Opening up the subsurface for the cities of tomorrow

Integrated design in… Urban infrastructures - *Subsurface*

Dr. Diarmad Campbell
British Geological Survey, Edinburgh

& Ignace van Campenhout, Fransje Hooimeijer, Stephanie Bricker, Carl Watson, Jeroen Schokker, Susie Mielby, Ingelov Erikkson, Michiel van der Meulen et al.

sdgc@bgs.ac.uk

Deltas, Infrastructures, and Mobility Initiative – DIMI On Tour
Orange Room, Library, TU Delft, 24.04.19

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Population Growth




Natural resource consumption




Physical expansion of cities




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In an increasingly urban world, cities are engines for growth; foci of economic activity; but are vulnerable

Cities cover

2% Earth surface

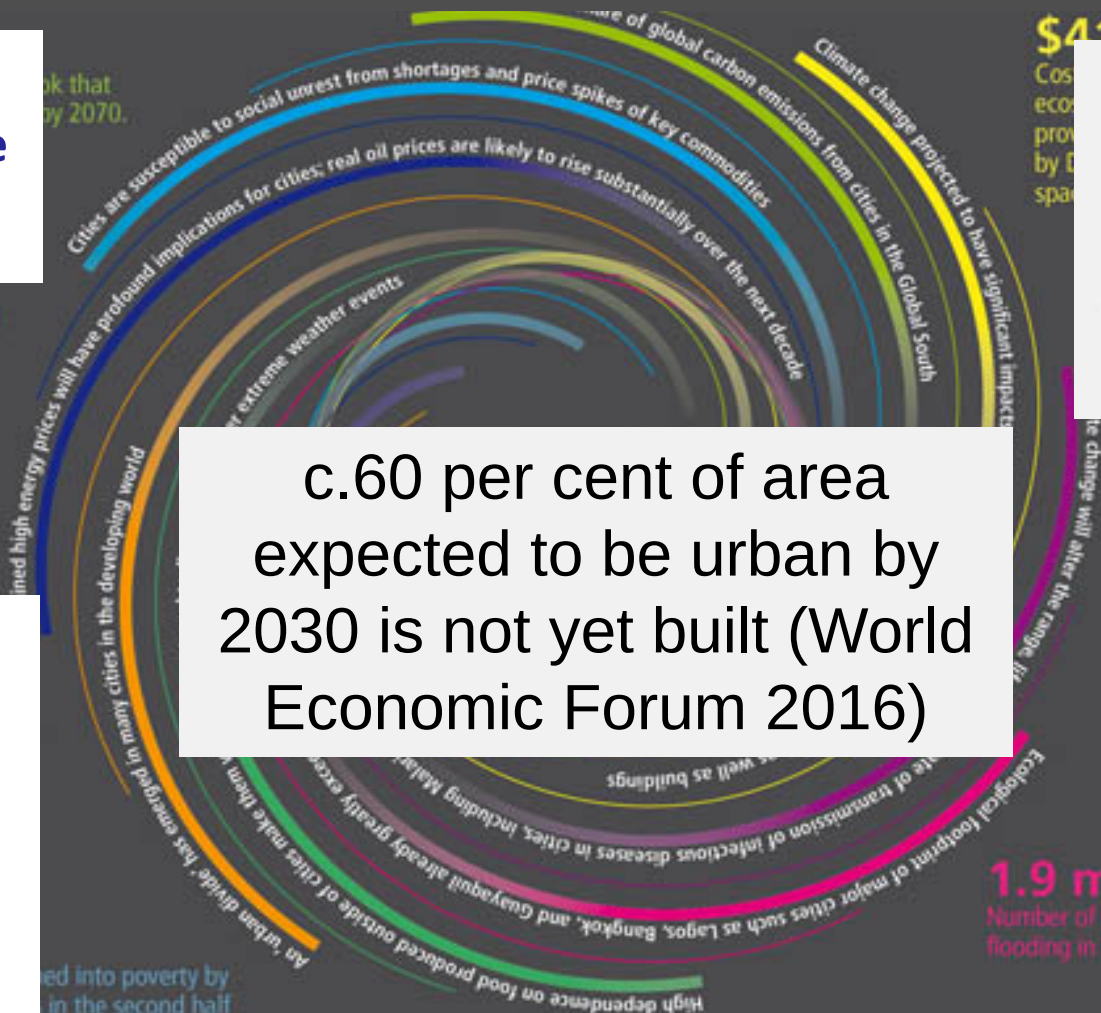
56% population

Cities account for

80% of world consumption

Top 600 cities will generate 65% of world economic growth by 2025 – and focus development

Mckinsey 2012: Urban world report



c.60 per cent of area expected to be urban by 2030 is not yet built (World Economic Forum 2016)

THE GLOBAL GOALS
For Sustainable Development

11 SUSTAINABLE CITIES AND COMMUNITIES

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

6 CLEAN WATER AND SANITATION

© Atkins, Future Proofing Cities (2012)

Global urban populations 2013 = 56% (c.3.5 billion people); 2030 = 60-70%; 2050 = 70-80%

UKaid Department for International Development | ATKINS | UCL | FUTURE PROOFING CITIES

Urban Growth

'Globally, 60% of the area expected to be urban by 2030 is yet to be built'

WORLD ECONOMIC FORUM

COMMITTED TO IMPROVING THE STATE OF THE WORLD

Industry Agenda

Inspiring Future Cities & Urban Services

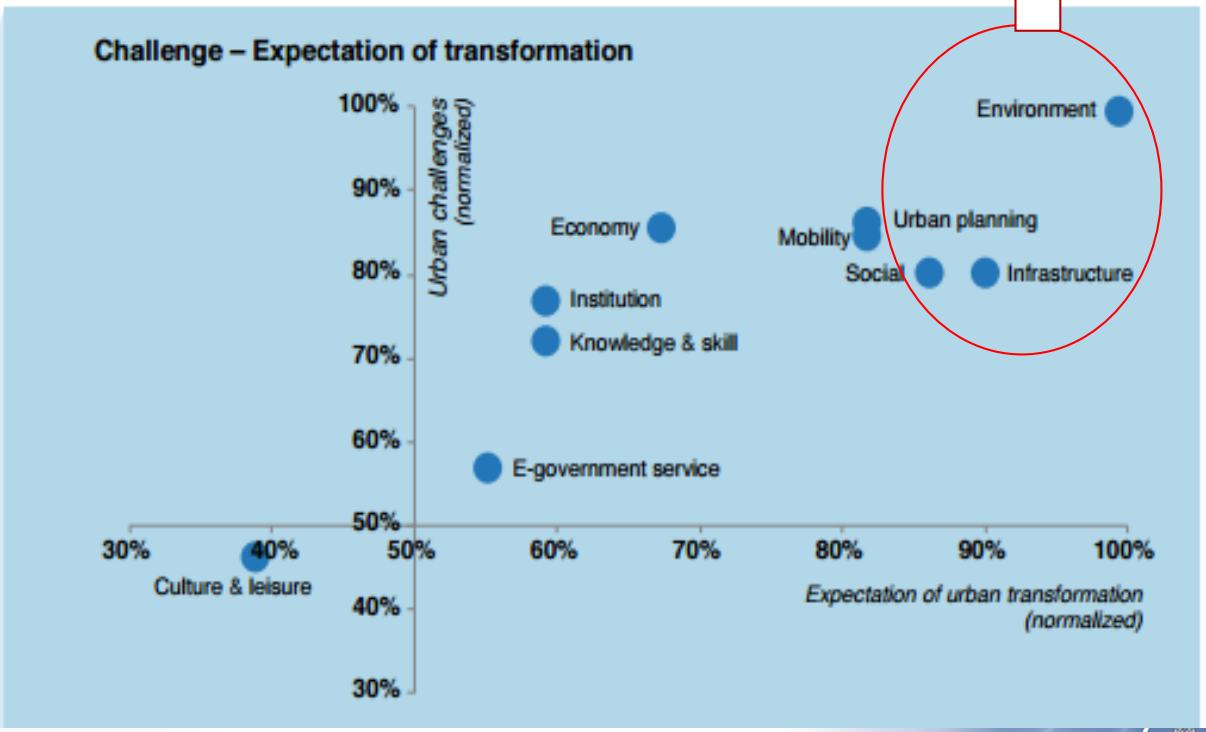
Shaping the Future of Urban Development & Services Initiative

April 2016

Geology

Expected transformation:

- Environment
- Urban planning
- Infrastructure



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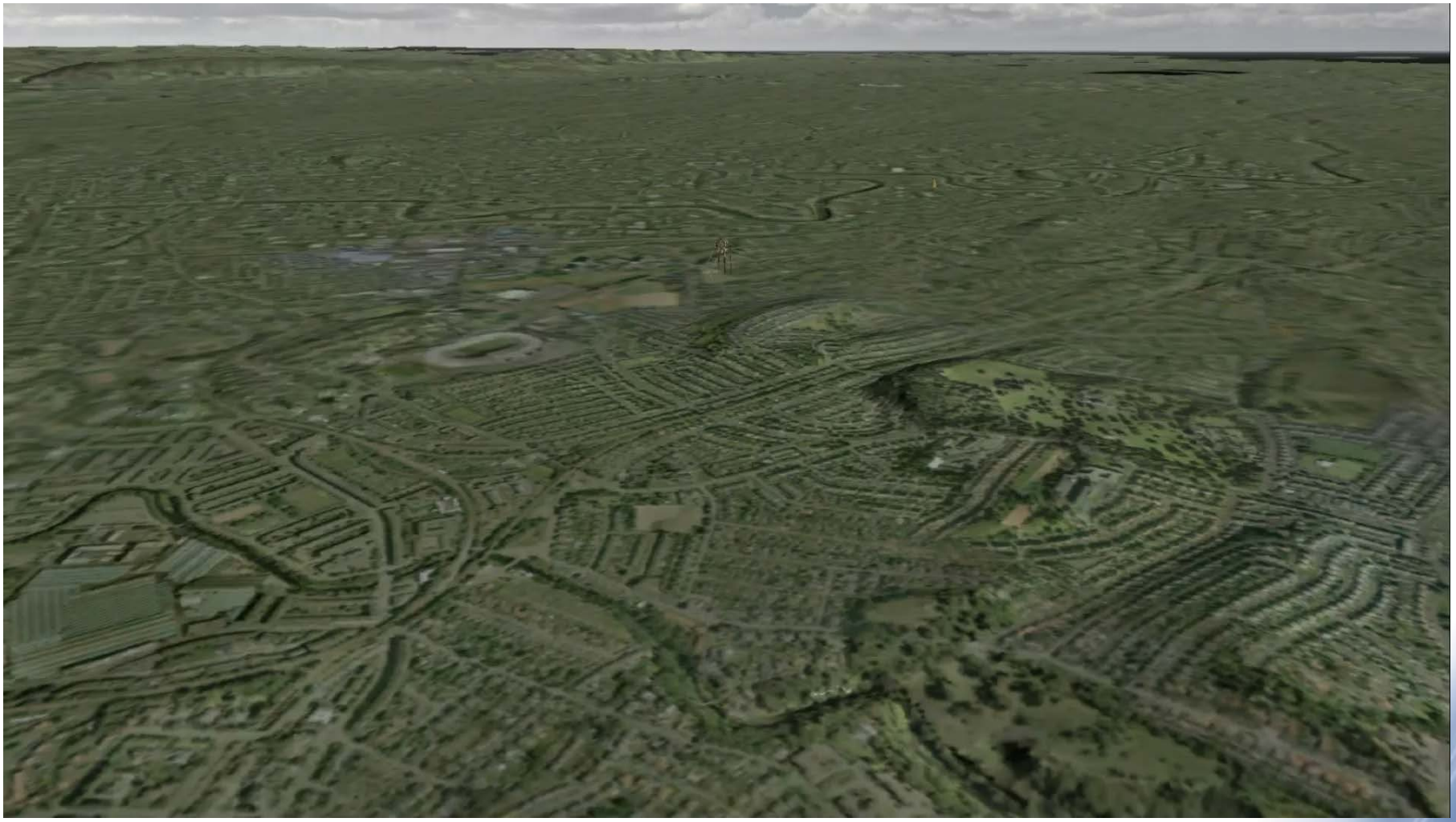
The importance of the urban Sub-Surface ...?

Contains elevation data from Intermap Technologies®: NEXTMAP



Improve Communication, e.g. Visualisation

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Urban Geoscience: Linking the natural and the built environment

Why is geology important?

Ecosystem services

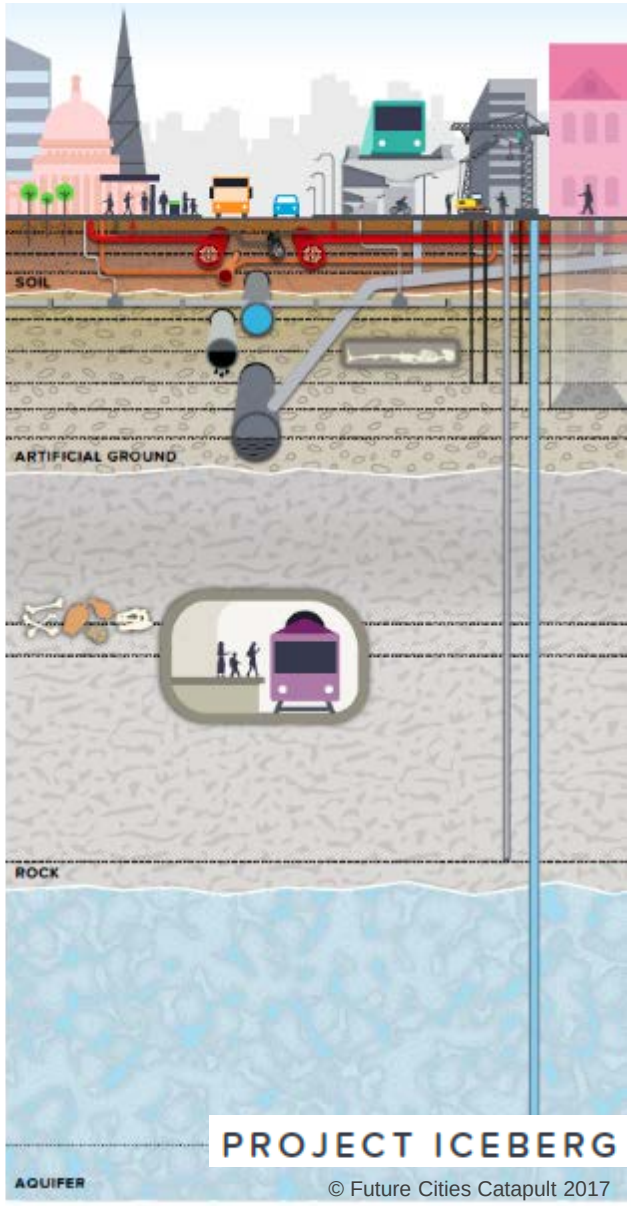
- Natural resources
- Waste regulation
- Platform for construction
- Green infrastructure

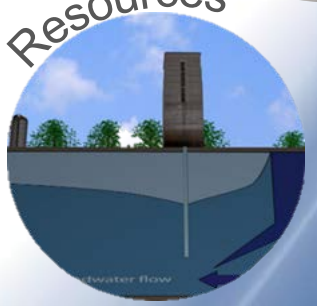
Geo-hazards

- Urban ground conditions
- Risks to infrastructure
- Impact on lives

Anthropogenic impacts

- Made ground
- Ground subsidence
- Land quality





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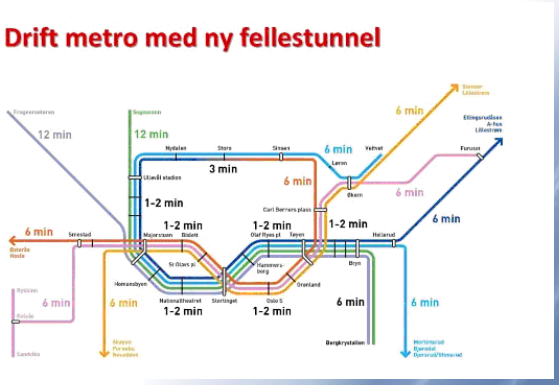
But the importance of ground beneath cities in ensuring their sustainability and resilience often poorly recognised – some exceptions: Helsinki, Montreal...

