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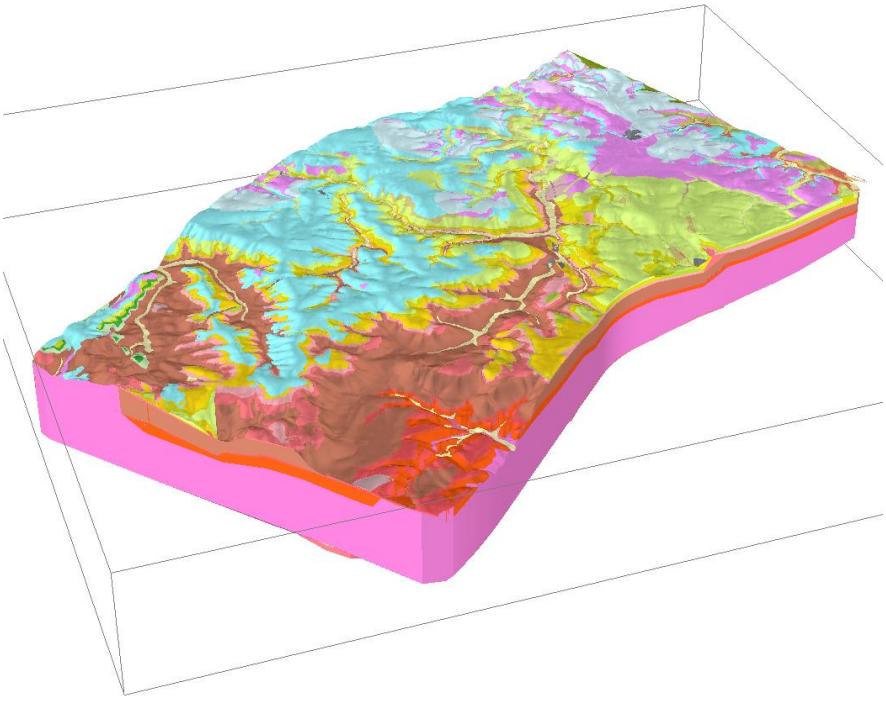
GSI3D model metadata report for HS2 Area 3 (Newton Purcell to Thorpe Mandeville)

Geology and Regional Geophysics Programme

Open Report OR/16/004



BRITISH GEOLOGICAL SURVEY

GEOLOGY AND REGIONAL GEOPHYSICS PROGRAMME

OPEN REPORT OR/16/004

GSI3D model metadata report for HS2 Area 3 (Newton Purcell to Thorpe Mandeville)

A J M Barron

Keywords

Report; 3D model; GSI3D; HS2; linear route; glacial deposits; Great Oolite Group; Lias Group.

National Grid Reference

SW corner 458500,229000
NE corner 457400,248700

Map

Sheet 201, 202, 219

Front cover

3D view of modelled volumes, from west.

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Contents

FIGURES

TABLES

Summary

This report describes the 3D geological model of HS2 (High Speed 2 rail link) Area 3 (Newton Purcell to Thorpe Mandeville), created by A J Mark Barron with support from Steve Thorpe. The model was created as part of a set of nine fitted GSI3D models that cover the proposed HS2 rail route from the end of the HS2 London model to Birmingham and the West Coast Main Line near Lichfield. They were funded from the NERC/BGS Science Budget to promote BGS modelling and geological interpretation services to this important infrastructure project and to test methodologies and procedures for fitted bedrock models by multiple compilers.

The report describes the model construction and purpose, with spatial limits and scale, sources of information, data processing, workflow, decisions, assumptions, rules and limitations, together with images of the model.

1 Modelled volume, purpose and scale

This model is of the bedrock, natural superficial deposits and artificially modified ground geology of an area along the proposed route of the High Speed Rail link between London and Birmingham (HS2). This is one of nine models along the proposed route (Areas 1 to 9). It covers the section of the HS2 route between Newton Purcell in Oxfordshire and Thorpe Mandeville in Northamptonshire, including a buffer 5 km wide (Figure 1), in common with the eight other HS2 models. The bedrock geology of this section of the route comprises Lower to Middle Jurassic strata, together with superficial deposits of glacigenic and fluvial origin. It is suitable for use at scales between 1:100,000-1:10,000, down to a depth of 30 m below OD.

Prior to the modelling work, an assessment of the quality and availability of the digital geological linework and existing 3D models of the whole HS2 route between London and Birmingham was undertaken (Barron et al., 2012). As a consequence of this review, the geological mapping of this sector was deemed to be adequate, dating from the 1950's to the 2000's. Thus this 3D model is based on geological line work from existing 1:10 000 and 1:50 000 scale DiGMapGB data.

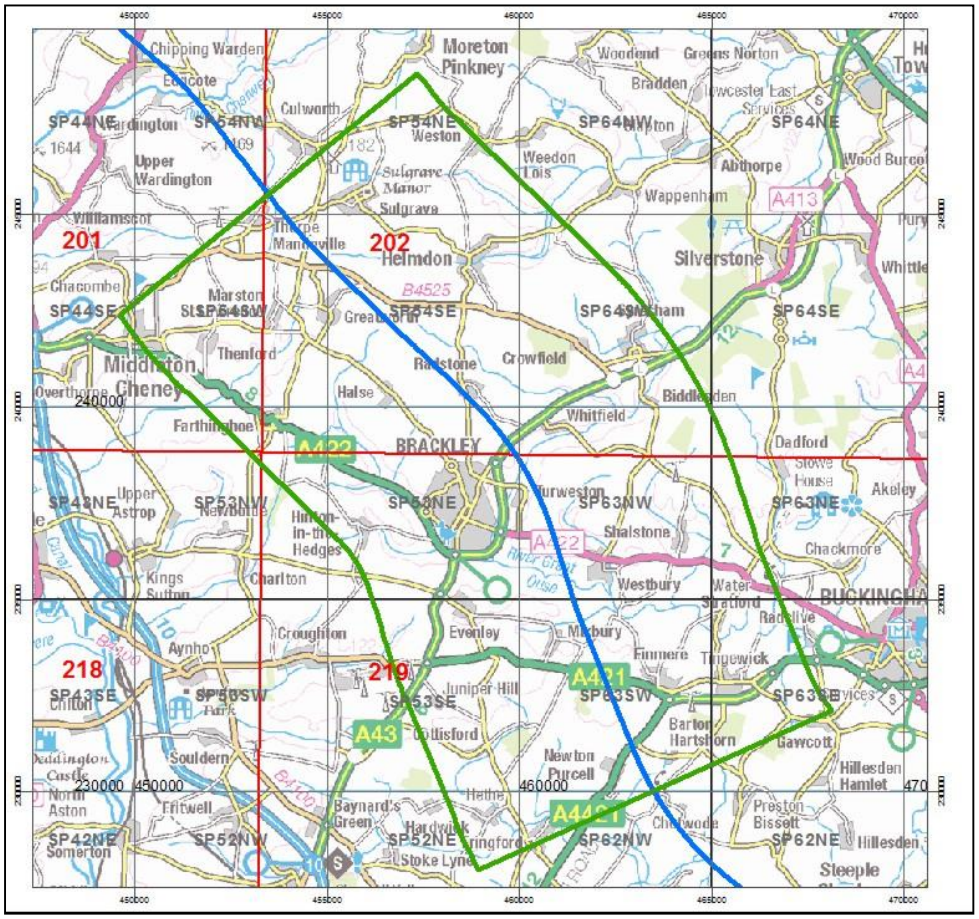


Figure 1. Location of the Area 2 model outlined in green.

The proposed route of HS2 is marked by a blue line. BGS 1:50 000-scale maps in red. National Grid 1:10 000 maps in grey. Contains Ordnance Survey data © Crown Copyright and database rights 2014.

2 Modelled surfaces/volumes

Table 1 is a list of the units modelled.

Name in model	LEXRCS	Description	Comments
NON-GEOLOGICAL MASS	NONE-NONE	For areas of woodland or buildings that mask the true DTM, especially in hollows	
WMGR-ARTDP	WMGR-ARTDP	WORKED AND MADE GROUND	
MGR-ARTDP	MGR-ARTDP	MADE GROUND	
WGR-VOID	WGR-VOID	WORKED GROUND	
LSGR-UKNOWN	LSGR-UKNOWN	LANDSCAPED GROUND	
ALV-XCZSV	ALV-XCZSV	ALLUVIUM	
HEAD-XCZSV	HEAD-XCZSV	HEAD	
TUFA-CATUFA	TUFA-CATUFA	TUFA	
GFDMP1-XSV	GFDMP1-XSV	GLACIOFLUVIAL DEPOSITS MID PLEISTOCENE, UPPER	Upper GFDMP unit. Occurrence limited
TILMP1-DMTN	TILMP1-DMTN	TILL MID PLEISTOCENE, UPPER	Upper Till unit. Includes parts of ODT of Towcester sheet
GFDMP-XSV	GFDMP-XSV	GLACIOFLUVIAL DEPOSITS MID PLEISTOCENE	Median GFDMP unit. Occurrence widespread
TILMP-DMTN	TILMP-DMTN	TILL MID PLEISTOCENE, LOWER	Main body of Till unit. Includes parts of ODT of Towcester sheet
GFDMP0-XSV	GFDMP-XSV	GLACIOFLUVIAL DEPOSITS MID PLEISTOCENE, BASAL	Basal unit of glacigenic succession. Occurrence very limited
PET-MDST	PET-MDST	PETERBOROUGH MEMBER	Uppermost bedrock unit, only present in overlap with Area 2 and Helper sections here
KLB-SDSM	KLB-SDSM	KELLAWAYS FORMATION	
CB-LMST	CB-LMST	CORNBRASH FORMATION	
FMB-LSMD	FMB-LSMD	FOREST MARBLE FORMATION	Includes BWC-MDST of Towcester sheet
BLAD-MDLM	BLAD-MDLM	BLADON MEMBER	
WHL-LMST	WHL-LMST	WHITE LIMESTONE FORMATION	Includes BWL-LMST of Towcester sheet
RLD1-MDST	RLD-MDST	RUTLAND FORMATION	Upper division of Rutland Formation
TY-LMOOL	TY-LMOOL	TAYNTON LIMESTONE FORMATION	Lateral equivalent of WBRO
WBRO-LMST	WBRO-LMST	WELLINGBOROUGH LIMESTONE MEMBER	Lateral equivalent of TY, present only in NE.

Name in model	LEXRCS	Description	Comments
SHHB-ARSL	SHHB-ARSL	SHARP'S HILL FORMATION	Lateral equivalent of RLD
RLD-MDST	RLD-MDST	RUTLAND FORMATION	Lower division of Rutland Formation mudstone beds in area where WBRO is present above. Lateral equivalent of SHHB
STAM-SDSL	STAM-SDSL	STAMFORD MEMBER	Lateral equivalent of HYSA, basal member of Rutland Formation in area where WBRO is present above
HYSA-SDST	HYSA-SDST	HORSEHAY SAND FORMATION	Lateral equivalent of WBRO in area where TY and SHHB are present above
GOG-LMAS	GOG-LMAS	GREAT OOLITE GROUP	In SE part of the model: includes WHL-LMST, RLD1-MDST, TY-LMOOL, SHHB-ARSL, HYSA-SDST
NS-SDLI	NS-SDLI	NORTHAMPTON SAND FORMATION	
WHM-MDST	WHM-MDST	WHITBY MUDSTONE FORMATION	
MRB-FLIR	MRB-FLIR	MARLSTONE ROCK FORMATION	
DYS-SIMD	DYS-SIMD	DYRHAM FORMATION	
CHAM-MDST	CHAM-MDST	CHARMOUTH MUDSTONE FORMATION	In north of model probably includes RLS-MDLM**
WLI-LMST	WLI-LMST	WHITE LIAS FORMATION	*
PNG-AROCLS	PNG-AROCLS	PENARTH GROUP	*

Table 1. Units modelled in Area 3

*NB The White Lias Formation and Penarth Group appear in only a few cross-sections in the base of the model, very close to the cut-off depth of 30 m below OD, and therefore it is not possible to construct meaningful envelopes.

**The Rugby Limestone Member (RLS-MDLM) of the Blue Lias Formation is modelled beneath the Charmouth Mudstone Formation to the north-west in Area 4, adjoining Area 3. Its extent into Area 3 is very uncertain, and the location of its south-easterly pinch-out is unknown. Hence it is not modelled, creating a misfit with Area 4 model.

The units from the Cornbrash Formation (CB) to the Horsehay Sand Formation (HYSA) inclusive form the Great Oolite Group (GOG) and the Whitby Mudstone Formation (WHM) to the Charmouth Mudstone Formation (CHAM) form the Lias Group.

The Mid Pleistocene glacigenic succession (GFDMP1 to GFDMP0) was deposited at the extreme southern limit of the Anglian ice advance (Sumbler, 2002) and is hence very complex. It was recommended against making any lenses (Section 5: 14/5/13) to aid calculation, resulting in the

erection in the GVS of a sequence of three variants of GFDMP and two of TILMP, which were separated. This is nonetheless simplified from that as mapped (see especially grid square SP 66 33), necessitating changes to the respective geological units at outcrop (see 5 below).

Area 3 lies in the area where the East Midlands Great Oolite Group succession passes into that of the Cotswolds (Sumbler, 2002, pp 8-13, fig. 5), and for some units the BGS Sheet 202 (Towcester) and Sheet 219 (Buckingham) boundary (Figure 1) is taken as an arbitrary line where the passage takes place. Thus on DiGMapGB-50, there is a line between the Blisworth Clay Formation (Lex code BWC) in the north, and its approximate southern correlative the Forest Marble Formation (FMB), and likewise for the Blisworth Limestone Formation (BWL) and the White Limestone Formation (WHL). For the purposes of calculation, it proved necessary to merge these pairs (see Section 5 below). For the lower formations in the Great Oolite Group (GOG), where they are at depth in the south and east (no outcrop information), borehole data generally was inadequate to differentiate the formations and it was necessary to construct the 'passage' between them e.g. at W16290 in NWSE_3 (Figure 2).

