MAPPING UNDERGROUND ASSETS IN THE UK

Project Iceberg: Work Package 1 – Market Research into Current State of Play and Global Case Studies

Prepared by Future Cities Catapult in collaboration with the British Geological Survey (BGS) and Ordnance Survey (OS) as part of the Project Iceberg

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EXECUTIVE SUMMARY

Project Iceberg is an exploratory project undertaken by Future Cities Catapult, British Geological Survey (BGS) and Ordnance Survey (OS). The project aims to address the serious issue of the lack of information about the ground beneath our cities and the un-coordinated way in which the subsurface space is managed.

Difficulties relating to data capture and sharing of information about subsurface features are well understood by some sectors and have been explored in previous research and industry reports, many of which are highlighted in this report. This study does not replicate past work, but rather reviews outcomes and explores the barriers to wider uptake of subsurface management systems within integrated city management.

The long-term goal is to help increase the viability of land for development and de-risk future investment through better management of subsurface data. To help achieve this, our study aims to enable a means to discover and access relevant data about the ground's physical condition and assets housed within it, in a way that is suitable for modern, data driven decision-making processes.

The project considers both physical infrastructure i.e. underground utilities and natural ground conditions i.e. geological data and is divided into three different work packages:

- **Work Package 1:** Market research and analysis
- **Work Package 2:** Data operation systems and interoperability for a subsurface data platform
- **Work Package 3:** Identification of use cases for a subsurface data platform

This report summarises the findings of work package 1 and identifies the following key findings and recommendations.

KEY FINDINGS

- There is substantial potential for commercialisation of data tools and data services using an integrated surface-subsurface data platform, which would support, for example, urban planning, redevelopment, infrastructure assessments and street works. Realising the full benefit of these opportunities relies on the sharing of data beyond statutory undertakers, albeit with suitable controls in place. Statutory undertakers do not necessarily have the national overview, capability or remit to develop an integrated platform.
- Stakeholders acknowledge that incomplete subsurface information means that land value is not being protected or worse, is being diminished and that organisations are incurring

indirect costs due to project delays and requirements for additional surveys. However, the direct costs of obtaining subsurface data and the indirect costs incurred because of incomplete access to subsurface data is largely unknown.

- Amendments to existing and introduction of new data standards (PAS 128 and PAS 256) make provision for more consistent and accurate data capture of buried utilities. Sharing of more accurate utility data will be facilitated and links to building information models and smart city standards will be more explicit. However, currently, storage of data and the integrity of data stores is not being addressed consistently at national level.
- There is a currently a lack of national standard that addresses commercial sensitivities and security risks concerning subsurface data sharing that can potentially guide "the right people getting access to the right and comprehensive set of data, at the right time without fear that parts of it have been redacted or manipulated"
- Investment in research and innovation to support the development of tools to identify the location of buried infrastructure has been successful and new systems are being brought to the market that will enable more accurate mapping of underground infrastructure.
- Precedents have been set for the sharing of underground utility data of national importance – exemplar projects, such as the VAULT and Greater Manchester Open Data Infrastructure Map (GMODIN), demonstrate successful collaboration across the utility sector to generate an integrated utility infrastructure map. Meanwhile adoption of AGS data formats by the ground investigation community has led to large-scale sharing of geotechnical data. National scale sharing of buried utility data has only been demonstrated in Scotland, largely driven by nationalised utilities. Upscaling of exemplar projects across the UK needs prioritising.

RECOMMENDATIONS

- The National Infrastructure Commission, Infrastructure Projects Authority and Digital Built Britain should take leadership of the development of an integrated data framework that combines surface and subsurface data. Future legislation and standards may be required to ensure the accurate and standardised capture and supply of buried infrastructure data.
- The benefits and business opportunities that may be delivered through an integrated data framework that embeds subsurface data are not sufficiently highlighted to stakeholders. Thus, the incentives and business drivers to collaborate on a subsurface data platform need to be better illustrated. Project Iceberg WP3 goes some way to addressing this but further work is needed.

Introduction

Project Iceberg is an exploratory project being undertaken by Future Cities Catapult, British Geological Survey (BGS) and Ordnance Survey (OS), with objectives to paint a picture of the subsurface – what is there, who holds data about it, who accesses it and how an integrated data platform that embeds subsurface data (that is BIM-ready) could drive radical efficiencies in workflow.

The project aims to build a holistic picture and market analysis of the current way in which the subsurface and its data is currently accessed and to outline the technical, legal and financial features of a digital platform that links surface and subsurface data. The project aims to make a robust case for change, providing stakeholders with an early indication of the 'preferred way forward' (not the preferred option).

The subsurface is an incredibly complex environment upon which the society places an increasing set of needs, such as holding significant utility assets, infrastructure assets and buildings. We are also increasingly reliant on the ground for its environmental functions, for example, flood control, waste storage and extraction of natural resources. The difficulties relating to capturing and sharing data about subsurface features are well understood having been explored in projects such as the National Underground Assets Group (NUAG) and Assessing the Underworld, and through the Association of Geotechnical and Geoenvironmental Specialists (AGS) and the ASK (Accessing Subsurface Knowledge) network.

Mounting pressures of affordable housing, infrastructure management and environment protection place significant pressure on the finite land resource. Late stage awareness of ground properties and physical constraints to planned development is costly – ground risks are one of main causes of project delay and of insurance claims on completed projects[xxvi]. Meanwhile, according to TfL, road works account for 38% of the most serious and severe traffic disruptions across London at a total cost of £752 million[xxvii].

Our long-term goal is to help increase the viability of land for development and de-risk investment through better management of subsurface data. To help achieve this, our study aims to enable a means to discover and access relevant data about the ground's physical condition and assets housed within it, in a way that is suitable for modern, data driven decision-making processes.

PROJECT SCOPE & ACTIVITIES

This study does not try to replicate past work, but to review outcomes and explore the barriers to benefits not being disseminated more widely. Given the multi-disciplinary nature of land and asset management, this review covers a spectrum of sectors, there area however a number of shared aims that inform the project scope:

- Optimisation of asset performance, maintenance and resilience,
- Effective planning and utilisation of subsurface space to support multiple functions,
- Regulatory oversight via a shared single version of the truth (giving improved transparency, accountability and governance).

The scope of this project is not limited to subsurface utility infrastructure but also includes subsurface ground property data obtained from ground investigations.

The project has been carried out in three different work packages:

Work Package 1: Market research and analysis through extensive desktop research, online survey of sector experts, followed by interviews with selected experts. This report summarises the outcome of Work Package 1 activities, broadly, divided into three work streams:

- o Understanding the current state of play in the UK
- o Reviewing previous projects relevant to Iceberg
- o Assessing international project case studies with similar objectives as that of Iceberg

The primary aim of the review of current and past projects, which either have similar objectives as that of Project Iceberg or are complementary to it, is to understand the key learnings from them and to identify any potential collaborations and, to avoid replication of activities, and to capitalise on the key outcomes and learning from these projects.

Work Package 2: Aimed at evaluating the level of interoperability of the data standards and operating system for an integrated data platform.

Work Package 3: Identified potential use case applications of an integrated data platform that embeds subsurface data.

PROJECT TEAM

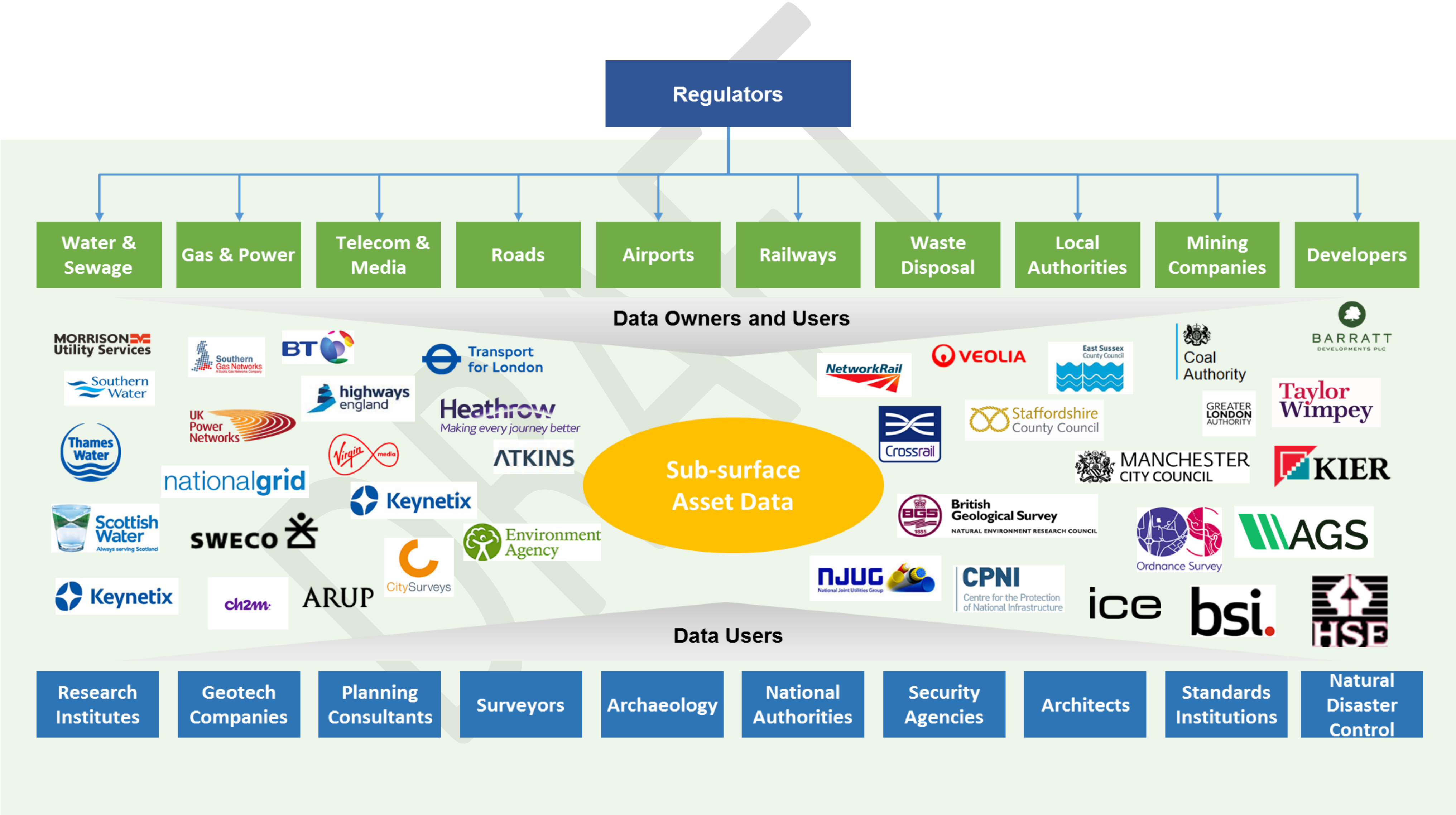
British Geological Survey (BGS): UK's provider of geoscientific data, information and knowledge and custodian of the UK's national geological data archives. BGS' remit includes geo-science research to support sustainable and resilient cities and development of technology for the digital transfer of subsurface geological data (e.g. to BIM) and 3D geological modelling systems.

Future Cities Catapult: Government's urban innovation agency, with a mission to advance innovation, to grow UK companies, to make cities better. For this project, we leveraged our Strategy, Markets & Standards (SMS) and Creative Design Services (CDS) teams to paint a picture of the sub surface and assess the current state of play, in the UK and globally.

Ordnance Survey (OS): Great Britain's national mapping agency. It carries out the official surveying of GB, providing the most accurate and up-to-date geographic data, relied on by government, business and individuals.

Photo BGS © NERC 2017

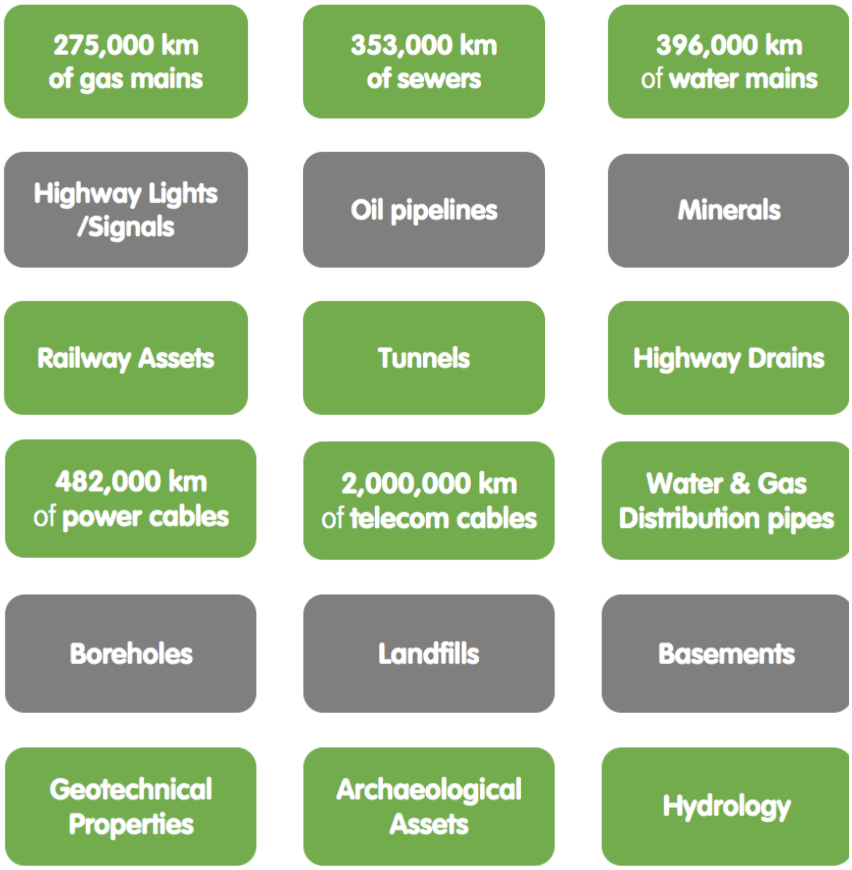
1. THE UNDERGROUND ECOSYSTEM



1.1 INTRODUCTION

'KNOWLEDGE OF THE SUBSURFACE IS KEY TO DELIVERING SUCCESSFUL CONSTRUCTION & REGENERATION PROJECTS.'

Underground assets, such as water, sewerage, electricity, gas or communications infrastructure, constitute the foundation of a country's infrastructure. The combined network of water, sewer, gas and electricity services in the UK extends over 1.5 million km and the data line network is estimated at over 4 million km.[i] Along with the diverse set of data on ground and underground properties, data pertaining to these assets, such as their location, depth, functionality and age, offer opportunities that can help address a range of challenges faced in spatial planning, congestion reduction and asset management.



SUBSURFACE ASSETS

As several research studies highlight, unavailable, inadequate or poor quality of underground data results in damages, strikes and

"THIRD PARTY DAMAGE TO UTILITY ASSETS COSTS £150 MILLION PER ANNUM, WHILE INDIRECT COSTS ARE ESTIMATED TO BE 10X OF THIS"

accidents during earth excavation leading to high repair and replacement costs, in addition to associated social and environmental costs.

c. 4 million
Holes dug per year

c. £5.5 bn
Annual Cost of Street works

c. 6 million
Man hours of road disruption

c. 12 deaths and 600 serious injuries due to strikes

c. 150 million[1]
third party damage to utility assets per annum

1) 2005 figures; Industry believes that current costs would significantly exceed this figure
Source: GLA; ARUP; McKinsey, 2016; University of Nottingham, 2006; Geovation; Mayor of London, 2013; GLA, 2016; DigDat; Zeiss, 2014; UK Water Industry Research

As per estimates made in 2005, third party damage to utility assets costs c. £150 million per annum, while indirect costs were estimated to be 10 times this; Current damage costs are expected to be significantly higher. The Centre for Economics and Business Research estimates the total economy-wide costs imposed by congestion across UK is forecast to rise by 63% from $20.5 bn (£16.6 bn) in 2013 to $33.4 bn (£27.0 bn) by 2030. Of this total, the Department for Transport (DfT) estimates that street works account for an estimated cost of £4.3 bn each year.

Lack of integrated subsurface data exchange system and siloed approach across the different sectors results in:

- **Slow information gathering and sharing:** Utilities respond to interactions on a request by request basis, internally validating locations, checking records and responding accordingly.
- **Frequent repetition of information gathering and sharing** for new works programmes.
- **Strikes due to incomplete view of the subsurface** – little coordination between underground data owners resulting in damages during excavation.
- **Variable data quality and lack of standardised data capture formats.**
- **No or little data on abandoned and old assets.**
- **Inadequate processes and protocols** for collaborative information management.
- **No central 'digital map'** showing the physical location and

characteristics of underground assets.

- **Difficult to get cross-electoral boundary asset data** to help see the wider contexts of utility networks.
- **Slow and hindered data sharing** across stakeholders.

Continued urban growth, demand for resources, increased city resilience and future sustainability concerns will lead to increased pressures and reliance on subsurface space, facilities and services.

To best harness these opportunities, accurate, comprehensive and reliable subsurface data is of paramount significance as subsurface investigations are essential for virtually all civil, mining and infrastructure projects. This data is necessary for the verification and design of foundations, slopes, retaining walls, tunnels, roads, rail and more. Access to this information is crucial for remediating potentially hazardous underground materials to preserve our environment.

“

Quite a lot of potential outputs simply cannot be made without the correct (subsurface) information

Geoscientist and Team Lead (Survey Respondent)

2. CURRENT STATE OF PLAY

"THE DIRECT COST OF OBTAINING SUBSURFACE DATA AND THE INDIRECT COSTS INCURRED DUE TO INCOMPLETE SUBSURFACE DATA IS LARGELY UNKNOWN. FURTHER ECONOMIC ASSESSMENT OF SUBSURFACE DATA IS NEEDED."

2.1 EXPERT INSIGHTS

A wide range of stakeholders are engaged in activities that aim to better understand the subsurface ground conditions and the buried infrastructure contained within in it. As part of Project Iceberg's market research, several stakeholders, working within the planning, utilities, mapping and research sectors, were interviewed and invited to take part in a survey. The detailed survey results can be found in the Appendix section of this report.

The aim of the market research was to capture information about existing investment and capability and enable experts to share learning and offer insights on this topic. All those that took part in the survey are either owners of subsurface data or users of third-party subsurface data.

Key insights from the survey are highlighted below:

- While the **exact costs of acquiring subsurface data have not yet been quantified or were unknown to survey respondents, they are deemed to be quite high by some of the respondents** as they usually require in-house experts, external consultants and liaisons with data owners for a comprehensive view of the subsurface.
- Two-thirds of stakeholders say that their organisation **incurs indirect costs** as a result of incomplete information about the subsurface.
- The two major impacts of incomplete subsurface information are **delays to projects** and the need for **additional surveys.**
- Around half of the responses quoted positional accuracy for their buried asset **locations measured at metre scale** – highlighting the low level of accuracy currently in place across asset owners.
- Respondents also mentioned the **continued use of traditional GIS - data transfer from (normally) 'quite poor databases'.**
- **With 75% of respondents using own and third-party subsurface data,** the need for a more efficient, data exchange framework is more apparent.
- Lack of subsurface information means that the **land value is not**

being realised. For example, developers will avoid land where there is high uncertainty on risks or costs.

