Environmental Geology & Geotechnical Consultants Ltd.

TECHNICAL NOTE:

Review of -

Envireau Water (2017) 'Hydrogeological Risk Assessment, Markwells Wood Site, Forestside, West Sussex'

(Appendix 9.1A to UK Oil & Gas (UKOG) Environmental Statement Addendum made under South Downs National Park planning application SDNP/16/04679/CM)

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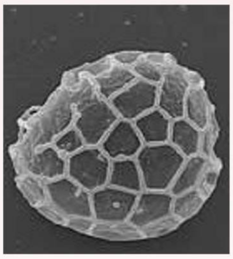

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This Technical Note was produced by Environmental Geology & Geotechnical Consultants Limited for Markwells Wood Watch for the specific purpose of a review of Envireau Water (2017) 'Hydrogeological Risk Assessment, Markwells Wood Site, Forestside, West Sussex' (Appendix 9.1A to UK Oil & Gas (UKOG) Environmental Statement Addendum made under South Downs National Park planning application SDNP/16/04679/CM)'. This Technical Note may not be used by any person other than Markwells Wood Watch without their express permission. In any event, Environmental Geology & Geotechnical Consultants Limited accept no liability for any costs, liabilities or losses arising from the use of or reliance upon the contents of this report by any person other than Markwells Wood Watch.

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General

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EXECUTIVE SUMMARY

This Technical Note presents a review of the adequacy and suitability for purpose of the Envireau Water (2017) report 'Hydrogeological Risk Assessment, Markwells Wood Site, Forestside, west Sussex', which forms a part of a UK Oil & Gas (UKOG) planning application for oil production from that site.

The Chalk Principal Aquifer underlying the site is the most strategically important pollution receptor associated with the proposed development. The groundwater resources of the region are heavily abstracted and much of the resource is subject to historical and ongoing contamination, from both diffuse and point sources. The prevalence of this pollution makes Chalk groundwater highly vulnerable to further impact, as it has little capacity left to absorb more pollution without endangering supplies. This situation is exacerbated by the high level of dependence of the local population on these water resources, and the water resource has been categorised as at high risk at a European level.

This Technical Note reviews conceptual understanding of the hydrological and hydrogeological regime of the Markwells Wood site and surrounding area as presented by Envireau Water (2017), including significant shortcomings, factual errors, omissions etc. where identified. The Technical Note is not an appraisal of risk associated with other groundwater receptors (e.g. deeper groundwater bodies), the proposed drilling methods, the proposed methods of well development, etc. The focus is the conceptualisation.

The Envireau Water (2017) report is the second attempt at a groundwater risk assessment made by the applicant (UKOG), the first produced by Hydrock (2016). That initial application gave rise to objections from the local water supply company, Portsmouth Water (PW), and from the Environment Agency (EA), specifically related to failure to consider the risks posed to groundwater, and in particular the Bedhampton & Havant springs, which supply upwards of 200,000 people in the Portsmouth district.

In this context, it is stated by Envireau Water (2017, pg. 1) that: *"...the objections can be addressed… focussing in particular on clarification of the hydrogeological conceptual model upon which to base a robust risk analysis."*. It is, therefore, the hydrogeological conceptualisation that underpins the risk assessment. Should the hydrogeological conceptual model prove not to be robust, neither will the risk assessment.

<u>Lack of conceptual rigour is demonstrated throughout the Envireau Water (2017) report. The report contains gross factual errors and misinterpretations of basic sources of information.</u> The principal failings of the hydrogeological conceptual model are as follows:

I) Interfluvial Site Location. Envireau Water (2017) insist that the UKOG site at Markwells Wood is located in the centre of an interfluvial plateau (or interfluve) between two principal dry valleys, the Havant and Emms valleys, and that this situation is of great significance. The significance is due to the increased likelihood of lower permeability Chalk in interfluvial areas. However, the interfluve between the Havant and Emms dry valleys is dissected by numerous other principal and minor dry valleys tributary to the Havant. The UKOG site itself is located immediately adjacent (<50 m) to the base of a minor dry valley, and as such is located much closer to a dry valley than to the centre of the adjacent interfluve. Later in the report, the additional dry valleys are acknowledged, but their potential high permeability is dismissed on the entirely circular basis that they are located on the 'low permeability interfluve' that was defined by excluding them in the first place(!).

II) Groundwater Contours. With respect to groundwater contours and flow in the Chalk, it appears that Envireau Water (2017) have mistaken contours on the base of the Palaeogene cover for groundwater contours in the Chalk. They subsequently enter into a discussion of the significance of the form of these contours, in terms of differences in permeability distribution between the confined and unconfined parts of the aquifer. This misinterpretation, and the subsequently confused discussion, illustrate a significant failure of hydrogeological understanding. Given the great importance and sensitivity of the water supplies in question, such a misunderstanding must represent a very serious challenge to the credibility of the entire assessment.

III) Groundwater Level Time Series. Earlier insistence that the site is situated on an interfluve constrains meaningful interpretation of groundwater level time series, and a number of basic but pertinent observations relating to hydrogeological conceptualisation are missed. For example:

- A brief assessment of time lags between peaks and troughs in annual rainfall and hydrographs indicates that the majority of winter rainfall recharge reaches the water table (through considerable unsaturated zone thickness in places) in under 3 months. Crude calculations suggest average (vertical) recharging groundwater velocities through the unsaturated zone of between ~0.1 and ~2 m/day.

- Groundwater typically fluctuates within the range 30 – 50 maOD in all of the monitoring boreholes used for the assessment, one of which is situated on a small interfluve. This suggests that there is a well-developed band of karstification at this level, certainly in proximity to the dry valleys, but also present on at least one interfluve in the area.

- On these and other grounds, arguments attempting to portray the UKOG site as situated on a hydrogeologically isolated block of Chalk are shown to be flawed.

IV) The Permeability of Sediment Fills in Solution Features in the Chalk. Envireau Water (2017) repeatedly claim that potential solution features (dolines) at the Chalk surface do not act as conduits for the rapid infiltration of water, due to the low permeability of the fill materials. This not only contradicts their own earlier assessment of doline fill material as 'sandy-clayey', but completely ignores significant conclusions from important sources of information that Envireau Water (2017) themselves cite. The potential permeability of doline fill deposits is significant, and numerous phenomena related to groundwater percolation through these features are listed to illustrate this.

V) The Distribution of Potential Solution Features in the Vicinity of the Site. It is concluded by Enviro Water (2017) that there are no large solution features at, or in the immediate vicinity, of the site. However:

- Significant drilling fluid losses occurred in the Upper Chalk at 131 and 231 metres below the ground (mbgl) during drilling of the first UKOG site well (MW1). As at 131 mbgl aggregates were required to be introduced to the borehole to stop the loss of drilling fluids (in an uncontrolled discharge), the cavity encountered must be of sufficient capacity to rapidly transport drilling fluids away from the well bore. This is strongly suggestive of solutional enhancement.

