

# **Applying 3D Geological Modeling to Infrastructure Design**

**Alan Keith Turner**

**Emeritus Professor of Geology & Geological Engineering CSM**

**Visiting Research Associate - British Geological Survey**

**Holger Kessler**

**3D Modelling Team Leader - British Geological Survey**

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# **SUMMARY**

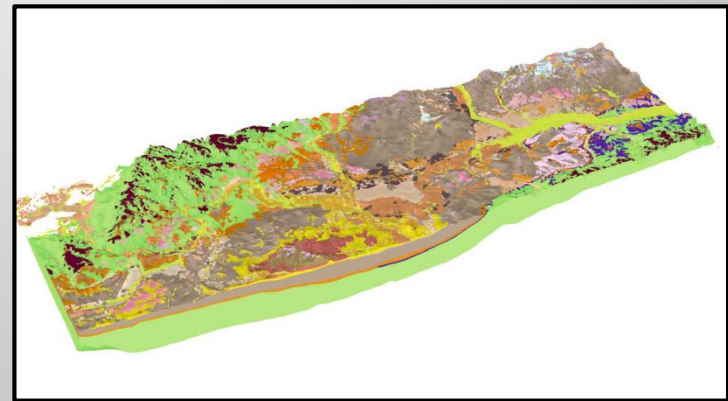
- **3D Geological Modeling at BGS**
- **Two Recent United Kingdom Infrastructure Applications**
- **Geotech-BIM Concepts**

# BGS Model Applications at Many Scales

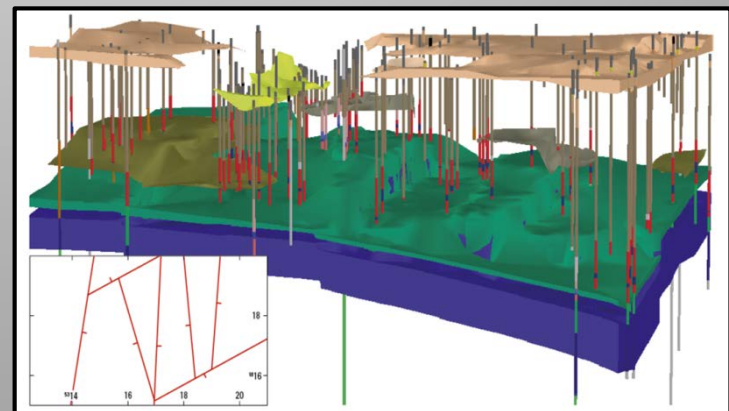
**National 3D UK Model**



**Regional 3D Model (London)**



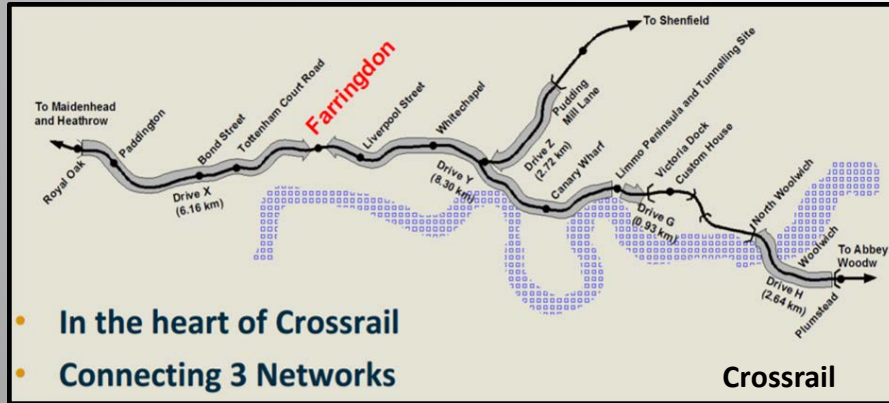
**Site 3D Model (Farringdon Station)**



# **Two Recent UK Infrastructure Applications**

- 1. Farringdon Station for London CrossRail Project (2009-2015)**
- 2. Planning for Electrification of Railway between Leeds and York (2015)**

# Farringdon Station



- Two 300 m (985 ft) platform tunnels plus multiple access tunnels
- 30 m (100 ft) below the surface

## Architect's Impression of Farringdon Platform

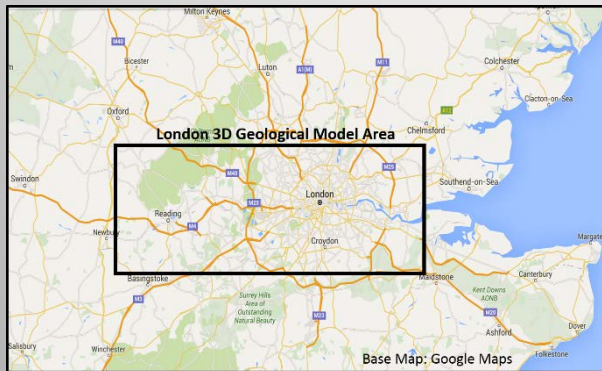


## PRIOR INVESTIGATIONS IDENTIFIED ADVERSE GROUND CONDITIONS:

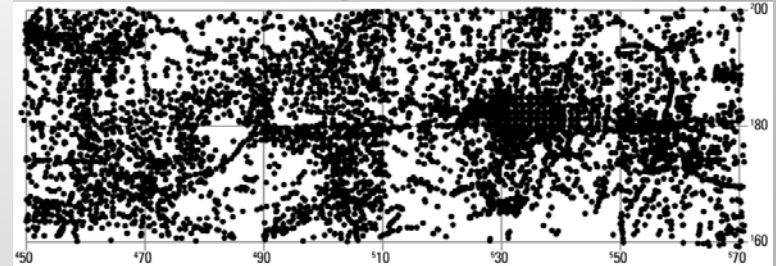
- Multiple faults,
- Buried valley of Fleet River
- Water-bearing sands within the tunneling medium (Lambeth Group)
- Potential surface settlement on old buildings and surface railway

