



British
Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

Gateway to the Earth

3D geological modelling for infrastructure projects in the context of a national geological model

Holger Kessler

Geologist, Team Leader Modelling Systems

including work by

Dave Entwisle, Helen Burke, Rachel Dearden, Luz Ramos, John Lee, Cath Cripps, Leanne Hughes, Ben Wood, Jon Ford, Ricky Terrington, Don Aldiss
and our external partners

**Effective Site Investigation
and Data Management**

24-25 May 2017, Birmingham

BGS @ NERC 2017



brownfieldbriefing

The British Geological Survey



- UK national Geological Survey
Founded in 1835
- UK custodian of geoscientific information
- 646 staff (510 multi-disciplinary scientists)
- Part of NERC not-for-profit Public Sector Research Establishment
- Funded by Government & external income through commissioned research
- Offices at Keyworth, Wallingford, Edinburgh & Cardiff

Maps to models in Great Britain

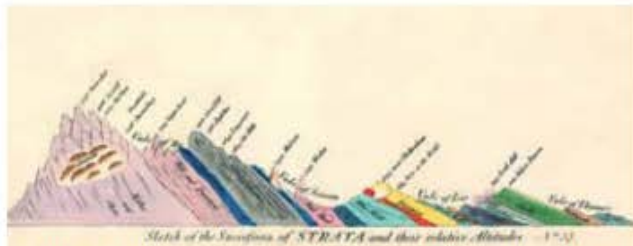
The mission has remained constant:
To understand & explain the Geology



1815



William Smith



Sketch of the Succession of STRATA and their relative Altitudes - 1793

1874



1939



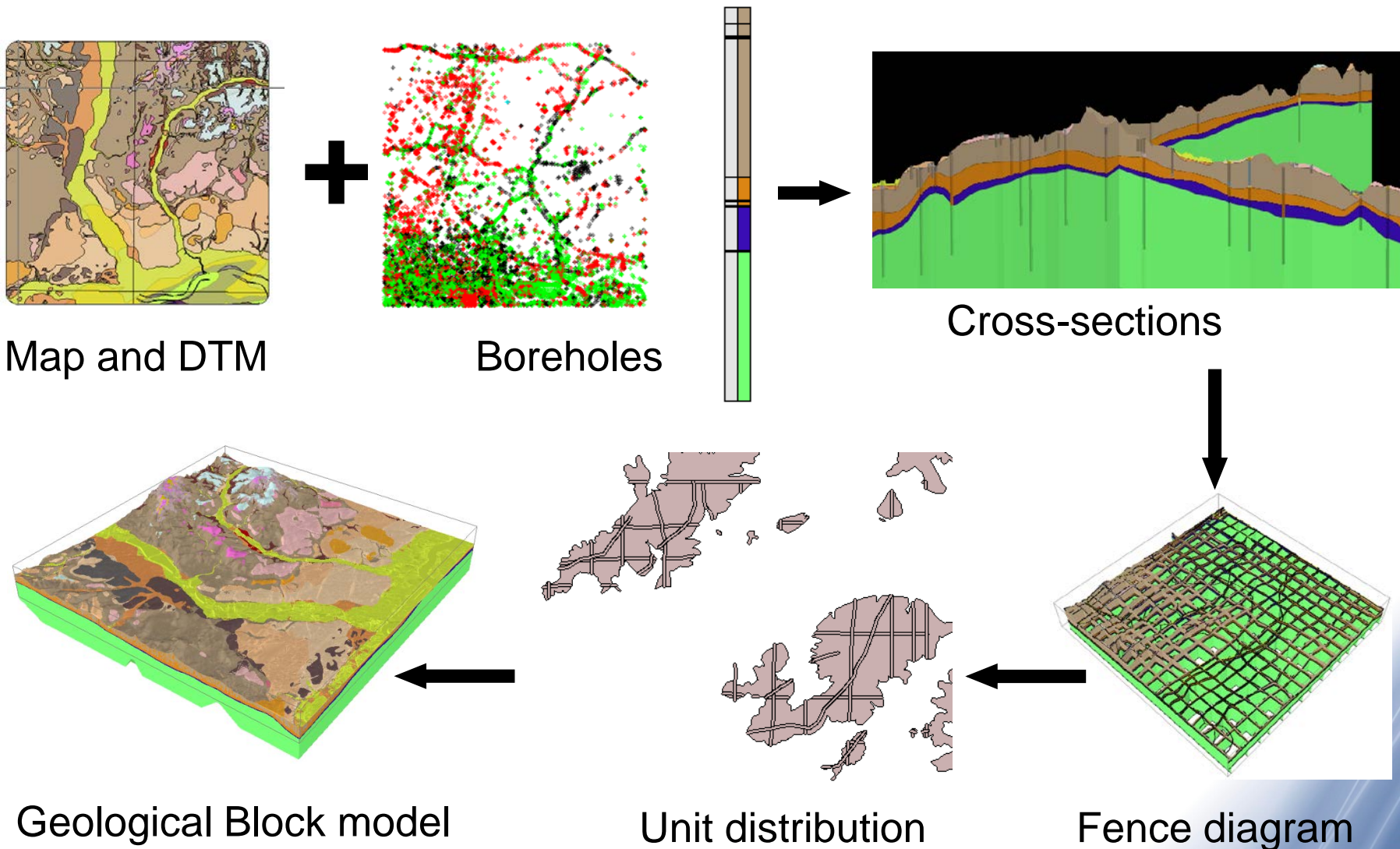
2007



2012

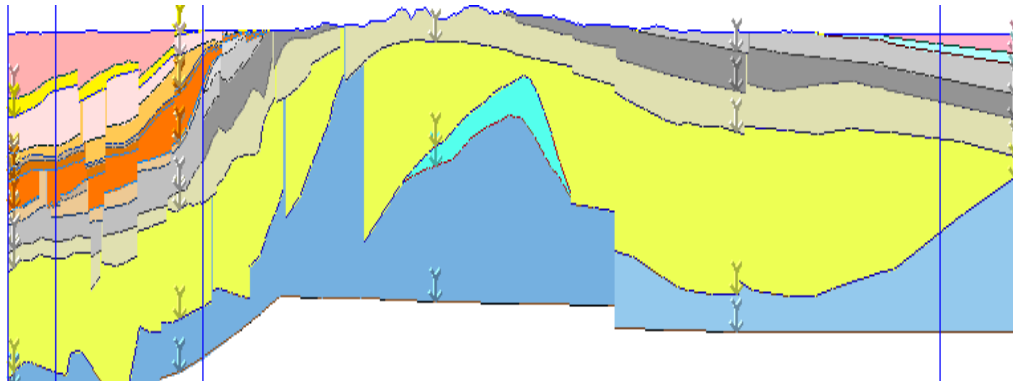
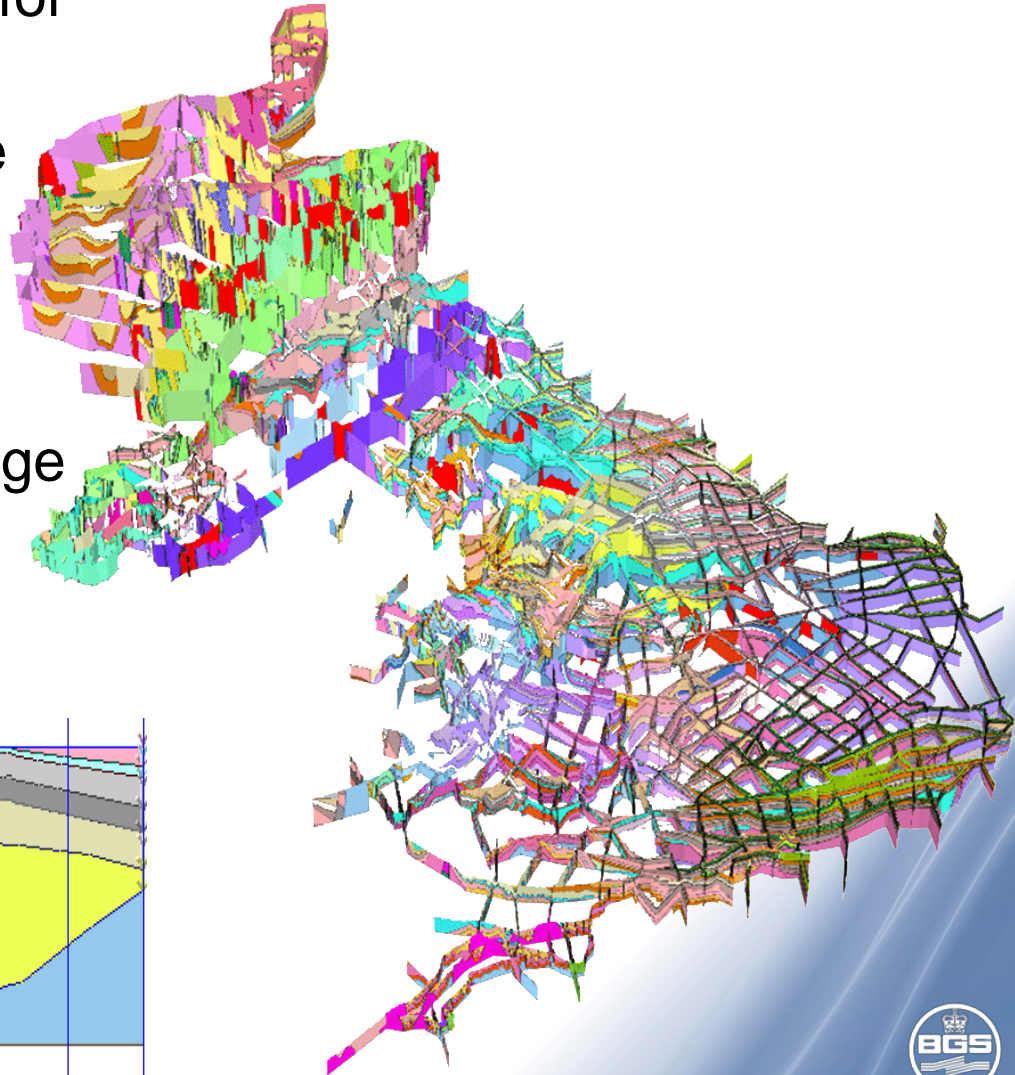


Building a geological model (aka 3D mapping)



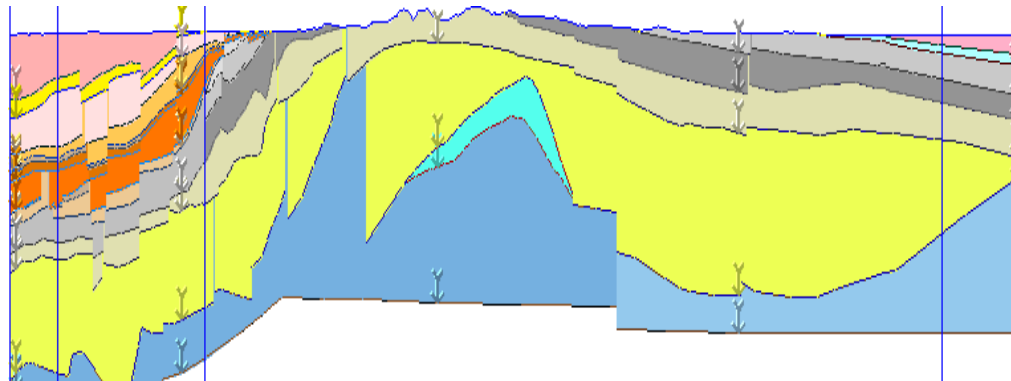
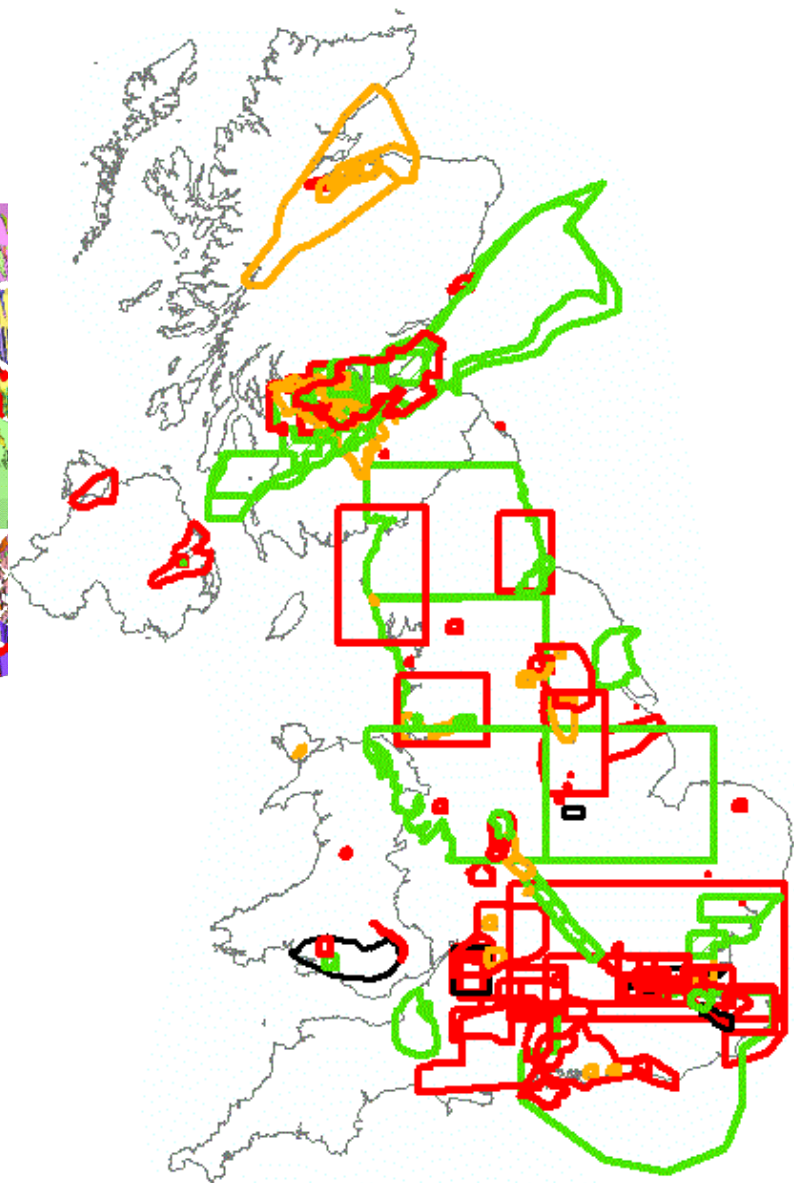
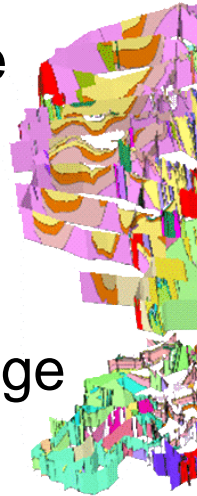
UK3D - National Bedrock Model

- An impartial reference-frame for the UK subsurface
- Successor to 1:625,000 scale map
- Synthesises a wealth of data and interpretation
- Captures geologists' knowledge in a consistent framework
- Peer-reviewed, open dataset



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Geology of Britain viewer



[More BGS map viewers](#)

- Surface Geology
- 3D Models
- Borehole Scans
- Earthquake Timeline

Groundhog 3D geological models

1) Choose Model:

Select from list

2) Drill virtual boreholes, or create virtual sections.

