12.0 PRODUCED WATER DISPOSAL

Introduction

12.1 This chapter of the ES assesses the likely significant effects of the Development in terms of the disposal of produced water and should be read in conjunction with Chapter 11 Flood Risk, Hydrology and Drainage of the ES which assesses the effects on the surface water environment. The description of the process of injecting water into the Sherwood Sandstone formation is provided in Chapter 5 Construction Methodology and Programme and Appendix 5.2.

12.2 This chapter describes: the approach to disposal; the technical assessment; the baseline conditions relating to the disposal; the likely significant environmental effects; the mitigation measures required to prevent, reduce or offset any significant adverse effects; and the likely residual effects after these measures have been employed.

Planning Policy Context

Relevant Legislation and UK Regulation

12.3 The European Water Framework Directive (2000/60/EC) (WFD)[i] came into force in December 2000 and became part of UK law in December 2003. Groundwater issues are addressed by the Groundwater Daughter Directive (2006/118/EC) (GWDD)[ii] and the preceding Groundwater Directive (80/68/EEC) (GWD)[iii].

12.4 Disposal of water into the natural environment is controlled by the Environment Agency under the Environmental Permitting Regulations (EPR) 2010[iv]. In order to be able to discharge water to groundwater a permit is required ("a groundwater permit") under these regulations.

12.5 The Environment Agency's groundwater protection strategy of prevention and limitation is informed by the publication, Groundwater Protection: Principles and Practice (Aug 2013, Version 1.1) (GP3)[v].

12.6 In 2013, the Applicant and its advisers had a number of constructive discussions with the Environment Agency at both local (area) and national levels about the proposed disposal of produced water to the Sherwood Sandstone formation at the Ebberston 'A' Well Site, 2 km north of the EMS site, prior to the submission by Third Energy UK Gas Limited of the EMA-

KGS gas pipeline planning application. Following the grant of planning permission by NYMNPA in December 2013 for the EMA-KGS scheme, a formal application for a groundwater permit was submitted to the Environment Agency (EA) under the EPR 2010 in February 2014 and a permit (Permit Ref. EPR/AB3593DU) was granted in May 2014. A Radioactive Substances (RSR) Permit covering the disposal of produced water containing naturally occurring radioactive substances (NORM) has also been obtained (Permit Ref. EPR/SB3730DE).

12.7 Third Energy was able to demonstrate to the EA that under European and English law and regulation the proposed discharge could be permitted because:

- The receiving water (the Sherwood Sandstone formation water) is permanently unsuitable and has no resource value at this location;
- That the discharge lies within the policy described by the Environment Agency in GP3;
- That the discharge represents best available technology (BAT) and best practicable environmental option (BPEO);
- That the discharge meets the requirements of the Water Framework Directive and Groundwater Daughter Directive.

12.8 Based on discussions with the Environment Agency, the Applicant and its advisers have applied the same criteria to an assessment of proposed water injection at the Ebberston South (EMS) Well Site. Accordingly, this chapter of the ES demonstrates that the disposal of produced water to the Sherwood Sandstone will not have any adverse environmental effects and can also be permitted at that location.

National Planning Policy

NPPF

12.9 The NPPF[vi] was published in March 2012 and sets out the new approach to streamlining the Planning System and encouraging growth. All previous Planning Policy Guidance (PPGs) and Planning Policy Statements (PPSs) listed in Annex 3 of the NPPF are replaced by the NPPF.

12.10 Fundamental principles underpinning the NPPF are the need to deliver sustainable development and build a strong, competitive economy nationwide. In terms of produced water disposal the following sections of the NPPF are considered of relevance to this assessment.

12.11 Conserving and enhancing the natural environment states in paragraph 109 that:

"The planning system should contribute to and enhance the natural and local environment by:

- *protecting and enhancing valued landscapes, geological conservation interests and soils;*
- *recognising the wider benefits of ecosystem services;*
- *minimising impacts on biodiversity and providing net gains in biodiversity where possible, contributing to the Government's commitment to halt the overall decline in biodiversity, including by establishing coherent ecological networks that are more resilient to current and future pressures;*
- *preventing both new and existing development from contributing to or being put at unacceptable risk from, or being adversely affected by unacceptable levels of soil, air, water or noise pollution or land instability; and*
- *remediating and mitigating despoiled, degraded, derelict, contaminated and unstable land, where appropriate."*

