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Accessible 3-D geoscientific spatial data to INSPIRE Scotland's planners, developers and regulators

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The INSPIRE Directive (2007/2/EC of the European Parliament and of the Council and in force from the 15th May 2007) establishes an infrastructure for spatial information in the European Community. By facilitating the availability and access of spatial (geographic) information, best use can be made of the data for the benefit of a wide variety of users in different sectors and disciplines. Planning and development in Scotland bring together such a broad mix of users of spatial data. Therefore, the INSPIRE Directive has a key role to play in promoting improvements to spatial data infrastructures on which the efficiency and effectiveness of the planning process and successful and sustainable development depend. As a result, the Scottish economy will benefit, and especially the construction sector (which accounted for 6.6% of GDP in 2004, with a £12 billion turnover (www.scotland.gov.uk/Publications/2006/12/19143801/0)), as will society as a whole.

Many ambitious urban and waterfront regeneration projects are either planned or are already underway in Scotland, with timescales running into decades, and overall budgets in billions of pounds, In the Glasgow area, local and national Government and private developers are investing heavily in areas prioritised for new housing, retail, industry and other infrastructure. These include for example the Clyde Waterfront, and the Clyde Gateway redevelopment area (budget of c. £1.6 billion) in the east of the city (Figure 1). However, although there are potentially many large and vacant brown field sites available for re-development, most can only be used in a successful and sustainable fashion if environmental issues stemming from their past uses are understood and overcome. For example, undermining is widespread, many sites are contaminated, and there is a need to provide sustainable drainage, prevent flooding, and consider potential sea level rise. These and many other environmental issues are geoscientific, and fundamentally 3-dimensional (3-D) in nature. To address them effectively, and so make best use of Scotland's available land, it is essential for Scotland's planners, developers (and their consultants, engineers and contractors), regulators, and local communities, to have ready access to, and to share relevant and reliable 3-D geoscience spatial data. Given the wide range of backgrounds and experiences of the potential end users of the data, they must also be in forms that can be widely understood, readily used, and integrated with other datasets.

In parallel with, and in support of, the many regeneration projects in Scotland, a new legislative framework has been enacted; *The Planning etc (Scotland) Act 2006*. This is intended to modernise the planning system, increase its efficiency, accelerate decision-making, promote greater community involvement, and contribute to sustainable development. However, legislation alone cannot guarantee such improvements. For example, the Scottish Chambers of Commerce (SCC, 17 February 2006), based on a survey in which 25% of construction firms cited planning delays as an impediment to growth of their business, identified a need to change <u>all</u> aspects of the planning culture if intended benefits of the Act are to be fully realised and potential barriers to economic development lowered. Improved access to, and sharing of relevant geoscience spatial data, in line with the INSPIRE Directive must surely have an important role to play. Large datasets are currently held by the British Geological Survey (BGS). However, some are confidential and are not generally available. Other major datasets are held by a range of other public bodies, and private organisations, and are variously accessible. Therefore, planning and development decisions are currently being made on the basis of limited access to the total of geoscience data potentially available in Scotland. Inevitably uncertainty and risk in developing projects is greater than necessary, ground investigation is less efficient, project designs are likely to be more conservative and so more costly, and delays and resultant claims due to 'unforeseen ground conditions' are more likely. All have cost implications that affect development and the Scottish economy.