- **Wide customer base** for the datasets exists and some organisations are realising the commercial opportunities of subsurface data products and services already.
- The existing subsurface **datasets** are **highly variable** in terms of coverage, accuracy, format, scales which limits accessibility and usability.
- One of the main barriers to sharing subsurface data relate to **security for data of national importance**; Other perceived barriers include intellectual property rights for data of commercial interest, lack of awareness of the benefits that subsurface data brings, lack of demand within utility sector for subsurface data services and a lack of time and resources to invest in resolving the issues.
- Despite the barriers, **two-thirds** of respondents would like to see a subsurface data exchange platform and increasing open access to data.
- The data exchange **system needs a geospatial interface**; GIS/Web formats are preferred with open and closed functionality; 3D/4D elements need to be considered; Open to commercialisation of services/products.

2.2 REGULATORY LANDSCAPE

The existing regulations guiding the recording, sharing and maintenance of underground asset data largely fall under two sets of regulations:

I. **The amended New Roads and Street Works Act 1991** (Section 79) requires all undertakers in the UK to record the location of every item of apparatus belonging to them as soon as is reasonably practicable after:

- Placing it in the street or altering its position
- Locating it in the street during executing any other works
- Being informed of its location

The records should state the nature of the apparatus and (if known) whether it is in use for the time being.

Section 79 also mandates the records to be kept up to date and making them available for inspection, free of charge, by other statutory undertakers.

"DEVELOPERS CHANGE THEIR MINDS ABOUT DEVELOPING SITES; GROUND CONDITIONS ARE SEEN AS A NEGATIVE NOT A POSITIVE; RIGHT SKILL SETS ARE NOT BROUGHT IN AT THE START OF A DEVELOPMENT. LACK OF SKILL SET AND UNDERSTANDING EXTENDS NEGOTIATIONS AND TIES RESOURCES"

TOWN PLANNER AND TEAM MANAGER, CITY COUNCIL

II. **The Street Works (Records) (England) Regulations 2002** prescribe the format of records to be maintained and their accuracy level, and make provisions on the use of electronic records.

Format and Accuracy of Records

- The regulations require the records to be made either in paper, or, electronic formats, or a combination of both, as:
  - A location or route map drawn on mapping related to the National Grid and prepared to an accuracy at least equivalent to Ordnance Survey maps of similar scales[1].
  - A statement of National Grid co-ordinates derived from a geographical information system.
- The location and route of the apparatus shall be recorded with the measured position **within 300mm of the actual position** and the recorded position shall be **within 500mm of the actual position.**
- Where an electronic record is kept, it must be capable of being reproduced in a sufficiently legible form to comply with the duty to make records available for inspection.

EXCEPTIONS TO THE REGULATION

The duty prescribed in the Section 79, NRSWA 1991 to keep a record of the location of buried apparatus provides for several exceptions, leading to a far less than comprehensive set of data on the assets

- Where compliance would lead to the disclosure of the information certified as restricted:
  - Due to the interest of national security[2]
  - Due to commercial interests of the undertaker[3]
  - To any apparatus placed by an undertaker within its existing apparatus where the location of the existing apparatus has already been recorded,
- To apparatus placed in the street prior to the date on which these Regulations came into force,
- To apparatus belonging to an undertaker discovered by him in the street during emergency works or urgent works carried out by him,
- To any apparatus not installed underground, and

[1] This was phased out over a period of 5 years
[2] Certified by or with the authority of the Secretary of State
[3] Certified by or with the authorisation of an undertaker

"OUR PROBLEM IS THE SILO NATURE OF OUR SPATIAL DATA; THE LIMITED ACCESS TO THE SPATIAL DATA AND KNOWLEDGE OF WHAT WE HOLD AND ITS TRUE POTENTIAL. ALSO, WE HAVE A REAL PROBLEM OF DUPLICATION OF SPATIAL DATA"

TOWN PLANNER AND TEAM MANAGER, CITY COUNCIL

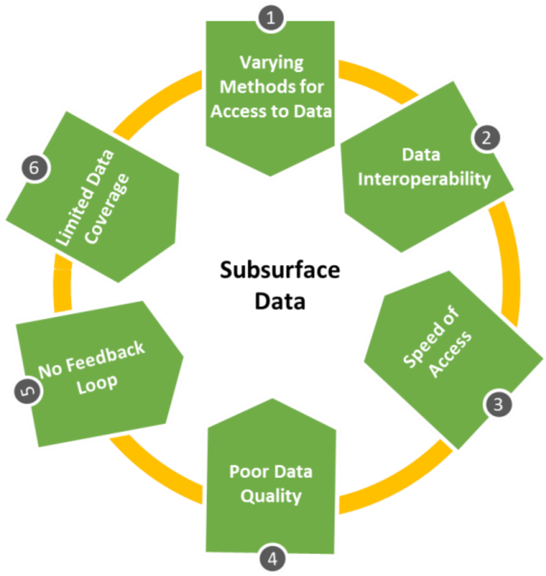
- To service pipes and lines[4].

2.3 CHALLENGES FACED BY SUBSURAFCE DATA USERS

While subsurface data and asset owners are meeting their statutory obligations on recording and sharing data with statutory undertakers, access to reliable data continues to be a major challenge.

VARYING METHODS FOR ACCESS TO DATA

- Identifying which companies own assets / data within the area of interest –there are over 300 organisations able to lay utility assets alone in the UK
- Inconsistent methods for obtaining data directly from asset /data owners



- In some cases, the access procedure is unclear, slow or even unavailable

DATA INTEROPERABILITY

- Varying and often unsuited data formats – usually, pdf plans or raw data.
- Often, unique processing is required on different data deliveries.

SPEED OF ACCESS

- Slow access to data – current requests to individual asset owners can take up to 15 days, as requests for data are often considered on case by case basis.

[4] Apparatus of any length by means of which a supply of gas, electricity or water or sewage service is afforded or intended to be afforded to premises or underground telecommunication apparatus for the purpose of providing a service by means of a telecommunication system to or from particular premises (as opposed to apparatus for the general purposes of such a system).

POOR DATA QUALITY

- Low accuracy, certainty and precision of data, particularly for old or inherited assets.
- Location data is largely relative and attributes (ex. depth) are often missing.

NO FEEDBACK LOOP

- Limited feedback of site discrepancies (no standard way of reporting incorrect records - no feedback loop).

LIMITED DATA COVERAGE

- Identifying which companies own assets / data within the area of interest –there are over 300 organizations able to lay utility assets alone in the UK.
- Limited geographic / data coverage of existing integrated data suppliers or 'Call before you dig' desks.

2.4 KEY BARRIERS TO A COMPREHENSIVE DATA SUPPLY

COMMERCIAL INTERESTS

- Controlling who has access to the data, given underground assets data has become a revenue stream for several utilities.

ENSURING ENGAGEMENT ACROSS THE INDUSTRY

- Providing business case that responds clearly to stakeholders' drivers
- Attitudes to sharing and collaboration vary amongst asset owners.

INSUFFICIENT RESOURCES

- Dedicated human, financial and technology investments required to effectively handle data requests.

DATA TERMINOLOGY

- Differences in naming conventions for data results in reduced data clarity – a full understanding of stakeholders' data schema will be required, and data dictionary may need agreement.

DATA CONFIDENTIALITY – SECURITY CONCERNS

- Security concerns over making data available, particularly for critical infrastructure.
- Publicly available data susceptible to misuse.

GUARANTEEING DATA ACCURACY

- Different organisations have varying guidelines, recording similar assets to different extents than other companies.
- Precision of data sets is likely to be highly varied – users need to be aware of levels of accuracy and completeness, feedback loops may improve accuracy.

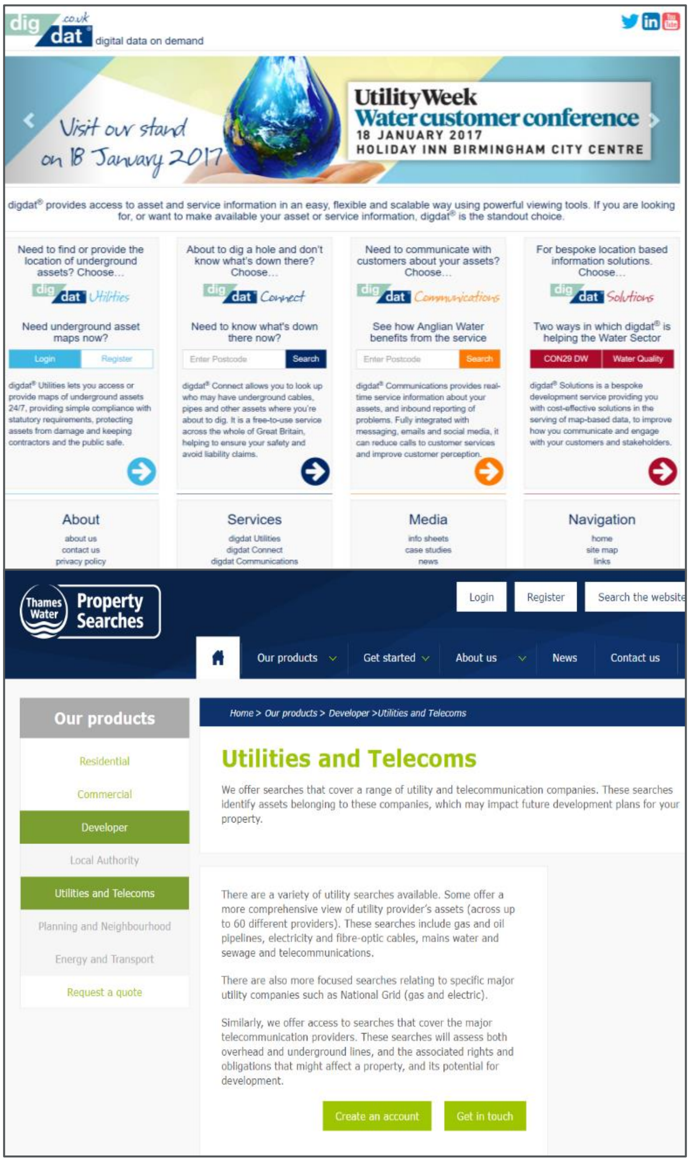
'A sample study of the causes of third party damage carried out by the Utility Strikes Avoidance Group in 2016, found that where teams had studied utility plans before excavating, 48% of the utilities were shown on plans.

Of these, ***84% were found to be inaccurately recorded****.'*

2.5 CURRENT METHODS OF DATA SHARING (UTILITIES)

Organisation	Asset Type	Data Availability	Data Sharing Portal	Format	Time Frame	Geographic Coverage
South West Water	**Water and Drainage Assets**	Sells data	Source for Searches[1]	A4 colour plans	Up to 5 working days	South West Water region (EX, TQ, PL and TR postcodes)
nationalgrid	**Electricity Network - Underground Cables**	Available on website	National Grid website	Shape files (GIS); PDF	Immediately	Country-wide
	Gas pipes	Available on website	National Grid website	Shape files (GIS); PDF	Immediately	Country-wide
love every drop anglianwater	**Water and Drainage Assets**	Sells data through 'digdat'; Free for statutory access	Digdat[2]	A variety of data types accessible in a multi-layered geo-spatial format (mapped)	**Statutory:** Within two working days **Non-statutory:** Immediately after registration	East of England
BRISTOL WATER	**Water and Drainage Assets**	Available to view on digdat; Free for statutory undertakers; Others need to contact the company	Digdat; Post/Email	Paper plans; Pdf plans; Multi-layered geo-spatial format	Up to 10 days	Bristol
Thames Water	**Clean and waste water assets**	Sells own and third-party data through own portal and available to view on digdat for statutory undertakers	Thames Water Property Searches	Paper plans; Pdf plans; Multi-layered geo-spatial format	1 to 5 working days	England & Wales
Virgin media	**Cable ducts, cables**	Available to view on digdat for statutory undertakers (free)	Digdat	Multi-layered geo-spatial format (mapped)	**Statutory:** Within two working days	Country-wide
Southern Water	**Sewers, Water mains pipes**	Sells location data by post or free viewing at its office	By Post	Maps are presented on A3 paper, but options from A0–A4 are available.	5 to 10 days	South East UK
BT	**Cable ducts, cables**	Email / Phone	https://www.swns.bt.com/	Paper / pdf plans	Unknown	Country-wide

Current methods of sharing asset records include hard copies, PDFs, CDs and online searches. While there is a growing demand to be able to request and receive data immediately, long delays in sharing data is a common practice. There is sufficient demand for access to aggregated utility asset information to support at least commercial three utility data suppliers currently operating in the industry.



Thames Water‘s Property Searches online portal provides asset location and ownership data for a range of utilities.
Available from https://www.thameswater-propertysearches.co.uk

3. SHARED UNDERGROUND DATA: KEY BENEFITS

"BETTER ACCESS TO SUBSURFACE INFORMATION CAN HELP IN SPATIAL MAPPING, DE-RISKING DEVELOPMENT; BETTER DEVELOPMENT PLANNING DECISIONS SO THAT SITE ZONING CAN BE ADAPTED AND CHANGED TO ENSURE THAT A HIGHER PERCENTAGE OF DEVELOPMENT ACTUALLY HAPPENS"

TOWN PLANNER AND TEAM MANAGER, CITY COUNCIL

BETTER ASSET MANAGEMENT AND STRATEGIC PLANNING

- Improved project planning will **reduce project downtime and avoid costly rescheduling.**
- **Digitisation of utility infrastructure services,** making it more usable, can enhance asset management, and **increase profitability by 20-30%** (Booth et al, 2016).
- Manually processing paper records is expensive and takes time. **Digitising records can increase productivity** in the utilities sector by 15% (McKinsey, 2016).

TARGETED EXCAVATION AND LESSER 'DRY DIGS'

- Comprehensive and reliable subsurface infrastructure data can enable targeted excavation as opposed to excavating simply to find out where the assets are, which often results in 'dry digs'.
    - This, in turn, reduces the time works occupy the highway and the ensuing congestion.
    - "International examples show that improving accuracy of UA location data can give returns on investment as high as 1:21" (Zeiss, 2014).

FEWER SERVICE DISRUPTION & LOWER REPAIR COSTS & INJURIES

- In 2011, 40% of incidents (asset strikes and injuries) were caused by inadequate excavation practice. Access to comprehensive underground data significantly **reduces the risk of damage to buried equipment, vital to maintain services.**
- Reduced **costs of repairing assets** damaged by strikes – less risk of connectivity downtime for utilities
    - Repair costs for a damage on average have been quantified as £970 for electricity, £485 for gas, £400 telecom, £2800 fibre-optics and £300–980 water (Nicole Metje, Bilal Ahmad, and Stephen Michael Crossland, 2015).

"UNTAPPED POTENTIAL FROM BURIED ASSETS TO HELP VALUE AND PROTECT THE HISTORIC ENVIRONMENT"

SPATIAL INFORMATION MANAGER

INFRASTRUCTURE SHARING AND EFFICIENT LAND USE

- Better planned underground space, with above ground planning priorities, would support more effective use of land supply assets, improved urban aesthetics, conservation of energy and sustainable development.
- Subsurface data can help in identification of apparatus where infrastructure sharing might be possible:
    - Greater cross infrastructure collaboration can save the economy an estimated £3 bn (HM Treasury, 2013).
    - An integrated data sharing solution can reduce asset data owner's operating costs in the provision of asset data by as much as 60% (Geovation, 2016).

BETTER PROTECTION AND UNDERSTANDING OF HERITAGE ASSETS

- Better awareness of subsurface heritage could lead to better conservation and protection:
    - Better understanding of survival of historic environment data and improved modelling of buried heritage features.
    - Currently, information on heritage assets acquired from third parties is "not necessarily digital and almost certainly not collated into a spatial dataset".

RETURN ON INVESTMENT (ROI) OF IMPROVING GEOLOCATION ACCURACY FOR UNDERGROUND UTILITIES

- If data sharing processes were digitised and automated, this could raise utility companies profits by 20-30%, and increase staff productivity by 15% (Booth et al, 2016).
- Furthermore, a set of research studies have quantified the ROI as substantially high from improving the quality of subsurface utility data, including location and condition of assets, as follows:
    - **USDOT/Purdue University:** According to a USDOT sponsored survey conducted by Purdue University[5], two broad categories of savings emerged from using Subsurface Utility Engineering (SUE)[6] — quantifiable and qualitative savings. The

[5] https://www.fhwa.dot.gov/programadmin/pus.cfm

[6] SUE is an engineering process that combines civil engineering, geophysics, survey and CADD/GIS and provides much more accurate information on the location and condition of subsurface utilities than has been traditionally available.

Purdue study quantified a total of US$4.62 in avoided costs for every US$1.00 spent on SUE. Although qualitative savings (for example, avoided impacts on nearby homes and businesses) were not directly measurable, the researchers believed those savings were significant, and arguably many times more valuable than the quantifiable savings.

- **Ontario Sewer and Watermain Contractors Association /University of Toronto:** In 2004, the Ontario Sewer and Watermain Contractors Association commissioned the University of Toronto to investigate the practice of using SUE on large infrastructure projects in Ontario, Canada. This study[7], determined that the average rate of return for each dollar spent on SUE services on those projects could be quantified at $3.41.
- **Pennsylvania DoT/Pennsylvania State University**: In 2007, the Pennsylvania Department of Transportation commissioned Pennsylvania State University to study the savings on Pennsylvania highway projects that used SUE in accordance with the mapping provisions of the American standard. The Pennsylvania State University found a return on investment of US$21.00 saved for every US$1.00 spent for SUE when elevating the quality level of subsurface utility information using SUE. **This significantly higher return on investment when compared to Purdue and Toronto studies is thought to be a result of maturation of process and possibly a consideration of the qualitative savings noted above.**
- **University of Toronto:** In 2010, a 12-month study conducted by researchers at the University of Toronto took an in-depth look at nine large municipal and highway reconstruction projects that developed an enhanced depiction of buried utilities. Based on this analysis, a cost model was proposed that takes into account both tangible and intangible benefits. All projects showed a positive return-on-investment (ROI) that ranged from $2.05 to $6.59 for every dollar spent on improving underground utility location data.

[7] http://conf.tac-atc.ca/english/resourcentre/readingroom/conference/conf2006/docs/s018/arcand.pdf

HEATHROW MAP LIVE PROJECT

The Heathrow Map Live project reduced strike incidents due to inaccurate data by six times as its underground assets mapping increased by 32%.