12.12 In addition paragraph 143 states that:

"In preparing Local Plans, local planning authorities should:

- *set out environmental criteria, in line with the policies in this Framework, against which planning applications will be assessed so as to ensure that permitted operations do not have unacceptable adverse impacts on the natural and historic environment or human health, including from noise, dust, visual intrusion, traffic, tip- and quarry-slope stability, differential settlement of quarry backfill, mining subsidence, increased flood risk, impacts on the flow and quantity of surface and groundwater and migration of contamination from the site; and take into account the cumulative effects of multiple impacts from individual sites and/or a number of sites in a locality;"*

Planning Practice Guidance[vii]

12.13 Key Provisions from The Planning Practice Guidance include:

- Water Supply, wastewater and water quality
  - Water supply – normally addressed through the Local Plan. Potential exceptions are large developments requiring significant quantities of water, and where a Local Plan requires enhanced water efficiency to manage local water demand.
  - Water quality – water quality is only likely to be an issue where the development involves physical modifications to a water body such as a flood storage area, or major works to a watercourse. Water quality may be affected by inadequate infrastructure to deal with wastewater. Controlling surface water through sustainable drainage systems can improve water quality and reduce flood risk.

Local Planning Policy

NYMNPA Local Development Framework

12.14 Mineral planning within the National Park comes under the jurisdiction of the North York Moors National Park Authority (NYMNPA). The Local Development Framework consists of a number of different documents to guide future development whilst ensuring that the National Park's special qualities are conserved and enhanced. The Core Strategy and Development Policies document, adopted in November 2008[viii] is key to the NYMNPA Local Development Framework. It sets out a spatial vision for the future of the National Park and provides Core Policies guiding a strategic framework for the scale and location of all types of new development and detailed development policies against which individual proposals such as waste and minerals will be assessed.

12.15 Development Policy 1 Environmental Protection states that

> *"To conserve and enhance the special qualities of the North York Moors National Park, development will only be permitted where:*
>
> 1. *It will not have unacceptable adverse impact on surface and ground water, soil, air quality and agricultural land.*
> 2. *It will not generate unacceptable levels of noise, vibration, activity or light pollution.*

3. *There will be no adverse effects arising from sources of pollution which would impact on the health, safety and amenity of the public users of the development.*
4. *Land stability can be achieved without causing unacceptable environmental or landscape impact.* "

Assessment Methodology

Desk Top Study

12.16 This assessment of the risk associated with the disposal of produced waters takes the form of a desk top study supported by water sampling and analysis undertaken in the summer of 2013 at other well sites. The assessment has covered the following key areas:

- A detailed, technical appraisal of the geology beneath the EMS Well Site and the quality of the relevant water bearing formations;
- A comprehensive risk assessment for the proposed method of disposal, conducted in accordance with the approach set out in DEFRA's Green Leaves III (GL III)[ix]. GL III is the latest edition of the Government's Guidelines for Environmental Risk Assessment and Management, providing generic guidelines for the assessment and management of environmental risks. The guidelines supersede earlier versions published in 1995 by the Department of the Environment, and in 2000 by the Department of the Environment, Transport and the Regions and the Environment Agency. Revision III brings the guidelines in England and Wales in line with current thinking in the field of environmental risk management;
- A robust justification for the proposed method of disposal, based on the principles of Best Practicable Environmental Option (BPEO) and Best Available Technology (BAT).

Technical Assessment

12.17 The desk top study reviewed the information provided by:

- Environment Agency;
- British Geological Survey;
- Geological Society;
- The Applicant's geological and geophysics (G&G) team;
- Laboratory analyses of water samples collected from other well sites; and
- Peer reviewed journals and other publications.

12.18 A full Bibliography of all reference materials used to inform the baseline study is presented in Appendix 12.1. A full description of the produced water injection proposals is contained within Chapter5 Construction Methodology and Programme..

12.19 The detailed technical assessment examined the following:

- The geographical, hydrological, geological and hydrogeological setting;
- Examination of water dependent features and protected water rights within a 70 km radius of the proposed injection site (EMS Well Site);
- Examination of the quality of the formation water within the Permian Kirkham Abbey Formation (KAF) reservoir and the Sherwood Sandstone formation, both by analysis of samples from other well sites and with reference to published information;
- Examination of proposed additives;
- Comparison of injection and formation waters with sea water; and
- Review of the injection method and rates.

