Ground Related Risk to Transportation Infrastructure

SUB-SURFACE RISKS FOR THE CONSTRUCTION OF HS2 IN MID-CHESHIRE

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Hazards Beneath Mid-Cheshire
Tree assessed as being almost on the HS2 centre line

Field was level in 1990

Cause – Salt dissolution at rockhead 50 to 80 m depth?
The Route & Risk

This section of HS2:

• Complicated geological conditions
• Salt subsidence
• Major infrastructure below ground

This length of HS2 has the highest ground risk (higher than tunnels & Camden deep excavations)
THE 2013 ROUTE
THE 2013 ROUTE

- Crewe
- Winsford
- Middlewich
- Northwich
- Knutsford

- 2 Rail Crossings
- 9 River/Canal crossings
- 10 Road Crossings
- Cuttings up to 11 m deep
- Embankments up to 18 m high
- 1.9 km viaducts up to 18 m high
THE NOV 2016 ROUTE

- 2 Rail Crossings
- 11 River/Canal crossings
- 10 Road Crossings & re-route
- 2.3 km of dual carriageway
- Cuttings - NONE
- Embankments up to 26 m high
- 3.1 km viaducts up to 26 m high
Talk in three parts:

- Geology
- Natural Risks
- Anthropogenic Risks
DRIFT GEOLOGY

From BGS Map Sheets 97, 98, 109 & 110 Reproduced under licence C08/053-CSL
BEDROCK GEOLOGY - Triassic

Formerly Keuper Mudstone
Cheshire - Lower Keuper Saliferous Beds

Mercia Mudstone (2008) -
• Blue Anchor Formation
• Branscombe Mudstone Formation
• Arden Sandstone Formation
• Sidmemouth Mudstone Formation
• Tarporley Siltstone Formation
BEDROCK GEOLOGY

Lower part of the Mercia Mudstone Group

Sidmouth Mudstone Formation (1.3 km thick):

In the Cheshire Basin it supersedes the former:

Wilkesley Halite Member - Upper Keuper Saliferous Beds
Byley Mudstone Member - Middle Keuper Marl
Wych Mudstone Member - Lower part of Middle Keuper Marl
Northwich Halite Member - Lower Keuper Saliferous Beds
Bollin Mudstone Member - Lower Keuper Marl, lower mudstone
From BGS Map Sheets 97, 98, 109 & 110 Reproduced under licence C08/053-CSL
1. The main salt bed in this area is the Northwich Halite Member
2. The Northwich Halite Member is 200 to 285 m thick, and is thicker in east Cheshire than west.
3. Overall it is composed of 75% salt, 25% marl.
4. There are individual thick beds of salt which are more than 95 % rock salt and also beds which are nearly all marl.
5. The principal mined units (both current and historic) are separated by marl beds.
SALT KARST

Wet & Dry Rockhead

Figure 15  Diagram showing the relationship of 'Wet' and 'Dry' rockhead to the subcrop of the Northwich Halite

GROUND AFFECTED BY NATURAL SALT SUBSIDENCE
GROUND AFFECTED BY NATURAL SALT SUBSIDENCE

Areas mapped as being underlain by the Northwich Halite with “wet rockhead”

49% of 2013 route, 54% of 2016 route

Groundwater flowing at rockhead in depressions – slow dissolution

Groundwater flow is not uniform, preferential pathways – depressions.

Ground in areas of “wet rockhead” often appear stable for long periods.
GROUND AFFECTED BY NATURAL SALT SUBSIDENCE

Voids at “wet rockhead”
Voids can migrate upwards and then choke
Voids can be stable for 1,000s of years.