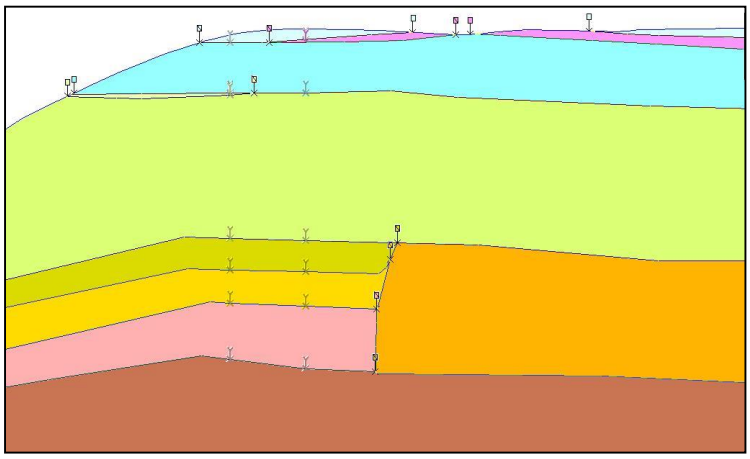


Figure 2. Passage between GOG and component formations in section NWSE_3

Orange – GOG, lime green – RLD1, yellow – TY, pink HYSA.

In addition, in DiGMapGB-50, the Till in the Towcester district is coded as Oadby Member (ODT) whereas that in Buckingham is Till, Mid Pleistocene, which description includes the Oadby Member, so the former is subsumed in the latter – the join visible across the centre of Figure 9.

3 Modelled faults

Several small faults, most with throws of less than 10 m were modelled as fault plane objects, dipping 60 degrees for drawing guidance, based on mapped surface faults (Figure 11) but were subsequently removed (see model Development Log, 15/5/13; 14/6/13; 10/3/14) as they were hindering calculation. Faults were modelled using the superficial engine as steps in the geological surfaces (rather than as a faulted bedrock model) where the unit is in contact across the fault. However, where unit envelopes intersected faults at depth and were present on both sides, but fault throw exceeds unit thickness, slits in envelopes were drawn to aid calculation. No major faults occur in the modelled area.

4 Model datasets

All data is contained within this folder:

W:\Teams\GLE\GLETeamLeader\Data\HS2\HS2\GSI3D_Modelling_files\Area3, except for the GVS/GLEG (which is an overarching HS2 project file) which is located here: W:\Teams\GLE\GLETeamLeader\Data\HS2\HS2\GSI3D_Modelling_files.

4.1 GVS AND GLEG FILES

The generalised vertical section (.GVS) and geological legend (.GLEG) files were assembled in a combination of Notepad, Wordpad and Excel and iterated as the model expanded and new units were encountered. A regional catch all approach was adopted from the very start. The GVS was created by S Thorpe using DiGMapGB-50 data. The GLEG files were also created by Steve Thorpe by clipping data from the BGS corporate DiGMapGB-10 and DiGMapGB-50 datasets along the route of the HS2 corridor, as defined by a 5 km buffer. Generic GVS and GLEG files were created for the whole HS2 route, rather than for each individual model area. Thus the units used in this model are only a subset of those available in the HS2 GLEG file.

4.2 BOREHOLE CONSTRUCTION

S Thorpe 31/7/12: extracted Area 3 borehole subset from SOBI to W:\Teams\GLE\GLETeamLeader\Data\HS2\HS2\ModelArea_3_MAB_JT\HS2_ModelArea3_Boreholes.xlsx.

A J M Barron 21/1/13-12/3/13: coding boreholes for Area 3 directly into the corporate BoGe data entry application and updating progress in above spread-sheet including (as per project guidance of S Thorpe 14/12/12), recording content code and coder (pre-existing and new), a rationale for inclusion/rejection, an indication of stratigraphical range proved, and an indication of whether to route a cross-section through. Bores were coded with bedrock units LEX from the project GVS, and RCS as appropriate to log lithology but from a preferred limited set (Table 2). ROCK may be used for 'stone' and UKNOWN where no lithology inferable. Where there were very dense clusters (including linear clusters) generally a subset of the deepest were examined and coded if required, with a view to a reasonable scatter and the likely layout of the sections, but in places the shallower logs were found to contain better detail. In the north-west around Middleton Cheney (SP44SE, SP54SW) there are a dense grid of bores for ironstone, into the Marlstone Rock Formation. Base of MRB was taken at the base of the lowest significant ironstone bed (>0.15 m) (also agreed with J Thompson who is coding Area 4 bores).

Formation	Lex	Log lithology or name	Preferred RCS	RCS translation
Northampton Sand Formation	NS		FLIR	FERRUGINOUS LIMESTONE AND IRONSTONE
Marlstone Rock Formation	MRB	Mixed ferruginous lithologies	FGLS	FERRUGINOUS LIMESTONE AND FERRUGINOUS SANDSTONE
Marlstone Rock Formation	MRB	Ironstone	FEST	IRONSTONE
Marlstone Rock Formation	MRB	Beds of ironstone separated by clay	MDFEST	MUDSTONE AND IRONSTONE
Dyrham Formation	DYS	'Sandy clay' etc.	SAMDST	MUDSTONE, SANDY

Formation	Lex	Log lithology or name	Preferred RCS	RCS translation
Dyrham Formation	DYS	Mixed siliciclastics	MDSS	MUDSTONE, SILTSTONE AND SANDSTONE
Dyrham Formation	DYS	'Middle Lias Clay' – probably mudstone and siltstone	MDST	MUDSTONE
Dyrham Formation	DYS	Mixed siliciclastics, sandstone dominant	SDSM	SANDSTONE, SILTSTONE AND MUDSTONE
Dyrham Formation	DYS		SIMD	SILTSTONE AND MUDSTONE, INTERBEDDED

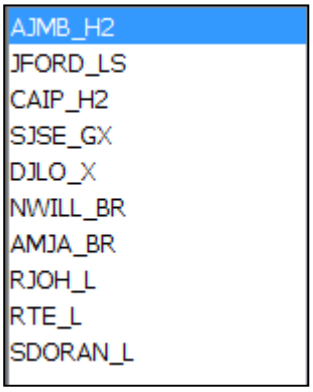
Table 2. Preferred RCS codes for lithology variants

Specific decisions about certain borehole logs are listed in Table 3.

Borehole SOBI id	Decision
SP53NE/165	Use log on p2
SP54SE/1	Used R J Wyatt log pp 1-2
SP53SE/3	Had to be hung from the DTM for EWrung_5
SP53NE/3	Had to be hung from the DTM for EWrung_8
SP54NW/23	Beyond a fault at end of NWSE_2: ignore
SP54NW?/331	Unclassifiable vs mapping
SP52NE/32	Log not trusted: ignore
SP62NW/32	Log not trusted: ignore
SP63SW/4	Site incorrect, thicknesses ok but ignore for correlation

Table 3. Boreholes used in the model on which decisions were made

S Thorpe 14th March 2013 - After boreholes coding was completed by Mark Barron (AJMB) the boreholes were extracted from the SOBI and BoGe databases by Steve Thorpe (ST) using a set of queries. The BLG needed to be de-duplicated and the Borehole Filter Tool was used to address this. The following priorities were applied to borehole records that were coded by more than one project. The records at the top of this list have a higher priority and the filter tool keeps these records and discards other matching records.



This left a total of 337 boreholes coded (area3_bid_coded.bid) out of a total borehole count in Area 3 of 973 (Figure 3), generating the file Area3_BLG_coded_deduped.blg.

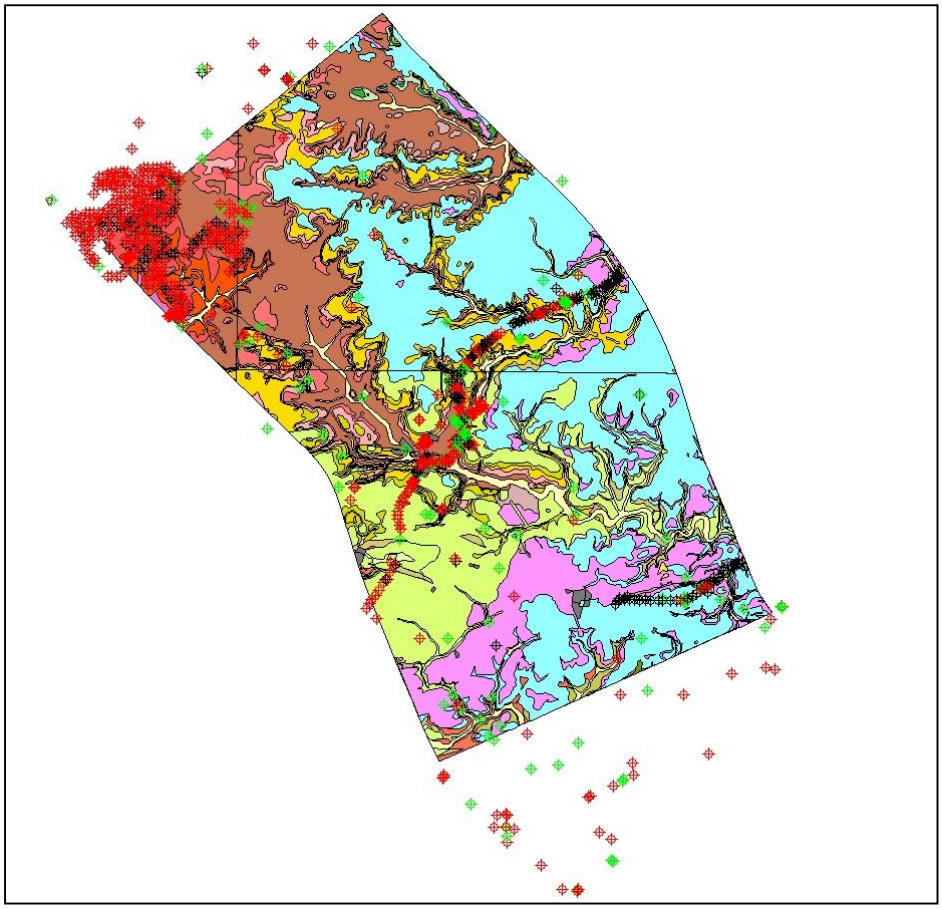


Figure 3. All boreholes in Area 3 set

Coded boreholes over 10 m depth in green, under 10 m in black, uncoded boreholes in red.

The boreholes which AJMB identified as being useful for routing cross-sections through (total of 65) have also been generated as an additional BID file (area3_route_xs_through_bid.bid; Figure 4).

4.3 DIGITAL TERRAIN MODEL

S Thorpe 18/3/13: 20m DTM obtained from the BaldEarth model and trimmed to the project area (5 km buffer of the route shapefile).

4.4 CROSS-SECTIONS

S Thorpe 18/3/13: Rung_16 and cross-sections running NW_SE were imported from Area 2. Buckingham 1:50 000 map cross-sections were imported from Area 2 with raster backdrops.

4.5 GEOLOGY AND OTHER SHAPEFILES

S Thorpe 18/3/13: Bedrock, Superficial and AMG geological DiGMapGB-50 shapefiles loaded. No mass movement mapped within project area.

ST handed over to AJMB 14th Mar 2013 for review and subsequent changes in base data will be recorded in this section.

4.6 OTHER DATASETS

- Mine plan data – none known or used
- Seismic data – none used

- Geophysical data – none used
- Previous models used by this model – none used. The London Lithoframe 250 model (2007) models only the base of the Lias Group with a 1000 m mesh spacing – too coarse for the current purposes.
- Chipping Norton memoir (Horton et al., 1987) figure 15 (Lower Lias isopachyte map = CHAM), figure 19 (Middle Lias Silts and Clays isopachyte map = DYS) and figure 21 (Upper Lias isopachyte map = WHM) were scanned and georegistered.

5 Model development log

All modelling done by A J Mark Barron.

14/3/13: Drew proposed lines of Area 3 cross sections in ArcGIS through as many as possible of the bores preselected during the borehole coding process, whilst retaining reasonably straight lines and a rectilinear grid (Figure 4). This excluded only five of the preselected boreholes.

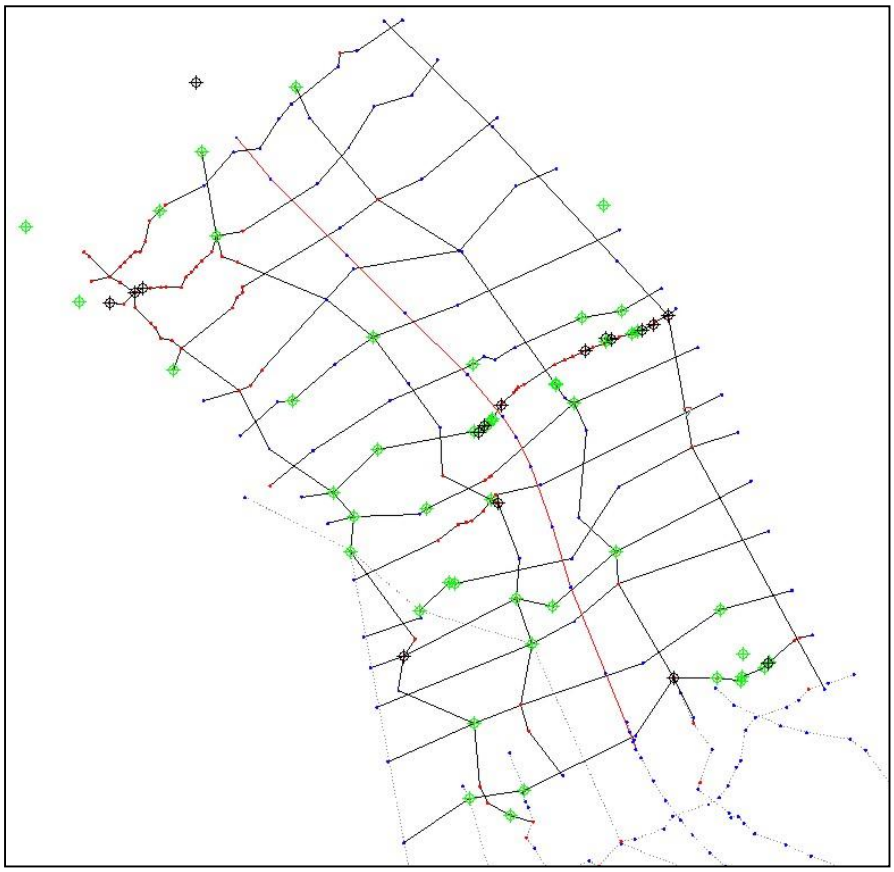


Figure 4. Original cross section lines and selected boreholes

Centreline (proposed HS2 route) in red, dotted lines are Area 2 and Buckingham 1:50 000 cross sections. For cross-section labels and helper sections added later to aid calculation see Figure 5 and Figure 6.

