

Report on geophysical logging and core description from five new Thames Water boreholes in the Chalk Group along the River Kennet, Marlborough, Wiltshire

ECAR Programme

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Report on geophysical logging and core description from five new Thames Water boreholes in the Chalk Group along the River Kennet, Marlborough, Wiltshire

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1 Introduction

This report provides a summary of borehole geophysical logging operations from five new Thames Water boreholes in the Chalk Group along the River Kennet between East Kennet and Marlborough, Wiltshire (Figure 1).

Borehole drilling (carried out by Soil Engineering Ltd) and geophysical logging (undertaken by BGS) took place during May and June, 2021. One of the boreholes (Marlborough STW) was cored and reached a maximum depth of 100.45 m. The other boreholes ranged from 40-47 m deep (Table 1).

The boreholes were drilled for research purposes to investigate the impact of Chalk stratigraphy on groundwater behaviour beneath this western part of the River Kennet, which is subject to highly variable flow. The coring and geophysical logging were an integral part of the borehole installation, guiding the drilling toward a target depth just beneath the Melbourn Rock.

The main purpose of this report is to provide Thames Water with a summary of work undertaken, some results and interpretative observations and an index of associated files and documents.

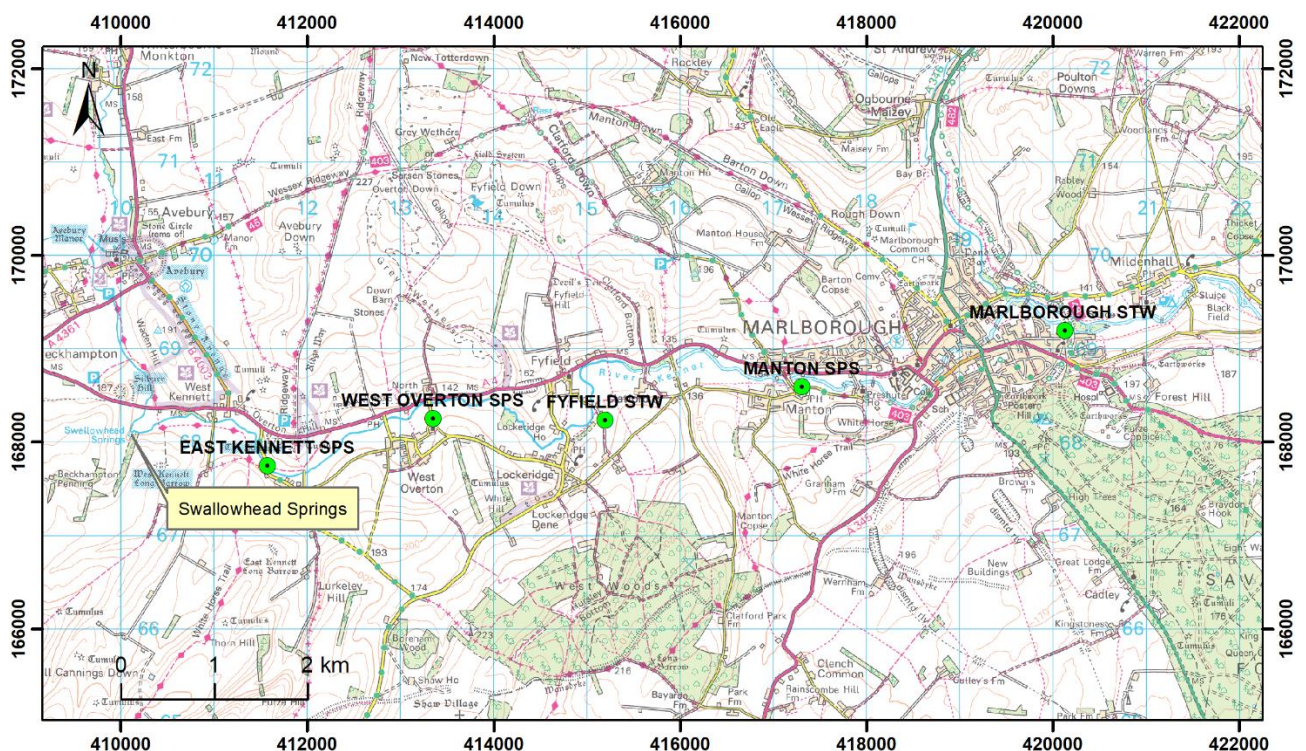


Figure 1 Location map showing the position of the five new boreholes at East Kennet, West Overton, Fyfield, Manton and Marlborough. The position of the Swallowhead Springs on the River Kennet is shown. Contains Ordnance Survey data © Crown Copyright and database rights [2022]. Ordnance Survey Licence no. 100021290.

Table 1 Borehole locations and total depths

Borehole	Surveyed Easting (m)	Surveyed Northing (m)	Surveyed Ground Elevation (mAOD)	Logging Datum (mAGL)	Logging Datum (mAOD)	Borehole depth (m)
MARLBOROUGH STW	420126.76	169193.78	126.44	1.12	127.56	100.45
MANTON SPS	417305.05	168592.54	130.38	0.30	130.68	43.45
FYFIELD STW	415193.57	168232.97	140.54	0.30	140.84	47.00
WEST OVERTON SPS	413350.51	168254.59	143.18	0.30	143.48	40.00
EAST KENNETT SPS	411574.27	167747.76	145.09	0.30	145.39	40.00

2 Index of associated files and documents

In addition to this report there are eight PDF enclosures (Table 2). Detailed notes on the Marlborough STW core are provided in Appendix 1.