And the situation is changing ... as the subsurface clearly has a role in urban resilience and sustainability



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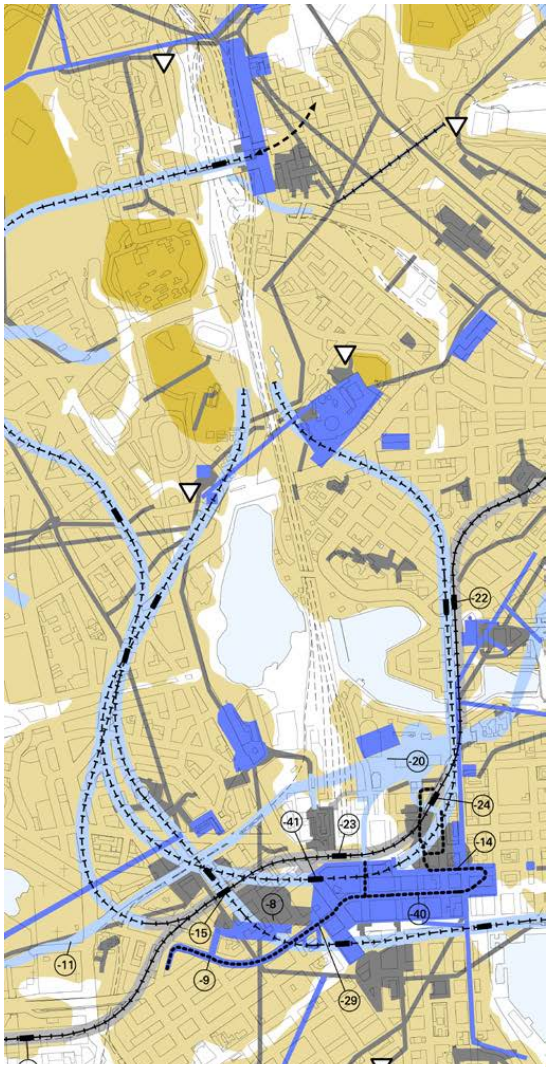
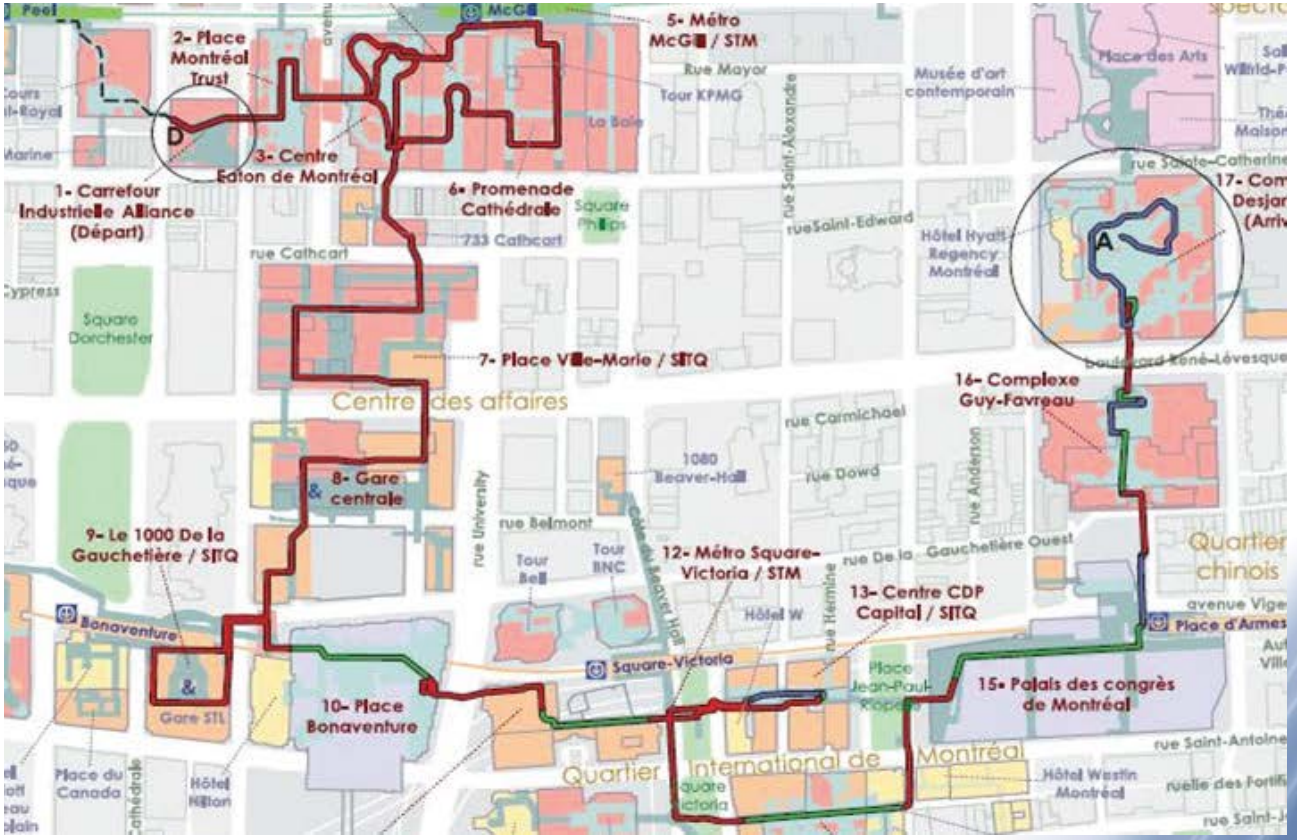


Montreal's Underground Network

privately-developed, climate-protected pedestian zone

Source: Observatoire de la Ville Intérieure

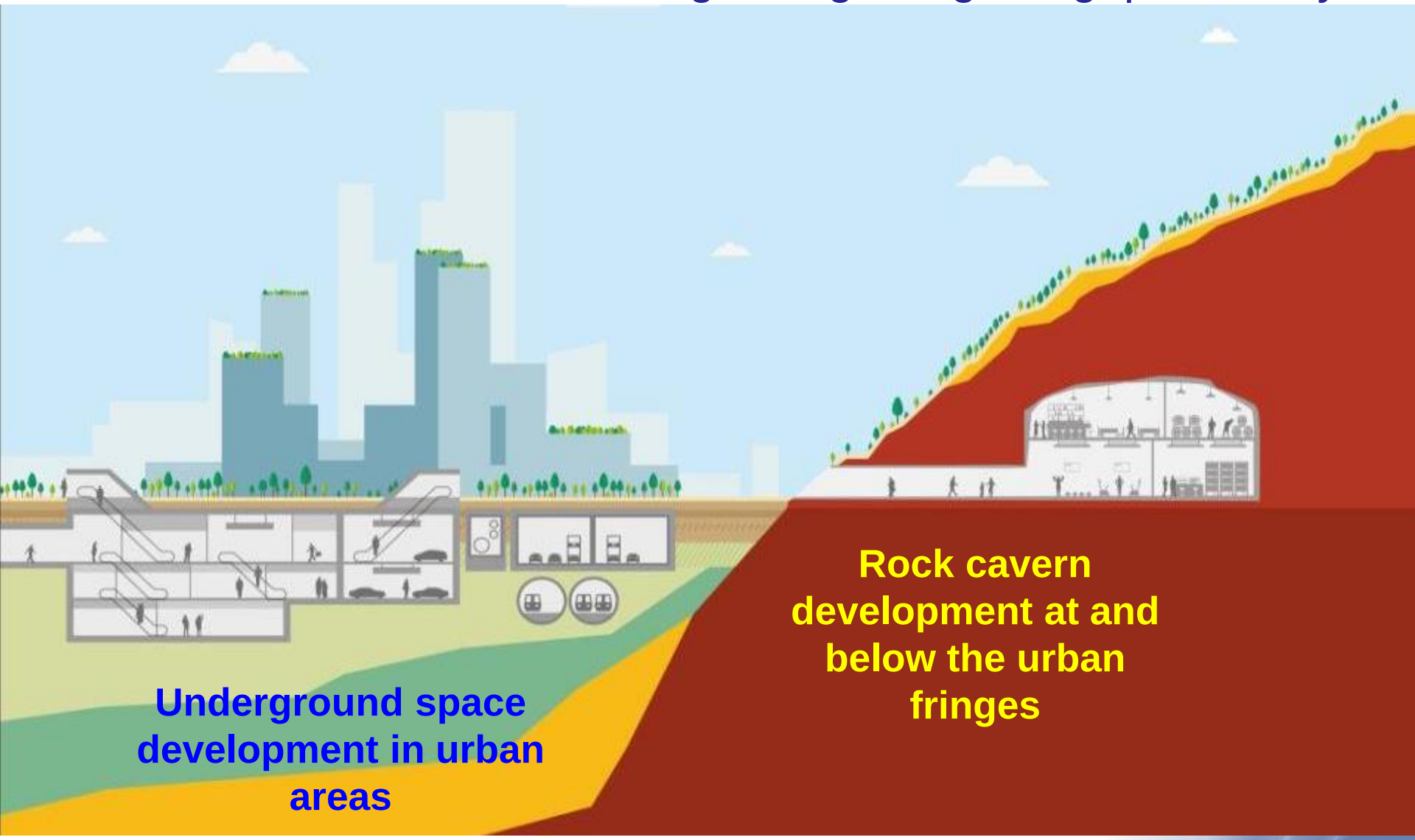


Helsinki

Reservation of underground space

© City of Helsinki

Greater Uses Made of Subsurface Where: Economic & Climatic Drivers, e.g. Hong Kong, Singapore, Tokyo..



© Hong Kong SAR Government

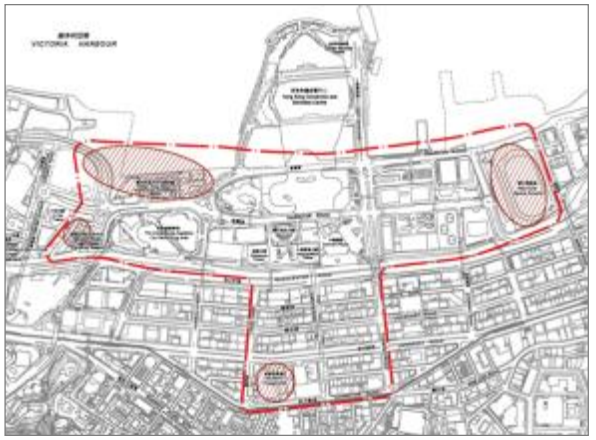
Strategic Areas in Hong Kong for Underground Development

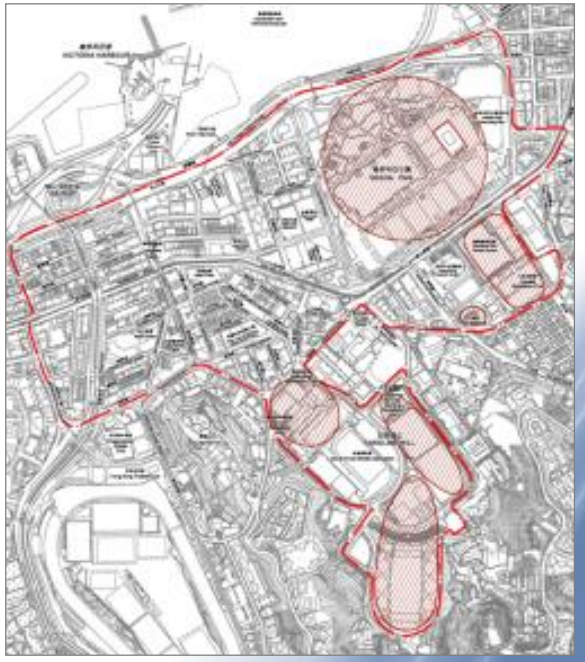
- Urban areas of high commercial, entertainment and tourism activities;
- Limited new land supply has hindered further development and improvement to the built environment
- Increasing traffic congestion and pedestrian overcrowding

✓ U/G space development could provide solution space to address these urban issues.

- High development potential brought by existing and/or planned MTR/transport network.

✓ U/G space development could decongest heavy pedestrian flow at ground level.





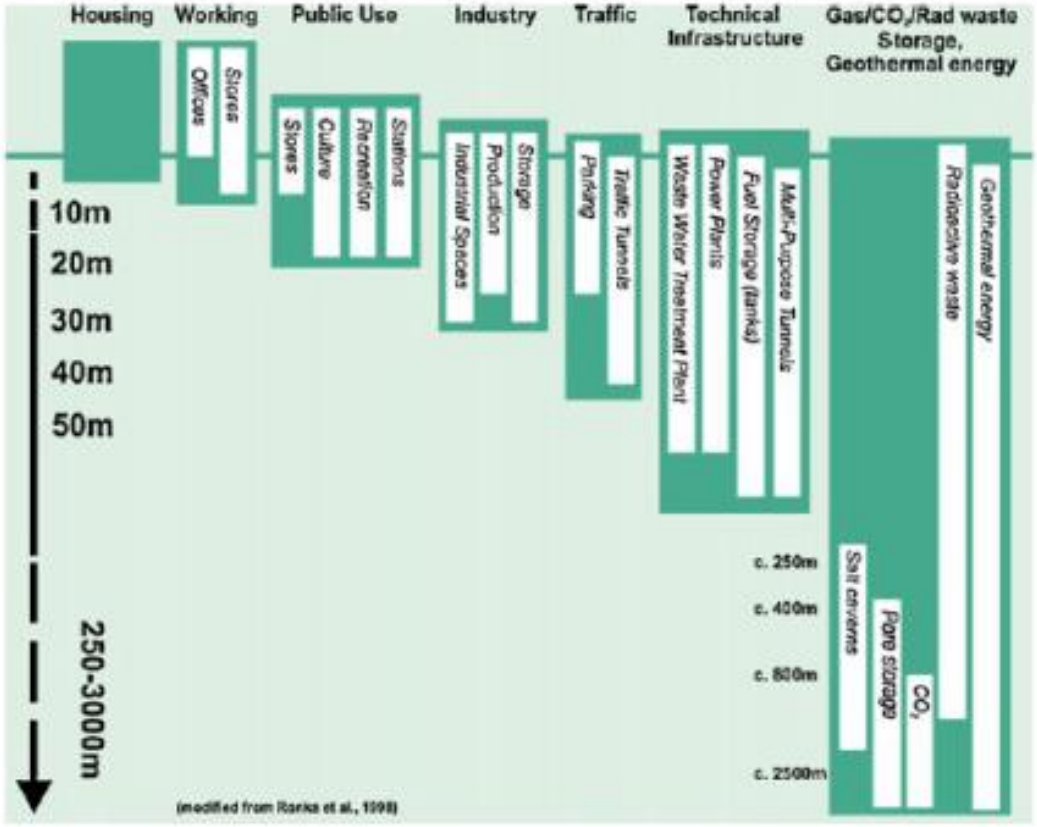
Better sub-surface use..

