TECHNICAL ADDENDUM:

West Newton A wellsite. WNA-2 reservoir stimulation HRA

Prepared for:	Rathlin Energy (UK) Limited
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Authors

	Name	Signed
Prepared by	David Banks - Principal Hydrogeologist	D. Banks
Checked by	Phil Ham - Principal Hydrogeologist	Philip Ham
Approved by	Phil Ham - Principal Hydrogeologist	Philip Ham

Midlands Office
The Bank Chambers
39 Market Place
Melbourne
Derbyshire
DE73 8DS

Tel: 01332 871 882
E mail: info@envireauwater.co.uk
Web: www.envireauwater.co.uk

1 INTRODUCTION

1.1 Background

1.1.1 Existing planning consent and environmental permit

Rathlin Energy (UK) Limited (Rathlin) submitted a planning application in 2021 for the proposed extension of its existing West Newton A Wellsite (the Wellsite) near Aldbrough in the East Riding of Yorkshire. Figure 1 shows the Wellsite location and surrounding area. At the Wellsite, Rathlin proposes to drill, test, appraise and produce from the two existing wells; and drill, test, appraise and produce from up to a further four new wells. The overall duration of all phases of the proposed development will be up to 25 years.

Envireau Water (Envireau) were commissioned to produce a comprehensive hydrogeological risk assessment (HRA) and flood risk assessment (FRA) to accompany the application (Envireau Water, 2021).

The application was approved by East Riding of Yorkshire Council on 17th March 2022.

On 23rd August 2023, an environmental permit was issued by the Environment Agency (EA, 2023) to (amongst other activities):

- Carry out further appraisal works and workover activities on the existing wells for the purpose of gathering additional information over the extent of the hydrocarbon reservoir.
- Drilling of a sidetrack from each of the existing wells.
- Drilling of up to six additional wells.
- Undertake well treatments and well cleanup activities for each additional well to be drilled (including all sidetrack wells).
- Appraisal testing of each additional well, including sidetrack wells.

1.1.2 Proposed reservoir stimulation work

It is now proposed to carry out a reservoir stimulation activity on the existing well WNA-2 (drilled 2019), targeting the Permian age Kirkham Abbey Formation (KAF) at approximately 1.7 km depth, to re-establish permeability within the KAF, having been impeded by formation damage as a result of the initial drilling and completion operation.

In support of the permit variation application, Rathlin has prepared a Waste Management Plan (Rathlin Energy, 2024), which includes a reservoir stimulation activity.

This Technical Addendum has been prepared to supplement the original HRA prepared in 2021 and, specifically, to support an application to the Environment Agency to carry out the reservoir stimulation activity, which may be classed as one, some or all of (a) a mining waste activity, (b) a groundwater activity, (c) a water discharge.

In April 2024 Envireau Water was engaged by Rathlin to prepare HRA of the reservoir stimulation activity in WNA-2 (this report) to support the original HRA prepared in 2021 (Envireau Water, 2021). This report is the result of that engagement and details a HRA specific to the reservoir stimulation activity. It is not intended to be a standalone document but is written as a supplement to the original HRA (Envireau Water, 2021), to which frequent reference is made in this report.

1.2 Scope of Work

This report assesses the potential hydrological and hydrogeological impacts of the proposed reservoir stimulation activity, over and above the impacts of the general wellsite development considered in the original HRA (Envireau Water, 2021). The HRA in this report is based on the hydrogeological conceptual model developed by Envireau Water following a comprehensive, desk-based review of the information listed in Section 1.4 of the original HRA (Envireau Water, 2021) and Section 1.3 of this report. The scope of work undertaken for this HRA will reference the conceptual hydrogeological model already developed and will specifically consider:

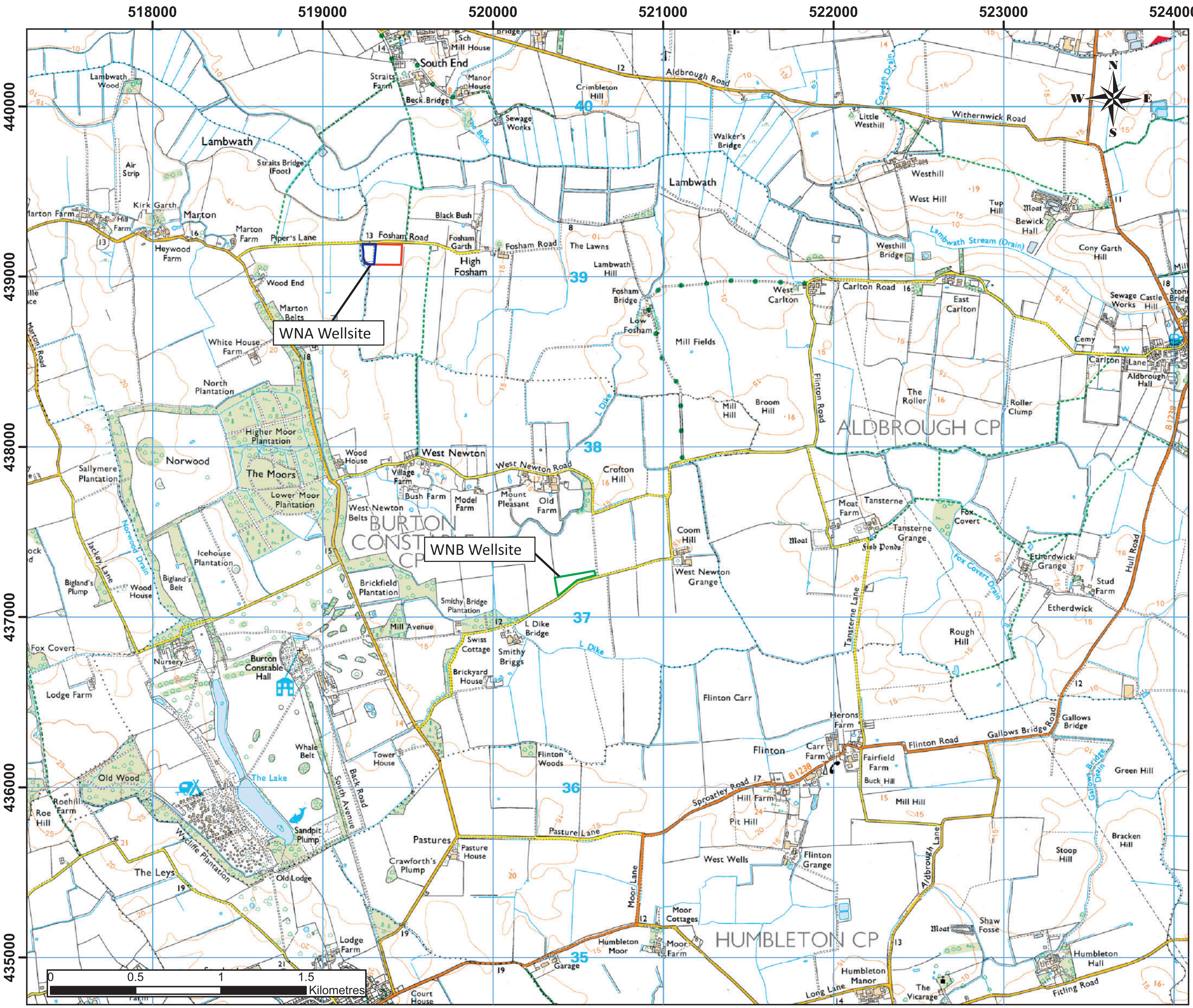
- Any additional risks from well workover / stimulation chemicals and fluids stored and applied at the surface well pad. These will be assessed against the existing risk assessment methodology and matrix documented in Section 6.3 of the original HRA (Envireau Water, 2021).
- Any additional subsurface risks from migration of hydrocarbons, formation waters or stimulation chemicals as a result of the reservoir stimulation activity. These will be assessed using the BGS 3DGWV methodology (Loveless S. , et al., 2018; Loveless S. , et al., 2019), applied in Section 6.3.11 of the original HRA (Envireau Water, 2021).
- Any potential seismic hazard resulting from the reservoir stimulation activity.