Schematic of subsidence feature
GROUND AFFECTED BY NATURAL SALT SUBSIDENCE

Viaducts over “wet rockhead”
Very long piles – Down Drag
Very difficult to construct

Schematic of subsidence feature
GROUND AFFECTED BY NATURAL SALT SUBSIDENCE

Numerous small ponds present
GROUND AFFECTED BY SALT SUBSIDENCE

HS2 2013 ROUTE

Lakes Caused by salt Subsidence

Lake Caused by salt Subsidence
Numerous small ponds present

Formed by:
- Glacial – kettle holes
- Excavations by farmers
- Salt subsidence
- Subsidence in drift
but part of HS2 in settlement bowl of Holford Brine Caverns & close to high risk caverns.

but there are subsidence features in this ground purportedly to be due to “uneven drainage and consolidation of heterogeneous drift deposits was the most likely cause for the observed surface subsidence effects.”

GROUND NOT AFFECTED BY SALT SUBSIDENCE

Pond not on 2004 OS Maps on centreline of HS2 2013 route

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GROUND NOT AFFECTED BY SALT SUBSIDENCE

Steep sided. Crown Hole?
From a HS2 report on another pond which formed about 1 km from here indicates subsidence feature due to:

“uneven drainage and consolidation of heterogeneous drift deposits was the most likely cause for the observed surface subsidence effects.”

This unusual mechanism could affect large lengths
Effects – Brine Pumping Induced

Reproduced from http://cheshireimagebank.org.uk/
Railway Lines North of Crewe...HS2 !!
ANTHROPOGENIC EFFECTS

Wild brine pumping
Conventional mining
Solution mining
Gas storage caverns
Oil storage caverns - storing UK strategic oil reserves (currently being decommissioned)
Wild Brine Pumping – Large Voids

Reproduced from http://cheshireimagebank.org.uk/
Approximate alignment and height of HS2 tracks

Trent and Mersey Canal

Billinge Flash
270 m long viaduct required from Ch 21+550 to 21+850.

Base plan from HS2 Design Stage Post-Consultation Preferred Route HSM10B Plan and Profile Spread Sheet 4 of 6.
WHATCROFT LANE BRIDGE

Original base of bridge deck

©TerraConsult Ltd
Fillet of brickwork to correct further differential settlement during construction.

Fillet of brickwork to correct differential settlement as abutment raising commenced.

Original base of bridge deck.

WHATCROFT LANE BRIDGE
WHATCROFT LANE BRIDGE

Original base of bridge deck

Later level of bridge deck

825 mm

2,700 mm

1,875 mm

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CONVENTIONAL MINING
WINSFORD SALT MINE
CONVENTIONAL MINING  
WINSFORD SALT MINE

Located to the northeast of Winsford
Owned & operated by Compass Minerals Ltd.
Salt mining began at Winsford 173 years ago.
An extensive network of caverns typically 140 to 220 m below ground but at about 75 depth in north.
Room and pillar mining:
• Caverns up to 20 m wide and 8 m high,
• Solid pillars of salt up to 24 m square.
• 68 to 75% extraction ratio.

NOW MINED AT TWO LEVELS
Room & Pillar Extraction Ratio Much Lower Than Historic

This is a 4 m initial cut
WINSFORD SALT MINE

Mining

Document Storage

Hazardous Waste Landfill

©Compass Minerals
Area in red with planning permission to mine one salt horizon

Area in green with planning permission to mine two salt horizons

The Stanthorne Area

160 m long viaduct over Puddinglake Brook, Whatcroft Lane & Trent and Mersey Canal

Hazardous Waste Landfill in Mine

1160 m long viaduct over River Dane flood plain & Trent and Mersey Canal
ANTHROPOGENIC EFFECTS

Areas of “Dry Rockhead”

Solution Mining – Holford Brinefield
– Feedstock for Chemical Industry

Gas Storage Caverns

Need Cover of Byley & Wych Mudstones
Salt Subsidence Crown Holes

PREASSALL, Nr FLEETWOOD

Extraction 1890 to 1992

1891 to 1933: 7 No crown holes
1961: New crown hole
2011: Blow out failure
Holford Brinefield 2013 route

1.5 km of brinefield

Intersected 14 brine cavities
Holford Brinefield

Geology:
- 20 m drift over Byley and Wych Mudstones.
- Solution Mine in the underlying Northwich Halite
- Shallowest cavern crown at 50 m depth.
Holford Brinefield