Requires

- Better Availability of Data, and Knowledge

This enables

- Better Planning and Management of increased sub-surface uses;
  - conflicting demands of subsurface volumes, and;
  - new subsurface opportunities



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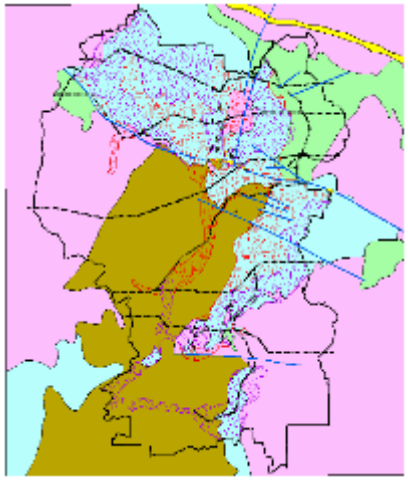
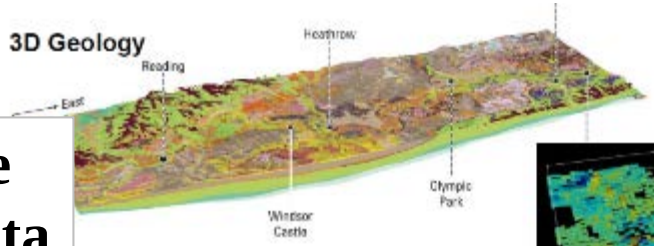
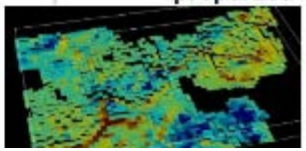
To Open Up the Subsurface for Future Cities …. Must:

- Demonstrate importance of geological setting for sustainable urban development and resilience
- Embed geoscience knowledge (information, modelling, visualisation) in urban policy and decision-making
- Co-develop interventions to improve urban resilience, appropriate for the local geological conditions



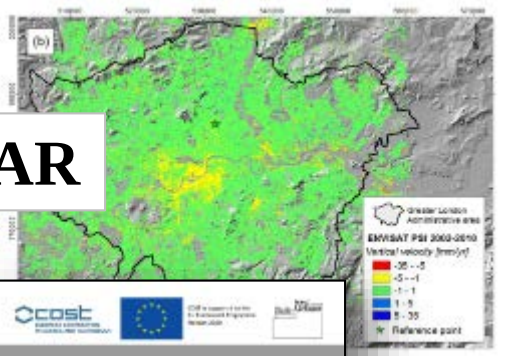


Geotechnical properties

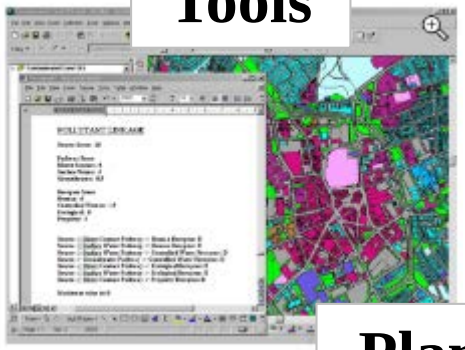


Subsurface Property Data & Models

InSAR



Tools



Urban (ground)water

Planning & Policy

The Economic value of subsurface knowledge and data

- **Large Indirect Costs incurred by developers, contractors** due to **incomplete subsurface information**
- **Unforeseen Ground Conditions** one of main causes of **project delay** and **Insurance claims** on projects
  - Institution of Civil Engineers (UK) estimates c. 50% of cost and time over-runs on civil engineering projects caused by 'unforeseen ground conditions', but
  - Farringdon U/G station 3D models: 70% reduction of in-tunnel probing, excavation 3 months ahead of schedule
- **Digitisation of subsurface data** made more accessible, (re-)usable enhance asset management, and **project profitability**

More and better urban subsurface **digital** data and knowledge can lead to wider and long-term benefits

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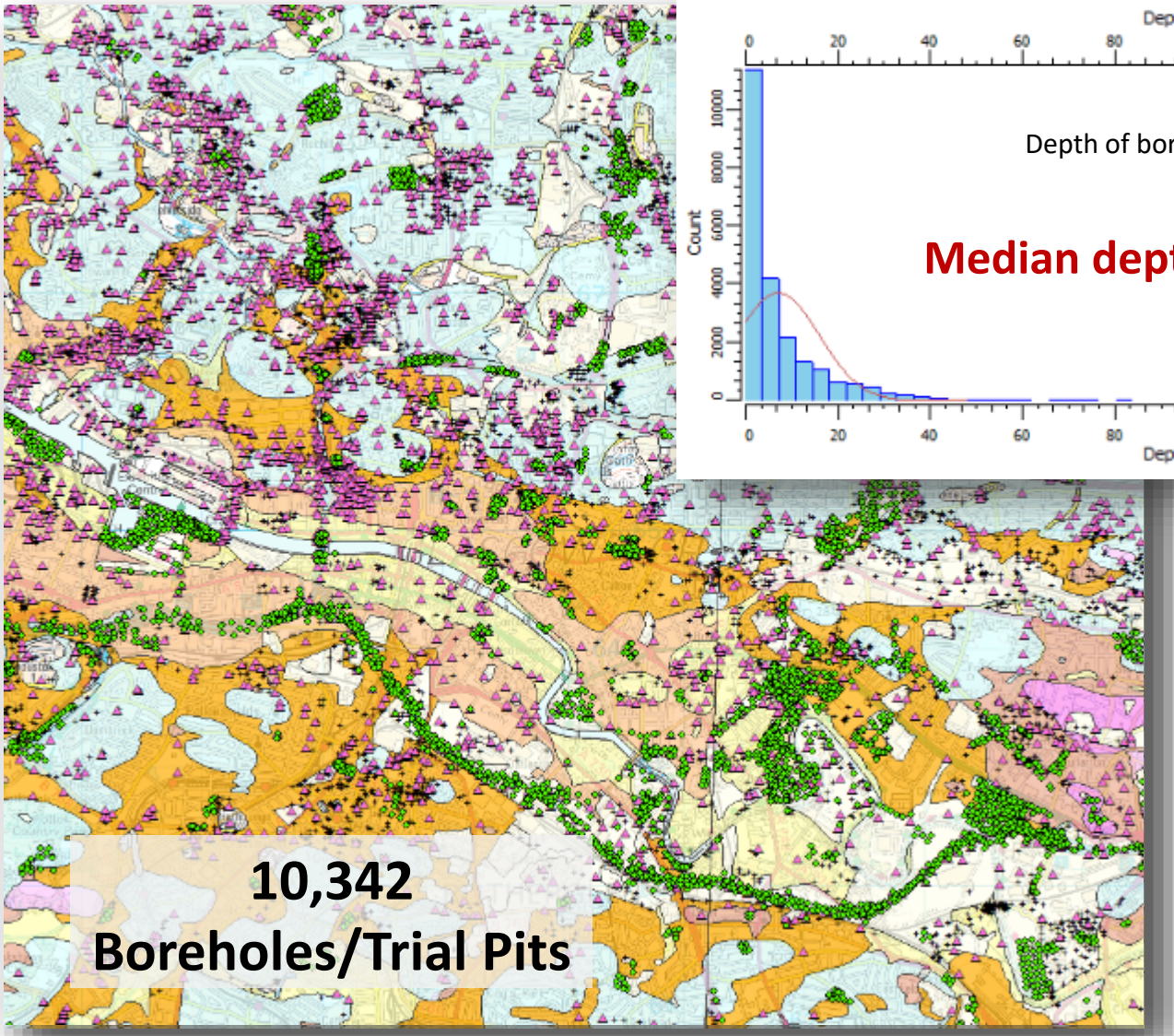
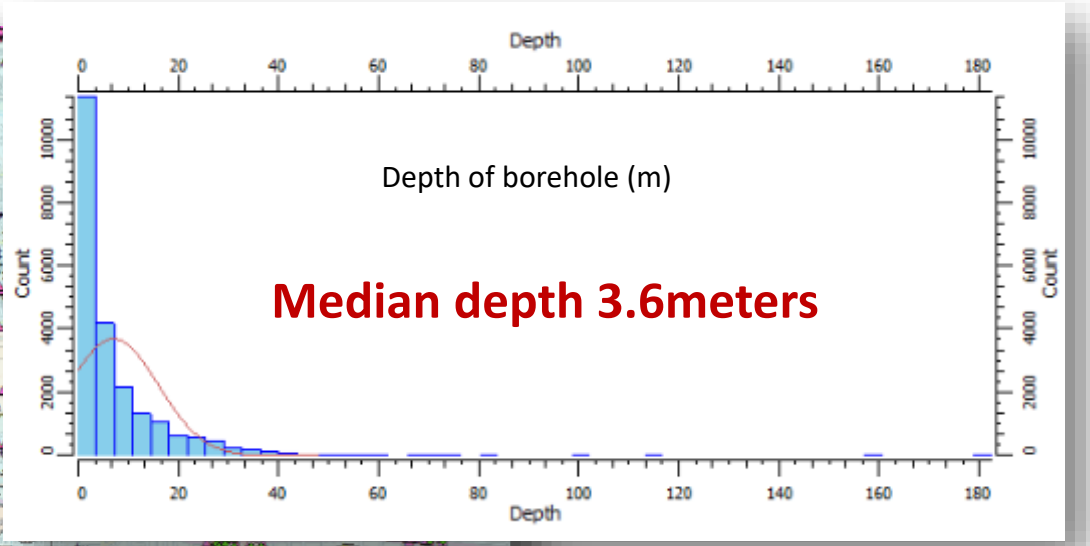
Geological/geotechnical data distribution in cities





All parties can play a role in improving subsurface data sharing and availability

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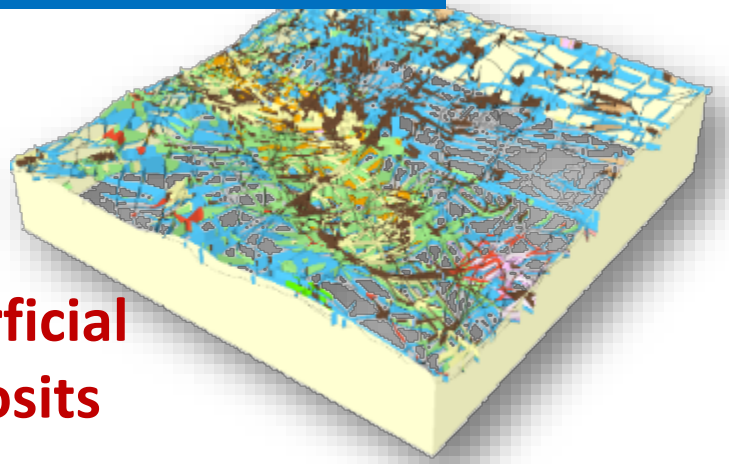
BGS' 3D urban models

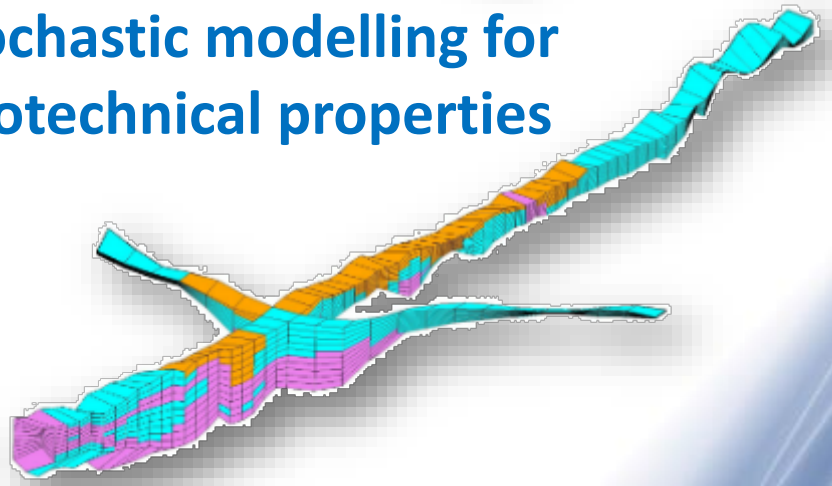
Methods/software/scale/content depend on geology, available data, user needs

- **Flexible approach essential**
- **QA**
- **Metadata**
- **Uncertainty**
- **Delivery**

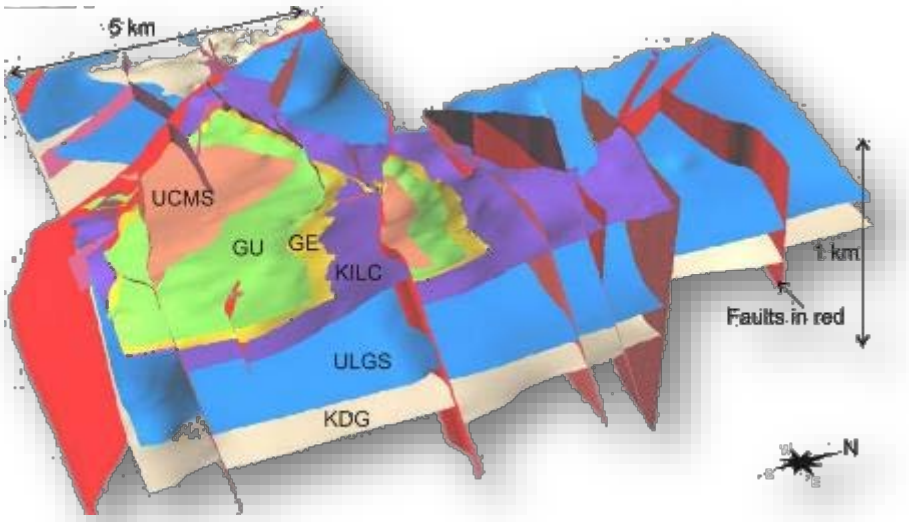


Superficial deposits

Stochastic modelling for geotechnical properties



Surfaces/faults



- Integrate infrastructure
- Groundwater Monitoring and Modelling Linkages: static to dynamic…

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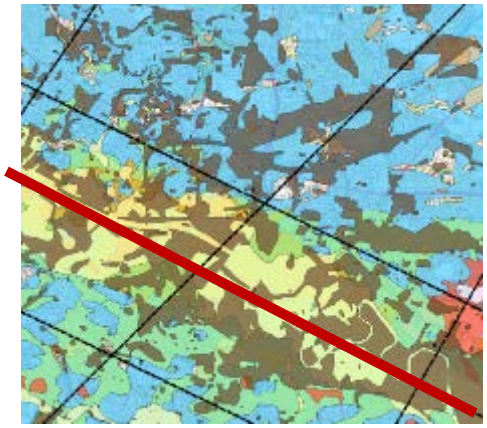
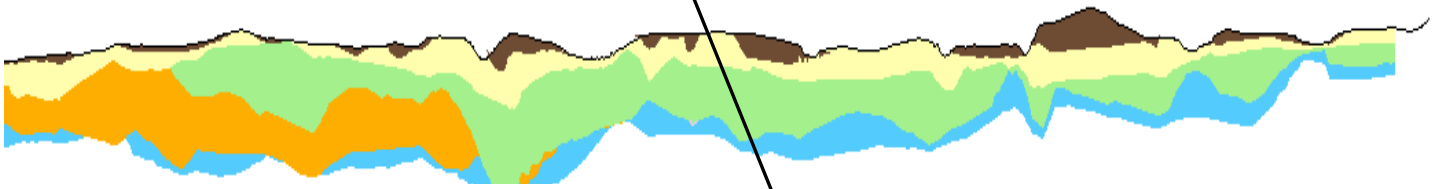
Comparing deterministic & stochastic models