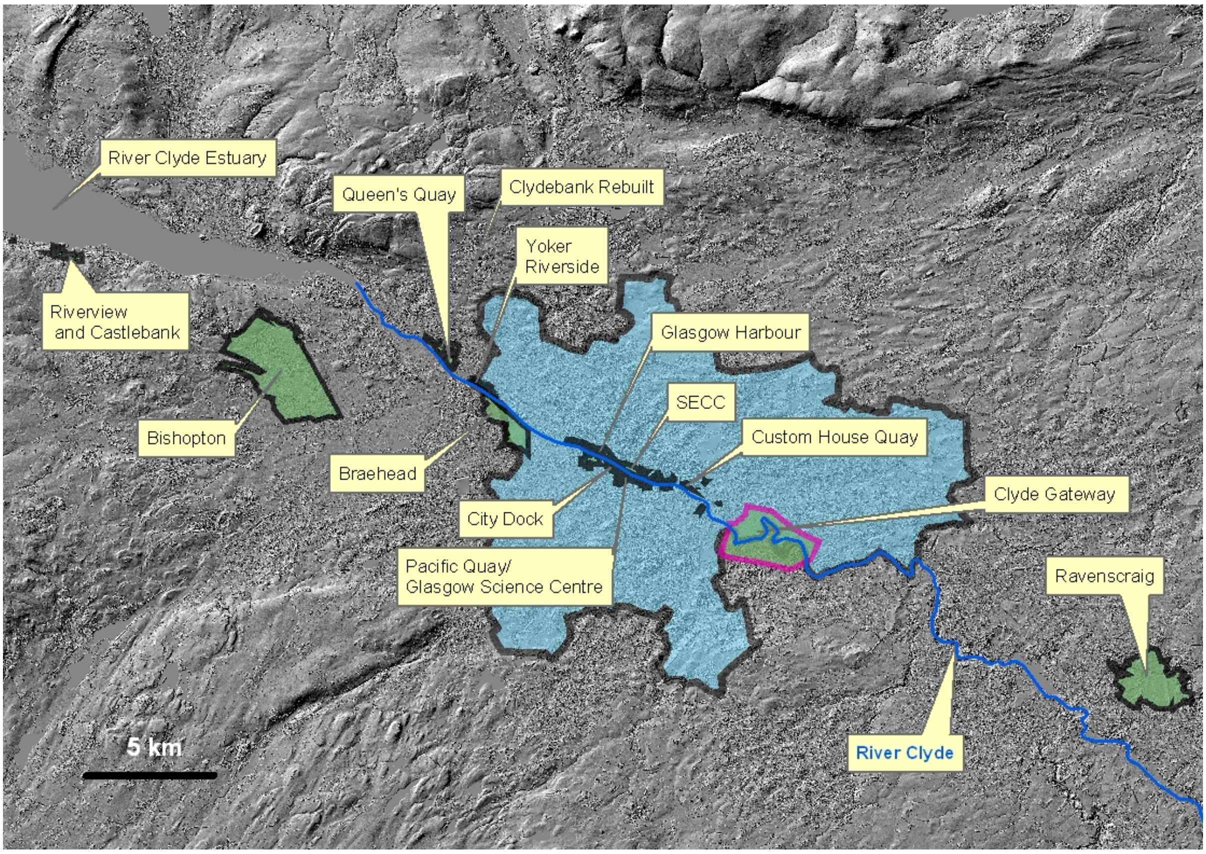

Figure 1. The lower Clyde Valley showing the City of Glasgow boundary, the Clyde Gateway area of development and regeneration and other notable development sites; elevation data taken from Intermap Technologies' NEXTMap Britain Data.

Traditionally, geological maps, supplemented by historical borehole records, mine plans and publications such as geological sheet memoirs have encapsulated geoscience knowledge. However, they are demanding documents to use, and the subsurface world they represent is hard to visualise without expertise. Their potential economic benefits, in helping to optimise development footprints, minimise mitigation costs, and reduce cost-over-runs due to unforeseen ground conditions, are often not fully realised. Thematic geological maps, which break down and simplify geological maps into their component parts, and present other key geoscience data, have been produced by BGS specifically for planners and developers since the 1980s (Browne et al, 1986, Ellison and Smith, 1999). They have proved more user-friendly than traditional geological maps, and consequently more fit-for-purpose. However, they still require significant knowledge to use effectively. 3-D digital geological models provide a contemporary, highly visual, interactive, and potentially much more efficient and cost-effective solution for transferring geological knowledge, and geoscience spatial data.

The British Geological Survey has embarked on a programme to make geoscience spatial data more readily available in Scotland in various digital forms that fully exploit its capabilities in:

- capturing and organising spatial geoscience data; sharing data and acquiring it in AGS(Association of Geotechnical and Geoenvironmental Specialists) digital format;
- modelling soil and rock data in 3-D (using bespoke GSI3D (©Insight GmbH), and GoCAD™ software) with metadata, and quantified uncertainty;

- attributing the models (with engineering geological geotechnical, geochemical and hydrogeological properties), identifying key geological faults, and the extents of past mining and quarrying,
- integrating disparate data sets to gain insights into environmental issues (using GIS and in-house conversion tools, e.g. ZOOMQ3D), identifying hazards and analysing risk (e.g. mining-related; surface-to-groundwater pollution), and
- delivering 3-D data in readily understandable forms which can be easily updated; using web-based portals, GIS, and BGS's in-house 3-D subsurface viewer. The viewer allows the user to generate synthetic boreholes and sections from the model, and the removal of successive modelled layers.