12.20 The technical assessment has been drawn together into a conceptual model which is illustrated in Figure 12.1. In summary the conceptual model comprises:

- Four hydrogeological units – namely:
  - The geology above the Oxford Clay (Layer 1);
  - The geology from the base of the Mercia Mudstone to the Oxford Clay (Layer 2);
  - The Triassic Sherwood Sandstone formation (Layer 3); and
  - The Zechstein (Permian) / Carboniferous (Layer 4);
- The lateral variation in geology, is controlled by dip and east west faulting;
- Natural recharge to the Sherwood Sandstone formation is limited to the outcrop and subcrop areas in Vale of York / Mowbray. Recharge to the geology above the Oxford Clay is limited to the outcrop on the North York Moors;
- Hydraulic properties of the layers have been defined by literature search, but broadly:
  - Layer 1 can be taken as having useful hydraulic conductivity and storage;
  - Layer 2 is poorly permeable (very low hydraulic conductivity) and has limited useful storage;
  - Layer 3 has useful hydraulic conductivity and storage; and
  - Layer 4 has limited hydraulic conductivity and storage, and poorly permeable clay and mudstone horizons effectively hydraulically separate the Permian (Layer 4) from the overlying Triassic water bearing formation;

- Differences in water quality between the water bearing formations has been defined by literature search and confirmed in the case of Layer 3 & 4, from water sampling and analysis at other well sites.
- The change in salinity of the formation water in the Sherwood Sandstone is illustrated by an arbitrary line on Figure 12.2. This line denotes a change from what can be described as groundwater to formation water. This line has been located based on the literature search and can be conceptualised as an isochlor (a line of equal salinity [or more accurately chloride concentration]); and
- To the west of the above line the Sherwood Sandstone can be considered to form an aquifer, where the groundwater has a resource value. The EMS Well Site is some 35 km to the east of the outcrop area, where the formation water has no resource value.

12.21 When combined, the various aspects of the conceptual model produce a system with no transfer of water vertically between the permeable Layers 1 and 3, either upward or downward. This is achieved by the low permeability and thickness of Layer 2 and low vertical hydraulic conductivity of Layer 4. The effectiveness of the hydraulic separation is demonstrated by the marked difference in water quality between Layers 1 and 3, where the sandstone is located in excess of 1km below ground level.

12.22 The quality of the sandstone water at depth demonstrates that circulation of recharge into the Sherwood Sandstone formation is limited to near the outcrop/subcrop areas, with very little deep circulation occurring. Evidence published in the literature (Bottrell 2006[x]) indicates that the sodium chloride (NaCl) in the sandstone formation water is mineral rather than sea water based. This demonstrates that the salinity is due to the long residence time of the water in the rock and the dissolution of salt based minerals. This further demonstrates that the significant down dip distance of the Sherwood Sandstone beneath the EMS Well Site (~35 km) effectively separates it from the aquifer zone.

12.23 This assessment has adopted the following descriptions of groundwater, aquifers and formation water, in order to differentiate between the relatively shallow, potable water supplies and the deep system with no resource value:

- Groundwater: That water which occurs in the strata above the Lias (in this case) and can be reasonably attributed to relatively geologically recent recharge and which would reasonably be considered to be wholesome (potable) unless it has been contaminated (altered) by anthropogenic activity;
- Aquifer: The strata that contains groundwater as described above;

- Produced Water: The water (brine) produced from the gas production formation in association with the extraction and separation of gas or the development of the well;
- Formation Water: The water (brine) within the deep geological horizons which can be considered as connate, or sourced from geologically old recharge and has no resource value; and
- Water Bearing Formation: A geological unit (or formation) which contains formation water.

12.24 The meaning of groundwater and aquifer are the same as that intended in the Water Framework Directive and Groundwater Daughter Directive, whilst the other terms are commonly used in the oil and gas industry.

Assessment of Effects

12.25 The assessment of effects will use the criteria stated in Chapter 2, including the matrix detailed in Table 2.1, reproduced below as Table 12.1, which defines the level of significance of effects. Where an effect is considered to be significant, this significance will generally be classified as major, moderate or minor (with these descriptions again being based on precedent or current guidance).