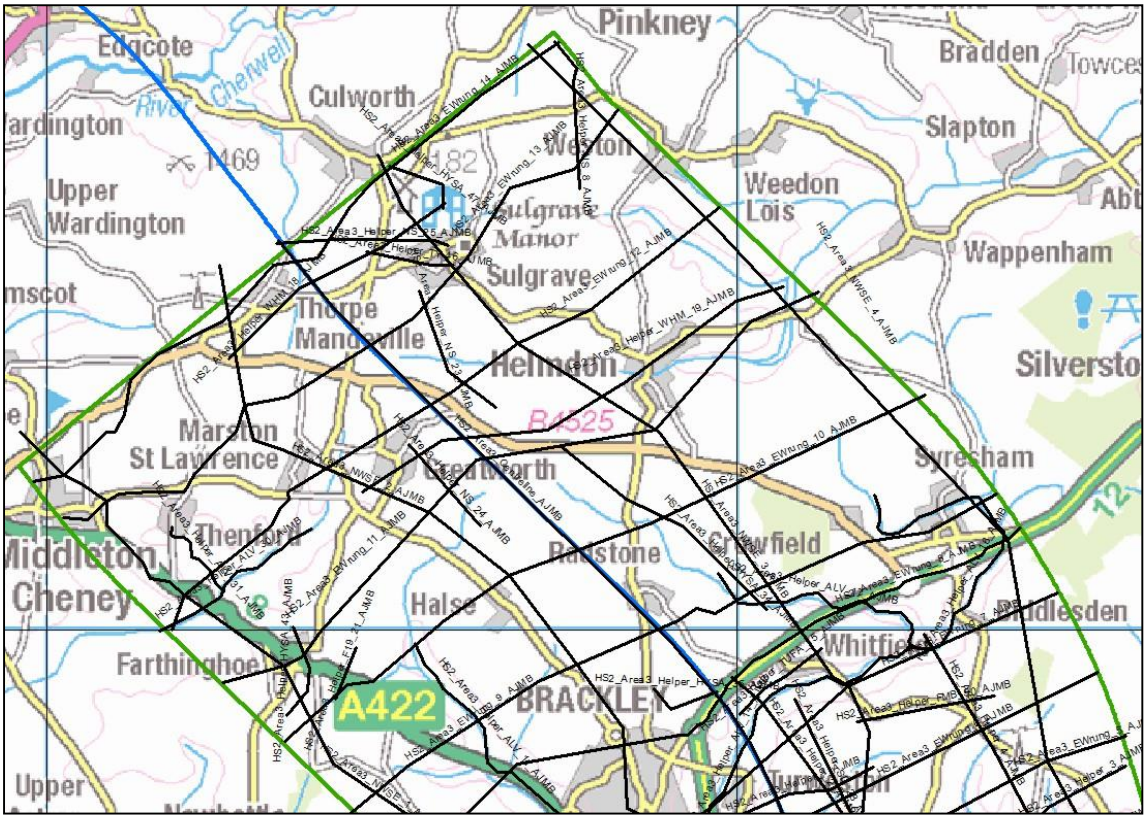


Figure 5. Cross sections and helpers – Area 3 north-west part

Proposed centreline in blue, model boundary in green. Contains Ordnance Survey data © Crown Copyright and database rights 2014.

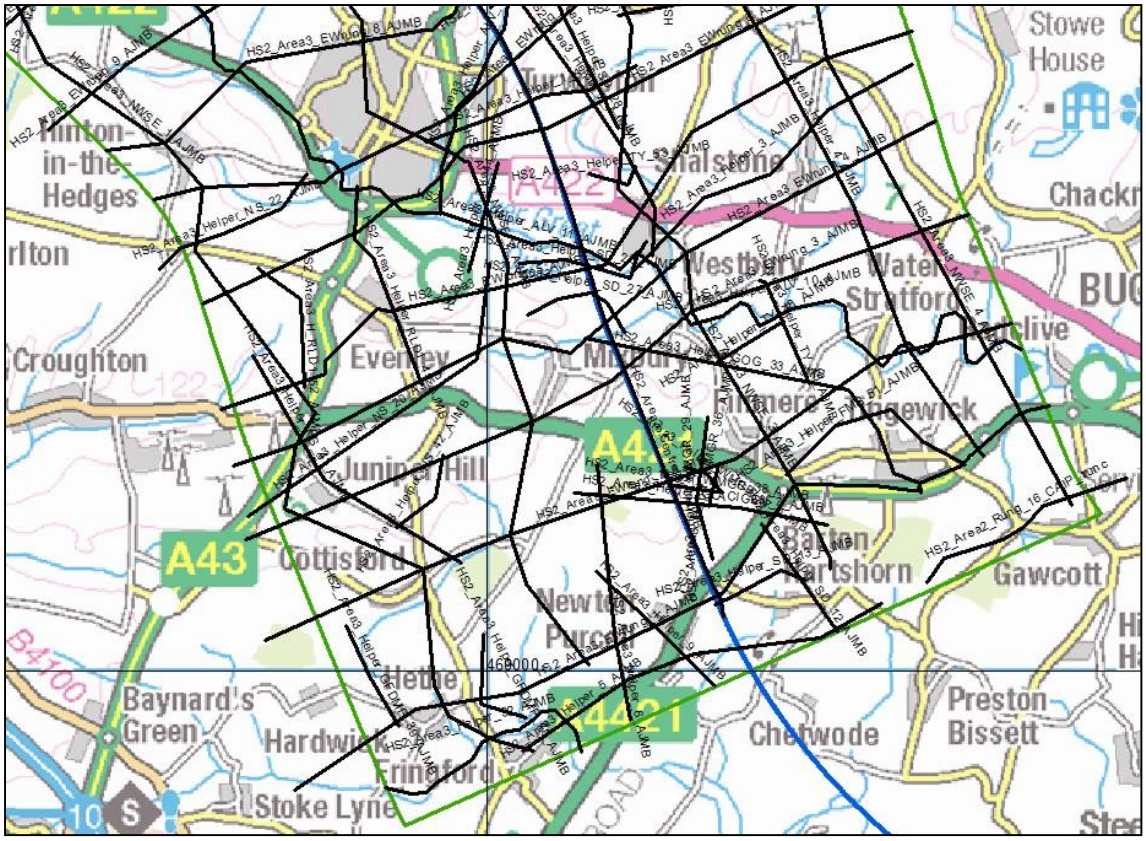


Figure 6. Cross sections and helpers - Area 3 south-east part

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Appendix 1 gives a dated section-by-section, version-by-version account of the model build. NB section comments ('bubbles') were used sparingly (e.g. NWSE_2; Centreline). Additional comments as follows.

The model was correlated throughout down to 30 m below OD as per project instructions. This level is very widely very close to the base of the Charmouth Mudstone Formation (CHAM), which is usually below, but in places just above (EWrung_14; Centreline; EWrung_4; EWrung_5). Here the underlying Penarth Group and Mercia Mudstone Group strata (WLI, PNG, MMG) are locally correlated but were not calculated.

14/5/13: Lenses of GFDMP and TILMP1 were created in several cross-sections in the south from v73 onwards to v152. 4/6/13 **S Thorpe advised <u>not</u> to use lenses if unit daylights at all**. Need a basal GFDMP unit.

15/5/13: Faults were drawn as NONE lines in cross sections from v77. See 14/6/13 below.

16/5/13-6/6/13: Polygons (polys) from the DiGMapGB-50 layer were added to their respective geological units (GU), apart from very minor outliers that are not intersected, and envelopes built and modified as indicated in Appendix 2. Exceptions/rules as Section 7 below, modifications in order of creation below:

- FMB-LSMD and BWC: DiGMapGB-50 polys do not fit across 202/219 boundary. Redrew as per MG Sumbler 1:10 000 map SP63NW (Figure 7).

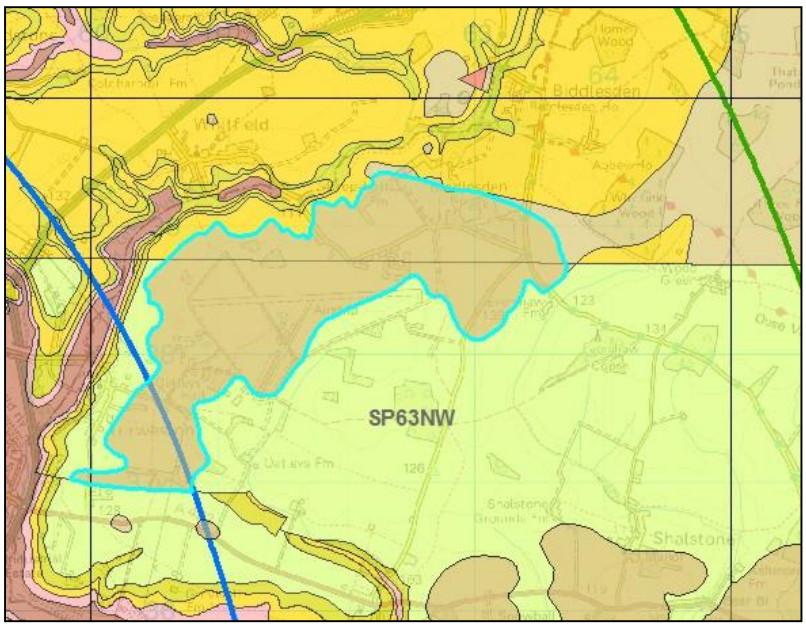

Figure 7. Modifications to BWC geological unit against DiGMapGB-50 at the Towcester-Buckingham sheet boundary

Merged FMB geological unit highlighted. Proposed centreline in blue, model boundary in green. NB BW (yellow) against White Limestone Formation. Contains Ordnance Survey data © Crown Copyright and database rights 2014.

- HEAD: Some modifications for sub-ALV coverages v141 (Figure 8).
- MGR: 31/5/13, 3&4/6/13 new polys drawn for railway embankments).
- WMGR: 31/5/13, 3/6/13 new polys for backfilled railway cuttings.
- ALV: 3/6/13 joined polys and extended under LSGR at EWrung 6 W2900 and EWrung 7 W2550*.
- LSGR: 3/6/13 extended at EWrung 6 W2900 v149*
- WGR: 4/6/13 made a poly for railway cutting.

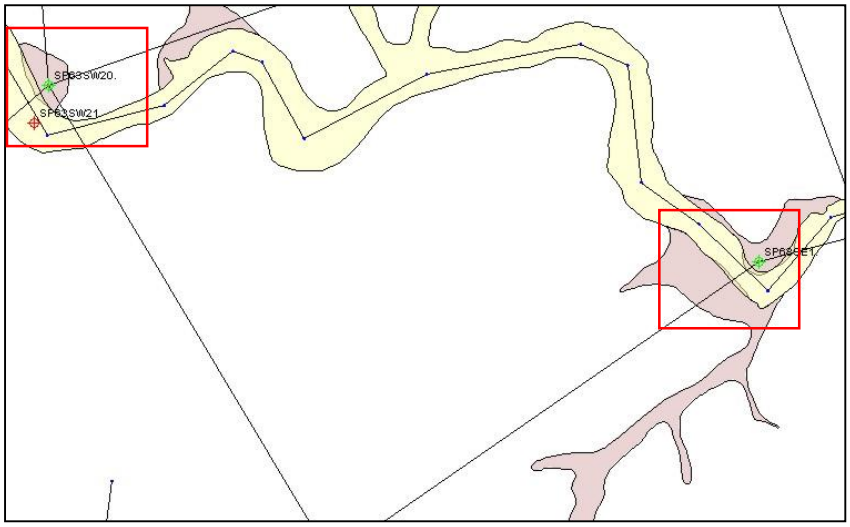

Figure 8. Examples of modifications to HEAD GU under ALV GU

- TILMP1: till unit created that lies above the most extensive GFDMP but not separated/ distinguished on survey maps from subjacent TILMP. 5-6/6/13 – coverages built above GFDMP and surface closures constructed where GFDMP is missing (Figure 9).

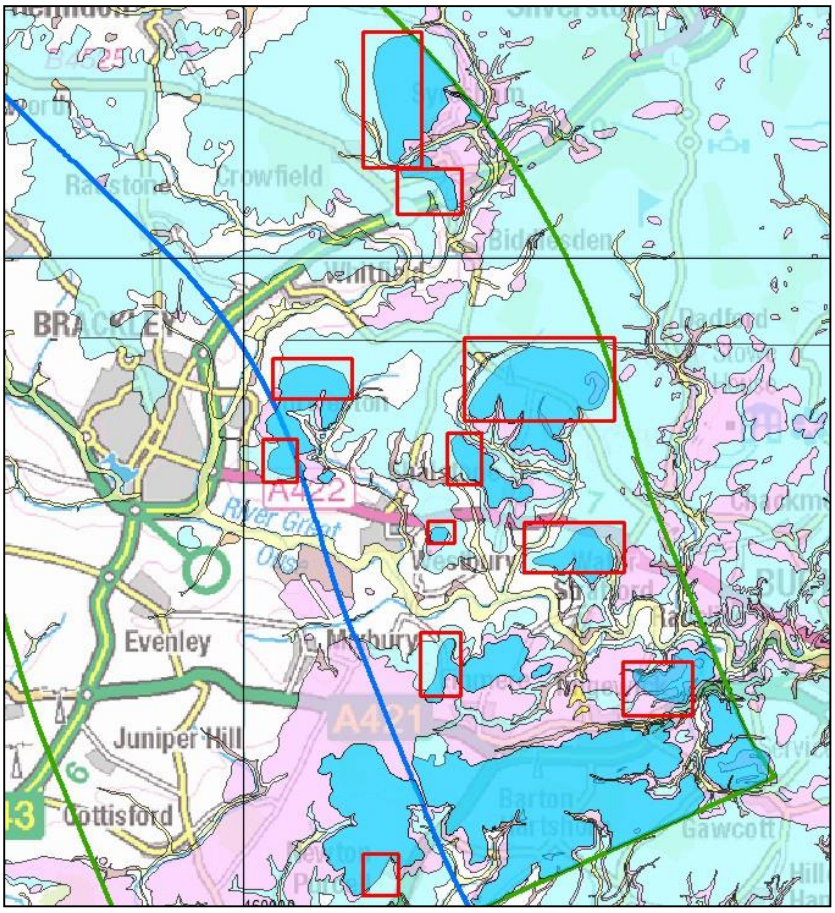

Figure 9. TILMP1 GU in bright blue superimposed on DiGMapGB-50 superficial layer

DiGMapGB TILMP polygons in pale blue, proposed centreline in blue, model boundary in green. Constructed base of TILMP1 indicated by red rectangles. Contains Ordnance Survey data © Crown Copyright and database rights 2014.

- WHM: GU modified vs DiGMapGB-50 in EWrung 14 W1100*.
- MRB: GU modified vs DiGMapGB-50 in EWrung 14 W1300*.

- GFDMP1: generally overlies TILMP1, but locally coverage surface closure was constructed cross-cutting very complex glacigenic stratigraphy (Helper_4 W7000-8000) in order to close the GU (Figure 10).

* requires modification to DiGMapGB, check 50 and 10.