OVERVIEW

With infrastructure networks stretching over several hundred kilometres, the Heathrow airport holds a dense network of underground assets that include:

- **More than 45,000 man holes, 72 miles of high pressure fire water mains, 81 miles of aviation fuel pipelines, and power cables with voltages ranging from 9V up to 400 kV.**

RATIONALE

The Heathrow Map Live project aimed to reduce infrastructure strike incidents involving utilities during excavation by improving data reliability and accessibility

- **In 2002, only 40% of its underground assets were mapped to within half a metre.**
- **The airport was faced with legal and contractual requirements, such as CDM (Construction Design Management) regulations, that necessitated the project.**

KEY FEATURES

As part of this effort, Heathrow defined a Common Data Environment (CDE) to cultivate a culture where data is created once only (i.e. single owner) and shared across organisation

- **Thus, under CDE, all standards, guidelines, and work processes are designed to support a single point of truth.**
- **CDE minimized rework, increased re-use of designs and provided efficient handover from design and construction to operations.**

OUTCOMES

- **The Heathrow Map Live system makes underground data accessible to everyone within the business to query and view information about Heathrow's above- and below-ground infrastructure through a web-based tool.**
- **By 2011, 72% of the underground facilities were mapped to half a meter and strike incidents caused by inaccurate data fell six folds.**

It will help us to use scare resources, whether staff or information, in a more constructive and productive way. We can make risk aware decisions about the spatial direction of travel for the city and be better equipped to enter discussion with developers to ensure that Planning is not the delaying factor in development being delivered.

It will allow us to explore the potential of positive outcomes from subsurface knowledge that could reduce the cost of development; create innovative climate ready, resilient solutions. This should help to deliver real benefits for healthy sustainable urban environments by reducing the amount of brown field and creating positive places.

Town Planner and Team Manager, City Council

4. PAST AND CURRENT INITIATIVES

4.1 PAS128 (2014) & DRAFT PAS256

“PAS256 BUILDS ON EXISTING LEGISLATIONS AND PAS 128, PROVIDING THE NECESSARY FRAMEWORK FOR SUCCESSFUL IMPLEMENTATION OF PROJECT ICEBERG”

OVERVIEW

British Standards Institution PAS 128, launched in 2014, provides specification for underground utility detection, verification and location, enabling the utility survey industry to deliver its services to a recognised level of accuracy.

PAS 128 focuses on levels of accuracy – referred to as Survey Category Types – that can be specified when requiring a PAS 128 compliant underground utility survey.

PAS256 sets a consistent, accessible data protocol to enable effective recording and sharing of the location, state, and nature of buried assets, and recommends how existing asset records should be updated, recorded and collated.

PROJECT OBJECTIVES

PAS128 aims to provide:

- Clarity in the underground surveys service provided and methods employed; consistency in the approach to data capture.
- Classification of the results and the confidence that can be associated with them.
- Standardization of the format of deliverables.
- Accountability for the work undertaken.

PAS 256[8] provides recommendations for the collection, recording and sharing of location data relating to underground and any associated above ground assets, decommissioned and abandoned assets.

[8] Sponsored by the Institution of Civil Engineers

It aims to encourage:

- A drive towards improved accuracy when collecting and recording information,
- Sharing of more accurate records collaboratively, with those working near their buried assets,
- Improvement in the linkage between assets that are part of the critical national infrastructure with initiatives such as Smart Cities and BIM.

OUTCOME

The PAS 128 was the UK's first specification for the detection of underground utilities. It has enabled provided the basis for consistent and reliable levels of service across the utility detection industry and to raise survey standards.

RELEVANCE TO ICEBERG

- PAS256 builds on existing legislation of the NRSWA Act 1991 and Traffic Management Act 2004 and the requirements set out in PAS 128, and if adopted widely, provides the necessary framework for successful implementation of Project Iceberg.
- PAS 256 covers recommendations for:
  - The gathering of geospatial data using absolute or relative accuracy, and associated evidence (such as photographic),
  - Measurable deviations from straight line installations, where appropriate,
  - The absolute depth of the asset,
  - The number of days to record and make available the asset data, once collected,
  - The sharing of collected asset data.
- PAS 256, however, does not cover how data are stored, where it is stored and how integrity of storage is assured.
- As in the case of existing legislation, PAS 256 also does not cover utility service pipes and cables supplying individual premises, only the main networks. This limits data collection of underground assets relating to individual buildings creating a potential mismatch with BIM protocols.

4.2 ASSOCIATION OF GEOTECHNICAL & GEOENVIRONMENTAL SPECIALISTS (AGS)

AIM

The Association of Geotechnical and Geoenvironmental Specialists (AGS) is a non-profit making trade association established to improve the profile and quality of geotechnical and geoenvironmental engineering.

The AGS Data Format was developed in 1992 to enable the means for ground investigation data to be shared across geotechnical experts and the construction sector. AGS promote the adoption of the AGS Data Format for the transfer of all geotechnical and geoenvironemntal data in the UK via electronic systems. The use of the AGS Data Format is monitored by the group and updates to the format as made as necessary to meet the needs of the community.

OUTCOME

Whilst the AGS Data Format was written specifically for use in accordance with UK practice the format is now used worldwide as a means to encourage the sharing of ground investigation data and help with data quality assurance.

RELEVANCE TO ICEBERG

.ags is a text file format used to transfer data between organisations in the site investigation industry, independent of software, hardware or operating system. The 'AGS Format' provides a standard way to transfer ground investigation, laboratory testing and geoenvironmental monitoring data between the project team members. Data is generated by a ground investigation contractor, laboratory or on-site drilling crew or technicians and then shared with other internal or external parties. The data can then be reused for onward project design and construction without the time-consuming and expensive data re-entry and without the associated potential errors or incomplete data entry. Following completion of the project, the AGS Format data is easily archived, for retrieval at a later date without requiring knowledge of the software used to generate it. For more information visit http://www.ags.org.uk/data-format/

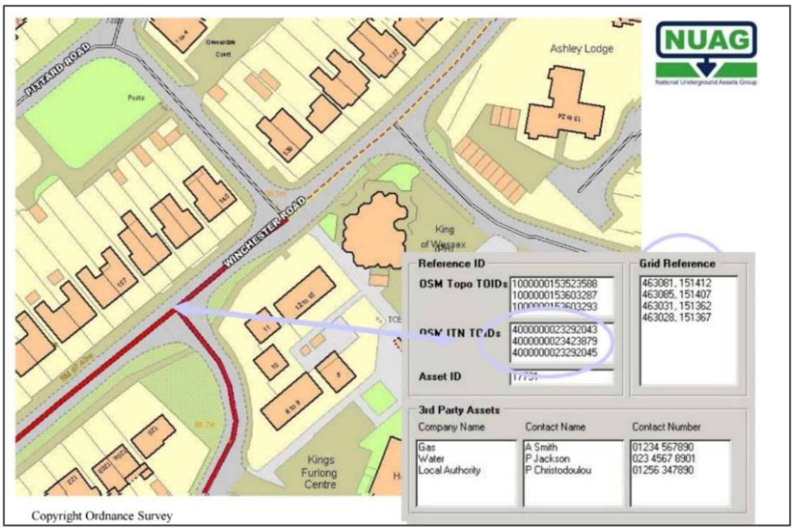
4.3 NATIONAL UNDERGROUND ASSETS GROUP (NUAG)

OVERVIEW

NUAG, an independent organisation set up in 2005, to represent stakeholders with an interest in, or affected by, capturing, recording, storing and sharing of information on buried and associated above-ground assets such as pipes and cables.

NUAG established the standards and processes for information creation and exchange to ensure consistency in referencing and recording asset information.

PROJECT OBJECTIVES



NUAG web-based map platform to view utility data. Contains Ordnance Survey data © Crown Copyright and database rights 2017.

- [NUAG proposed a national web-based solution service](), the National Asset Records Exchange, that enabled
    - Street works coordination/planning
    - Events/incident management
    - Project Collaboration
- The project aimed to create a definitive, GB-wide web-based service for the exchange of information on underground assets. Funding was secured from the Technology Strategy Board (now InnovateUK) for a demonstration of the proposed system for an area in London.
- The proposed service was planned to be rolled out in three stages; Asset owners retained and managed their own data in all stages,

thus, involving no central data storage

OUTCOME

- The project proposed a 'map-based' platform that allowed users to select a point and get data from all owners through NUAG portal
- In 2011/12, NUAG started a 12-month London Trial Project – a web-based national asset record information sharing service (NRS) to improve access information on buried assets. Project partners included Thames Water, London Underground, Southern Gas Networks, BT and the City of London.
    - The trial was expected to be followed by UK-wide implementation within 2-3 years
    - Lack of funding stalled the project midway
- Recommendations from NUAG are being carried forward into a new BSI PAS (256) on buried assets

RELEVANCE TO ICEBERG

- The NUAG was the first initiative of its kind and established the basis for the creation of the standards and processes for underground information exchange in the UK
- It received consensus from a range of utilities and local authorities including Thames Water, Virgin Media, TfL, Network Rail and LOTAG (representing all London Boroughs)
- Interviews with the project team suggest the following factors that led to the premature termination of the project:
    - Lack of funding
    - Over-ambitious objectives

4.4 GLA NETWORKED UTILITIES (2014)

OVERVIEW

An assessment funded by the Greater London Authority (GLA) to evaluate how a co-ordinated system of utility mapping could be implemented across London. This included reviewing and summarising existing smart utility mapping projects across London. Key stakeholders were identified in order to secure industry support for integrated utility mapping.

London Utility Companies, Arup, Network Rail, NUAG, Morrisons UK, COLT, Crossrail, TfL and National Grid were involved in the project.

PROJECT OBJECTIVES

- Assess the capabilities of existing and potential solutions and who might provide them.
- Assess obstacles that have stopped an efficient, collaborative data management service being adopted to date and the means and costs of overcoming those obstacles.
- Develop a detailed understanding of data owners' information management arrangements, the processes involved in aligning them and the associated costs.
- Establish an implementation plan and exit strategy for the GLA investment that is most likely to lead to a system and overall approach that is viable, sustainable and has sector wide adoption.

OUTCOME

The assessment report outlines:

- Little evidence of stakeholder consensus for change.
- Efficiency and safety benefits are not realised and not effectively communicated by various parties.
- Utility owners perceive minimal financial and business reasons to change their approach as they currently meet the statutory requirements.
- Need for regulatory change to enable wider industry and societal benefits from improved data management.

RELEVANCE TO ICEBERG

The identified challenges to the implementation of the GLA assessment are very relevant to Project Iceberg, these include:

- **Speed of access to utility asset data** – current requests to individual asset owners are c. 10-15 days.
- **Interoperability of data** – usually provided as pdf plan, with limited data regarding attribution i.e. depth.
- **Accuracy and reliability of data** – historical data is incomplete from asset inheritance, gaps in records); different records of "truth".

- **Limited feedback of site discrepancies** – no standard way of reporting incorrect records - no feedback loop.
- **Data confidentiality and controlling** who has access.
- **Ensuring engagement across the industry** and providing a business case that responds clearly to stakeholders' drivers.

The project also assessed different solutions that can be further explored by the Project Iceberg.

4.5 MAPPING THE UNDERWORLD

OVERVIEW

Mapping the Underworld (MTU) is a 4-year research programme, funded by a £3.5m programme grant from the EPSRC, which seeks to develop the means to locate, map in 3D and record infrastructure assets, using a single shared multi-sensor platform, so that the position of all buried assets can be known without excavation.

Assessing the Underworld (ATU) is a further 4-year research programme grant that advances MTU. As part of a vision to make street works more sustainable, this new phase of research uses geophysical tools combined in the MTU multi-sensor platform to assess the condition of the buried pipelines and cables, and of the ground in which they are buried, and of the surface transport infrastructures beneath which they are buried.

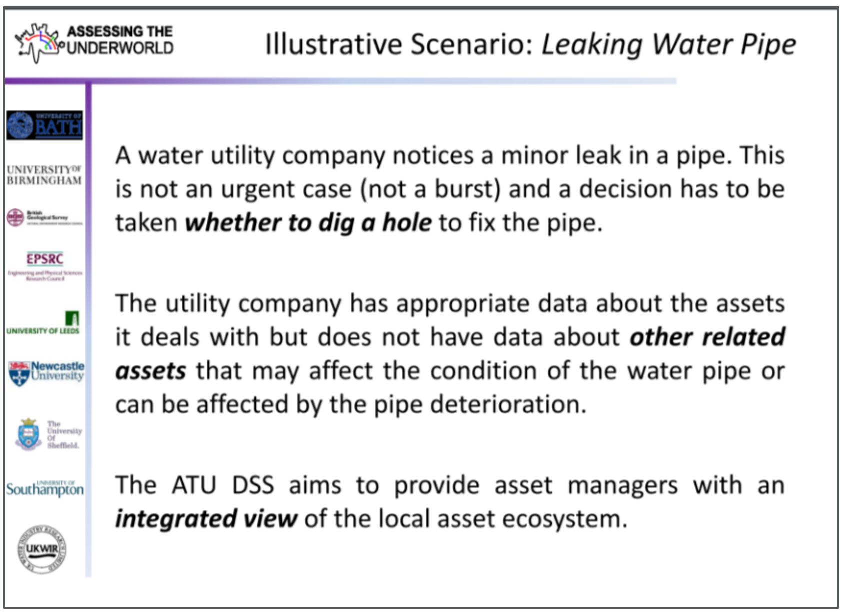
PROJECT OBJECTIVES

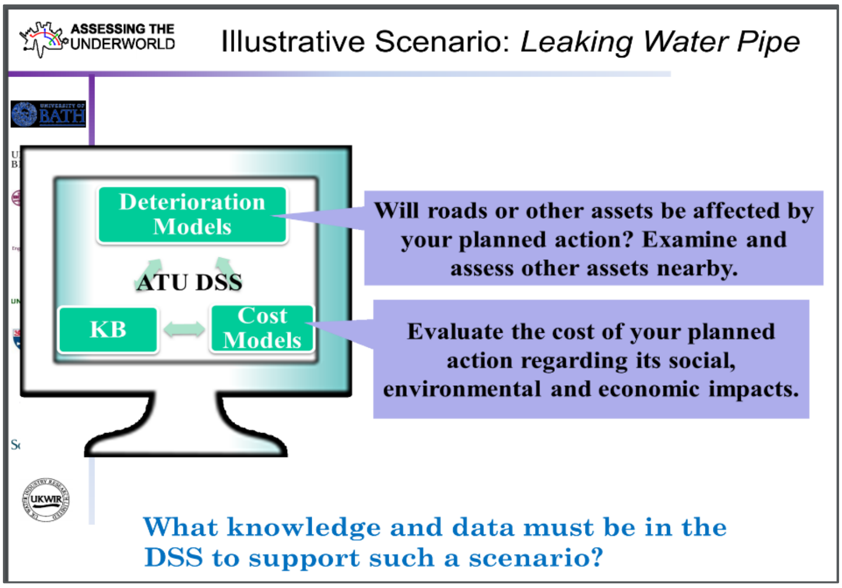
- **MTU:** Create a prototype multi-sensor device and undertake fundamental enabling research for detecting underground assets.
- **ATU:** Is undertaking fundamental enabling research to allow condition assessment of: (1) buried utility service pipelines and cables; (2) road and pedestrian pavement structures; (3) the ground to:
    - Prove the concept of a single integrated assessment and modelling framework using a range of techniques.
    - Develop a robust decision support system with embedded sustainability requirements, for use with the integrated

infrastructure framework to inform intelligent street works.

OUTCOME

- **MTU:** Research findings are providing a strong evidence base for a commercially-developed multi-sensor device.
- **MTU** findings will be combined with existing shallow surface soil and made ground 3D maps prepared by the BGS to prove the concept of creating UK-wide geophysical property maps for the different technologies. This would allow the users of the device to make educated choices of the most suitable operating parameters for the specific ground conditions in any location.
- **ATU** is using MTU's multi-sensor platform, with amendments and additions, and robotic in-pipe pigs to assess the condition of buried assets, and use the best available information and knowledge of the ground in which they are buried to enable better management of underground assets.
- **ATU Decision Support System (DSS)**: One of the ATU outcomes includes an interactive software tool that supports asset management decisions by integrating and reasoning with diverse information sources about surface and subsurface assets (e.g. roads, utilities, ground) and the relationships between them. Decisions it can help with include addition/replacement of new/old buried assets, Emergency repairs, Abandon and Diagnostics (more surveys).





Illustrative scenario from the Assessing the Underworld Decision Support System (DSS).

RELEVANCE TO ICEBERG

ATU project addresses one of the key challenges faced in developing an underground data sharing platform – inaccurate or incomplete underground data.

Successful development of a multi-sensor tool capable of accurately locating underground assets would improve the quality of data available for use.

4.6 PROJECT VISTA (VAULT)

OVERVIEW

Project VISTA (Visualising integrated information on buried assets to reduce streetworks) was a follow-on activity to the MTU project to develop visualisation techniques which integrate subsurface data, and enhance their legacy - disseminating the information to digging teams and network planners. The VISTA project was funded by Innovate UK and led by UK Water Industry Research (UKWIR) in collaboration with the University of Leeds and the University of Nottingham.

PROJECT OBJECTIVES

- VISTA aimed to provide a framework for data sharing which enables underground asset knowledge from multiple sources to not only be integrated but reused, updated and efficiently disseminated.

- Similar objectives underpinning the two projects VISTA and MTU led to the collaboration of 22 utilities and partners to create and trial one combined system, now commercially realised as VAULT.
- VAULT has been designed to provide users with information on underground pipes and cables from one centralised location.
- Wider benefits include reduced disruption to the public, and significant time and cost savings to utility suppliers, by accessing a comprehensive asset database.

OUTCOME

- The VAULT system was initially trialled in the East Midlands (later Scotland) which led to all partners agreeing on the methods of mapping involved, along with the level of granularity required.
- The system is now live across Scotland and securely delivers integrated information on utility and other underground apparatus to over 300 unique users across 47 different organisations, with an average of 30 unique users daily.
- VAULT has made a diverse set of data available instantly to users in an integrated downloadable form, building on the earlier Scottish Road Works Register's system that let users to request utility records and delivered them by post, days or weeks later.

RELEVANCE TO ICEBERG

- The aim of the VISTA project is in line with that of Project Iceberg with respect to drawing together data from multiple sources into a single platform.
- The project has brought together collaboration from 22 utility companies and partners, and now has over 300 unique users from over 47 different organisations. This level of engagement and success in VISTA lays a significant platform which Project Iceberg, and others, can develop.
- VAULT's success validates the need for a similar platform in the UK and can be leveraged for Iceberg's development and commercialisation.