Enclosure	Name	Description
Enclosure 1	Manton_log_compilation.pdf	Combined geophysics
Enclosure 2	Marlborough_STW_log_compilation.pdf	Combined geophysics
Enclosure 3	West_Overton_log_compilation.pdf	Combined geophysics
Enclosure 4	East_Kennet_PS_log_compilation.pdf	Combined geophysics
Enclosure 5	Fyfield_log_compilation.pdf	Combined geophysics
Enclosure 6	Marlborough_STW_core_log.pdf	Core log
Enclosure 7	Marlborough_STW_geophysics_and_core_log.pdf	Core/geophysical log
Enclosure 8	Borehole_Compilation_Chalk_Stratigraphy.pdf	Log stratigraphy
Enclosure 9	Marlborough_STW_core_log_and_stratigraphic_guide.pdf	Stratigraphic guide

Table 2 List of files accompanying this report

3 Geological setting

The boreholes were drilled in the Chalk Group of the North Wessex (or Marlborough) Downs. Four of the boreholes started in New Pit Chalk Formation with the easternmost Marlborough STW borehole starting in Lewis Nodular Chalk Formation. None of the boreholes reached the base of the Chalk Group, the deepest (Marlborough STW) reaching the West Melbury Marly Chalk, the lowest formation in the Grey Chalk Subgroup (Figure 3).

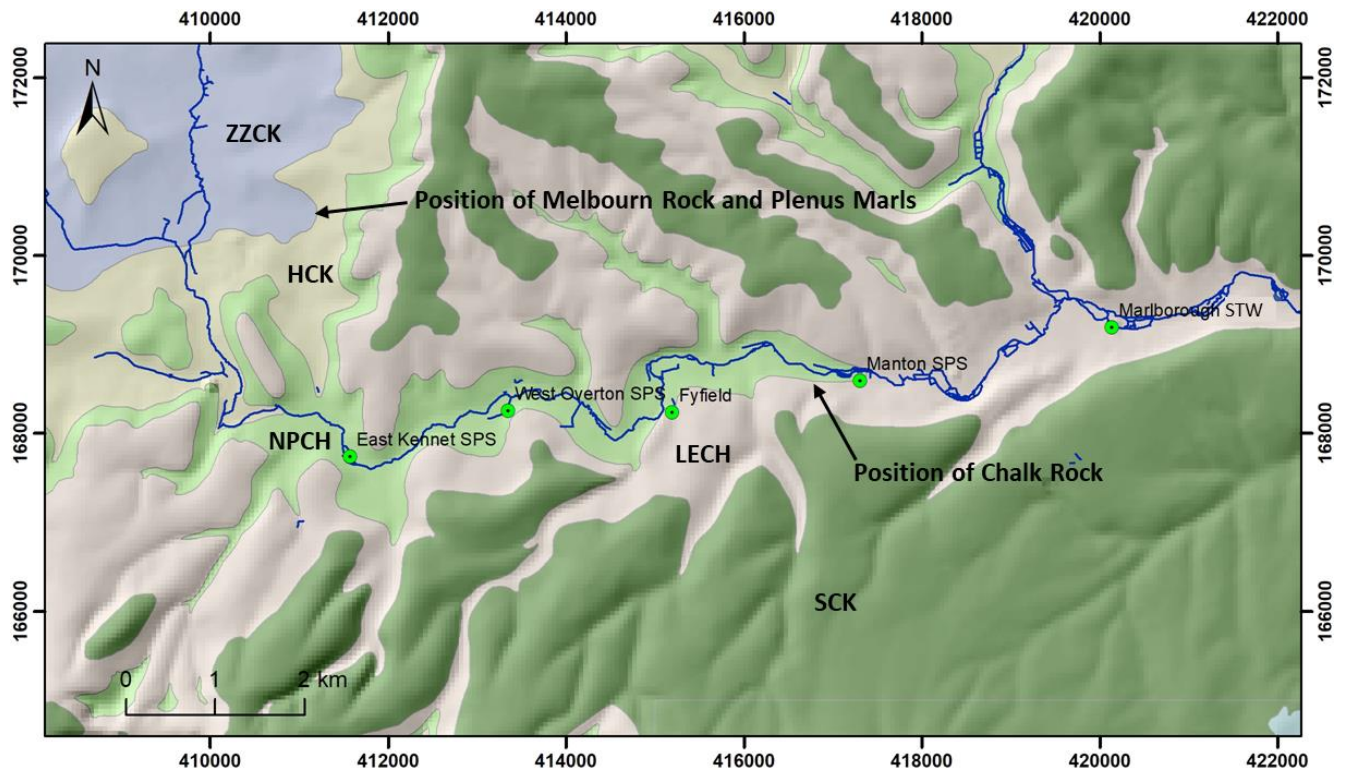


Figure 2 Bedrock geology in the area of the boreholes (ZZCK=Zig Zag Chalk Formation, NPCH=New Pit Chalk Formation; LECH=Lewes Nodular Chalk Formation; SCK=Seaford Chalk Formation. Geological mapping from BGS Geology 50K (DigMapGB-50).