Drill Borehole

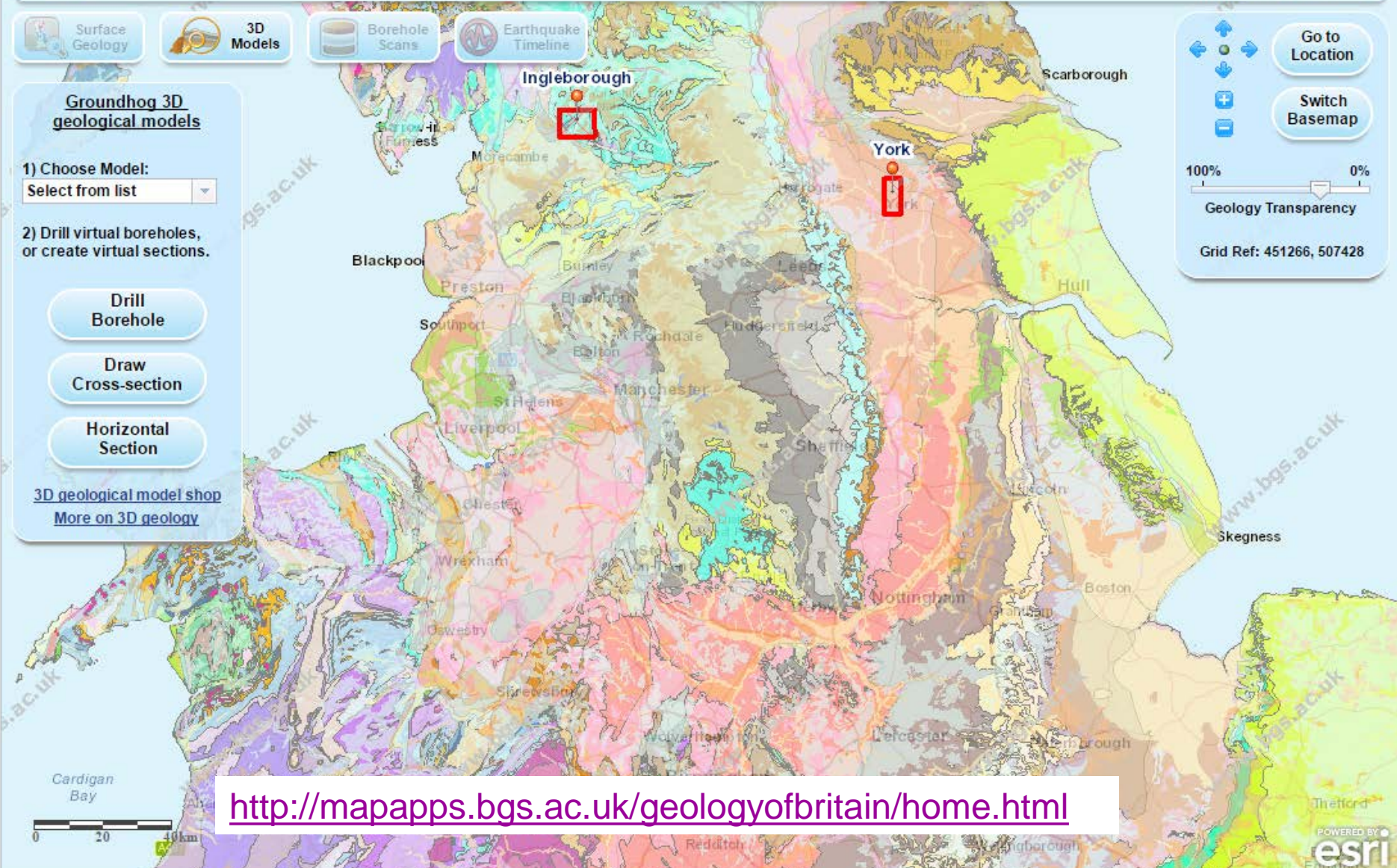
Draw Cross-section

Horizontal Section

[3D geological model shop](#)
[More on 3D geology](#)

Navigation controls:

- Go to Location
- Switch Basemap
- Scale: 100% to 0%
- Geology Transparency
- Grid Ref: 451266, 507428



<http://mapapps.bgs.ac.uk/geologyofbritain/home.html>

Point and section prognosis

[Home](#) [Browser](#) [Basket](#) [Info](#) [Help](#) [T&Cs](#) [Privacy](#) [Contacts](#)

3D Geological Models from the British Geological Survey

The British Geological Survey's National Geological Model is a 3D representation of the UK subsurface. This model shows not only the geological units at the surface (akin to a map), but also their variation with depth.

Models can be used to identify the thickness and order of geological units as well as provide information about how the elevations of geological surfaces vary spatially.

Currently, there are two types of model available:

- **Deep, regional-scale models**
typically used for natural resource estimates and groundwater studies
- **Shallow, local-scale models**
typically used for ground investigations, groundwater studies and tunnelling projects

Model coverage will increase over time as we load more models, so please visit us regularly.

Use the Model Browser to view our 3D geological model coverage and explore what outputs are available.



Explore models and shop

3D Geological Model Outputs

	Synthetic Borehole Reports Place a point on a map and obtain a prediction of the depths of the modelled units at that location. Download an Example Synthetic Borehole Report (PDF 903KB)	£10.00 (+VAT)
	Cross Section Reports Place two points on a map to define a line and obtain a predicted cross section of the modelled geological units. Download an Example Cross Section Report (PDF 963KB)	£30.00 (+VAT)
	Horizontal Section Reports Select a rectangular area on a map and obtain a geological map at an elevation below the ground surface. Download an Example Horizontal Section Report (PDF 896KB)	£30.00 (+VAT)
	3D Geological Model Data Geological unit surfaces, thicknesses and 3D grids can be exported from the models and licensed in GIS/text formats. Some models can be delivered in interactive 3D viewers. Please contact us to discuss your requirements.	

Commercial service via the BGS shop

<https://shop.bgs.ac.uk/groundhog>

Geological models

A geological model is a virtual representation of the geology in three dimensions. Geological models can provide information on geological unit surface elevations or thicknesses and can be queried to generate synthetic boreholes and vertical and horizontal cross-sections.

Geological models are created by geologists using geological data and expert knowledge. Data such as borehole records, geophysics, field observations and digital terrain models are interpreted and the conceptual geological understanding is captured via geological cross sections, geological maps and/or point interpretations that describe a surface. The 3D geological model is created by interpolation between all interpreted points.

The accuracy of the geological model is dependent on, for example, the data density, the prevailing understanding of the geology at the time of modelling and the geological complexity. The geological map herein indicates the sites of borehole records considered by the geologist and also the locations of interpreted cross sections; the density of these around the area of interest provides an indication of uncertainty.

Limitations

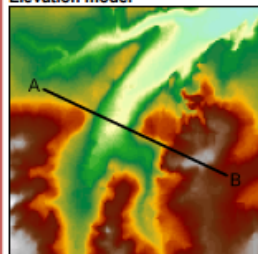
The quality of observations and interpretations may be affected by the availability of new data, by subsequent advances in knowledge, improved methods of interpretation, improved databases and modelling software, and better access to sampling locations. The top surface of the geological model is constrained by the digital terrain model; this may contain artefacts and may have been sub-sampled at a lower resolution and thus minor mismatches between geomorphological features and modelled units may occur.

The information herein should not be used as a replacement for site investigation. For further information on the limitations of modelling in this area, see the relevant metadata report available from enquiries@bgs.ac.uk and view the current terms and conditions at <http://shop.bgs.ac.uk/Groundhog>. For comprehensive information of the geology at this point, please use our BGS GeoReports Service at <http://shop.bgs.ac.uk/GeoReports/>.

Feedback

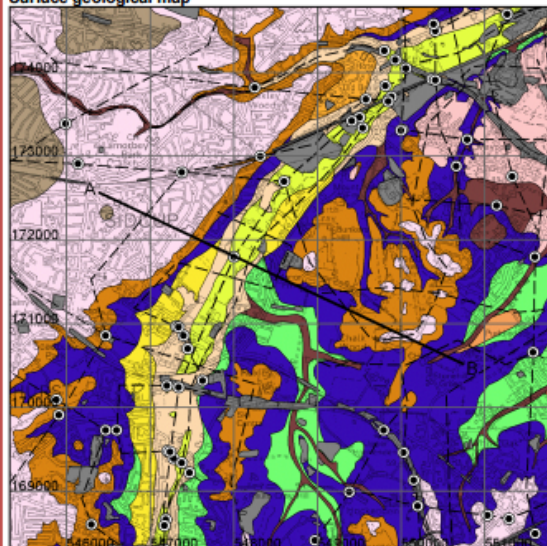
To improve geological models your feedback is essential. Please contact enquiries@bgs.ac.uk if your site investigations yield data that could improve our interpretations.

Elevation model



© NEXTMap Britain elevation data from Intermap Technologies

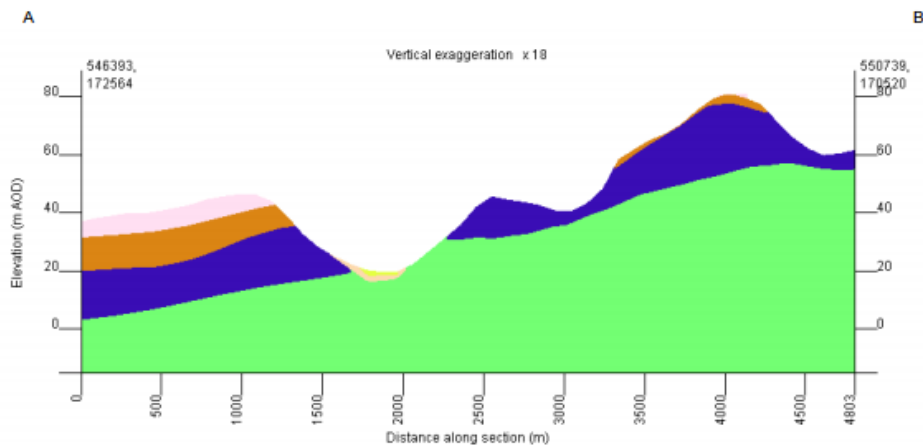
Surface geological map



Legend

- Worked Ground (Void)
 - Made Ground (Variable composition)
 - Infilled Ground (Variable composition)
 - Landscaped Ground (Variable composition)
 - Alluvium (Clay, Silty, Sandy, Gravelly)
 - River Terrace Deposits (Gravel, Sandy)
 - Head (Clay, Silty, Sandy, Gravelly)
 - Crayford Silt Formation (Silt, Sandy)
 - Taplow Gravel Formation (Gravel, Sandy)
 - Lynch Hill Gravel Formation (Gravel, Sandy)
 - Boyn Hill Gravel Formation (Gravel, Sandy)
 - London Clay (Clay, Silty, Sandy)
 - Harwich Formation (Sand, Gravelly)
 - Lambeth Group (Clay, Silty, Sandy, Gravelly)
 - Thanet Sand Formation (Sand)
 - Chalk Formation, undifferentiated (Chalk)
 - Gault and Upper Greensand Formations (Mudstone, Sandstone and Limestone)
 - Lower Greensand Formation (Sandstone and Mudstone)
 - Wealden and Jurassic strata, undifferentiated (Mudstone, sandstone and limestone)
- Borehole record
 Interpreted cross section
 Synthetic cross section

Geological cross section



Sidcup to Hextable

Report ID: GH_100074/134

Model: London and Thames Valley geological model

Regional geological model originally created by H Burke, S Mathers, J Ford, R Terrington, S Thorpe, P Williamson. Model released: 2014.

The information on this map sheet, including the surface geological map and the synthetic cross section, is derived from the National Geological Model. Geological models provide an indication of reality; alternative interpretations of the same data are possible. The surface geological map is based on the published geological map, with revisions based on new interpretations and may therefore differ from published geological maps and products. Truncation of the lowest unit in the cross section does not necessarily denote its basal depth. Heights are in metres.

Deposits of artificial ground, head and clay with flints typically form thin veneers and whilst they are present on the surface map, they may be absent in the synthetic borehole or section.

Boreholes shown on the map were considered during the construction of the geological model. The original borehole records can be viewed at <http://shop.bgs.ac.uk/Groundhog>.