4.7 GREATER MANCHESTER OPEN DATA INFRASTRUCTURE MAP (GMODIN)

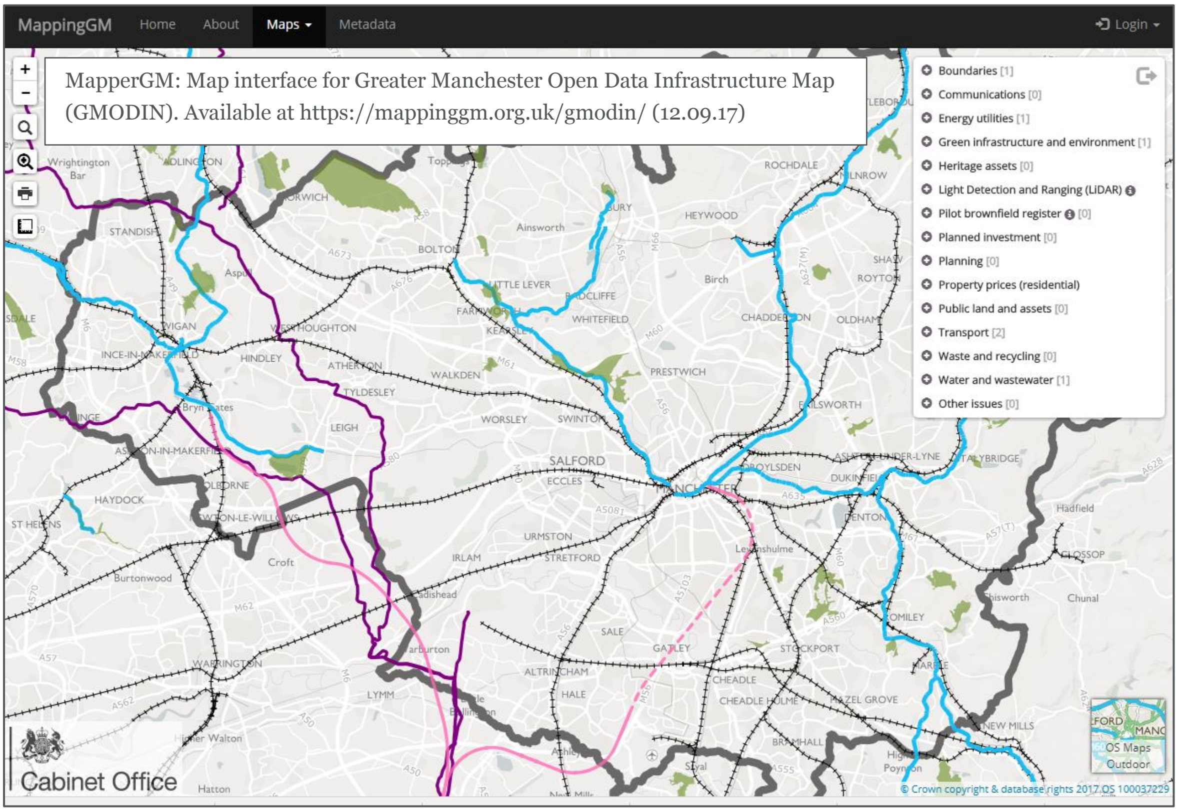
OVERVIEW

The GMODIN is an open map of relevant public and private infrastructure data, making use of existing local, regional and national datasets on a variety of areas – from open public sector and environmental assets to energy utility networks.

PROJECT OBJECTIVES

- Reduce barriers to new development within Greater Manchester, with a particular focus on brownfield regeneration,
- Provides a general overview of physical, social and green infrastructure (e.g. green networks, sustainable urban drainage). It also includes datasets such as planned transport works, communication links, streetlight locations and designated nature reserves.

OUTCOME



MapperGM: Map interface for Greater Manchester Open Data Infrastructure Map (GMODIN). Available at https://mappinggm.org.uk/gmodin/ (12.09.17)

The first map was built and delivered in five months, drawing in data from both the public and the private sector to provide a general overview of physical, social and green infrastructure. Since then, the map has been expanded with further datasets on areas such as heritage, flooding, property prices and river quality.

The platform is used by planners, architects, developers to access infrastructure and housing related information across Greater Manchester on a single, easily accessible map.

RELEVANCE TO ICEBERG

One of the issues many projects have faced is fitting their datasets into a pre-agreed, top-down schema. The GMODIN took away that hassle for local authorities, and instead asked for any data they had, in any format. From these datasets, a series of schemas were built up, utilising the data present in every dataset, which were then passed back to the local authorities to use in future. Regional planning authorities elsewhere in the UK are beginning to undertake this role of developing schema to integrate local authority datasets across regional planning framework areas, to inform strategic decisions on planning and development, e.g. to identify viable brownfield sites for development.

Many of OS's datasets are used within the map, such as Boundary Line, Code-Point Open and many private datasets were verified and geo-coded against OS data. The OS Maps API is used to deliver the tool.

4.8 THE ASK NETWORK

OVERVIEW

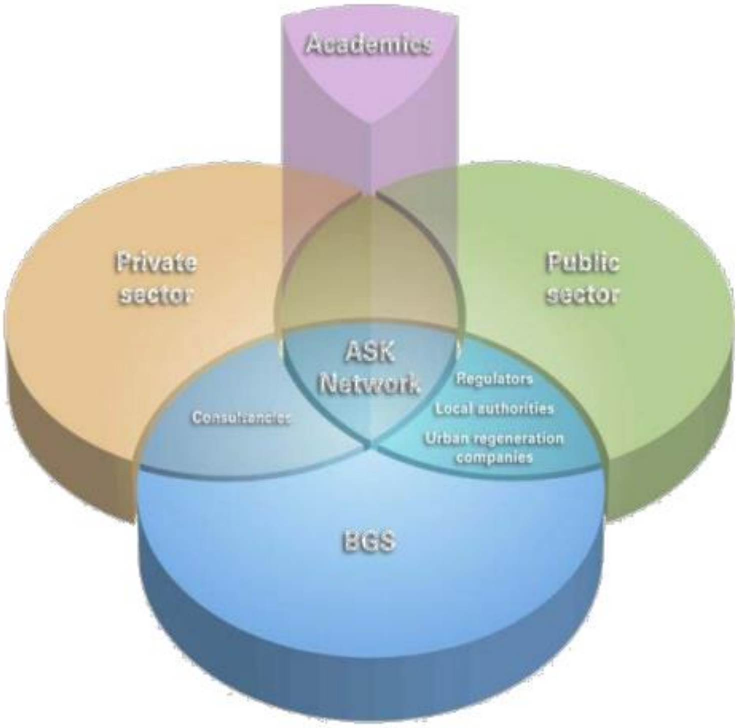
Launched in 2012, the Accessing Subsurface Knowledge (ASK) Network is a data and knowledge exchange network between public and private sectors developed by BGS and Glasgow City Council (GCC) with support from other partners in the public and private sectors.

Now in its third year, the ASK network has over 20 partners from industry, and 12 public sector bodies, and 261 members across Scotland. ASK Wales was launched in 2015.

PROJECT OBJECTIVES

- Develop and exchange high quality systematic subsurface data sets and methods (primarily borehole site investigation data)
- Facilitate effective re-use of subsurface (borehole) data to better inform decision making and management of urban resources

- Establish a data transfer mechanism to a centralised repository for raw subsurface borehole data in standardised formats, to maximise accessibility and re-use of data.
- Provide access to BGS's attributed 3D model coverage and related GIS data sets
- Enable users to influence outputs from models to improve usability
- Assess ASK Network expansion, and/or use as an exemplar for in other cities/areas of the UK
- Explore integration of geotechnical data and 3D models within BIM (Building Information Modelling).



The ASK Network[9]. BGS ©NERC 2017

OUTCOME

- The ASK network offers an improved data exchange mechanism between the public and private sectors.
- It provides a web portal to check data compliance before data can be accepted by public and private contractors.

[9] Bonsor, H.C.; Entwisle, D.C.; Watson, S.; Lawrie, K.; Bricker, S.; Campbell, S.; Lawrence, D.; Barron, H.; Hall, I.; O Dochartaigh, B.E. 2013. Ground Engineering, 46 (2). 25-28 Maximising past investment in subsurface data in urban areas for sustainable resource management: a pilot in Glasgow, UK. Technical note

- Enables information generated from public and private-funded ground engineering construction projects to be added to a secure and centralised database for long-term re-access.
- Government departments, researchers and the public can then access this data to provide more cost-effective ground investigations and engineering solutions, and to protect the environment.
- Within Glasgow, members of the ASK Network can access superficial deposits and bedrock 3D subsurface models of central Glasgow through a collaboration agreement.
- In Sep 2015, the ASK network launched in Wales with the goal of reducing the costs for construction firms and planners caused by unforeseen ground conditions.
- The database will also help future proof Wales for the new environmental legislation around BIM and Sustainable Drainage Systems (SuDS).
- In 2016 deposition of validated geotechnical data to BGS through the BGS web portal between a requirement of framework contracts of two national infrastructure suppliers in Scotland.

RELEVANCE TO ICEBERG

- The collaboration demonstrates the value in a step change in how subsurface data is reported and exchanged between the public and private sectors.
- The project demonstrates that better re-use of subsurface data and knowledge may extend the capabilities of BGS 3D models and increase their relevance to practical issues.
- The successful outcomes of the project in Glasgow and Scotland nationally is being used to inform solutions that project Iceberg aims to develop – a data transfer mechanism for information on subsurface ground conditions.

4.9 BIM FOR THE SUBSURFACE

OVERVIEW

This two year, £540,000 project, BIM for the Subsurface, funded by Innovate UK under its Digitising the Construction Industry initiative started in April 2015 and expected to run for 2 years.

The project aims to address issues such as project delays due to unforeseen ground conditions by applying the BIM process directly to ground investigation & subsurface infrastructure design.

PROJECT OBJECTIVES

- To deliver the first geotechnical BIM solution through a cloud based repository that will allow the storing, sharing & re-use of subsurface data & interpretations throughout the supply chain.
- Enable geotechnical engineers to use/create more detailed site models which can be shared to enhance the national knowledgebase.
- Incorporate BGS modelling methods into AutoCAD Civils3D with direct commercial API access to BGS Geological Object Store allowing collaborative geological modelling.

OUTCOME

- Ongoing two-year project, results available from 2017.
- Through the integration with BGS' national databases, the solution "Geotechnical BIM Suite" will allow for historical data to be digitally accessed, providing improved accessibility to BGS maps & geotechnical data & implement BGS methodologies & standards for 3D geological modelling. The approach will significantly reduce future ground investigation risks & costs.
- Enables collaborative 3D geological modelling, improved data sharing and streamlined access to 2D and 3D geological data.

RELEVANCE TO ICEBERG

- A comprehensive understanding of the subsurface, through an understanding of its geological/geotechnical properties complements the objectives of the Project Iceberg.

4.10 EU COST SUB-URBAN ACTION

OVERVIEW

The four-year SUB-URBAN COST Action (2013-17) has provided a long-needed contribution to greater interaction and networking, to transform the relationship between experts who develop urban subsurface knowledge and those who can benefit most from it – urban decision makers, practitioners and the wider research community. The Action has established a European network across 30 countries of Geological Surveys, Cities and Research Partners.

COST1 Action TU1206 Sub-Urban2 explores management of the urban subsurface and the use of subsurface information in urban planning.

PROJECT OBJECTIVES

The main aim of the Action is to enable better and increased interaction and networking, and so transform the relationship between experts who develop urban subsurface knowledge and those who can benefit most from it - urban decision makers, practitioners and the wider research community. Further, to maximise the economic, social and environmental benefits of urban subsurface resources and ecosystem services on which cities depend, the Action aims to:

- Draw together collective research capabilities in: 3D/4D characterisation, prediction and visualisation of the subsurface; subsurface (borehole) data acquisition and management practices; groundwater monitoring and geothermal practices in urban areas; management of below-ground cultural heritage.
- Deliver a series of briefing reports, and a guidance toolbox, to disseminate the curated and collated knowledge to geoscientists, planners and practitioners in appropriate forms.
- Provide training and continuing support and advice to better inform and empower decision makers and other end-users.
- Foster development of policy which reflects the importance of the urban subsurface.
- Recommend the basis for improved availability, initial use and re-use of subsurface data.

OUTCOME

The Action, and its network has worked to co-ordinate and integrate best practice research in data management and modelling the subsurface taking place in European institutions, as well extensive engagement with above and below ground city planning and subsurface resource utilisation and management in cities around Europe. The Action has published a series of reports which are available (and forthcoming) from the project website.

The city study reports and overview report provide a synthesis of the current baseline of subsurface planning practices, and data use in cities within Europe at present, drawing on key examples. The work package two reports review existing good practice in data management, 3D modelling, geotechnical properties and data, groundwater and geothermal resource management and utilisation in cities, and management of cultural heritage (above and below ground).

There are also a series of informative knowledge exchange reports between key experts in Geological Surveys, city municipalities and their key partners, in the Action on topics of data management, modelling, resource use and management.

A toolbox has been developed to draw together the collective research capabilities within the network, and to provide an accessible platform for both city planners, and subsurface specialists to access leading research and city examples. The Action has provided training and continuing support and advice to better inform and empower decision makers and other end-users.

RELEVANCE TO ICEBERG

The WG2.2 Data Acquisition and Management group have identified the following key recommendations to develop efficient and effective data management systems and workflows:

- There is a need for clarification of legislation related to data acquisition and management policies
- Need to adopt standard naming conventions and use of controlled glossaries
- Data validation tools which are independent of software vendors would assist the community move to increased standardisation
- Maximise use of open data discovery and data access platforms, with low financial and security costs
- More metadata is needed, especially within the commercial stakeholders in urban developments. Metadata should encompass data discovery, how to use the data, tailored to each audience and finally it should capture terms and conditions of use

There is a wide held belief amongst those who have adopted these recommendations that the development costs are outweighed by the benefits, however, there is a lack of hard evidence to support this belief.

This is in part due to the fact that many of the web services developed by the community are un-secured read-only mechanisms for sharing public data, few have attempted to develop services that authorise and authenticate data access and data editing functions. The use of such uncontrolled public services has grown rapidly and the rate of growth seems to be increasing, this is starting to impact on the systems which power these services and results in the need for new rules to regulate their use.

Going forward, there is a need to develop secure web services that support the definition of rights and responsibilities based upon legislation and commercial considerations as well as ensure data integrity, i.e. messages must remain unaltered in transit.

4.11 DIGITAL BUILT BRITAIN

OVERVIEW

Digital Built Britain is a government-led strategy, utilising Building Information Modelling (BIM) in combination with the Internet of Things (IoT), advanced data analytics and the digital economy, to enable better planning of new infrastructure, at lower costs, with improved efficiencies in operation and maintenance. BIM is a business work flow that uses 3D digital modelling of infrastructure to optimise CAPEX spend, and through holding large amounts of information about its design and current condition, offer savings in the OPEX spend. In 2011, the UK Government mandated the use of Level 2 BIM on all public-sector projects by 2016.

PROJECT OBJECTIVES

Within BIM Level 3, the key objectives are:

- Creating a set of new, international 'Open Data' standards, enabling easy sharing of data across the entire marketplace.
- Establishing a new contractual framework for projects for use with projects utilising BIM, ensuring consistency and encouraging open collaborative working.
- Creating of a cultural environment which is cooperative, seeks to learn and share.
- Training the public sector in the use of BIM techniques, such as data requirements, operational methods and contractual processes.

- Driving domestic and international growth and jobs in technology and construction.

The OS has been involved within the Consultation group, alongside academics and private sector construction and consultancy firm.

4.12 CITYVERVE

OVERVIEW

CityVerve is the UK IoT demonstrator project, aiming to build and deliver a smarter, more connected Manchester. In 2015 Manchester won £10 million awarded by the Department for Culture, Media and Sport (DCLG), aiming to become the area for in-field innovation trials to demonstrate the capability of the Internet of Things.

PROJECT OBJECTIVES

CityVerve aims to create a blueprint for smart cities worldwide through its 'five steps' to a smarter city:

- A truly open platform, treating the city as a living breathing organism by giving it a technology layer that acts as a central nervous system; smartly supporting and connecting independent systems and applications.
- Identifying opportunities for projects that specifically meet the needs and challenges of Manchester's citizens, driven and benefit led focusing on four key areas: Health & Social Care, Energy & Environment, Travel & Transport, Culture & Public Realm.
- Using technology to enrich the local experience for residents, business and tourists - aiming to reignite the connections that turn a neighbourhood into a community.
- Innovation through collaboration, with open calls and events offering challenges, opportunities and APIs to developers and innovators.
- Rigorously evaluating projects to understand if the theory translates into real-world, assessing whether the desired result has been achieved and confirming whether commercially viable.

OUTCOME

CityVerve is being delivered by a consortium of 21 organisations – including Manchester City Council, Manchester Science Partnerships, the University of Manchester, Cisco, BT and other tech players.

The project has identified and is working on more than 16 individual projects, including Talkative bus stops, smart lighting, bike sharing and Smart air-quality monitoring.

RELEVANCE TO ICEBERG

OS is a part of a consortium of over 20 public and private organisations who over the next two years will design and deliver a series of citizen-focused solutions around the themes of Transport, Energy, Health and Culture, using IoT sensor and collaborative platform technology. The OS' specific role is to provide the geospatial framework and location expertise upon which solutions may be based.

4.13 CALLS FOR INNOVATION

OVERVIEW

In June 2016, the Mayor of London in partnership with BRE, launched a challenge-led competition to bring forward innovative technologies that could help London's major infrastructure providers gain a shared understanding of the location and state of their underground assets

The challenge was set by members of the Smart London Infrastructure Network, comprised of water utilities (water, energy, telecom and waste management)

OBJECTIVES

The challenge was designed to look for solutions that would:

- Accurately identify the location of their own and others' assets – in terms of precise geographical position, depth, size, and asset components (e.g. joints, meters, valves) and/or,
- Determine the asset condition - in terms of damage, degradation or failure to deliver the required operational performance.

OUTCOME

There were a total of 36 entries from 31 companies. These included:

- End-to-end products which could provide location and mapping services and tools.
- Platforms using Artificial Intelligence to gather and interpret data on location and condition using photos of underground assets.
- Platforms for the display of data supplied by the utility companies.
- Eleven innovations were selected as being the best match to the challenge.