# Existing 3D Subsurface Information

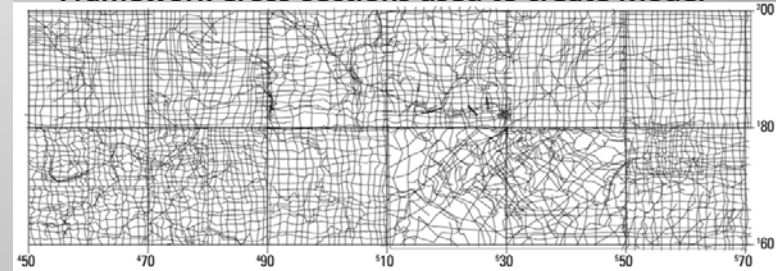
## BGS Regional 3D London Model



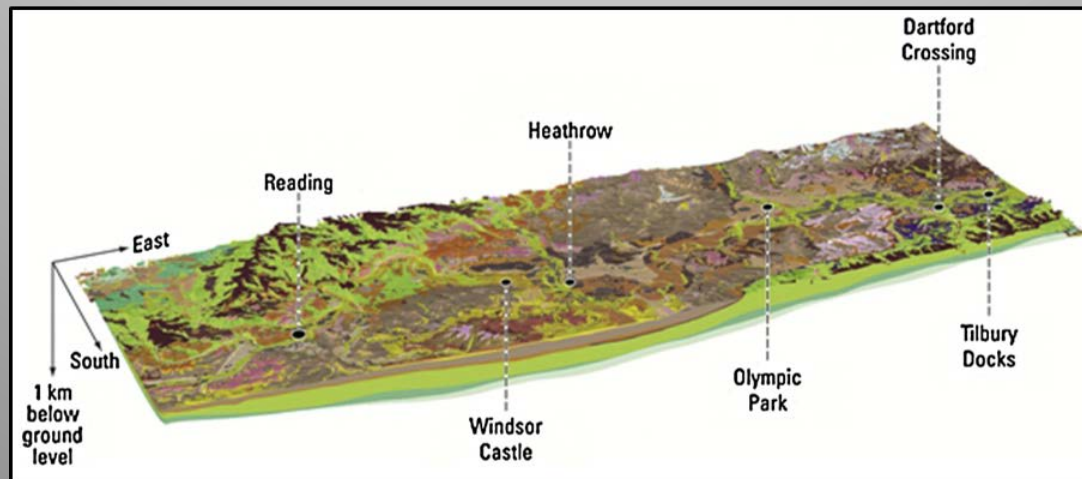
7174 Borehole logs used to create Model



Framework Cross-sections used to create Model



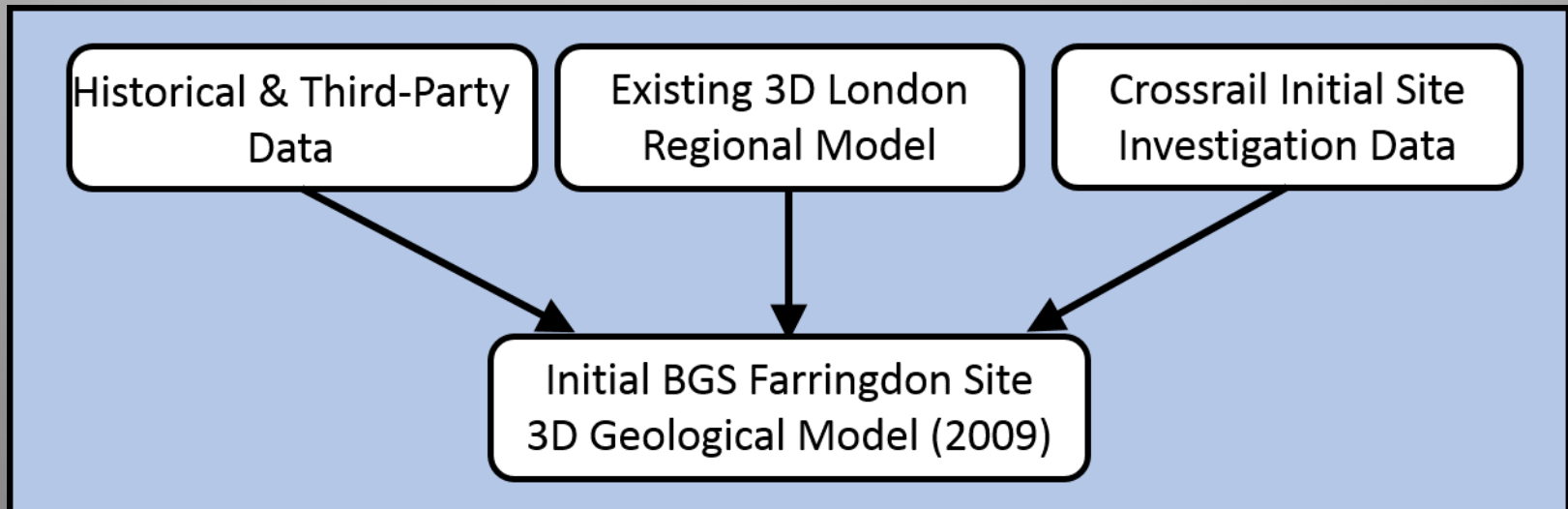
Oblique View of Completed London Model



(From Mathers et al., 2014)

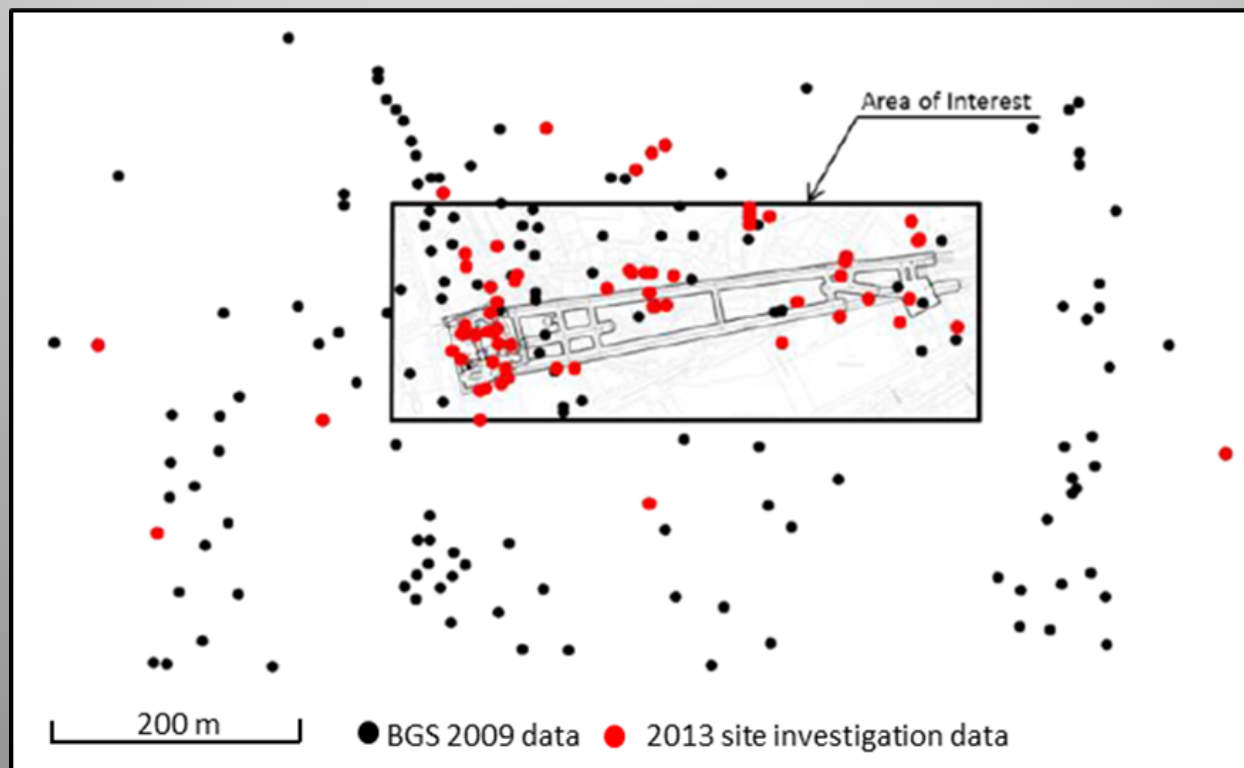
# Initial 3D Geological Model of Farringdon Station Site

- By 2008 Crossrail had completed initial ground investigations, at least on fault has been identified but little confidence in the ground model.
- In 2009 Crossrail commissioned BGS to develop a 3D geological site model to guide future investigations
- Model constructed using existing London regional model, historical & third-party data, and available Crossrail data