The HRA has been conducted taking account of the risk assessment approach described by the Department for Environment, Food and Rural Affairs (DEFRA) in Green Leaves III (GL III) (DEFRA and Cranfield University, 2011) and the Environment Agency's approach to groundwater protection (EA, 2018) and associated technical guidance (EA and DEFRA, 2018; EA, 2020a).

1.3 Data Sources

The information and assessments in this report are based on:

- The data sources already documented in Section 1.4 of (Envireau Water, 2021).
- A seismic risk assessment subcontracted from Outer Limits Geophysics LLP by Rathlin, to specifically evaluate this hazard (Outer Limits, 2024).
- A report prepared in February 2024 by RPS Energy Canada Ltd to assess the potential of the West Newton A wells (RPS, 2024).



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Scale 1: 25,000 at A3

KEY

- WNA Wellsite Extension Boundary (red)
- WNA Wellsite Boundary (blue)
- WNB Wellsite Boundary and Access Track (green)

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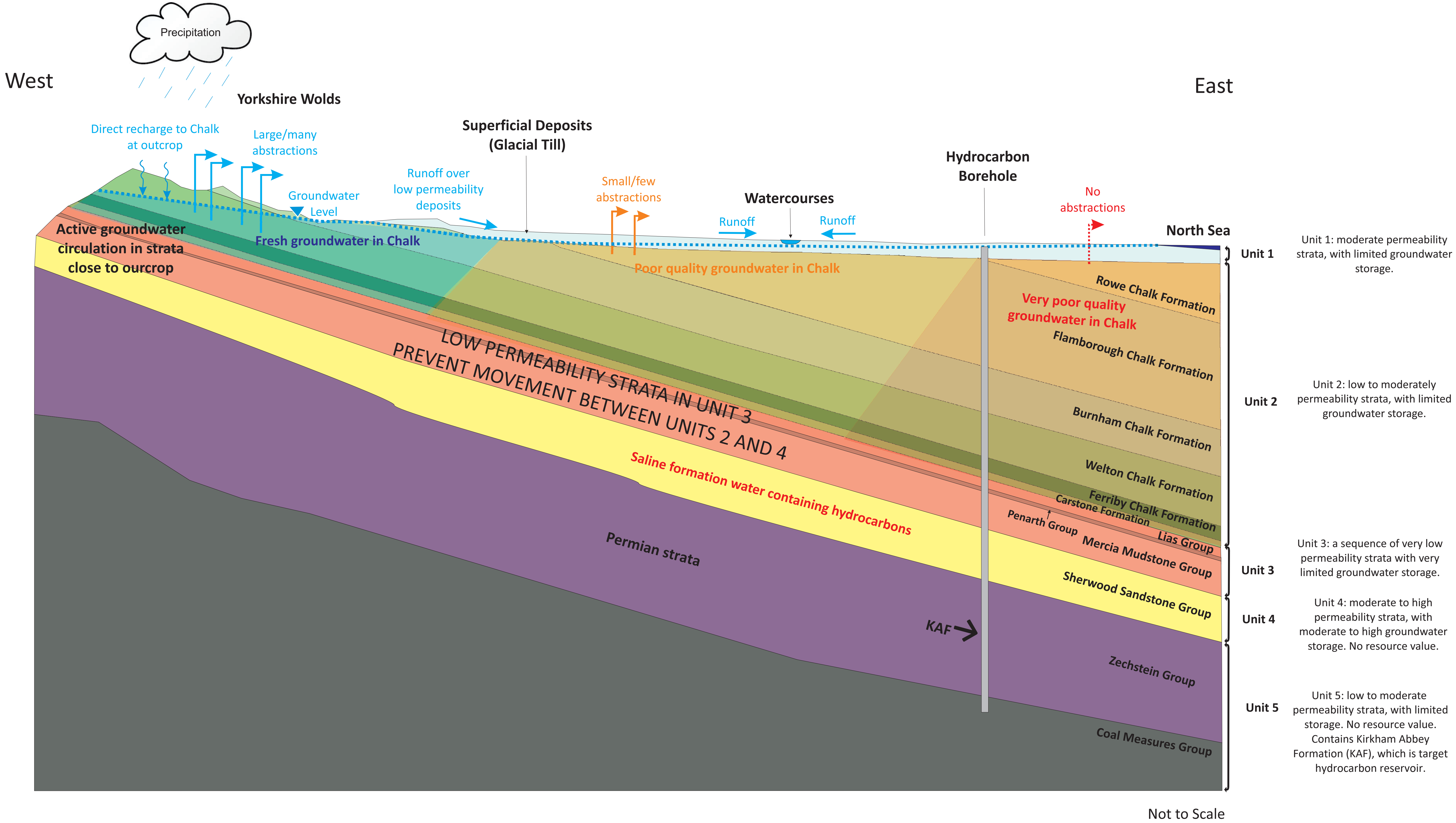
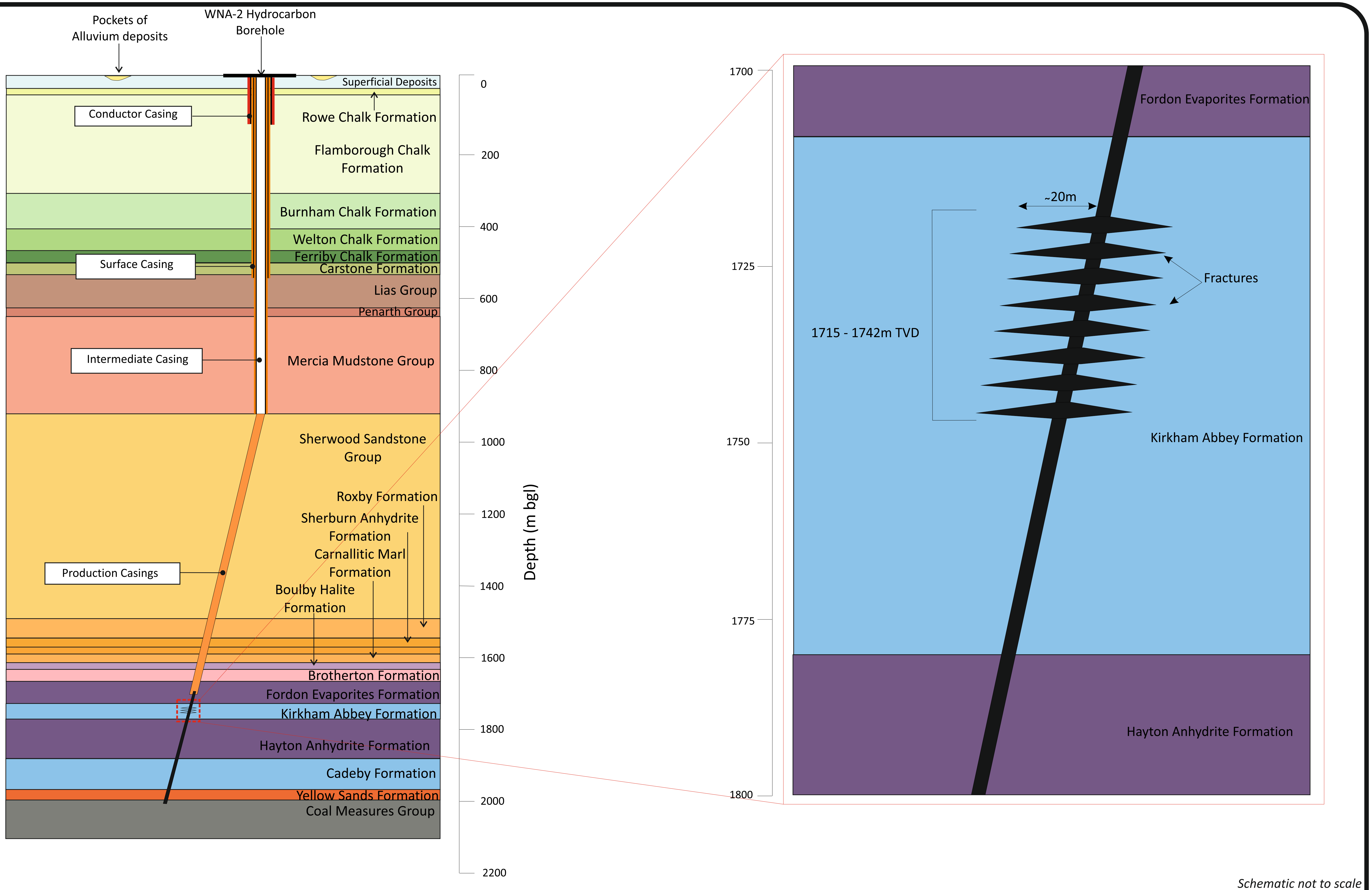
Ref: 3490933 - Rathlin WNA Well Stim\ FIG1 WNA All Wellsites Date: 25/06/2024	**Rathlin Energy**
Figure 1	West Newton Well Sites