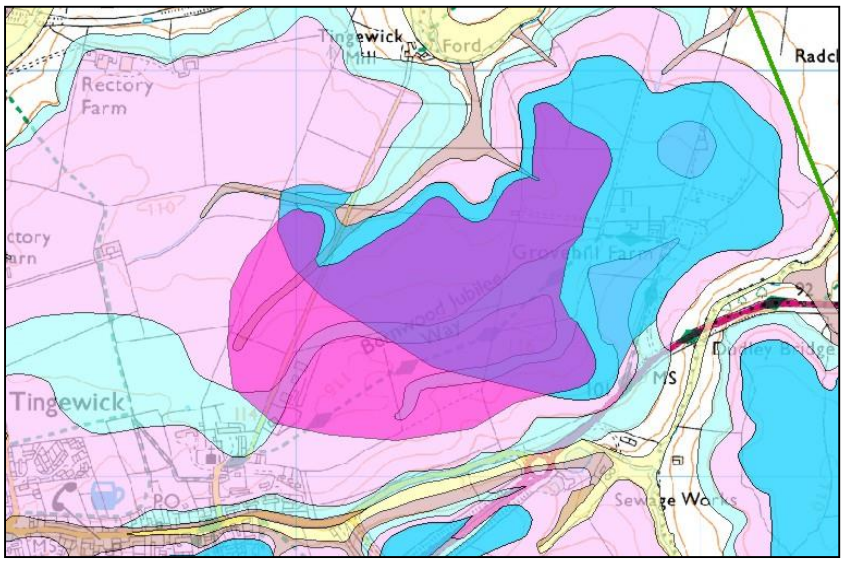

Figure 10. TILMP1 (bright blue) and GFDMP1 (bright pink) GUs superimposed on DiGMapGB-50 superficial layer in SP 66 33 showing cross-cutting lines

DiGMapGB TILMP polygons in pale blue, GFDMP in pale pink, model boundary in green. Contains Ordnance Survey data © Crown Copyright and database rights 2014.

30/5/13: GFDMP lenses fixed and colour up v138.

10/6/13: by now all lenses translated to non-lens correlated lines v194.

11/6/13: first attempt at calculation of all failed.

14/6/13: excluded all CAIP cross sections and two Buckingham cross sections from calculation. Calc all – stalled at WHM, then at GOG. S Thorpe suggested the join between GOG and its component formations could be the problem – made all these into near vertical 'L' forms with GOG v208 (e.g. Figure 2). Also need to make 'L' forms at faults where coverage ends – did up to EWrung 4 v214.

14/6/13: H Kessler suggested make proper modelled faults which can be used in GoCAD. Reopened v208, created faults HS2_Area3_F1_AJMB to HS2_Area3_F31_AJMB (Figure 11) and fixed faulted line v224. 20/6/13: Calculate all, stalled at NS. Requested help from S Thorpe.

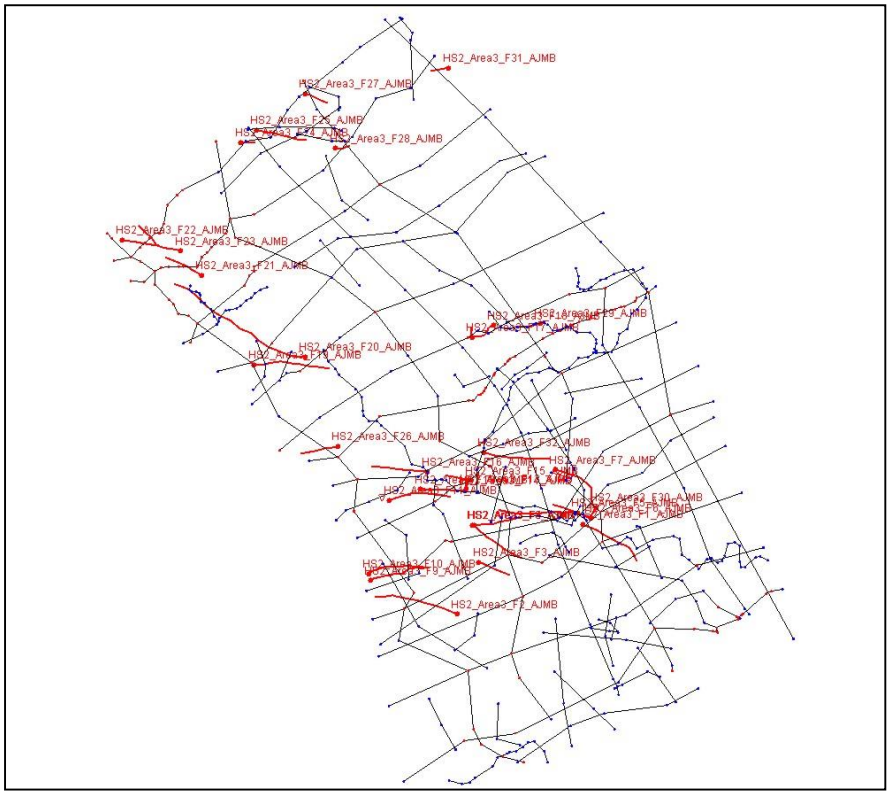

Figure 11. Faults drawn and modelled

Total of 32 faults drawn. These were later removed as they hindered model calculation.

28/6/13: S Thorpe reviewed v224:

"I can see that it halts when trying to calculate the Whitby Mudstone. This is usually a result of one, or a combination of, the following reasons:

- *The Whitby Mudstone isn't consistently snapped/tied into control points*
- *The unit(s) above which create the top of the WHM aren't snapped/tied into control points*
- *There are units which don't make geological/topological sense (you pointed one of these out to me when we last spoke) there are a number of these in your model*

From looking through your sections and envelopes I'd say that most of the above reasons are applicable. However, I don't want you to think I'm criticising your model as it looks like a huge amount of effort has gone into it, and this is clearly reflected!!

One issue I do have is the splitting of units along the sheet boundary. The Forest Marble and Blisworth Clay boundary is completely arbitrary for example, and I don't think this should be replicated in the modelling especially as you have clearly shown that they share a common depth and shape in section. The other that I found was the White Limestone and Blisworth Limestone, in fact these four units share this common boundary. Is there a way to remove this manmade boundary, perhaps by subsuming one unit into the other for each pair? Or maybe creating a new unit to hold both descriptions? (WHL_BWL for example). This would remove a lot of ambiguities from the calculation, in addition to removing a lot of hard meticulous work on your part to get the pairs of units to sit neatly underneath each other where sections don't constrain them precisely."

3/3/14: opened v224. Merged all BWC into FMB, fixed in all cross sections v225. ST recommends not to merge WHL and BWL but TY still won't calc – problem is WHL/BWL.

5/3/14: Merged all BWL into WHL, fixed in all cross sections v228.

5/3/14-7/3/14: Repeated Calculate all commands stalled at various bedrock units – HYSA, NS, WHM.

10/3/14: ST also says that modelled faults will not assist calculation – need to join same lines across (Ctrl+click) as steps and ensure these do not cross ones above (Figure 12). May also need to densify nodes here and elsewhere to assist calculation.

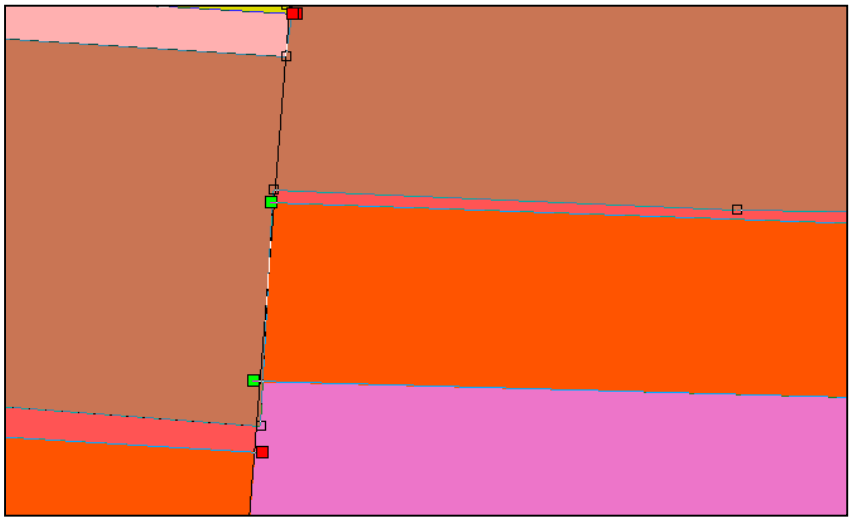

Figure 12. Problems at fault planes of correlation line crossovers

17/3/14: v246 calc all, stalled at STAM, sent to 3D. Layers needing help: STAM SHHB TY RLD1 WHL FMB CB KLB TILMP GFDMP TILMP1 GFDMP1 HEAD ALV.

18/3/14: ST advises *"a few more helpers are needed. You also need to check your snapping and/or envelopes in the areas ... where some units are faulted and GSI3D thinks they should be interconnected somehow. The bottom right corner showing blue triangles could be the edge of the DTM, in which case you may need to just* ***enlarge your envelopes outside the area*** *to ensure a tighter calculation before the cookie-cutting takes place."*

20/3/14-21/3/14: Added Helper sections 1 to 4 (0; Figure 5; Figure 6). Calc all excl CAIP sections, stalled at FMB, with CAIP sections stalled at WHL.

24/3/14: del CAIP old sections, added in new from her v1_93. Edited various bedrock coverages: STAM NS RLD1 WHL FMB CB KLB v254. Added PET GU. Mod GFDMP in NE and NS below STAM v256.

25/3/14: extended NS envelope south into Area 2, ref 10ks SP52NE (2m thick), SP52SE (2.5 m) and SP62NW (0-1m) and Sumbler (2001, p.8), and GOG envelope SE across CAIP Rung 16 v259.

28/3/14: added nodes to fault steps and to the joins between GOG and component formations: EWrungs 1-14, NWSE1-4, Centreline v263.

28/3/14: added in CAIP rung 16 from her v112, calc all, stalled WHM. Extended HYSA and WHM beyond DTM v265.

31/3/14: extended ALV, HEAD Gus. Added Helper_SD_12 and 13 v266. Deleted old CAIP sections, added new from her v113.

31/3/14 calculate all (excl all CAIP sections) completed (17 mins), sent to 3D, various bleed problems, extended envelopes of all bedrock units from KLB to DYS outside DTM, calc all stalled at WHM.

1/4/14: Added Helpers ALV_14 to WHM_19 v275.Calc stalled at WHM. Densified various bedrock lines v277.

2/4/14: calc all stalled NS v279.

3/4/14: calc all completed v282

4/4/14: calc all completed v284. Snap to Helpers and synthetic render check of all main sections – all ok except EWrung 8, no colour v287.

7/4/14: calc all completed v288.

8/4/14: calc all completed v290, v294.

9/4/14: ST looked at EWrung 8's rendering problem and redrew an MGR line v295.

12/5/14: calc all complete, sent to 3D render probs in NE, added nodes to Lias fms here, del phantom polys in GFDMP that were TILMP. Added Helpers ALV_30, ALV_31 in NW.

13/5/14; mod TILMP under ALV N of EWrung 9 v297.

14/5/14: deleted small TILMP1 poly v298.

15/5/14: calc all stalled at TY. Various snaps improved v299.

21/5/14: requested Ben Wood look at v302 model to determine reason for part-calculation and stall. Is it connected with 'Points not used' e.g. for TY? Ben examined and advised that lines from DiGMap were too node-dense, and to apply the 'Simplify all map units command' ('Points not used is not a problem – refers to coverage outside). We tried with a tolerance of 10 m – makes lines rather polygonal. Calculation successful. Recommends do not re-snap correlated lines to outcrop flags, but save simplified calculated model as a distinct version and reopen previous version for further edits. Line simplification used is based on the Douglas-Peucker algorithm http://en.wikipedia.org/wiki/Ramer%E2%80%93Douglas%E2%80%93Peucker_algorithm. The implementation used is from a code library called the Java Topology Suite (JTS) http://www.vividsolutions.com/jts/JTSHome.htm.

22/5/14: opened v305, applied Simplify lines with 5 m tolerance – very quick, looks ok, calculation successful, saved as v305_calc_complted_tol_5. Extended all GU coverages out beyond ends of sections (as appropriate within outcrops) to preclude edge effects v311. Added Helpers GFDMP_39, _40, NS_41 checking GU coverages bottom up: CHAM, DYS v312.

23/5/14: opened v312, applied Simplify lines with 5 m tolerance, saved as v312_calc_complted_tol_5. Various edits calc and save v313_calc_complted_tol_5. Added MRB lines to Helpers 5, 6 and 20 v314. Added Helpers NS_42, checking GU coverages MRB, WHM, NS, GOG, added Helpers HYSA_43 correlated d/t NS, Helper_TY_44 correlated d/t WHM v315, Helper_TY_45 correlated d/t GOG, Helper_TY_46 correlated d/t NS v316.

27/5/14: opened v316, auto-densified MRB base in Helpers 2, 3 v317, NWSE_2 and 3, EWrungs 1, 2, 7, 6, 8, 14, Helpers 18 and 28 v318, in EWrung 12, auto-densified WHM in EWrung 12 and WHM and MRB in Helper 15, and NS in NWSE_1. Checked GUs: GOG, HYSA, added Helper_HYSA_47 drew d/t MRB, checked GUs STAM, RLD, SHHB (simplified linework to 5m), WBRO and TY, densified TY lines in H_NS_41, NWSE_1. Added Helper_TY_48, drew d/t WHM v319. Checked GUs: WHL, BLAD, FMB, auto-densified FMB in EWrung 6 and Helper_4, added Helper_FMB_50, drew d/t FMB. Checked GUs: CB, KLB, GFDMP0, TILMP, GFDMP, TILMP1, GFDMP1, HEAD, ALV, extended H_HYSA_34 NW and drew d/t WHM, densified ALV in Helpers ALV 30 and 31 v320.

30/5/14: cross-snapped Helpers 47 to 50 v321.

31/5/14: Modified DYS and MRB coverages at north end v322. Fixed problems with TILMP and WHL coverages in NE, calculation successful v323.

16/6/14: calculated GU grids sent to Arc. Many discrepancies seen compared with thicknesses cited by Horton et al. (1987) and Sumbler (2002), and likely variations inferred from modelling. Require interventions.

18/6/14: all croplines simplified to 5 m tolerance, detaching many from correlated lines. These were autosnapped section-by-section with some manual intervention and saved to v324-v334.