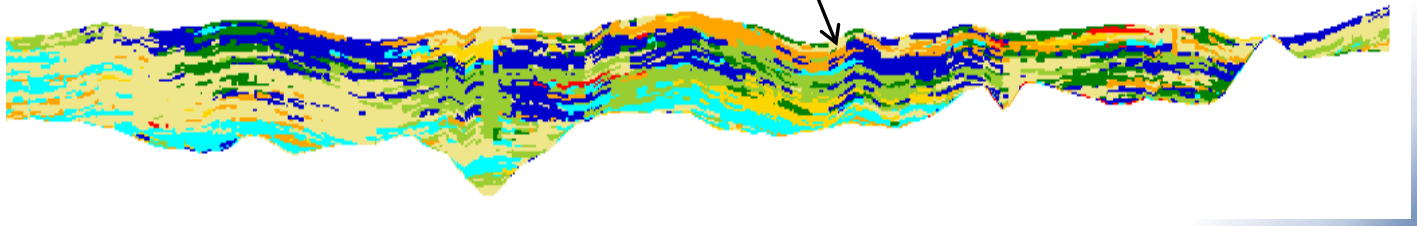


Captures greater lithological variability than the stratigraphy

Deterministic



Stochastic



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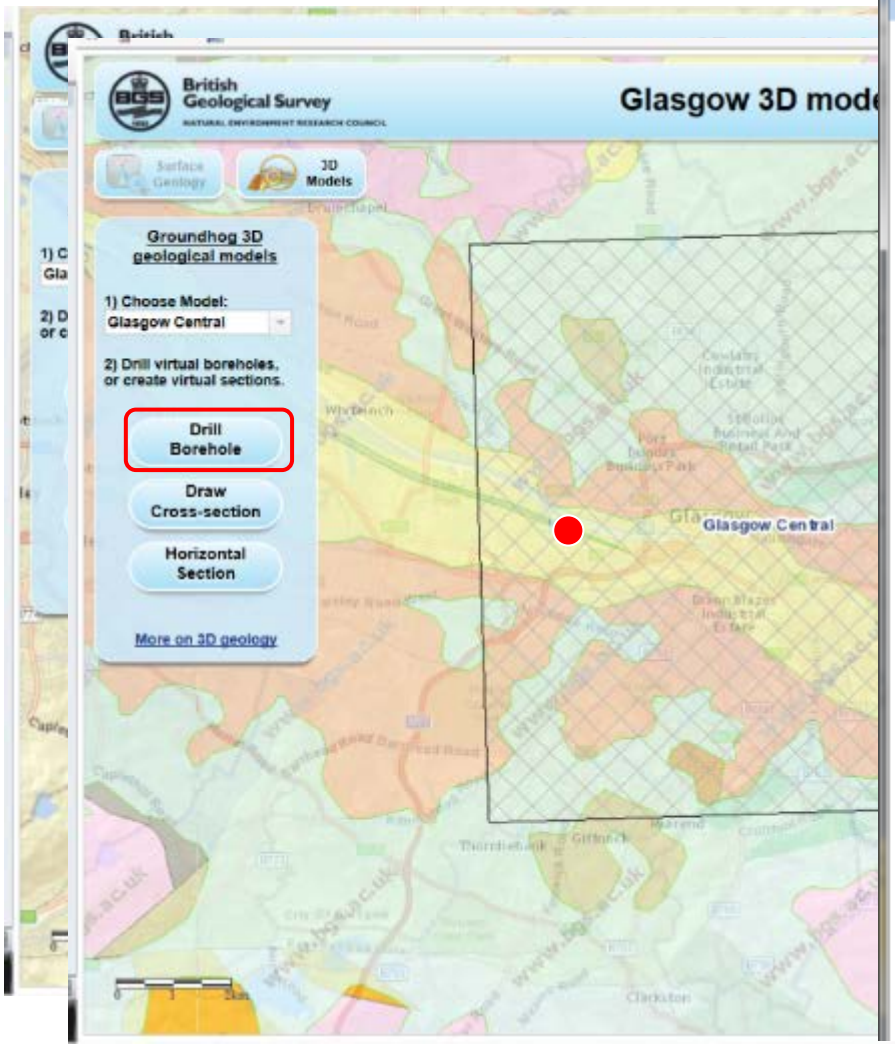
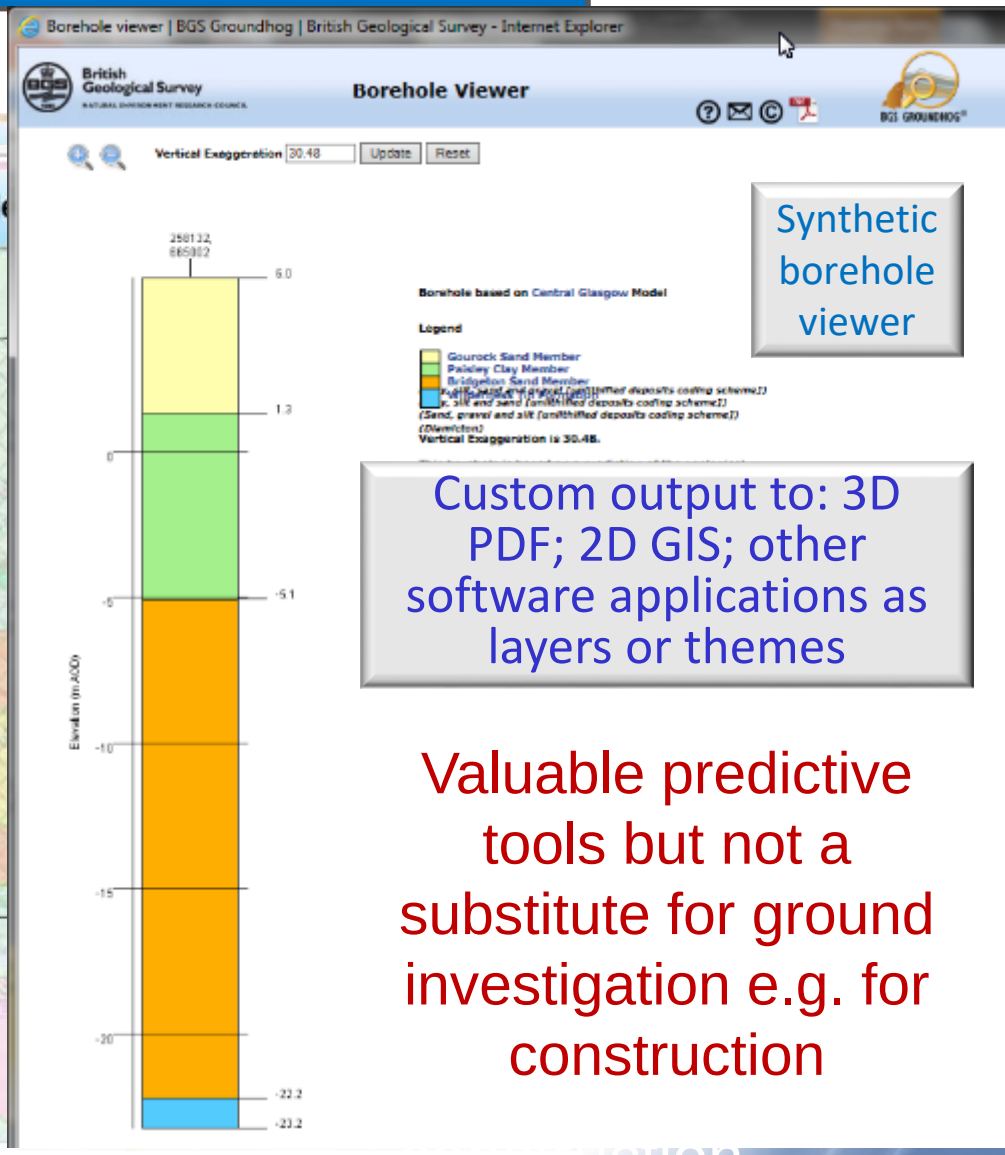
Web based 3D model explorer





Synthetic borehole viewer

Custom output to: 3D PDF; 2D GIS; other software applications as layers or themes

Valuable predictive tools but not a substitute for ground investigation e.g. for construction

ESRI Server / GeoSciML compatible maps / Java powered 3D model viewer (produce synthetic boreholes / cross sections)

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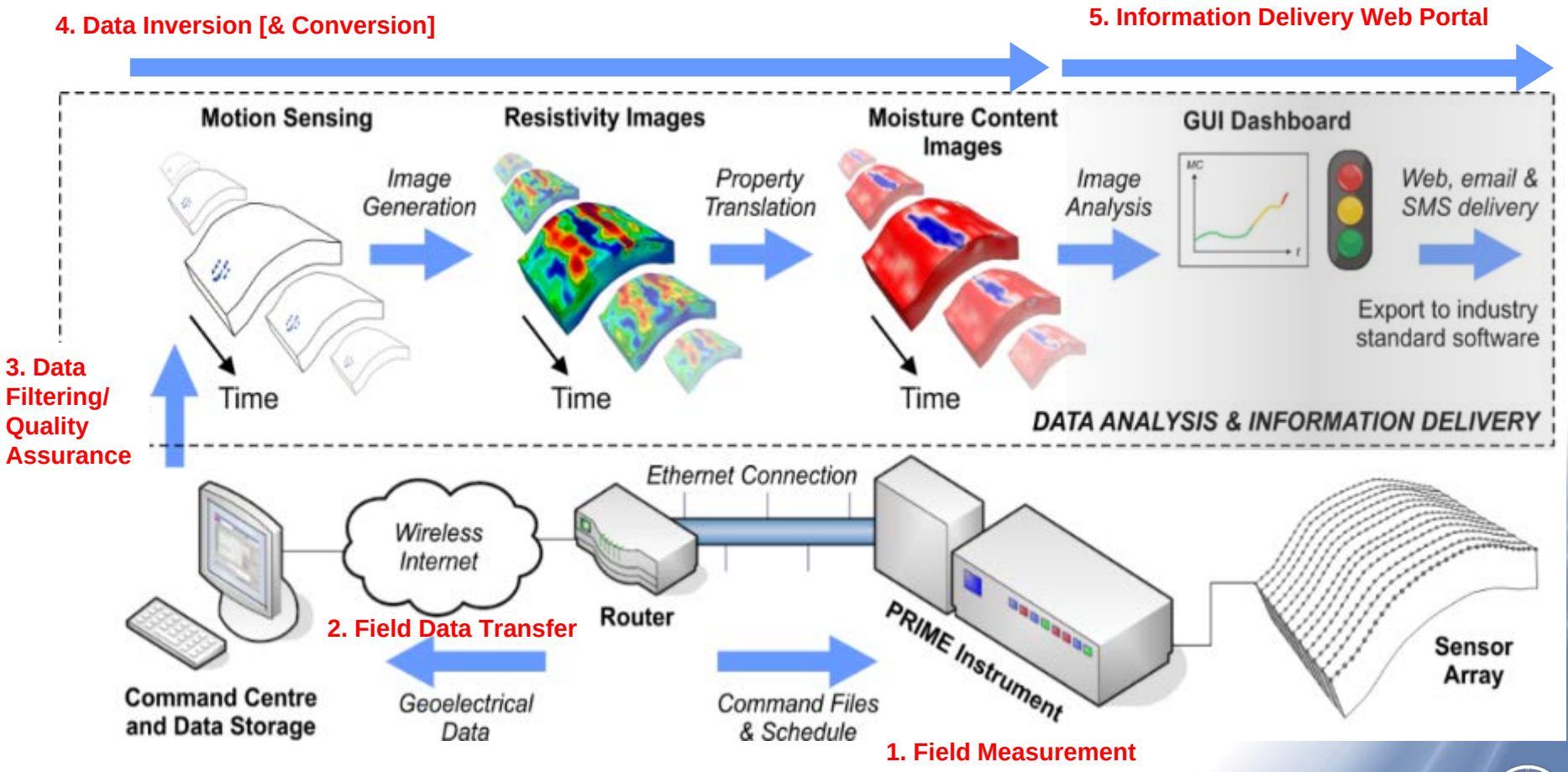
4D ground property models – adding time

(Jon Chambers and GTOM team)

Real-time 4D soil moisture data from sensors → Early Warning System → Slope stability on transport embankments



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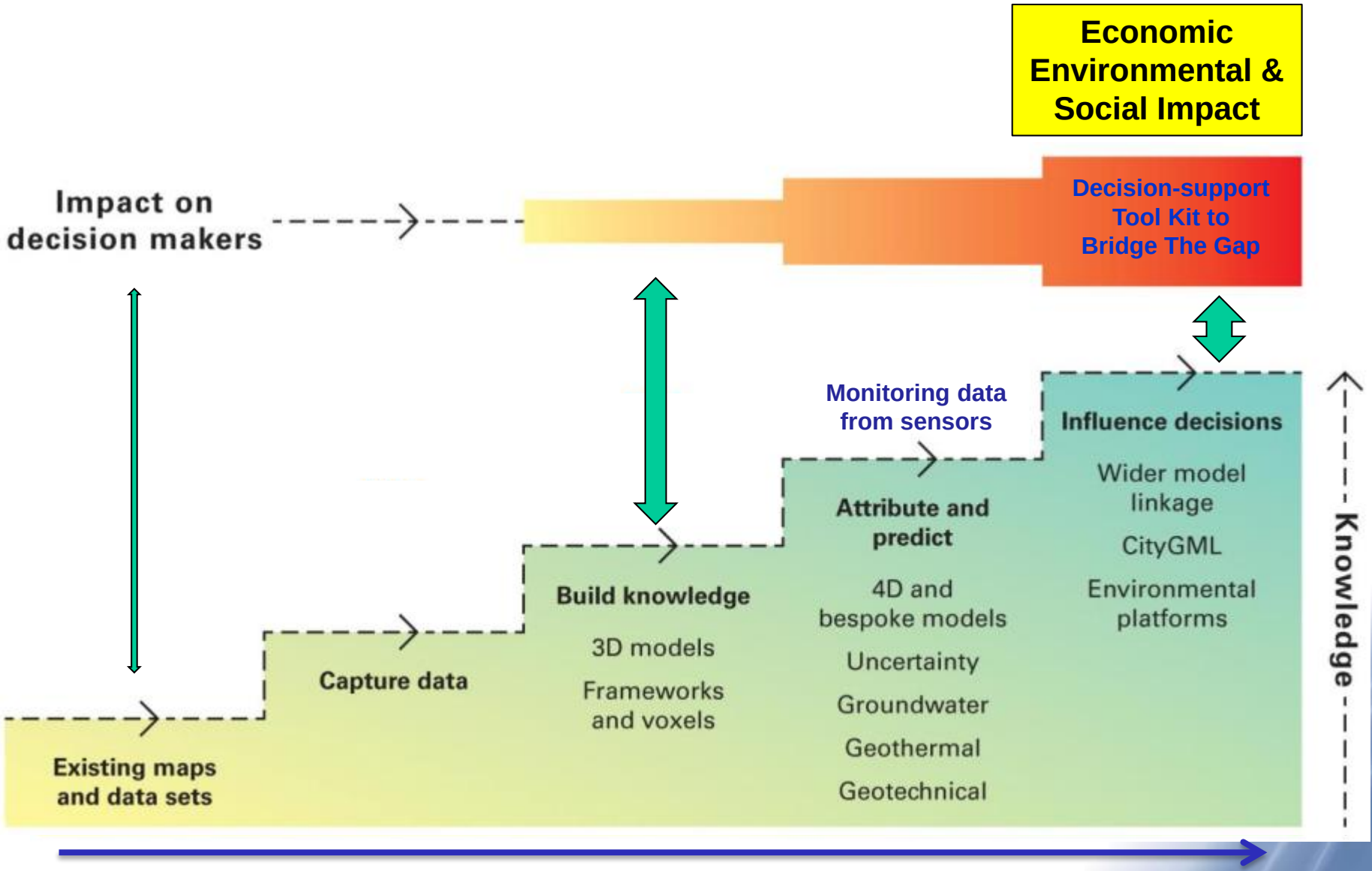
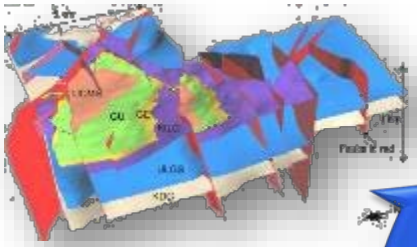
The Urban Sub-Surface: Staircase from Data to Impact