Table 12.1: Significance Matrix

Sensitivity /Value of Receptor	**Magnitude of Effect**		
	High	**Medium**	**Low**
High (England, UK, International)	Major	Major/Moderate	Moderate
Medium (County, Regional)	Major/Moderate	Moderate	Moderate/Minor
Low (Local, Borough)	Moderate	Moderate/Minor	Minor

12.26 The three levels of significance defined by the generic matrix are:

- Major – an effect which in isolation could have a material influence on the decision making process;
- Moderate – an effect which on its own could have moderate influence on decision making, particularly when combined with other similar effects; or
- Minor – an effect which on its own is likely to have a minor influence only on decision making but when combined with other effects could have a more material influence.

12.27 Effects are also described as:

- Adverse – detrimental or negative effects to an environmental resource or receptor; or
- Beneficial – advantageous or positive effect to an environmental resource or receptor.

12.28 Where an effect is considered to be not significant or have no influence, irrespective of other effects, this is classified as "negligible".

12.29 Where an effect is not relevant for any reason then "NA" (not applicable) is used.

Limitations and Assumptions

12.30 This assessment is based on a desk study, supported by analysis of data on water quality in the KAF from a wellsite at Kirby Misperton in the Vale of Pickering and the Sherwood Sandstone formation at the Ebberston 'B' Well Site. The locations of all the wells are shown on Figure 12.3.

12.31 Appropriate geological and hydrogeological techniques have been used to extrapolate data to the EMS Well Site and where necessary the extrapolations have been compared with published data to check validity.

12.32 The underlying assumptions therefore, are that the water quality identified from the samples which have been analysed are representative of the water quality at the EMS Well Site and that the hydrogeological properties of the underlying geology is consistent with published information on those properties elsewhere in the region.

Baseline Conditions

Produced water quality

12.33 The Applicant is currently producing gas from wells targeting the KAF in the Vale of Pickering. The water produced from the wells is considered to be representative of the produced water that would be obtained from the production well targeting the KAF at the EMS Well Site. This is based on the fact that the geological setting and the depth of the geological units is similar in both cases.

12.34 It is not possible to obtain samples of the produced water from the production wells prior to gas separation and addition of additives. A sample of injection water has been collected from an existing gas production wellsite at Kirby Misperton in the Vale of Pickering and was analysed in the RPS Mountainheath laboratory for a basic chemistry suite and EU defined hazardous and non-hazardous substances. The results are provided in Appendix 12.2, whilst Table 12.2 presents the principal components of the water sample.

Table 12.2: Major Cations, Anions and General Chemistry of Produced Water

Component	Result	Units
pH	5.6	pH units
ammonia	46.9	mg/l NH_3
chloride	170000	mg/l
fluoride	< 100.0	mg/l
nitrite	< 1000.0	mg/l
nitrate	< 1000.0	mg/l
phosphate	< 100.0	mg/l
sulphate	1050	mg/l
aluminium	63.0	µg/l
copper	< 2.0	µg/l
zinc	11.0	µg/l
potassium	5300	mg/l
magnesium	620	mg/l
calcium	6700	mg/l
iron	0.32	mg/l
manganese	220	µg/l
mercury	< 0.10	µg/l
sodium	84000	mg/l
conductivity	208000	µS/cm
total dissolved solids	Not Determined	mg/l
density	1212	g/l

12.35 The sodium, chloride and conductivity results are indicative of deep formation water and confirm that the produced water from the KAF is highly saline. Salt (sodium chloride) concentrations are greater than would be found in seawater (Hem 1985[xi]).

12.36 Table 12.3 gives a summary of the main hydrocarbon analyses and shows that the production water contains in the region of 7.4mg/l of hydrocarbons, which is consistent with the fact that the production water is from a hydrocarbon (gas) reservoir.

Table 12.3: Diesel & Petrol Range Organics plus Mineral Oils

Component	Result	Units
aliphatic C5-C6:	280	µg/l
aliphatic C6-C8:	1200	µg/l
aliphatic C8-C10:	610	µg/l
aliphatic C10-C12:	820	µg/l

Component	Result	Units
aliphatic C12-C16:	550	µg/l
aliphatic C16-C21:	75	µg/l
aliphatic C21-C35:	73	µg/l
aromatic C5-C7:	1600	µg/l
aromatic C7-C8:	1100	µg/l
aromatic C8-C10:	940	µg/l
aromatic C10-C12:	120	µg/l
aromatic C12-C16:	72	µg/l
aromatic C16-C21:	5.9	µg/l
aromatic C21-C35:	< 1.0	µg/l
aliphatic C5-C35:	3600	µg/l
aromatic C5-C35:	3800	µg/l
TPH ali/aro:	7400	µg/l

Sherwood Sandstone formation water quality

12.37 Samples were collected from the Ebberston 'B' Well Site during drilling operations on 21 August 2013 at depths of 1131m and 1141m below ground level. Full results are provided in Appendix 12.3 and Table 12.4 provides a summary of the key components.