- Assessment of LiDAR data by EGG Consultants Ltd (2017) illustrates a large number of potential solution features (dolines) at the surface in the immediate vicinity of the site, the two closest being less than 50 m from the site. Only a small subset of these are identified by Envireau Water, despite access to equivalent LiDAR data.

Given these observations, the statement that there are no 'large' solution features at (or in the immediate vicinity) of the site cannot be accepted as valid.

VI) The Level of Groundwater Protection Afforded by the Clay-with-Flints. Envireau Water (2017) again contradict themselves by concluding that the Clay-with-Flints *"...is a low permeability material which affords considerable protection against vertical migration of fluids",* after having initially stated that the soil on site is classified as *'freely draining slightly acid loamy soils'.* Soils developed on the Clay-with-Flints are also classified by the Environment Agency (2014) as having a soil vulnerability category of Intermediate 1 (I1), which is described as *'Soils which can possibly transmit a wide range of pollutants'.* Further details regarding sand lenses, basal gravels and other commonly encountered permeable components of the Clay-with-Flints are given throughout the literature. Although relevant parts of that literature are cited by Envireau Water (2017), the findings are not incorporated into their conceptual understanding.

VII) Argument. The overall manner of argumentation adopted by Envireau Water (2017) is to present a conceptualisation of Chalk permeability which is broadly correct, but based only on generalisations for which there are many exceptions, and to then insist that the UKOG site must be located on impermeable ground because it satisfies the criteria presented by a general model.

In conclusion, whilst Envireau Water do show basic understanding and have attempted to frame a broad hydrogeological conceptualisation, they never proceed to any greater insight than this and ultimately fail to capture much of the pertinent available information. Several serious misinterpretations and omissions undermine the credibility of the conceptualisation, and thus the basis of the risk assessment. The conceptual model as presented seriously underestimates the potential capacity of the Chalk to rapidly transport contamination in the Markwell Wood area, and for this reason is not fit for purpose.

It is unfortunately apparent that the majority of errors made by Envireau Water (2017) favour the position of their client.

1.0 INTRODUCTION & SCOPE OF WORKS

This Technical Note presents an assessment of the adequacy and suitability for purpose of the Envireau Water (2017) report 'Hydrogeological Risk Assessment, Markwells Wood Site, Forestside, West Sussex'.

That report forms Appendix 9.1A to the UK Oil & Gas (UKOG) Environmental Statement Addendum (Barton Willmore, 2017) made under South Downs National Park (SDNP) planning application SDNP/16/04679/CM 'Appraisal and production of oil incorporating the drilling of one side track well from the existing well (for appraisal), three new hydrocarbon wells and one water injection well, and to allow the production of hydrocarbons from all four wells for a 20 year period.'

The assessment presented in this Technical Note reviews conceptual understanding of the hydrological and hydrogeological regime of the site and surrounding area as presented by Envireau Water (2017), including significant shortcomings, factual errors, omissions etc. where these have been identified. This assessment is informed by an earlier report by Environmental Geology & Geotechnical Consultants Ltd (EGG Consultants Ltd, 2017) entitled 'A Review of Karstic Potential and Groundwater Vulnerability of the Chalk Principal Aquifer in and around Markwells Wood, West Sussex.'[1] That report should be read prior to this Technical Note, as it informs the following discussion and (for those unfamiliar) introduces some important concepts relating to Chalk hydrogeology.

To contextualise the importance of this work, please consider the following statement from Isherwood *et al* (2016) in their conclusions regarding overall hydrogeological risk for the Wessex and Weald Basins (the Hampshire basin forms a part of the Wessex basin):

> *"The groundwater resources within southern and south-eastern England are already heavily abstracted, owing in part to the high population density, giving very limited scope for additional groundwater development within the region...*
>
> *Much of the groundwater present within the main aquifers in the Wessex and Weald area is subject to contamination, mainly from surface-derived contaminants from diffuse and point sources....*
>
> *The prevalence of anthropogenic pollution across the Wessex and Weald area makes much of the groundwater in the area very vulnerable to further changes in water chemistry, as it has limited tolerance for mitigating further effects. With this in mind, it has been assigned a status of 'highly sensitive', relating particularly to areas underlain by the major water supply aquifers.*
>
> *The high dependence of much of the English population on groundwater as a supply of drinking water makes the water resource 'high value'.*

1 Available on the SDNP planning portal at http://planningpublicaccess.southdowns.gov.uk/online-applications under Emily Mott, Objection, 20th March 2017.

The groundwater resource in Wessex and Weald is therefore considered to be at 'high' risk."

Isherwood *et al* (2016), pgs 246-7

Thus, for the ongoing security of water supply in these high risk areas, it is absolutely essential that hydrogeological risk assessments for significant industrial developments are conducted to the highest standards of scientific rigour and best practice.

The Chalk Principal Aquifer is both the most strategically important, and vulnerable, pollution receptor associated with the proposed development. This Technical Note confines itself to only critiquing hydrogeological understanding, conceptualisation and groundwater vulnerability assessment relating to that aquifer, as presented by Envireau Water (2017) and summarised in Barton Willmore (2017). It is not an appraisal of risk associated with other groundwater receptors (e.g. deeper groundwater bodies), the proposed drilling methods, the proposed methods of well development, etc.

Please also note that little additional background to the site is given in this Technical Note. The reader is referred to Barton Willmore (2017) and Envireau Water (2017) for full details of the proposed works including hydrology and hydrogeology, is also discussed in that report. EGG Consultants Ltd (2017) also provide a review of the hydrogeology of the site, with a greater emphasis on identifying local karst features and processes present in the locality.

1.1 Sources of Information

The principal document to be assessed is:

- **Envireau Water (2017).** 'Hydrogeological Risk Assessment, Markwells Wood Site, Forestside, West Sussex'. Forming Appendix 9.1A to Barton Willmore (2017) Environmental Statement Addendum to UK Oil & Gas planning application SDNP/16/04679/CM to the South Downs National Park.

And which forms the basis of:

- **Barton Willmore (2017).** Markwells Wood, Forestside, Environmental Statement Addendum 9.0A Ground Conditions & Groundwater. Forming part of UK Oil & Gas planning application SDNP/16/04679/CM to the South Downs National Park.

And, research conducted for production of the following report forms the principal basis for the assessment:

- **Environmental Geology & Geotechnical Consultants Ltd (2017).** A Review of Karstic Potential and Groundwater Vulnerability of the Chalk Principal Aquifer in and around Markwells Wood, West Sussex[1].

For the reader to fully understand the material presented in this Technical Note, they should be familiar with both Envireau Water (2017) and Environmental Geology & Geotechnical Consultants Ltd (2017). Additional references drawn upon in this Technical Note text are provided at the end of the document.

1.2 Structure of this Technical Note

This Technical Note approaches Envireau Water (2017) on a point-by-point basis identifying where EGG Consultants Ltd:

- Have found factual errors;
- Are in disagreement regarding interpretation of the available information; and
- Have identified where the available information has been taken into account either only partially or not at all.