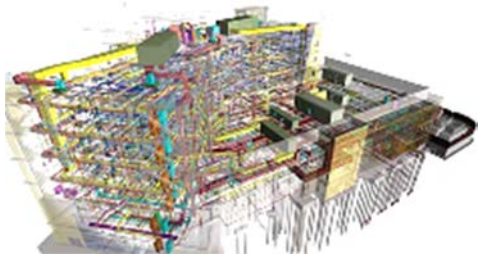
Improving Translation of data to Useable Forms and Relevant Timeframes

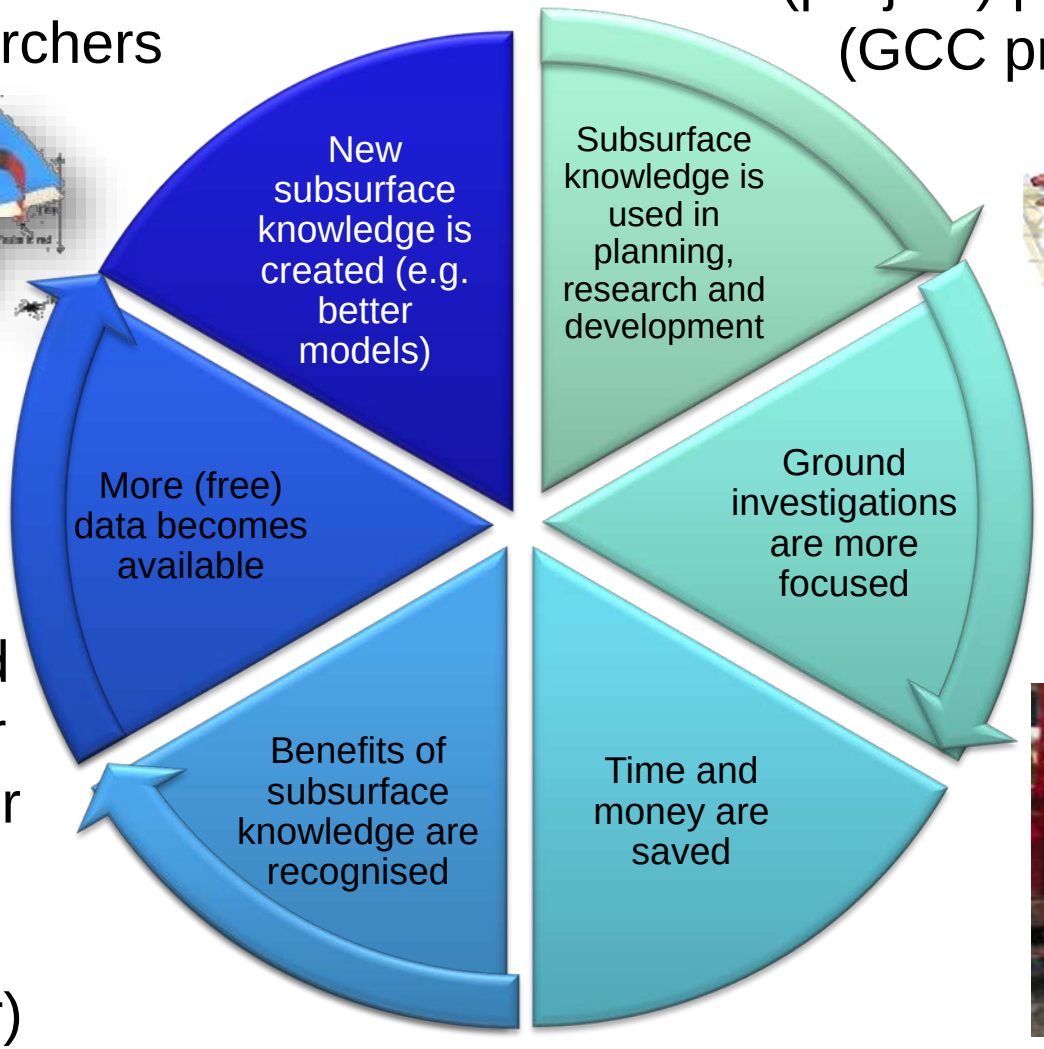
Key Elements – Virtuous Circle of Data and Knowledge;

2/3/4D "Modelling" and outputs BGS and other researchers



Decision-makers / Practitioners for (project) planning GI, design (GCC private sector)





Database: Standardised templates for digital transfer / acquisition (BGS & private sector)

Borehole logs and other ground data Most private sector

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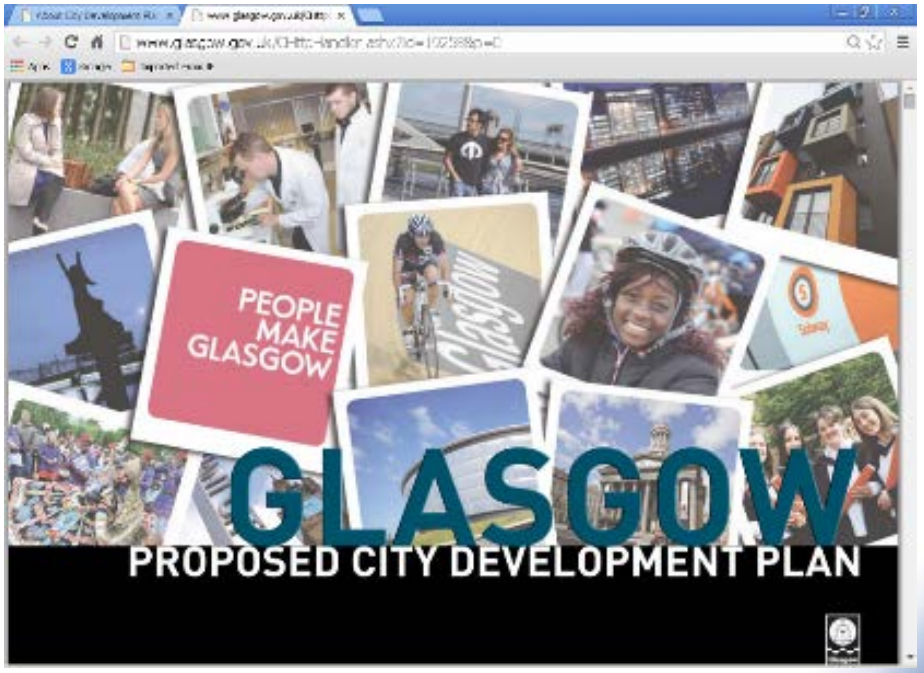
Ultimate goal – establish knowledge driven urban subsurface practice

Subsurface planning now integral to Glasgow's City Development Plan – Explicit Committment

«...recognises the importance of the subsurface environment in the development of spatial strategy, policies and proposals for the future use of land and infrastructure in Glasgow, reflecting the growing awareness of the importance of subsurface knowledge for the City»



www.glasgow.gov.uk/developmentplan

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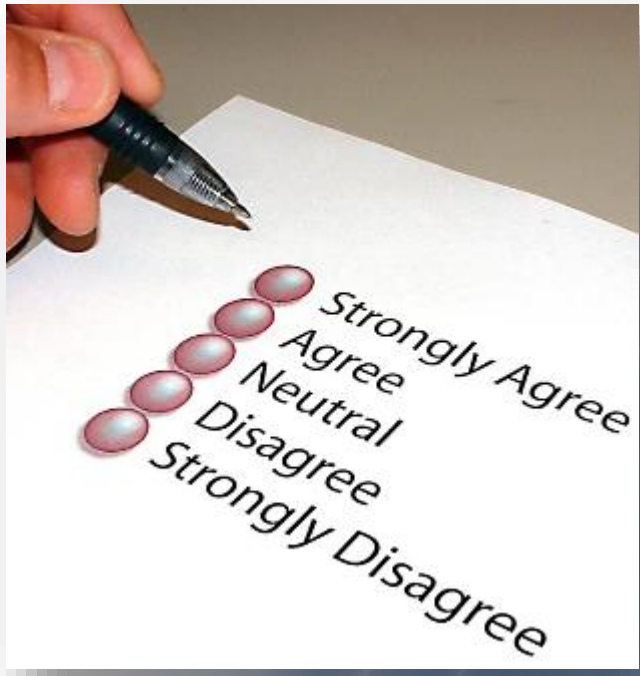
Legal requirements: Netherlands Key-register for the subsurface (BRO)

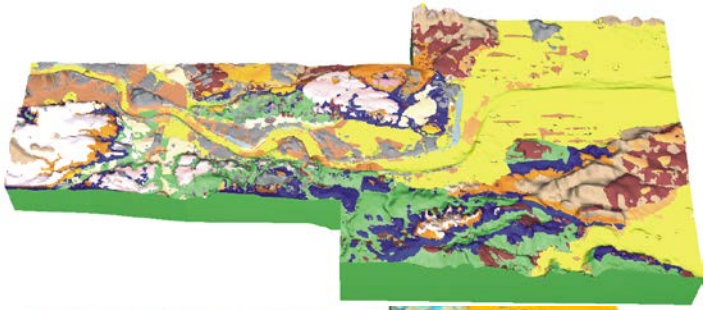
- Survey database part of Dutch *e*-Government
- By law, government bodies will have to feed and consult TNO/GSN database
- “Single acquisition and storage, multiple use”
- Data and models
- Operational in 2015

- More use by more users
- Higher expectations
  - accountability, reproducibility
  - detail, resolution
  - reliability, credibility
  - Definitions – data type model, infrastructures rights of use

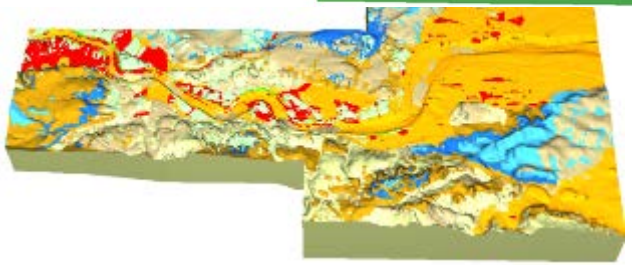


Geospatial Data for Urban Development

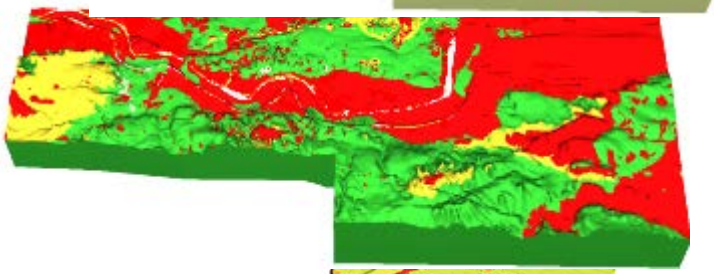
Geological formations



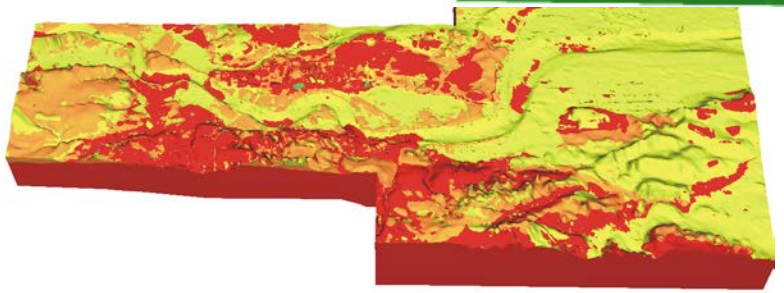
Foundation conditions



Sulphate potential



Permeability



Need to identify and address specific needs of:

- Cities,
- Geological Surveys
- other stakeholders; private sector partners and researchers

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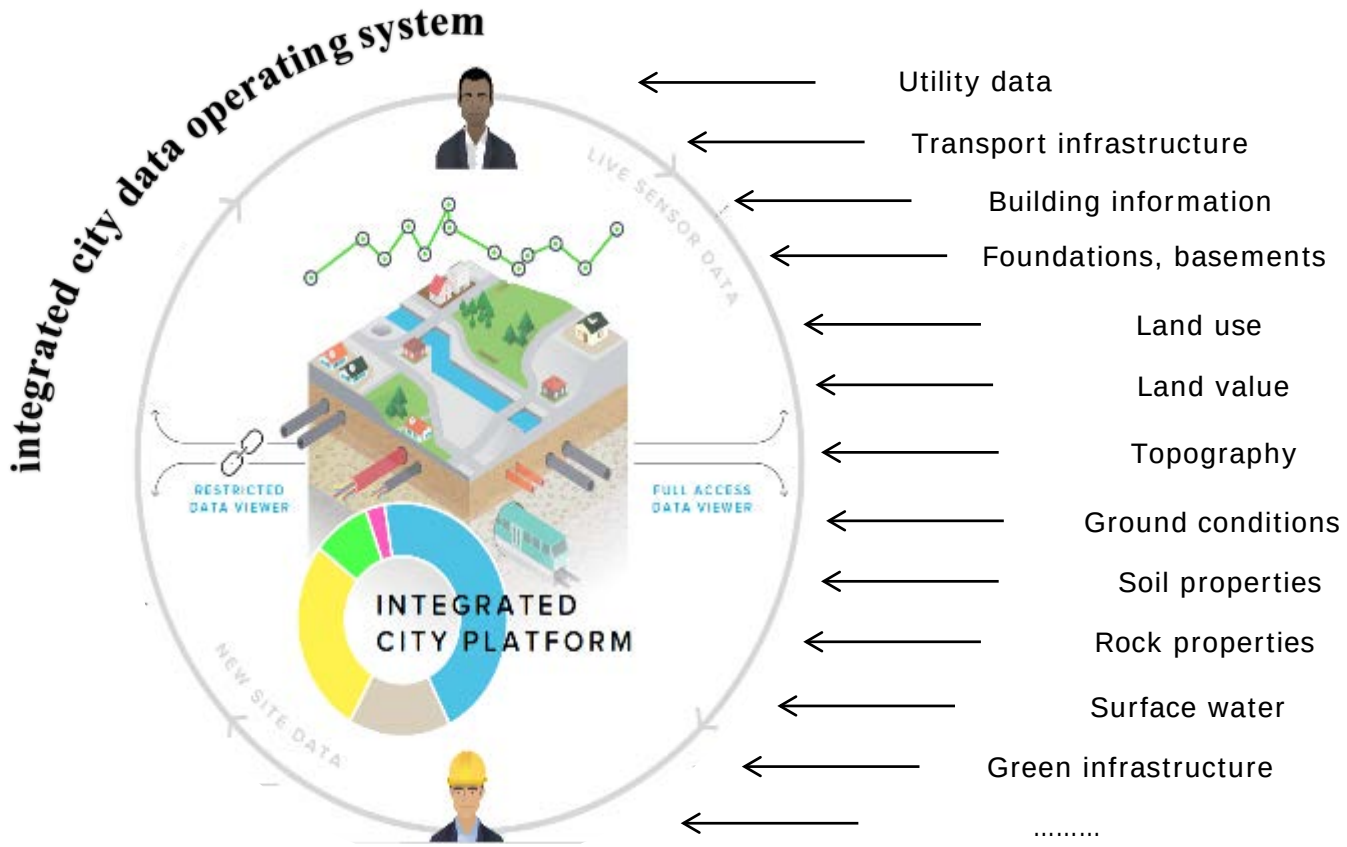
An integrated data operating system above and below ground

…what are the benefits?