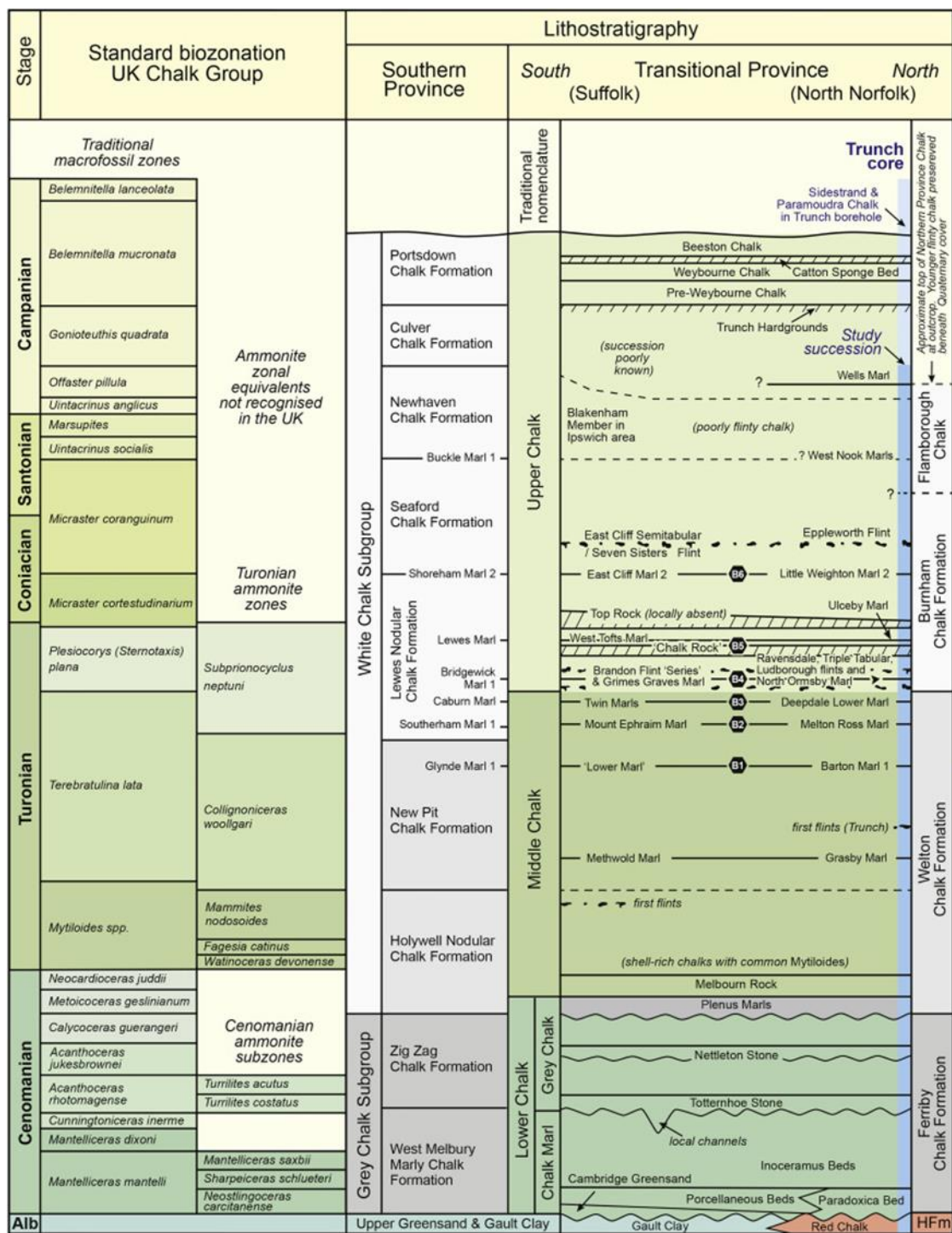


Figure 3 Chalk stratigraphy of England with thick blue arrow showing the approximate stratigraphic range covered by the new boreholes. The Marlborough Downs are within the Southern Chalk Province.

The emphasis of this project is on Chalk stratigraphy and hydrogeology but a thin and discontinuous cover of superficial deposits overlies the Chalk Group (Figure 4). Plateau areas are covered in Clay-with-flints (remnant Palaeogene deposits), particularly in the area to the south of Marlborough. The Kennet Valley has a thin infill of alluvium. Minor dry valleys and hillslopes are locally covered by head (mass movement deposits).

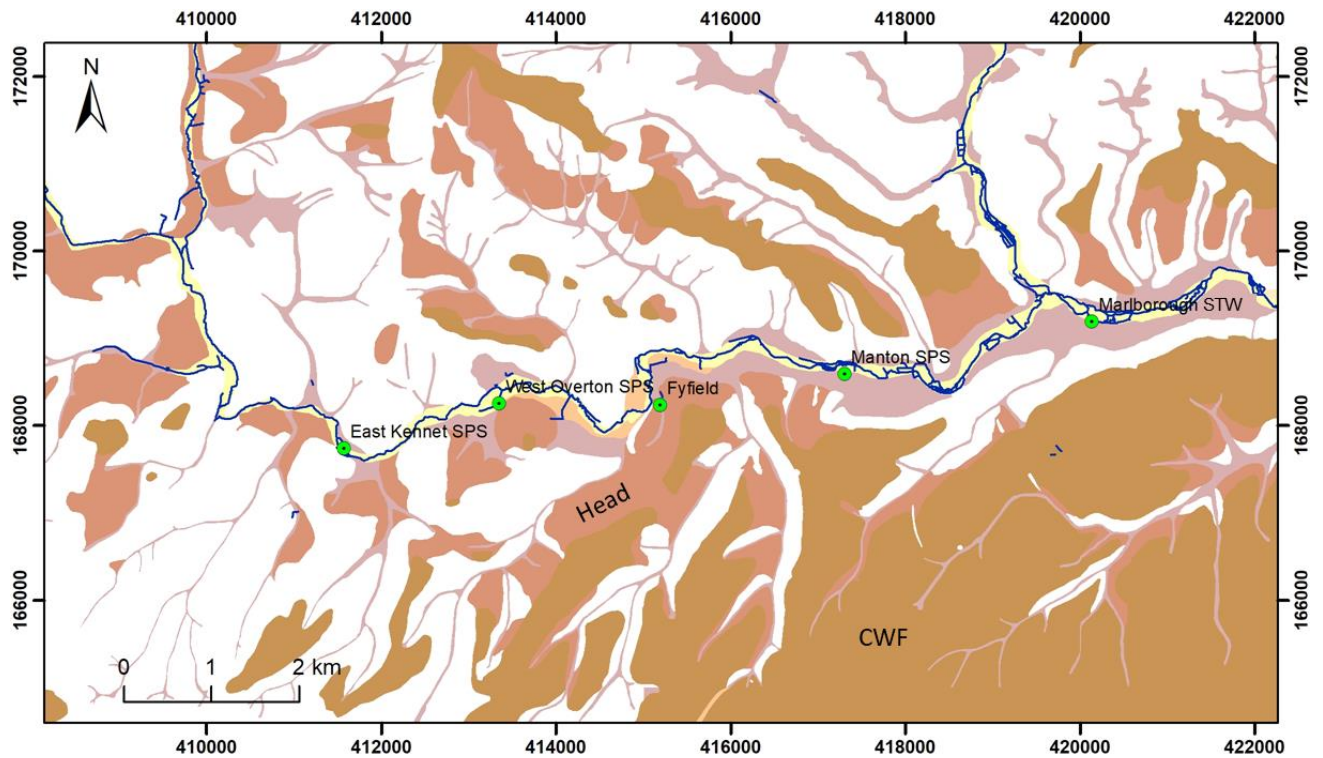


Figure 4 Superficial geology in the area of the East Kennet-Marlborough boreholes. Geological mapping from BGS Geology 50K (DigMapGB-50).

