OR/19/052 Geological and hydrogeological context

Kingdon, A, Fellgett, M W, and Spence, M J. 2019. UKGEOS Cheshire Energy Research Field Site - Science infrastructure. *British Geological Survey Internal Report*, OR/19/052. *Contributors:* Midgley, J, Elsome, J W, Dearden, R A, Chapman, C, Burke, S P, Hough, E, Luckett, R R, and Bianchi, M.

Site location

Current Land Use and Made ground

Much of the area is artificially drained reclaimed land, close to the River Mersey and the Manchester Ship Canal. The area is flat, much of it is only slightly above sea-level, less 10 metres OD), reaching around 26 mOD in the Ince–Elton area.

The area includes large areas of present and historic industrial development, agriculture, transport infrastructure, urbanisation and residential development. Potential sources of anthropogenic groundwater contamination include the Stanlow oil refinery and historic landfill sites (neither of these will be sampled directly by CERFS drilling).

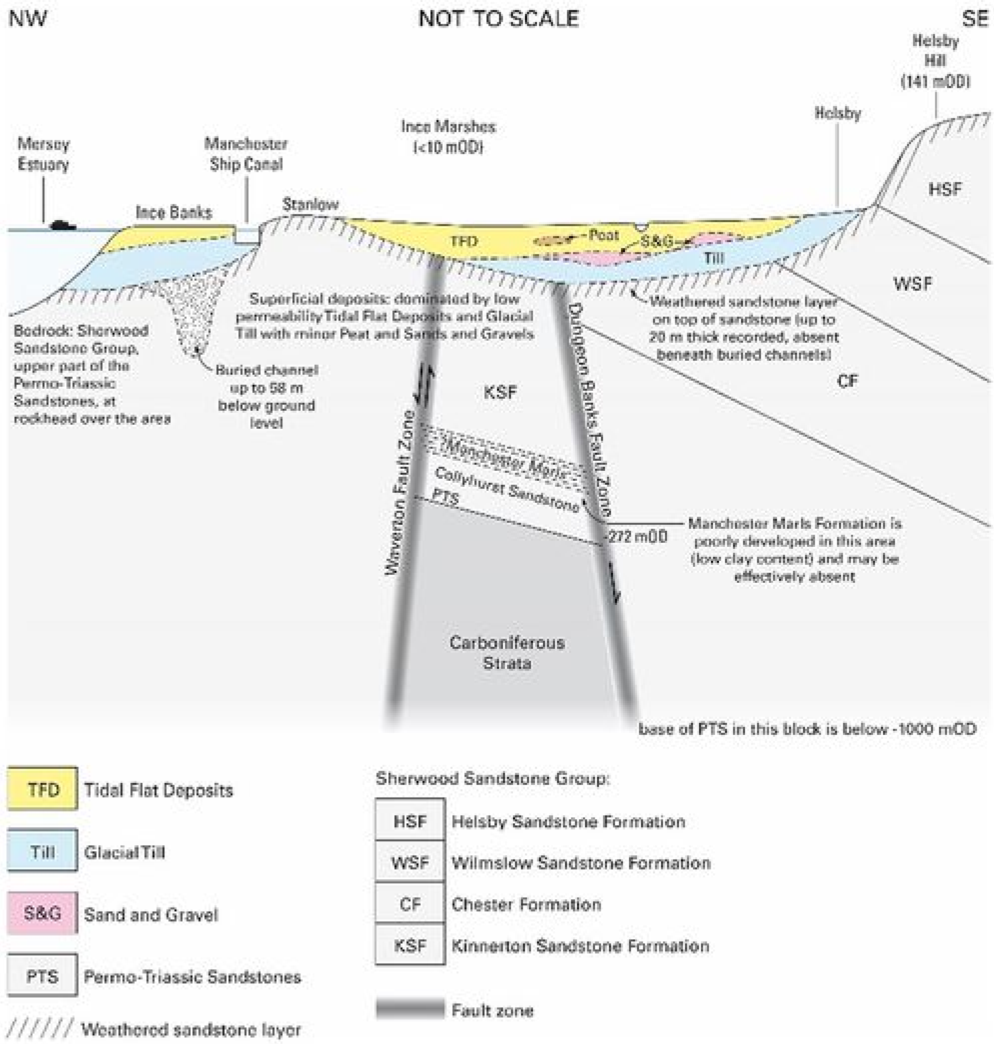

Figure 4 A diagrammatic cross-section of the geology of the Ince Marshes area including, anthropogenic, superficial, and bedrock geology.