# Farringdon Station Design Modeling (2009-2013)

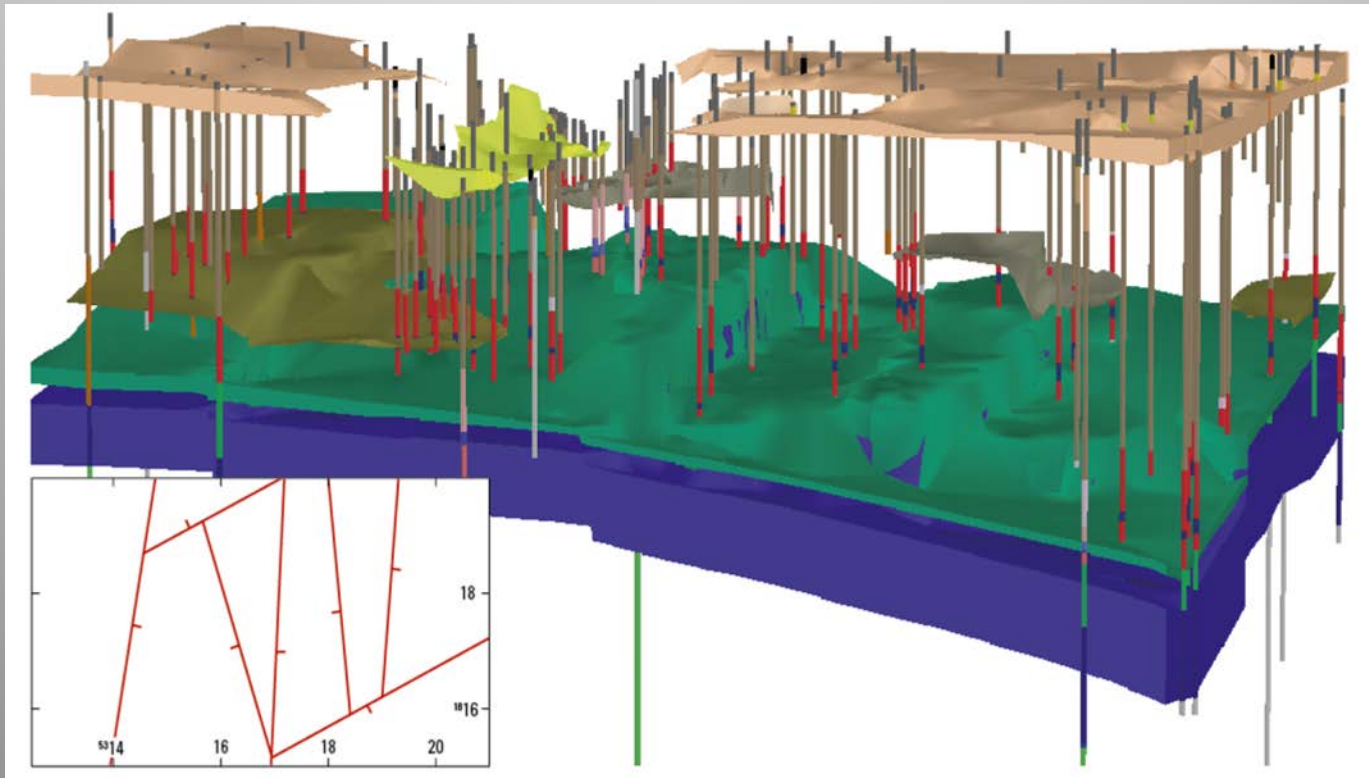
Initial 2009 BGS 3D geological model of Farringdon station was progressively updated as new Crossrail exploration data received





# Farringdon Station 3D Model

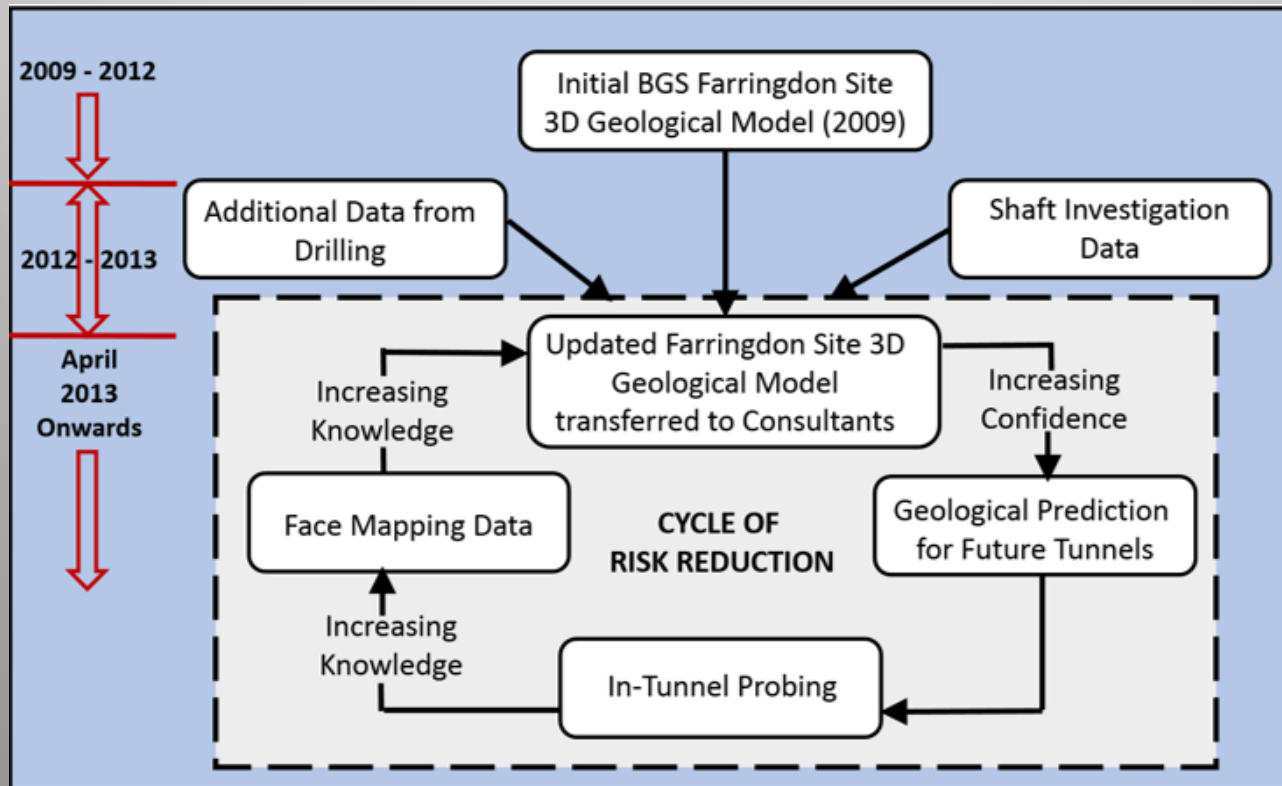
3D model display of sand and gravel (water-bearing) units and faults



(Aldiss et al., 2012)