4 Geophysical logging

Geophysical logging was undertaken using a 4x4 vehicle-mounted digital stackable system manufactured by Geovista Ltd.

Table 3 shows the array of logs that were run in the boreholes. Compilations of log data for each borehole are provided in Enclosures 1-5.

Log mnemonic	Log description	Unit
DEPTH	Measured depth from logging datum	m
CAL	Caliper log (2 arm) of borehole width	mm
IL_S	Induced resistivity (shallow)	mmho
IL_D	Induced resistivity (deep)	mmho
NGAM	Natural gamma	CPS
COND	Conductivity	uSIE
TEMP	Temperature	°C
EC25	Conductivity (corrected to 25 Deg C)	uSIE
RLLS	Resistivity (shallow)	OHMM
RLLD	Resistivity (deep)	OHMM
OPTV	Optical Imaging (360 degree image)	

Table 3 List of log types run down the boreholes

The application of the optical imaging (OPTV) tool below the water table was dependent on clarity of the groundwater in the borehole. This depends on the time available and practicalities of borehole cleaning by pumping. Where this was possible a correlation between the caliper (CAL) measurements and boreholes structure can be seen in the composites of the logs.

Fluid logs (TEMP COND EC25) are similarly affected by the amount of development of the borehole but can then be used as indicators of flow regimes, particularly where this is enhanced by pumping.

Resistivity logs include measurements at two depths of penetration away from the borehole ('shallow' and 'deep'). The shallow measurement includes wellbore properties whilst the deep measurement is restricted to formation properties. These dual measurement tools are run to highlight any impacts of the drilling (e.g. drilling fluids /residues) which were not significant at the sites detailed in this report.

5 Borehole stratigraphy

In the Marlborough STW borehole, Chalk stratigraphy was determined by the examination of core at National Geoscience Data Centre, BGS, Keyworth. The results of the core logging are given in Enclosure 6 with detailed notes and discussion of the core in Appendix 1 of this report.

In the remaining uncored boreholes the stratigraphy was determined by using the downhole geophysical logs. The Marlborough STW borehole which was both cored and geophysically logged provided a control on these stratigraphic interpretations (see Enclosure 7).

Table 4 provides a summary of the borehole stratigraphy.

Borehole	Stratigraphic horizon	MD (m)	MaOD
East_Kennet_SPS	Top Holywell Nodular Chalk Fm	10.0	135.39
East_Kennet_SPS	Top Zig Zag Chalk Fm	27.3	118.09
Fyfield	Top Holywell Nodular Chalk Fm	27.5	113.34
Fyfield	Top Zig Zag Chalk Fm*	44.4	96.44
Manton_SPS	Top HolyWell Nodular Chalk Fm	23.6	107.08
Manton_SPS	Top Zig Zag Chalk Fm	40.2	90.48
Marlborough_STW	Top New Pit Chalk Fm	11.4	116.16
Marlborough_STW	Top HolyWell Nodular Chalk Fm	38.0	89.56
Marlborough_STW	Top Zig Zag Chalk Fm	54.0	73.56
Marlborough_STW	Top West Melbury Marly Chalk Fm	89.2	38.36
West_Overton_SPS	Top HolyWell Nodular Chalk Fm	15.7	127.78
West_Overton_SPS	Top Zig Zag Chalk Fm	33.0	110.48

Table 4 Depths of stratigraphic horizons in the boreholes. Measured depths are relative to the geophysical logging datum. The Top Zig Zag Chalk Formation pick in Fyfield is estimated.

Figure 5 and Figure 6 show the stratigraphy graphically. A detailed correlation panel with additional stratigraphic information is provided in Enclosure 8.

In Figure 5 the boreholes are plotted at their elevation relative to Ordnance Datum and show the progressive increase in depth of the various stratigraphic horizons from west to east. Progressively younger Chalk strata are preserved to the east and the Marlborough STW

borehole includes the base of the Lewes Nodular Chalk Formation at the top. The other boreholes are truncated within the New Pit Chalk Formation. The deep Marlborough STW extends into the West Melbury Marly Chalk, while the others (with the exception of Fyfield) stop just below the Plenus Marls in the uppermost Zig Zag Chalk. The Fyfield borehole terminated just at the top of the Plenus Marls.