Digitisation of subsurface data,

making it more usable,

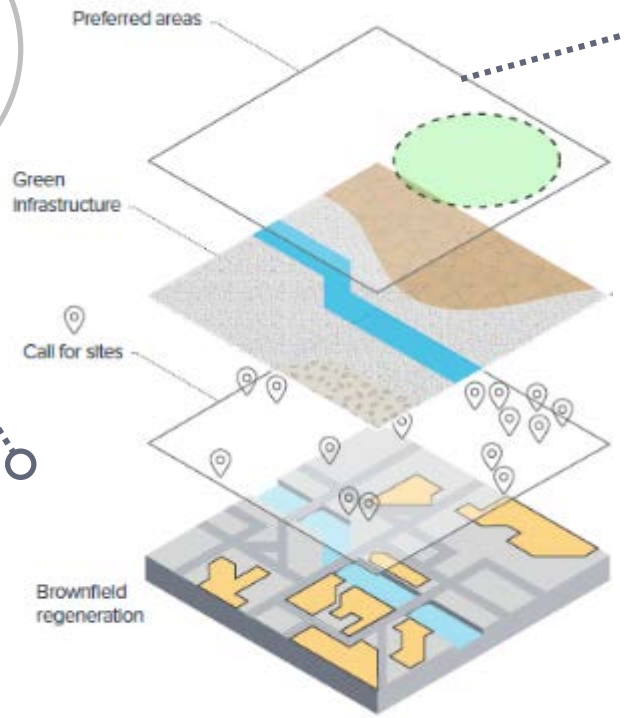
can enhance asset management,

and increase profitability

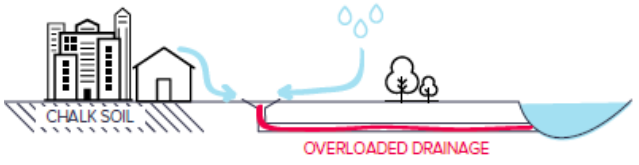
Developing tools, services and solutions

- Interactive tools
- Forecasts
- Early warning systems using sensors

Integrated city data operating system



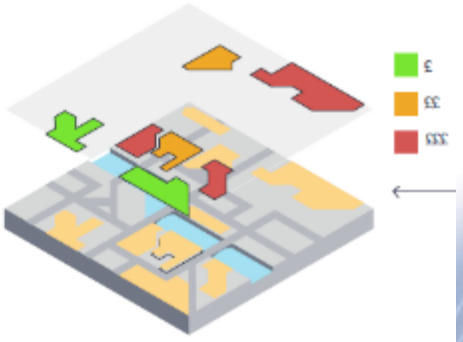
LOCAL DEVELOPMENT PLANS



GREEN INFRASTRUCTURE AND SUDS TOOL

BROWNFIELD REMEDIATION COSTING TOOL

REFINED BROWNFIELD REGISTER



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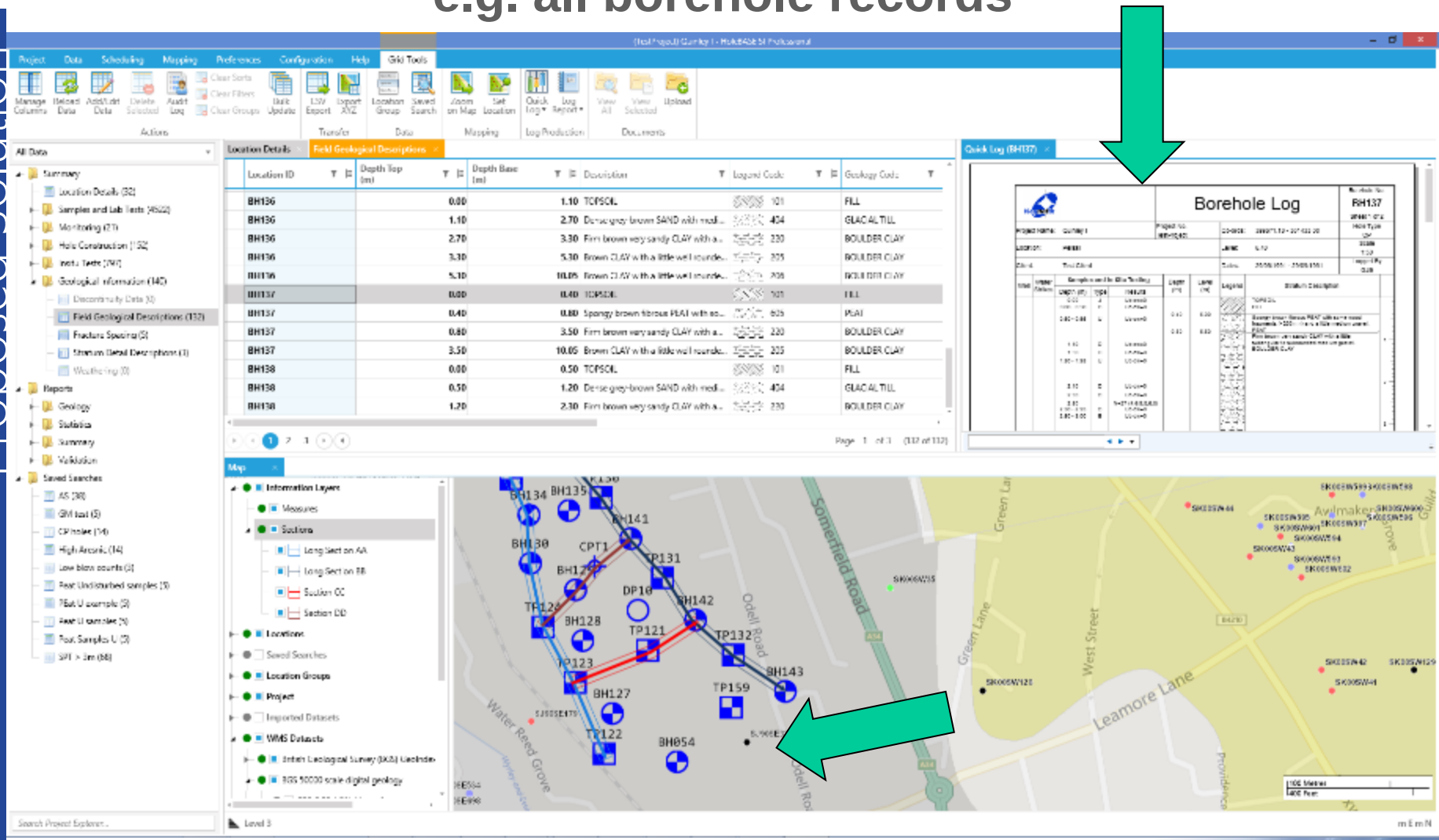
Direct access to subsurface data in BIM software

e.g. all borehole records

Proposed Solution



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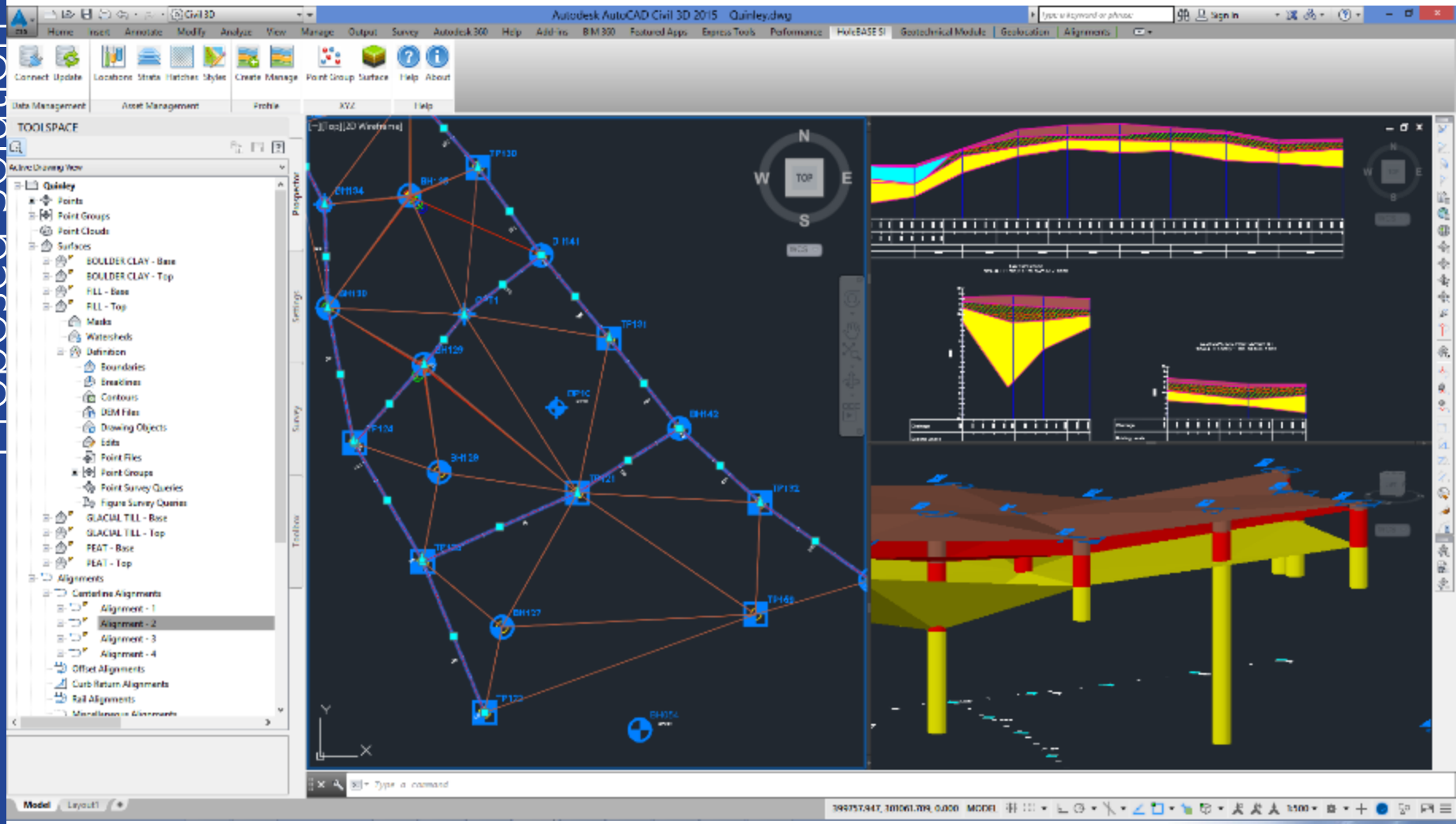
BIM: Direct access to geology model outputs

e.g cross-sections, geology surfaces, volumes and faults.

Proposed Solution



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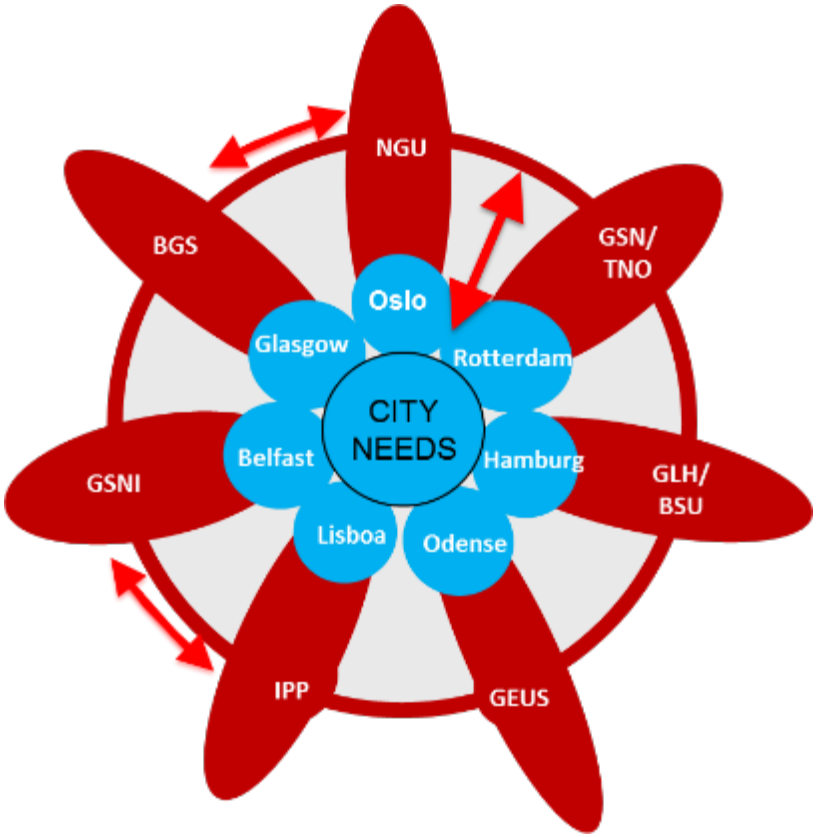
Making the data and knowledge accessible for city planners?