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East Anglia - Geological 3D Model

Geological 3D model prepared by S J Mathers, S Thorpe and R L Terrington
Interactive 3D PDF by C Ritchie



Produced by the British Geological Survey www.bgs.ac.uk

Orfordness, Suffolk from the southwest
Photograph © Mike Page 2016

This model provides a unique visualisation of the 3D geology of the East Anglia region. It is provided to accompany the new regional guide to the geology of this area produced by BGS. The model shows the subsurface arrangement of the sedimentary rocks and associated igneous intrusions to a depth of 1.5 kilometres.

This document is divided into four pages: this introductory page; the 3D geological model with display and interrogation tools; an expanded geological legend for the model and instructions on how to navigate and use the tools with the model. You can navigate quickly between pages using the page links to the right.

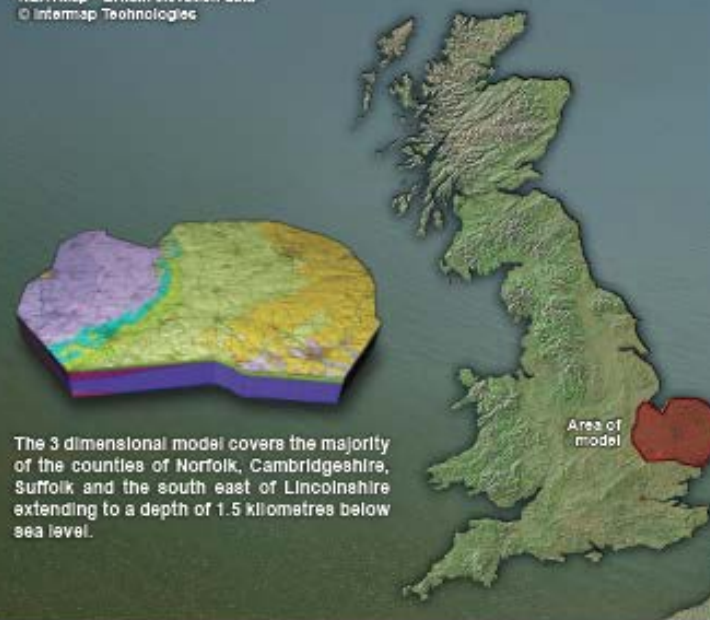
- [Geological Model](#)
- [Detailed Legend](#)
- [Instructions](#)

This publication forms part of an ongoing program to improve delivery methods for BGS geological information – we welcome your feedback. Please feel free to send us your comments at the following email address: imap@bgs.ac.uk

Based on British Geological Survey geological data © NERC 2016

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NEXTMap™ Britain elevation data
© Intermap Technologies



The 3 dimensional model covers the majority of the counties of Norfolk, Cambridgeshire, Suffolk and the south east of Lincolnshire extending to a depth of 1.5 kilometres below sea level.

East_Anglia_3D.pdf (SECURED) - Adobe Acrobat Pro

File Edit View Window Help

Open Create

2 / 4 71.3%

Tools Fill & Sign Comment

This file includes fillable form fields. You can print the completed form and save it to your device or Acrobat.com. Highlight Existing Fields

Key to geological units

- Neogene
 - Crag Group
- Palaeogene
 - Thames Group (including London Clay)
 - Lambeth Group
 - Thanet Sand Formation
- Cretaceous
 - White Chalk Subgroup
 - Grey Chalk Subgroup
 - Gravel Formations and Upper Greensand Formation
 - Lower Greensand Group
 - Wesdon Group (Mudstone, siltstone & sandstone)
 - Wesdon Group (Sandstone & siltstone, interbedded)
- Jurassic
 - West Walton Formation, Ampthill Clay Formation and Fildesbury Clay Formation
 - Kettlewell Formation and Oxford Clay Formation
 - Inferior Oolite Group and Great Oolite Group
 - Lias Group
- Permo-Triassic
 - Mercia Mudstone Group
 - Sherwood Sandstone Group
 - Zechstein Group
 - Other Permian Rocks
- Devonian and Carboniferous
 - Coal Measures Formation
 - Dumfries Rocks (Carboniferous Limestones)
 - Devonian Rocks
- Lower Palaeozoic
 - Intrusive igneous Rocks
 - Silurian Rocks
 - Ordovician Rocks
 - Cambrian and Ordovician Rocks (Undifferentiated)
 - Cambrian Rocks
- Pre-Cambrian
 - Neoproterozoic to Palaeozoic Rocks (Undifferentiated)
 - Neoproterozoic Rocks

Ground surface

National grid (major 20km, minor 5km)

Topography

Transparency

Bedrock geology

Transparency

Block display control

All on All off

Selected feature

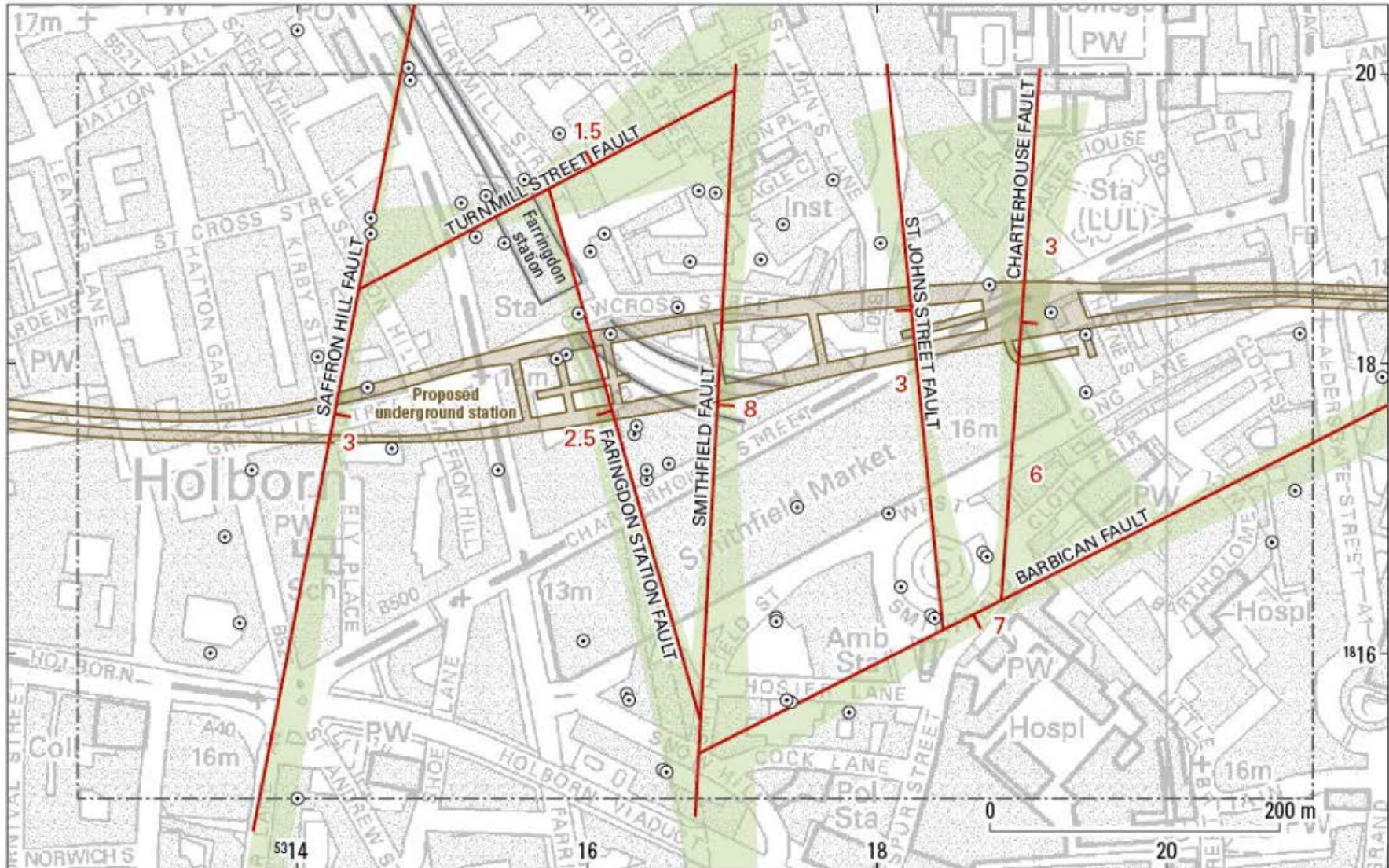
Stratigraphy:
Lithology:
Age:
GBS Lesson code:

Direction: N
Bearing: 349°
Pitch: -20°
Roll: -4°

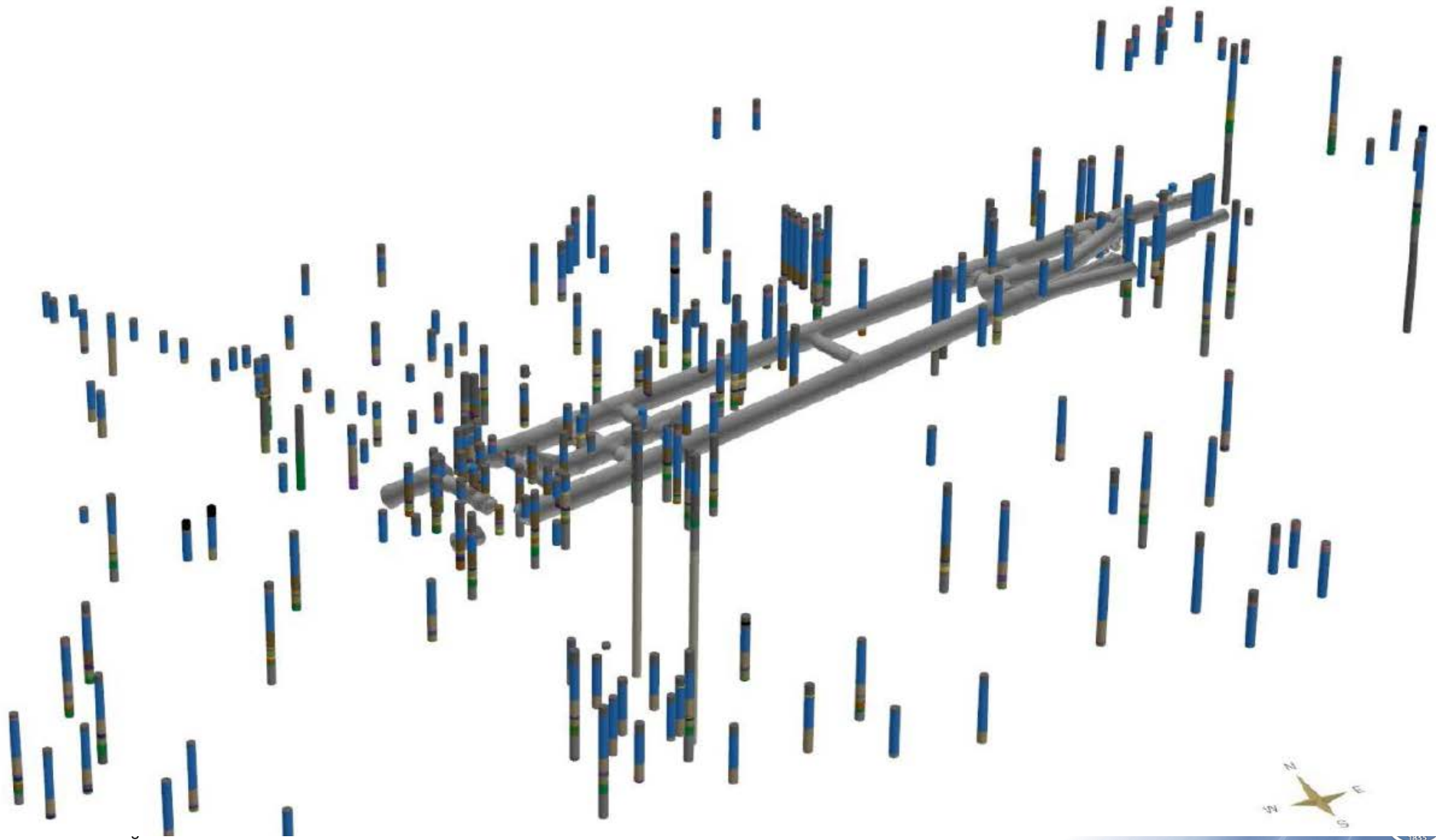
Vertical Exaggeration Factor: x 9

Introduction ▶
Detailed Legend ▶
Instructions ▶

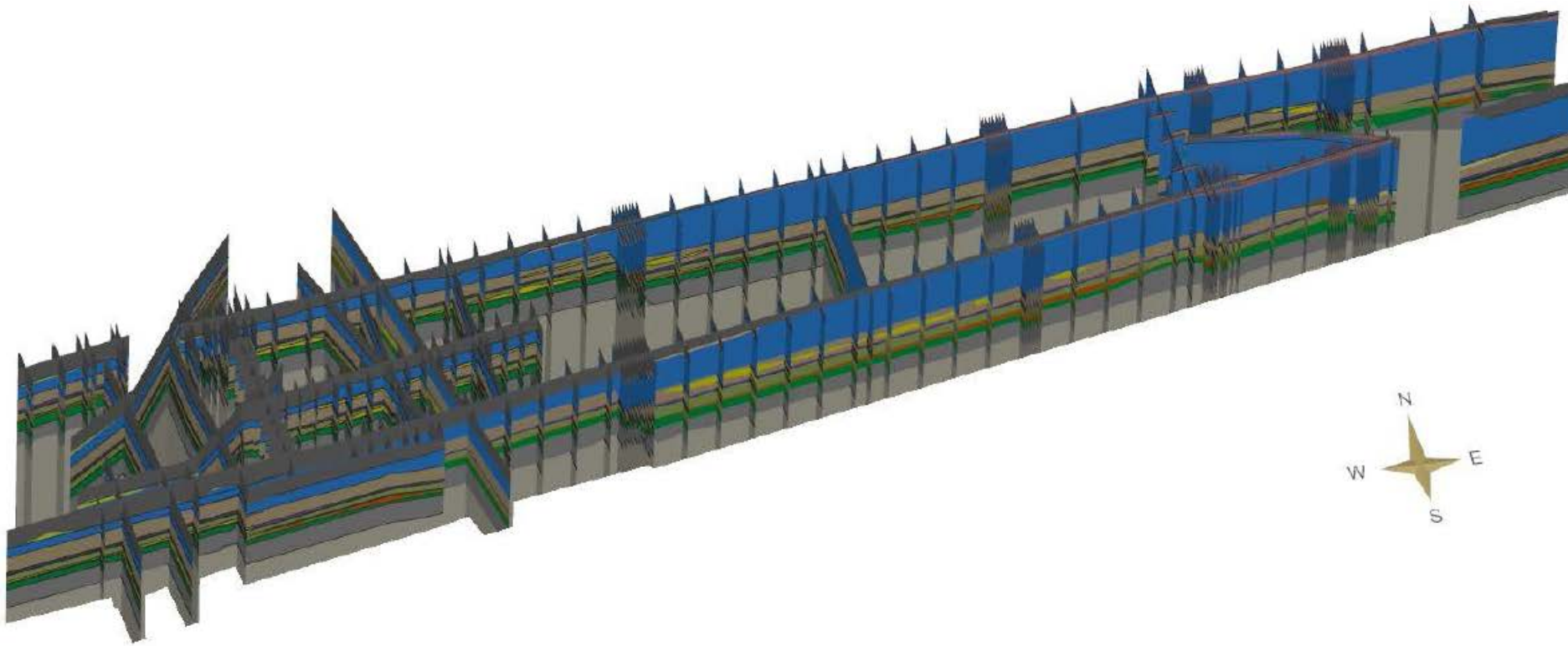
3D geological risk management approach at Farringdon Crossrail Station