Quaternary geology

The research site is located on estuarine marshes and tidal flats on the southern bank of the Mersey estuary. It is covered by Quaternary-age superficial deposits of variable thickness up to 60 metres deep, although these are absent beneath parts of Ince and Elton. The upper surface of the bedrock was deeply incised during the Quaternary, with thicker accumulations of alluvium deposits infilling a series of broadly north-trending buried channels. These follow the modern north-flowing tributaries of the River Mersey — the River Gowy and Mill Brook to the west and the Hornsmill/ Peckmill Brook to the east. The extent at depth of these channels is very difficult to prove without drilling as they are hard or impossible to distinguish using surface geophysical techniques. The Quaternary sequence typically comprises unconsolidated sand, silt and clay and may include lenses of peat or organic-rich muds. Peat and blown sand are also present.

The Quaternary deposits overlie a complex sequence of glacial deposits principally comprising till (boulder clay), with lenses of glacio-fluvial sand and gravel and glacio-lacustrine clay. The glacial deposits are complex, varying laterally and vertically across short distances, making geological interpretation difficult in areas where borehole data are sparse or absent.

Permo-Triassic sandstones are present at rockhead over most of the area, with a thick, weathered zone reaching a maximum thickness of at least 20 metres.

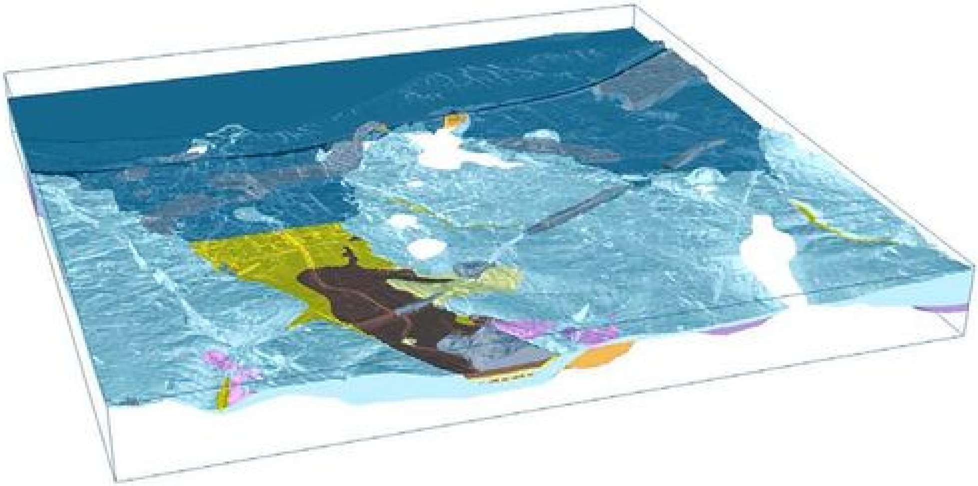

Figure 5 Lithoframe viewer model of the Quaternary deposits in the area around Ince Marshes.

Further information is available in Burke et al (2016)[1]; Lee and Hough (2017)[2] and the BGS Quaternary 3D model.

Hydrogeology of the superficial deposits

The variable composition and thickness of the Quaternary superficial deposits affects the hydrogeological regime, with low permeability tidal-flats and glacial till dominating because of their lateral extent. These deposits are expected to be saturated within a few metres of the ground surface, with the water level being strongly influenced by human induced drainage. More permeable deposits, such as glaciofluvial sands and gravels, tend to be present in lenses of limited lateral extent and surrounded by lower-permeability deposits, which limit recharge or discharge. Therefore natural groundwater flow will be minimal within the superficial deposits, with the exception of buried channels. Buried channels are up to tens of metres deep and occasionally up to hundreds of metres wide, infilled with glacial deposits comprising mainly sands, gravels, clays and silts. Depending on the composition of the infill, these may influence groundwater flow in the area.

Bedrock and structural setting

The Cheshire Energy Research Field Site is located on the northern margin of the Cheshire Basin. Made ground and a variable thickness of Quaternary deposits unconformably overlay faulted Permo-Triassic sandstone bedrock, which varies in thickness from approximately 250 metres to over 1000 metres. This comprises the Triassic Sherwood Sandstone Group, which is underlain in some locations by the Permian Collyhurst Sandstone Formation and/or the Manchester Marl Formation. Below the Permo-Triassic succession are older Carboniferous strata, with deep boreholes proving sedimentary rocks of the Warwickshire Group, Coal Measures, Millstone Grit and Craven Group at depth.