Critical sections of Envireau Water (2017) text are identified by report section number and heading/sub-heading (e.g. EW 1.1 Background), followed by an excerpt of text if required, or simply an analysis of the statements made. Excerpts are presented in italics and quotation marks. All figures (drawings) referred to, with the exception of Technical Note Figure 1, are the figure numbers given by Envireau Water (2017).

Following examination of the text on a point-by-point basis, the Technical Note concludes with an appraisal of the key elements of the conceptual model as summarised in Envireau Water's (2017) summary, where some additional remarks are also made.

2.0 ASSESSMENT

EW 1.1 Background.

With respect to the initial Environment Agency (EA) and Portsmouth Water (PW) objections to the UKOG proposal, it is stated that:

> *"...the objections can be addressed… focussing in particular on clarification of the hydrogeological conceptual model upon which to base a robust risk analysis."*
>
> Envireau Water (2017) pg. 1

This is highlighted here to illustrate that, should the hydrogeological conceptual model prove not to be robust, neither will the risk assessment. Lack of conceptual rigour is widely demonstrated throughout the remainder of the Envireau Water (2017) report, and discussed in detail below.

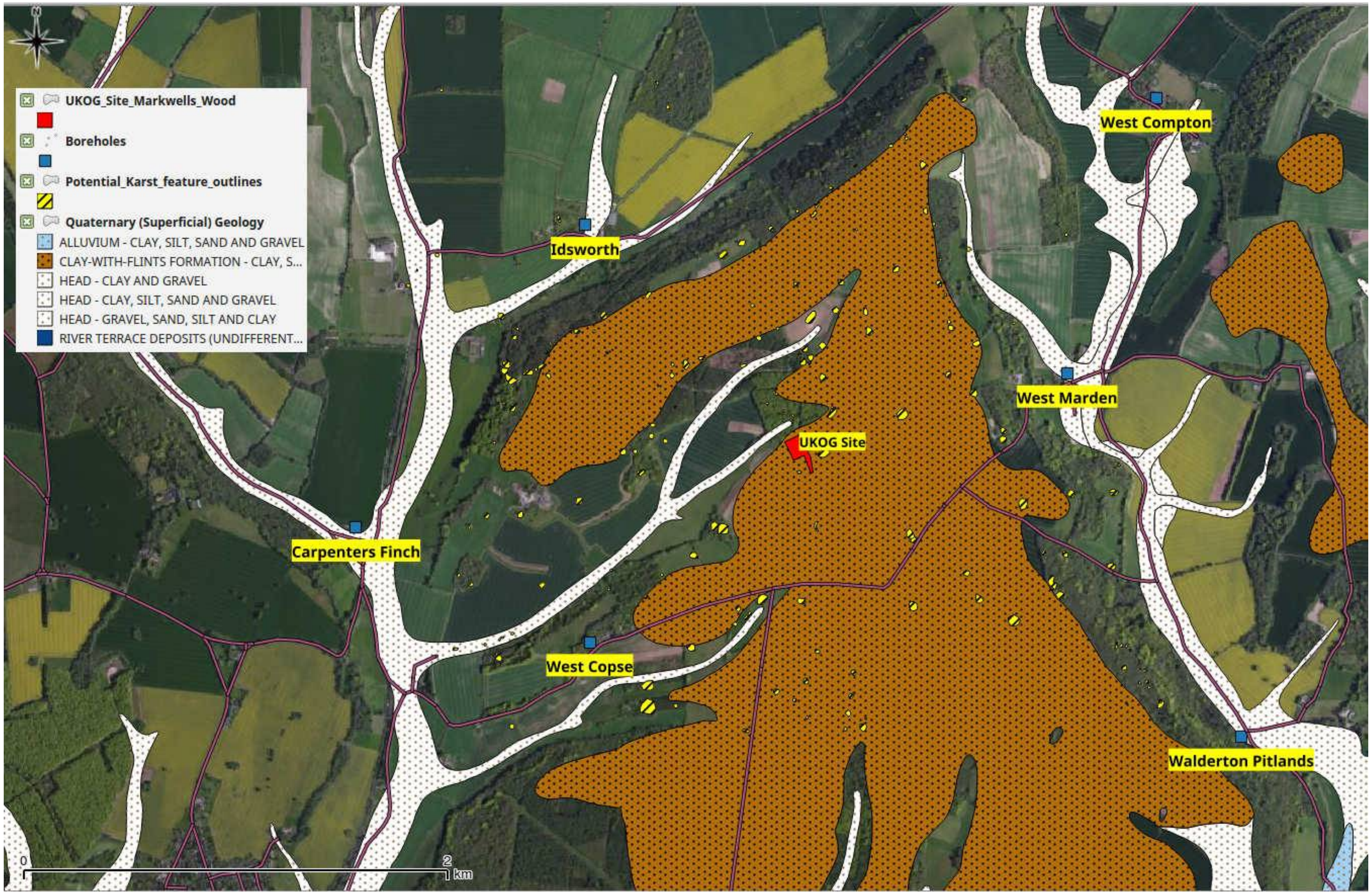
EW 2.2 Topography

From the outset (e.g. Figure 1a) Envireau Water (2017) insist that the UKOG site at Markwells Wood is located on an interfluve, and that the only dry valleys of importance to an assessment of hydrogeological risk are the two principal Havant and Emms dry valleys. <u>This is simply not the case.</u> The interfluve between the Havant and Emms dry valleys is dissected by numerous other dry valleys tributary to the Havant and Emms valleys. The UKOG site itself is located immediately adjacent (<50 m) to the base of a minor dry valley and as such is much closer to the dry valley than to the centre of the interfluve.

Due to the central importance of this point it will be addressed in detail throughout this Technical Note. However, for clarity at the outset, Technical Note Figure 1 is presented below, in which dry valleys are shown by the presence of 'Head' deposits as determined from the 1:50,000 geological map (BGS, 1998).

EW 3.1 Catchment Characterisation

The hydrological catchment area is given as 2.58 km^2. This is determined solely from topographic criteria as shown in the cited figure (Figures 2a and 2b). The baseflow index given as ~95% indicates that virtually all drainage proceeds via groundwater flowpaths.



Technical Note Figure 1. Map of dry valleys (as depicted by Head deposits), Clay-with-Flints deposits and monitoring boreholes in the vicinity of the UKOG site at Markwells Wood. Showing also potential surface karst features determined from LiDAR data (incomplete coverage). Scale ~ 1:18,000.

(Contains Environment Agency information © Environment Agency and/or database right and geological data under Licence No. 2011/3PDL/xxxxxx British Geological Survey © NERC.)

EW 3.2 Surface Water Features

It is agreed that the closest surface water course issues at Dean Lane End approximately 2 km south-west of the site and at an elevation of approximately 40 maOD. As the report states, the very high groundwater component of the flow implies that this location is dependent upon groundwater levels – i.e. that it is a surface expression of the groundwater level, and as groundwater levels rise and fall, so will the position of the head of the watercourse.