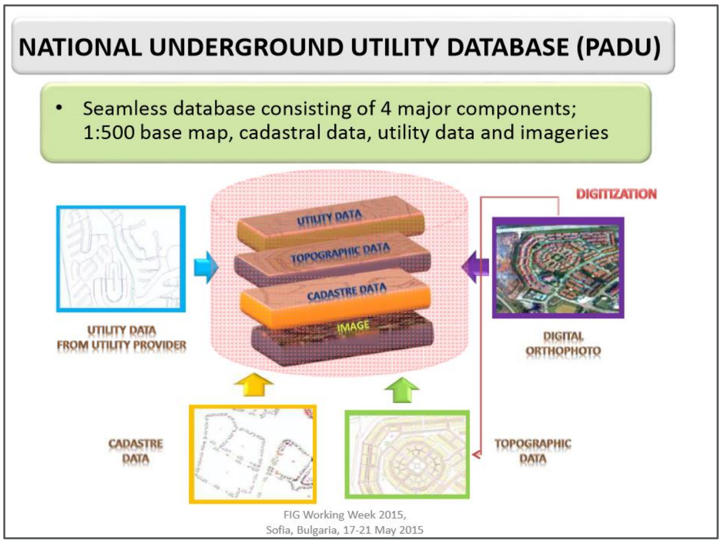
5. INTERNATIONAL EXAMPLES

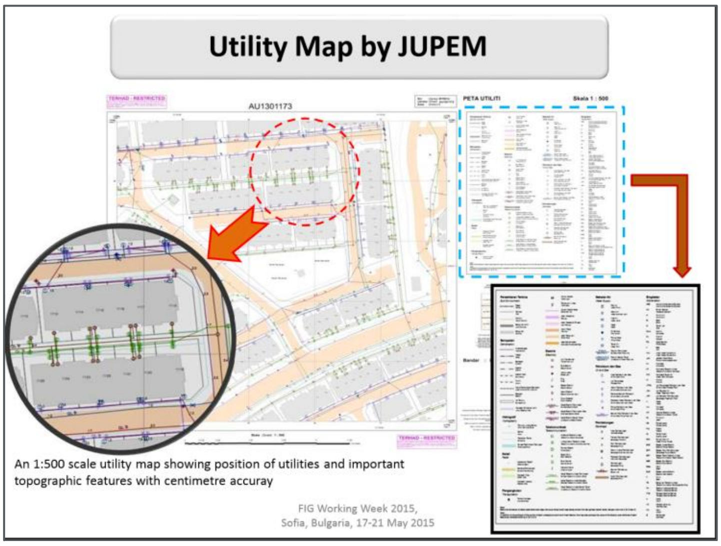
5.1 MALAYSIA

OVERVIEW

"MALAYSIA SERVES AS KEY EXAMPLE WHERE GOVERNMENT MANDATE HAS DIRECTED THE DEVELOPMENT OF A CENTRALISED, NATIONAL REPOSITORY FOR UNDERGROUND UTILITY."

The Malaysian Department of Survey and Mapping Malaysia (JUPEM), as part of its mandate, has developed a national underground utility database (PADU) to act as a repository of underground data provided by utilities in a GIS format.





Malaysian Department of Survey and Mapping Malaysia (JUPEM), national underground utility database (PADU).

RELEVANVCE TO ICEBERG

As in the UK, the challenges faced by PADU lie primarily in its data content. Most of the data compiled or provided by the utilities have low accuracy and not reliable or fit to be used as referenced for excavations works.

Also, utility companies in Malaysia have no legal requirement to maintain or provide quality data or as-built data to PADU – thus, JUPEM has to perform the detection and survey of underground utilities itself to upgrade the accuracy of the data.

However, a decision by the National Council for Local Governments (MNKT) in Sep 2014 stated:

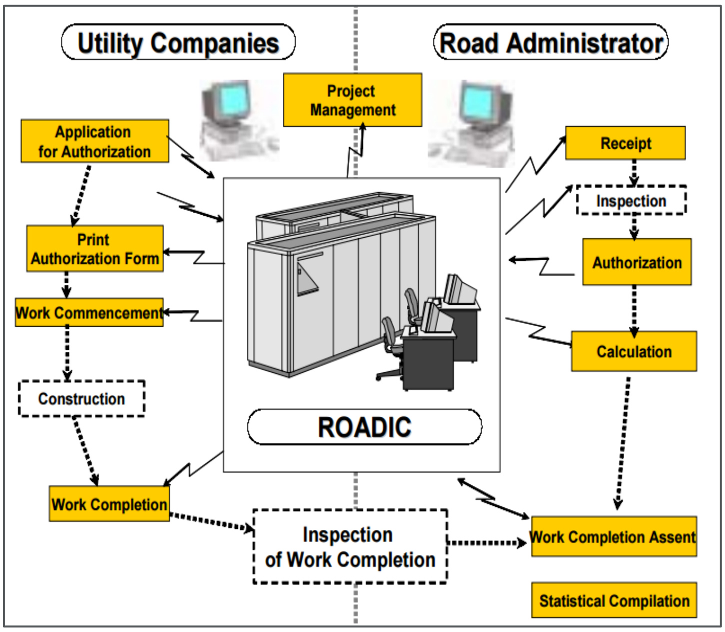
- All new underground utility installed using open trenching shall be surveyed during installation.
- An Accurate positioning method must be used when installing using Horizontal Directional Drilling.
- A copy of the digital data must be submitted to JUPEM for updating on PADU.

“ROADIS USES GIS TECHNOLOGY TO PROVIDE COMPREHENSIVE MANAGEMENT OF THE DIVERSE INFORMATION RELATED TO ROADS AND THE ASSETS THAT OCCUPY SPACES ABOVE AND BELOW THE ROAD.”

5.2 JAPAN

OVERVIEW

Japan's ROad ADministration Information System (ROADIS) was created in 1986 after a destructive gas explosion in a major city. The system enables a central oversight of the locations of on-ground and below-ground critical infrastructure, which in turn, helps to maximise inter-agency cooperation for infrastructure planning and incidence response.



Workflow of road utility authorization in Japan. Image reproduced from Miyamoto and Doi (undated) ONLINE ROAD UTILITY AUTHORIZATION SYSTEM UTILIZING GIS DATABASE. Available from http://www.gita-japan.com/pdf/English.pdf (12.09.17)

ROADIS is headquartered at the Tokyo Road Administration Information Center (ROADIC) office, with 11 other ROADIC offices throughout Japan, using GIS technology to provide comprehensive management of the diverse information related to roads and the assets that occupy spaces above and below the road.

KEY FEATURES

- Online connections between host computers installed at each ROADIC branch office and the terminals and mapping systems of road administrators and utilities enable mutual utilisation of data.
- Its GIS database includes Road Database (road and topographical data) – constructed by the extraction and digital conversion of essential information from1/500-scale road

registration drawings.

- On this base map layer, public utilities enter information about their facilities, creating the Utility Database.
- In operation since 1998, the Online Road Utility Authorisation System (a subsystem of ROADIS) realises electronic processing of street work applications and notifications.

OUTCOME

- ROADIS enables easy retrieval of road and topographical data from the Road Database and use it as the background data to prepare the necessary drawings for work applications.
- It allows automatic retrieval of corresponding area data based on entry of utility site information during application preparation.

5.3 FRANCE

A nationwide ten-year, multi-billion-euro project, involving French National Institute of Geographic and Forest Information (IGN) and France's utilities, is underway to improve the quality of the geolocation information about France's underground utility infrastructure.

The project is intended to map all underground utility infrastructure in 3D to an accuracy of 40cm.

5.4 OTHER INTERNATIONAL PILOT PROJECTS

I. SYDNEY DOWN UNDER

OVERVIEW

The NSW Emergency Information Coordination Unit (EICU) and the City of Sydney collaborated to develop an intelligent 3D model of buildings and infrastructure, above and below ground in the central business district (CBD), spread over an area of 2.8 square kilometres.

The Building and Infrastructure 3D database, developed in collaboration with major infrastructure agencies operating in the Sydney CBD, supports full attribute and 3D spatial queries on all features: buildings (both above and below ground), utilities and tunnels.

The strategy was to take data of existing underground infrastructure from asset owners along with above ground building data, and put it into a single database.

The data was held in a mix of databases with their own data models and was integrated using data integration software (Safe Software's FME solution).

In addition to the CBD's 3D model, it developed the Emergency Services Spatial Information Library (ESSIL), combining data from c. 200 agencies and c. 11,000 spatial layers into 350 seamless state-wide layers.

This is front-ended by the Spatial Information and Mapping System (SIMS), which bundles applications and data into an easy to use interface for decision makers.

CHALLENGES

- **Large dataset:** Requires big machines to manipulate and store it. Even with big machines, displays are overly cluttered
- **Scale:** The 3D dataset contains multi-storey buildings and single strands of wire – not possible to show both on the same screen at meaningful size
- **Accuracy and completeness:** No guarantee that all services are recorded in the data, and for those that are, they may not be shown in the right place

OUTCOME

The project has been underway for over five years, but only recently achieved the critical mass required to find broad application. While the project is focussed on emergency and disaster management, it has realised other savings by reducing infrastructure maintenance costs such as digging up streets, reducing public inconvenience and increasing responsiveness to faults.

Data from the 3D building and Infrastructure database has been used in the planning of major projects like the proposed Sydney Metro, the George Street light rail and the City of Sydney's Tri-generation Project. Further, it brings together into a single database, utility infrastructure together with buildings (above and below ground) including interior spaces. The project integrates 3D BIM and 2D spatial data.

II. CITY OF CHICAGO

Using the City of Chicago as a testbed for the platform's development, the pilot team is deploying the new technology to create an accurate 3D map of underground assets, located in city streets and alleys.

An engineering-grade, cloud-based data platform enables this critical infrastructure information to be securely stored and shared among city departments and utilities.

Following the completion of the initial prototype, the technology components will soon be deployed on a larger site, demonstrating the platform’s effectiveness in a real-world setting.

III. CALGARY, CANADA

The City Government passed a by-law which mandated that all utilities working within city limits to provide data showing the geolocation of their infrastructure to the city's Joint Utility Mapping Project (JUMP).

JUMP provides a single database that shows the geolocation of all underground utilities.

IV. STATE OF JALISCO, MEXICO

The Instituto de Información Territorial del Estado de Jalisco developed an integrated infrastructure database, SITEL, for the State of Jalisco.

The project integrates more than 2,500 layers of information that can be consulted online and publishes more than 70 Web services allowing users to access vector images and cartography online using GIS and other applications.

V. PENANG, MALAYSIA

Penang-s Sutra D'Bank (Penang State Government Subterranean Data Bank), formed as a joint venture between Equarater Sdn Bhd (ESB) and the Penang Development Corporation, serves as an integrated database of all utilities underground data.

The joint venture was given a concession for a period of thirty (30) years to systematically build-up of the database. All the underground utility network is surveyed, detected and located using specialised equipment., before being converted into digital maps with 2D or 3D images.

VI. BRAZIL

Sao Paulo: The City of Sao Paulo's GeoCONVIAS project integrates data from 20 to 30 utilities which operate in the city of Sao Paulo.

Utilities are not asked to provide detailed information about their underground facilities, just "a simple line" showing the location of their facilities. The system now has c.95% of the permissible underground networks and estimated 30% of the drainage cadastre.

Rio de Janeiro: The City of Rio de Janeiro has a similar project GeoVias funded by the government of the City of Rio de Janeiro and four utilities.

THE 'WHY BOTHER?' PROBLEM

There is a general lack of awareness of data availability and a lot of uncertainty about how the data can be used

Geoscientist and Team Lead (Survey Respondent)

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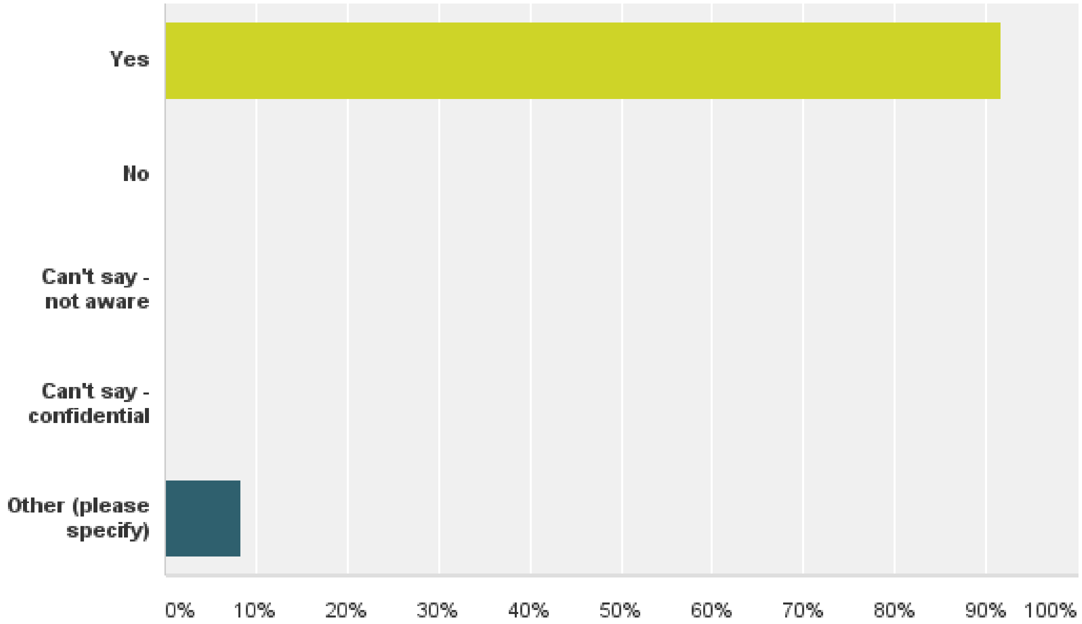
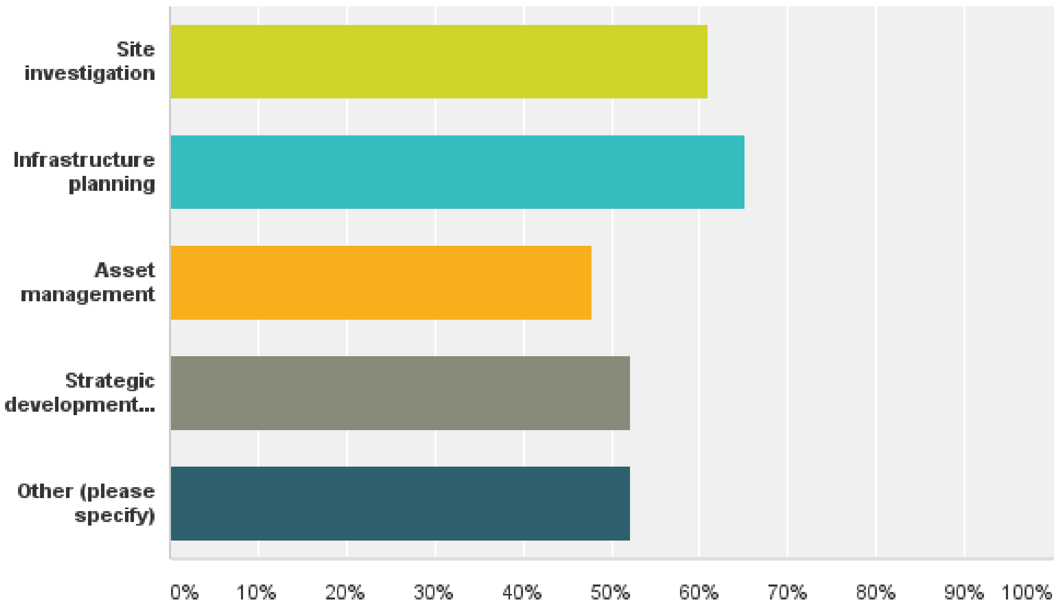
6. APPENDIX – SURVEY RESULTS

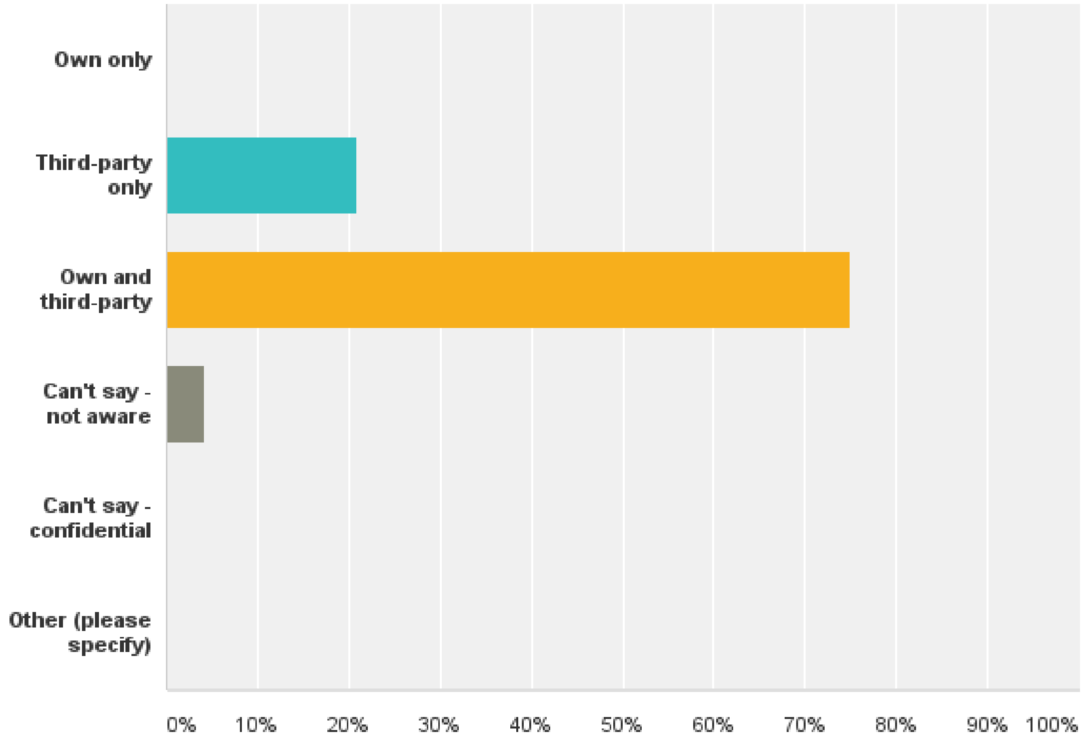
Q1 Does your organisation use subsurface information (e.g. location of buried assets, ground properties, buried assets' functionality)?



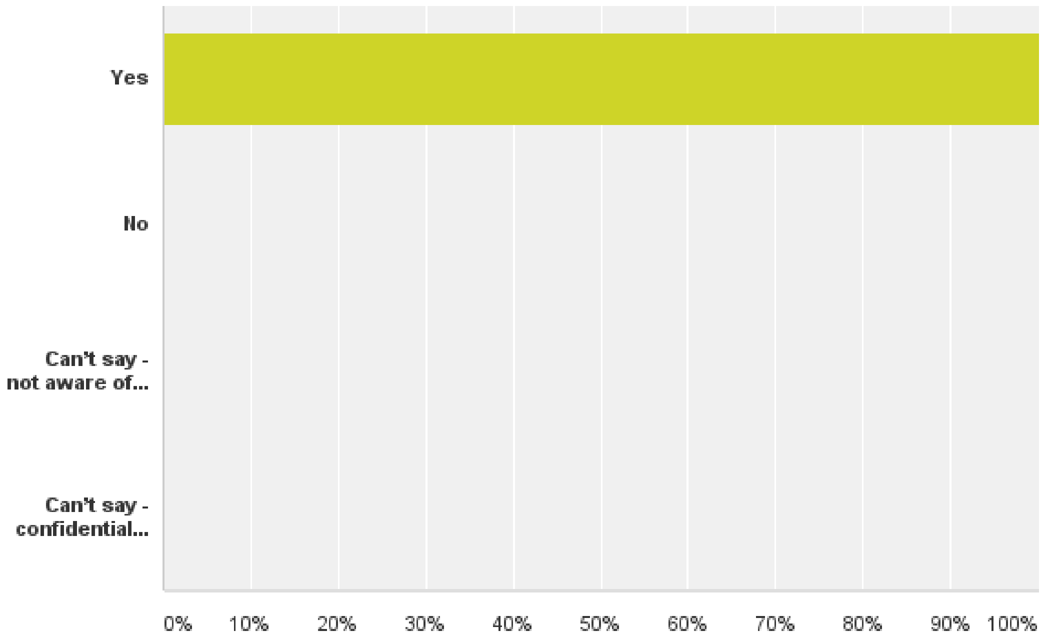
Q2 If yes, what is the subsurface information used for?