Analysis of 2D seismic-reflection data indicates that the bedrock structure is characterised by a north-trending horst block that is 1–2 kilometres wide in the Thornton area (Figure 6). The horst is defined by the Waverton fault zone to the west, and the Dungeon Banks fault zone to the east. Evidence from deep boreholes sunk for hydrocarbon exploration gives information on bedrock stratigraphy in the area. The Ince Marshes 1 borehole proves the succession on the horst, while the succession in the graben to the east is proved by the Kemira 1 borehole (Table 1).

Table 1 Stratigraphic depths on the horst and eastern graben.

Stratigraphy (depths quoted in metres to base of unit)	Bedrock geology: horst, as proved by the Ince Marshes 1 borehole	Bedrock geology: eastern graben, as proved by the Kemira 1 borehole
Permo-Triassic	272	1042
Carboniferous Warwickshire Group	331	1221
Carboniferous Pennine Coal Measures Group	945	1438 (terminal depth)
Carboniferous Millstone Grit Group	1577 (terminal depth)	Not proved

Sherwood Sandstone Geology

The Sherwood Sandstone Group typically comprises red and grey fine- to medium-grained sandstone with rare pebbles. Deformation bands (zones of grain-size reduction formed in response to stress) are developed locally. The upper part of the bedrock has locally been weathered to an uncemented sand and gravel to a depth of 10–20 metres. Further information is available from Hannis and Gent (2017)[3] and Fellgett et al. (2017)[4].