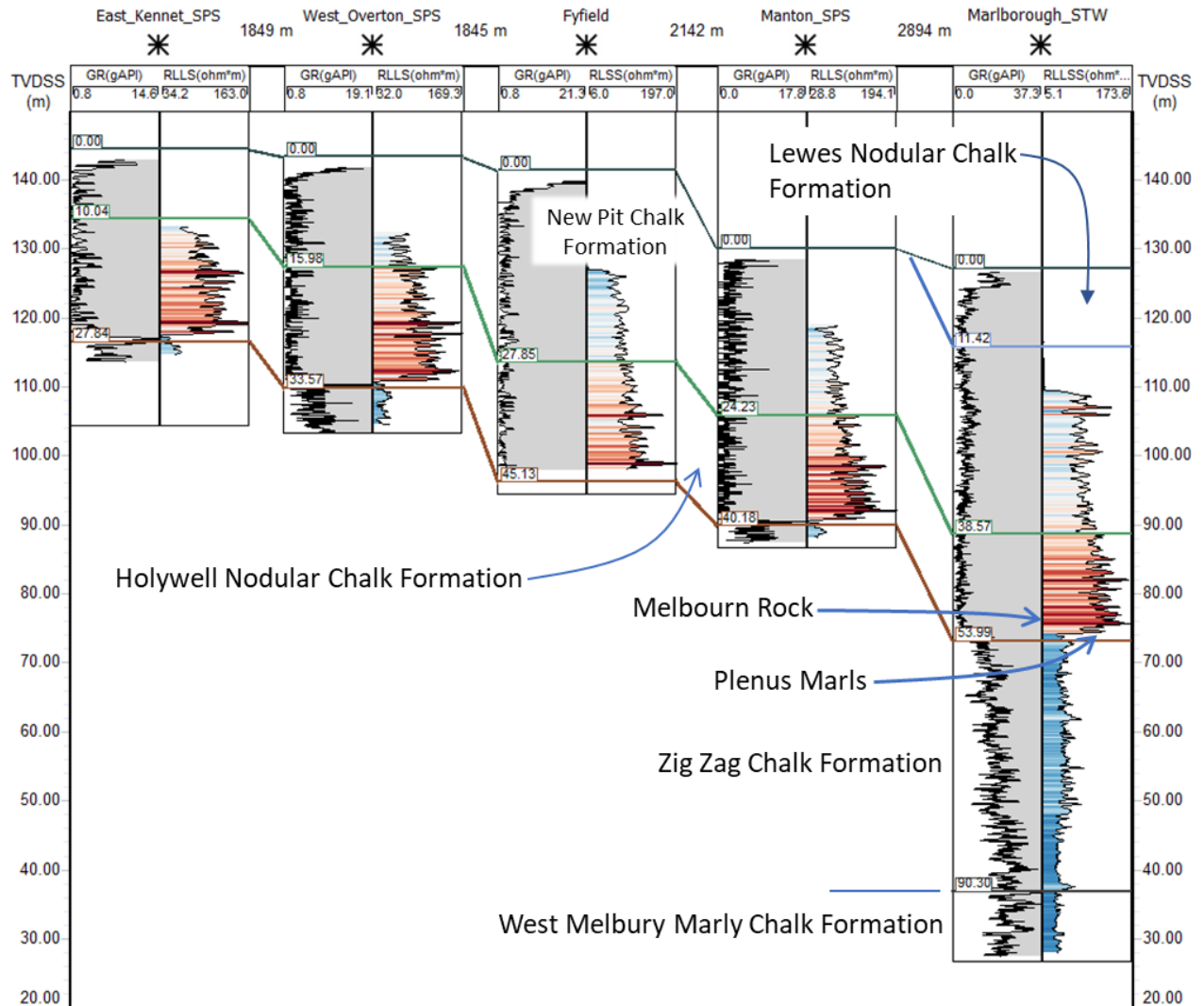


Figure 5 Boreholes plotted at elevation relative to Ordnance Datum. The eastward (downstream) fall in ground level elevation and the underlying geological horizons is clear.

Figure 6 shows the boreholes aligned (flattened) on an intra Holywell Nodular Chalk horizon which highlights the high resolution and consistent stratigraphic response of the resistivity (RLSS) log. The resistivity values shown by the curve are graphically enhanced by filling the curve with a blue (low) to red (high) colour ramp. Bulk shifts in the resistivity curve correspond to stratigraphic boundaries. The relatively porous New Pit Chalk has a low resistivity (blue colours). Resistivity increases abruptly (pale red colours) as the dense, low porosity nodular chinks of the uppermost Holywell Chalk are encountered. There is a further stepwise shift when the hard chinks and chinkstones are entered in the lower part of the Holywell Nodular Chalk (zone of dark red resistivity spikes). These include the Melbourn Rock toward the base of this interval. The Plenus Marls is marked by a sharp decrease in resistivity (dark blue) and increase in gamma ray response which continues downward into the marl-rich chinks of the Zig Zag Chalk Formation.

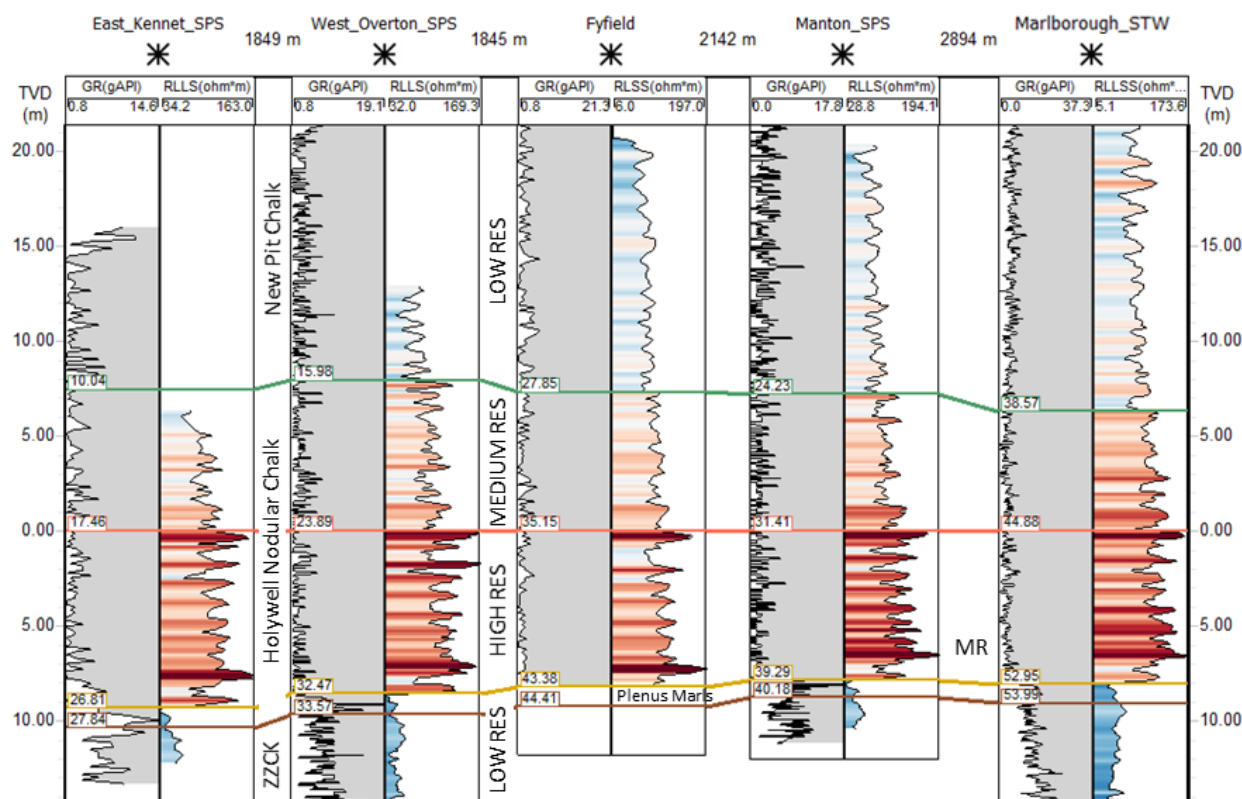


Figure 6 Gamma-ray and resistivity logs aligned (flattened) on an intra Holywell Chalk marker to show the consistent relationship between stratigraphy and log response.