# Farringdon Station 3D Model Integrated into Site Supervision Workflow (2013-2015)

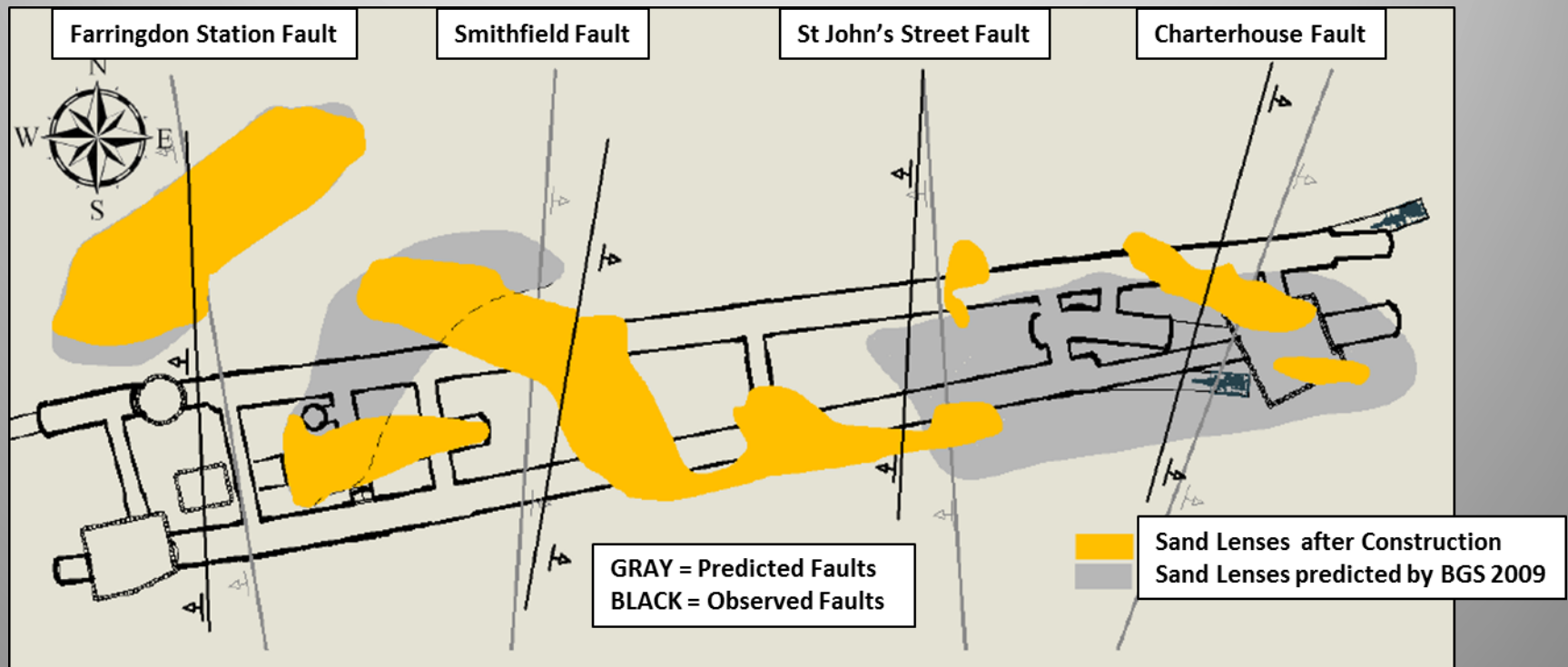
In 2013, this model was handed over to the contractor and integrated into the site supervision workflow



(Modified from Cabrero & Gakis, 2014)

# Farringdon Station

## Predicted vs Observed locations of sand lenses and faults

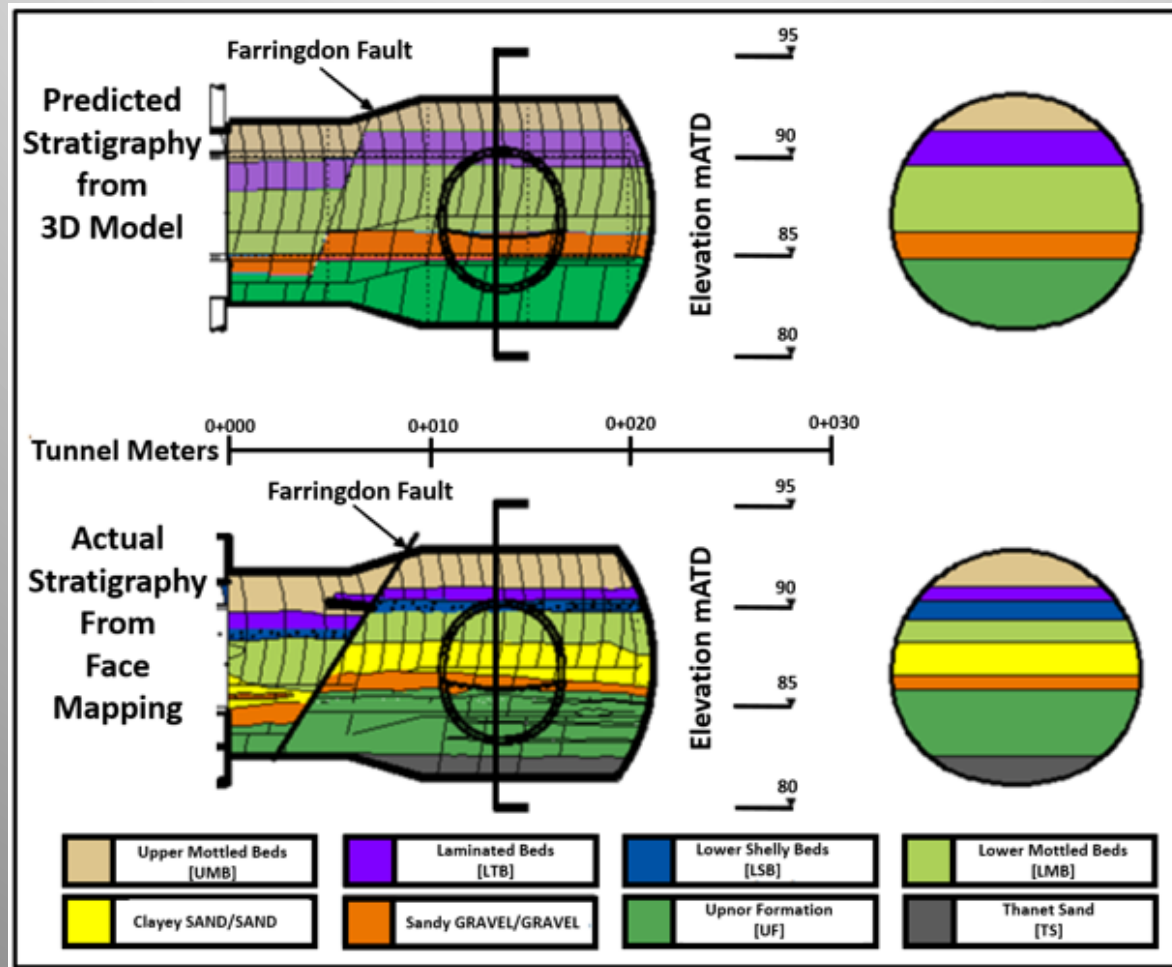


(Gakis, 2014)