TU1206: SUB-URBAN - A European network to improve understanding and use of the ground beneath our cities



- Network of >30 countries
- >150 researchers, practitioners and urban decision-makers,
- 23 actively participating cities

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Key Aspiration

- Transform relationships between experts who develop urban subsurface knowledge and those who can benefit most from it - urban decision makers, practitioners and the wider research community

To Bridge the Gaps

Sub-Urban
cost EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY
COST is a component of EU H2020 Framework Programme

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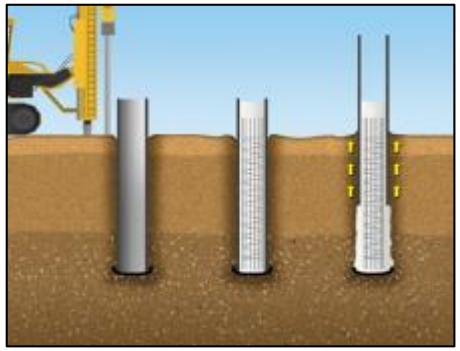
ACTION'S Aims

To provide those who manage and deliver cities with knowledge and tools that will enable them to:

- **Maximise** the economic, social and environmental **benefits** of their **subsurface resources**
- Recognise, and manage in a responsibly, the **conflicting demands** placed on the subsurface in our cities
- **Safeguard**, through informed stewardship, the **subsurface ecosystem services** on which cities depend

Ultimately to make a difference to our cities



Good Practice from European COST Action Sub-Urban (TU1206) State-of-the-art City Reports (2015-17)

city setting (typology), acquisition and transferability of subsurface data, planning issues with subsurface, economic aspects, livability, governance, infrastructure, legal framework

From http://www.sub-urban.eu

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Good Practice Reports (2015-17) & Short-term Scientific Missions

Subsurface urban planning,
Data management
3D modelling,
Groundwater / geothermal,
Geotechnical,
Geochemistry,
Cultural Heritage

http://www.sub-urban.eu

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National Exemplar Modelling Projects
Lighthouses and Followers - Cascading

- Ground conditions
- Contaminated Land
- Flooding, SuDS
- Aquifer protection
- Unstable ground
- Thermal resources

To Inform decision makers:

- Municipalities and Regulators
- Developers, consultants, contractors
- Wider community

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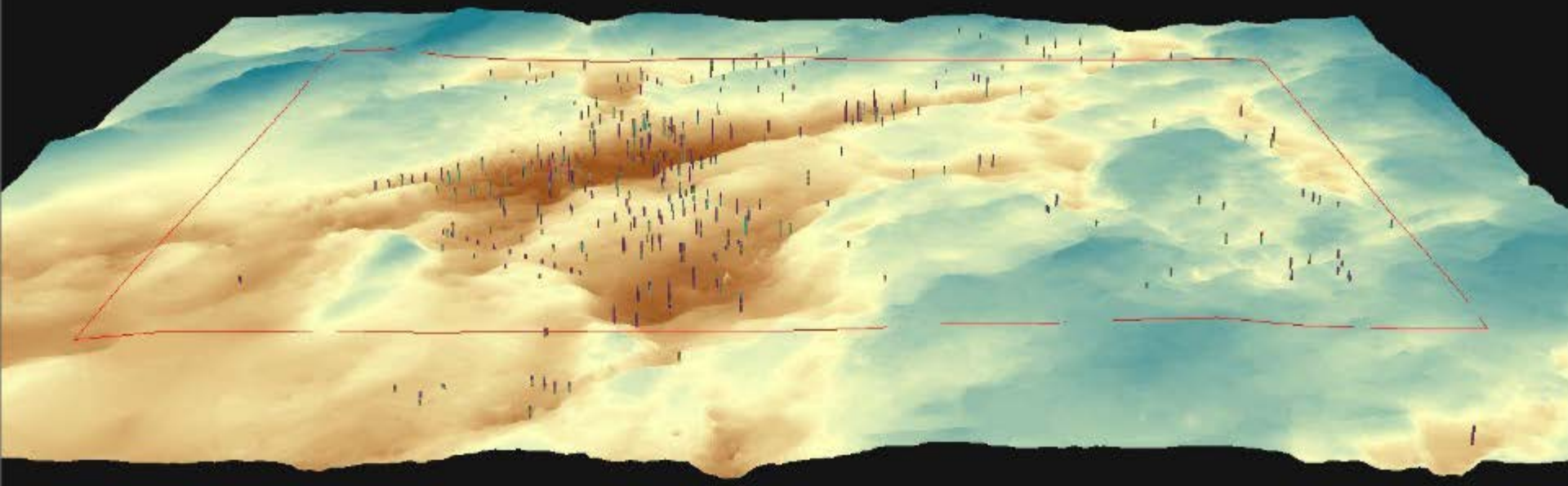
Construct Models for Specific Purposes

Example: Oslo, Norway



Problem: Very variable bedrock depth causes problems for foundations

- Top of buried bedrock
- Man made structures

Geotechnical boreholes

source: Cecilia Cerdeira, Oslo kommune

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Geological cross-sections - interpretation

source: Cecilia Cerdeira, Oslo kommune

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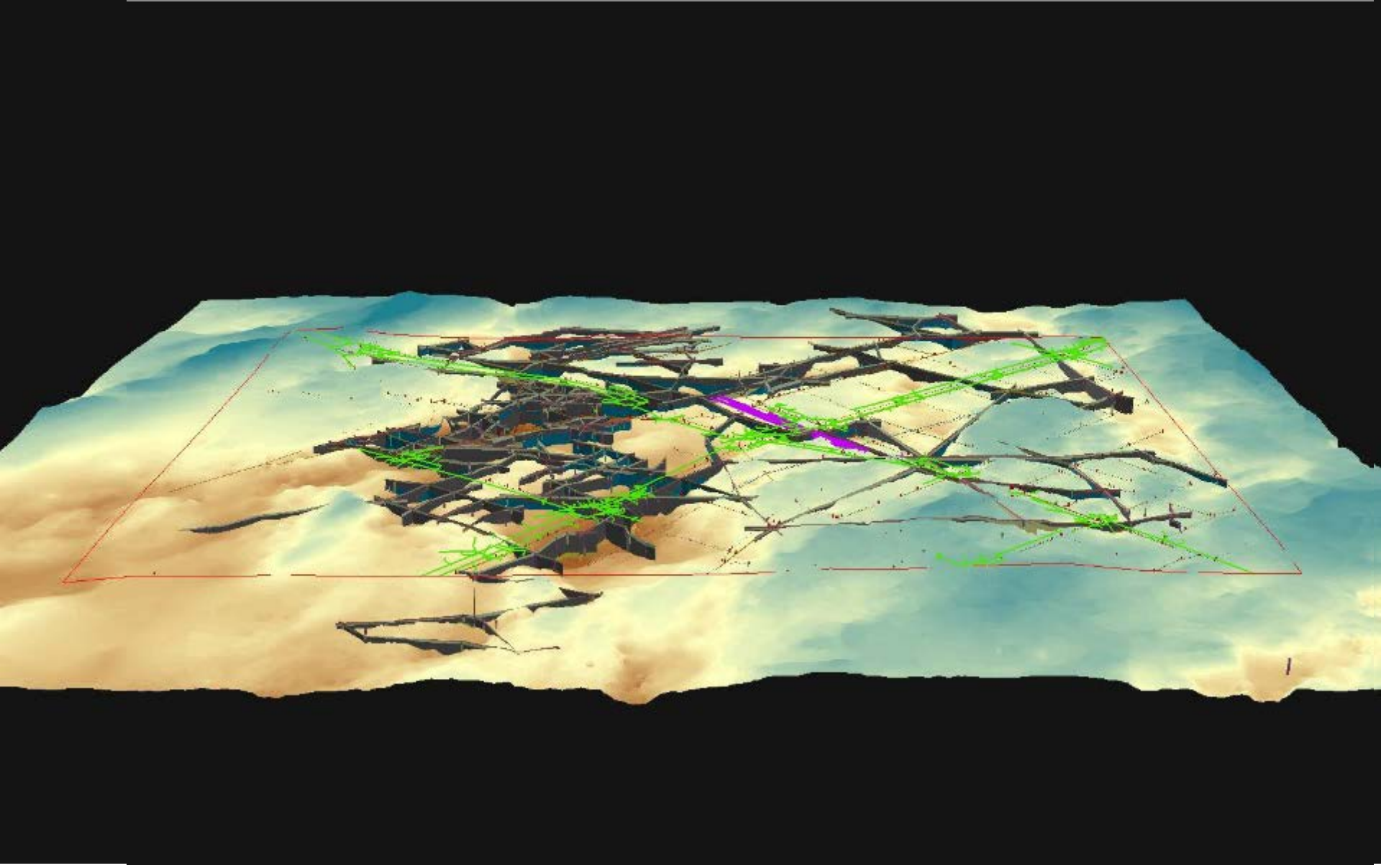

Infrastructure – pipelines - ++

source: Cecilia Cerdeira, Oslo kommune

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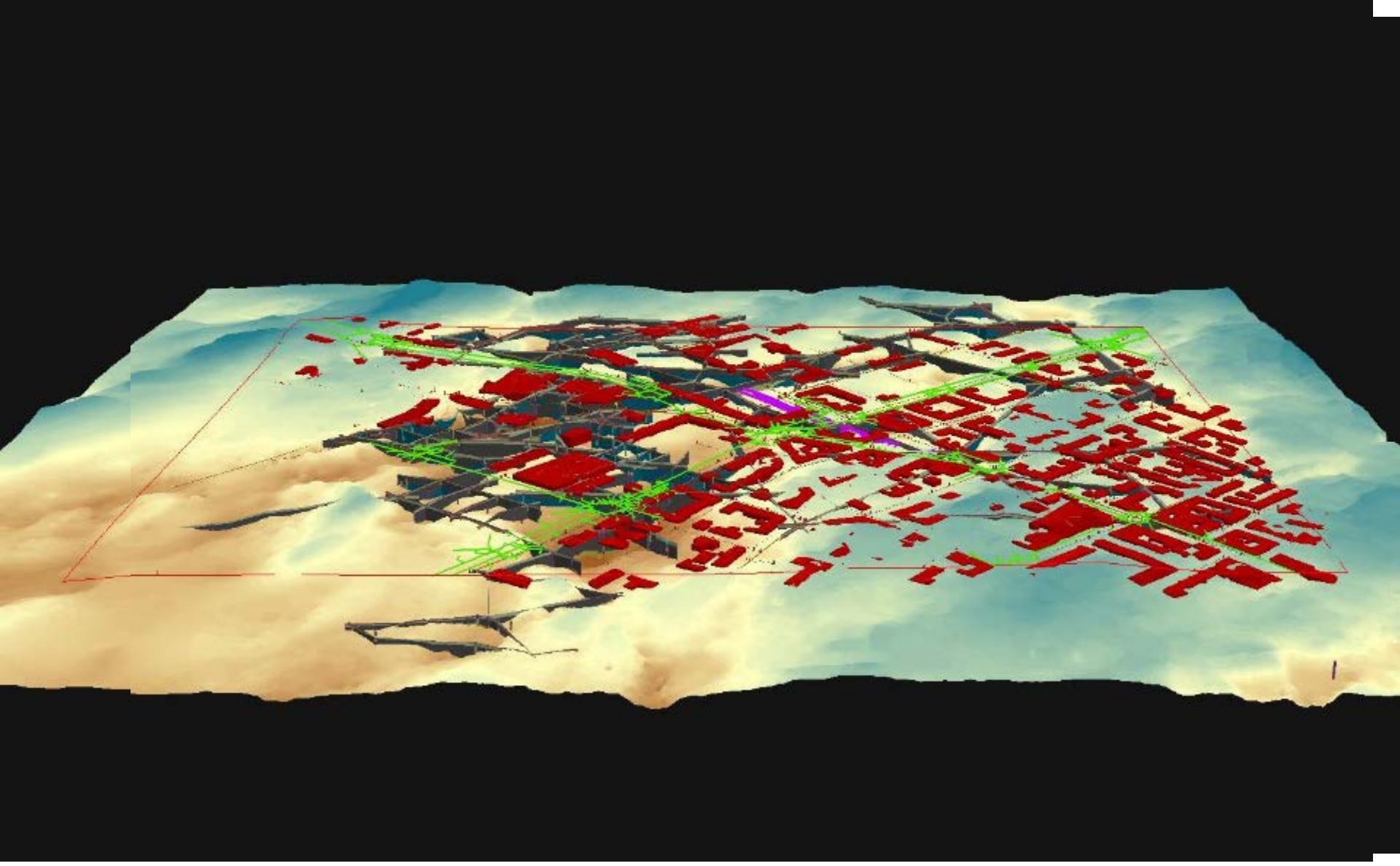

Basements

source: Cecilia Cerdeira, Oslo kommune

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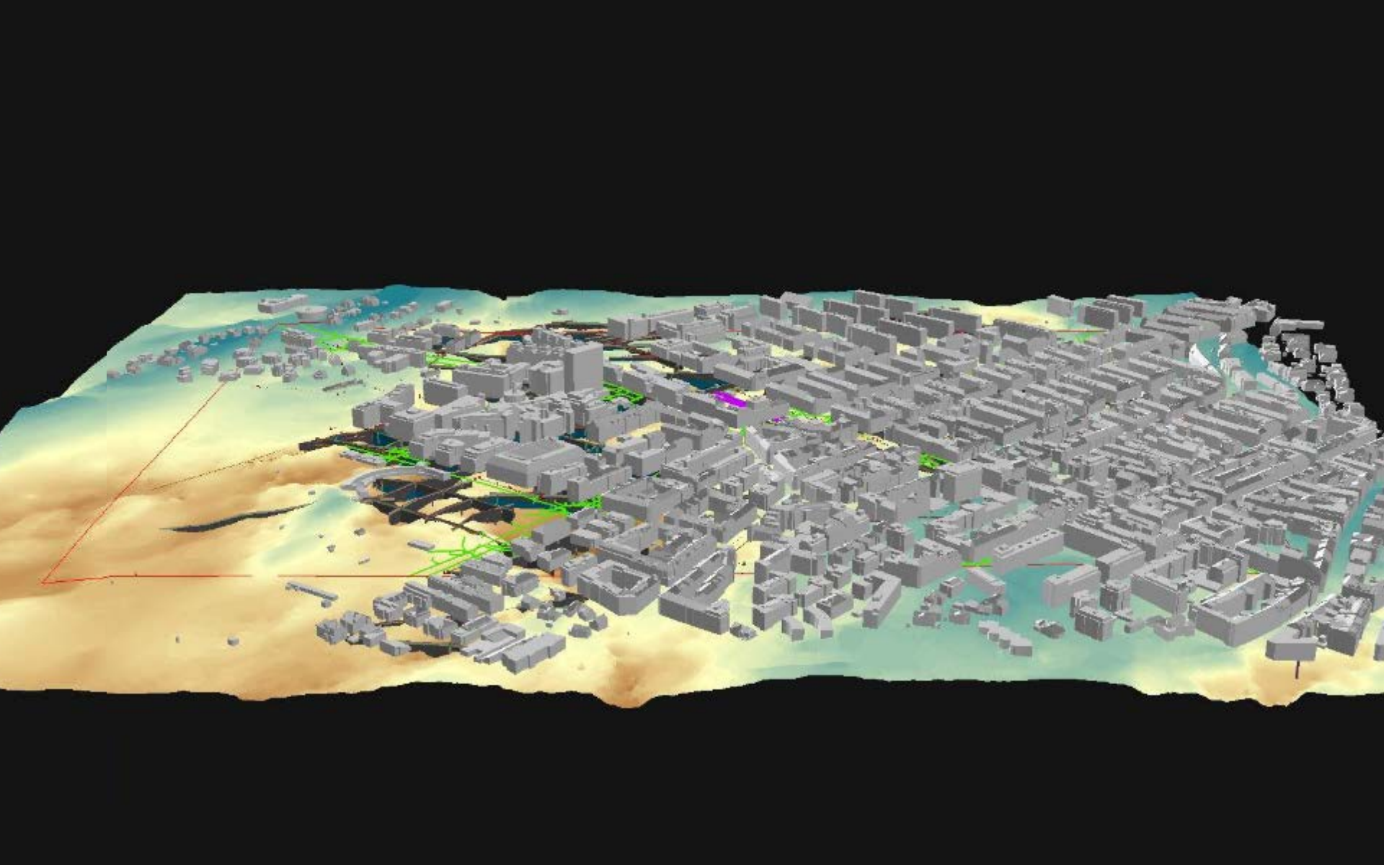