Adapted from Figure 3.3 of BGS Baseline Report Series: The Chalk Aquifer of Yorkshire and North Humberside (2004).

Ref: 3490933 - Rathlin WNA Well Stim F \FIG2 - WNA HCM Regional Date: 16/07/2024	**Rathlin Energy**
Figure 2	Hydrogeological Conceptual Model



Schematic not to scale

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Ref: 3490933 - Rathlin WNA Well Stim\FIG 3 - Reservoir Stimulation Date: 15/07/2024	**Rathlin Energy**
Figure 3	Reservoir Stimulation

2 BASELINE CONDITIONS

2.1 Topography, Hydrogeology, Hydrology

The baseline topographic and hydrological conditions are comprehensively documented in the original HRA (Envireau Water, 2021). These remain essentially unaltered and will not be recapitulated here.

2.2 Geology, Hydrogeology and Groundwater Quality

The geological and hydrogeological conditions at the site are also documented in the original HRA (Envireau Water, 2021) and summarised in Figure 2. We will here recapitulate Tables 2 and 4 of the previous report as Table 1 (generic stratigraphic sequence of the wellsite, updated from Envireau Water (2021) to reflect specific vertical sequence in WNA-2) and Table 2 (hydrogeological succession), as they are key to the assessment presented in the report.

Table 1 Stratigraphic sequence at the Wellsite[1,2,3]

Period	Group/Formation		Description	Thickness (m)[4]	Approximate Depth to Base of Unit (m TVD)[5]
Quaternary	Glacial Till		Clay, silt, sand, and gravel	53	53
Cretaceous	White Chalk Subgroup	Rowe Chalk Formation	Flint-bearing chalk with sporadic marl bands.	18	71
		Flamborough Chalk Formation	Well-bedded, flint-free chalk with common marl seams (typically about one per metre). Common stylolitic surfaces and pyrite nodules.	265	336
		Burnham Chalk Formation	Thinly bedded chalk with common tabular and discontinuous flint bands and sporadic marl seams	95	431
		Welton Chalk Formation	Thickly bedded chalk with common flint nodules; generally lacking tabular flint bands; sporadic marl seams including the Plenus Marls Member	60	491
	Grey Chalk Subgroup	Ferriby Chalk Formation	Marly, flint-free chalk, some harder, gritty, beds, and thin discrete marl seams.	10	501
	Cromer Knoll Group	Hunstanton Chalk Formation	Rubbly to massive chalks with marl bands. The lower part of the formation is commonly weakly sandy.	5	506
	-	Carstone Formation	Coarse sandstone with interbedded mudstone	26	532

Period	Group/Formation		Description	Thickness (m)[4]	Approximate Depth to Base of Unit (m TVD)[5]
Jurassic	Lias Group		Well-bedded marine calcareous mudstones and silty mudstone with thin beds of argillaceous limestones and sandstones	93	625
Triassic	Penarth Group		Mudstones with subordinate limestones and sandstones	19	644
	Mercia Mudstone Group		Mudstones with subordinate siltstones, sandstones and evaporites.	284	928
	Sherwood Sandstone Group		Sandstones with some conglomeratic beds and subordinate siltstones/mudstones	562	1490
Permian	Zechstein Group (Undifferentiated including: Roxby Formation, Sherburn Anhydrite Formation, Carnallitic Marl Formation, Boulby Halite, Billingham Anhydrite Formation)		Mudstone and siltstone overlying an evaporite sequence (predominantly anhydrite and halite)	97	1587
	Zechstein Group	Brotherton Formation	Dolomitic limestone	55	1642
		Fordon Evaporite Formation	Varied sequence of evaporites including anhydrite and halite, with some gypsum and dolostone	51	1693
		Kirkham Abbey Formation	Oolitic dolostone with subordinate thin beds of fine-grained dolomite. Breccias also present.	64	1757
		Hayton Anhydrite	Anhydrite and dolomite	163	1919
		Cadeby Formation	Dolomite with variable amounts of anhydrite	37	1956
	Rotliegend Group	Yellow Sands Formation	Sandstone	18	1974
Carboniferous	Coal Measures Group		Mudstone, sandstone, siltstone, and coals	>500	>2500

[1]*Target hydrocarbon reservoir is highlighted green*

[2]*Major geological unconformities are depicted by red undulating lines*

[3]*Well sequence has been updated from* (Envireau Water, 2021) *to reflect specific sequence in WNA-2*

[4]*Thicknesses based on well schematic in End of Well Report for WNA West Newton A-2 well and geological map*

[5]*TVD stands for True Vertical Depth in m below ground level*

Table 2 Hydrogeological Sequence

Superficial Deposits	Secondary (undifferentiated)	The superficial deposits at the Wellsite and surrounding area comprise glacial till; alluvium around the Lambwath Stream to the north; and sporadic pockets of glacial sand and gravel deposits. The glacial till is classified by the Environment Agency as a Secondary (undifferentiated) aquifer, an aquifer with only minor value. Layers of sand and gravel within the glacial till have the potential to contain and transmit groundwater. These layers are likely to be discontinuous but may support small, locally important supplies. Recharge to the superficial deposits will be via direct infiltration of rainfall at surface. Based on the geological logs local to the Wellsite, the glacial till has a high clay content and therefore will have a low permeability. Where shallow higher permeability material is present both in the glacial till, alluvium and glaciofluvial deposits, surface water features may receive some flows from groundwater. However, due to its substantial thickness, the till will act as a hydraulic barrier between the surface water system and underlying groundwater in the bedrock.
Chalk Group & Carstone Formation	Principal Aquifer and Secondary A	The Chalk Group is classified by the Environment Agency as a Principal Aquifer and is an important source of water for drinking, agricultural and industrial use at a national and regional scale. However, in the Holderness Peninsula, the Chalk Group is confined by ~50 m of low permeability superficial deposits and is rarely used for water supply due to the restricted groundwater circulation and the resulting poor quality of the groundwater (Allen, et al., 1997). The Carstone Formation is a thin sandstone unit classified as a Secondary A aquifer by the Environment Agency. It is generally considered to be in hydraulic continuity with the overlying chalk. Groundwater movement within the chalk occurs through joints and fractures with very limited contribution from the rock matrix. Fracture networks are well developed within the top 30 – 40 m of the unconfined formation but much less so where the chalk is overlain by glacial till in the Holderness Peninsula (Smedley, Neumann, & Farrell, 2004). Recharge to the chalk occurs via direct infiltration of effective rainfall at outcrop, the nearest outcrop lies in the Yorkshire Wolds ~21 km west of the Wellsite. Groundwater flows west to east down dip from the Yorkshire Wolds and either emerges as springs at the edge of the superficial cover or is abstracted for use. Further east, where the Chalk is overlain by a thick sequence of superficial deposits (as is the case at the Wellsite), there is very limited active recharge/circulation. Groundwater flow and at the Wellsite is therefore limited. Test pumping data from the BGS show transmissivity values are highly variable, but transmissivity values recorded in the chalk aquifer of the Holderness Peninsula are towards the lower end of the range, and typically less than 50 m^2/day as a result of minimal fissuring and limited groundwater flow (Smedley, Neumann, & Farrell, 2004). Storage coefficient values range from 1.5×10^{-4} to 1.0×10^{-1} with a geometric mean of 7.2×10^{-3} (British Geological Survey, 2006). The wide ranges reflect the difference in confined and unconfined chalk aquifer properties across the region. In the Holderness Peninsula, groundwater levels are controlled by (and are therefore close to) sea level. The low-lying topography means groundwater levels are typically close to surface and may be locally artesian (Smedley, Neumann, & Farrell, 2004). Monitoring boreholes drilled at the Wellsite targeting the Chalk Group, show that