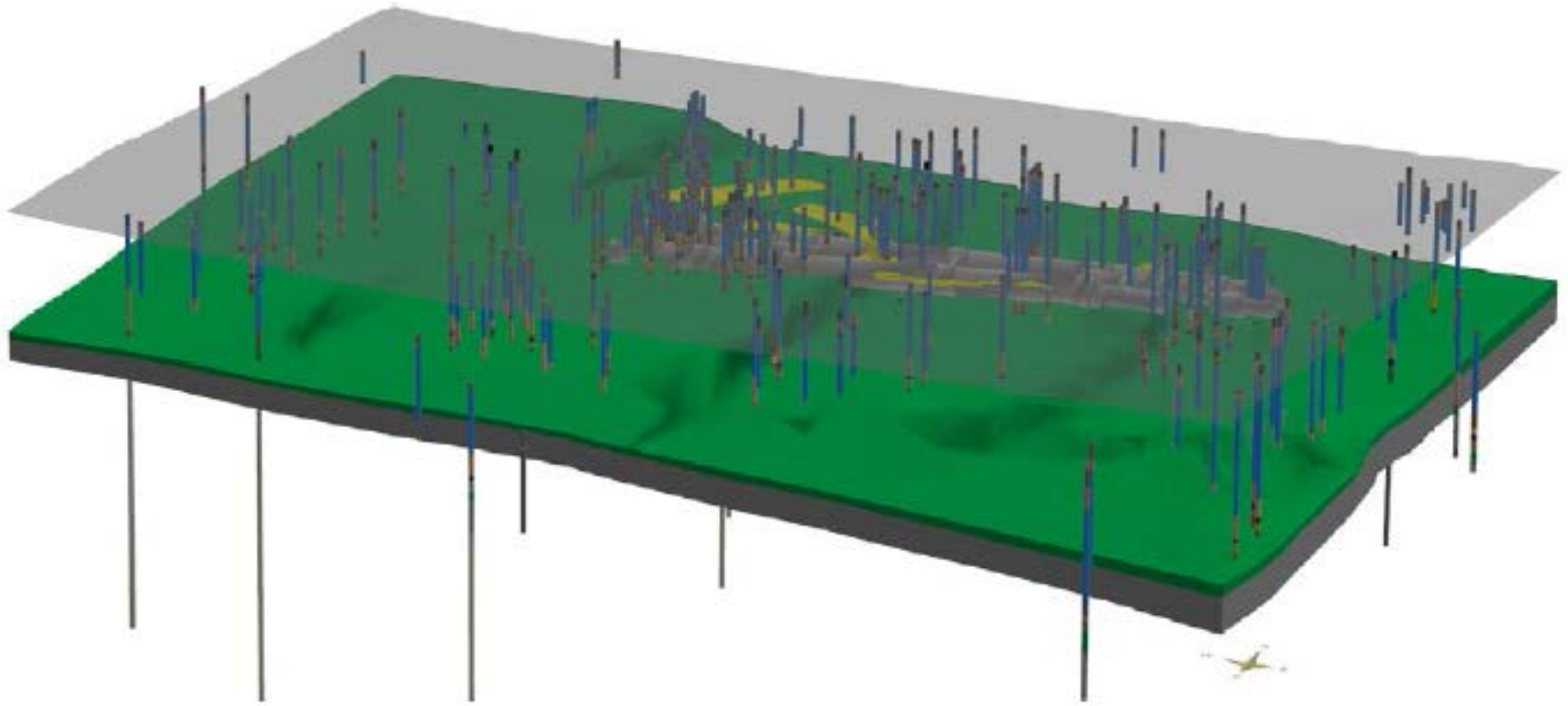
3D geological risk management approach at Farringdon Crossrail



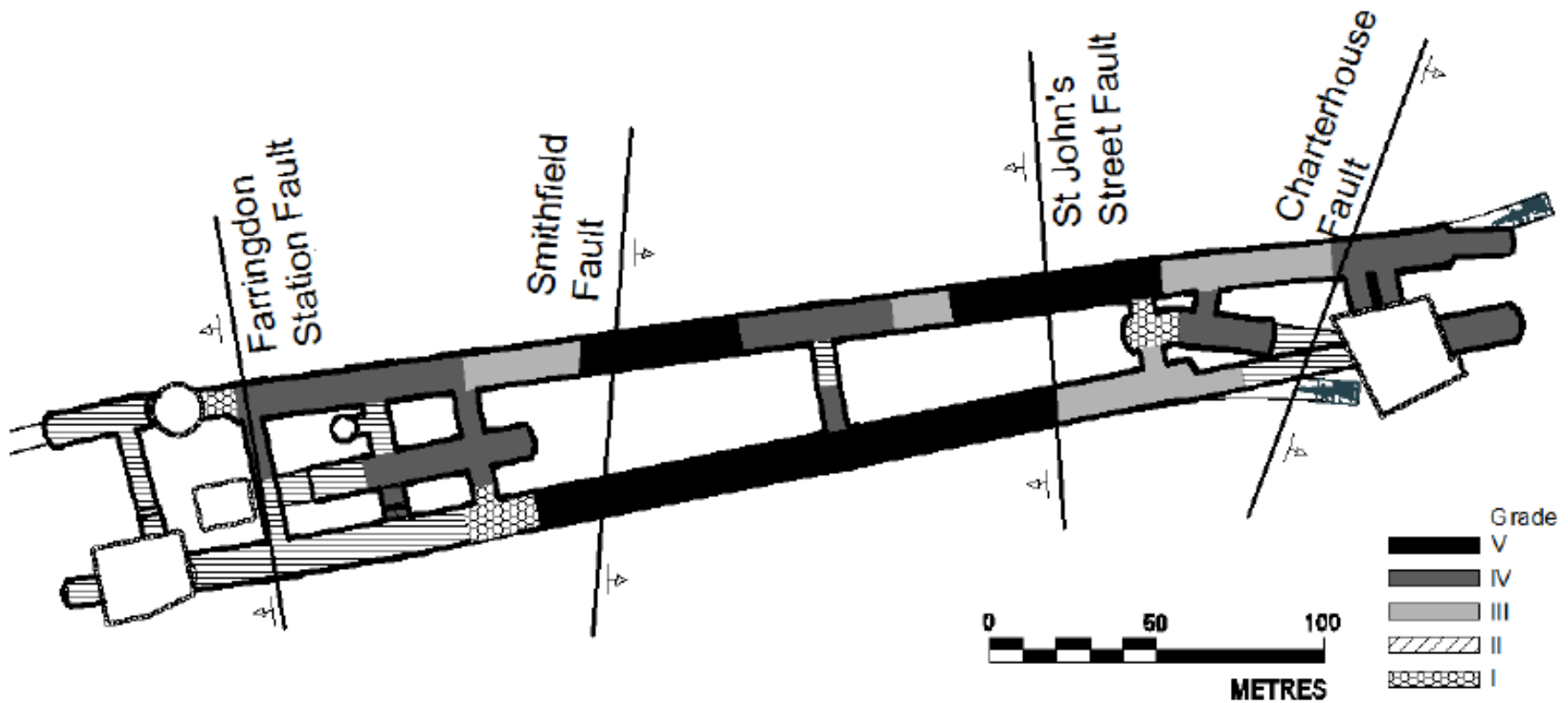
3D geological risk management approach at Farringdon Crossrail



3D geological risk management approach at Farringdon Crossrail



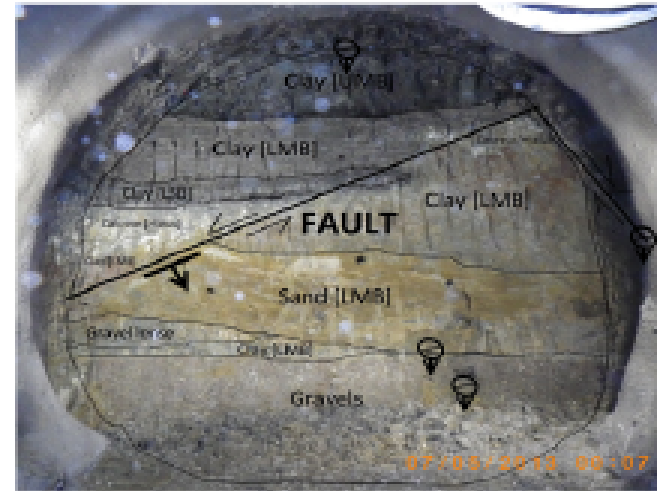
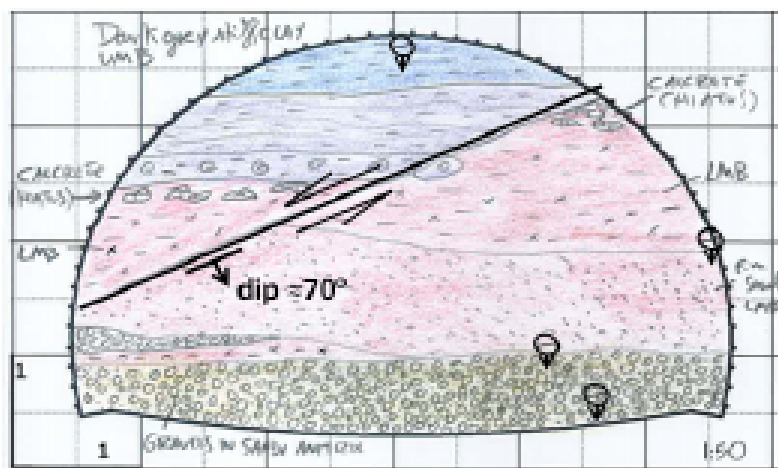
Geological risk mapping prior to tunnelling – based on 3D geological model



(LSB) stiff, dark grey silty CLAY with white shell fragments
 (LMB) stiff to very stiff, multi-coloured, mottled, partly silty sandy CLAY

Notes:

Notes: Some water dripping on right sidewall through discontinuity line



Water Inflow

Seepage was noted in the topmost probe hole, the gravels of LMB and the RHS sidewall.

Excavation Stability

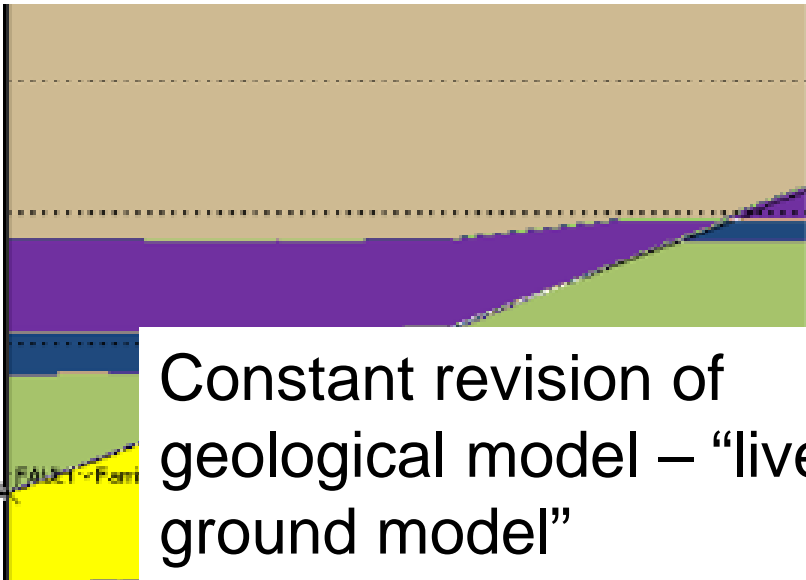
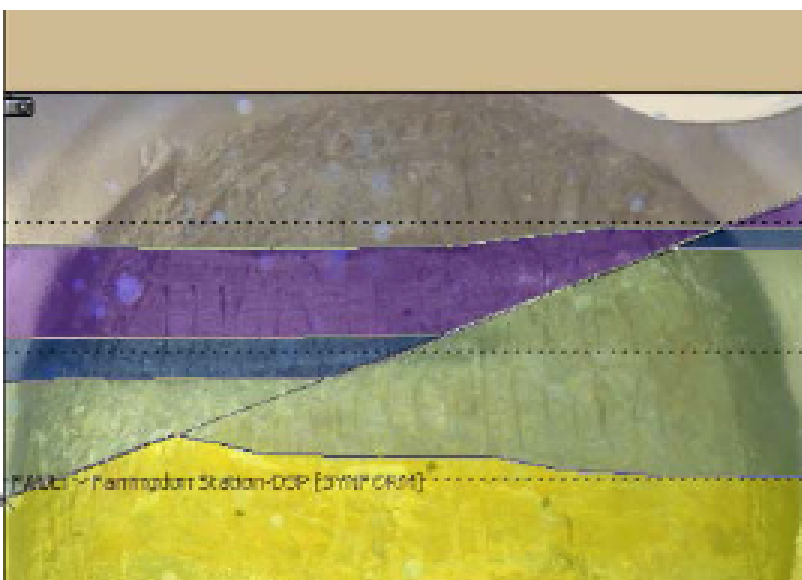
Face was in general stable with minor instabilities occurring in the areas where seepage occurred.