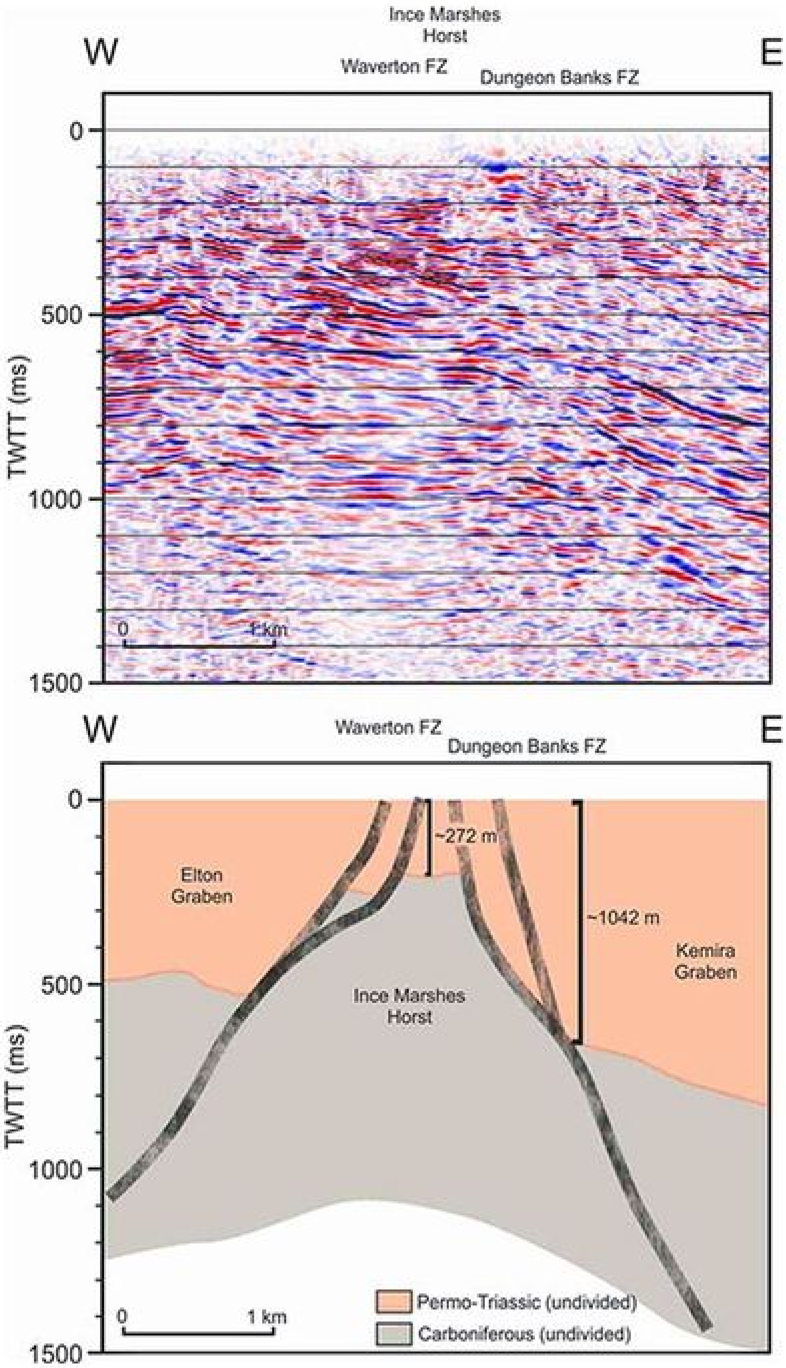

Figure 6 General structure of the Ince Marshes area, based on interpretation of seismic-reflection line SC-83-128V, illustrating the Ince Marshes horst structure defined by the Waverton fault zone to the west and Dungeon Banks fault zone to the east. FZ = fault zone. (Seismic data courtesy of UKOGL).

Hydrogeology of the bedrock

The Sherwood Sandstone Group is a principal aquifer. Groundwater abstraction is important in this region for public water supply, for example at Plemstall 5 kilometres south of Elton, and also industry and agriculture. A key feature of this aquifer is slow response to change, with observation wells showing a damped response to recharge and abstraction. Groundwater levels have been modified over time by large abstractions.

The Permo-Triassic sandstones have moderate matrix permeability with fractures providing secondary permeability. The hydraulic conductivity is highly anisotropic, with considerably higher horizontal hydraulic conductivity than vertical, due mainly to the presence of marl horizons within the sandstones. Bulk permeability declines with increasing depth and salinity increases; thus the effective aquifer is considered to be about 200 metres thick. The aquifer has high storativity, which accounts for its slow response to perturbations (e.g. abstraction) compared to other UK aquifers.

The regional groundwater head gradient suggests flow in a west to north-west direction from the main recharge area in the east (the higher ground of the Mid-Cheshire Ridge) towards Ince Marshes and the Mersey Estuary. Faulting can affect the Permo-Triassic sandstone aquifer and groundwater flow in a range of ways, with faults sometimes acting as barriers to flow, or having a high permeability forming a preferential flow path. These are documented regionally, but the behaviour of the groundwater flow in the vicinity of the faults near the proposed site is not known.

The Sherwood Sandstone aquifer is mostly confined by low-permeability superficial deposits and the piezometric surface is above the top of the sandstone but below ground level. The hydraulic gradient is very low, and groundwater flow is expected to be very slow. A schematic cross section from the area is shown in Figure 7.