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Some cavities are known to have coalesced.
Pressurised to reduce creep of Halite.
Cavities 170 m dia, as little as 30 m apart or less!
A556 RE-ALIGNMENT

Approximate location of three solution cavities thought to have coalesced into one cavity

Holford Brinefield

Two solution cavities not in use - ethylene waste storage

Brinefield Extension

Active chemical slurry settlement lagoons

2.3 km of joint embankment
9.5 to 18.6 m high
Complex joint road & rail structures
Services

King Street Energy
GAS STORAGE FACILITIES

2013 & 2016 routes avoid the EDF gas storage facility Wramingham between Crewe & Middlewich

Three facilities southwest of Northwich:

• Byley Gas Storage,
• Holford Gas Storage Facility (E.ON)
• Stublach Gas Storage Project (Storengy)

Crossed by 2013 route

King Street Energy - planning permission for a field of nine gas storage caverns crossed by the 2013 HS2 alignment – three caverns affected
GAS STORAGE FACILITIES

UK Government classifies the gas storage facilities as “nationally strategic.”

COMAH regulated
(Control of Major Accident Hazards)

The 2016 route also avoids the gas storage caverns but it crosses the surface facilities for the planned King Street Energy Storage Facility.
2016 ROUTE & RISK

The net result of the proposed changes increased the risk profile outside the solution mined area:

• Increase over higher risk wet rockhead (1,080m increase, +11%).

• Elimination of all cuttings – thus removing the possibility of re-using excavated soil as fill.

• More Embankment fill – + 3.5 M m³

• Embankments higher – 18 m max increased to 26 m

• Longer Embankments – length + 42%

• More embankment on wet rockhead – + 81 %
2016 ROUTE & VIADUCTS

Viaducts are now:

• Higher (26 m) - increasing costs due to both the increased structural above ground costs and the larger foundations required to support the increased loads.

• Longer - 1.9 km more (120% increase) - hence the cost of the route increases of which nearly all (1.8km) is an increase in viaduct length over the higher risk wet rockhead.

• Differential settlement - With higher embankments & viaducts the potential for differential settlement between the embankment & the viaduct increases.
HS2 2013 – 33% cuttings
HS2 2016 – none

HS2 changed the design philosophy due to assessed risk from subsidence caused from drainage of water in areas of wet rockhead.
DRAINAGE

Still need to manage drainage from structures which are now larger.

Dr Tony Waltham – “95 % of all subsidence collapses are the result of engineering structures interfering with natural drainage.”

54 % of route with wet rockhead needs careful design and management of drainage to prevent the HS2 structures reinvigorating existing subsidence features and creating new areas of subsidence.
GLOBAL WARMING

Well known effects on embankment slopes.

Main issue groundwater & increased subsidence:
- BGS has liked major storms December 2013 to January 2014 to increased subsidence.
- Climate change more & bigger storms.
- More subsidence in areas of wet rockhead.
Global Warming – Subsidence rate increasing
CONCLUSION

This 20.1 km section of HS2 Phase 2B route passes through ground which is technically challenging for the construction of a high speed rail link.
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This 20.1 km section of HS2 Phase 2B route passes through ground which is technically challenging for the construction of a high speed rail link.

All of the engineering difficulties can be overcome but this section will cost significantly more per km than a comparable section of HS2 which also passes through rural countryside which does not have such challenging ground engineering conditions.
The 2016 Route & Risk

It can be built to produce a safe railway by:

- Site Investigation
- Design
- Construction
- Monitoring & Maintenance
The 2016 Route & Risk

It can be built to produce a safe railway by:

• Site Investigation
• Design
• Construction
• Monitoring & maintenance
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<td>Colchester, Essex</td>
</tr>
<tr>
<td>WA9 4TX</td>
<td>CO3 0UL</td>
</tr>
<tr>
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</tbody>
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