The scanning and digitisation of geological maps and borehole records held in BGS's national archives have paved the way for development of digital products that address the evolving requirements of planners and developers for geoscience data (Culshaw 2005).

Delivery of 3-D models

The Clyde valley, and Glasgow in particular, is the initial focus for delivery in Scotland, but the ultimate vision is for national coverage, at appropriate scales. The BGS has taken a similar approach to sustainable land development through modelling projects in areas of urban regeneration elsewhere in the UK, including the Manchester to Liverpool corridor in the NW of England, and London and the Thames Gateway in the SE of England.

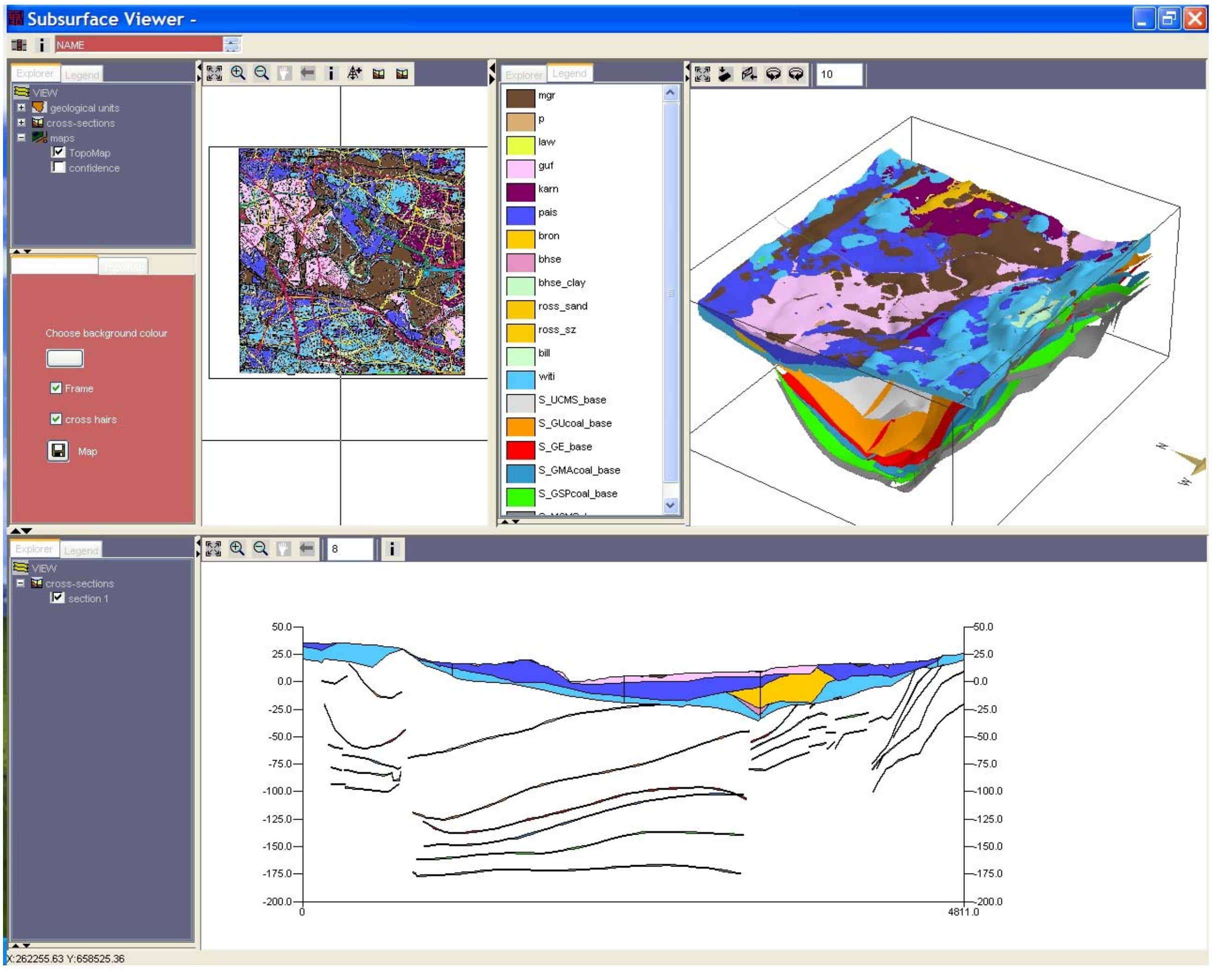

Figure 2. GSI3D Subsurface Viewer interface showing 2D map window, 3D model window and cross-section window. Borehole viewer window not shown. The model can be used to generate virtual cross-section and boreholes that are useful in predicting ground conditions for site investigations and planning.

