geological model, and brings together a range of geoscientific information, including data on geology, hydrogeology, rivers, flood potential, source protection zones (areas which provide groundwater for public consumption, such as around wells or springs), the sources and sizes of potential contaminants, and groundwater levels.

The tool evaluates the source of possible pollution and the pathways (flooding, for example) that might move it to an area where it could affect people or the environment. We can then rank various proposed development scenarios according to our assessment of their potential to cause contamination, providing planners with a report on the spatial distribution of potential contaminant sources in their area, and the hazards associated with each.



Hazard susceptibility map for drift-filled hollows in London.

Finding drift-filled hollows

A drift-filled hollow is a depression in the bedrock which has been filled with a mixture of unconsolidated materials like sands and gravel. The variability of these deposits, and the difficulty of predicting where they will occur, cause problems for engineers. These include foundations settling into the ground at varying rates in different parts of the building and instability in excavations and tunnels. The hollows can also form pathways for contaminants to travel into our groundwater supplies.

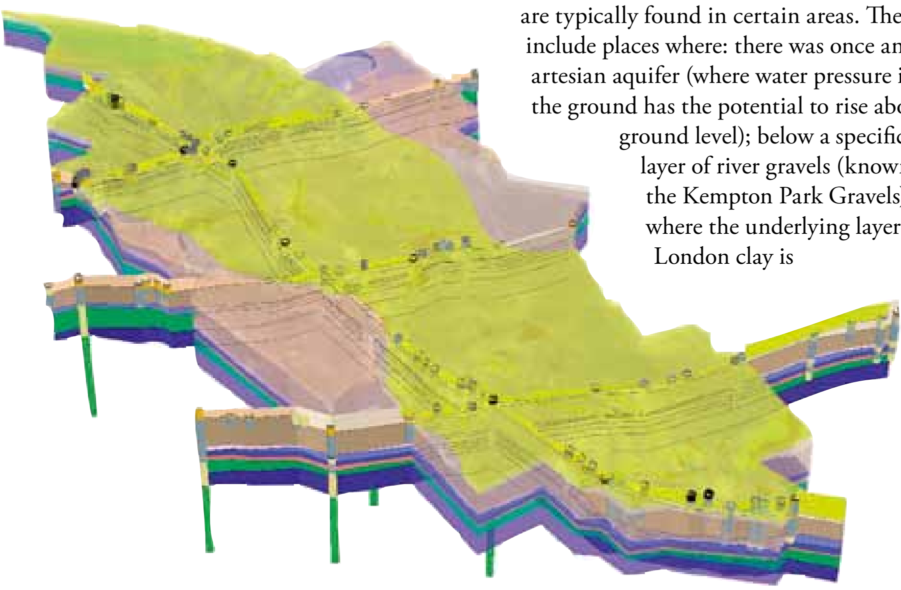
Over the years, 31 of them have been revealed by development in London. In London and the Lower Lea Valley they are primarily found beneath the First River Terrace Deposit. At Blackwall, a drift-filled hollow was found which was over 60m deep and 475m wide.

Their location is difficult to predict, but it has been shown that drift-filled hollows are typically found in certain areas. These include places where: there was once an artesian aquifer (where water pressure in the ground has the potential to rise above ground level); below a specific layer of river gravels (known as the Kempton Park Gravels); where the underlying layer of London clay is less than 35m thick; within 300m of existing or former rivers; and near geological faults.

We have used our 2D and 3D data within a GIS to create a map of areas of greater likelihood of drift-filled hollows. This gives planners a broader awareness of the potential location of difficult ground conditions associated with these features, presents information that can be used to reduce the potential for unforeseen ground conditions through effective site investigation, and improves our understanding of how drift-filled hollows are formed.

3D geological property modelling does not only allow geoscientists to present data in a more meaningful way to non-specialists. It is also a valuable scientific tool. In the long term, 3D geological models will give us a better understanding of the zone of human influence.

It is clear that the scientific community needs to understand and be able to predict the effect that large-scale developments will have on the environment. Only the continued development of 3D models and the integration of currently separate geological disciplines will eventually allow us to answer these questions. ■



3D geological model of the Lower Lea Valley, London.

MORE INFORMATION

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