6 Geological structure

A simple structure contour map for the Chalk in the Marlborough area can be created by combining the elevations for the base of the Holywell Nodular Chalk determined in the five boreholes with the elevation of the base Holywell Nodular Chalk crop-line provided by BGS 1:50 000 scale geological mapping (Figure 7). This confirms the eastward plunging W-E synclinal structure of the Chalk with the River Kennet running along the axis, particularly from a point east of East Kennet. The southern limb of the syncline, adjacent to the Pewsey Fault inversion anticline, is significantly steeper than the northern limb.

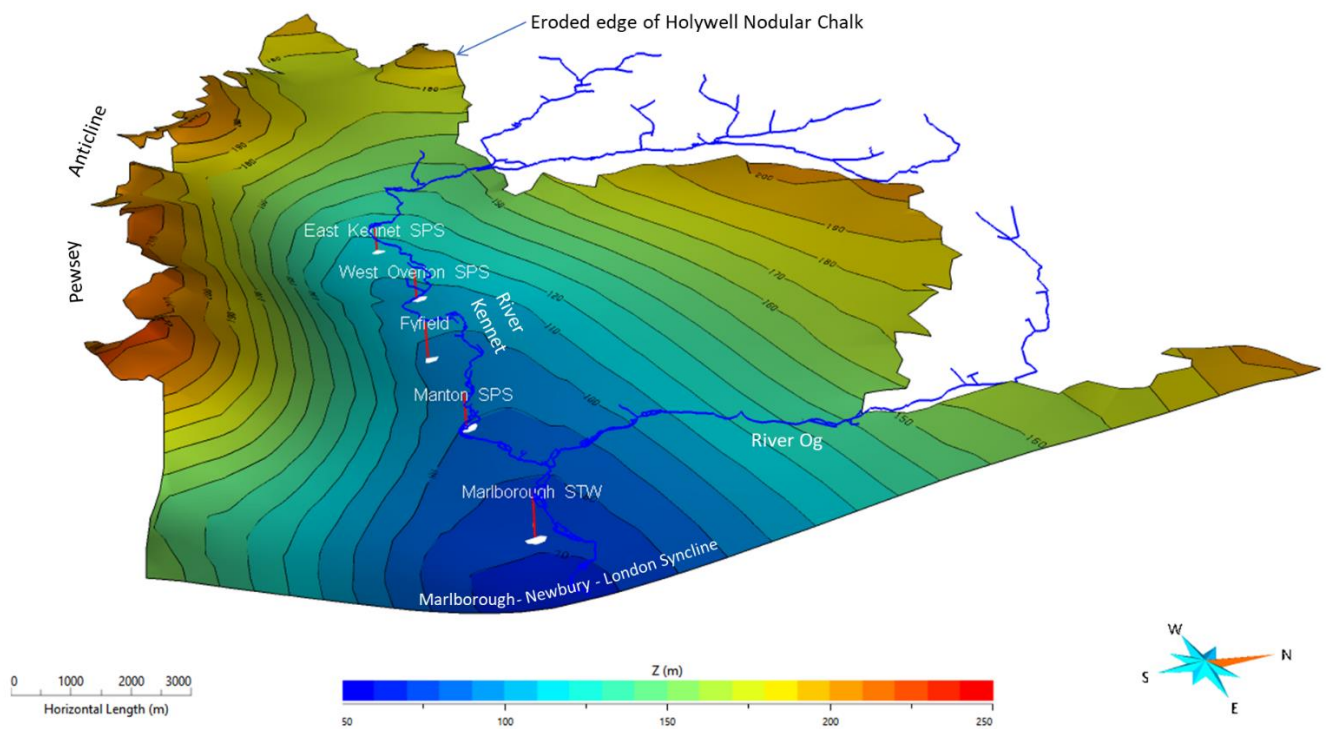
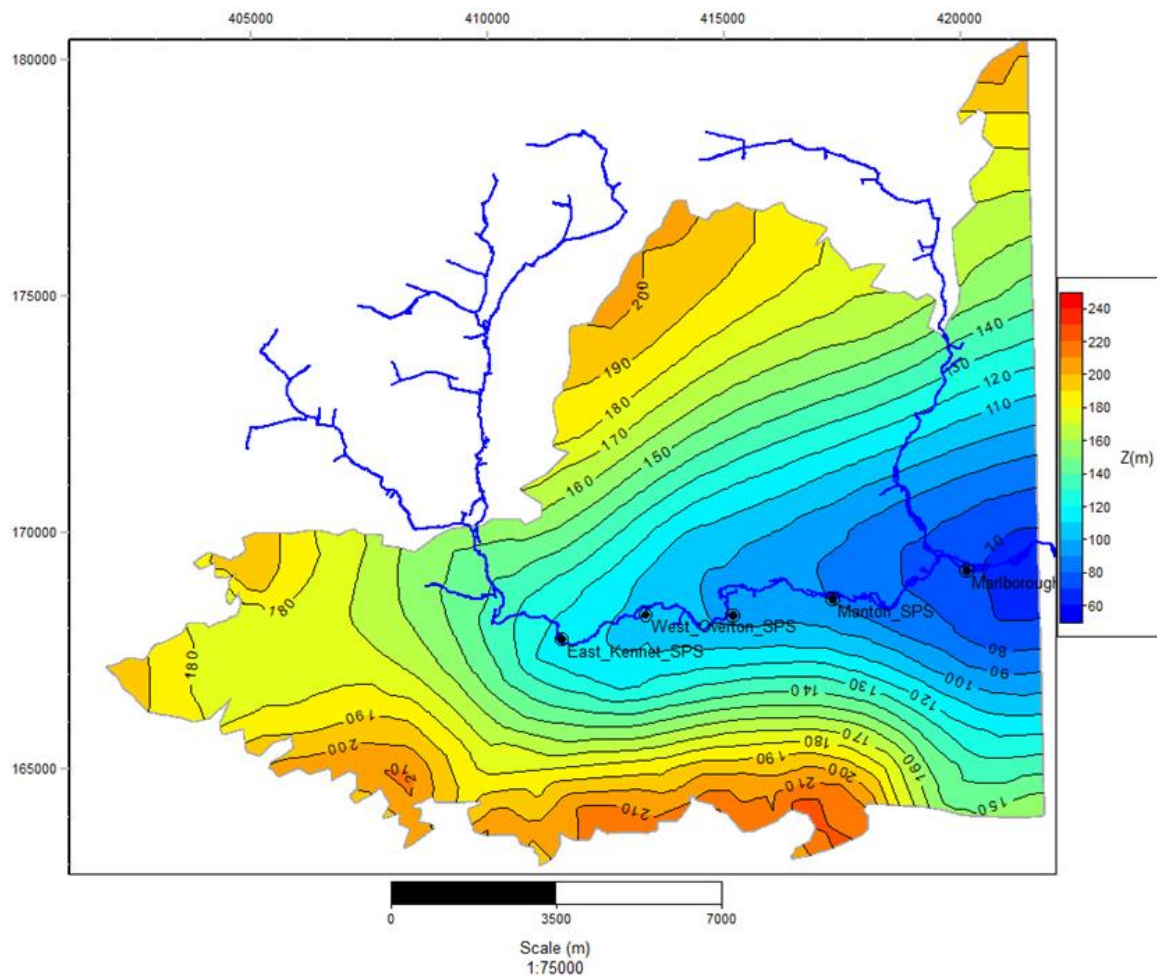