EW 4.5 BGS Water Well Records

It is agreed that productive zones and 'fissures' are described in a number of British Geological Survey (BGS) records for wells local to the site. These are available on the BGS website and described in more detail in EGG Consultants Ltd (2017).

EW 5.1 Groundwater Setting

> *“As shown very clearly on the geological map on Figure 3a, there are two principal dry valleys that are relevant to this assessment...”*

It is not demonstrated why only these two dry valleys are relevant. There are two other principal dry valleys, and at least one minor dry valley which are all much closer to the site and which have been de-emphasised on Figure 3a.

EW 5.2 Groundwater Flow and Levels

As this section of the report is critical to the hydrogeological conceptualisation put forward by Envireau Water (2017), the Technical Note here divides discussion into three principal components – A) Groundwater Contours; B) Dry Valleys; and C) Groundwater Levels and Fluctuations.

A) Groundwater Contours

A major part of the analysis presented in section EW 5.2 is based on the groundwater contours depicted on the Institute of Geological Sciences (IGS) (1978) 'Hydrogeological map of the South Downs and adjacent part of Weald' and the IGS (1979) 'Hydrogeological map of Hampshire and Isle of Wight'. These have been combined to form Envireau Water's (2017) Figure 4a. Figure 4b is derived solely from the IGS (1978) map.

Regarding the mapped contours, Envireau Water (2017) make the following statement (pg. 10):

> *“To the north of the region, where the Chalk is unconfined, groundwater level contours are not linear and are affected by the presence of the dry valley systems and intervening interfluves. The pattern of groundwater contours not only shows that groundwater is draining southwards,*

> *but also into the dry valleys. In contrast, groundwater contours in the south of the region are linear where the Chalk is overlain by Paleogene deposits and confined, reflecting the permeability and topographic contrasts in the unconfined and confined systems.”*

Whilst it is agreed that a basic outline of the conceptual model should be one of groundwater converging toward dry valleys in the unconfined zone of the aquifer and moving southward toward the coast, there are problems with this statement:

I) All groundwater contours are in fact linear, as they are lines. Presumably what is meant is that either they are not straight, or they are not parallel (or both).

II) Regarding the contours in the south of the region beneath the Palaeogene, these are claimed to be linear (i.e. straight/parallel), where in fact there are virtually no groundwater contours shown for the Chalk beneath the Palaeogene in the Havant/Bedhampton springs catchment as shown on Figure 4a. Only the +10 maOD and +20 maOD contours (in purple) are shown for the Chalk, which in any case are obviously not straight/parallel (and neither are the Chalk groundwater contours shown further to the east). The reason for the lack of contours is because there are no monitoring boreholes located in this area (the monitoring boreholes are shown by the orange hat symbols '^').

III) <u>Rather</u>, it appears that the only 'linear' (straight/parallel) contours that could possibly be referred to are the blue lines labelled '+50', '0' and '-100' (and others which are unlabelled) on Figure 4a, and which are in fact <u>contours depicting the base of the Palaeogene</u>, and not groundwater contours at all.

IV) Thus, the conclusion that this reflects “...*permeability and topographic contrasts in the unconfined and confined systems.”* is nonsensical.

Regarding points III to V above, flow in groundwater systems discharging towards point locations, such as springs or wells, whether confined or unconfined, tends to exhibit increasing convergence as the discharge point is approached[2]. As the Havant & Bedhampton springs are one of the largest public supply springs in the country, one may expect *a priori* to observe significant flow convergence, and that this would be shown by curved contours of equal hydraulic head as opposed to straight ones on a plot of regional contours. This is in fact what is demonstrated by the only two visible contours (+20 and +10 maOD)

As described elsewhere in the report, It is well understood (e.g. Atkinson & Smith, 1974), that the karst groundwater system present to the north of the Palaeogene/Chalk boundary (as demonstrated by numerous productive boreholes and well records), continues beneath the Palaeogene, and supplies the Bedhampton & Havant springs. Thus, there is no great difference in the type of permeability between the confined and unconfined aquifer, which will include bedding planes, fractures, tubules and fissures etc., much of which solutionally enhanced. A greater degree of permeability development might be expected to occur moving from the catchment boundaries to the springs, with a concomitant increase in permeability. <u>However</u>, that

2 See for example Freeze & Cherry (1979).

development extends well to the north of the Palaeogene/Chalk boundary and throughout Maurice *et al's* (2012) Karst Zone 2[3], in which the UKOG site is situated. Critically for the purposes of this assessment, groundwater velocities of up to kilometres per day are known to be present beneath the Palaeogene cover, and this is likely to extend well into Karst Zone 2 in the central part of the catchment.

Section EW 5.2 offers no discussion of the potential for vertical flows that such a system might be expected to display, and nor of the implications of such flows for the interpretation of regional groundwater contours as relied upon by Envireau Water (2017). The low resolution of the groundwater level data at a local scale is not discussed either. However, significant weight is placed upon the regional picture to form an opinion about the specific site without accounting for these important considerations.

Figure 4a also purports to show an interfluve area, but this is drawn directly across the Emms dry valley, which is obviously not an interfluve, and this representation is therefore also incorrect. The curved black line in Figure 4a appears to be roughly based on the 30 maOD Chalk groundwater contour. The general point that the UKOG site is located above a 'lobe' of high groundwater levels will be discussed further below.

Overall too much site-specific emphasis is placed on the low-resolution regional mapping presented in IGS (1978; 1979), on top of which several of the contours are so badly misinterpreted by Envireau Water (2017) as to seriously challenge the credibility of their entire assessment.

B) Dry Valleys & Interfluves

The black lines with the solid arrows marked on Figures 4a & 4b are labelled on the original IGS (1978) map as 'Course of Principal Dry Valleys'. (These are much clearer on Figure 4b than on Figure 4a).

Figures 4a and 4b show two NE/SW oriented Principal Dry Valleys in much closer proximity to the site than the Havant and Emms dry valleys. They also downplay the presence of the immediately adjacent minor dry valley as shown on their Figures 3a and 3b. The potential significance of these features is almost entirely dismissed from the Envireau Water (2017) assessment, and this selective use of the available information undoubtedly influences their later conclusions regarding groundwater vulnerability at the UKOG site.

C) Groundwater Levels and Fluctuation

Regarding Figures 5 & 6 illustrating monitored groundwater levels. The monitoring boreholes are well distributed around (although mostly not within) the Markwells Wood area (please see Figure 5 and Technical Note Figure 1). They all exhibit a predominant range of groundwater level variation between 25 – 50 maOD, irrespective of differences in ground level between the sites. Woods Copse Forest borehole is situated at approximately 85 maOD, Compton at ~70 maOD, Old Idsworth Farm at ~65 maOD, West Marden at ~ 60 maOD, Carpenters Finch at ~45 maOD. The elevation of the Walderton Pits logger is uncertain as the peak

3 The UKOG site falls within Karst Zone 2. Please see EGG Consultants (2017) and references therein for a fuller discussion of Markwells Wood within this context.

water level appears higher than the ground level (~50 maOD) here. The lowest seasonal variations in groundwater level fluctuations are approximately 5 m, and the greatest are approximately 40 m.