Obstructions / Voids

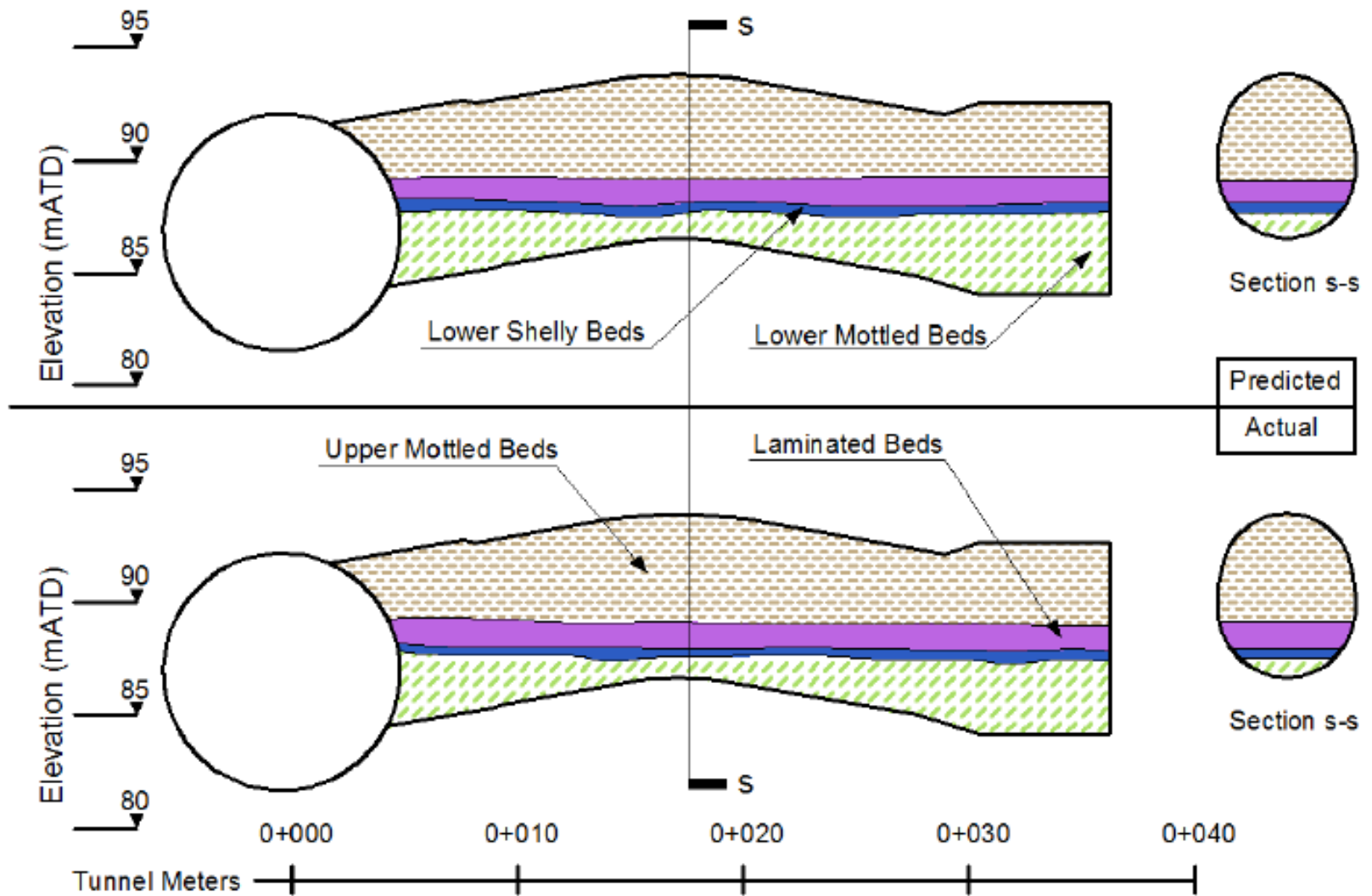
No obstructions were encountered during the excavation of the current advance.

Notes

Farringdon Fault was encountered.

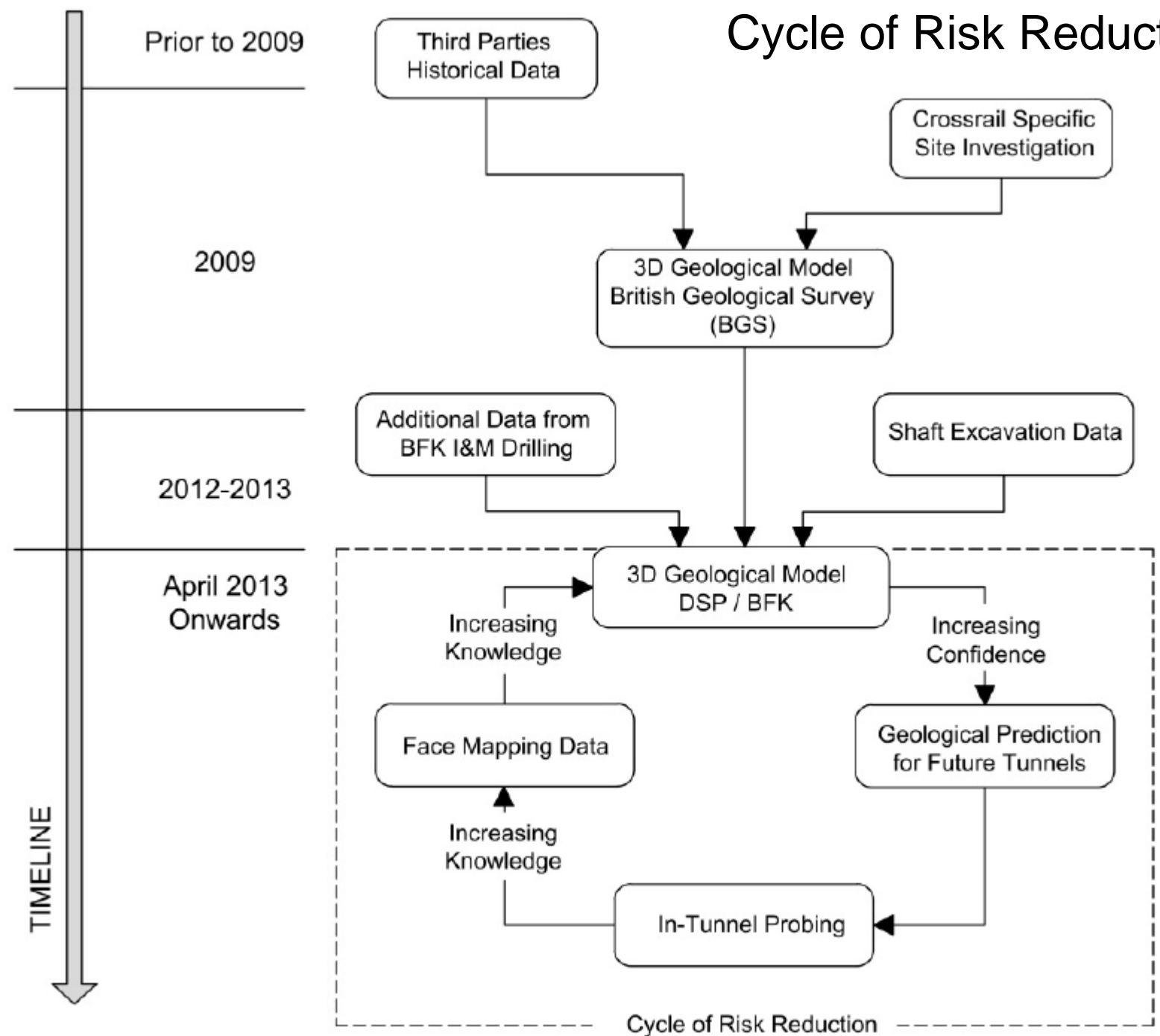


Constant revision of geological model – “live ground model”



Comparison between predicted and actual geological conditions in adit VA1

Cycle of Risk Reduction





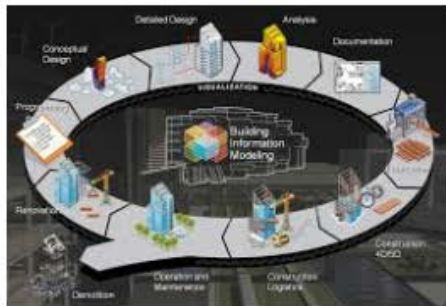
bim cycle



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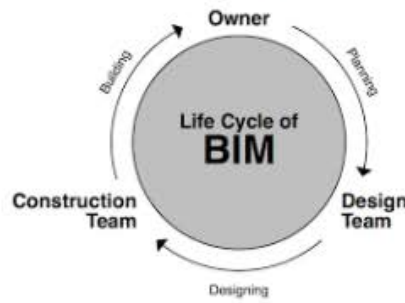
View saved SafeSearch



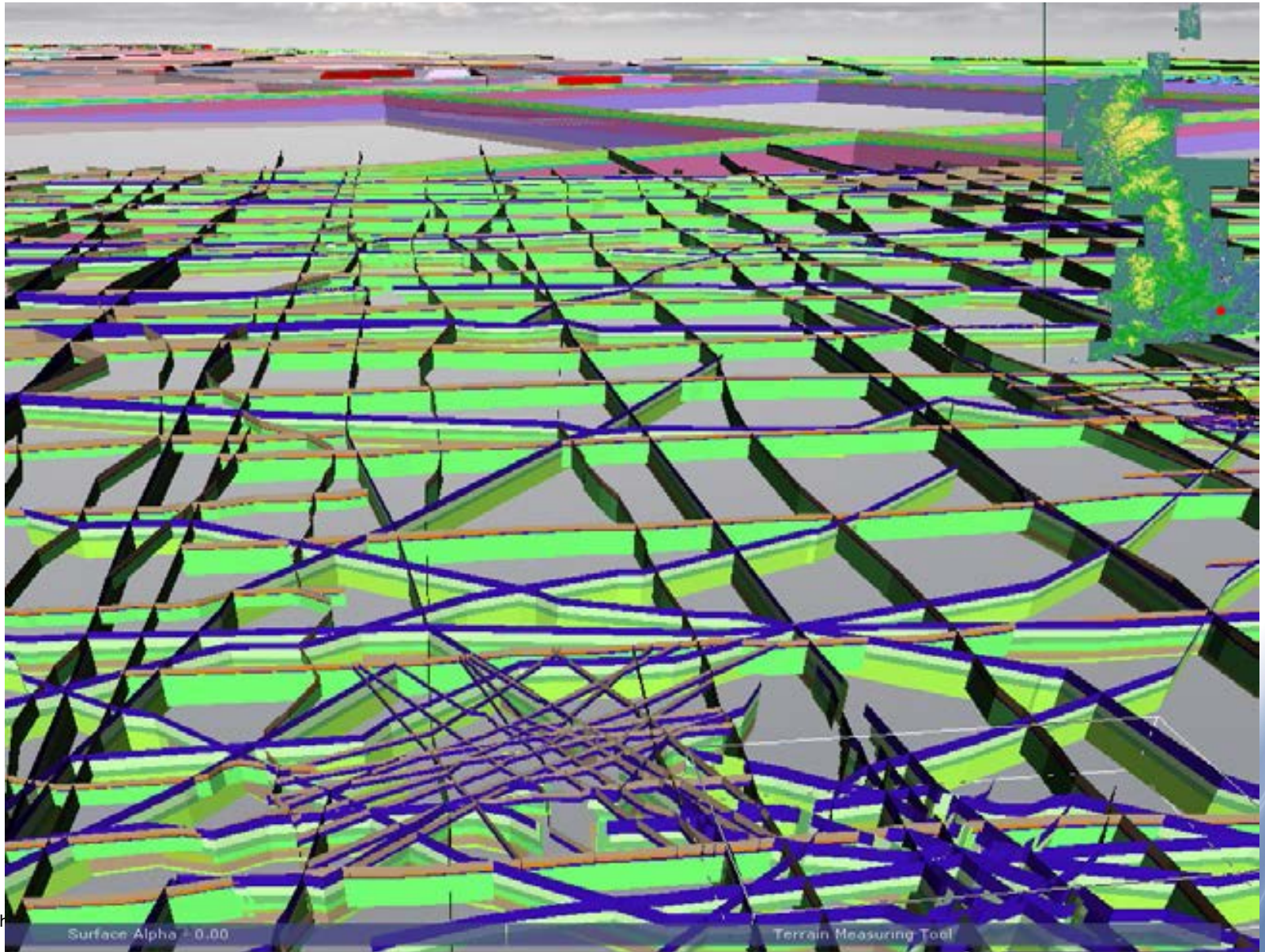
BIM Lifecycle View



WHAT CAN BIM DO?