# Farringdon Station

## Success in Predicting Geological Conditions

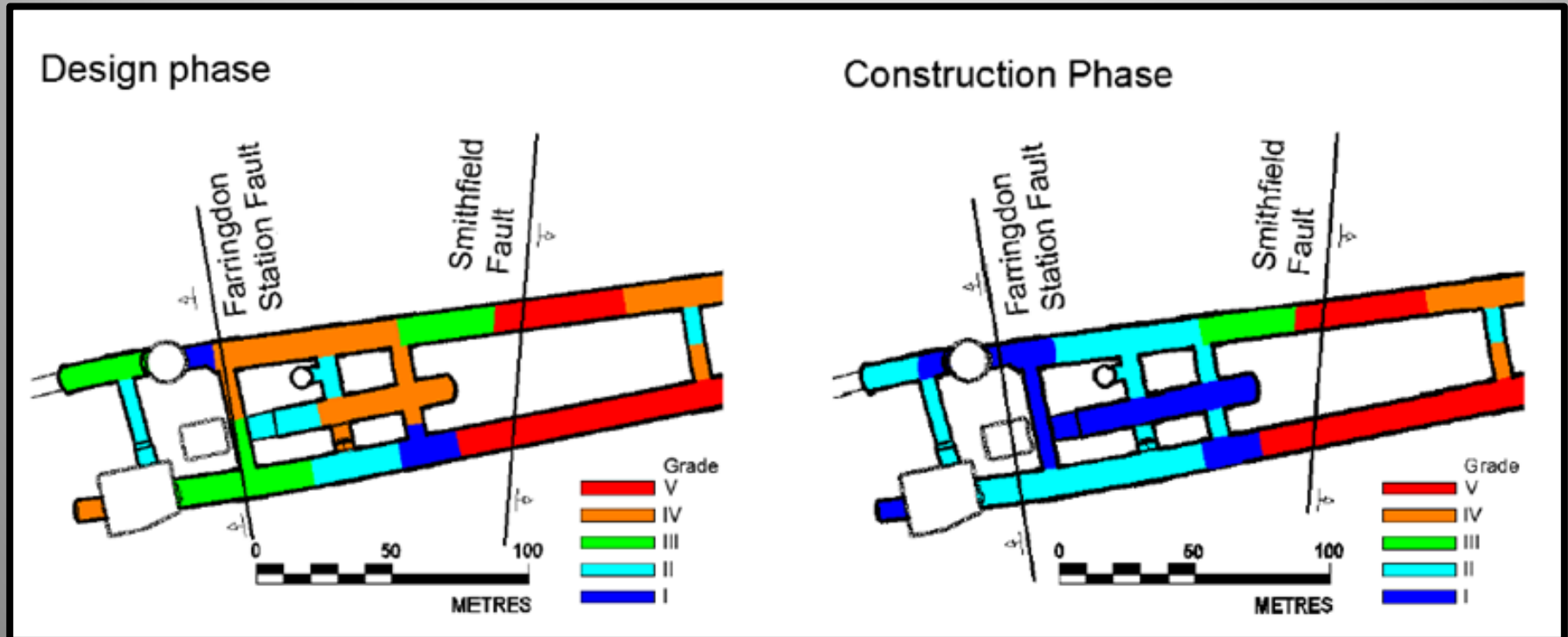
Geological predictions at one section of Farringdon station



(Gakis, 2014)

# Farringdon Station

## Comparison of Estimated Risks to SCL Tunneling from Water-Charged Sand Units



(Gakis et al., 2014)

# Consequences of Employing Farringdon Station 3D Model

Because the Ground Model was updated daily as station excavated:

- Enabled geological predictions ahead of excavation
- Provided a geological database to collate and store all acquired data
- Confidence increased as tunneling progressed
- Key Element in reducing Geotechnical Risk
- 70% reduction of in-tunnel probing compared to original plan
- Efficient SCL design and installation
- Station excavation completed 3 months early!

# **Planning for Electrification of Railway between Leeds and York (2015)**

- **28 km (17.5 miles) existing railway line is planned for electrification.**
- **Concern for foundations of support masts**
  - **Depth to bedrock, type of rock, weathering**
  - **Old mine workings, karst features, fault structures**
- **Long narrow 3D model created along railway**
  - **28 km long; 80 m wide, 30 m deep**
  - **Outputs transferrable to Bentley Microstation**
- **BGS completed/delivered model in 1 month**

# Planning for Electrification of Railway between Leeds and York (2015)

- A 4 km long section of central portion of route

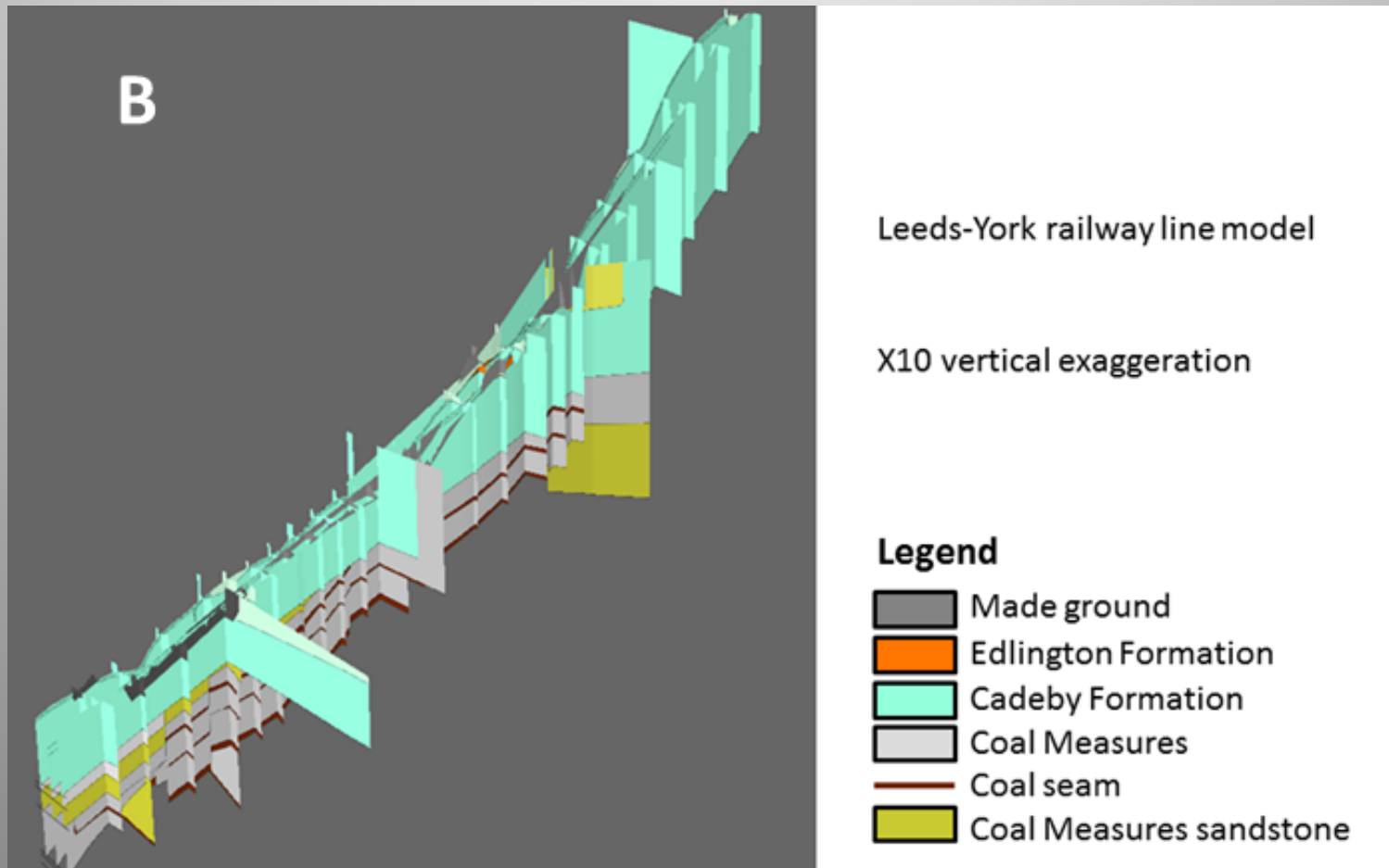


- Model consists of 3 parallel sections, and numerous short “rung” sections (25 shown in this portion of route)
- Model based on 1:10,000 BGS maps and 102 borehole logs
- Model contains 57 geological units, 11 coal seams, 29 faults