Envireau Water (2017) pg. 11 state that:

> *"The least variation in water levels is seen at the Wood Copse Forest monitoring borehole, which is located on the edge of the interfluve area."*

What they mean is that the Wood Copse Forest borehole is located near the edge of <u>their own defined interfluve</u> which, as discussed and illustrated above, takes no consideration of the other dry valleys that dissect the interfluvial plateau between the Havant and Emms dry valleys.

By claiming that the lowest seasonal groundwater variation is present on the edge of their defined 'interfluve', Envireau Water (2017) appear to be suggesting that this must represent a greater degree of variation than in the centre.

Closer inspection, however, reveals that the Wood Copse Forest borehole is situated on almost the exact centre of a small interfluve between two dry valleys (see Technical Note Figure 1). It is therefore unsurprising that this borehole, being the most closely situated to the centre of an interfluve, exhibits the lowest range of seasonal groundwater variation.

Nonetheless, whilst Wood Copse exhibits the lowest comparative seasonal variations, this is still commonly on the order of ~10 m (e.g. in years 1994, 1995, 2000, 2001, 2003, 2007, 2010, 2013, 2014, 2015 & 2016), and the inter-annual variation is on the order of ~14 m (e.g. between 2001 and 2004). A 10 m seasonal variation in water table[4] compared with a 30 m variation does not imply that the 10 m variation represents a low permeability. It may not be as high as in the dry valley itself, but on the other hand may indicate a particularly transmissive fissure that the water table only very infrequently rise above. As Price (1987) points out, the water table is dictated by the presence of fractures, rather than the other way round. That is, where a fissure is of sufficient permeability, it will (crudely speaking) drain all of the water that approaches it, so that water table does not rest above this level. That groundwater typically fluctuates within the range 25 – 50 maOD, this suggests that there is a well-developed band of karstification at this level, certainly in proximity to the dry valleys, but also, though probably less well-developed, still present on the interfluves (as Woods Copse indicates).

As discussed in Egg Consultants (2017), Maurice *et al* (2012) showed that flowing features in interfluve areas in their Karst Zone 2[5] occurred at approximately half their frequency in the major dry valleys. Younger (1989) notes that *"...wide fissures also occur in interfluve areas above the present level of the water table... Some of the larger fissures in this setting contain recent deposits of sand and mud washed in from the land*

4 The term 'water table' is slightly misleading in that it suggests a planar surface throughout the ground, but this is an oversimplification of a complex three-dimensional network of interconnected, partially connected and isolated fractures & fissures etc distributed throughout a porous matrix.

5 This idea was developed following studies in the Pang & Lambourne catchments.

surface.". And so, even if we did accept the Envireau Water (2017) insistence that the site lies in the centre of an interfluve, this would still imply a virtual certainty of the presence of flowing features beneath the site, as it falls fairly and squarely inside Karst Zone 2. Given groundwater level observations, it is likely that such development occurs in the locality of the UKOG site at elevations of 25 – 50 maOD.

Figure 6 also indicates the response time of the aquifer to recharge; that is, how long it takes for seasonal rainfall, highest over the winter and lowest over the summer, to appear in the borehole hydrographs; i.e. to traverse the unsaturated zone and enter the saturated zone. This indicates a predominant response time across the area, including the interfluvial Woods Copse Forest borehole, of less than 3 months between peak rainfall in a year and peak groundwater level. The same approximate lag is also apparent from a comparison of annual lows. It is notable that data from the Woods Copse borehole, located at ~85 maOD on a small interfluve, do not indicate any delay in the time to peaks as compared with the boreholes closer to or within dry valleys. For an unsaturated zone of (for the sake of argument) between 10 m and 60 m thick[6], and a groundwater response time of 3 months, a very crude calculation suggests average groundwater velocities through the unsaturated zone of up to between 0.1 and 0.66 m/day.

If we assume for the sake of argument that groundwater levels have an average level of approximately 50 maOD, (Envireau Water, 2017, pg. 11), a crude gradient calculation can provide an initial assessment of how 'isolated' the 'lobe' of groundwater is in the area of the UKOG site. For example, if we take the Havant Valley watercourse emergent at Dean Lane End as representing groundwater intersecting the ground surface an average elevation of 40 maOD (Envireau Water, 2017, pg. 3), then the average difference in hydraulic head is 10 m over a distance of ~2,000 m, or with an approximate hydraulic gradient of 0.005, which is not a particularly steep gradient. But whatever the hydraulic gradient is, the permeability of the ground is clearly sufficient to permit drainage of the aquifer at Woods Copse within the same seasonal time frame as it does on the Havant dry valley.

The foregoing discussion may be summarised as follows:

1. Although as a general rule there may be reduced permeability on the interfluves in comparison to the dry valleys, this does not prove that the specific interfluves in question are of low permeability.

2. Analysis of groundwater levels indicates a likely band of karstification centred around 30 – 50 maOD, especially where dry valleys are present, but also likely to be present in a (probably) less-well-developed form on the interfluves. Permeable features may well also be present within the unsaturated zone above the 50 maOD level.

3. Thus, even were the site to be situated in the centre of a large interfluve, this would not in any case prove that the Chalk beneath the site is of low permeability.

4. A cursory assessment of time lags between peaks and troughs in rainfall and hydrographs indicates

6 Perhaps 10 m thick in the vicinity of Idsworth Farm, and 60 m at the UKOG site.

that the majority of winter rainfall recharge reaches the water table (through considerable unsaturated zone thickness in places) within 1 to 3 months.

5. Data from the one interfluvial borehole available indicate groundwater drainage at occurs over the same seasonal timescale as it does in the Havant dry valley.

On the basis of these arguments it is unreasonable to conclude that the UKOG site locality is hydrologically isolated and 'very different' from 'elsewhere in the catchment' as Envireau Water (2017) attempt.

EW 5.4 Dry Valleys

Section EW 5.4 presents a discussion of the formation of dry valleys on the basis of geological structure and glacial and periglacial geomorphic processes, illustrated with bullet points derived from McDowell *et al* (2008) and additional information from UKOG's own seismic data. However, It does not discuss karst formation during the late Cretaceous, which is likely to form a component of karst in the area, as also described by McDowell *et al* (2008).

The concluding statement to section EW 5.4 regarding the lower permeability of the Chalk at the location of the site is a non-sequitur given the preceding discussion in this section.

EW 5.5 Solution Weathering and Groundwater Movement

The phrase *"...similar to karst flow in limestone systems..."* (pg. 13) betrays a lack of understanding on the part of the authors, given that the Chalk is a limestone, and that the system is karstic.