Farringdon model in context of the regional and national geological model





Crossrail Project: Infrastructure design and construction – Volume 3
ISBN 978-0-7277-6129-3

ICE Publishing and Crossrail 2016: All Rights Reserved
doi: 10.1680/cpid.61293.431



3D geological model of the completed Farringdon underground railway station

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Paula Cabrero BSc, MSc, Dr. Sauer & Partners Ltd, London, UK

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Holger Kessler MSc, FGS, British Geological Survey, Nottingham, UK

Abstract

The complexity and the unknowns of the geology at Farringdon, primarily associated with the Lambeth Group, required a state-of-the-art geotechnical approach in order to manage the risks related to the open face, sprayed concrete lining (SCL) tunnelling. This was aided by the 3D geological model developed by the British Geological Survey (BGS) in 2009 for the proposed Farringdon underground railway station and which was provided to the contractor's team in 2013, in order to continue the revision of the model.

The model was initially updated with additional ground data from boreholes and shaft excavation (2009 to 2013). It then became an integral part of the site supervision workflow, being updated daily with data from the tunnel face.

This dynamic model became a 'live' geological database of increasing accuracy with time, allowing for geological predictions for the forthcoming tunnel excavations. In parallel, the understanding of the complexity of the Lambeth Group geology was significantly improved, refining the location and characteristics of the multiple faults and the thickness and continuity of the high-risk sand lenses.

This paper aims to describe how a BGS 3D geological model was developed to be used in combination with tunnelling works for the first time, the benefits from its use and the lessons learned with respect to the geology of the Lambeth Group.

Notation

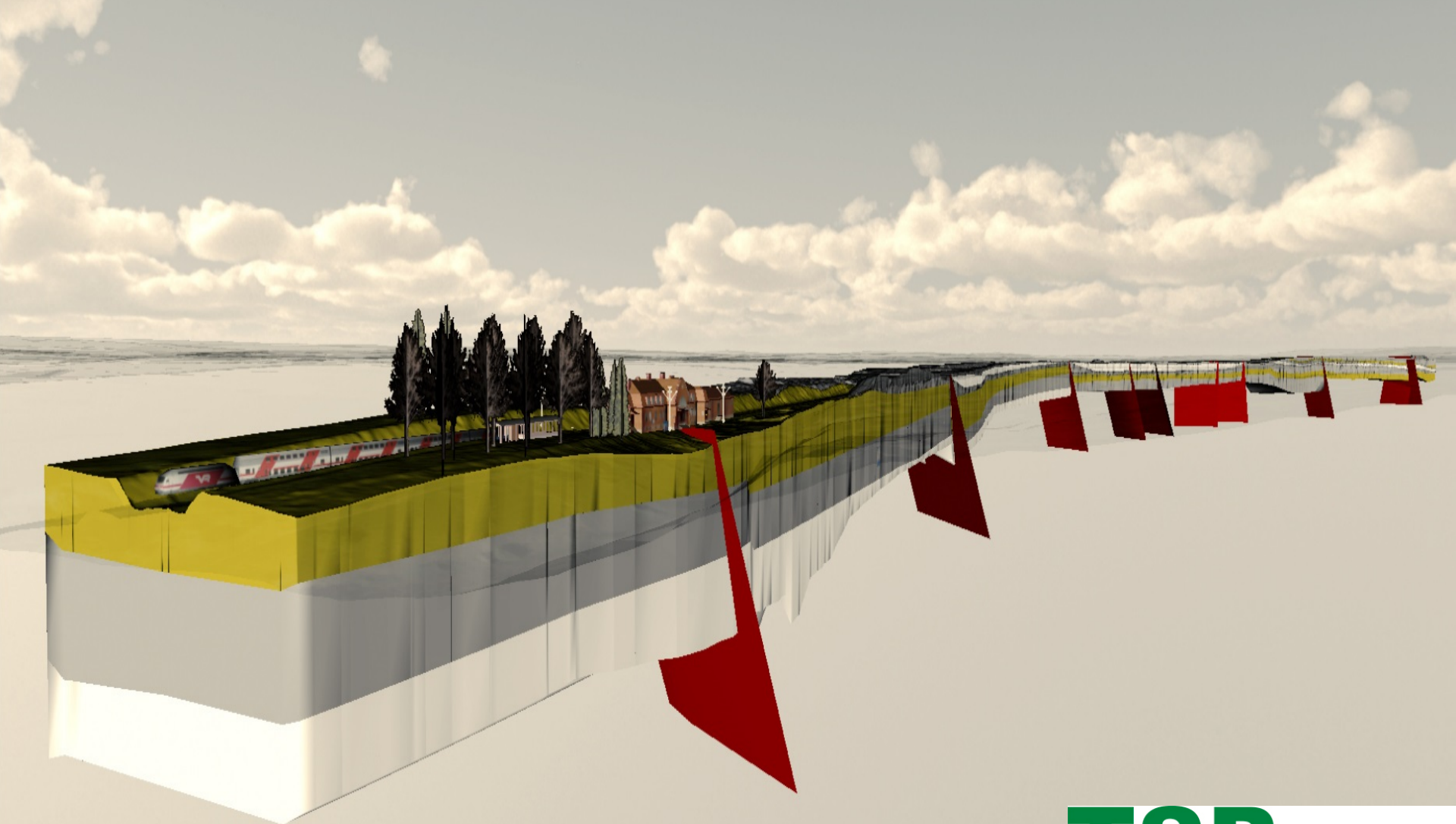
BFK BAM Ferrovial Kier Joint Venture, the main contractor
BGS British Geological Survey
CAD Computer Aided Design
DSP Dr. Sauer & Partners, BEK's specialist SCL designer



<http://learninglegacy.crossrail.co.uk/documents/3d-geological-model-completed-farringdon-underground-railway-station/>



3D geological model for railway electrification between Leeds and York



Model Tree

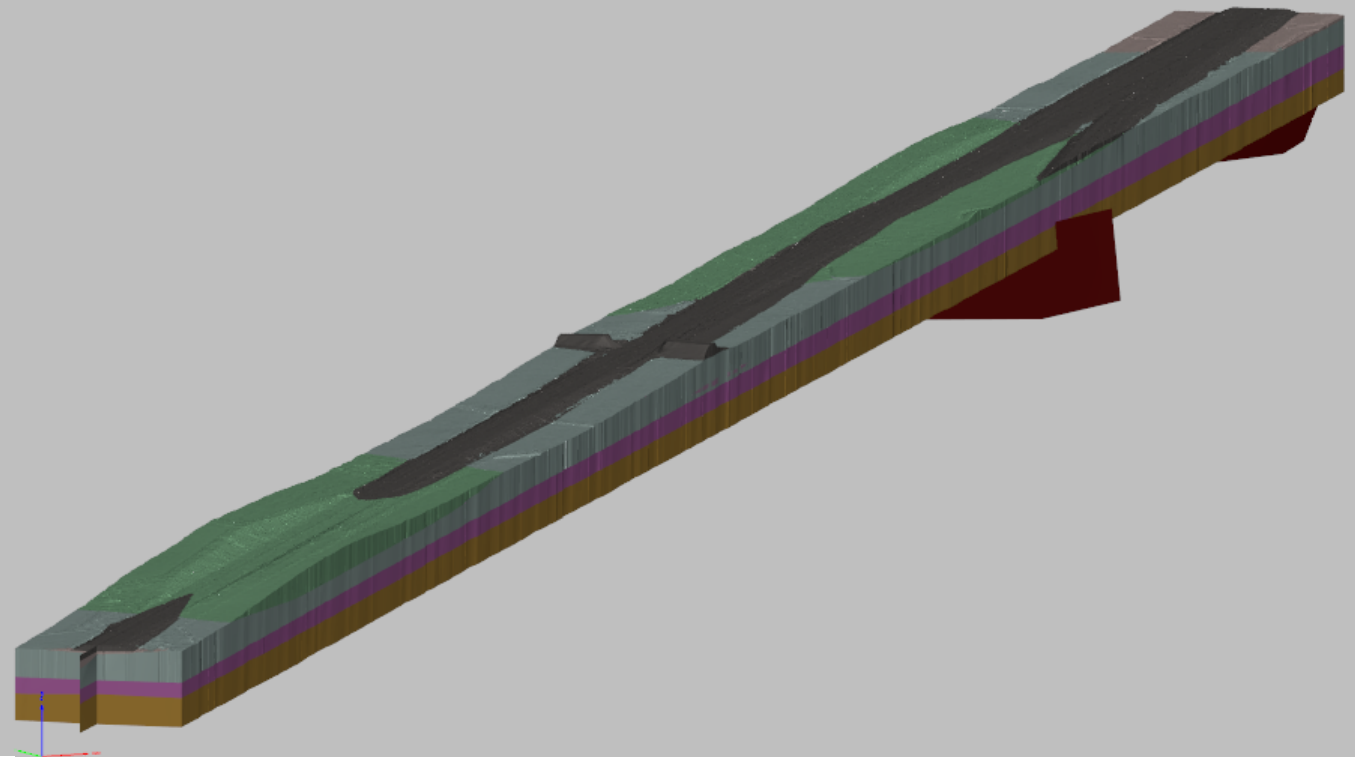
- model
 - Levels
 - References
 - MOD9_Esrick_Moraine_Member-tecton
 - MOD9_Glaciolacustrine_Deposits-lamin
 - MOD9_Made_Ground-embankments.dg
 - MOD9_Sherwood_Sandstone_Group-Sa
 - MOD9_Vale_Of_York_Formation-sand_a
 - MOD9_Vale_Of_York_Formation-till.dgr
 - MOD9_Weathered_Sherwood_Sandston
 - MOD9_Section.dgn
 - MOD9_Weathering_Surface_Upper.dgn
 - MOD789_Leeds_Tata_14_Fault.dgn