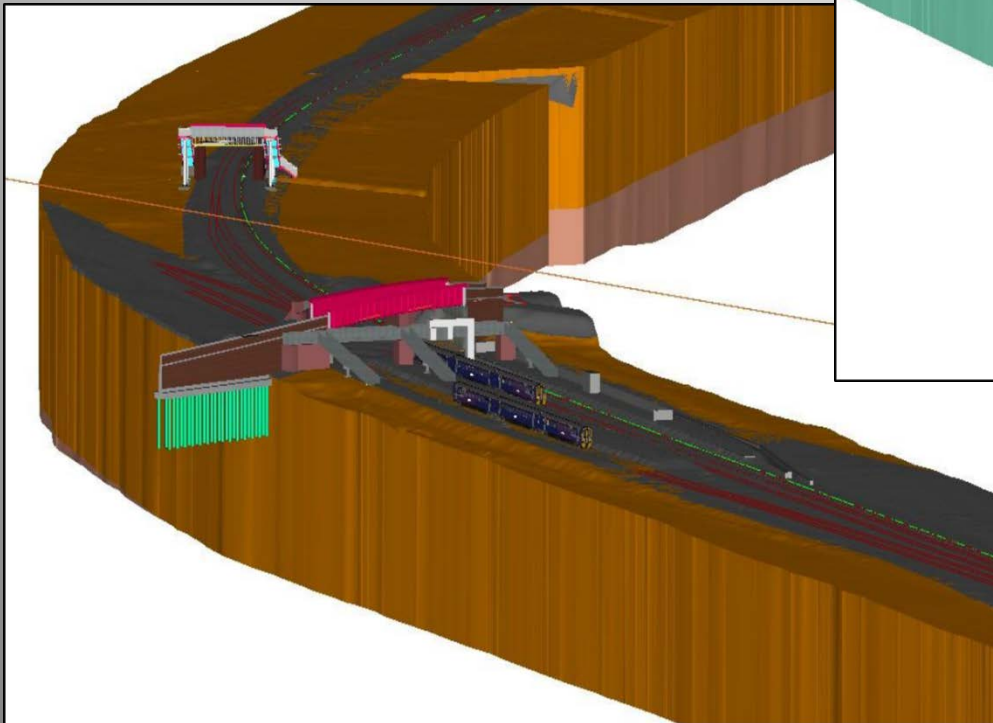
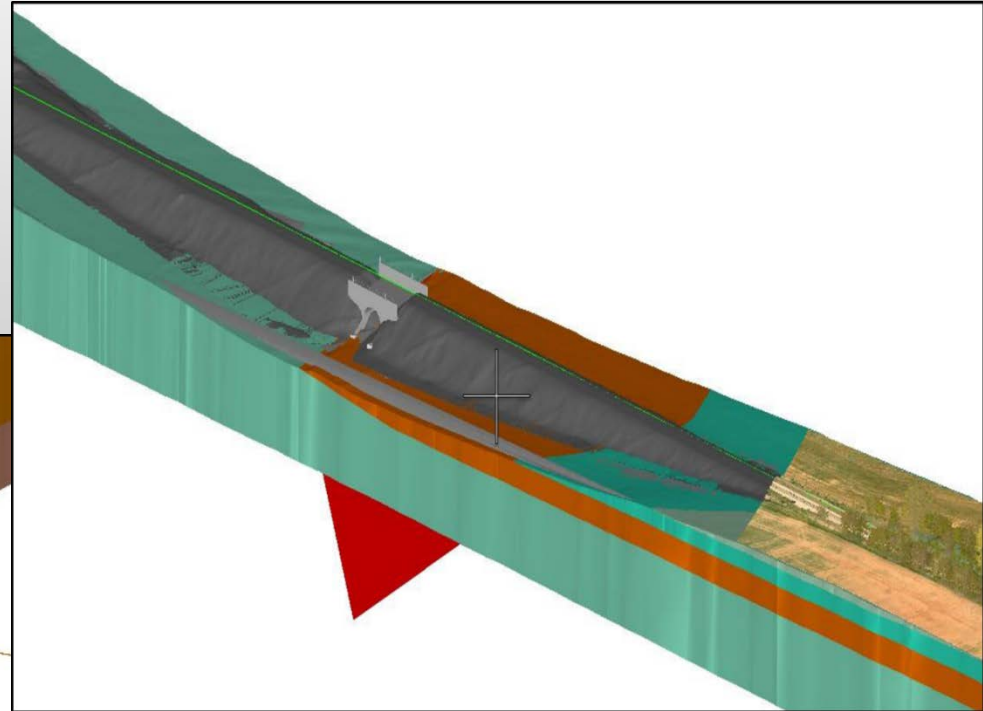
# Planning for Electrification of Railway between Leeds and York (2015)

- Isometric view of 3D model (central 4 km section)



# How Did Client Use the Model?

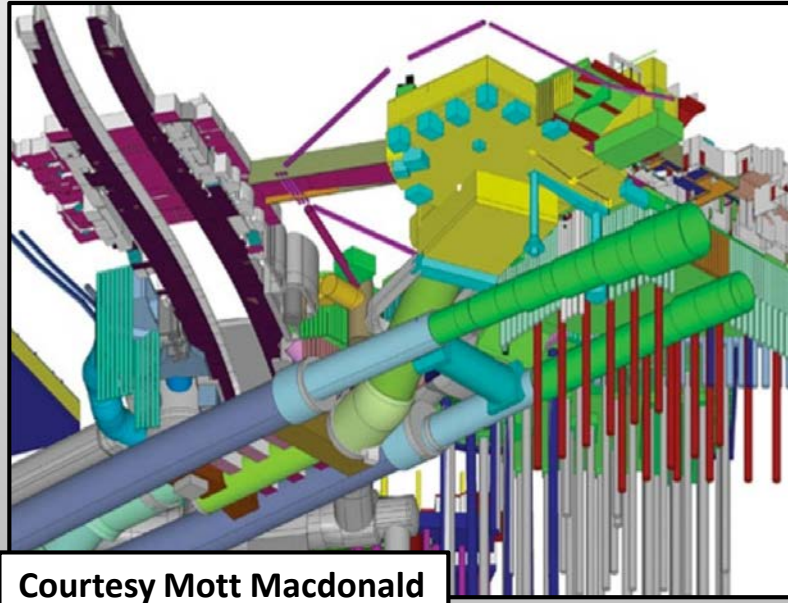
Combined geological model information with CAD infrastructure design files