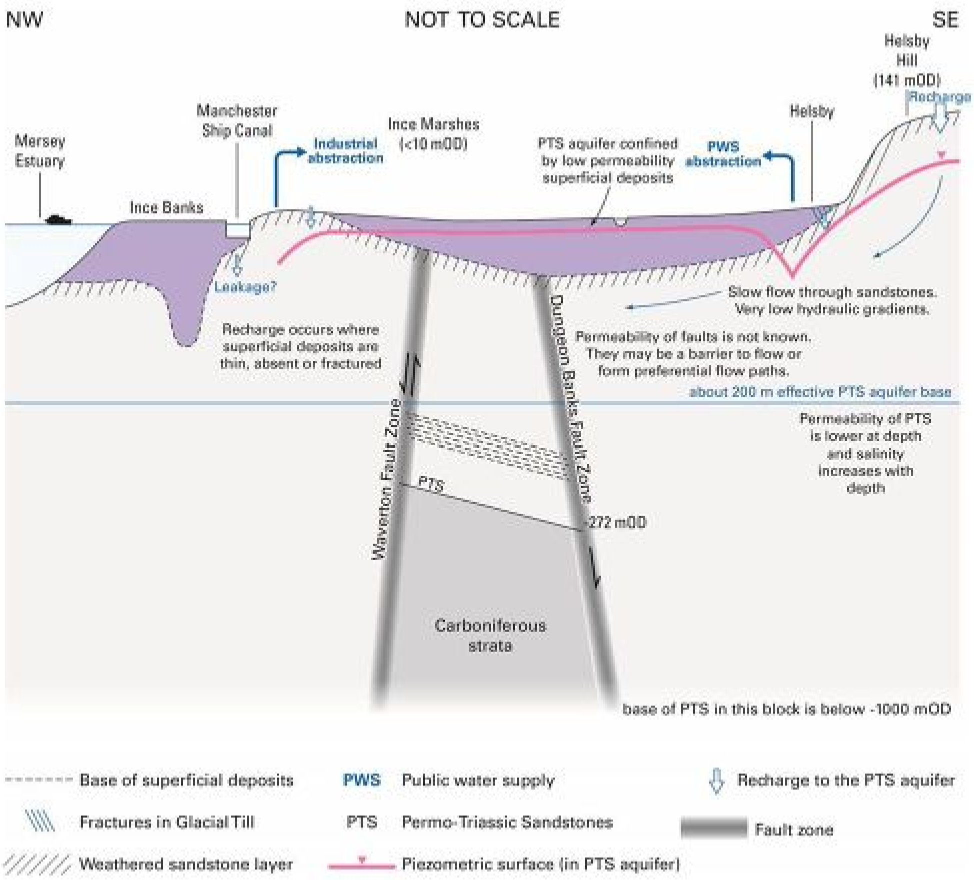

Figure 7 Schematic cross-section identifying key hydrogeological features of the Permo-Triassic sandstone aquifer in the Ince Marshes area.

Hydrochemistry

The natural hydrochemistry of the Sherwood Sandstone aquifer, where measured, is dominated by natural salts, and gives an insight into geological processes.

The Sherwood Sandstone aquifer regionally has zoned salinity; saline palaeo-waters are found at depth with fresh waters at the surface. Saline palaeo-waters are thought to result from halite dissolution and ponding of the resulting saline water during an interglacial (55 000 to 50 000 years ago). The saline water was then pushed to depth due to sea-level fall and refreezing of the ground.

Past and present land use have had considerable effects on the groundwater chemistry. Inundation by abstraction-related marine salinity is seen close to the Mersey Estuary within the upper aquifer, especially around the Stanlow oil refinery. A similar zonation is expected for the redox conditions of the aquifer and associated redox-sensitive hydrochemical parameters. Waters close to the surface are found to be oxic, with low concentrations of dissolved redox-sensitive ions such as iron and manganese, however, deeper groundwaters are reducing with high iron and manganese. The depth of the zones will be variable within the different areas. Faulting will affect zonation with low-permeability faults restricting water movement; this may result in saline palaeo-waters being trapped within faulted blocks.

The historical and recent industrial activity in the area is a significant source of contamination of groundwater in the made ground, superficial deposits and the sandstone. Historical landfill sites used by industry including the refinery and the former Ince power station were often unlined and represent possible point sources of contamination. Run-off and effluent from historical industrial activity along the Mersey's banks flowed into the Mersey Estuary and the Manchester Ship Canal. Although the water quality within the estuary and canal's surface waters has improved, their sediments are still highly contaminated and are a potential source of contamination of surface water and groundwaters, especially where dredged material has been deposited locally on the land surface.

Nitrate contamination is also a widespread issue within the Permo-Triassic sandstone aquifer. This is believed to be mostly agricultural in origin but leaking sewers may also contribute.

For more information on the hydrochemistry of the area see Griffiths et al, 2002[5].

References

1. ↑ Burke, H F, Gow, H V, Cripps, C, Thorpe, S, Hough, E, Hughes, L, and Horabin, C G. 2016. The 3D Quaternary geology of the area around Thornton, Cheshire. *British Geological Survey report OR/16/056*, 25pp.
2. ↑ Lee, J R, and Hough, E. 2017. A conceptual geological model for investigating shallow subsurface geology, Thornton-le-Moors, Cheshire. *British Geological Survey report OR/17/042*, 43pp.
3. ↑ Hannis, S, and Gent, C. 2017. Petrophysical interpretation of selected wells near Liverpool for the UK Geoenergy Observatories project. *British Geological Survey report OR/17/037*, 44pp
4. ↑ Fellgett, M W, Kingdon, A, Williams, J D O, and Gent, C M A. 2017. State of stress across UK Regions. *British Geological Survey report OR/17/048*, 60pp.
5. ↑ Griffiths, K, Shand, P, and Ingram, J. 2002. Baseline report series. 2, the Permo-Triassic sandstones of west Cheshire and the Wirral Environment Agency, 52pp. (CR/02/109N)

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