Options

<No Views>

No available information>

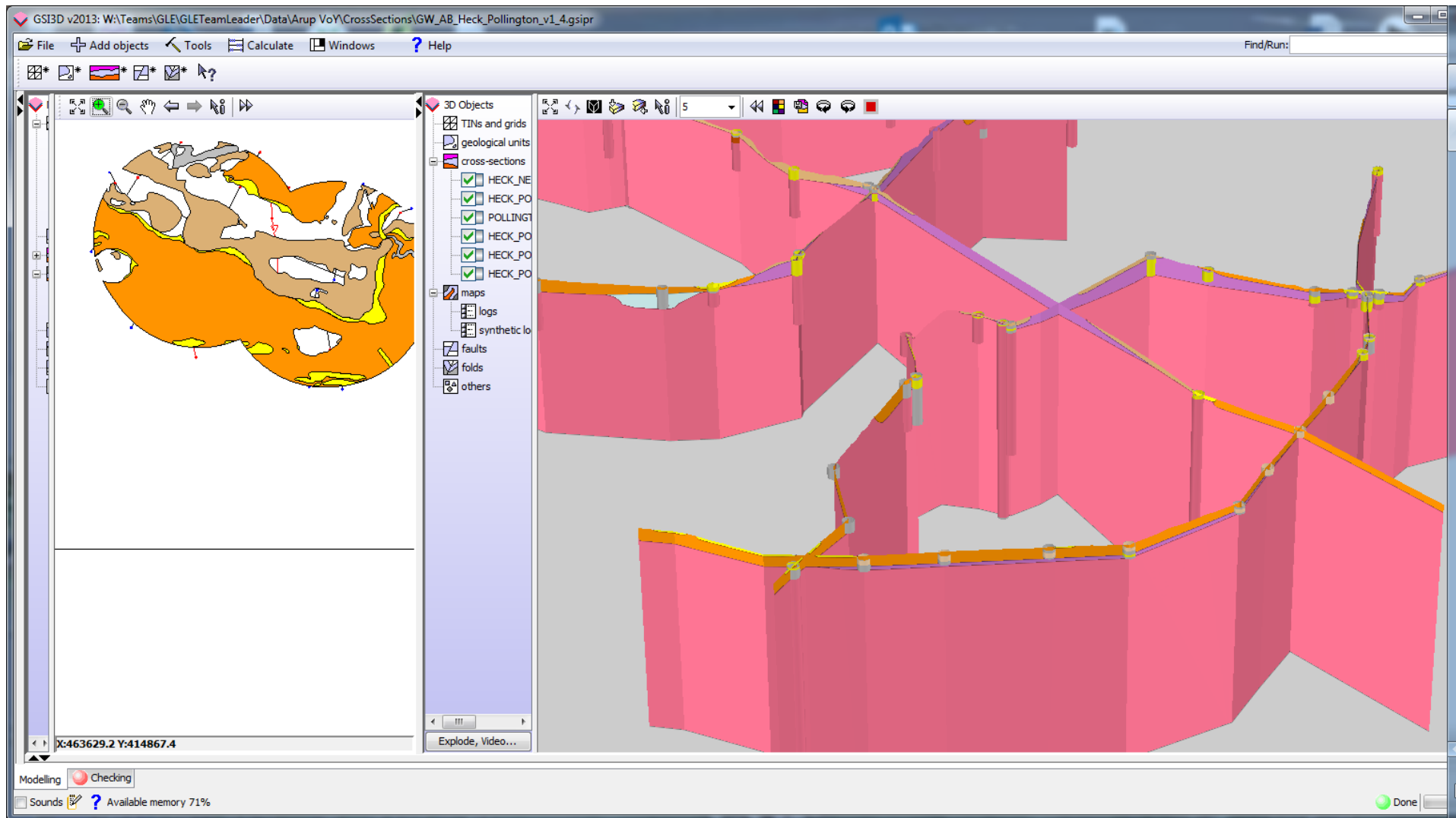
Views



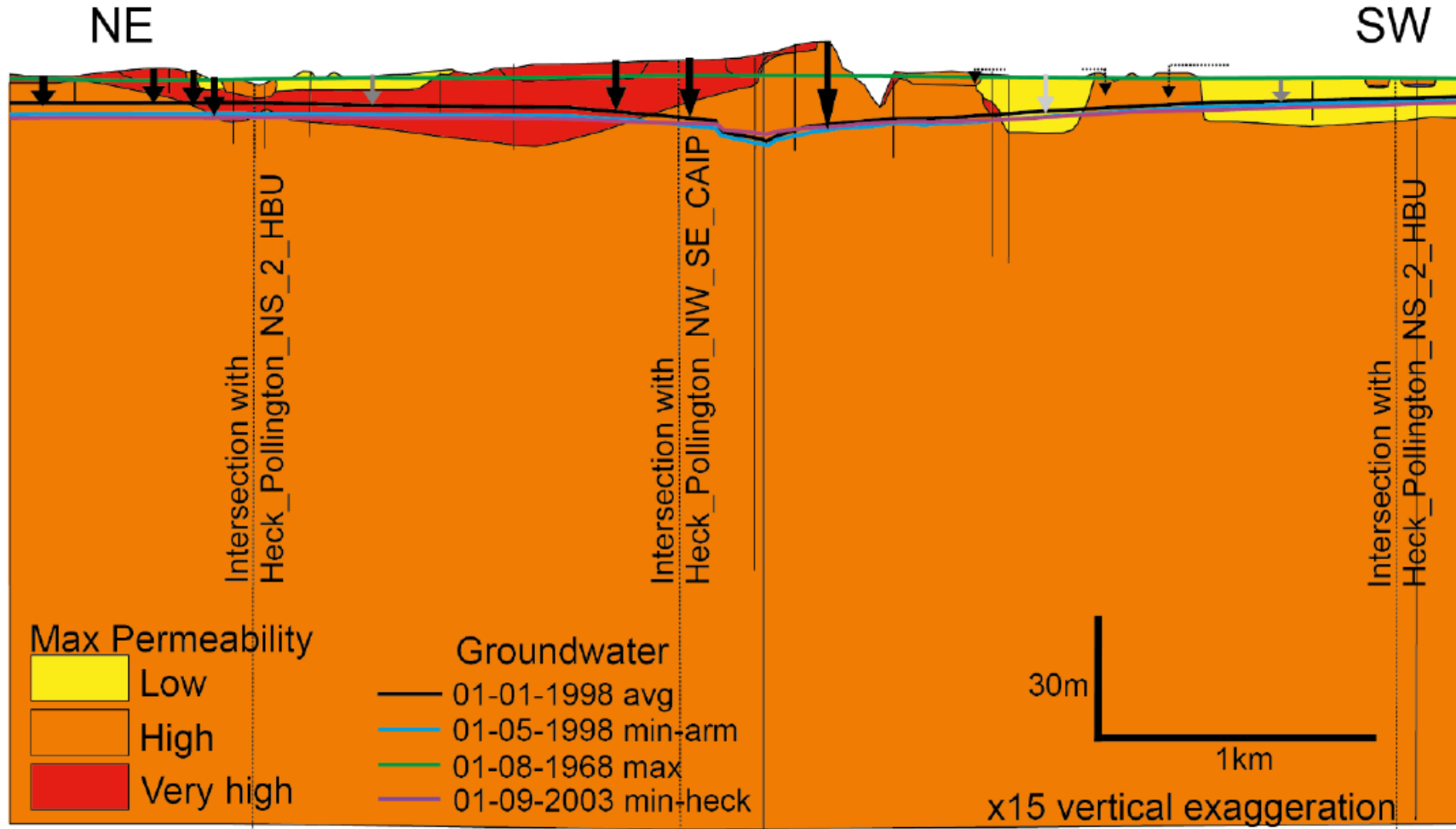
TSP Projects

Technical Solutions in Partnership

Site specific ground model to understand recharge and pathways at Yorkshire Water abstraction sites



Site specific ground model to understand recharge and pathways at Yorkshire Water abstraction sites



- Fast
- Slow
- Very slow
- Ponding
- Edge

ARUP



The BGS HS2 route 3D geological model visualised in map, section and 3D

LithoFrame Viewer: C:\2_SAMPLE_MODELS\HS2_Aldiss_licensed\4_8_LFV\HS2_London_V4_8_LFV.GSIPRe - (version 2013)

File Perspectives (F3) ? Help

Legend Colour scheme attribute: Stratigraphy Log Finish section Slice

BGS LithoFrame Viewer

Map Objects

- surfaces
- geological units
- cross-sections
- maps
- os_open_d

Map

3D Objects

Section Objects

Section

Syn section 1

Distance along section (m):1248.32 Elevation (m):72.48

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hs engine for growth

Done

BIM for the subsurface

2 year project funded by InnovateUK

- **Unforeseen ground conditions - major causes of project delay contributing to ~ 1/3 of construction programme over-runs.**
- **Partly due to limited availability of high quality geotechnical data & interpretation.**
- **Project to apply BIM process to ground investigation & subsurface infrastructure design.**
- **Integrate with BGS's national databases and implement BGS methodologies & standards for 3D geological modelling.**

Direct access to free geological maps and boreholes in HoleBASE SI - released

(TestProject) Quinley I - HoleBASE SI Professional

Project Data Scheduling Mapping Preferences Configuration Help Grid Tools

Manage Columns Reload Data Add/Edit Data Delete Selected Audit Log Clear Sorts Clear Filters Clear Groups Bulk Update CSV Export Export XYZ Location Group Saved Search Zoom on Map Set Location Quick Log Log Report View All View Selected Upload

Actions Transfer Data Mapping Log Production Documents

All Data Location Details Field Geological Descriptions

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 medi...	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	0.80 TOPSOIL	101	FILL
BH137	0.40	0.80	3.50 Spongy brown fibrous PEAT with so...	605	PEAT
BH137	0.80	3.50	5.30 Firm brown very sandy CLAY with a...	220	BOULDER CLAY
BH137	3.50	10.05	12.05 Brown CLAY with a little well rounde...	205	BOULDER CLAY
BH138	0.00	0.50	1.20 TOPSOIL	101	FILL
BH138	0.50	1.20	2.30 Dense grey-brown SAND with medi...	404	GLACIAL TILL
BH138	1.20	2.30	2.70 Firm brown very sandy CLAY with a...	220	BOULDER CLAY

Page 1 of 3 (132 of 132)

Quick Log (BH137)

Water		Samples and In Situ Testing		Depth (m)	Level (m)	Legend	Stratum Description
Well	Strikes	Depth (m)	Type	Results			
		0.00 - 0.80	U	Urbow=0	0.40	6.00	TOPSOIL FILL
		0.80 - 0.95	U	Urbow=0	0.80	5.80	Spongy brown fibrous PEAT with some wood fragments (<20mm) and a little medium grained PEAT
		1.10 - 1.30	O	Urbow=0			Firm brown very sandy CLAY with a little subangular to subrounded medium grained BOULDER CLAY
		1.80 - 1.85	U	Urbow=0			
		2.10 - 2.30	O	Urbow=0			
		2.80 - 2.85	O	N=27 (4.6 (E), 6.6 (S))			
		2.90 - 3.00	D	Urbow=0			

Map

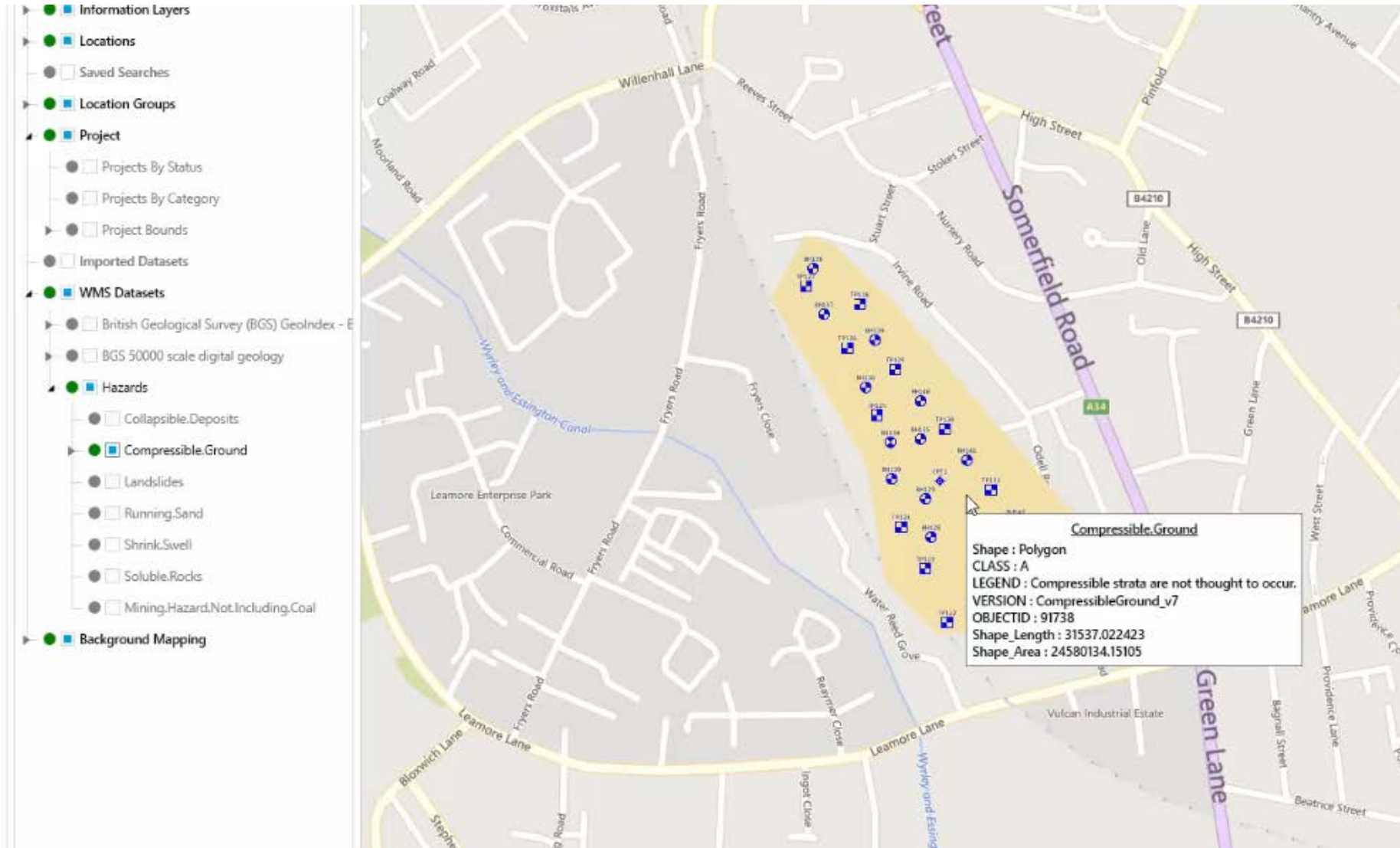
- Information Layers
 - Measures
 - Sections
 - Long Section AA
 - Long Section BB
 - Section CC
 - Section DD
- Locations
 - Saved Searches
 - Location Groups
 - Project
 - Imported Datasets
 - WMS Datasets
 - British Geological Survey (BGS) GeolIndex
 - BGS 50000 scale digital geology

Level 3

Search Project Explorer...

Direct access to BGS products in HoleBASE SI

– released in beta



Upload and download of AGS data from BGS data centre

Coming soon!

Location ID	Location Type	Status	Easting (m)	Northing (m)	National Grid Ref...	Ground Level (m)
BH127	CP		399887.72	301130.66		
BH128	CP		399809.58	301145.90		
BH129	CP		399887.72	301130.66		
BH130	CP					
BH134	CP+RC					
BH135	CP					
BH136	CP					
BH137	CP					
BH138	CP					
BH139	CP					
BH140	CP					
BH141	CP					
BH142	CP					
BH143	CP					
CPT1	SCP					
TP121	TP					
TP122	TP					
TP123	TP					
TP124	TP					
TP125	TP					
TP126	TP					
TP127	TP					
TP128	TP		399777.28	301446.00		
TP129	TP		399763.28	301362.00		

Export data to BGS

Dataset and metadata ownership

Contact for the dataset

Description of the dataset

Confidentiality of the dataset

Contact for the metadata

Confidentiality of the metadata

Location Selection

Group Selection

Upload Data

Contact for the dataset

Providing these contact details confirms you are happy for this data to be stored and used in line with our [Privacy Policy](#) which incorporates all aspects of UK Data Protection.