Figure 7 Map (top) and perspective view (bottom) on the base Holywell Nodular Chalk surface created from Z-attributed map linework and stratigraphic picks from the five new boreholes.

The formation boundaries determined in the boreholes can be extended on cross-sections to corresponding mapped boundaries at outcrop (Figure 8).

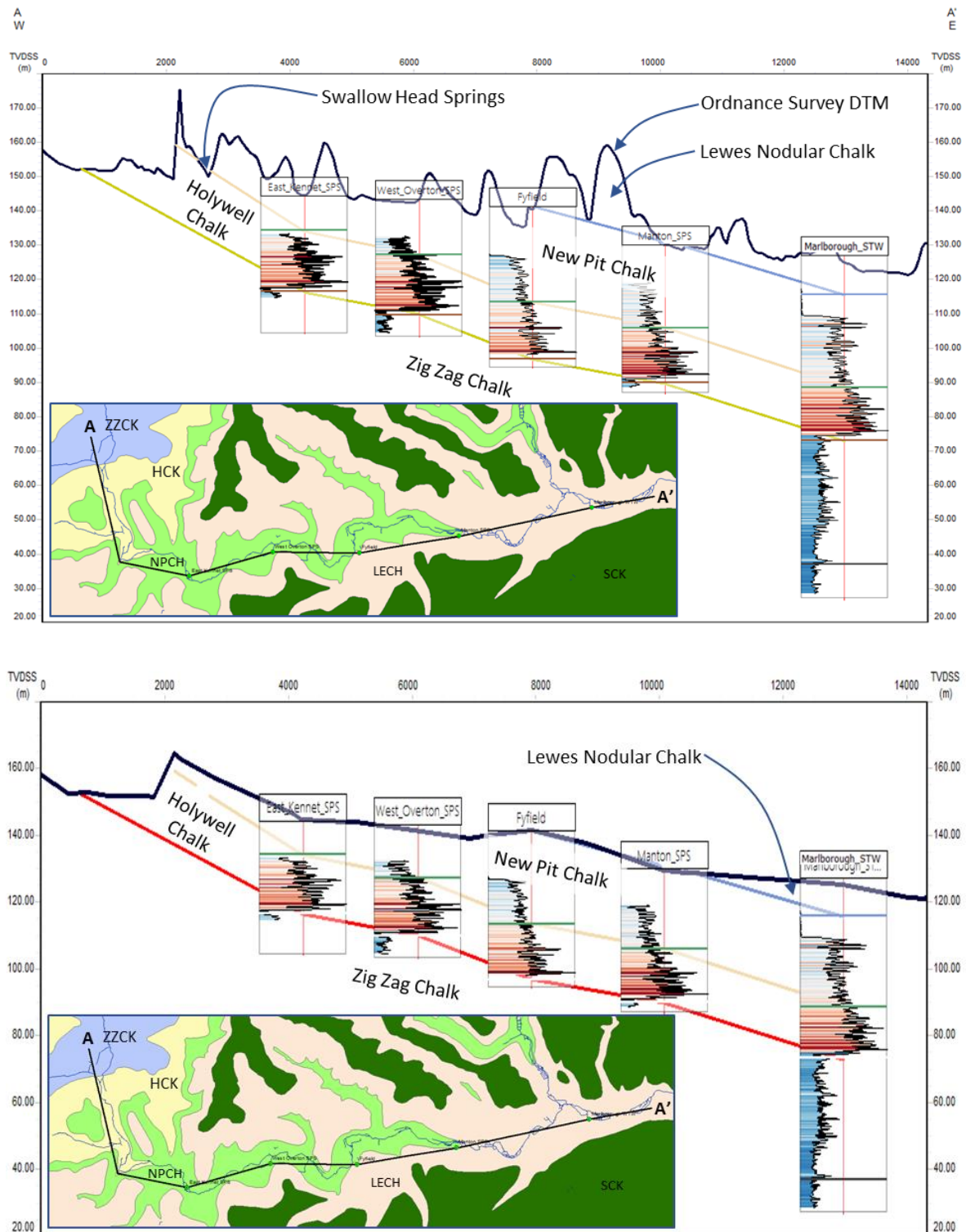


Figure 8 Cross-section that extends the formation boundaries picked within the boreholes to mapped extents at outcrop. Lower version shows simplified terrain.