3D buildings

source: Cecilia Cerdeira, Oslo kommune

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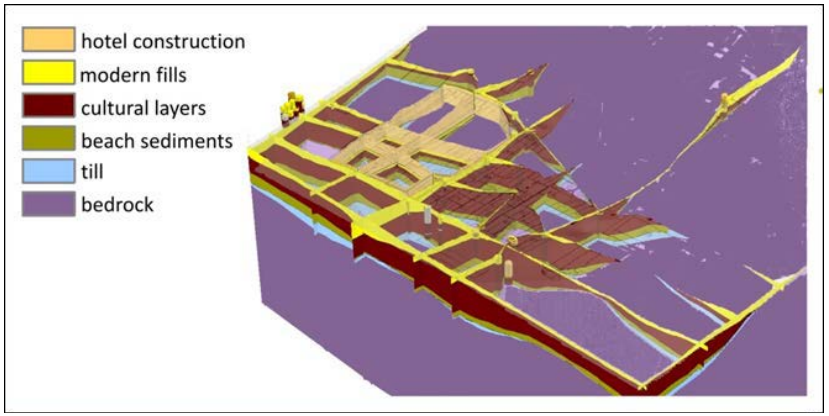
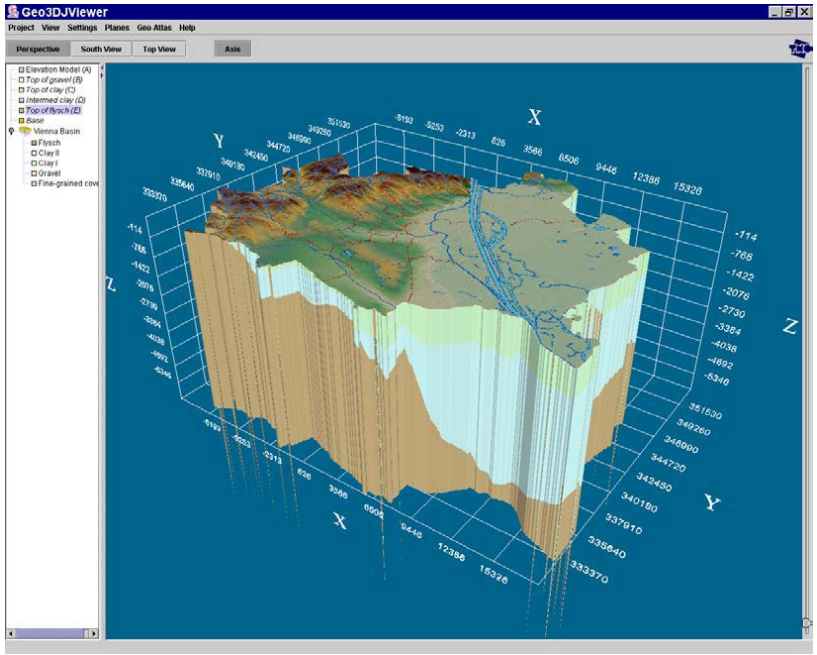
Bergen, Norway: To preserve buried 1000 year old archaeological deposits

- 6 layer model of man made, archaeological, glacial and bedrock deposits
- Hydrogeological model





Vienna: To understand groundwater movement and flooding risk

- 4 layer geological model
- Attributed with hydraulic and engineering parameters ,e.g. permeability, grain size, water content

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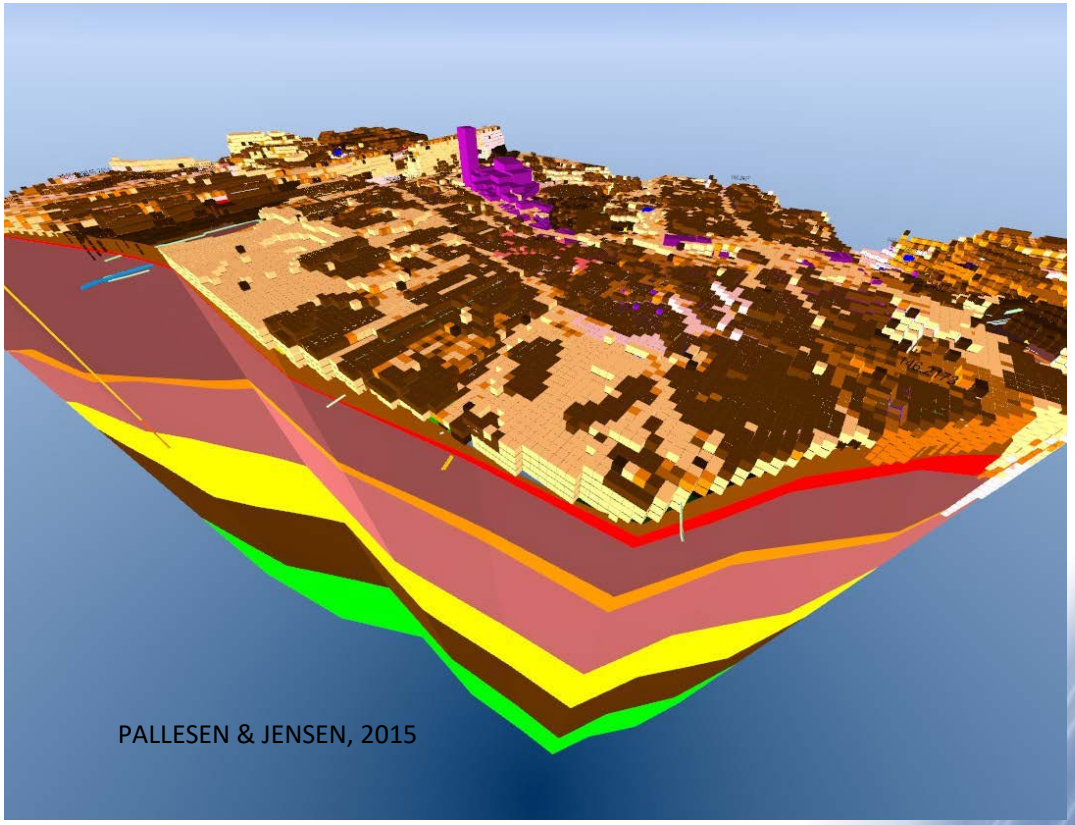
Odense, Denmark To understand groundwater infiltration for SuDS, abstraction and effects on former wetlands

- 9 layer hydrostatic model
- Voxel model of man-made deposits
- Pipes and underground infrastructure



Hamburg, Ljubljana, Bucharest ……..

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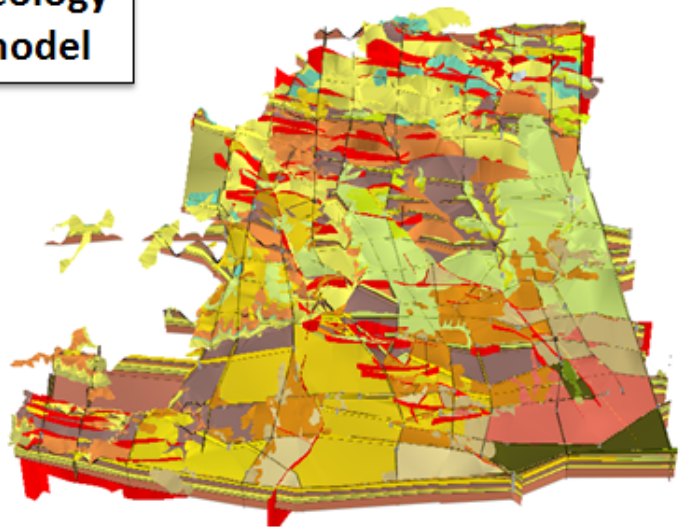
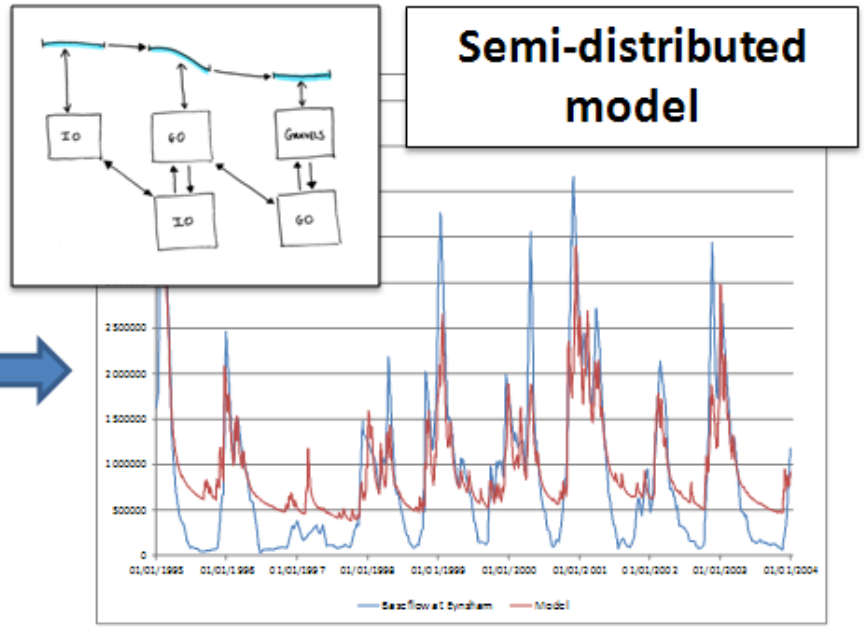
Model Linkages – Static to Dynamic and Predictive

Geology model





Hydrogeology: The meeting of two models

parameterise: engineering properties, geochemistry, thermal properties, sustainable drainage, archaeological assets, buried infrastructure etc

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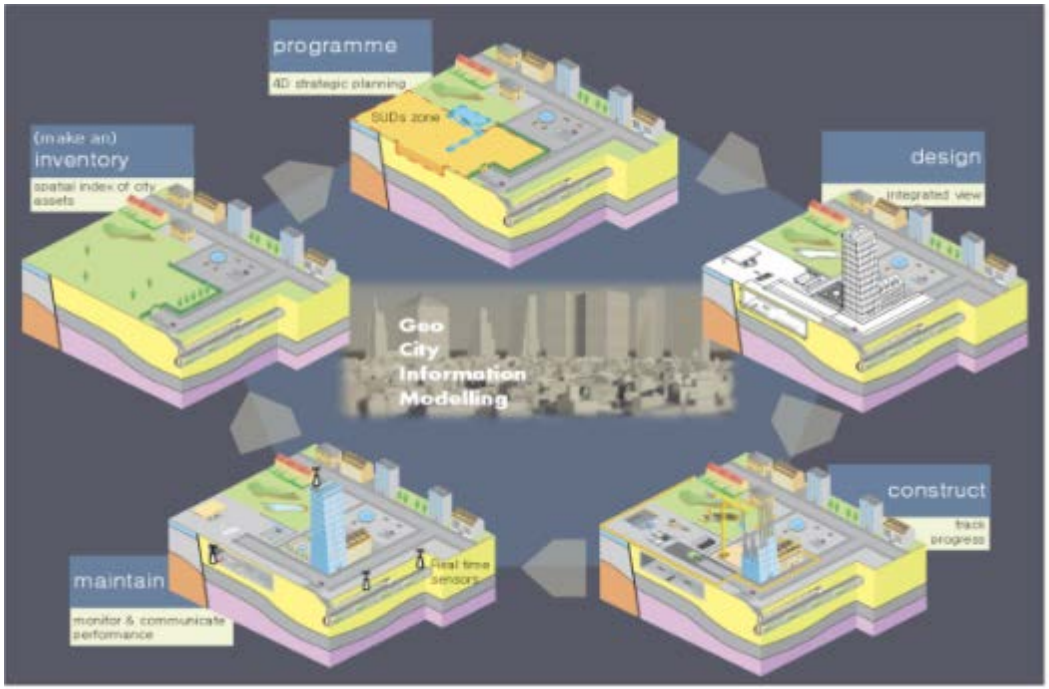
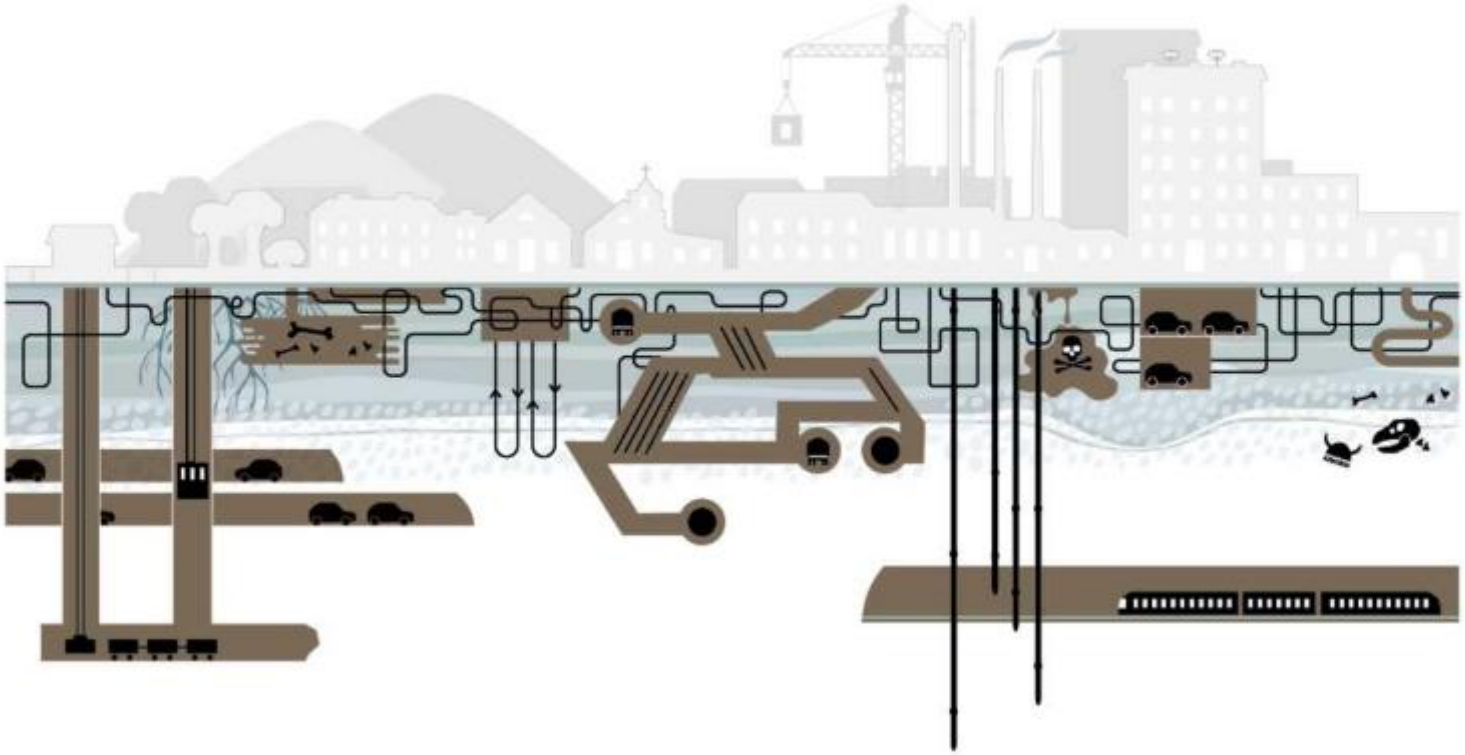
GeoCIM (City Integrated Modelling)

- Making all spatial data relevant to planning decisions available in a common data environment,
- Supporting strategic planning and effective delivery of infrastructure projects by easy access to all related information at each stage of the process



The Vision is for Future Cities that develop sustainably, and in harmony with their subsurface



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