19-23/6/14: thicknesses of various GUs assessed and action to fix taken as follows:

- GFDMP where >15 m in extreme SE – Area 2 Rung 16 included in calculation fixes this: cross section truncated at SW end to within DTM and resaved as Area_2_Rung_16_CAIP_trunc v341.
- CB where >4 to10 m in south – mods to Helper_SD_13 fix.
- FMB where >7 to 17 m in SE – added Helper_FMB_51 drawn d/t FMB thro SP63SE7 and sl mod to TILMP coverage to fix v336
- WHL where 15 to >25 m in SE – extndd Helper_FMB_51 to Centreline, drew d/t WHL in and densified WHL here, in Rung 1 and Helper_TY_45 v336.
- RLD1 where <17 m – densified in Rung 4, Centreline; Fault F32 added and drew displacement in Centreline (3 m) and Rung 6 (3 m); extndd Helper_4 north to Rung_9 and drew d/t WHM v337.
- TY where 7 to >18 m – added Helper_TY_53 drew d/t TY v338 and x-snapped; densified TY in Rung_11, NWSE_3. Disregard at W end Rung_5 as edge effect.
- SHHB where 4 to 11 m – amended TY coverage at SE end Helper_41 and in Rung_2, extndd Helper_49 to SE, added MRB, all densified v339.
- HYSA where 7 to 15 m – W end Rung_8 OK, HYSA densified in Rung_5 and Helper_3 v339.
- NS where 6 to 25 m – disregard at W end Rung_5 as edge effect; 20/6/14 densify in NWSE_2 and Rung_3 v340.
- MRB – up to 6 m in NW ok. Holes in south: densified in Rung_7, Rung_6, added and densified in Helper_NS_22, Helper_GOG_33, Helper_TY_45 and 48 v340.

23/6/14: calculation completed v341.

28/7/14: raster backdrop deleted from EWRung_14,

NB the model version v342 submitted for QA on 28/7/14 includes the two Buckingham map cross-sections and eight cross-sections form Cath Cripps' Area 2 model (+1_HS2, +2_HS2, -1_HS2, -2_HS2, 0_HS2, TILL_helper_1, TILL_helper_2 and TILL_helper_3. All were used to inform correlation and the Area 2 sections are fitted to, but all are excluded from the calculated model. It may be appropriate to remove these from the delivered model.

5.1 UPDATES

GVS

5/6/13: v5 GFDMP0 added below TILMP

GLEG

2/6/14: changed GOG to more orange and SHHB to more bluish to distinguish. GLEG saved as W:\Teams\GLE\GLETeamLeader\Data\HS2\HS2\GSI3D_Modelling_files\HS2_GLEG_v5.GLEG.

GSIPR (post QA)

7/1/15: Technical check by Ian Cooke v343_tol_5m_ilc.gsipr.

21-27/5/15: QA undertaken and QA form compiled by Helen Burke (HBU) v344.

8-12/6/15: AJMB undertook post-QA amendments as Appendix 2 v360.

12/6/15: Steve Thorpe tested Area 3 for calculation v360_post_HBU_QA_AJMB_ST_fortesting_1_3.gsipr.

23/6/15: AJMB added Helper_ALV_54 v362 calc stalled TY.

24-30/6/15: S Thorpe has got a version to calculate: HS2_Area3_3D_Model_v364_post_HBU_QA_ST_TEST_AJMB.gsipr. Use this for packaging for LithoFrame viewer.

6 Model workflow

A standard GSI3D workflow for superficial geological models was followed, as modified by project-specific guidance compiled by S Thorpe from notes by A Farrant on 14/12/12 (W:\Teams\GLE\GLETeamLeader\Data\HS2\HS2\HS2_3DModelling_Guidance_ST.docx). Faults were handled as noted in Section 8.

7 Model assumptions, geological rules used etc

The Charmouth Mudstone is regarded as corresponding approximately to the Lower Lias Clay of previous accounts (Horton et al., 1987) at least in the southern half of Area 3 (Sumbler, 2002), and although northwards into the Banbury and Towcester districts the interbedded limestone beds typical of the Blue Lias Formation are thought become more numerous towards the base (Edmonds et al., 1965), the formation is not correlated in Area 3. It was also found that over much of the model area the Charmouth Mudstone's base lay almost exactly at -30 m OD. However, where it lay below, it was drawn nominally at just below -30 m (as per project instructions, to allow truncation), and where it lay above, the underlying strata were drawn, also just below -30 m.

Exceptions/rules and additional polys in order of creation:

- TILMP-DMTN: usually closed beneath fingers of ALV or HEAD. Underlies main GFDMP, locally appears to be absent (e.g. part of Helper_5, Centreline between W10000 and 12000).
- WHL: all BWL merged into WHL, see Section 8 below. See for example Figure 7 where the BWL (yellow) to the north was to be merged with the WHL (pale green).
- BWL: subsumed in WHL, see above.
- FMB: all BWC merged into FMB, see Section 8 below.
- RLD above TY or WBRO changed into RLD1.
- RLD under WBRO retained as RLD.
- SHHB always underlies TY by definition
- GFDMP0: relatively limited coverage at base of glacigenic succession.
- TILMP1: till unit that lies above the most extensive GFDMP but not separated/ distinguished on survey maps from the subjacent Till. Surface closures constructed where GFDMP is missing (Figure 9) are fitted to topographic contours where possible, but locally where the glacigenic stratigraphy is very complex (Helper_4 W7000-8000), constructed boundary cross-cuts mapped leaves of GFDMP in order to close the GU (Figure 10).
- GFDMP1: highest unit in glacigenic succession, generally overlies TILMP1, but locally coverage surface closure constructed cross-cutting very complex glacigenic stratigraphy (Figure 10).

8 Model limitations

The glacigenic stratigraphy is laterally variable and locally very complex, and the succession modelled (GFDMP1/TILMP1/GFDMP/TILMP/GFDMP0) is a simplification to aid modelling. No lenses are used. Surface closures were constructed for TILMP1 where GFDMP is missing (Figure 9; Figure 19) and are fitted to topographic contours where possible, but locally where additional leaves/lenses are mapped (see grid square SP 66 33; Figure 10), the constructed boundaries of GFDMP1 and TILMP1 cross-cut these in order to close the GUs. If this complexity is required in the model, this will have to be revised.

The Forest Marble (FMB) and Blisworth Clay (BWC) formations are approximate correlatives (Sumbler, 2002, fig. 5); and as mapped by Sumbler in 2000 they are fitted in the model area at the line taken as the arbitrary join (see Section 2 and Figure 7). For the purposes of the model they can be regarded as equivalent and BWC is merged into FMB-LSMD to aid modelling.

The White Limestone (WHL) and Blisworth Limestone (BWL) formations are approximate correlatives (Sumbler, 2002, fig. 5); the uppermost Bladon Member of the former is absent within the model area at the line taken as the arbitrary join (see Section 2) and for the purposes of the model they can be regarded as equivalent and BWL is merged into WHL to aid modelling.

The Rugby Limestone Member (RLS-MDLM) of the Blue Lias Formation is modelled beneath the Charmouth Mudstone Formation to the north-west in Area 4, adjoining Area 3. Its extent into Area 3 is very uncertain (see Section 7), and the location of its south-easterly pinch-out is unknown. Hence it is not modelled, creating a misfit with Area 4 model.

In order to achieve a successful volume calculation, it was necessary to simplify the linework in all geological units. A tolerance of 5 m does not degrade the map linework to an unacceptable degree and the calculation succeeds in about 12 minutes. All versions after v323 are simplified to this tolerance.

Faults were finally drawn as NONE lines (which were later deleted) dipping 60 degrees for drawing guidance. If the fault throw is less than the unit thickness (i.e. unit in contact across fault and envelope ‘unbroken’), correlated lines are stepped across, to join into the same unit in the footwall. If absent in the footwall, they are drawn to join the edge of the envelope at the surface or base of overlying unit. Where units are present on both sides at depth, but fault throw exceeds unit thickness (i.e. unit not in contact across fault and envelope ‘broken’), correlation lines are also broken and snapped to slits drawn in envelopes to aid calculation.

Many thin units (e.g. MRB) or those thinning laterally beneath others or the DTM, required node densification (automatically, to 100 m-spacing, or manually) to avoid thin-skin effects in 3D. Not all these effects are fixed.

Figure 3 shows all boreholes available in Area 3 with those coded in green. Figure 4 shows the boreholes chosen as possibly useful in cross sections in green with the lines of cross-sections, indicating where this subsurface data may constrain the model. This gives the model user some idea where the model is most and least certain.

The three isopachyte maps from the Chipping Norton memoir (Horton et al., 1987, figs 15, 19 and 21) were used as far as reasonably possible, with allowances made for new data and uncertainties near the edges of the figures.

9 Model images

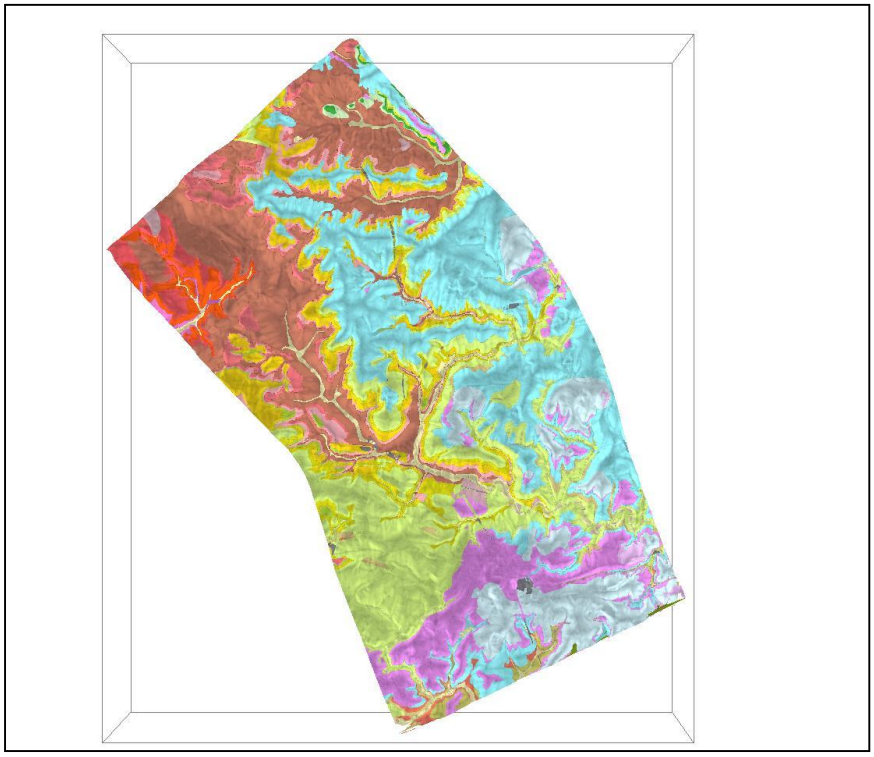

Figure 13. 3D vertical view of calculated volumes of all units

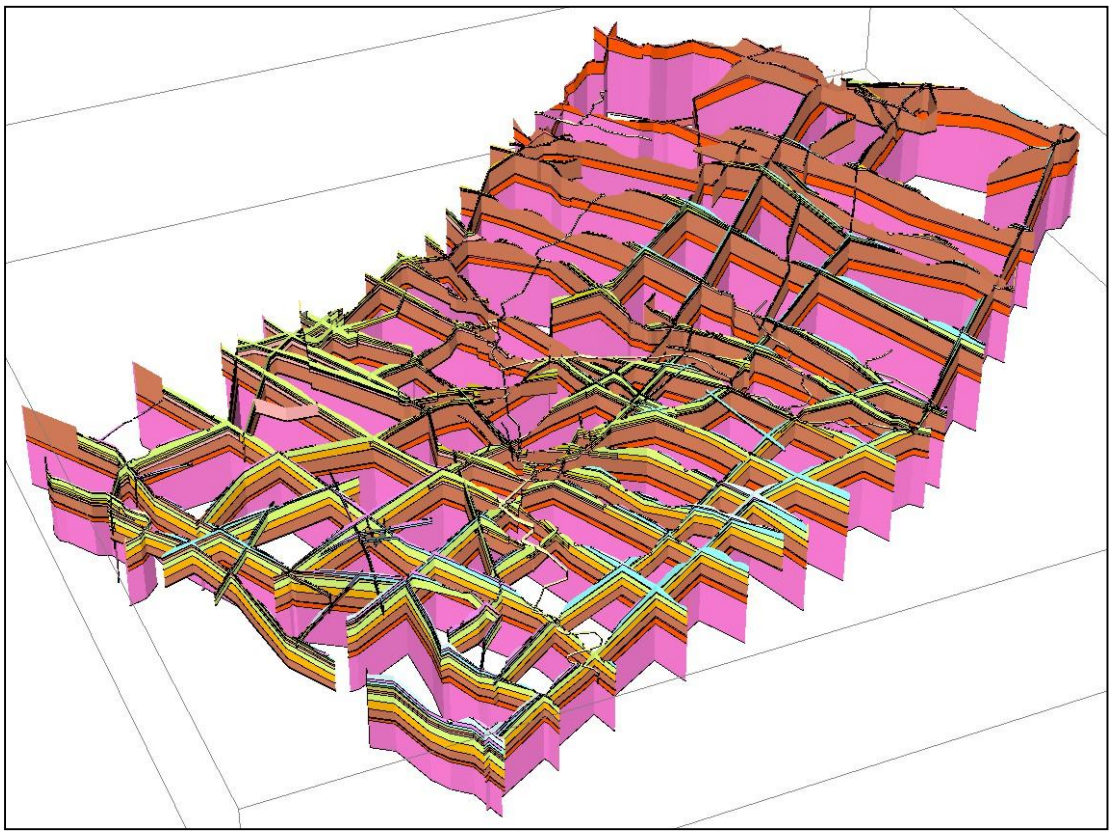

Figure 14. 3D oblique view of all Area 3 cross sections from the east, 10X exaggeration