		groundwater levels observed during construction were ~2 m AOD (approximately 10 m bgl) (Rathlin Energy, 2014) Groundwater levels in the West Newton B Wellsite monitoring boreholes (GWMBH01 and GWMBH02) located ~2.1 km southeast from the Wellsite, are at ~1 m AOD (Envireau Water, 2020). Although the two tells are located 150 m apart, groundwater level varies by only 1 – 2 cm, which confirms the very low hydraulic gradient in the chalk aquifer locally. Groundwater levels recorded in the Environment Agency monitoring borehole located ~1.6 km southeast range between 1 – 2 m AOD, which further confirms the locally low hydraulic gradient in the chalk aquifer (EA, 2020b).
Lias Group	Secondary B	The Lias Group is comprised primarily of low permeability mudstone. The Lias Group outcrops ~29 km west of the Wellsite and due to the deep confinement (>500 m) by the overlying Chalk and superficial deposits, will be unproductive at the Wellsite.
Penarth and Mercia Mudstone Groups	Secondary B	The Penarth Group and Mercia Mudstone Group form a thick succession of very low permeability mudstones with some subordinate sandstones and limestones. The Mercia Mudstone Group has an extremely low, vertical hydraulic conductivity and forms a confining layer above the underlying Sherwood Sandstone Group (Jones, et al., 2000). Any groundwater within the Mercia Mudstone Group will be limited to the thin limestone and sandstone horizons ('skerries'), which are classified by the Environment Agency as Secondary B aquifers. However, the Mercia Mudstone Group at the Wellsite is deeply confined by >600m of overlying formations and will therefore act as unproductive strata at this location. The Penarth and Mercia Mudstone Groups, together with the Lias Group, provide a significant low permeability hydraulic barrier between the overlying Chalk Group and the deeper water-bearing Sherwood Sandstone Group.
Sherwood Sandstone Group	Principal Aquifer	The Sherwood Sandstone Group is classified by the Environment Agency as a Principal aquifer and is an important aquifer resource at a national scale. The aquifer provides a significant source for public water supplies where it is at or close to outcrop. However, at the Wellsite it is deeply confined by in excess of 900 m of overlying strata and is not targeted for public or private water supplies. Recharge to this unit occurs via infiltration of rainfall in areas of outcrop ~45 km west of the Wellsite. Due to the depth of the Sherwood Sandstone, the distance from outcrop, and lack of a driving head for groundwater flow to occur, there is no active recharge and circulation of groundwater locally, and the strata contains connate, saline water (formation water). Studies of the deep Sherwood Sandstone Group in the Lincolnshire and Yorkshire area record permeability values of ~1 x 10^{-6} m/s. Whilst the permeability of the sandstone is likely to reduce with depth, high permeability horizons in the deep saline Sherwood Sandstone may be present (Envireau Water, 2014a) (Bricker, Barkwith, MacDonald, Hughes, & Smith, 2012). The overlying low permeability Lias Group, Penarth Group and Mercia Mudstone Group act as a significant hydraulic barrier between formation water within the Sherwood Sandstone Group and the more recently recharged water within the chalk.
Permian Strata	Principal and Secondary Aquifers	The Brotherton and Cadeby Formations are classified by the Environment Agency as Principal aquifers regionally, whilst other Permian formations are classified as Secondary aquifers. However, due to the distance from outcrop (>65 km west of the

		Wellsite) and depth of these strata at the Wellsite, they are unlikely to contain significant quantities of groundwater. Some formations will be unproductive. The Kirkham Abbey is being targeted for petroleum exploration and appraisal by Rathlin. These strata contain layers of mudstones and evaporites with a very low vertical hydraulic conductivity, which provide a 'capping layer' for the petroleum to accumulate, and a hydraulic break between any overlying water bearing formations. Well pressure tests carried out in the exploratory well at the Wellsite show that the petroleum reservoir in the Kirkham Abbey Formation confirm the 'capping layer' in the Kirkham Abbey Formation, which hydrodynamically isolates it from the other formations (Rathlin Energy, 2020b).
Carboniferous Strata	Secondary Aquifers	Productive sandstone layers in the Coal Measures Group are classified by the Environment Agency as Secondary aquifers where at, or close to, outcrop. Primary porosity and permeability generally decrease with depth due to the greater weight of overburden, compaction, and increased cementation (Jones, et al., 2000). Due to their depth at the Wellsite, and distance from outcrop (> 80 km west of the Wellsite), the Carboniferous strata are unlikely to contain significant quantities of groundwater.

2.2.1 Structure and Faulting

The published BGS geological map (British Geological Survey, 1998) indicates that the geological sequence below the site has a very shallow dip. The structure contour map on the base of the chalk suggests a general dip of around 1.2 to 1.4° to the NE.

Faults can act as barriers or conduits for groundwater flow and are therefore an important consideration for the development of a hydrogeological conceptual model, and the potential for hydraulic connectivity between different geological strata. Although the Carboniferous strata at depth are significantly eroded and faulted, Mesozoic strata are largely undeformed, and no significant fault structures have been encountered during drilling works at the Wellsite. Information previously prepared by Rathlin (Rathlin Energy, 2008) broadly confirms this interpretation, but maps and sections therein do suggest that faults in the Carboniferous extend up into the Permian in the vicinity of West Newton and play a role in creating structural hydrocarbon traps in the Permian. One section in the Rathlin report (Figure 10: Central Regional GeoSeismic cross-section) suggests that faulting may extend up to the base of the Sherwood Sandstone in a few cases.

The seismic hazard evaluation (Outer Limits, 2024) states there is "*no evidence for large faults cross-cutting through the Permian section into over- or underlying strata",* in the proximity of the site but that there is *"potentially some evidence for minor intra-Permian faults".* The map provided by Outer Limits (2024) as their Figure 4.1 suggests that the nearest fault is >500 m NW of the site. Outer Limits (2024) also *"conclude that there are no identified critically-stressed faults within a distance of the WNA-2 well that could be influenced by fluid injection of the scale and volume under consideration in this case".*

The published geological map (British Geological Survey, 1998) does show a fault structure extending from the Carboniferous into the base of the Chalk on a stratigraphic section around 5 km NW of the WNA wellsite, although the factual basis for this interpretation is not clear.

On balance, faulting is therefore not expected to provide a likely pathway at stratigraphic levels higher than the Permian for the migration of fluids and gases between the hydrocarbon bearing formations and the overlying strata containing useful groundwater.

2.3 Water Quality / Chemistry

2.3.1 Superficial Deposits

There are no published data on water quality of the superficial deposits close to the Wellsite. Water quality is expected to vary dependent on the composition of the strata and interaction with activities at surface. A BGS borehole record (30 m deep) targeting the superficial deposits located approximately 3.3 km southeast of the Wellsite records 'bad' water quality with elevated iron concentrations and hard water.

Being close to the surface, superficial deposits are susceptible to pollution from anthropogenic sources. Mixed farming dominates both the region and the land surrounding the Wellsite. Therefore, water quality in the superficial deposits is likely influenced by the historical use of fertilisers leading to the potential for elevated concentrations of common contaminants, including nitrate, sulphate, sodium, and chloride (Smedley, Neumann, & Farrell, 2004).