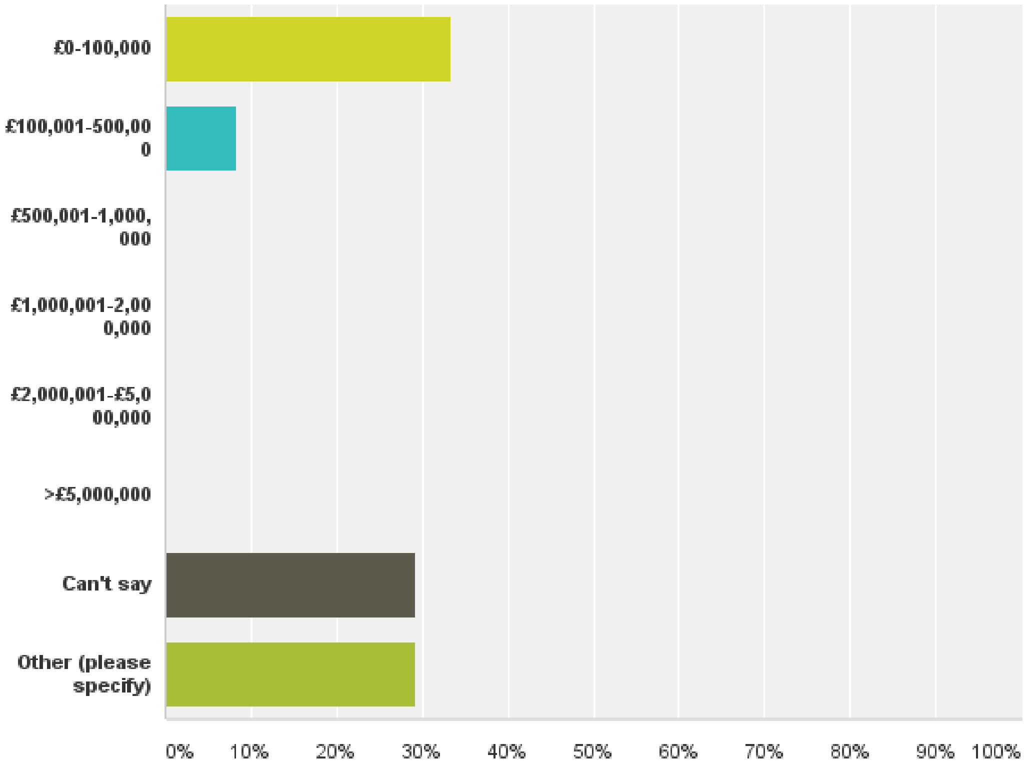
Q3 Does your organisation use only its own subsurface data, or does it also use third party data?



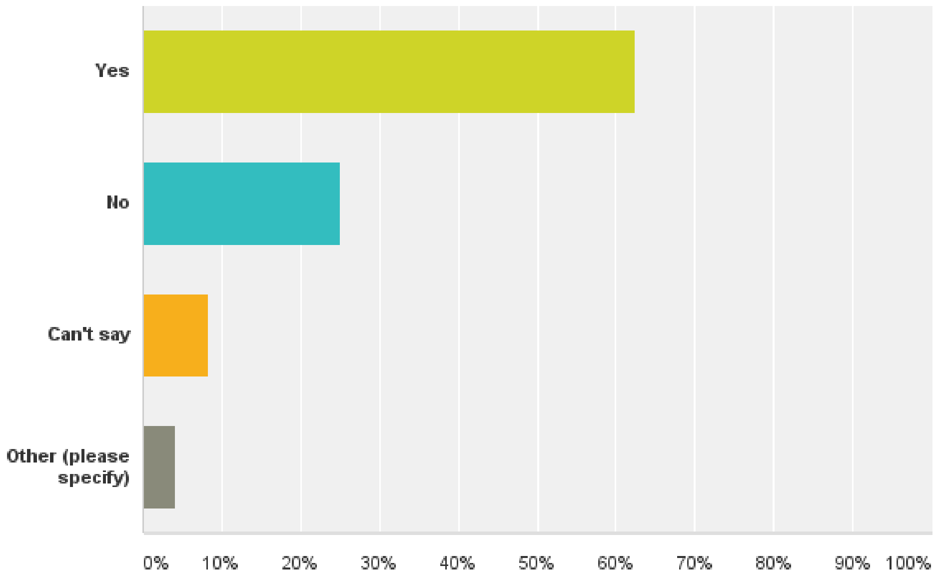
Q4 If not currently, do you think subsurface information would be useful for your organisation in the near future?



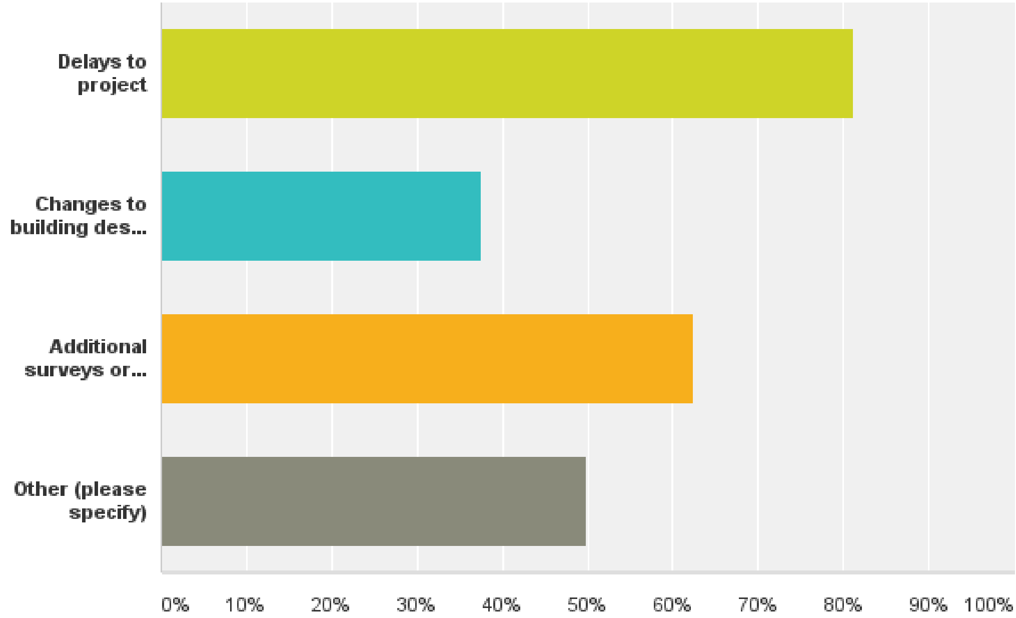
Q5 On a high-level basis, how much does your organisation currently spend on acquiring subsurface data from third parties per annum?



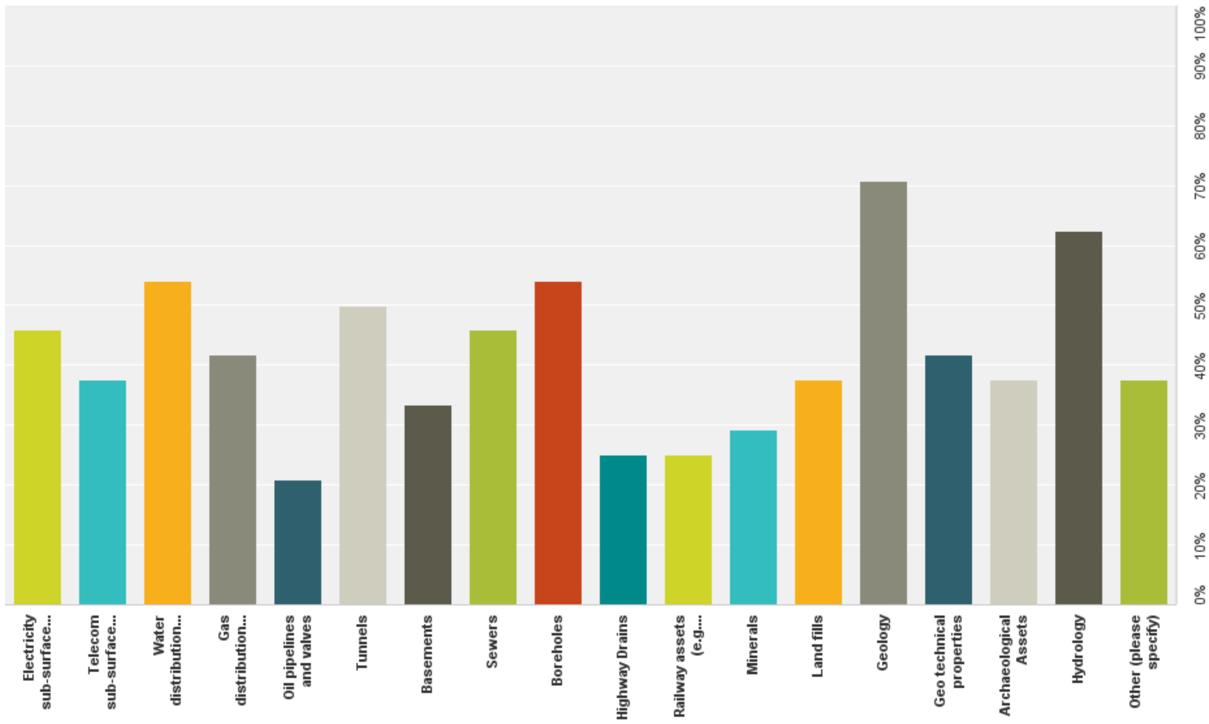
Q6 Does your organisation incur indirect costs because of incomplete information about the subsurface, e.g. delays to projects?



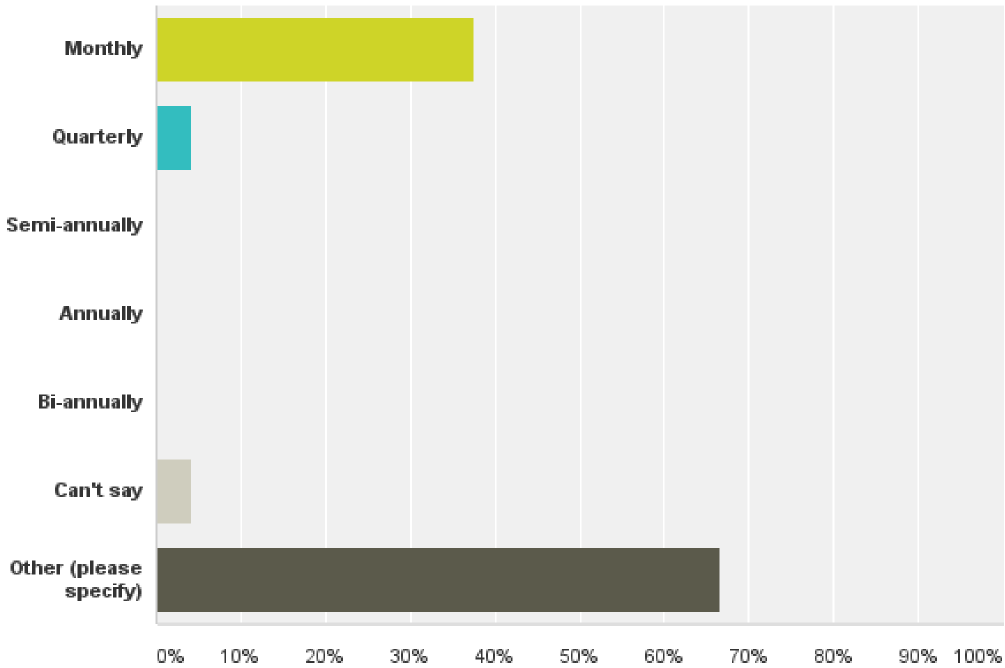
Q7 If yes, in what way is your organisation affected?



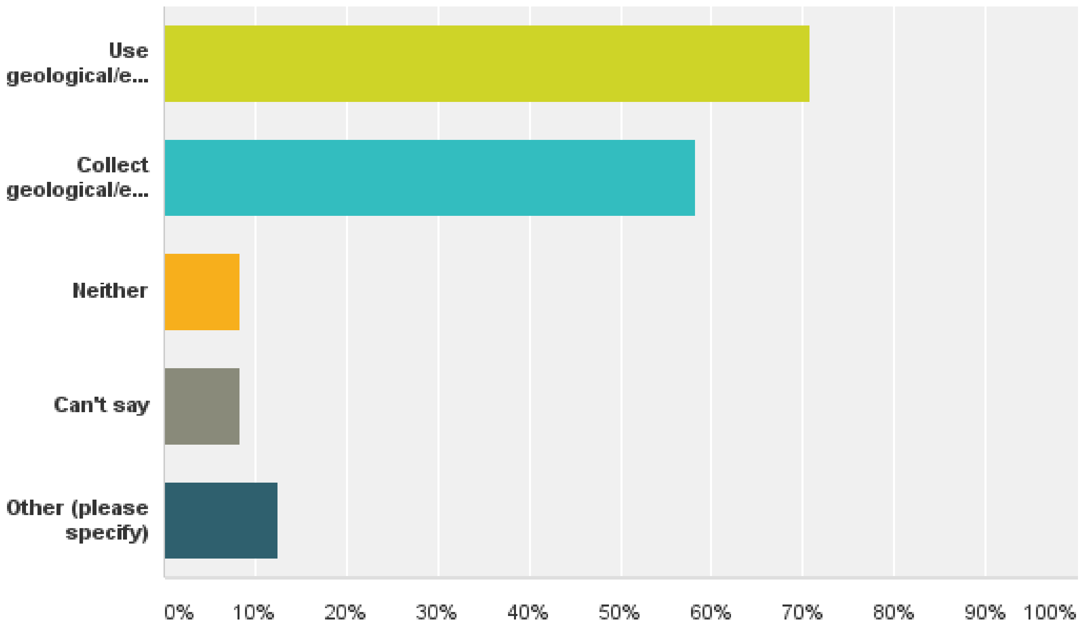
Q8 What subsurface assets and/or subsurface information does your organisation currently have?



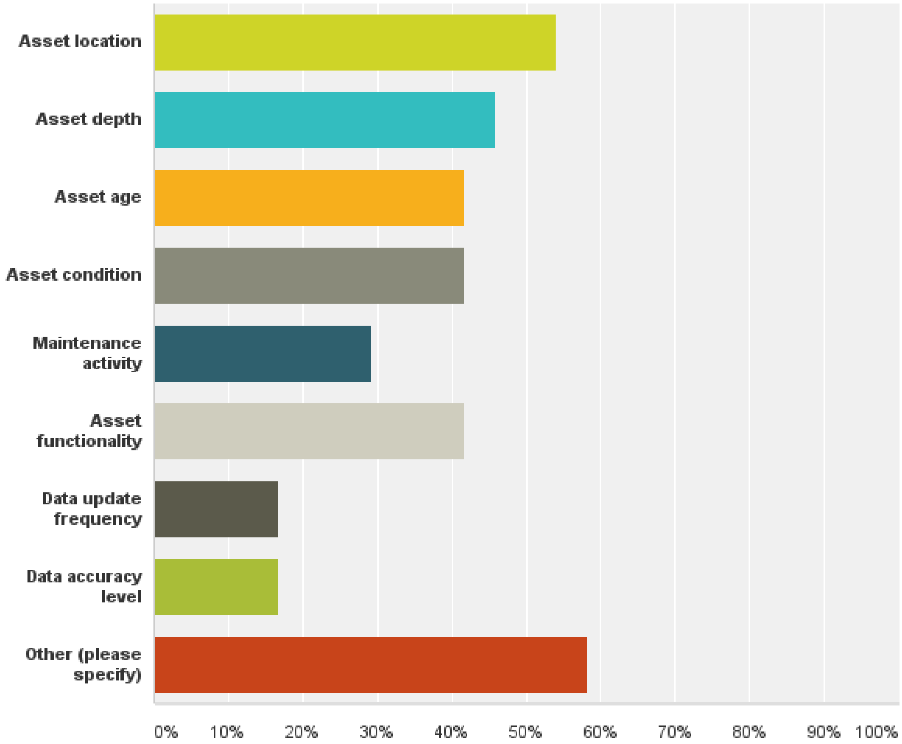
Q9 How often do you need to access subsurface assets or information?



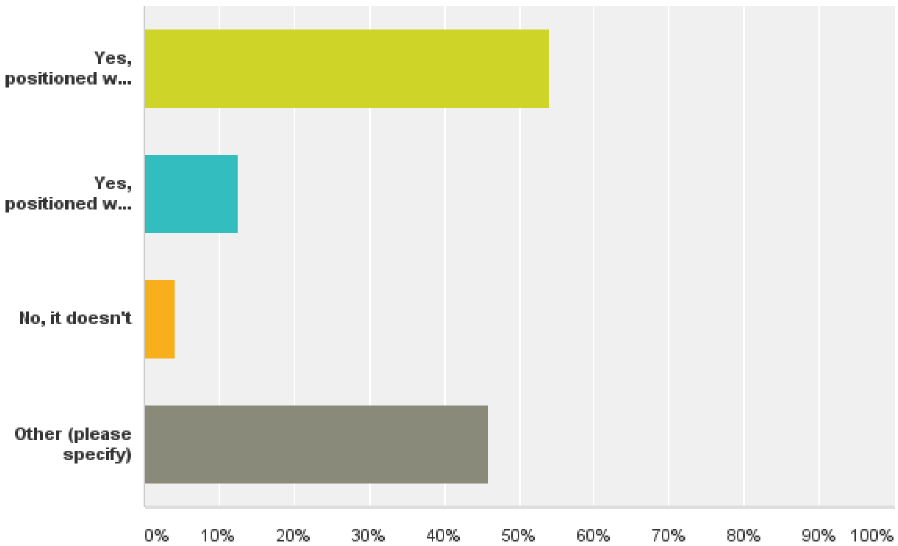
Q10 Does your organisation use or collect geological or engineering property information about the subsurface?