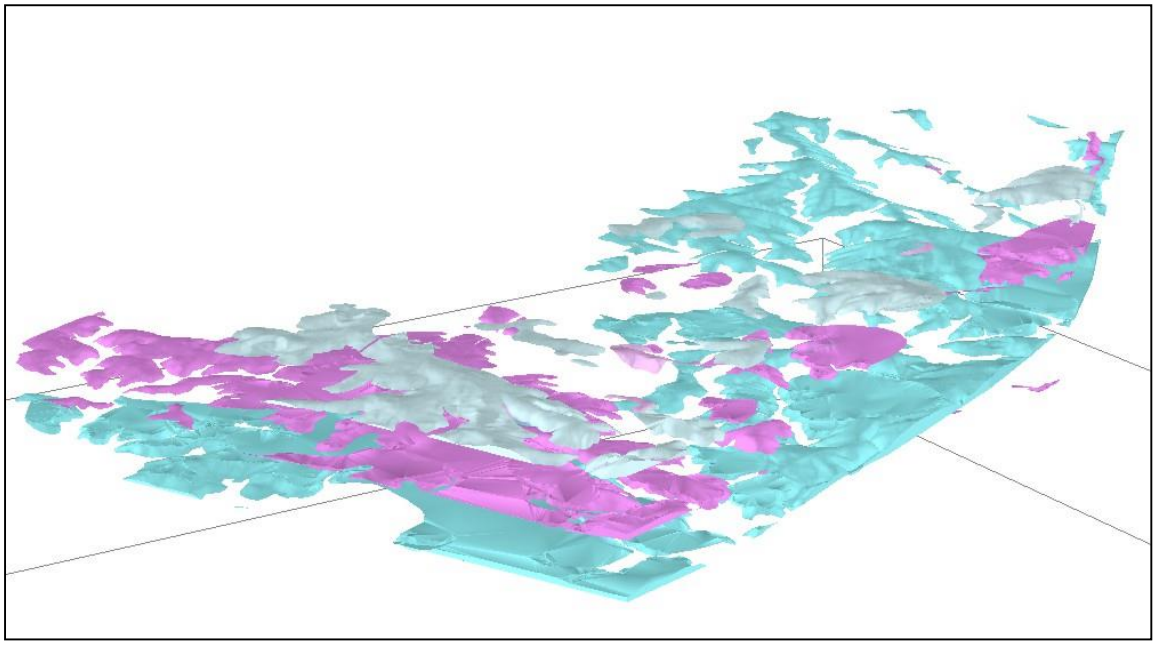

Figure 15. 3D oblique exploded view of glacigenic deposits volumes, from east, 10x exaggeration

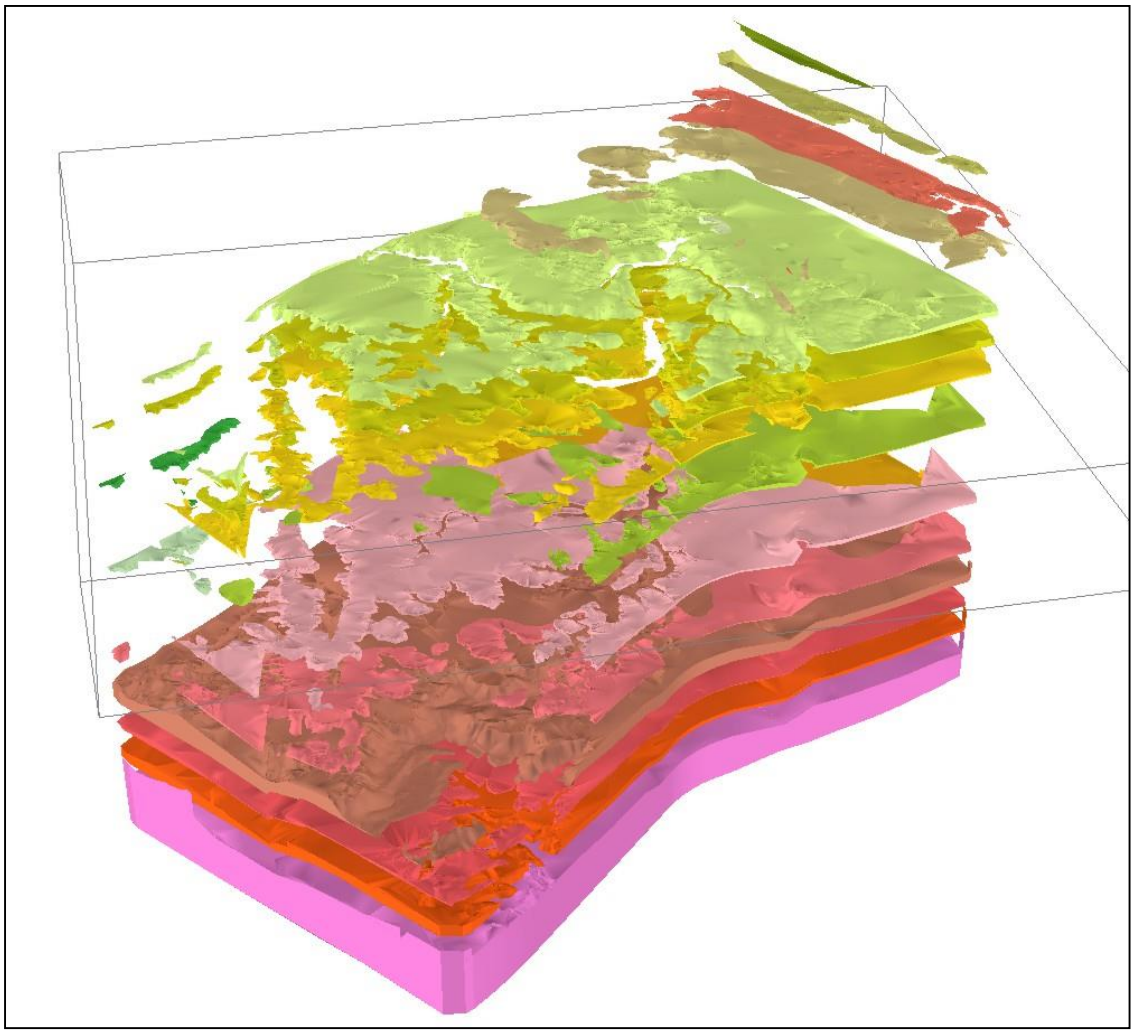

Figure 16. 3D oblique exploded view of all bedrock volumes, from west, 10X exaggeration

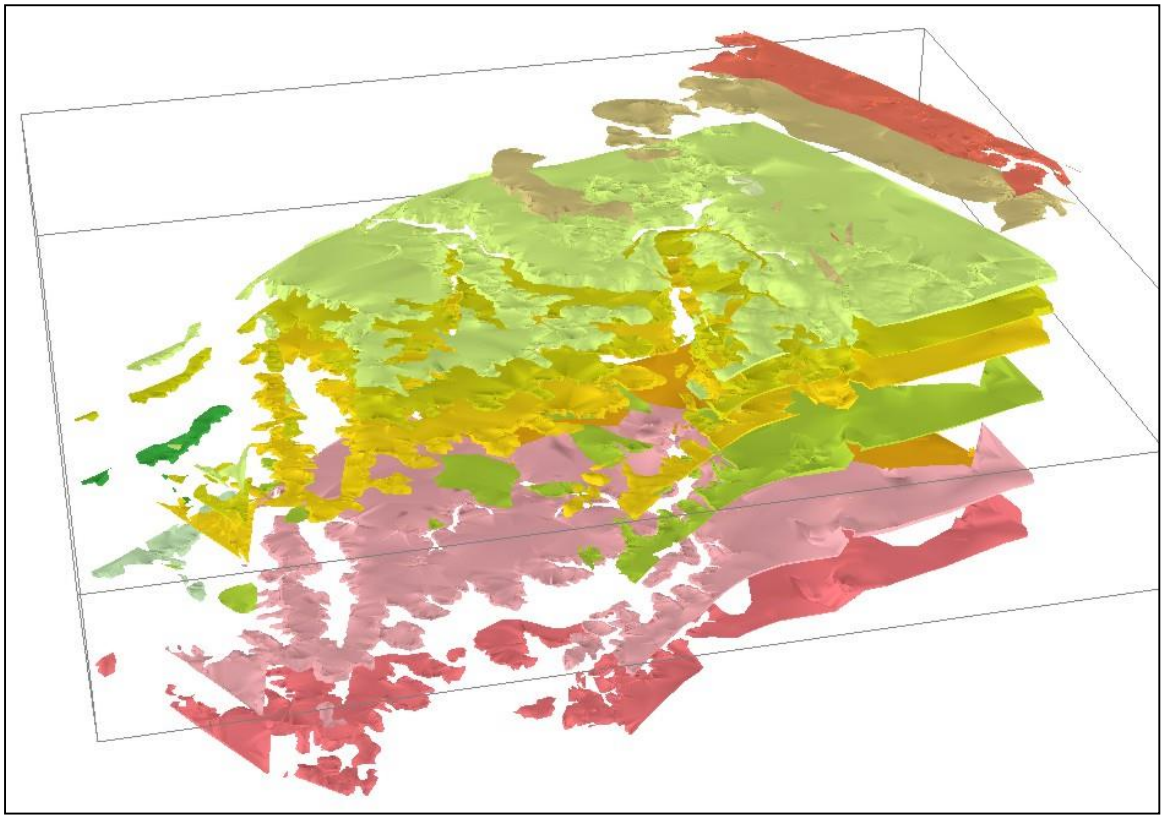

Figure 17. 3D oblique exploded view of Great Oolite Group formations and Northampton Sand Formation volumes, from west.

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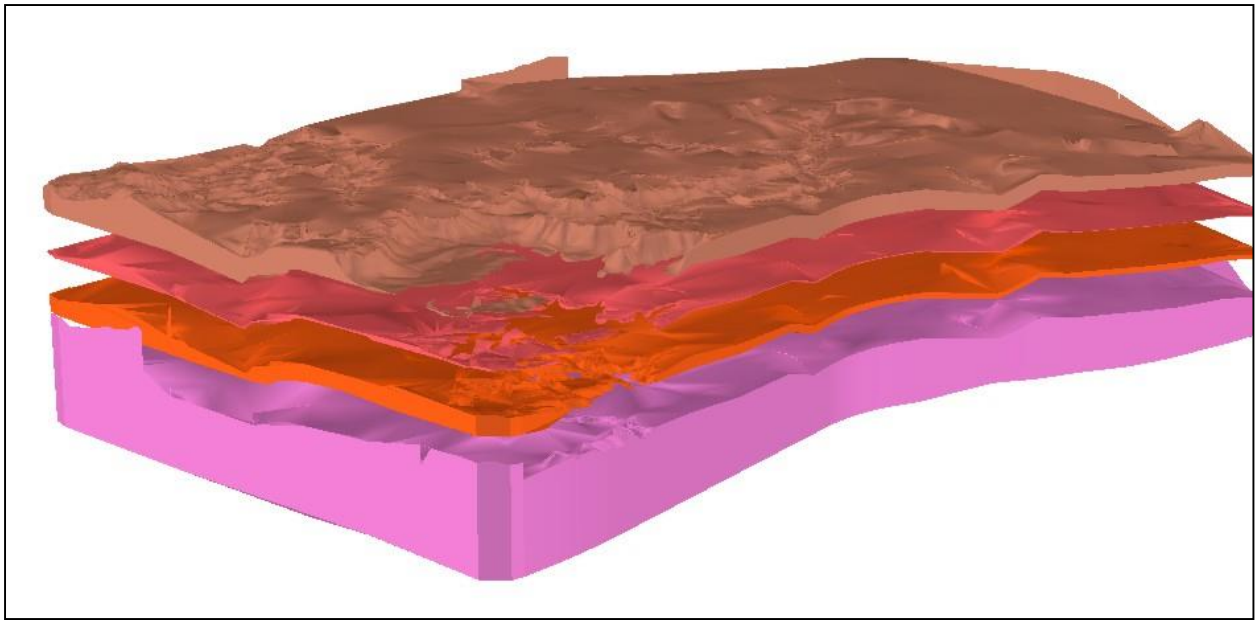

Figure 18. 3D oblique exploded view of Lias Group formations volumes, from west

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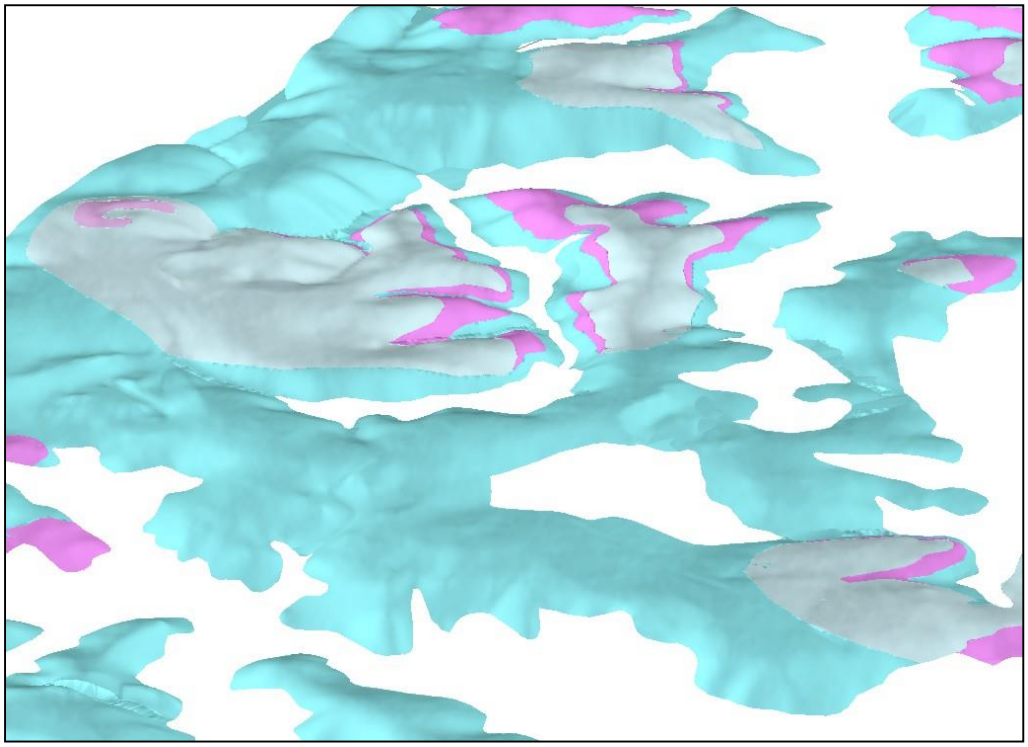

Figure 19. Oblique view of glacigenic succession detail

Turquoise – TILMP, pink – GFDMP, pale blue – TILMP1, pale pink – GFDMP1.