2.3.2 Cretaceous Chalk Group & Carstone Formation

Although the Chalk Group is classified by the Environment Agency as a Principal aquifer, the Chalk in the Holderness Peninsula is rarely exploited for water supply due to its poor water quality (Smedley, Neumann, & Farrell, 2004). Water quality is poor in this region because of its confined nature and limited groundwater circulation/active recharge. Regionally, groundwater in the confined Chalk aquifer is typically reducing and highly mineralised (Smedley, Neumann, & Farrell, 2004).

Saline intrusion in the eastern areas of the region further affects groundwater quality with elevated concentrations of sodium and chloride. Elevated iron concentrations have also been observed in the region. Dissolved methane concentrations typically range between 0.07 and 4.7 µg/l, although concentrations of up to 1,320 µg/l have also been reported (Downing, et al., 1985). Studies of dissolved methane in groundwater carried out by the BGS in Yorkshire and Lancashire indicate that the methane is likely to be of a biogenic origin (Darling & Gooddy, 2006; British Geological Survey, 2021).

Groundwater samples taken from monitoring boreholes at the West Newton A Wellsite and West Newton B Wellsite have been analysed; they are considered to be characteristic of the region and are summarised below:

- Groundwater is characterised as sodium-chloride-bicarbonate [Na^+-Cl^--HCO_3^-] type.
- Salinity at the Wellsite West Newton A is notably lower than at West Newton B. Sodium concentrations range between 160 and 190 mg/l at the Wellsite (compared to 400 and 500 mg/l at West Newton B.) whilst chloride concentrations range between 170 and 210 mg/l at the Wellsite (compared to 530 -720 mg/l at West Newton B). As the Wellsite is located over 1 km west of West Newton B (and therefore further from the coast) it is expected to have a lower salinity.
- Sulphate concentrations are also lower at the Wellsite ranging between 123 and 147 mg/l (compared to 178 and 208 mg/l at West Newton B) but are similar to the regional mean of 135 mg/l.

- Iron concentrations are variable ranging from 360 to 6,076 µg/l, which is within the reported regional values of 230 to 3,800 µg/l . Some observed concentrations at the Wellsite are higher than the reported regional maximum of 3,800 µg/l (Smedley, Neumann, & Farrell, 2004).
- Nitrate concentrations are typically less than 0.2 mg/l (the limit of detection) and consistent with the low expected concentrations resulting from the confined nature and reducing conditions.
- Dissolved methane concentrations of 13 to 21 µg/l were observed at the Wellsite and West Newton B and are consistent with regional literature data.

Water quality data is not available for the Carstone Formation. This unit is permeable, thin, and hydraulically connected to the Chalk aquifer and therefore groundwater quality may be similar to the Chalk.

2.3.3 Jurassic & Triassic Strata

There are no local water quality datasets available for the Lias Group, Penarth, and Mercia Mudstone Groups. Groundwater within these strata is likely to be highly mineralised and of poor quality due to deep confinement by overlying formations and the distance from outcrop (>29 km west). The stratigraphic situation is likely to result in limited recharge and low groundwater circulation.

The Sherwood Sandstone Group underlying the Wellsite is present at depths in excess of 900 m and is known to contain extremely poor-quality groundwater (formation water) in the region. Salinity concentration maps have been produced across the Yorkshire region and suggest that salinity increases from 5,000 mg/l in the Vale of York to in excess of 200,000 mg/l on the eastern extent of Yorkshire (Gale, Smith, & Downing, 1983; Downing, et al., 1985; Shand, et al., 2002). More recent data collected from well-sites in North Yorkshire demonstrate close alignment with the salinity mapping data. A salinity of 180,000 mg/l was reported for the Sherwood Sandstone (depth of approximately 1,141 m bgl) at Ebberston Moor in the North York Moors (Envireau Water, 2014a), which matches well with the mapped value of ~170,000 mg/l.

Naturally occurring petroleum at concentrations of around 0.5 - 1.2 mg/l was also observed in the Sherwood Sandstone at Ebberston Moor (Envireau Water, 2014b).

2.3.4 Permian & Carboniferous Strata

The Permian age Zechstein Group is comprised of halites and evaporites and, based on the above, will contain poor quality water with high salinity and significant petroleum present. Data collected from the Kirkham Abbey Formation (KAF) at an onshore oil and gas site in North Yorkshire was characterised by a sodium concentration of 84,000 mg/l, a chloride concentration of 170,000 mg/l and an electrical conductivity of 208,000 µS/cm (Envireau Water, 2014b). The results are indicative of deep formation water with salinities far higher than seawater. Petroleum was observed in the region of 7.4 mg/l, consistent with water produced from a petroleum reservoir. Due to the depth of the Permian and Carboniferous strata (> 1000 m) at the Wellsite, any water found in these formations is of extremely poor quality and has no resource value as defined by UKTAG (2021).

The well logs for WNA-1 and WNA-2 specifically record the presence of massive halite within the Boulby and Fordon formations. This suggests strongly that the groundwater associated with these deposits will be close to saturation with respect to halite and will have a salinity significantly in excess of 10,000 mg/l.

3 THE PROPOSED WORKS

3.1 Wells WNA-1 and WNA-2

WNA-1 (Table 3) was drilled by Rathlin in 2013. It was drilled to a total measured depth (MD) of 3175 m below rotary table (RT; 3,168 m bgl). It terminated in the Dinantian Carboniferous Limestone at a true vertical depth relative to sea level (TVDss) of -2995 m OD TVDss. The bottomhole location was approximately 740 m ESE of the well pad. The well commenced deviating away from the vertical within the Mercia Mudstone formation. The well log is published by the British Geological Survey under borehole number TA13NE46.

The hydrocarbon-bearing reservoir of the Kirkham Abbey Formation (KAF) was encountered at 1818 m MD (1811 m bgl; -1683 m OD TVDss). The base of the KAF was at 1911 m MD (1904 m bgl; -1765 m OD TVDss), implying a thickness of 82 m.

Table 3 Wells WNA-1 and WNA-2

ID	WNA-1	WNA-2
Drilled date	2013	2019
NGR top of well	519266 439140	519271 439160
Ground level	+13.4 m OD	+13.4 m OD
Rotary table	6.9 m above ground level +20.3 m OD	4.1 m above ground level +17.49 m OD
Top KAF	1818 m MD below RT 1811m MD bgl 1696 TVD m bgl -1683 mOD (TVD)	1715 m MD below RT 1711 m MD bgl 1692.9 TVD m bgl -1679.5 mOD (TVD)
Base KAF	1911m MD below RT 1904 m MD bgl 1778 TVD m bgl -1765 mOD (TVD)	1780 m MD below RT 1776 m MD bgl 1756.9 TVD m bgl -1743.5 mOD (TVD)
NGR base of well	519998 439024	519482 439260
Base of well	3175 m MD below RT 3168 m MD bgl 3008 TVD m bgl -2995 mOD (TVD)	2061 m MD below RT 2057 m MD bgl 2033.7 TVD m bgl -2020.3 mOD (TVD)

WNA-2 (Table 3) was drilled in 2019 and is shown schematically in Figure 3. It was drilled to 2061 m MD below RT (2057 m bgl). It terminated in Carboniferous Westphalian strata at -2020 m OD TVDss. The bottomhole location was approximately 230 m ENE of the well pad.

The hydrocarbon-bearing reservoir of the KAF was encountered at 1715 m MD (1711 m bgl; -1680 m OD TVDss). The base of the KAF was at 1780 m MD below RT (1776 m bgl; -1744 m OD TVDss), implying a thickness of 64 m.

WNA-2 starts deviating significantly from the vertical below around -900 m OD TVDss. The horizontal offset of WNA-2 in the KAF is reported as around 80 m (RPS, 2024). WNA-2 is reported to have already been perforated in the productive reservoir and acidised.