This illustrates the future of 3D model applications

# Building Information Modeling (BIM)

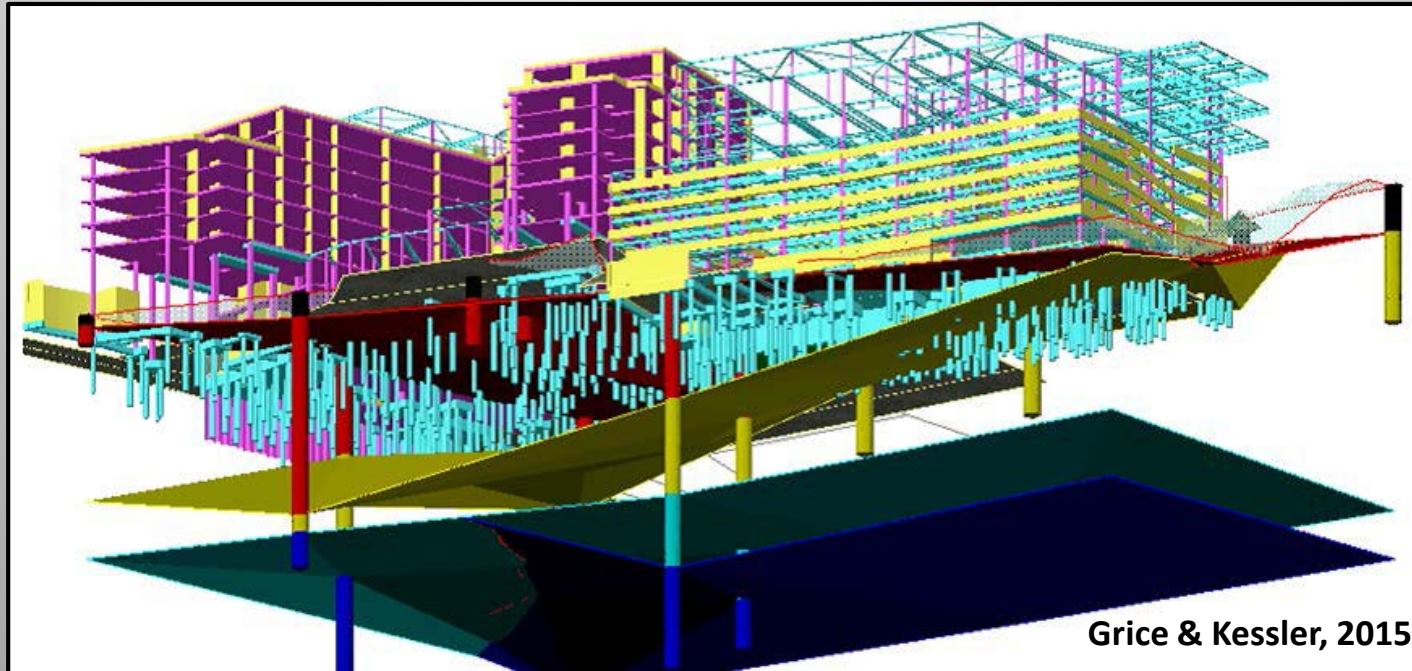
## But Where is the Geology?



- Process involving the generation and management of digital representations of physical and functional characteristics of places
- BIM files can be exchanged or networked to support decision-making about a place.
- Used by individuals, businesses and government agencies who plan, design, construct, operate and maintain diverse physical infrastructures.

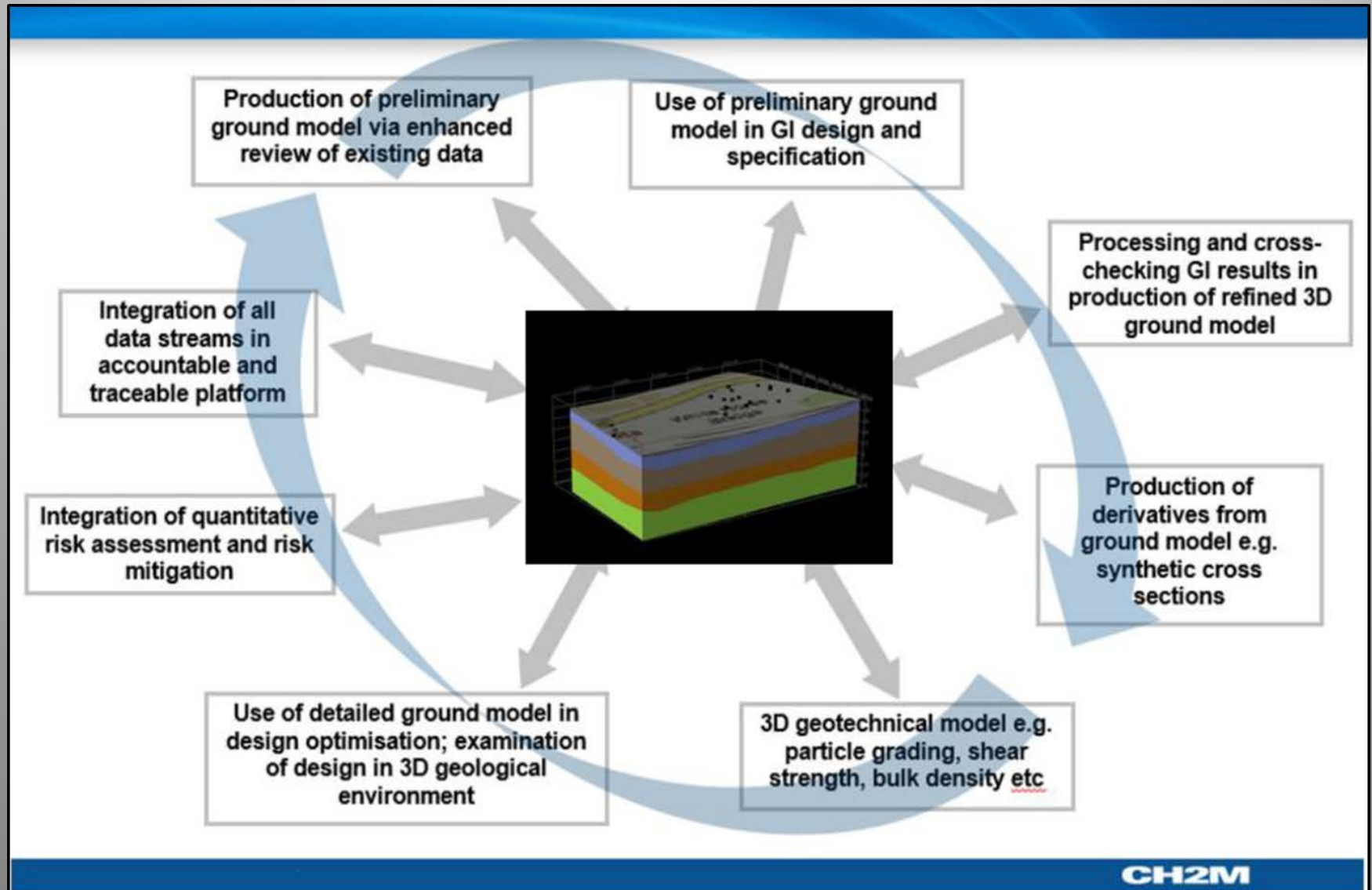
# “Geotech-BIM”

## *BIM and the Subsurface*



- **Extend/Integrate 3D Geological Modeling techniques to the BIM environment**

# Potential Geotech-BIM Workflow



# **Current Capability: City of London on 3D Geology Model**



**City model courtesy of ARUP**

# Available Now –

## Direct access to BGS geological maps and boreholes through web map services

The screenshot displays a software interface with a menu bar (Project, Data, Scheduling, Mapping, Preferences, Configuration, Help, Grid Tools) and a toolbar with various icons for data management and mapping. The main window is divided into several panes:

- Left Pane:** A tree view showing project structure with categories like Summary, Location Details, Samples and Lab Tests, Monitoring, Hole Construction, In situ Tests, Geological Information, Reports, and Saved Searches.
- Center Pane:** A table titled "Field Geological Descriptions" with columns for Location ID, Depth Top (m), Depth Base (m), Description, Legend Code, and Geology Code. The table lists various borehole entries such as BH136, BH137, BH138, and TP123.
- Right Pane:** A "Borehole Log" for BH137, showing a detailed log of soil and rock layers with depth, lithology, and a station description.
- Bottom Pane:** A map showing the geographic distribution of boreholes and other data points. The map includes a legend for Information Layers (Measures, Sections, Locations, etc.) and a scale bar (100 Meters / 300 Feet).