Further comments on pg. 13:

> *"Not all dry valleys are high velocity zones as the transmissivity of the Chalk decreases towards the head of the valley system, where permeability and effective aquifer thickness is lowest, and the volumes of water in the catchment are greatly reduced. Small dry valleys in the head of the system are rarely associated with high permeability features."*

With respect to the UKOG site setting there is no evidence or references presented to substantiate the claim made in the last sentence. Furthermore, the transmissivity of the Chalk is known to be highly variable, and the tendency for higher transmissivity to occur in dry valleys than on interfluves is a general trend that does not preclude high transmissivity from occurring elsewhere. This is amply demonstrated by, amongst others, Maurice (2009) and Allen *et al.* (1997).

Overall, the manner of argumentation adopted by Envireau Water (2017) is to present a conceptualisation of Chalk permeability which is broadly correct but based only on generalisations (for which there are many exceptions), and to then insist that the UKOG site must be located on impermeable ground because it satisfies the criteria presented by a general model. They continue:

> *The Havant dry valley to the west of the site has a number of branches, the closest of which is located adjacent to the north-western side of the site and runs to the southwest where it joins the main dry valley approximately 2km away at Finchdean. Another branch is present to the south of the access track at Forestside and also runs to the southwest towards the main dry valley feature. As shown on the hydrogeological map (Figures 4a and b), these two features are also located on the lower permeability interfluve area and groundwater movement along such features will be much lower than along the axis of the main valleys."*

The last sentence presents an entirely circular argument as the 'interfluve' has been defined only by excluding the dry valleys that are now at this late stage acknowledged. That exclusion is then used to dismiss the potential high permeability of those very features. This is extremely poor reasoning.

A more rigorous, and perhaps honest, scientific discussion of the situation would place acknowledgement of those (dry valley) features within their correct context of 'Principal Dry Valleys' as is clear from (at least) 1978 onwards. Such a discussion should appear much earlier in the report as it forms an integral part of not only the geological and groundwater setting, but also the topography and surface hydrology.

EW 5.6 Sinkholes and Other Solution Features

EW 5.6.1 Geological Relationship

> *"Solution features can extend to depths of 10m and are typically filled with sandy-clayey sediment without any surface expression..."*

The potential permeability of such sand-containing deposits is significant. Edmonds (1987) and (1988) present detailed discussions of solution feature sediments noting brecciated soil fabrics, small-scale shear surfaces, slickensides, geochemical alterations, and the development of networks of small tubular pores and microvoids (not mention macro-scale voids that can migrate to the surface causing sinkhole collapse). All of these phenomena are related to groundwater percolation through these features (well, the term 'solution' feature is a bit of clue!).

EW 5.6.2 Databases

The databases referred to in EW 5.6, as discussed in EGG Consultants (2017), are incomplete partly as a function of focus on the more obvious solution features in the district, and partly due to the focus of particular studies relating mostly to commercial and infrastructure developments (e.g. the Hazleton Landfill Public Inquiry). The BGS record cited is also incomplete as noted. This section does however note the importance of the boundary of the Clay-with-Flints with respect to the development of solution features.

EW 5.6.3 Site level verification

With respect to the aerial photography and LiDAR data presented on Figures 8 & 9, this may be compared directly with the LiDAR assessment presented in EGG Consultants Ltd (2017), the results of which are also shown on Technical Note Figure 1. It appears that the majority of potential karst solution features in the wider Markwells Wood area have not been recorded by the Envireau Water study.

Additionally, insufficient thought has been given to the potential origin of the observed 'flint pits', and no justification is given for this interpretation of the origin of those observed features. Please refer to EGG Consultants Ltd (2017) for further discussion.

EW 5.6.4 Site experience

Please compare the following statements from Envireau Water (2017) and the original hydrogeological risk assessment by Hydrock (2016):

Envireau Water (2017), pg. 15:

> *"The only fluid loss was recorded at a depth of -20mAOD (~130mbgl), which suggests a higher permeability zone within the Chalk at this elevation."*

Hydrock (2016), pg. 14

> *"Circulation losses (i.e. loss of drilling fluid into the formation) were experienced when drilling into the Upper Chalk at 131 m, which was cured by placing pebbles and aggregate into the borehole. Circulation losses occurred again at 231m (still in Upper Chalk) which continued throughout the drilling of the 17 1⁄2" hole into the Wealden Beds."*

Not only is this a negligent omission of facts by Envireau Water, they consistently fail to recognise that drilling fluid losses illustrate not only the likely ubiquity of karst features within the area, but that the generalisations upon which the risk assessment is based are inadequate for determination of risk at the specific site in question.

Overall, multiple wells/boreholes within the vicinity of the site, including the one on the site for which the risk assessment is specifically being made, tap some kind of karstic flowing feature. It is therefore entirely possible that local groundwater velocities may be in the region of ~km/day.

EW 5.6.5 Summary

The bullet points of the summary are addressed as follows:

- *“The occurrence of the majority of features is associated with the Chalk-Palaeogene boundary”*

As discussed above, the studies associated with mapping these features are incomplete, and the Envireau Water (2017) assessment has missed many such (potential) features in the vicinity of the site. Thus they are not in a position to state where the majority of those features occur.

- *The density of features on exposed Chalk is very low*

EGG Consultants Ltd (2017) found a higher incidence based on the same LiDAR imagery data.

- *The density of features associated with the clay-with-flints is low*

This is completely incorrect. Please see Technical Note Figure 1 and EGG Consultants Ltd (2017).

- *There are no large solution features at, or in the immediate vicinity, of the site*
- *Fractures have been encountered at depth within the saturated chalk below the site*

There is no knowledge (presented) of the nature of the cavities developed at depth on site, apart from the fact that they must be of sufficient capacity to rapidly transport drilling fluids away from the well bore. This itself suggests potential (if not probable) solutional enhancement, as turbulent flow is required for the transport of sediments. Additionally, as the LiDAR data and Technical Note Figure 1 illustrate, there are potential solution features in the immediate vicinity of the site, the two closest being less than 50 m from the site. Given these observations, the statement that there are no 'large' solution features at (or in the immediate vicinity) of the site cannot be accepted as valid.

<u>EW 5.7.1 Havant Bedhampton Springs</u>

Worthington (2015) presents a whole series of examples in which Source Protection Zones in carbonate aquifers have completely failed to reflect the actual velocities and travel times of groundwater. He draws one example from the Chalk (after Cook *et al*., 2012) in which he states:

> *“ In the Lee Valley north-east of London, source protection zones for three public-supply wells gave 50-day time-of-travel zones that extended about 1 km upgradient from the wells. However, tracer studies showed that the travel time for a distance of 16 km to the wells was a mere four days, demonstrating that the modeled source protection zones were far too small”*

(Worthington, 2015).

There are numerous other experiments with similar results (see for example Ward *et al* (1998) for summary details of 42 groundwater tracer tests in the English Chalk).

The matter of SPZs and their validity was discussed in EGG Consultants (2017), the conclusion was that:

> *“...there is little argument to substantiate the boundaries of the current SPZ1 and SPZ2 divisions. The delineation of those zones appears to be based on incomplete mapping of*

surface karst features; a highly simplistic transmissivity distribution used for making basic contaminant transport calculations; and that those contaminant transport calculations were in any case inappropriately selected."