Table 12.4: Major Cations, Anions and General Chemistry of Sherwood Sandstone Formation Water

Component	Result		Units
	232206 1131mbgl	232207 1141mbgl	
pH	6.7	6.3	pH units
ammonia	13	13	mg/l NH3
chloride	108000	101000	mg/l
fluoride	<100	<100	mg/l
nitrite	<3000	<3000	mg/l
nitrate	<100	<100	mg/l
phosphate	<100	<100	mg/l
sulphate	12600	11600	mg/l
aluminium	79	200	µg/l
copper	220	390	µg/l
zinc	340	350	µg/l
potassium	5700	6900	mg/l
magnesium	440	310	mg/l
calcium	2100	2100	mg/l
iron	8.9	17.0	mg/l
manganese	620	600	µg/l
mercury	1.99	.25	µg/l
sodium	65000	61000	mg/l
conductivity	260000	250000	µS/cm
total dissolved solids	190000	180000	mg/l

Component	Result		Units
	232206 1131mbgl	232207 1141mbgl	
density	1100	1100	g/l

12.38 The results are consistent with a detailed literature review of Sherwood Sandstone formation water chemistry and are considered representative of the likely quality of the formation water in the Sherwood Sandstone at the EMS Well Site.

12.39 Table 12.5 gives a summary of the main hydrocarbon analyses and shows that the formation water in the Sherwood Sandstone formation contains in the region of 0.5 – 1.2mg/l of naturally occurring hydrocarbons, which is consistent with the fact that the Sherwood Sandstone formation is a hydrocarbon reservoir on a regional scale.

Table 12.5: Diesel & Petrol Range Organics plus Mineral Oils in the Sherwood Sandstone

Component	Result		Units
	232206 1131mbgl	232207 1141mbgl	
aliphatic C8-C10:	<0.1	<0.1	µg/l
aliphatic C10-C12:	72.0	29.0	µg/l
aliphatic C12-C16:	550	160	µg/l
aliphatic C16-C21:	200	110	µg/l
aliphatic C21-C35:	200	110	µg/l
aromatic C8-C10:	<0.1	<0.1	µg/l
aromatic C10-C12:	7.4	1.3	µg/l
aromatic C12-C16:	77.0	14.0	µg/l
aromatic C16-C21:	35.0	8.3	µg/l
aromatic C21-C35:	79.0	30.0	µg/l
aliphatic C8-C35:	1022	409	µg/l
aromatic C8-C35:	198.4	53.6	µg/l
TPH ali/aro:	1220.4	462.6	µg/l

Sea Water Quality

12.40 In order to provide a context of the salinity of the produced water from the Sherwood Sandstone formation, a comparison has been made to the salinity of the North Sea.

12.41 The Royal Belgian Institute of Natural Sciences provides monitoring data on the salinity of the North Sea. Data collected from their website (www.naturalsciences.be)[xii] shows that the salinity (total dissolved solids) is in the order of 34,000 to 35,000 mg/l. This is consistent with data provided from the Environment Agency at Fixed Offshore Monitoring Point No.2, at Scarborough.

Comparison of Water Types

12.42 Table 12.6 gives a summary of the main constituents of the two different waters with a comparison of the North Sea salinity. The results show that the KAF water is approximately two times more saline than the Sherwood Sandstone formation water, owing to a higher concentration of sodium chloride. However, this is within the context of both waters having total dissolved solids concentration (TDS) in excess of 180,000mg/l. Both waters show significant amounts of naturally occurring hydrocarbons, with the produced water showing more, as would be expected.