Appendix 1

Detailed notes on Marlborough STW core

The core logging was undertaken by Mark Woods following transportation of the core from the Marlborough site to the NGRC, BGS Keyworth. This text accompanies the Enclosures 6 (core log) and 7 (relationship of core log to geophysical logs).

Core log data

The youngest part of the cored succession, around 7 m depth, comprises extremely hard chalk with patchy iron-staining. This chalk is interpreted as belonging to the lower part of the Lewes Nodular Chalk Formation.

Core recovery is very sporadic down to ca. 11.4 m, where there is a downward change to softer, smoother textured chalk with regularly developed marls and marly chalk horizons, marking the top of the underlying New Pit Chalk Formation. Fragments of sheet flints and large/medium/small nodular flints occur a little lower in the succession, and firm – soft marly chalk, typical of the New Pit Chalk, extends down to a plexus marl seam at 37.5 m. Immediately below the plexus marl the chalk becomes rougher textured and patchily hard and nodular, and common pinkish-coloured shell fragments representing the bivalve *Mytiloides* appear a short distance beneath. These features are typical of the Holywell Nodular Chalk, and the plexus marl at 37.5 m marking this change is inferred to equate with the Gun Gardens Main Marl, which marks the top of the Holywell Nodular Chalk in Sussex (Mortimore, 1986).

Around 49 m depth, nodular chalk transitions downwards into intensely hard chalk that extends to 51.3 m. This interval represents the Melbourn Rock towards the base of the Holywell Nodular Chalk, and includes a conspicuous succession of marl seams, inferred to represent the Meads Marls of Mortimore (1986). The base of the Holywell Nodular Chalk is marked by the Plenus Marls, with the top sharply marked by the downward change from massive, hard, dense, creamy-coloured chalk to soft, greenish-grey mudstone at 51.3 m. The Plenus Marls comprise an alternating succession of marls and chalky limestones, divided into 8 beds by Jefferies (1963). Bed 3 of Jefferies (1963) is a significant hard limestone, seen around 52 m depth in the borehole core. The base of the Plenus Marls is less easily defined in the core. A provisional boundary is placed around 52.3 m, assuming that the arrangement of the core in the core boxes is correct. However, the nodular chalk recorded at the top of the Zig Zag Chalk (immediately above an interval of core loss) is very similar to the lithology inferred to represent Jefferies' (1963) Bed 3 a little higher in the succession, and might (if there are errors in the depth arrangement of core in the core boxes) partly correspond with the interval marked as core loss at 51.9 – 52 m depth. In this case, it is likely that the base of the Plenus Marls is within the interval of core loss marked in the top of the Zig Zag Chalk Formation on Enclosure 6.

The succession below the Plenus Marls belongs to the Grey Chalk Subgroup, typically having a higher marl content and lacking flint. The bulk of the Grey Chalk Subgroup penetrated in the River Kennet Borehole is represented by the Zig Zag Chalk Formation, although this appears unusually marly compared to typical developments of this unit. The most noticeable lithological features are bands of paler and darker grey chalk, some showing concentrations of bioturbation. The base of the Zig Zag Chalk is marked by the Cast Bed, inferred to occur between 88.1 and 88.7 m based on the record of somewhat silty chalk with remains of the bivalve *Entolium orbiculare* (characteristic of the Cast Bed).

The oldest Chalk in the River Kennet Borehole belongs to the upper part of the West Melbury Marly Chalk. In areas where erosion at the base of the Cast Bed is likely to be limited, such as the Marlborough district, a hard limestone (Tenuis Limestone of Gale, 1995) occurs immediately beneath it at the top of the West Melbury Marly Chalk. This bed is inferred to be represented by the hard, sponge and pyrite-rich limestone at 88.7 – 88.95 m in the River Kennet Borehole. The West Melbury Marly Chalk is typified by the rhythmic alternation of marls and hard limestones, seen in the lowest 10 m of succession in the River Kennet Borehole.

Relationship of core and geophysical log data

The interpretation of the River Kennet core log allows detailed comparison with the corresponding geophysical and borehole image logs. This comparison provides a basis for interpreting other borehole geophysical logs in the vicinity where core logs are lacking.

In the River Kennet succession, resistivity log data across the base of the Lewes Nodular Chalk are lacking, and gamma log amplitudes (useful for identifying both marls and hardgrounds) are reduced by the presence of casing. Lower in the succession, the boundary of the Holywell and New Pit Chalk corresponds with a significant upward decline in resistivity and increase in average gamma log values. This change reflects the reduction in hardness and increase in marl content of the New Pit Chalk compared to the Holywell Nodular Chalk.

Geophysical logs typically record a very sharp inflection pattern in the basal part of the Holywell Nodular Chalk, reflecting a change from the generally soft Plenus Marls below to intensely hard Melbourn Rock above (Woods, 2006). In the geophysical logs for the River Kennet borehole this occurs around 53 m, marked by a significant upward reduction in average gamma log values and sharp increase in resistivity log values. As discussed above, there is a mismatch in the correspondence of the top of the Plenus Marls indicated by core log data compared to geophysical log data. Assuming no depth correction is needed for the geophysical log data, and given the potential problems of core loss and incorrect core arrangement (see above), the geophysical logs appear to provide the most definitive interpretation for the depth of the Plenus Marls at ca. 53 – 54 m.

In the lower part of the Zig Zag Chalk, between 80 and 88.5 m, core log data shows a significant increase in marl content, reflected by a corresponding shift in average gamma log values and a fall in average resistivity log values.

Geophysical logs for the River Kennet Borehole show that the best guide to the position of the base of the Zig Zag Chalk is the inferred Tenuis Limestone in the top of the West Melbury Marly Chalk, which corresponds (allowing for a ca. 0.5 m depth offset) with a sharp spike in the resistivity log (Fig. 2).

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