Regional scale (1: 10 000 – 1: 50 000) detailed models, which focus on characterising the near-surface superficial deposits and shallow bedrock (less than 200m depth) (Kessler et al. 2005), are of most use in urban planning and development. BGS is producing a first generation of regional scale digital 3-D attributed geological models of the Glasgow area (Merritt et al. 2006), and will extend these across the river catchment and estuary of the Clyde. These models synthesise the available digital data from boreholes, geological maps, mine plans and terrain models.

A 3-D geological model (for a 25 km^2 area) including superficial deposits and key coal seams has already been supplied by BGS under an evaluatory license to Glasgow City Council (GCC) in the Subsurface Viewer (Figure 2) for use in planning the redevelopment of the Clyde Gateway area in eastern Glasgow. Further models are under preparation in a partnership between BGS and GCC.

The 3-D models are then able to illustrate and interpret:

- the distribution and thickness of superficial deposits and artificial ground
- variations in the complex bedrock geology, including major fault locations and displacements, and the extent and depth of known and probable past mine workings, and
- geotechnical, geochemical, hydrological and geophysical properties

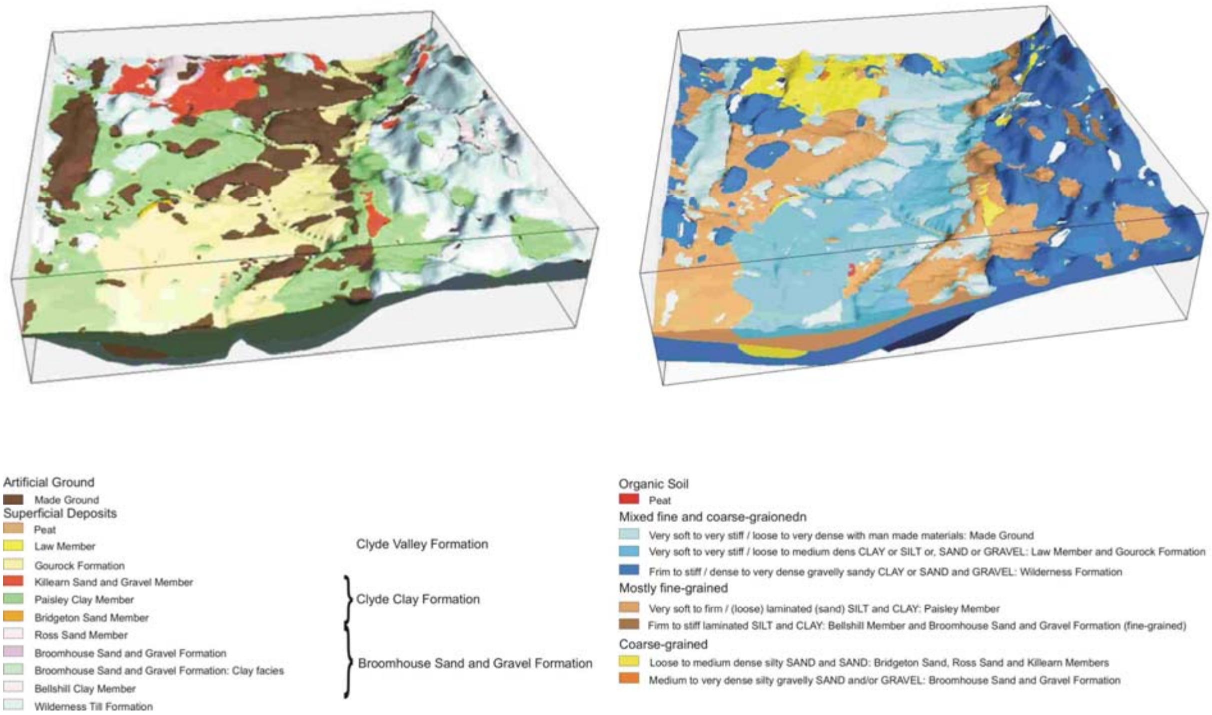

Figure 3. GSI3D attributed geological model for central Glasgow coloured up by lithostratigraphy (left) and geotechnical properties (right).