Table 18.6: Comparison of Produced, Formation and Sea Waters

Component	**Result**			**Units**
	KAF Produced Water	**Sherwood Sandstone Formation Water**	**North Sea**	
Conductivity	208000	255000		µS/cm
TDS	349	180	34 - 35	g/l
Density	1212	1100		g/l
Chloride	170	104.5		g/l
Sulphate	1.05	12.1		g/l
Sodium	84	63		g/l
Calcium	6.7	2.1		g/l
Potassium	5.3	6.3		g/l
aliphatic C8-C35:	3600	715		µg/l
aromatic C8-C35:	3800	126		µg/l
TPH ali/aro:	7400	841		µg/l

12.43 The produced water and Sherwood Sandstone formation water are 10 and 5 times more saline than the North Sea, respectively. The literature review suggests that the salinity of the formation water observed at the Ebberston B Well Site is likely to be a similar magnitude to that at the EMS Well Site.

Likely Significant Effects

12.44 The proposed disposal route for produced water is injection into the Sherwood Sandstone formation at the EMS Well Site. This section provides an assessment of the effects resulting from the injection activities without the inclusion of mitigation measures beyond those incorporated directly into the design of the Development.

Construction

12.45 The proposal at the EMS Well Site is to inject produced water to the Triassic Sherwood Sandstone formation rather than injection to the Permian Kirkham Abbey Formation (KAF). It is proposed to modify the existing borehole at the EMS Well Site to facilitate gas and water extraction from the KAF; and produced water disposal to the Sherwood Sandstone.

12.46 The diameter and construction of the existing borehole will physically limit the amount of water that can be injected into the Sherwood Sandstone to a maximum of 573m^3/day (3,500bbl/day). In order to achieve higher rates of production and injection, it is also proposed to construct a second borehole to extract water from the KAF and inject it into the Sherwood Sandstone.

12.47 Both the modification of the existing borehole and the construction of a second well will be controlled by The Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996[xiii] and the environmental impacts via a notice to the Environment Agency under section 199 of the Water Resources Act 1991[xiv].

12.48 These regulations ensure that the wells are designed and planned such that there is no unplanned escape of fluids and that the risks to the health and safety of persons from it or anything in it, or in strata to which it is connected, are as low as is reasonably practicable.

12.49 Any unexpected issues encountered during well construction, such as loss of drilling fluids and contamination of groundwater, would be temporary and limited to the immediate environs of the well and would be of a low magnitude. Thus, the overall effect would be minor adverse.

Operation

12.50 The injection well(s) will be cased and grouted and injection will take place through a perforated section. The injection zone may target the full thickness of the Sherwood Sandstone, depending on the exact nature of the formation at that location.

12.51 The proposed maximum rates and volumes of injection for the Development are presented in Table 12.7 below. The rates and volumes are based on the conservative assumption that the existing well and the new well would be in operation simultaneously for the full duration of the Development. In practice, this would not occur.

Table 12.7: Proposed Injection Rates for the Development

Well	Maximum Duration (years)	Maximum Daily Injection	
		(m^3/day)	(bbl/day)
Existing well (1)	15	556	3,500
New Well (2)	15	1,344	8,451
Total (1+2)	15	1,900	11,951

12.52 Injection will be achieved by low pressure injection from surface; the hydrostatic pressure of the water column will assist the water injection with only limited additional pressure added from pumping.

12.53 The moderate hydraulic conductivity of the Sherwood Sandstone formation means that no high pressure injection is anticipated, since the “injectivity” of the well should be sufficient to provide the required injection flow rates.

12.54 During the life of the injection well(s), the injection pressure will always be maintained below the material strength of the Sherwood Sandstone formation and therefore below the pressure required to fracture or displace the rock. The risk of induced seismicity occurring is therefore very low and the overall effect is minor adverse.

12.55 The conceptual model has been used as the basis of a risk assessment for the proposed disposal of produced waters to the Sherwood Sandstone at the EMS Well Site in accordance with the GL III methodology. The risk assessment has covered:

- Hazard Identification;
- Source – Pathway – Receptor linkage analysis;
- Consequence – Likelihood – Risk analysis; and
- Mitigation analysis.

12.56 The analysis shows that while the consequence of contamination would be high, the likelihood and therefore the risk of occurrence is very low. The likelihood of occurrence is low because:

- Approximately 700m of low permeability formations provide a vertical separation between the point of injection and the nearest groundwater supplies; and
- The lateral distance between the point of injection and the Sherwood Sandstone outcrop area is in excess of 35 km.

12.57 Owing to the natural geology at the EMS Well Site, disposal of produced water will not present any discernible impact on the quality of groundwater, the Sherwood Sandstone formation water, any potential receptors; or beneficial users which may be abstractors for domestic or industrial / agricultural uses; or the natural environment where groundwater feeds springs, wetlands and base flow to rivers.