Location ID	Depth Top (m)	Depth Base (m)	Description	Legend Code	Geology Code
BH136		0.00	1.10 TOPSOIL	101	FILL
BH136		1.10	2.70 Dense grey-brown SAND with med...	404	GLACIAL TILL
BH136		2.70	3.30 Firm brown very sandy CLAY with a...	220	BOULDER CLAY
BH136		3.30	5.30 Brown CLAY with a little well rounde...	205	BOULDER CLAY
BH136		5.30	10.05 Brown CLAY with a little well rounde...	206	BOULDER CLAY
BH137	0.00	0.40	TOPSOIL	101	FILL
BH137	0.40	0.80	Spongy brown fibrous PEAT with so...	605	PEAT
BH137	0.80	3.50	Firm brown very sandy CLAY with a...	220	BOULDER CLAY
BH137	3.50	10.05	Brown CLAY with a little well rounde...	205	BOULDER CLAY
BH138	0.00	0.50	TOPSOIL	101	FILL
BH138	0.50	1.20	Dense grey-brown SAND with med...	404	GLACIAL TILL
BH138	1.20	2.30	Firm brown very sandy CLAY with a...	220	BOULDER CLAY

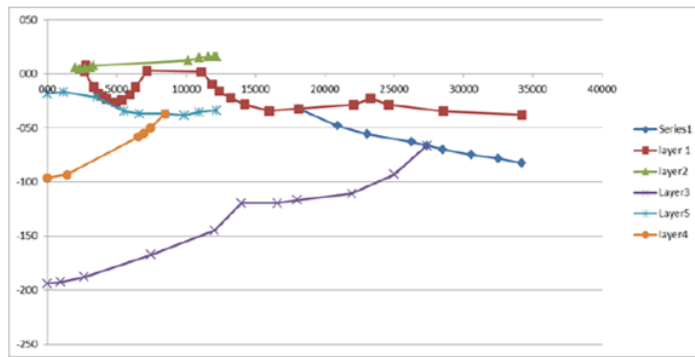
# Current Research – Integrating Digital Field Information with 3D Models

## Working with the AGS

(equivalent too DIGGS in North America)

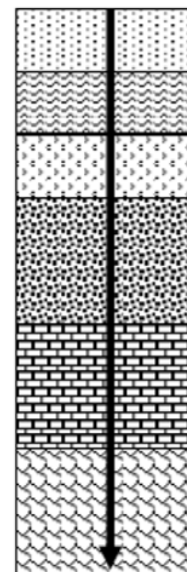


A new initiative to include interpreted data and the concept of layers in the next phase of the AGS data transfer format (AGSi)



Geological cross-section transmitted via xml and visualised in Excel

### Electronic Reporting

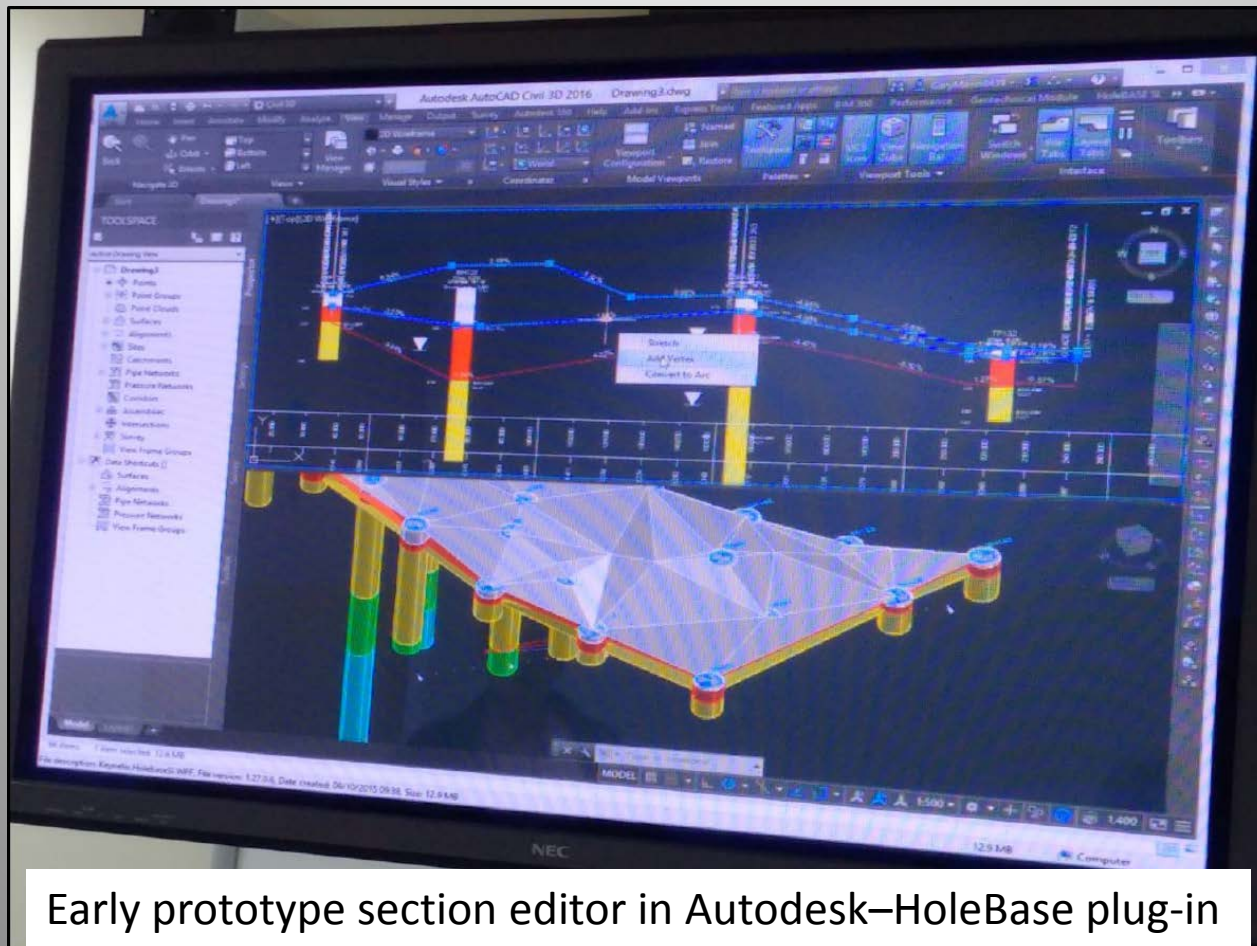


- Site Exploration
- Laboratory Testing
- SI Presentation
- Engineering Analysis
- CAD Presentation, 3D modelling and GIS
- Local or national Archive



# In The Future –

Ability to edit sections and surfaces and submit them back to the BGS to be incorporated in the national geological model



Early prototype section editor in Autodesk–HoleBase plug-in