3.2 Proposed stimulation

The proposed activity in well WNA-2 involves:

- re-completing the well.
- carrying out a diagnostic fracture injection test (DFiT) (see below).
- carrying out a reservoir stimulation activity to re-establish permeability within the KAF, having been impeded by formation damage as a result of the initial drilling and completion operation.

The proposed activity is discussed in greater detail in the subsections below. To aid the reader, terminology used in reservoir stimulation is detailed in Section 3.2.3.

3.2.1 Diagnostic Fracture Injection Test (DFiT)

A Diagnostic Fracture Injection Test, or DFiT, will be carried out using up to 15 m^3 of gelled hydrocarbon-based fluid. The purpose of the DFiT is to determine the breakdown pressure, propagation pressure and carrier fluid leak-off rate, which, in turn, will inform the main proppant reservoir stimulation treatment.

3.2.2 Reservoir stimulation

The WNA-2 well will be re-entered and a single-stage oil-based "reservoir stimulation" will be carried out. This operation involves a slurry of proppant and a gelled hydrocarbon-based fluid (carrier fluid) being pumped through casing perforations into the target formation at a pressure exceeding the fracture pressure of the formation. Injecting pressure and pump rates high enough to propagate a fracture in the formation creates channels of communication through any pre-existing wellbore formation damage. When the pressure is released, the proppant remains in situ propping open the small fractures, through which natural hydrocarbons can flow. Unlike high volume hydraulic fracturing, the proposed "reservoir stimulation" requires the use of only small volumes of proppant and carrier fluid, as it seeks to only bypass the formation damage rather than to specifically enhance the natural permeability of the formation. It is, however, acknowledged that the reservoir stimulation will extend beyond the near wellbore damage, providing some degree of secondary benefit in the form of enhanced permeability within the target formation. The operation proposed at WNA-2 has the following characteristics (RPS, 2024):

- Single stage.
- Stimulation fluid – gelled hydrocarbon – 60 m^3 to 70 m^3.
- Proppant – 12.5 tonnes of 20/40 sand (or other grade / size, as informed by DFiT).
- Fluid introduced at low flow rate and a surface pressure of up to 9000 psi for less than 1 hour (Rathlin Energy, 2024; RPS, 2024).

- Height of stimulated fractures – 30 m.
- Half-length of stimulated fractures – 16.4 m.

In the case of the WNA-2 reservoir stimulation, the carrier fluid proposed is a hydrocarbon-based fluid, with an alkyl ester gelling agent. A hydrocarbon-based fluid is selected, as studies consistently indicate that water-based fluids have had a detrimental effect on the permeability of the formation. Taken together, the total amount of gelled hydrocarbon applied during the DFiT and the reservoir stimulation will not exceed 85 m^3.

The stimulation is designed to be confined to the target (Kirkham Abbey) Formation only, which is in excess of 60 m thickness and is bounded by the thick, low-permeability Hayton Anhydrite (below) and Fordon Evaporite (above) formations.

It is estimated that approximately 30% to 50% of the gelled hydrocarbon stimulation fluid will be recovered to surface via the well clean-up equipment and stored on site for subsequent offsite transfer to an Environment Agency approved waste treatment facility for disposal in accordance with the receiving waste treatment facility's environmental permits.

Flowback fluid following the stimulation has the potential to contain low levels of NORM. Samples of the flowback fluid will be sent to a laboratory holding the appropriate accreditations for radionuclide analysis by gamma spectrum. Depending on the outcome of radionuclides analysis, the flowback fluid will be transported via a licenced haulier to either an Environment Agency permitted wastewater treatment works facility where it will be processed, treated and discharged in accordance with the permitted controls of the water treatment facility, or to a bespoke RSR (radioactive substances regulation) permitted waste treatment facility for treatment and disposal in accordance with the best available technology.

3.2.3 Reservoir stimulation terminology

The proposed reservoir stimulation treatment is designed to create relatively short fractures that by-pass any zone of skin damage around the well (e.g. damage caused by drilling, drilling mud etc. or other permeability impairment). It is not designed to extensively fracture large volumes of the formation (see Figure 3).

"Gelled hydrocarbon" is a hydrocarbon-based fluid with an alkyl ester gelling agent as an additive (Li, Ozden, Zhang, & Liang, 2020). Laboratory testing results show that the formation is sensitive to aqueous fluids (mobilises fines) but much less sensitive to hydrocarbon-based fluids - this is the reason for using a gelled hydrocarbon based fluid instead of water. The gelling agents proposed to be utilised at West Newton A are alkyl esters, with crosslinking agents including ferric sulphate, dibutylaminoethanol, n-polyethoxylated oleyl amine and proprietary ethanolamine and ethoxylated alkyl amines.

"Proppant" is a solid particulate material, injected with a stimulant fluid, designed to hold fractures open after the active reservoir stimulation has ceased.

"20/40" sand refers to the standard US sieve sizes through which sand grains pass; in this case the sand grain size falls between mesh sizes 20 and 40 (0.43 to 0.85 mm) (PFS Aggregates, 2024; Kramer Industries Inc, 2024). The sand comprises overwhelmingly quartz.

"NORM" is an abbreviation for naturally occurring radioactive material. Due to the highly reducing conditions in hydrocarbon reservoirs and the long residence time, formation waters may contain moderate concentrations of natural radioactive elements (such as radium). Thus, formation water recovered at the surface, or scales formed on well casing or downhole equipment, may contain elevated total alpha and total beta radioactivity counts.

3.2.4 Chemicals inventory

A complete list of the chemicals (and associated safety data) proposed to be used, and potentially stored at surface, in connection with the DFiT and reservoir stimulation activities has been compiled. The full chemical inventory will be included in support of the permit application.

The chemicals associated with the DFiT and reservoir stimulation will be:

- a hydrocarbon base fluid (this avoids permeability damage due to wax formation caused by water injection into a hydrocarbon reservoir), predominantly in the range C11-C20.
- with a phosphate-containing alkyl ester gelling agent.

The additives to be used in conjunction with the stimulant fluid include:

- predominantly amine-based cross-linking agents, including ferric sulphate, dibutylaminoethanol, n-polyethoxylated oleyl amine and proprietary ethanolamine and ethoxylated alkyl amines.
- a metal oxide breaker system to de-gel the fluid following stimulation, reducing its viscosity and aiding recovery.

4 HYDROGEOLOGICAL RISK ASSESSMENT (HRA)

4.1 Conceptual Model

The hydrogeological conceptual model presented in the original HRA (Envireau Water, 2021) remains unchanged, and has been used as the basis of the following HRA.

4.2 Updated hydrogeological risk assessment (HRA)

4.2.1 Sources

The HRA described in the original HRA (Envireau Water, 2021) remains valid for the purpose of characterising risks associated with, for example, chemical usage and storage, conventional drilling and operational activity at the wellsite itself. The purpose of this report is to update the original HRA to account for the proposed reservoir stimulation activity described in Section 3.2.

In line with the previous source-pathway-receptor model, the new sources of risk that are to be considered are:

1. The storage and usage of chemicals and fluids associated with the reservoir stimulation activity.
2. The downhole application of the reservoir stimulation programme, described in Section 3.2.

4.2.2 Pathways

The risk pathways remain as described in the original HRA (Envireau Water, 2021), with the additional pathway of:

- The possibility of subsurface migration of wellbore, stimulation or reservoir fluids during or after reservoir stimulation, potentially along fractures stimulated by the downhole procedures.

The standard HRA matrix applied in the original HRA (Envireau Water, 2021) is not ideally suited to capturing risks from this pathway. The British Geological Survey (BGS) and Environment Agency (EA) have, however, developed a 3-dimensional groundwater vulnerability model (3DGWV) to evaluate the risk via such potential pathways through a thick sequence of sedimentary strata (Loveless S. , et al., 2018; Loveless S. , et al., 2019). This 3DGWV tool was included within the original HRA to provide confidence in the standard HRA matrix and has been used to assess the risk associated with reservoir stimulation.