12.58 During operation of the injection system, there will be no change from the baseline situation in the overall risk to the groundwater system. The only plausible risk of contamination of water supplies would therefore relate to inadequate construction of the injection well, resulting in groundwater contamination. As such, the effect of any issues arising during operation would be limited to the immediate environs of the well and would be of a low magnitude. Thus the overall effect would be minor adverse.

Decommissioning

12.59 The decommissioning of the injection system will involve shutting down the well and removal of the equipment. All pipelines and ancillary equipment will be drained and then dismantled down to their original components in order for them to be transported away from the well site. Any residual water in the pipelines will be collected and stored, for safe disposal at a suitable facility.

12.60 The injection well will be decommissioned before the impermeable base to the well site is removed. Therefore any saline water that is spilt will be captured and recovered by the water management system on the EMS Well Site.

Contaminant Risk during Decommissioning of the System

12.61 During decommissioning of the injection system, there will be no change from the baseline situation in the overall risk to the groundwater system. As such, there is no significant effect.

Restoration

12.62 Restoration will result in cutting the well casing at 2m below ground level; sealing the top of the well with a steel plate and placement of a 1.5m x 1.5m x 300mm concrete block over the plate. Pest free sub-soil and topsoil will be replaced on the well site separately to the original depth before excavation to achieve a loose, uniform fill. The finished contours on the EMS Well Site will be close to the original site contours.

Contaminant Risk during Restoration

12.63 During restoration, there will be no change from the baseline situation in the overall risk to the groundwater system.

12.64 Completion of the restoration phase will result in the appropriate sealing of the well and removal of potential contaminants from the well site so that there will be a long term negligible beneficial significance.

Mitigation Measures

12.65 This section provides a description of the mitigation measures to be incorporated into the Development to minimise the possible minor adverse effects, identified above.

12.66 The Significance Analysis above has identified that the only plausible risks of contamination of water supplies is during the construction and operational phases which would relate to inadequate construction of the injection well.

12.67 In accordance with best practice, a number of mitigation measures will be taken to minimise the risks associated with the disposal of produced waters to the Sherwood Sandstone formation. These will be based on The Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996 to ensure that the well is designed, modified, constructed, commissioned, operated and abandoned, such that there is no unplanned escape of fluids from the well and that the risks to the health and safety of person from it or anything in it, or in strata to which it is connected, are as low as is reasonably practicable. This will be confirmed in writing by an independent competent person before the design of the well is commenced, to ensure that the well is designed and constructed properly and is maintained adequately. These regulations ensure that the well is designed and planned to the highest standards.

12.68 In addition, the injection pressures required to achieve successful injection of produced water into the Sherwood Sandstone will be low and it is envisaged that the hydrostatic head of the produced water column will provide a sufficient driving force. In any event, injection pressures will be controlled to ensure they do not exceed the fracturing pressure of the formation.

12.69 Injection pressure will be monitored and recorded "continuously" during injection to ensure that pressures do not rise too high or too quickly. In the highly unlikely event that this is the case then injection will stop and the pressures will decline and dissipate, leaving no residual risk or impact.

Residual Effects

12.70 Based on the application of these mitigation methods, the residual risk associated with the proposed injection of produced water to the Sherwood Sandstone formation through all phases of the Development is negligible.

Cumulative Effects

12.71 The Applicant holds a groundwater permit (Permit Ref. EPR/AB3593DU) to inject up to 1,900m^3/day (11,951bbl/day) of produced water at the Ebberston 'A' Well Site, 2 km to the north. The rate was based on the expected maximum rate of injection required if the gas field was developed through wells constructed at the Ebberston 'A' Well Site.

12.72 This application seeks planning permission for the gas field to be developed instead through wells at the EMS Well Site. As both the EMA and the EMS Well Sites are in the control of the Applicant, the Applicant is able to confirm that the combined rates of injection at the EMS Well Site and Ebberston 'A' Well Site will not exceed the 1,900m^3/day (11,951bbl/day) rate that has been permitted. Consequently, there are no cumulative effects, over and above that which has already been permitted, to consider.