Appendix 1 Detailed model development log

Cross section name (prefixed with HS2_Area3_, suffixed _AJMB)	**Progress (March-Aug 2013, March-June 2014, June 2015 following QA and synthetic rendering check)**
EWrung_1	10/5/13 prov drew all d/t NS SP52NE4-NWSE1 v65, re-exam SP62NW32 - poor log, ignore, drew all d/t -30 CHAM from W end & Buck XS2 to SP63SE6 GFDMP lenses in TILMP NO COLOUR v66; 13/5/13 drew all d/t -30 CHAM to E end where GOG 13m, ?no NS, WHM c14, MRB 1, DYS c10, CHAM 80 v71,72 DRWG + FITS COMPLETED **GOG used, no faults; 31/5/13 added new MGR @ W6200, W11400 v143;** 17/6/13 GOG=RLD1+TY+SHHB+HYSA fix v204; 5/3/14 rechecked snap esp to Centreline v229; 11/3/14 denser nodes, fixing fault steps v242; 19/6 densified WHL v336; 9/6/15 man dens WHL,NS,TILMP,TILMP1 nodes to aid calc v348
EWrung_2	3/5/13 SDs,WHL,HYSA,WHM prov drawn fr NWSE1-SP63SE1 v58; 9/5/13 all d/t -30 CHAM Buck XS2-SP63SE1 v61; 10/5/13 refit all @ NWSE3 v63; 15/5/13 drew all d/t -30 CHAM to E end DRWG + FITS COMPLETED v75 **GOG used, no faults; 17/6/13 GOG=RLD1+TY+SHHB+HYSA fix v204; 6/3/14 rechecked snap esp to Centreline; 11/3/14 denser nodes, fixing fault steps v242; 3/4/14 densify v282; 19/6 amended TY coverage v339**; 9/6/15 man dens WMGR,GFDMP,TILMP1 nodes to aid calc v348
EWrung_3	23/4/13 drew all d/t -30 CHAM W end to NWSE3 v45; 13/5/13 prov drew thro NWSE4 to E end, WHM too thick @ NWSE3, fault @ W6900 est 15m, drew d/t -30 CHAM to E end, DRWG + FITS COMPLETED v72. **GOG used, faults fixed v78; 22/5/13 mods v121; 19/6/13 faults drawn v216**; 6/3/14 rechecked snap esp to Centreline and fault steps v230; 11/3/14 denser nodes, fixing fault steps v242; 1/4/14 densified HYSA NS WHM v277; 3/4/14 adj and densify v282; 8/4/14 sl edits v292; 20/6 densified NS v340; 9/6/15 man dens WHL,GFDMP,TILMP nodes to aid calc v348; 11/6/15 cut TY,MRB,DYS corrln lines at F1 and slit envs V360
EWrung_4	17/4 drew d/t -30 CHAM from NWSE2 to NWSE3 v23; 23/4 drew all d/t -30 CHAM to NWSE1 v44; 15/5 drew all d/t -30 CHAM to E end GFDMP lens, DRWG + FITS COMPLETED v76 **GOG used, faults fixed v79; 17/6 GOG=RLD1+TY+SHHB+HYSA fix v207; 19/6 faults fixed v217;** 6/3/14 rechecked snap esp to Centreline and fault steps v230; 11/3/14 denser nodes, fixing fault steps v243; 2/4/14 added FMB poly and mod F2 v279; 19/6 densified RLD1 v337; 9/6/15 man dens WHL, GFDMP nodes to aid calc v348; 11/6/15 cut MRB corrln lines at F1 and slit envs V360
EWrung_5	15/4/13 hung SP53SE3 fr DTM, drew d/t HYSA v16, d/t WHM to SW end v17; drew d/t -30 CHAM W end to C/L v20; extndd all to NWSE3 v24; 15/5/13 drew all d/t -30 CHAM to E end, GFDMP lens @ NWSE4 v77 GOG used,faults fixed v78; 7/6/13 check and snap glacigenics, mod GFDMP coverage v186; 17/6/13 GOG=RLD1+TY+SHHB+HYSA fix v208; 6/3/14 rechecked snap esp to Centreline and fault steps v231; 11/3/14 denser nodes, fixing fault steps v244; 1/4/14 densified HYSA WHM v277; 8/4/14 sl edits v292; 19/6 densified HYSA v339; 8/6/15 snapped CHAM to NWSE1, and fitted to SP53SE2 v344; 9/6/15 man dens NS nodes to aid calc v348; 11/6/15 cut MRB corrln lines at F5,F6 and slit envs V360

Cross section name (prefixed with HS2_Area3_, suffixed _AJMB)	**Progress (March-Aug 2013, March-June 2014, June 2015 following QA and synthetic rendering check)**
EWrung_6	18/4/13 drew all d/t -30 between NWSE2 and 3, pushed TY thro RLD in SP53NE64 v31; 19/4/13 drew all d/t -30 CHAM W end to NWSE3, pref given to my mapping over classn of logs of SP53NE60, 27 and 12, v36; 16/5/13 drew d/t -30 CHAM to E end fit to NWSE4 v82; 7/6/13 check and snap glacigenics, mod GFDMP coverage v186; 17/6/13 WHL/BWL V203, GOG=RLD1+TY+SHHB+HYSA fix v208; 6/3/14 rechecked snap esp to Centreline and fault steps v232; 13/3/14 denser nodes, fixing fault steps v245; 22/5/14 densify nodes at NE end d/t WHM v306; 19/6 drew F32 displ 3m v337; 9/6/15 man dens SHHB,TY,RLD1 nodes to aid calc v348; 11/6/15 cut TY,HYSA corrln lines at F11,F12 and slit envs V360
EWrung_7	16/4/13 drew d/t WHM W end to SP53NE45 v21; drew d/t -30 CHAM W end to NWSE3 v22; 16/5/13 drew d/t -30 CHAM to E end fit to NWSE4 v83 fault fixed GOG used; 7/6/13 check and snap glacigenics v187; 17/6/13 FMB/BWC, WHL/BWL V203, GOG=RLD1+TY+SHHB+HYSA fix v208; 6/3/14 rechecked snap esp to Centreline and fault steps v232; 13/3/14 denser nodes, fixing fault steps v245; 3/4/14 densify v282; 22/5/14 densify nodes at NE end d/t WHM v306; 9/6/15 man dens TY,SHHB,ALV nodes to aid calc v348
EWrung_8	18/3/13 drew shallow along A43 v7. 8/4 drew west end thro SP53NE1, 3, 8 down to -30 (within CHAM) v8; 22/4/13 drew all d/t -30 NE to NWSE_3 (use of Non-geol lines) v39-41; 16/5/13 drew d/t -30 CHAM to E end fit to NWSE4 v84 no faults; 31/5/13 HEAD mods V139; 7/6/13 check and snap glacigenics v187; 6/3/14 rechecked snap esp to Centreline v233; 13/3/14 denser nodes, fixing fault steps v246; 7/4/14 fixed tiny NS subcrop, resnapped v288; 8/4/14 sl edits v291, fix TY window for ALV v292, added HEAD poly at W5080 and NGM line changed to MGR, add MGR at W6200 v293, adj MGR at W5530 to fix SHHB v294; 22/5/14 densify nodes at NE end d/t WHM v307; 9/6/15 man dens SHHB,MGR nodes to aid calc v348
EWrung_9	19/4/13 drew all d/t -30 CHAM v35; 21/5/13 faults fixed v98; 4/6/13 added NG line at W10650 on ALV and HEAD v153; 7/6/13 check and snap glacigenics v188; 6/3/14 rechecked snap esp to Centreline and fault steps v233; 13/3/14 denser nodes, fixing fault steps v246; 9/6/15 man dens TY,TILMP,GFDMP nodes to aid calc v348
EWrung_10	10/4/13 SP54SE2 missing, redrew XS thro v9; drew W end to NWSE3 d/t -30 CHAM v38; 21/5/13 drew all d/t -30 CHAM to E end v97; 4/6/13 added MGR v154; 5/3/14 rechecked snap esp to Centreline v229; 6/3/14 rechecked snap esp to Centreline and fault steps v233; 31/3/14 drew TILMP1 & GFDMP at E end v267; 9/6/15 man dens WHL,TY, TILMP nodes to aid calc v348
EWrung_11	24/4/13 drew all d/t -30 CHAM W end to NWSE2 (WHM thick suspect) Non-geol line used v47, drew d/t -30 to NWSE3 v48; 20/5/13 drew all d/t -30 CHAM to E end v91,92 fault fixed; 4/6/13 edit MRB and WHM v155, fitted units to cutting at W7500 v156; 6/3/14 rechecked snap esp to Centreline and fault steps v233; 8/4/14 sl edits v291; 19/6 densified TY v339; 9/6/15 man dens WHM,RLD1,TILMP,SHHB nodes to aid calc v355
EWrung_12	23/4/13 drew all d/t -30 CHAM W end to NWSE2 v46; 30/4/13 drew all to NWSE3 v52; 17/5/13 drew d/t -30 CHAM to E end fit to NWSE4 v90 fault fixed; 4/6/13 added WMGR and mod units to it @W7700 v157;

Cross section name (prefixed with HS2_Area3_, suffixed _AJMB)	**Progress (March-Aug 2013, March-June 2014, June 2015 following QA and synthetic rendering check)**
	6/3/14 rechecked snap esp to Centreline and fault steps v233; 8/4/14 sl edits v291; 9/6/15 man dens WBRO, STAM nodes to aid calc v348
EWrung_13	30/4/13 drew all d/t -30 CHAM NWSE1-3 v53; 17/5/13 drew d/t -30 CHAM to E end fit to NWSE4 v89 faults fixed; 6/3/14 rechecked snap esp to Centreline and fault steps v233; 11/6/15 no action required
EWrung_14	23/4/13 some progress v46; 30/4/13 all d/t -30m CHAM+PNG NWSE1-2 v54, revised NE end of line into Area 3, some progress here, fit NWSE3 v55_1; 1/5/13 sl prog v57; 17/5/13 drew all d/t -30 CHAM to E end, faults fixed v88 faults fixed; 5/6/13 GFDMP0 added, MRB and WHM correlation thro bhs @ W1100-1300 requires mods to DiGMapGB V160; 6/3/14 rechecked snap esp to Centreline and fault steps, TILMP extndd, NON-GEOL added outside DTM v233; 12/5/14 added nodes to Lias fms & HEAD v296; 9/6/15 man dens WHL,RLD1,TY,SHHB nodes @F25 to aid calc v348; 11/6/15 cut MRB corrln lines at F24,25 and slit envs V360
NWSE_1	16/4/13 drew d/t -30 CHAM fr rung 11 to SP53NE5 v19; SE to rung 2 v43; NW to end all d/t -30 CHAM v46; 10/5/13 fitted to r2, SP52NE32 re-exam - not trusted - ignore! V64, all d/t -30 CHAM to SE end v65; 13/5/13 drw minor ALV - DRAWING + FITS COMPLETED v69; 21/5/13 faults fixed v98 no GOG; 7/6/13 check and snap all v189; 6/3/14 rechecked snap and fault steps v236; 3/4/14 densify v282; 8/4/14 sl edits v291; 12/5/14 added nodes to Lias fms v296; 11/6/15 cut HYSA, NS corrln lines at F26 and slit envs, F2,9,10 not done V360.
NWSE_2	10/4/13 drew from SP53NE165 NW thro rung8 fit d/t WHM, SP54SE2 missing, redrew XS thro v10; drew d/t WHM to rung 13 v11, end bh SP54NW23 is beyond fault in Area 4 - ignore; 11&12/4/13 drew SE d/t WHM to SP63SW1 v13; 15/4/13 drew d/t -30 CHAM from rung 3 to N end using CN figs 15, 19 v15; 8/5/13 fettled @ rung 2,3 v60; 13/5/13 drew minor HEAD DRWG + FITS COMPLETED v69 GOG used; 7/6/13 check and snap all v190; 17/6/13 WHL/BWL V203, GOG=RLD1+TY+SHHB+HYSA fix v205; 6/3/14 rechecked snap and fault steps v237; 1/4/14 densified HYSA NS WHM v277; 8/4/14 sl edits v291; 20/6 densified NS v340; MRB <6 m ok; 9/6/15 added ALV nodes 50m to aid calc v346; man dens WHL,NS nodes to aid calc v348; 11/6/15 cut TY,SHHB,HYSA corrln lines at F8 and slit envs V360
Centreline	10/6/13 drew from N end, all Lias done to S end, and shallow to rung6 v196; 11/6/13 added WMGR and MGR polys @ Rung5 & mod HEAD, added 23m fault w comments, all drawn and snapped to S end v199 GOG used; 17/6/13 GOG=RLD1+TY+SHHB+HYSA fix v205; 6/3/14 rechecked snap and fault steps v238; 8/4/14 sl edits v291; 19/6 densified RLD1, drew F32 displ 3m v337; 11/6/15 fixed ALV, RLD1, TY,HYSA, WHM,MRB,DYS corrln lines at F5 and slit envs V360