4.2.3 Receptors

The relevant risk receptors remain as described in the original HRA (Envireau Water, 2021):

1. The surface water drainage system, including the Lambwath Stream and any downstream surface water abstractions providing water for agricultural use.
2. The superficial deposits aquifer, including any associated groundwater abstractions.
3. The Chalk (and Carstone Formation) aquifer, including any associated groundwater abstractions.
4. Deep water bearing formations beneath the Lias Group/Penarth and Mercia Mudstone Group with no resource or environmental support value.

The closest designated site is Lambwath Meadows SSSI, located 850 m northeast of the Wellsite. This SSSI is supported by surface water but is located upstream of the Wellsite. Given this, and the underlying glacial till that separates the groundwater and surface water systems, Lambwath Meadows SSSI is not hydraulically connected with the Wellsite, is not at risk from surface or near-surface risks connected with the proposed development and is not considered further.

As documented in the original HRA (Envireau Water, 2021), there are no known abstractions or private water supplies within approximately 1.4 km of the Wellsite; however, they have been included as a hypothetical receptor in the risk assessment for completeness.

4.3 Risk of storage or usage of chemicals and conventional drilling / operations

The risk of storage or usage of chemicals associated with site preparation, conventional drilling, operation and testing activities is considered in Table 12 of the original HRA (Envireau Water, 2021). The risks to all receptors are "None" or "Very Low".

The HRA risk assessment matrix considered in Section 9.3.1 to 9.3.9 and Table 12 of the original HRA (Envireau Water, 2021) is still valid as regards its description of risks related to surface activities, storage of chemicals and conventional drilling / operations.

The chemicals that are proposed for use during reservoir stimulation will not result in a different risk profile to those considered in the original HRA (Envireau Water, 2021).

Thus, the conclusion still stands that *"with the embedded mitigation measures in place,* ***the risks to all receptors reduce to very low or none, which are not significant*** *in EIA/planning terms".*

4.4 Risk of subsurface migration from reservoir stimulation

The British Geological Survey / Environment Agency 3DGWV tool has been re-run to evaluate the risk from such activities via potential pathways through a thick sequence of sedimentary strata (Loveless S. , et al., 2018; Loveless S. , et al., 2019). This is especially important in capturing any risk of fluid migration associated with reservoir stimulation in any deep drilled lateral wells in the KAF, which is problematic to fully capture in the standard HRA referred to in Sections 4.2 and 4.3.

The 3DGWV tool has already been implemented to assess this risk from the initial drilling proposal, as documented in Table 20 of the original HRA (Envireau Water, 2021), under the assumption that hydrocarbon extraction would be via "conventional" passive oil and gas extraction methods (Hazard parameter 1 in the 3DGWV model).

The tool has been re-run, now assigning a Hazard Parameter 3 to the hydrocarbon extraction method – i.e. *"Permeability enhancement from low volume hydraulic fracturing (e.g. conventional oil and gas with hydraulic fracturing".*

Our application of the 3DGWV model is based on stratal thicknesses and aquifer designations detailed in Table 1 and Table 2. For simplicity, the following assumptions have been made:

- The entire thicknesses of Lias, Penarth Group and Mercia Mudstone are assumed to comprise argillaceous strata (the well logs from WNA-1 and WNA-2 support this assertion, and the small thickness of non-argillaceous strata will be compensated by thin layers of argillaceous strata in other formations such as the Permian and Sherwood Sandstone formations).

As compared with the assessment using the 3DGWV model in the original HRA (Envireau Water, 2021), the following minor amendments have been made:

- The stratigraphic interval *"Zechstein Group (Roxby Formation, Sherburn Formation, Carnallitic Marl Formation, Boulby Halite)"* is not designated a Principal Aquifer. According to the well logs of WNA-1 or WNA-2, almost the entire interval is effectively comprised of claystone and evaporite.
- Moreover, because of the presence of massive halite (and anhydrite) beds in the sequence *"Zechstein Group (Roxby Formation, Sherburn Formation, Carnallitic Marl Formation, Boulby Halite)"* and *"Fordon Evaporite",* these sequences and the intervening Brotherton Formation are considered almost certainly to contain highly saline formation water of salinity >10,000 mg/l. They are therefore demoted to Receptor Classification D (Loveless S. , et al., 2019).
- The mudstone content of the stratigraphic interval *"Zechstein Group (Roxby Formation, Sherburn Formation, Carnallitic Marl Formation, Boulby Halite)"* has been reduced to around 70 m on the evidence of well logs WNA-1 and WNA-2 (category 3 – between 50 – 100 m mudstone).
- The Grey Chalk and Hunstanton Chalk have all been designated as Principal Aquifers and have all been given receptor classification "A" – although they are located more than 400 m bgl, there is a possibility they contain fresh water, being part of the presumed "well connected" Chalk aquifer system.
- The vulnerability factor "lateral separation" has been set to 0 for most stratal units on the basis of the very low dip and the fact that lateral separation must be judged solely on the basis of the same horizontal plane.
- The "faulting" vulnerability factor has been increased to 2 for strata up to the Sherwood Sandstone (Table 6) on the evidence for possible faulting of deep strata near West Newton in the report by (Rathlin Energy, 2008).

The results of the 3DGWV analysis are shown in Table 4, Table 5, Table 6 and Table 7 below. As compared with the initial (Envireau Water, 2021) assessment, the Chalk remains in the "Low/Medium" risk group, which is the lowest possible class available to a classification "A" receptor such as the Chalk aquifer.

The only material difference is that the Sherwood Sandstone has moved from the "Low" to the "Low/Medium" risk group. Note that this designation rests on the salinity of the Sherwood Sandstone groundwater being <3,000 mg/l (receptor classification B (Loveless S. , et al., 2019)), which we regard as highly unlikely – but in the absence of site-specific information to the contrary, has been adopted as a conservative scenario. If the salinity in the Sherwood Sandstone is >3000 mg/l, it would fall to an overall "Low" risk classification.

Table 4 3DGWV Hazard Assessment

FACTOR	Release mechanism of hydrocarbon (H1)		Head gradient driving flow (H2)		HAZARD	CONFIDENCE
GEOLOGICAL UNIT	RANKING	CONFIDENCE	RANKING	CONFIDENCE		
Glacial till / Glaciofluvial Deposits	3	high	2	medium	6	medium
White Chalk subgroup			2	medium	6	medium
Grey Chalk subgroup			2	medium	6	medium
Hunstanton Chalk Formation			2	medium	6	medium
Carstone Formation			2	medium	6	medium
Lias Group			2	medium	6	medium
Penarth Group			2	medium	6	medium
Mercia Mudstone Group			2	medium	6	medium
Sherwood Sandstone Group			2	medium	6	medium
Zechstein Group (Roxby Formation, Sherburn Formation, Carnallitic Marl Formation, Boulby Halite)			2	medium	6	medium
Brotherton Formation			2	medium	6	medium
Fordon Evaporite Formation			2	medium	6	medium

NOTES: Release mechanism of hydrocarbons H1 = 3 (Permeability enhancement from low-volume hydraulic fracturing)
Head gradient driving flow H2 = unknown

Table 5 3DGWV Vulnerability Assessment (Part 1)

FACTOR	Vertical separation between source and base of receptor		Lateral separation between source and receptor		Mudstones and clays in intervening units between source and receptor	
WEIGHTING	1.5		3		3.5	
CONFIDENCE	high		high		medium	
Glacial till / Glaciofluvial Deposits	1	1.5	0	0	1	3.5
White Chalk subgroup	1	1.5	0	0	1	3.5
Grey Chalk subgroup	2	3	0	0	1	3.5
Hunstanton Chalk Formation	2	3	0	0	1	3.5
Carstone Formation	2	3	0	0	1	3.5
Lias Group	2	3	0	0	1	3.5
Penarth Group	2	3	0	0	1	3.5
Mercia Mudstone Group	3	4.5	0	0	3	10.5
Sherwood Sandstone Group	6	9	0	0	3	10.5
Zechstein Group (Roxby Formation, Sherburn Formation, Carnallitic Marl Formation, Boulby Halite)	7	10.5	0	0	5	17.5
Brotherton Formation	8	12	1	3	5	17.5
Fordon Evaporite Formation	8	12	4	12	5	17.5

NOTES: Vertical separation: >1200 m = 1; 900-1199 m = 2; 600-899 m = 3; 200-299 m = 6; 100-199 m = 7; <99 m = 8

Lateral separation: This refers to separation if receptor and source occur in the same horizontal plane. On the basis of a regional dip of 1.4°, a 100 stratal thickness would provide about 4 km of lateral separation. For this reason, the lateral separation ,for all horizons except the Fordon and Brotherton Formations, has been scored as 0 (>2000 m).