Summary

12.73 The water to be produced during the production of gas is from the gas reservoir within the Permian Kirkham Abby Formation (KAF). The produced water is highly saline with salt concentrations greater than would be found in seawater. The produced water will be injected into the Sherwood Sandstone formation which is located above the KAF. The produced water originating from the KAF will typically have twice the salinity than the Sherwood Sandstone formation water. In addition both waters show significant amounts of naturally occurring hydrocarbons related to the presence of natural gas. The water found in the KAF and Sherwood Sandstone beneath the EMS Well Site is not used for drinking water or any other uses and is separated from drinking water and other usable water supplies vertically by impermeable rock and horizontally by a considerable distance.

12.74 The injection system into the Sherwood Sandstone formation involves the movement of water from one very saline water bearing formation to another. In both cases the formation water has no resource value. The geological units involved are at great depth; are distant from any groundwater with resource value; and lie below a great thickness of clay rich, low permeability geological units.

12.75 Based on the nature of the natural geology and the application of appropriate mitigation methods, the residual risk associated with the proposed injection of produced water through all phases of the Development is negligible.

12.76 The disposal of produced water to the Sherwood Sandstone has been discussed with the Environment Agency at both local and national levels, in the context of a similar activity at the Ebberston 'A' Well Site. The same baseline conditions exist at EMS Well Site and the permit application and determination process will run in parallel with the planning process.

12.77 The combined rates of injection at the EMS Well Site and Ebberston 'A' Well Site will not exceed the rate that has been permitted at the Ebberston 'A' Wellsite. There are no cumulative effects to consider.

12.78 Table 12.7 contains a summary of the likely significant effects of the injection system.

Table 12.7: Table of Significance – Produced Water Disposal

Potential Effects	**Nature of Effects** (Permanent/ Temporary)	**Significance** (Major/Moderate/Minor) (Beneficial/Adverse / Negligible)	**Mitigation / Enhancement Measures**	**Geographical Importance***							**Residual Effects** (Major/Moderate/Minor) (Beneficial/Adverse/Negligible)
				I	UK	E	R	C	NP	L	
Construction											
Contamination of Aquifer	Temporary	Minor Adverse	Wells cased into injection horizon. Implement rigorous site management of the construction process using The Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996						*	*	Negligible
Operation											
Contamination of Aquifer	Temporary	Minor Adverse	Geology of site naturally controls risk						*	*	Negligible
Induced seismicity	Temporary	Minor Adverse	Injection pressure will not exceed fracture pressure. Continuous monitoring to ensure pressures do not rise too high or too quickly						*	*	Negligible
Decommissioning											
None	N/A	N/A	N/A								N/A
Restoration											
Reinstatement of original environment	Permanent	Moderate Beneficial	None						*	*	Negligible Beneficial
Cumulative Effects											
None	N/A	N/A	N/A								N/A

***Geographical Level of Importance**

I = International; UK = United Kingdom; E = England; R = Regional; C = County; NP = National Park; L = Local

[i] European Water Framework Directive - DIRECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal of the European Communities.
[ii] Groundwater Daughter Directive - DIRECTIVE 2006/118/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 12 December 2006 on the protection of groundwater against pollution and deterioration. Official Journal of the European Union.
[iii] Groundwater Directive - Council Directive 80/68/EEC of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances. Official Journal of the European Communities.
[iv] Environmental Permitting (England and Wales) Regulations 2010.
[v] Groundwater Protection: Principles and Practice (GP3), Version 1.1, Environment Agency, August 2013.
[vi] Central Government, March 2012 – 'National Planning Policy Framework
[vii] Central Government, March 2014 – Planning Practice Guidance (PPG)
[viii] North York Moors National Park Authority Local Development Framework
[ix] Green Leaves III - Guidelines for Environmental Risk Assessment and Management: Green Leaves III. Revised Departmental Guidance Prepared by Defra and the Collaborative Centre of Excellence in Understanding and Managing Natural and Environmental Risks, Cranfield University, November 2011.
[x] Bottrell, S.H., et al (2006) Combined isotopic and modelling approach to determining the source of saline groundwaters in the Selby Sherwood Sandstone aquifer, UK. Geological Society, London, Special Publications, v263 pp325-338.
[xi] Hem 1985, Study and Interpretation of the Chemical Characteristics of Natural Water. USGS Water Supply Paper 2254.
[xii] The Royal Belgian Institute of Natural Sciences (www.naturalsciences.be).
[xiii] The Offshore Installations and Wells (Design and Construction etc.) Regulations 1996.
[xiv] Water Resources Act 1991.