Cross section name (prefixed with HS2_Area3_, suffixed _AJMB)	**Progress (March-Aug 2013, March-June 2014, June 2015 following QA and synthetic rendering check)**
NWSE_3	18/4/13 drew d/t HYSA rung 4-5 v25, need to pick up WHM v/b at W10200 - redrew v27, drew d/t -30 CHAM rungs 4-8 v30; 19/4/13 thro rungs 9-11 d/t HYSA, d/t -30 CHAM in rung 9 v32, drew d/t -30 CHAM to rung 10 v37; drew all d/t -30 CHAM SE to r4, d/t -30 CHAM to r3 v46, drew all d/t -30 CHAM to r11 v49; 30/4/13 drew all d/t -30 CHAM to r14 v51; 1/5/13 drew d/t WHL to S end no fit CAIP NWSE4 v57; revised @ r3 and 2 (WHM thickn), refit r3 v62; 10/5 drew all d/t -30 CHAM to S end, GFDMP lenses in TILMP NO COLOUR V63; 13/5/13 added minor TUFA DRWG + FITS COMPLETED v70, refit WHM,MRB,DYS to r3 v72; 21/5/13 faults fixed v99; 22/5/13 mods v121 GOG used; 10/6/13 check and snap all & adj BWL WGR RLD1 TILMP1 TY SHHB v192; 17/6/13 FMB/BWC, WHL/BWL V203, GOG=RLD1+TY+SHHB+HYSA fix v206; 6/3/14 rechecked snap and fault steps v240; 7/4/14 edits v290; 8/4/14 sl edits v291; 16/5/14 sl edits to GOG fms v300; 19/6 densified TY v339; 9/6/15 added ALV nodes 50m to aid calc v346; 11/6/15 cut NS @ F27, RLD1,TY,HYSA,MRB @F7, RLD1,TY,SHHB,HYSA,MRB,DYS corrln lines at F1 and slit envs V360
NWSE_4	19/4/13 minor fit to r9 d/t WHM v33; 13/5/13 fitted to Area2 r16 d/t FMB all good, and Area3 rung1 d/t WHL, drew SDs,FMB, WHL thro rungs 2,3,4 v72; 14/5/13 GFDMP lens @ rung 4, 7 & 9, drew d/t -30 CHAM from S end to beyond rung 9 v73,74; 17/5/13 drew d/t -30 CHAM to N end v87; 31/5/13 HEAD mods V139. GOG used faults ok; 7/6/13 check and snap all v194; 17/6/13 FMB/BWC, WHL/BWL V203, GOG=RLD1+TY+SHHB+HYSA fix v208; 6/3/14 rechecked snap and fault steps v241; 8/4/14 sl edits v291; 22/5/14 densify nodes fr Helper_3 to rung10 d/t WHM v306; 11/6/15 NO ACTION
Cross-section_Buckingham_x1	21/5/13 checked XS but topo profile to DTM fit v poor in parts. Base GOG and Lias fms fit is mostly ok NWSE1 & 2, rungs 6,5,4,3,2,1 v98. NOT USED IN FINAL MODEL
Cross-section_Buckingham_x2	3/5/13 drew GOG,WHM,DYS,CHAM - good fit to rungs 3,4,5 v59. NOT USED IN FINAL MODEL
Helper_1	20/3/14 added, drew d/t WHM v248; 9/6/15 man dens TY,HYSA nodes to aid calc v348
Helper_2	20/3/14 added, slight edit to Fault 7, drew d/t WHM v248; 1/4/14 add PEAT, extnded NW to rung 8, add TUFA poly v271, TUFA under ALV v272; 9/6/15 man dens WHL nodes to aid calc v348
Helper_3	21/3/14 added, mod to TILMP1 env, added poly to GFDMP1, drew d/t WHM v249; 19/6 densified HYSA v339; 10/6/15 checked ok v348
Helper_4	21/3/14 added, mod to TILMP1 poly, drew d/t TILMP v250; mod GFDMP1, TILMP, HEAD, added MGR at Tingewick, drew all d/t WHM v251; 19/6 extndd N to Rung_9 drew d/t WHM v337; 9/6/15 man dens TILMP,WHM nodes to aid calc v348
Helper_5	24/3/14 added, mod TILMP1 in south, PET g-u, drew all d/t WHM incl GOG v255; 8/6/15 added nodes to aid calc v345; 10/6/15 man dens TILMP1 nodes to aid calc, added MGR @ Centreline, fixed GOG 'step' v349
Helper_6	24/3/14 added, added poly to GFDMP in south v252; drew all d/t WHM v254; 10/6/15 checked ok v349
Helper_GLACIGEN_7	24/3/14 added, drew all d/t CB v257; 10/6/15 checked ok v349
Helper_NS_8	24/3/14 added, drew all d/t CHAM v257; 10/6/15 man dens RLD1 nodes to aid calc v349

Cross section name (prefixed with HS2_Area3_, suffixed _AJMB)	**Progress (March-Aug 2013, March-June 2014, June 2015 following QA and synthetic rendering check)**
Helper_9	24/3/14 added, drew all d/t WHL v257; 10/6/15 checked ok v350
Helper_ALV_10	28/3/14 added, ALV drawn v264; 9/6/15 added ALV nodes 30m to aid calc v347; 10/6/15 checked ok v350
Helper_ALV_11	28/3/14 added, ALV drawn v264; 9/6/15 added LSGR nodes 25m to aid calc v346; 9/6/15 added ALV nodes 30m to aid calc v347; 10/6/15 checked ok v350
Helper_SD_12	31/3/14 added, drew d/t TILMP v266; 19/6/14 extndd W to Centreline, drawn d/t CB v336; 10/6/15 man dens CB,KLB nodes to aid calc v350
Helper_SD_13	31/3/14 added, drew d/t GFDMP v266; 19/6/14 extndd W to Centreline, drawn d/t CB, x-snapped v336; 10/6/15 man dens TILMP, nodes to aid calc v350
Helper_ALV_14	1/4/14 added, ALV drawn v272; 9/6/15 added ALV nodes 25m to aid calc v346; 10/6/15 checked ok v350
Helper_TUFA_15	1/4/14 added, TUFA drawn v272; extndd NE to NWSE3 drew all d/t WHM, snapped all v301; 10/6/15 checked ok v350
Helper_ALV_16	1/4/14 added, ALV drawn v272; 21/5/14 extnded west and ALV correlated v303; 9/6/15 added ALV nodes 30m to aid calc v347; 10/6/15 checked ok v350
Helper_ALV_17	1/4/14 added, ALV drawn v272; 9/6/15 added ALV nodes 30m to aid calc v347; 10/6/15 checked ok v350
Helper_WHM_18	1/4/14 added, drew all d/t WHM v274; 10/6/15 cut NS,MRB corrln lines at F25 and slit envs V350
Helper_WHM_19	1/4/14 added, drew all d/t WHM v274; 3/4/14 added NS v280; 10/6/15 man dens TY,HY nodes to aid calc and added MGR @ W4200 v351
Helper_NS_20	1/4/14 added, drew all d/t WHM v277; 2/4/14 extended SW to NWSE_1, did not add BLAD poly v279; 3/4/14 densify v282; 11/6/15 cut TY,SHHB,HYSA corrln lines at F8 and slit envs V356
Helper_F19_21	2/4/14 added, drew all d/t WHM v278; 11/6/15 cut HYSA,NS corrln lines at F19 and slit envs V351
Helper_NS_22	2/4/14 added, drew all d/t WHM v278; 20/6 densified MRB v340; 10/6/15 man dens SHHB,TY,RLD1 nodes to aid calc v352
Helper_NS_23	3/4/14 added, drew all d/t WHM v280; 10/6/15 checked ok v352
Helper_NS_24	3/4/14 added, drew all d/t WHM v280; 10/6/15 checked ok v352
Helper_NS_25	3/4/14 added, drew all d/t WHM v281; 10/6/15 checked ok v352
Helper_SD_26	4/4/14 added, drew HEAD ALV v283; 10/6/15 man dens HEAD nodes to aid calc v352
Helper_SD_27	4/4/14 added, drew HEAD GFDMP v283; extndd SE to ALV v300; 10/6/15 man dens GFDMP nodes to aid calc v352
Helper_SD_28	4/4/14 added, drew all d/t TILMP v284; 10/6/15 checked ok v352
Helper_WMGR_29	before 12/5/14 added, all d/t TILMP v 296; 10/6/15 man dens GFDMP nodes to aid calc v352
Helper_ALV_30	12/5/14 added, ALV drawn v296; 9/6/15 added ALV nodes 30m to aid calc v347; 10/6/15 checked ok v352
Helper_ALV_31	12/5/14 added, ALV drawn v296; 9/6/15 added ALV nodes 30m to aid calc v347; 10/6/15 checked ok v352
Helper_32	12/5/14 added, all drawn d/t CHAM v296; 10/6/15 added ALV,FMB nodes 30m to aid calc v352; 10/6/15 man dens SHHB,TY,RLD1,HYSA,NS nodes to aid calc v352

Cross section name (prefixed with HS2_Area3_, suffixed _AJMB)	**Progress (March-Aug 2013, March-June 2014, June 2015 following QA and synthetic rendering check)**
Helper_GOG_33	16/5/14 added, drew all d/t WHM, snapped to all v300; 21/5/14 extndd SE to rung 1 and correl all d/t WHM v305; 20/6 densified MRB v340; 8/6/15 added nodes to aid calc v345; 10/6/15 checked ok v352
Helper_HYSA_34	16/5/14 added, drew all d/t WHM v301; 10/6/15 man dens TY nodes to aid calc v352
Helper_HYSA_35	16/5/14 added, drew all d/t WHM snapped to all v302; 10/6/15 checked ok v352
Helper_WMGR_36	21/5/14 added and correl all d/t TILMP and cross-snapped to all v305; 10/6/15 man dens GFDMP nodes to aid calc v352
Helper_WMGR_37	21/5/14 added and correl all d/t TILMP and cross-snapped to all v305; 10/6/15 man dens WMGR nodes to aid calc v352
Helper_WMGR_38	21/5/14 added and correl all d/t TILMP and cross-snapped to all v305; 10/6/15 man dens WMGR nodes to aid calc v352
Helper_GFDMP_39	22/5/14 added and correl all d/t TILMP and cross-snapped to all v312; 10/6/15 checked ok v352
Helper_GFDMP_40	22/5/14 added and correl all d/t TILMP and cross-snapped to all v312; 27/5 added CB v320; 10/6/15 checked ok v352
Helper_NS_41	22/5/14 added and correl all d/t WHM and cross-snapped to all v313; 19/6 amended TY coverage v339; 10/6/15 NO ACTION, NEAR EDGE
Helper_NS_42	23/5/14 added and correl only HYSA and NS and cross-snapped to all v314; 10/6/15 checked ok v352
Helper_HYSA_43	23/5/14 added and correl all d/t NS and cross-snapped to all v315; 8/6/15 split NS line to aid calc at F19 v345, and HYSA & slit envs V352
Helper_TY_44	23/5/14 added and correl all d/t WHM and cross-snapped to all v315; 10/6/15 man dens TY nodes to aid calc v352
Helper_TY_45	23/5/14 added and correl all d/t GOG and cross-snapped to all v316; 19/6 densified WHL; 20/6 densified MRB v340; 10/6/15 man dens TY nodes to aid calc v352
Helper_TY_46	23/5/14 added and correl all d/t NS and cross-snapped to all v316; 10/6/15 checked ok v352
Helper_HYSA_47	27/5/14 added and correl all d/t MRB and cross-snapped to all v321; 10/6/15 checked ok v352
Helper_TY_48	27/5/14 added and correl all d/t WHM and cross-snapped to all v321; 20/6 densified MRB v340; 10/6/15 man dens RLD1 nodes to aid calc v352; 10/6/15 cut RLD1,GOG,TY corrln lines at F1 and slit envs V352
Helper_RLD1_49	27/5/14 added and correl all d/t WHM and cross-snapped to all v321; 19/6 extended SE, added MRB throughout, all densified; 10/6/15 cut RLD1,TY,HYSA,MRB corrln lines at F11,F12 and slit envs V353
Helper_FMB_50	27/5/14 added and correl all d/t FMB and cross-snapped to all v321; 10/6/15 checked ok v353
Helper_FMB_51	19/6/14 added and correl all d/t FMB and cross-snapped to all v336; extnd to CL added WHL densified v336; 10/6/15 man dens HEAD,GFDMP nodes to aid calc v353
Helper_RLD1_52	19/6/14 added and correl all d/t TY and cross-snapped to all v337; 10/6/15 checked ok v353
Helper_TY_53	19/6/14 added and correl all d/t TY and cross-snapped to all v338; 10/6/15 checked ok v353
Area_2_Rung_16_CAIP_trunc	23/6/14 added (from Area 2) and truncated to DTM v341
Helper_ALV_54	23/6/15 added v362
HS2_DOCKER_area2_to_area3	24/6/15 added v364

Abbreviations: adj – adjusted, calc – calculation, corrln – correlation, dens – densified, d/t – down to, man – manually, mod – modified/modification, XS – cross section, v – version, prov – provisionally, correl – correlated, extndd – extended, W[number] – distance along cross section in metres.

Appendix 2 Geological unit construction

NB: all coverages simplified to 5 m tolerance from v323 onwards.

Unit	GU created	Polys added. Major modifications
WMGR	31/5/13 v144	Drawn in rungs 2, 3, 8, 5, 13 v149, rung 12 v157, Centreline v199
MGR	31/5/13 v143	31/5-4/6/13 polys drawn in Rung1, Centreline v199, NWSE_4, EWrung_8, 4, 10 v156
WGR		4/6/13 new drawn at NWSE3, Rung11 v157
LSGR	3/6/13 V148	3/6/13 extended at EWrung 6 W2900 v149
ALV	1/5/13 v57	1/5/13 all v57. 3/6/13 joined polys and extended under LSGR at EWrung 6 W2900 and EWrung 7 v149
HEAD-XCZSV	31/5/13 v139	31/5/13 poly added part under MGR in EWrung 8 at W5080 from bh data v141.
PEAT	31/3/14 v266	31/3/14 v266
TUFA	31/5/13 v139	31/5/13 v139
GFDMP1	6/6/13 v179	6/6/13 partly constructed outcrop coverage v181
TILMP1	5/6/13 v160	6/6/13 edited with constructed lines v171
GFDMP	1/5/13 v57	4/4/14 V283
TILMP	1/5/13 v57	16/5/13 V80. 6/6/13 Widely extended beneath narrow ribbons of ALV or HEAD v182
GFDMP0	5/6/13 V159	10/6/13 v193
PET	24/3/14 v255	24/3/14 v255
KLB	20/5/13 v94	20/5/13 v94. 22/5/13 v114
CB	20/5/13 v94	20/5/13 v94. 22/5/13 v114
FMB-LSMD	16/5/13 V81	16/5/13 V81. 22/5/13 modded in Biddlesden area to match MGS 10k v115
BWC	16/5/13 V83	16/5/13 V83. 22/5/13 modded in Biddlesden area to match MGS 10k v115. 3/3/14 subsumed into FMB v225
BLAD	20/5/13 v95	20/5/13 1 poly v95
WHL-LMST	16/5/13 V80	16/5/13 V80 + some BLAD v94. 22/5/13 incl most BLAD v116
BWL	16/5/13 V81	3/3/14 subsumed into WHL v228
RLD1	16/5/13 V84	17/5/13 V85. GU subcrop modified to fit SP54SE/7 in EWrung 12; 12/6/15 added slit for F1 v360
TY	20/5/13 v91	20/5/13 v91, 22/5/13 v122; 12/6/15 added slit for F1, 7, 11, 12, v360
WBRO	17/5/13 V85	17/5/13 V85, 20/5/13 v106
SHHB	20/5/13 v94	20/5/13 v94, 30/5/13 v136; 12/6/15 added slit for F8 v360
RLD	20/5/13 v95	23/5/13 v125
STAM	17/5/13 V85	17/5/13 V85, 20/5/13 v107
HYSA	17/5/13 V90	17/5/13 V90, 23/5/13 v130; 12/6/15 added slit for F11, 8, 1, 7, 12, 26 v360
GOG	14/6/13 v201	12/6/15 added slit for unnamed fault v360
NS	17/5/13 V86	24/5/13 v133, 135; 8/6/15 added split for F19 v344; 12/6/15 added slit for F25, 26, 27 v360
WHM	20/5/13 v95	5/6/13 outcrop coverage mod at Rung 14 v160; 12/6/15 added slit for F5 v360
MRB	21/5/13 V111	5/6/13 outcrop coverage mod at Rung 14 v160; 12/6/15 added slits for F1, 5, 6, 24, 25, v360
DYS	22/5/13 V112	22/5/13 V113; 12/6/15 added slit for F1, 5 v360
CHAM	22/5/13 V113	22/5/13 V114
WLI		11/6/13 decided not to make coverage
PNG		11/6/13 decided not to make coverage

References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://geolib.bgs.ac.uk.

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