The units in the 3-D (GSI3D) models can be individually attributed with typical physical properties characteristics (Figure 3). Synthetic boreholes and synthetic cross sections can then be generated from the variously attributed 3-D models, and attributions with respect to variations in depth below ground surface (Figure 4), or any other modelled surface e.g. water surfaces, can be displayed, to assist with the selection of foundation types etc.. The models, if used for example for planning a site investigation, can subsequently be revised with the addition of new site investigation data to develop the local scale (<10 000) ground model of the site.

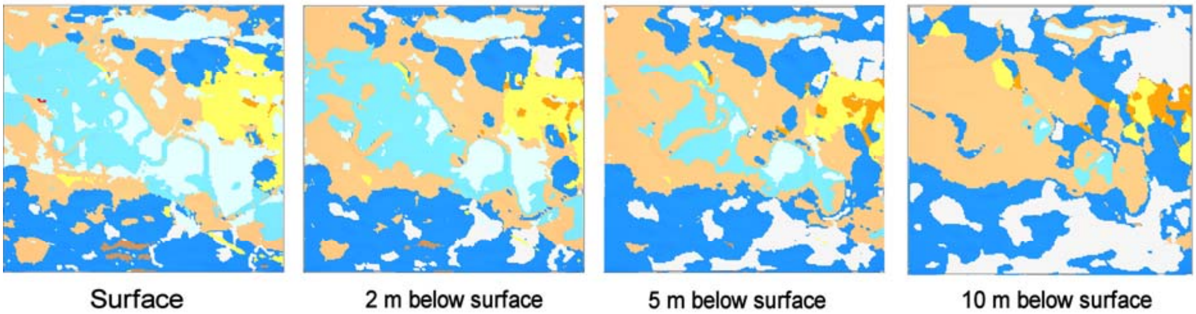

Figure 4. Horizontal depth slices of the Glasgow model (attributed for engineering geology classification) can be used to predict foundation conditions at depth.

Data sources and access

In urban areas, most geoscience spatial data come from site investigation boreholes. Some deeper mineral and water boreholes are deposited with BGS under statutory requirements. Otherwise, BGS's archive depends on private and public sector donations. BGS currently holds 35,000 borehole records from Glasgow alone, but coverage is uneven and these are only a minority of all boreholes. Furthermore, many of these records are restricted by confidentiality (c.40% of records in central and western Glasgow, c.29% of 250,000 borehole records for Scotland as a whole) at the request of the original data owners. Other parties, most notably Glasgow City Council (GCC), also hold large numbers of borehole records. GCC have already contributed many borehole and other site investigation records for which they are the owners to the BGS archive, including many in the geotechnical industry standard AGS digital format, which greatly facilitates the process of transfer. However, they hold many others for which they are not the primary owners. As such, they have not previously been able to make these available to third parties. Recently, however, GCC has been proactive in seeking the approval of the data owners to declassify many of these records for third-party access. Following an extensive consultation exercise, including advertisements in the press, they have succeeded in gaining overwhelming support from the data owners to make them available. This suggests that there is a groundswell in favour of data sharing that should be capitalised on for mutual benefit.

It is hoped, therefore, that others in the public and private sectors (public authorities, Government agencies, private consultants and contractors, clients, developers, and individuals) will follow GCC's good example in line with the impetus provided by the INSPIRE Directive. As a result, the use of the spatial data they collectively, but at present separately, hold, can be maximised to meet, not only their own direct needs, but also those in various sectors and disciplines across the wider community.

As the various data are held by many organisations in a variety of media (although new data are increasingly being captured in AGS format) and in disparate locations, the ultimate vision is to facilitate, using appropriate technology and standards, more general government-industry-public partnership to share borehole and other data for mutual benefit through a web-based portal similar to that which BGS successfully operates for offshore data owners (DEAL). Such a public-enabled GIS would be a definitive database of metadata and single repository for UK spatial geoscience data relevant to land use in the public domain. It would allow users to access comprehensive data via 2-D map–based, and 3-D model-based interfaces over the internet, and directly download from a website.