Intervening mudstone and clay: 1 = >250 m mudstone and clay; 3 = 50 – 100 m mudstone and clay; 5 = <20 m mudstone and clay

Table 6 3DGWV Vulnerability Assessment (Part 2)

FACTOR	Groundwater flow mechanism in intervening units between source and receptor, including the receptor		Faults cutting intervening units and receptor		Solution features in intervening units and receptor		Anthropogenic features-mines close to site of interest		Anthropogenic features-boreholes close to site of interest		VULNERABILITY SCORE (V)
WEIGHTING	3		4.5		2		8		4		
CONFIDENCE	medium		medium		medium		high		high		medium
Glacial till / Glaciofluvial Deposits	2	6	1	4.5	2	4	0	0	2	8	27.5
White Chalk subgroup	2	6	1	4.5	2	4	0	0	2	8	27.5
Grey Chalk subgroup	2	6	1	4.5	2	4	0	0	2	8	29
Hunstanton Chalk Formation	2	6	1	4.5	2	4	0	0	2	8	29
Carstone Formation	2	6	1	4.5	1	2	0	0	2	8	27
Lias Group	2	6	1	4.5	1	2	0	0	2	8	27
Penarth Group	2	6	1	4.5	1	2	0	0	2	8	27
Mercia Mudstone Group	2	6	1	4.5	1	2	0	0	2	8	35.5
Sherwood Sandstone Group	2	6	2	9	1	2	0	0	2	8	44.5
Zechstein Group (Roxby Formation, Sherburn Formation, Carnallitic Marl Formation, Boulby Halite)	3	9	2	9	1	2	0	0	2	8	56
Brotherton Formation	3	9	2	9	1	2	0	0	2	8	60.5
Fordon Evaporite Formation	3	9	2	9	1	2	0	0	2	8	69.5

NOTES: Flow mechanism: 2 = "> 50 % principal or secondary aquifers (EA designation) fractured, poorly connected fracture flow or mixed fracture and intergranular flow (e.g. well fractured sandstones, multi-layered Carboniferous rocks)"; 3 = "> 50% principal or secondary aquifers (EA designation) fractured, well connected (e.g. limestone), predominantly fracture flow"

Faults: 1 = Faults not known in the area of interest; 2 = Known faults within 2 km of the hydrocarbon activity; 3 = Known faults within 0.5 km, or transmissive fault within 2 km of the hydrocarbon activity. The score of 2 has been applied to strata up to and including the Sherwood Sandstone, based on sections provided in (Rathlin Energy, 2008).

Solution feature: 1 = potential for solution in evaporite / soluble rocks; 2 = potential for karst or known solution features in evaporite.

Mines: 0 = No known mine (and assumed to be absent) within 2 km of maximum lateral extent of hydrocarbon activity, or 600 m vertically

Boreholes: 2 = Known boreholes extending to within 200 m vertically, and/or 0.5 km laterally of hydrocarbon activity

Table 7 Risk Calculation

GEOLOGICAL UNIT	RECEPTOR CLASSIFICATION	VERTICAL SEPARATION BETWEEN HYDROCARBON SOURCE UNIT AND BASE OF POTENTIAL RECEPTOR (M)	CUMULATIVE MUDSTONE THICKNESS (M) IN INTERVENING UNITS	INTRINSIC VULNERABILITY SCORE (IntV)	SPECIFIC VULNERABILITY SCORE (SpecV)	RISK GROUP
Glacial till / Glaciofluvial Deposits	B	1640	468	27.5	165	Low
White Chalk subgroup	A	1202	468	27.5	165	Medium/Low
Grey Chalk subgroup	A	1192	468	29	174	Medium/Low
Hunstanton Chalk Formation	A	1187	468	29	174	Medium/Low
Carstone Formation	C	1161	468	27	162	Low
Lias Group	C	1068	375	27	162	Low
Penarth Group	C	1049	356	27	162	Low
Mercia Mudstone Group	C	765	72	35.5	213	Low
Sherwood Sandstone Group	B	203	72	44.5	267	Medium/Low
Zechstein Group (Roxby Formation, Sherburn Formation, Carnallitic Marl Formation, Boulby Halite)	D	106	0	56	336	Low
Brotherton Formation	D	51	0	60.5	363	Low
Fordon Evaporite Formation	D	0	0	69.5	417	Low

5 SEISMIC HAZARD ASSESSMENT

Rathlin has commissioned an independent probabilistic assessment of seismic hazard resulting from the proposed reservoir stimulation activities (Outer Limits, 2024).

In the report, a magnitude of M 2.5 is evaluated as a threshold of tolerability *"at which the nuisance associated with the resulting vibrations would become unacceptable"*. The main conclusions of the assessment are as follows (cited directly from the report):

- The most likely largest event size is a magnitude of M -2.0. There is a 95 % likelihood that the largest event is less than M 0.0, and a 99 % likelihood that the largest event is less than M 0.8.
- The 99 % exceedance event, M 0.8, would not be felt at the surface. The most likely largest event (M -2.0) would not be detectable even with a dedicated local monitoring array. As such, we conclude that the proposed activities pose a very low risk with respect to induced seismicity.
- The installation of a local seismicity monitoring array is not warranted, given the very low levels of risk posed by the proposed operation, and the fact that the planned injection volume is so low that the injection process itself will be very short.

6 CONCLUSION

The original hydrogeological risk assessment (HRA) for proposed exploration activities at the West Newton A well-site (Envireau Water, 2021) has been re-evaluated to consider additional risks from a reservoir stimulation activity in well WNA-2.

This reservoir stimulation activity will be carried out in the Permian Kirkham Abbey Formation (KAF) at a depth of around 1700 m below ground level. Hydrogeological risks associated with the activities include:

- The storage and usage of chemicals and fluids associated with the reservoir stimulation activities.
- The downhole application of the reservoir stimulation programme.

The activities carry the possibility of creating new subsurface pathways for migration of wellbore, stimulation or reservoir fluids during or after reservoir stimulation, potentially along fractures stimulated by the downhole procedures.

An assessment of the activities shows that the findings of the original HRA remain valid as regards risks related to surface activities, storage of chemicals and conventional drilling / operations. The chemicals that are proposed for use during reservoir stimulation or testing will not result in a different risk profile to those considered in the original HRA; thus, the conclusion still stands that *"with the embedded mitigation measures in place, **the risks to all receptors reduce to very low or none, which are not significant** in EIA/planning terms".*

A re-evaluation of the risk associated with the proposed reservoir stimulation using the BGS/EA 3DGWV tool demonstrates that the downhole procedures do not present an unacceptable risk to surface water and groundwater receptors.

Rathlin has also commissioned a seismic hazard assessment of the reservoir stimulation activity (Outer Limits, 2024), which concludes that the proposed activities pose a very low risk with respect to induced seismicity. The assessment demonstrates that *"the most likely largest event size is a magnitude of M -2.0. There is a 95 % likelihood that the largest event is less than M 0.0, and a 99 % likelihood that the largest event is less than M 0.8"*. This is in the context of a magnitude of M 2.5 being the threshold of tolerability at which the nuisance associated with the resulting vibrations would become unacceptable.

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