EGG Consultants Ltd (2017) pg. 6

To their credit Envireau Water (2017) do describe the Karst Zones of Maurice et al. (2012) and state that there could potentially be solution features at or around the site, but this is at general variance with the insistence that the site is located in a *'very different hydrogeological setting'* and is not given sufficient weight in the conceptual model.

EW 5.7.2 Other Sources

The location of the site on the eastern edge of the Outer (Source Protection) *Zone of the catchment reflects the much lower permeability of the Chalk at this location and low groundwater flux relative to the Chalk in the axis of the valley.*

Modern catchment boundaries bear little resemblance to catchments as they were during the earliest phases of Chalk karst development (i.e. between 60 and 70 million years ago), and they probably don't reflect catchments throughout much of the early Pleistocene[7]. McDowell *et al* (2008), who are cited numerous times by Envireau Water (2017), devote a significant portion of their paper to describing karst development in the area. At best what Envireau Water are left with is another another non-site-specific argument from general conceptualisation.

5.8.1 Private Access Track

"The private access track is shown within the context of underlying geology on Figure 3b, which shows that for almost all of its length it is underlain by the clay-with-flints deposit. This is a low permeability material which affords considerable protection against vertical migration of fluids"

Envireau Water (2017), pg.17

The Clay-with-Flints are classified by the Environment Agency (2014[8]) as a having a soil vulnerability category of Intermediate 1 (I1), which is described as *'Soils which can possibly transmit a wide range of pollutants'.* The two descriptions are at considerable variance.

Regarding Clay-with-Flints permeability, one clue may have been had with regard to information presented in section EW 2.4 Soils (pg. 2), where it is stated that:

"The soil type at the site… is classified as 'freely draining slightly acid loamy soils' and 'draining to local groundwater and rivers'"

7 The dates of which Envireau Water get wrong.

8 Environment Agency (2014). New groundwater vulnerability mapping methodology.

Further details regarding sand lenses, basal gravels and other commonly encountered permeable components of the Clay-with-Flints are given throughout the literature, for example McDowell *et al* (2008), Allen *et al* (1997) and Maurice (2009), all of whom are cited by Envireau Water (2017). In opposition to this wealth of information, Envireau Water (2017) continue (pg. 18):

> *“It can be concluded that there are no special geological or hydrogeological pathways associated with the private access track, and that almost the entire length affords protection to the underlying chalk aquifer by virtue of the presence of the clay-with-flints deposit.”*

This conclusion is also incorrect.

EW 6 Conceptual Hydrogeological Model

This has mostly been dealt with above, however (pg. 19):

> *“No solution features were encountered during the construction of the site in 2010 and therefore it is known that there are no features below the well pad itself.”*

Regarding construction of the site; the diagrams presented at EW Appendix B show the proposed pad construction details (Barton Willmore (2016) drawing no. P49). The pad is shown and cited as constructed employing a cut-and-fill platform with a base level of approximately 113 maOD, with what appears to be at most 2 m of ground removed at the deepest point of the cut. 113 maOD is approximately the original ground level as per the Ordnance Survey mapping (e.g. Figure 2b). The site visit reported (EW4.2 pg. 5) that less than 5 m of Clay-with-Flints is expected on site. Where the site has been cut, there is thus a potential 3 m discrepancy. Where it has been filled, it unlikely any significant excavation took place at all, perhaps only some surface preparation. Therefore, without further photographs or supporting evidence it is not clear whether the surface of the Chalk was exposed, as it would only be at that point that solution features would become apparent.

EW 7 Environmental Setting

EW 7.3 Source Protection Zones (SPZs)

A very perfunctory description of SPZs is given, with no analysis of the potential suitability or otherwise of these defined areas. Please see EGG Consultants Ltd (2017) for further details.

EW 8 UKOG's Development at Markwells Wood

No comments on this section.

EW 9 Hydrogeological Risk Assessment

Please note in the first instance that the methodology cited by Envireau Water (2017) (H1 Environmental Risk Assessment framework – Annex J: Groundwater. (Environment Agency, 2010)) was withdrawn on 1st February 2016[9]. However, the selection of the Risk Assessment Tier remains the same under the replacement guidance[10] and the Tier selected was Tier 1: Qualitative Risk Screening. The Tier 1 screening is deemed appropriate on the basis that:

> *"The assessment of geology and hydrogeology carried out by Envireau Water demonstrates a good understanding of the local geology and hydrogeology."* (Envireau Water pg. 24).

This is clearly not the case as discussed extensively throughout this Technical Note.

As a general point, considerable effort is taken to demonstrate the 'low permeability' of the Chalk in the area of the site, yet in the final assessment the aquifer is given a 'Very High' receptor sensitivity, and a 'High' magnitude of impact, and a correspondingly 'Major' significance of effect for the realisation of potential hazards. However, this is then, again more-or-less summarily, dismissed on the basis of claiming likelihood as either 'Unlikely' or 'Very Unlikely' and the risks, according to the methodology, become either 'None' or 'Very Low'.

This begs the question as to why so much effort has been spent attempting to illustrate 'low permeability' at the UKOG site. The answer is probably that having claimed that only a Tier 1 assessment is appropriate, they then need to demonstrate why. However, given the levels of uncertainties in the conceptualisation, combined with the sensitivity, vulnerability and strategic national importance of the receptor, there is a strong case for demanding that additional Tiers of Risk Assessment are performed (if the application isn't immediately rejected on the basis of the flaws outlined throughout this Technical Note).

There has not been sufficient time available to fully assess all of the potential source-pathway-receptor pollutant linkages against definitions of risk, or the basis for claims made by Envireau Water (2017) regarding risk mitigation. However, notwithstanding the above comments, one issue that does stand out:

> *"The likelihood that drilling operations will result in loss of fluids into groundwater in the Chalk is considered as 'moderate'."*

Referring to Table 4 from which the qualitative likelihood of occurrence is described, a 'Highly Likely' scenario is described as one in which an uncontrolled known discharge has a high probability of occurrence. As this did already occur at the original UKOG MW1 well at multiple depths, there is certainly a high probability of it occurring again. Thus, the likelihood should be 'Highly Likely'. Such downplaying of risk challenges the notion that Envireau Water represent an objective assessor of the available information.

9 https://www.gov.uk/government/publications/h1-environmental-risk-assessment-for-permits-overview
10 https://www.gov.uk/guidance/groundwater-risk-assessment-for-your-environmental-permit

3.0 SUMMARISING REMARKS

EW 10 Summary

Comments will be made on a paragraph-by-paragraph basis for the summary of the main findings of the hydrogeological assessment. This is somewhat repetitive of the criticisms made above, but some additional remarks are made.