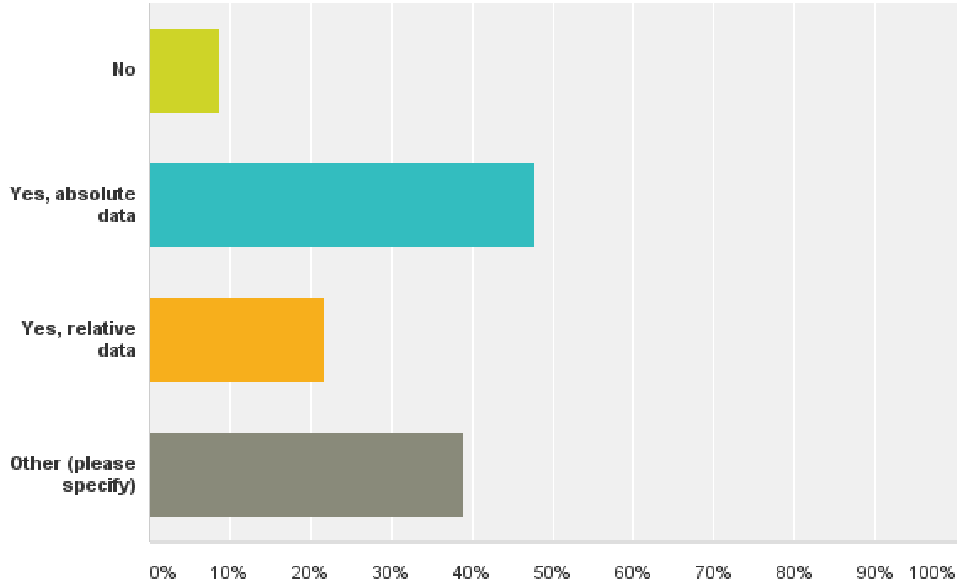
Q11 What information does your organisation currently capture about subsurface assets?



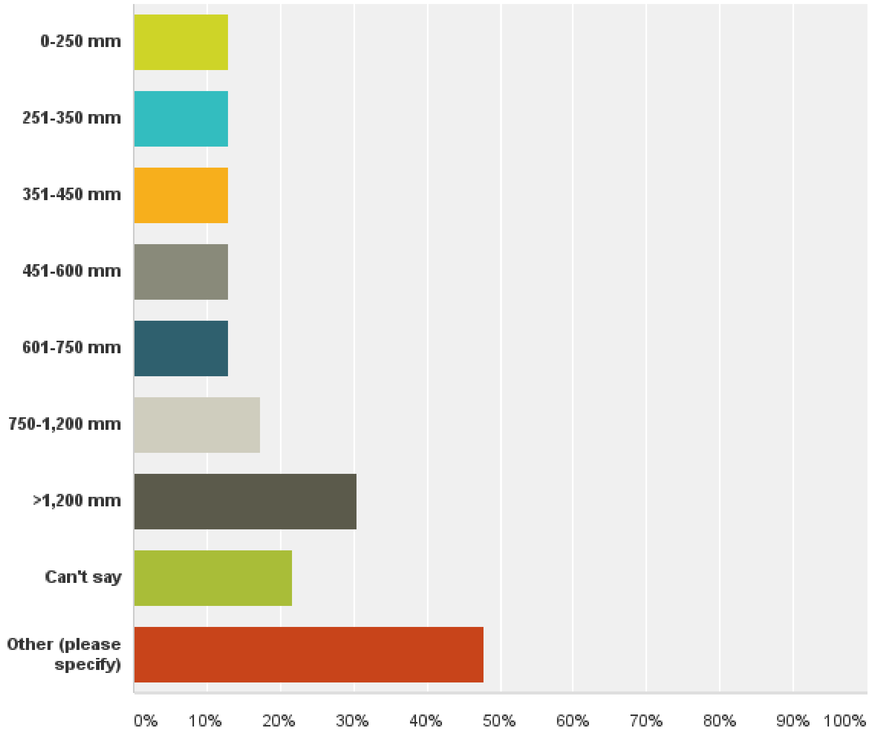
Q12 Does your organisation map the location of its underground assets?



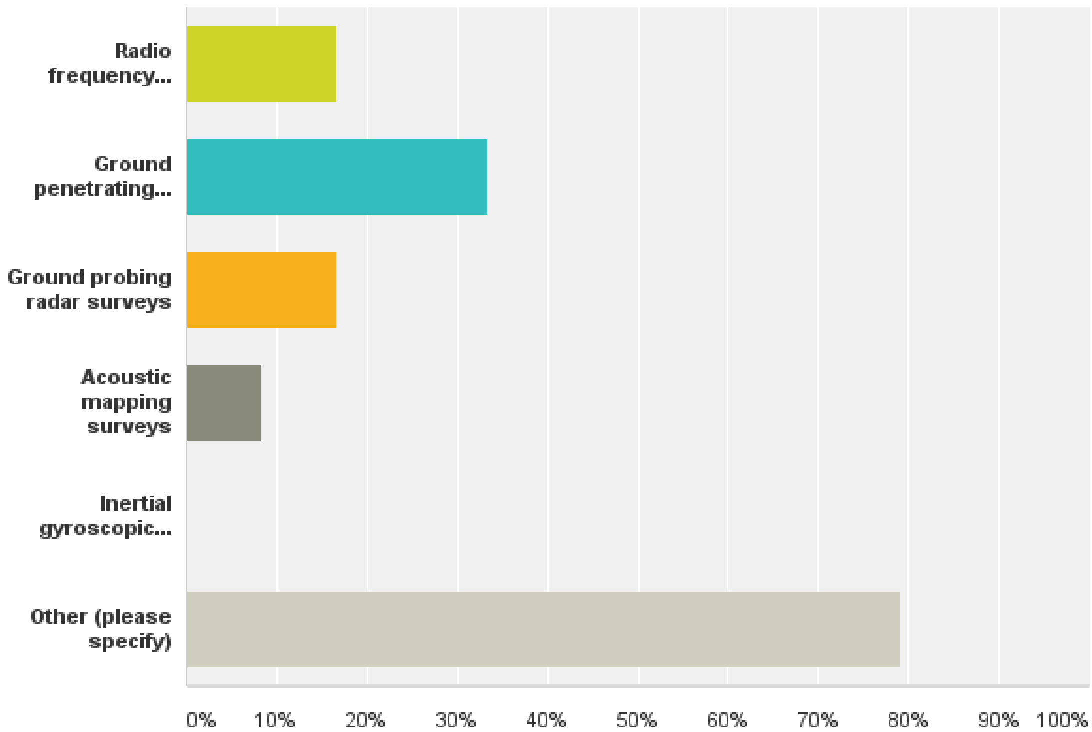
Q13 Does the information referenced in Q12 contain additional data about the depth of your organisation's assets? Is this relative or absolute?



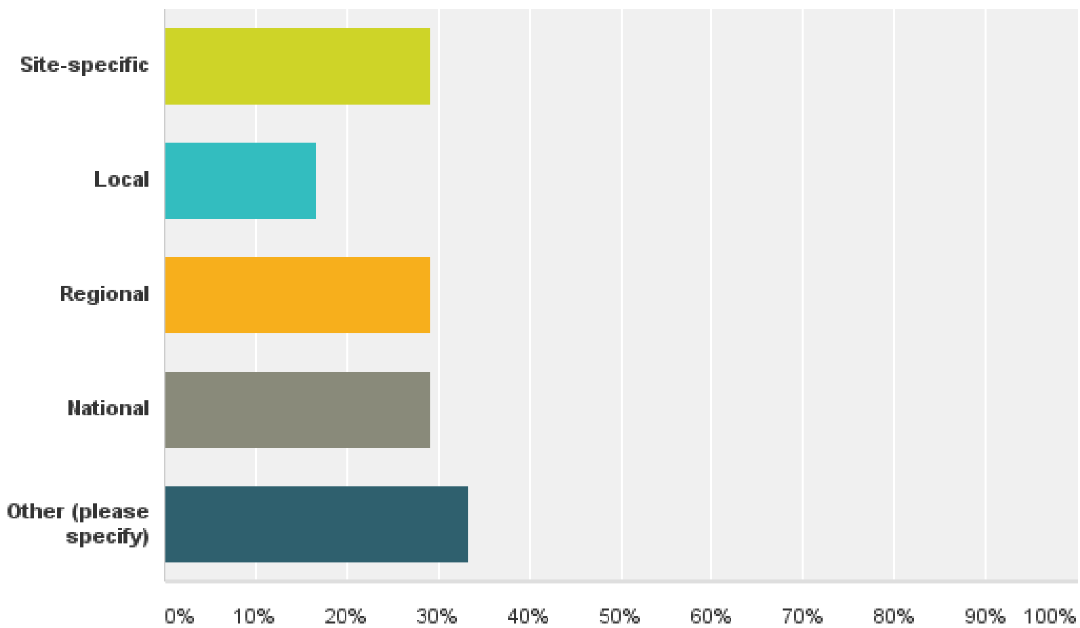
Q14 If known, what is usually the depth of your subsurface assets or data?



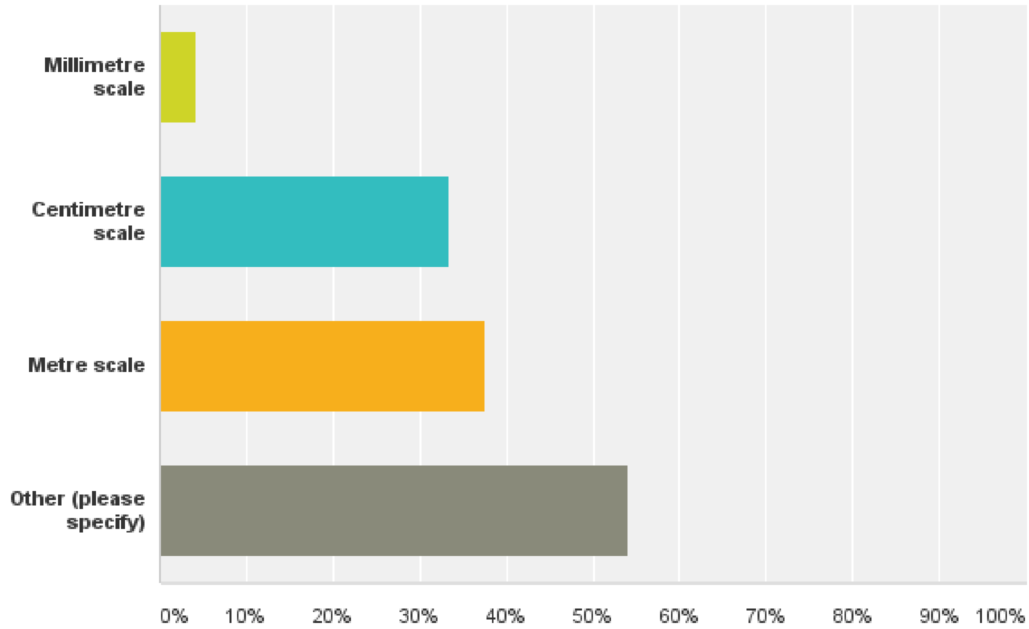
Q15 What technology/tools/surveys does your organisation use to obtain information about the location of the underground assets?



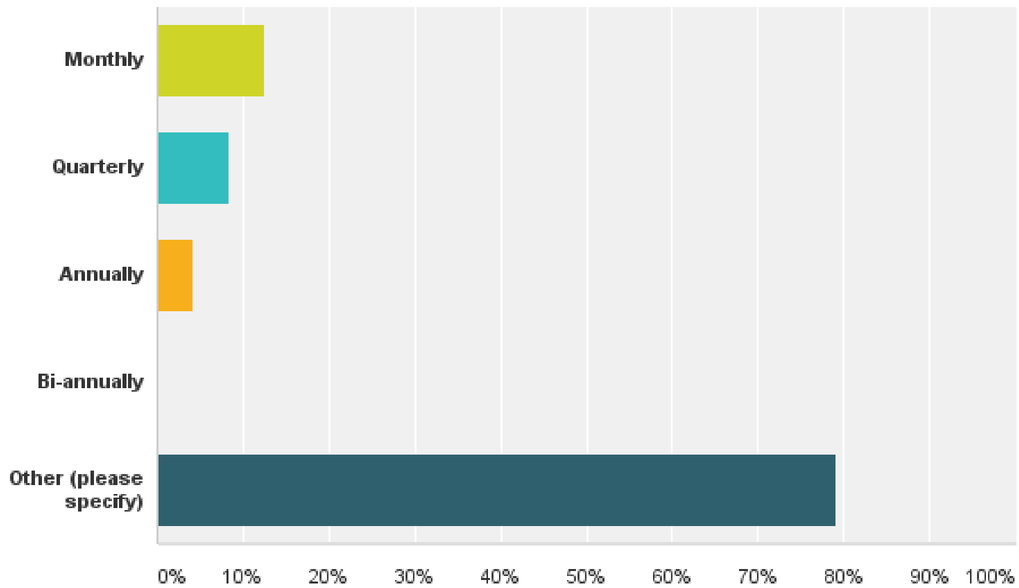
Q16 What is the geographic coverage of your organisation's subsurface assets/data?



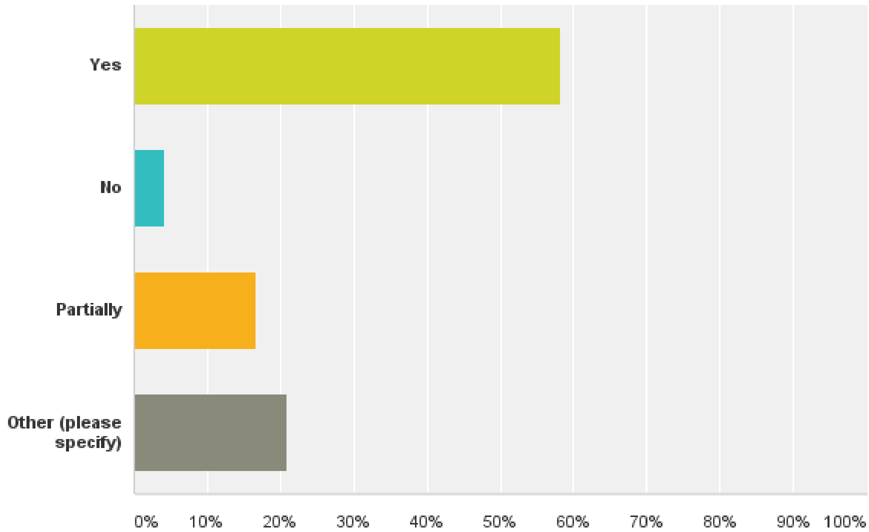
Q17 What is the positional accuracy scale of your organisation's subsurface data?



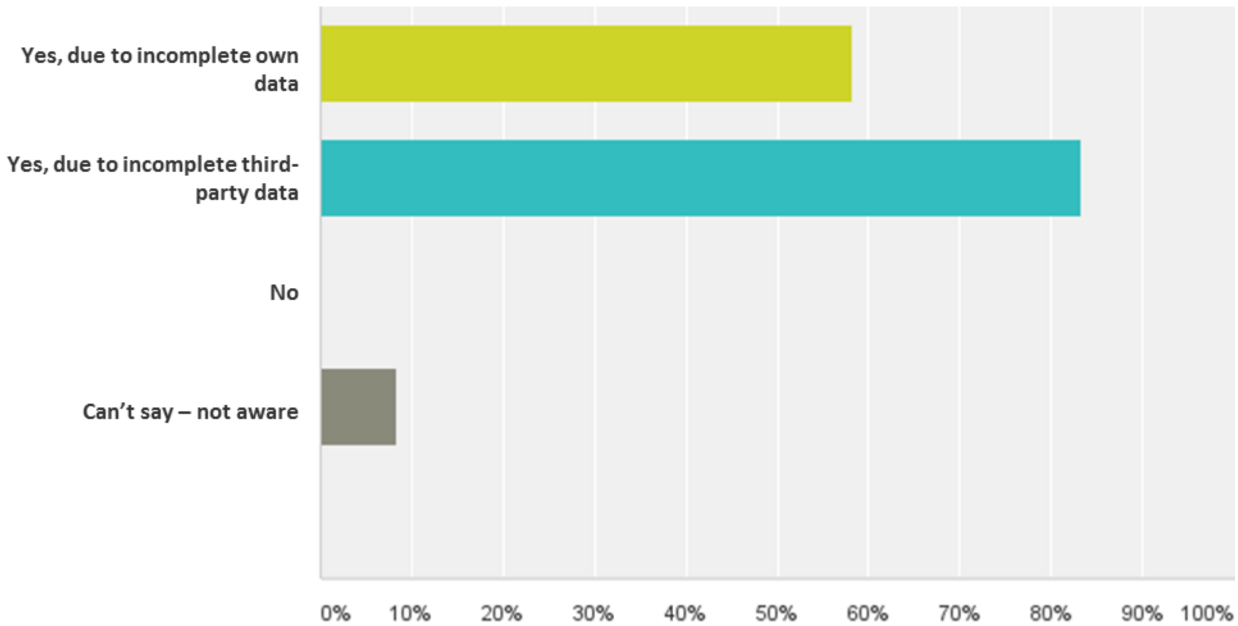
Q18 How often is this data updated?



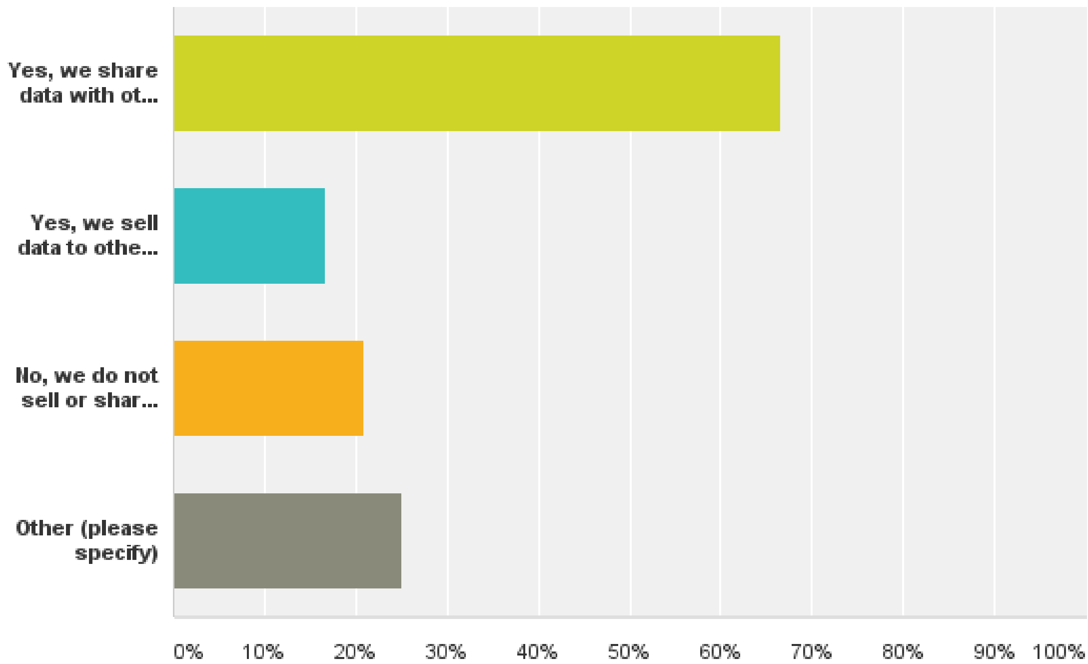
Q19 Is this data in a digital format?