Applications and potential benefits of the models

The 3D models and related GIS layers are the keys in Glasgow to:

- influencing planners and developers in key decision making
- identifying and investigating problematic ground conditions and so improving ground models,
- optimising developers' site investigation budgets and providing a context for site-specific modelling and development,
- researching environmental issues (as covered by the Environmental Assessment (Scotland) Act 2005 etc.), such as the migration of surface contaminants into the groundwater system, (e.g. in line with the EU Water Framework Directive (2000/60/EC) etc.),
- finding ways to mitigate hazards (such as from past undermining and the migration of surface contaminants into the groundwater system), and so encouraging innovative solutions for sustainable urban drainage, flood prevention, aquifer protection, and pollution
- ensuring that the land is redeveloped in a safe and sustainable fashion for the long-term benefit of the community
- integrating geodiversity with biodiversity and archaeology as issues to consider in planning and development

Ground models and unforeseen (problematic) ground conditions

In any major building project, the vast majority of risk is held in the ground works portion of the project (Chan and Kumaraswamy, 2002). Unforeseen ground conditions are especially costly in terms of the significant delays they cause. Some 25-50% of all construction projects in the UK suffer delays of more than one month as a result of unforeseen ground conditions according to the Institution of Civil Engineers (ICE, 1993) and other surveys by the National Economic Development Office, the Public Accounts Committee and the Transport and Road Research Laboratory, UK (Architects Journal); almost all building projects on redeveloped sites appear to meet such conditions. Similar results are reported from elsewhere (Halligan et al., 1987; Creedy, 2006 etc.), and unforeseen ground conditions constitute one of the largest, if not the largest, sources of post-construction claims (e.g. Halligan et al., 1987), accounting for up to 50% of total cost overruns of projects. However, unforeseen ground conditions are not necessarily unforeseeable, if greater use can be made of the geoscience knowledge and data already available, and there is improved understanding of those data. There is considerable scope, with improved access to existing data, to substantially reduce the extent to which 'unforeseen ground conditions' are encountered during construction, with consequent benefits in terms of cost and delivery.

Development of a ground model that represents the ground conditions lying at and beneath the surface of a site, requires an initial desk study based on existing spatial geoscience data, and the acquisition of further data from ground investigation. Typically, this is the role of consultants and contractors, working on behalf of developers, which may include public bodies. With better initial knowledge of a site, better informed planning of subsequent ground investigation, which typically accounts for 1-5% of the whole project value (www.ags.org.uk/aboutus/AGSreponseNigelGriffiths.pdf) (e.g. in the case of Clyde Gateway this could represent up to £80 million) should follow, as should a reduction in the extent to which unforeseen and problematic ground conditions are encountered during construction. Better initial knowledge of a site depends not only on greater accessibility to all existing and potentially relevant data from the site and its near surrounds, but also on cumulative knowledge of the context of the site, based on broader interpretation. The latter is generally beyond the scope and resources of all but the largest projects, but with increasing availability of attributed 3-D geological models, could become generally available to projects.
This is important because geological problems are best understood on the scale at which they operate, for example, in the case of surface water, in terms of the surface catchment,

and equally in the case of groundwater behaviour within natural confines, typically delimited by the distribution, internal geometry and physical properties of superficial deposits, and similarly of the underlying bedrock. These models are therefore potentially powerful predictive tools and time saving assets, as they assimilate large amounts of urban geodata in one easy-to-use package. Although, they must not be regarded as a substitute for detailed site investigation, they can be expected to help to make best use of available budgets and to reduce uncertainty in ground models to acceptable levels.

Conclusions

The tangible economic and societal benefits of a more efficient and effective planning process are at the heart of recent 2006 legislation in Scotland. Making key geoscience data more accessible to, and more readily understandable by planners, developers and the public, will help to realise these aims. In particular, increased access to all relevant data, through data declassification and web-based integration, and improved presentation of data in attributed 3-D models and GIS, will enable their greater use. This is especially important during the early stages of project planning when the data are of greatest potential economic benefit, and most likely to ensure that the land is redeveloped in a safe and sustainable fashion for the long-term benefit of the community. Collation of further types of data such as mine grouting records and the nature of the recycled materials imported for land raise in projects should also be encouraged.

Acknowledgements

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