Depositor organisation

Keynetix

Depositor name

Fred Bloggs

Depositor address

Systems House
Burnt Meadow Road
Redditch
B98 9PA

Depositor email

fb

Depositor phone

Back Next



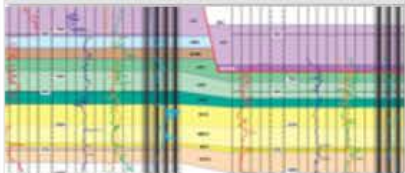
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Gateway to the Earth

About us
Downloads

Home » Our data » NGDC information & data » Data management » Digital accessions

Our data

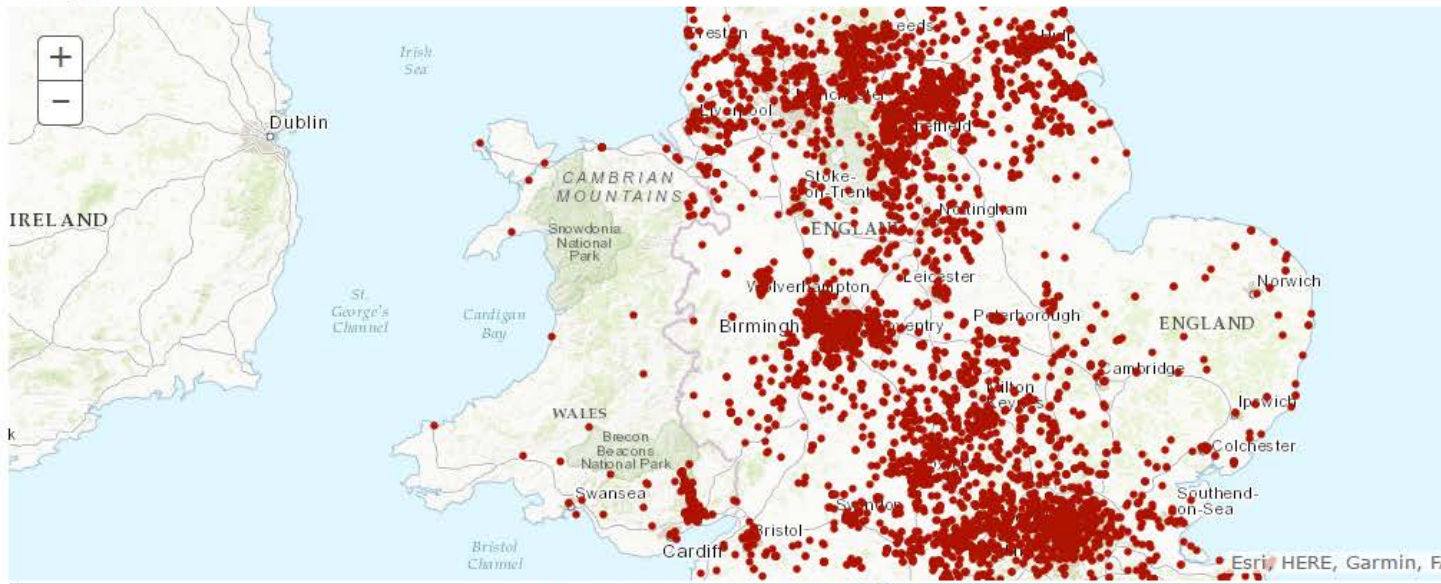


- Our products
- OpenGeoscience
- National Geological Repository
- National Geoscience Data Centre**
- NGDC index
- Cited data
- Data management
- Earth Science Academic Archive
- National Hydrocarbons Data Archive
- Premium data services

Detailed accession search

Map Search

Map Filter



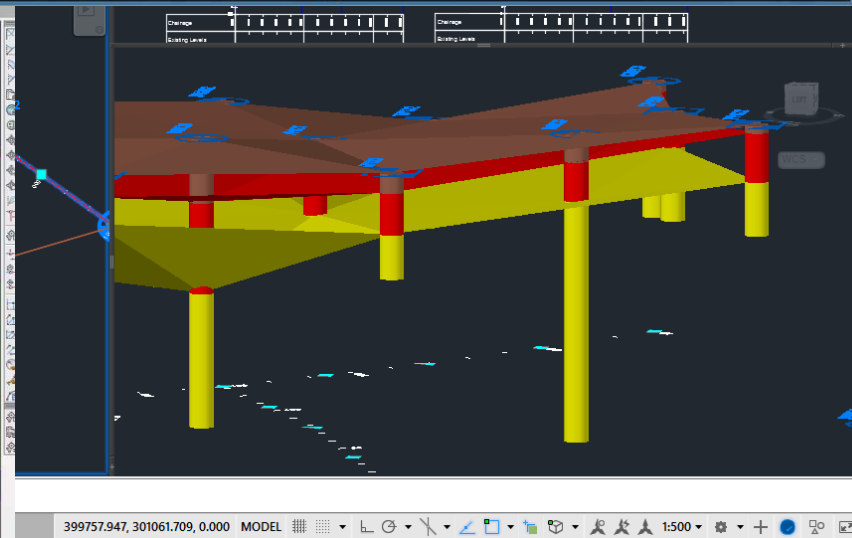
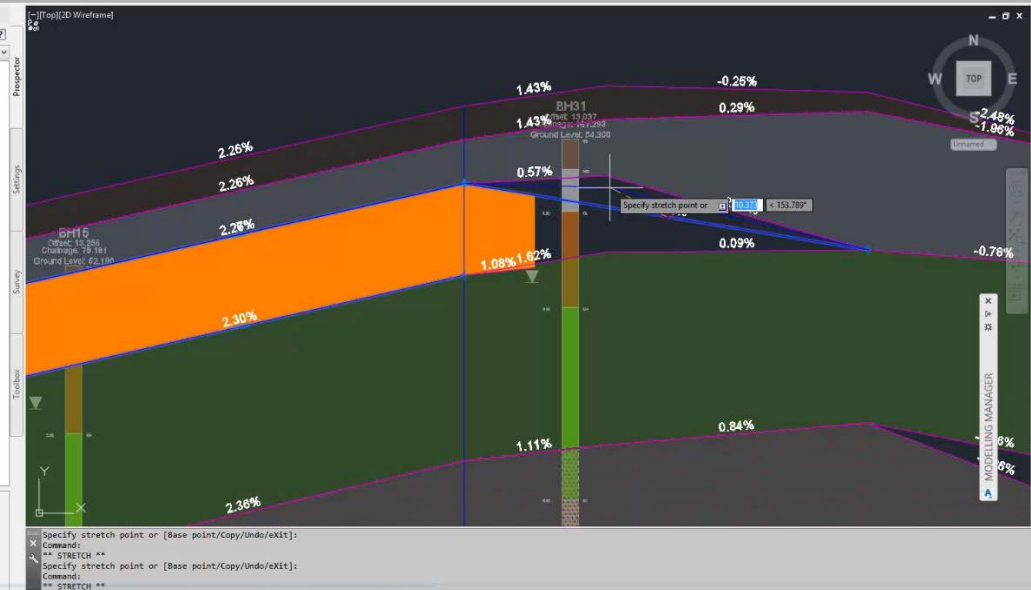
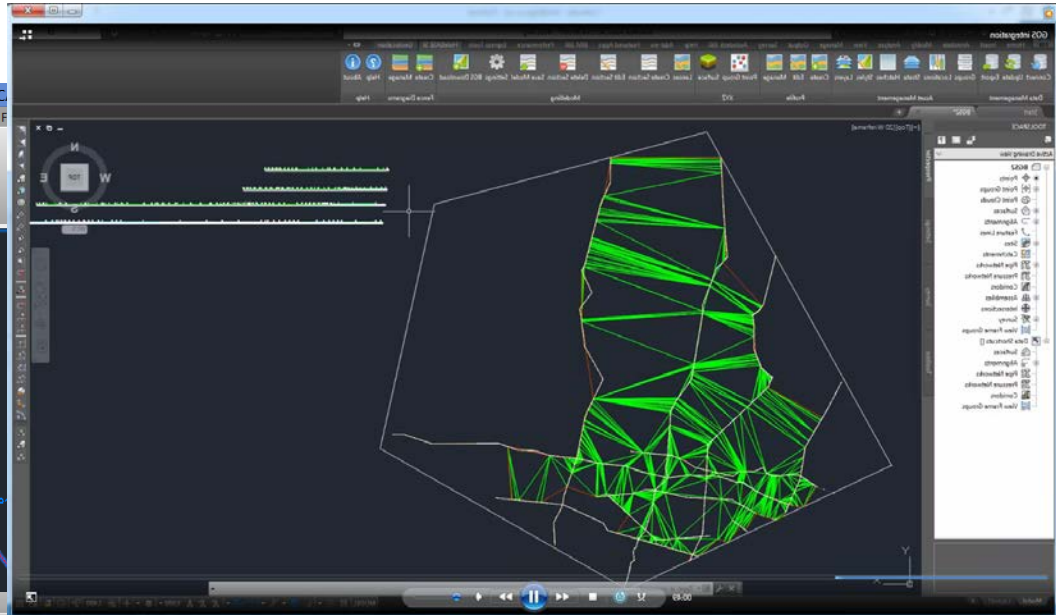
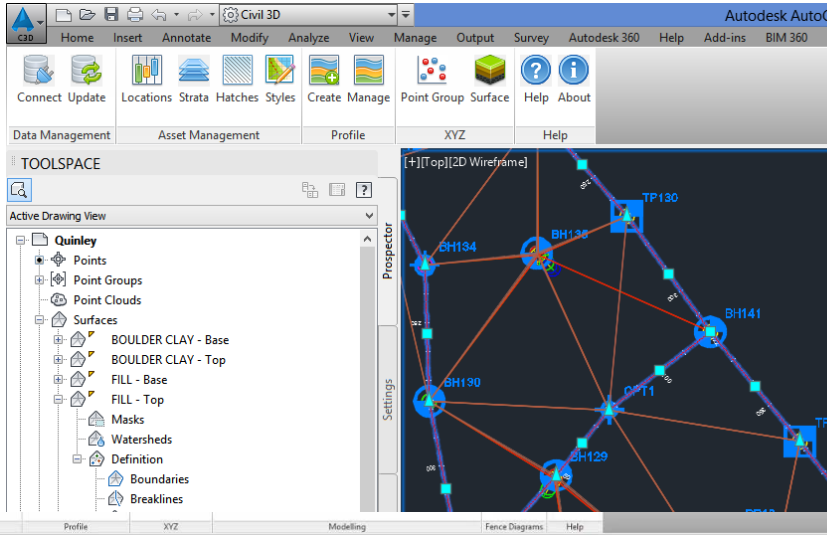
Draw Extent Clear Extent

Simple Search: ?



Implementation of 3D modelling in AutoCAD Civil 3D

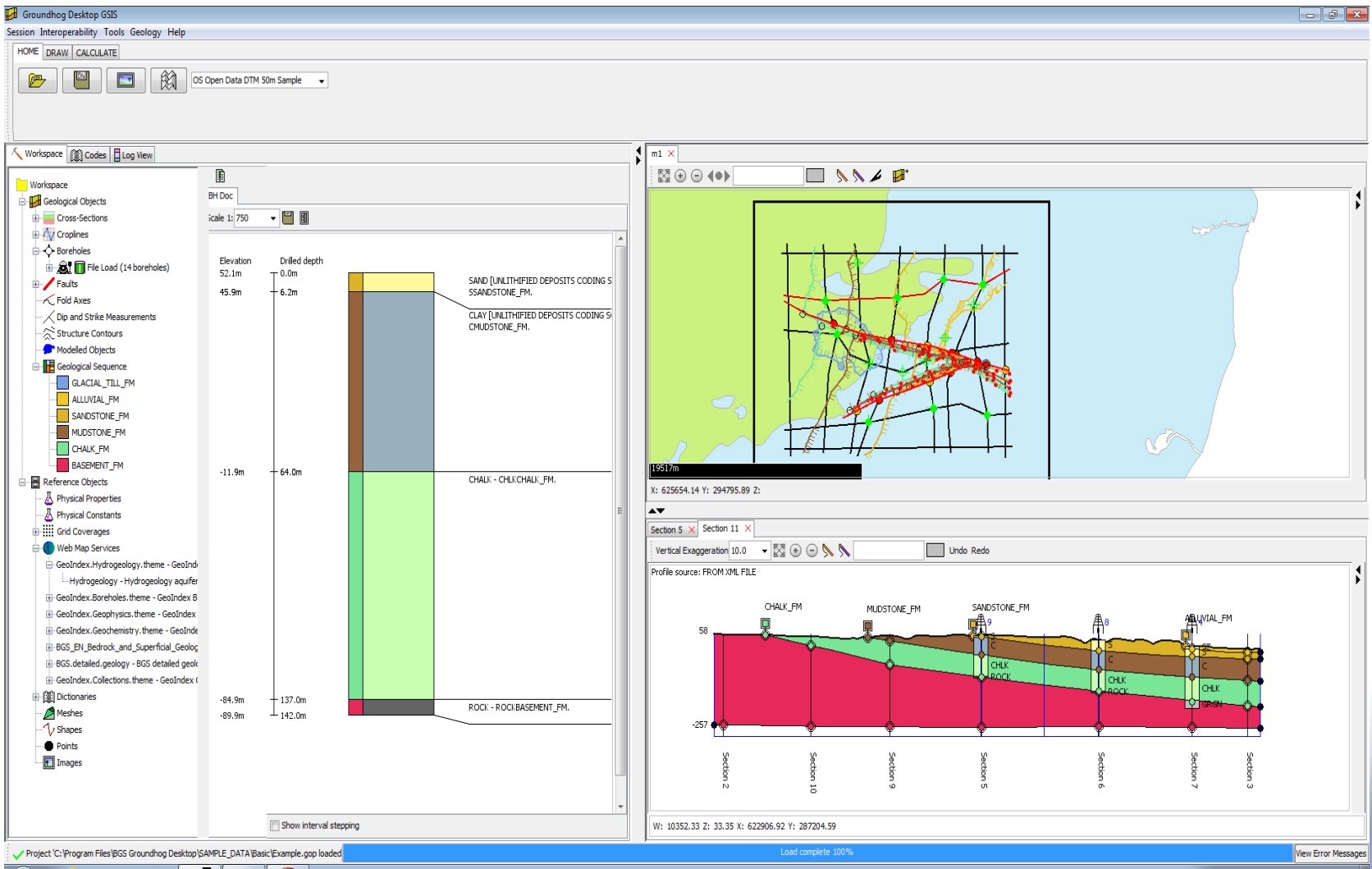
Coming soon



Future possibility of direct access to geological sections...



Groundhog Desktop GSIS - free tool for geological interpretation and visualisation



<http://www.bgs.ac.uk/research/environmentalModelling/groundhogDesktop.html>



Serious gaming....

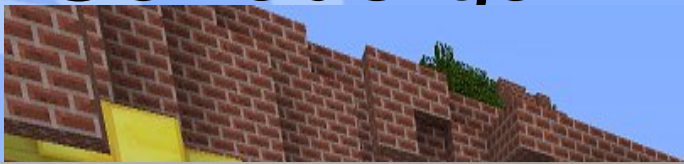
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Serious gaming....



Serious gaming....





Thank You – Any Questions?

hke@bgs.ac.uk



Open 3D Geological Modelling Community

1,629 members