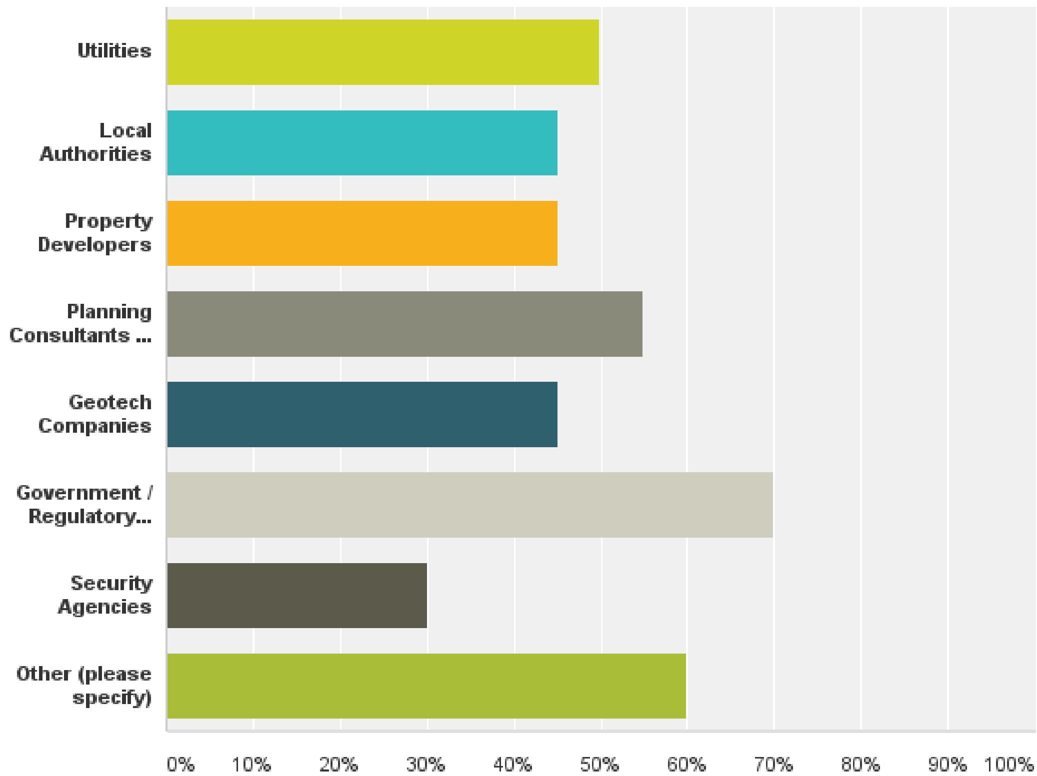
Q20 Do you currently face challenges occurring due to incomplete subsurface data?



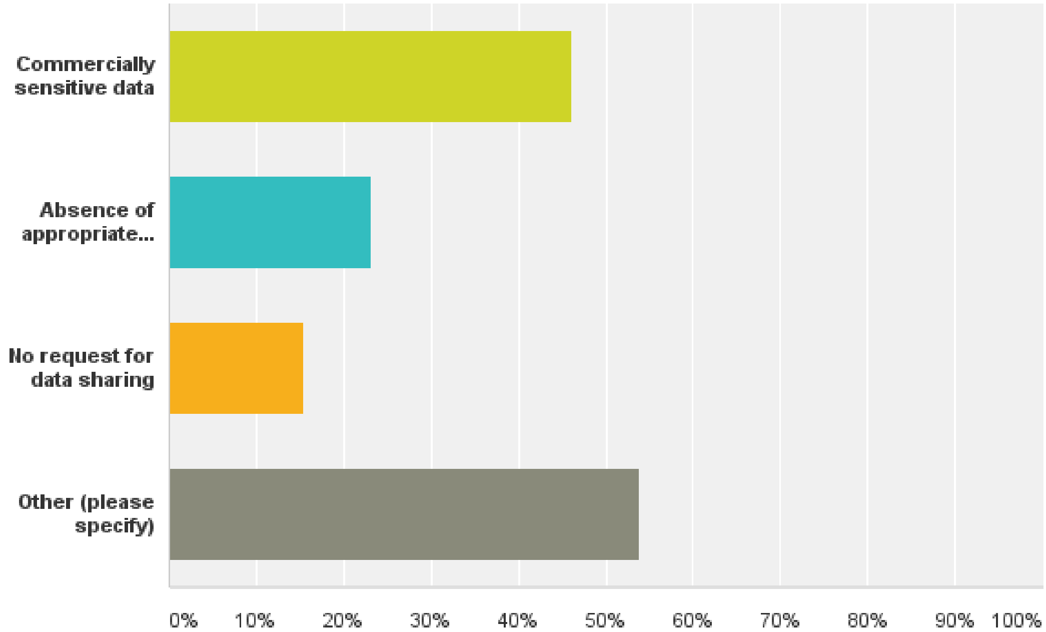
Q21 Does your organisation currently share/sell its subsurface data?



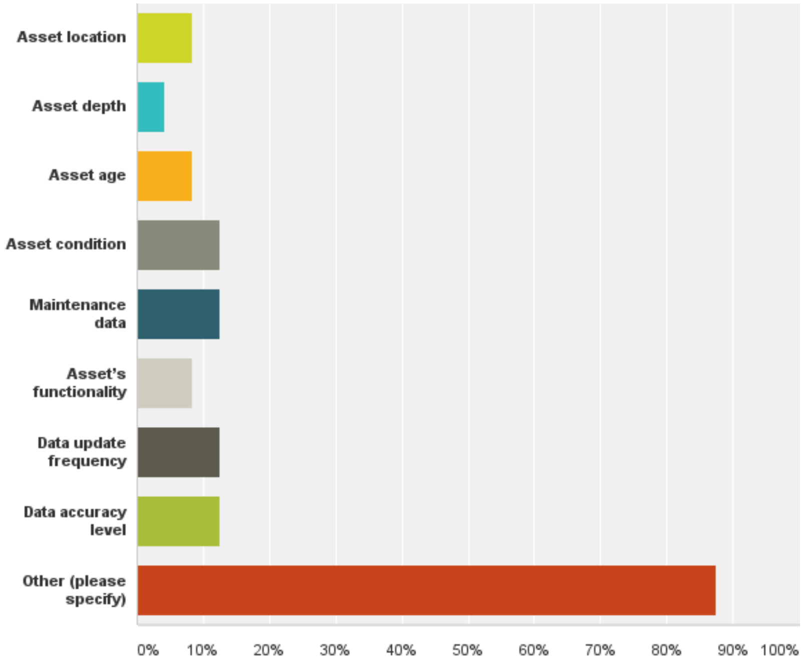
Q22 If yes, who does it share/sell the data to?



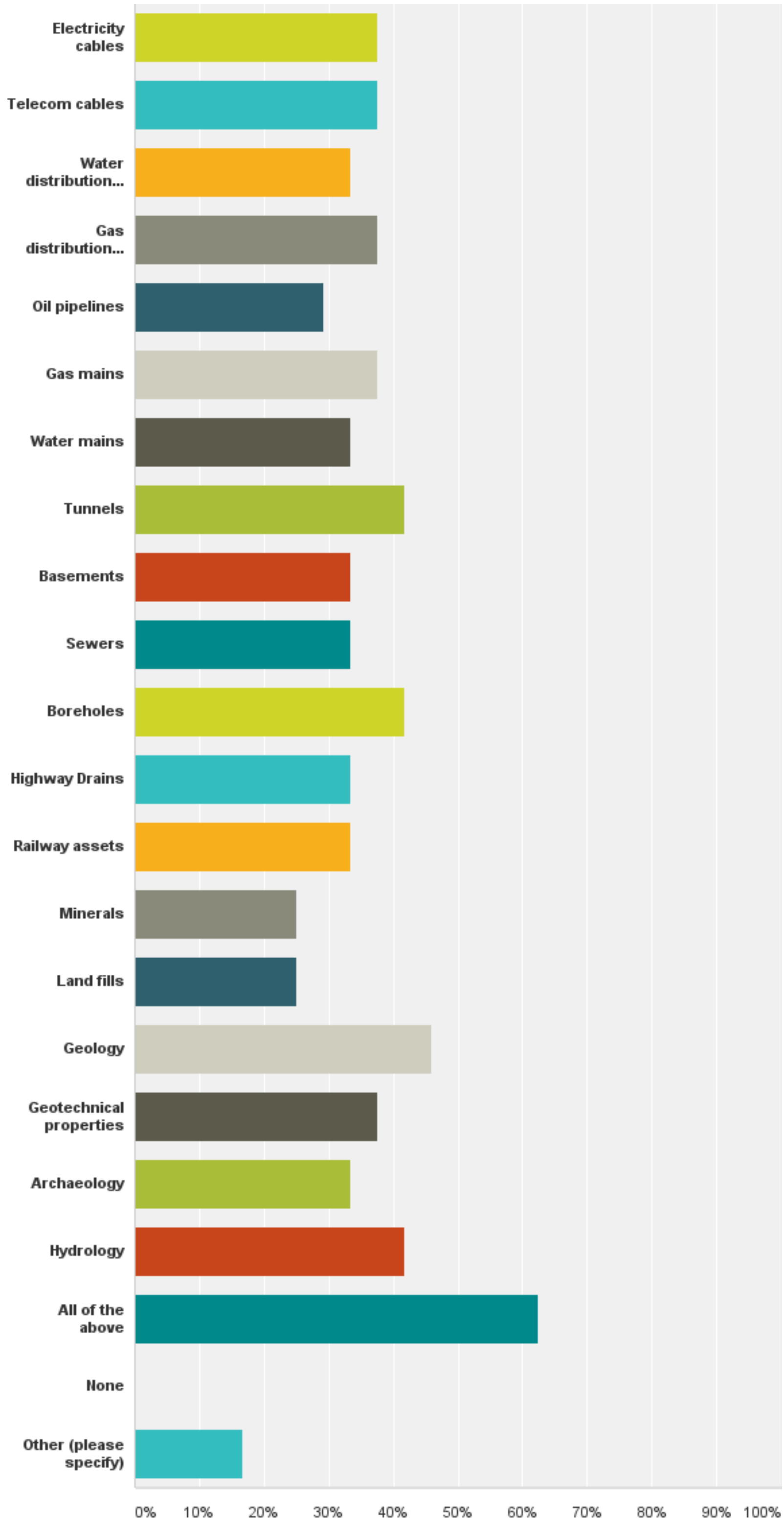
Q23 If no, what are the main reasons stopping it from sharing/selling the data?



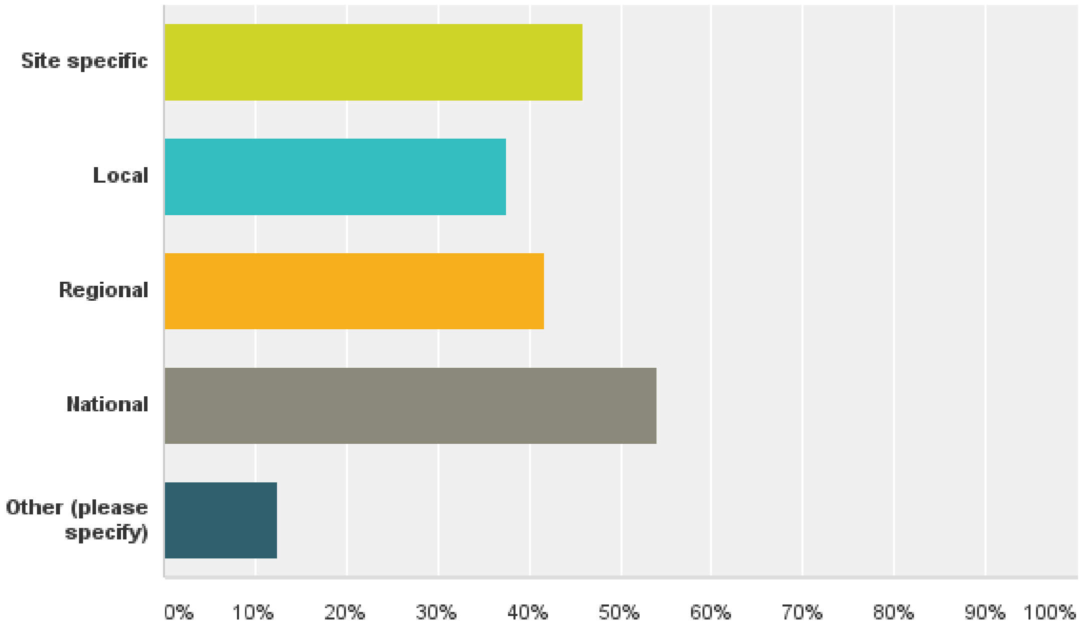
Q24 What information relating to your organisation's subsurface assets would you be reluctant to share and why?



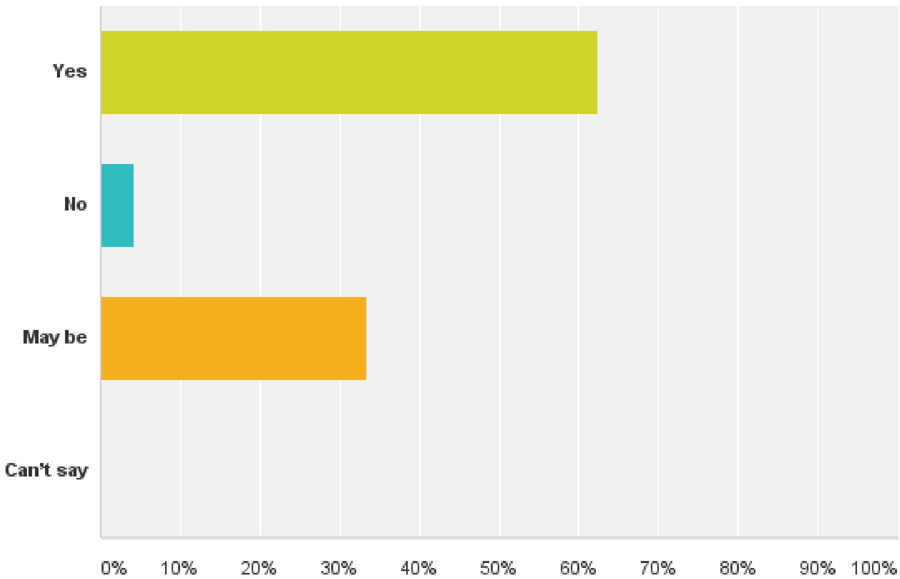
Q25 Which subsurface assets/asset data would you like to have data access to?



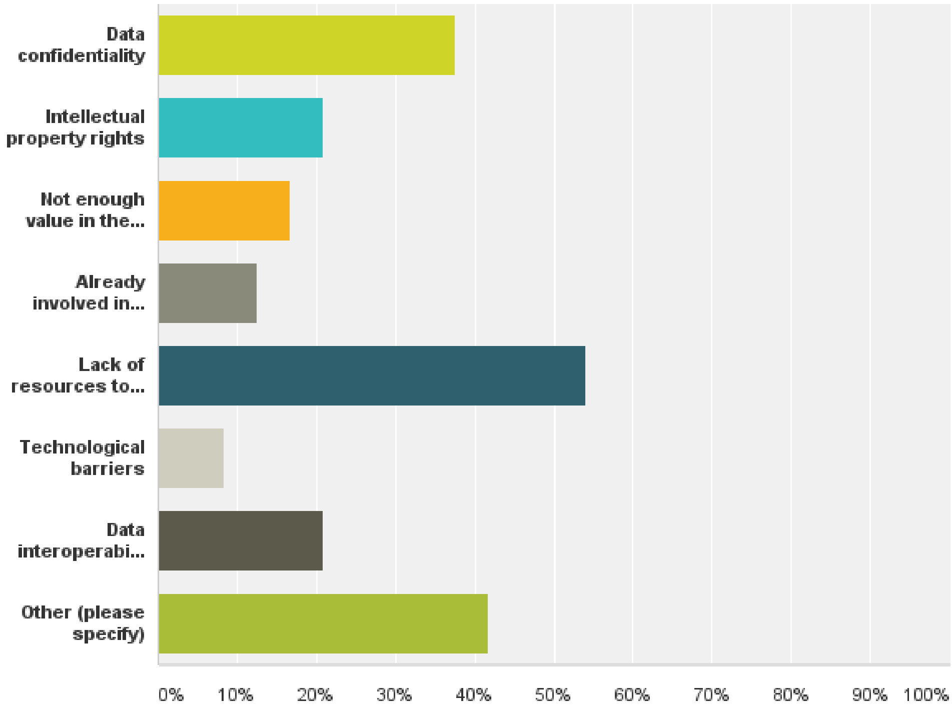
Q26 What geographic coverage would you require for data/information on these subsurface assets?



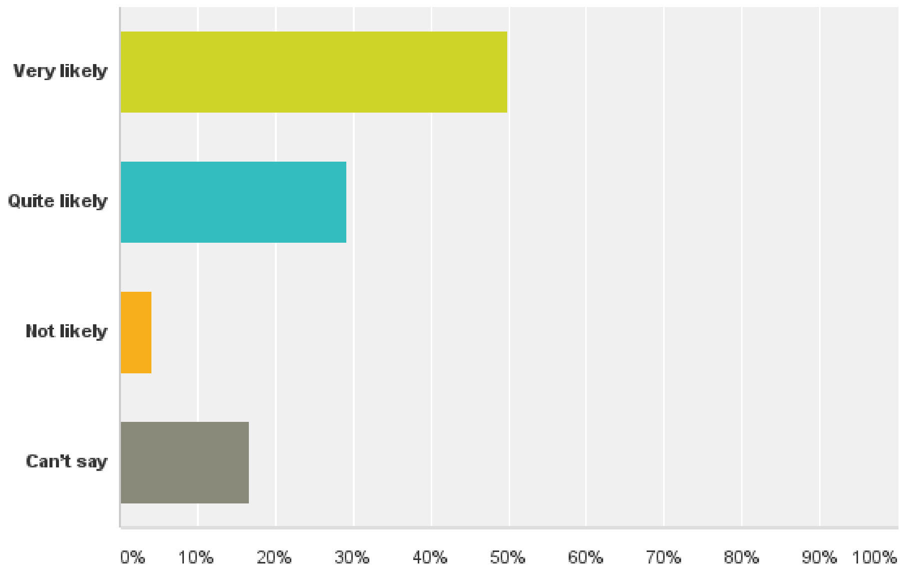
Q27 Do you think a single subsurface data exchange platform, capable of providing a complete view of the subsurface, would be beneficial to your organisation?



Q28 What specific factors would stop your organisation from participating in a project such as this?



Q29 How likely would your organisation collaborate on such a project if it meant you could have a complete view of the subsurface?



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