> *The hydrogeology of the South Downs is dominated by a series of chalk dry valley features, which drain southwards towards the sea. The dry valleys have developed through solution weathering along lines of structural weakness associated with lineaments in the underlying geology and basement structure. Groundwater flow is concentrated along solution features leading to rapid groundwater movement; particularly in the lower reach of the valleys. Sinkholes and other solution features are observable at surface at the junction between the Chalk and the overlying Paleogene strata.*

So far so good. However;

> *The existing Markwells Wood site is situated at the head of a dry valley on the edge of an interfluve between two significant dry features – the Havant and Emms valleys. Available data demonstrates that the chalk in the interfluve area exhibits a lower permeability than the chalk within the main reach of the dry valleys. The potential for solution weathering and rapid groundwater movement is therefore greatly reduced.*

The only site-specific data presented to support the contention that there is lower permeability at Markwells Wood than the surrounding area are A) The lack of karstic depressions at the surface, B) Groundwater fluctuations at the Woods Copse Forest borehole, C) Groundwater contours on the IGS regional-scale hydrogeology maps (IGS (178, 1979). Of these, the first is incorrect as it is based on an incomplete survey; the second indicates where the strongest development of solution features is likely to be; and the third is of low spatial resolution on the scale of the UKOG (sub)catchment. The implication of the fact that the only site investigation borehole drilled on the site (MW1) did encounter cavities at multiple depths is to refute the entire argument of low permeability and hence low groundwater vulnerability at the UKOG site.

> *"Solution features are known to develop at the edge of the overlying clay-with-flints deposit that is present at the site. Such features tend to be up to 10m in depth and sediment filled with little if any surface expression. They do not act as a conduit for rapid infiltration of water into the saturated chalk."*

The statement that "*They do not act as a conduit for rapid infiltration of water..."* is badly wrong. There is no material presented to support this contention other than Envireau Water's general hope that such conduits might be full of deposits derived from the Clay-with-Flints, which is clayey. This not only directly contradicts their own assessment of conduit fill material being 'sandy-clayey', but completely ignores significant conclusions from important works in the field that they themselves cite.

Overall Envireau Water (2017) demonstrate only a very limited understanding of the mechanisms of formation of different types of solution feature. No distinction is drawn between types of solution feature, and no consideration is given to how these features may transmit sediments and runoff from the surface into the aquifer. This represents a significant weakness of the risk assessment.

> *Groundwater levels in the Chalk at the site are at least 60m below ground level at the site. Consequently, there is a significant hydraulic break between activities at the site and the saturated chalk.*

This ignores understanding of how rainfall recharge passes through the Chalk unsaturated zone (e.g. Butler *et al,* 2012), and also misses the point that solutionally enhanced permeability features (e.g. dolines) may facilitate rapid flow through the unsaturated zone. Continuing:

> *The Havant and Bedhampton Springs receive water from a large catchment area and the site is located at the edge of this catchment, some 9 km to the northeast. Based on the known hydrogeological setting, there is unlikely to be a significant flux of groundwater from the chalk at the site towards the springs. Groundwater movement in the Chalk at the site will be greatly reduced in comparison to movement along the axis of the dry valleys. Consequently, there is not the same potential for rapid groundwater movement from the site to the public water supply at Havant and Bedhampton Springs, as there is elsewhere in the catchment.*

These statements represent no more than generalisations describing average Chalk hydrogeological conditions, which, at such a sensitively located site, does not form an adequate substitute for a site-specific risk assessment. Regarding groundwater flux, we know it is a function of hydraulic head, and so some degree of flux may be estimated from the information held. Whilst no attempt is made, it is an obvious area in which to begin tightening the conceptualisation.

> *The hydrogeological conceptual model is based on an extensive literature review, supported by site specific information in the form of high-resolution aerial imagery, site walkover observations and information obtained during the construction of the site and the Markwells Wood-1 well. The conceptual model presented is consistent with that put forward by the BGS.*

These claims to rigour and authority are not borne out by the results, as the contents of this Technical Note illustrate. The conceptualisation presented by Envireau Water (2017) is not consistent with many of the findings underpinning the BGS conceptual model, e.g. the permeability of the Clay-with-Flints, the potential permeability of sediment infill of solution features, and the distribution of flowing karst features across interfluvial areas. The BGS conceptualisations (e.g. Allen *et al,* 1997; Maurice *et al,* 2012) are much more thorough than the one presented here. Much pertinent material has been omitted by Envireau Water (2017) to the detriment of the risk assessment.

> *"A risk assessment carried out in accordance with Green Leaves III demonstrates that the risks associated with the proposed development and transport route can be mitigated and residual risks are 'very low'. The only exception is the 'low' risk that is associated with drilling new wells through the Chalk aquifer to set casings. This risk cannot be eliminated but can be mitigated and is no greater than the risks associated with conventional water well drilling"*

To recap, the starting point of this hydrogeological risk assessment was that *"...the objections can be addressed… focussing in particular on clarification of the hydrogeological conceptual model upon which to base a robust risk analysis." (*Envireau Water, 2017, pg. 1). This has clearly not been achieved.

> *Given the sensitivity of the proposed development, the risk assessment has been carried out conservatively. The findings are a result of the high level of embedded mitigation within the design and construction of the existing site and the existing Markwells Wood-1 well, combined with additional mitigation that will be provided through the implementation of robust environmental management systems including waste management plans, traffic management plans and UKOG's own in-house operating systems.*

Envireau Water (2017) would have us believe that this hydrogeological risk assessment forms part of a 'robust environmental management system'. However, it is unfortunately apparent that the majority of errors made by Envireau Water (2017) favour the position of their client. There is a consistent downplaying of the groundwater vulnerability on and around the site, including:

- Arbitrary dismissal of dry valleys tributary to the Havant as likely high permeability corridors;
- Claiming that dolines cannot form rapid pathways to groundwater due to the composition of their fill materials, when the literature is very clear on well-recognised permeability features throughout these fill materials (e.g. sand & gravel lenses and voids);
- Claiming that the Clay-with-Flints deposits offer a significant barrier to contaminant transport when again the literature (and the Environment Agency designation) is very clear on the well-recognised permeability features throughout these deposits;
- Claiming that the distribution of potential solution features on or near site is very low when in fact surface solution features are very frequent in the area and fall within 50 m of the site boundary, and that solution features were encountered at several depths immediately beneath the site during drilling;
- Misinterpretation of groundwater level time series.

- The manner of argumentation adopted presents an unsophisticated conceptualisation of Chalk permeability which, whilst broadly correct, both misses a considerable amount of information, and is based predominantly on generalisations to which there are many exceptions. The conceptual model as presented insists that the site must be located on low-permeability Chalk because it satisfies the criteria presented by a general model.

In conclusion, whilst Envireau Water do show some basic understanding, and have attempted to frame a broad hydrogeological conceptualisation, they never proceed to any greater insight than this and ultimately fail to capture much of the pertinent available information. Several serious misinterpretations and omissions undermine the credibility of the conceptualisation, and thus the basis of the risk assessment. The conceptual model as presented seriously underestimates the potential capacity of the Chalk to rapidly transport contamination away from the Markwells Wood area and toward the springs at Havant & Bedhampton, and for this reason is not fit for purpose.

It is unfortunately apparent that the majority of errors made by Envireau Water (2017) favour the position of their client.

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