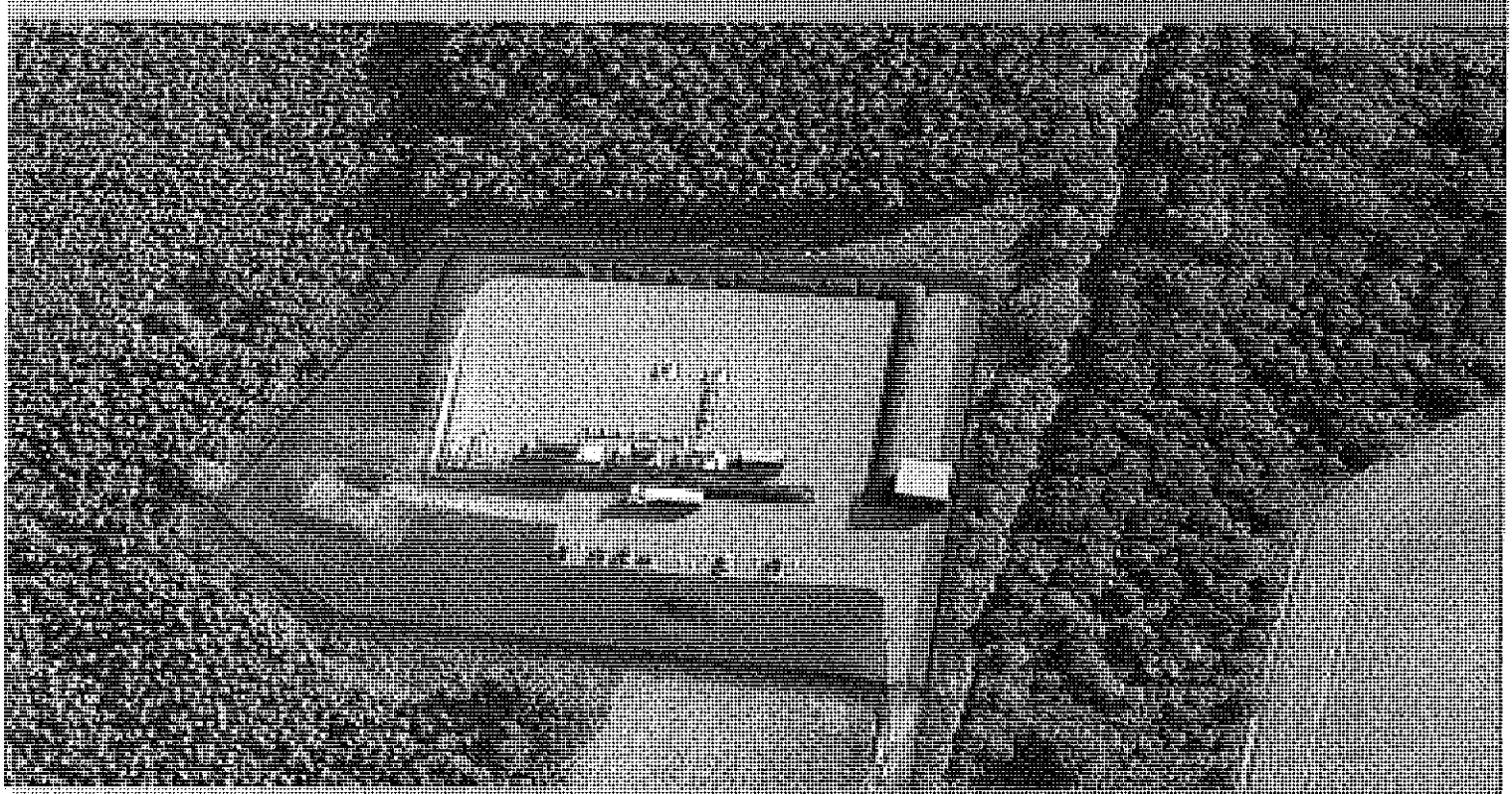
Ebberston Moor South Wellsite – Knapton Gas Pipeline
Ebberston, North Yorkshire

NYMNPA Planning Application
Ref NYM/2014/0587/EIA

Further Supplementary Information



June 2015

MOORLAND

THIRD ENERGY

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Ebberston Moor South (EMS) to Knapton Generating Station (KGS) Gas Pipeline

Introduction

This Further Supplementary Information of Cumulative Effects is in response to a request for additional information from the North York Moors National Park Authority (NYMNPA) about two specific matters arising from the cumulative effects of the consented EMA-Knapton pipeline permission (ref NYM/2013/0593/EIA), the consented Early Development Scheme (EDS) permission at EMA wellsite development (NYM/2013/0477/EIA) and the current planning application (ref NYM/2014/0587/EIA) which seeks planning permission for gas production at the EMS wellsite and a connecting pipeline from the wellsite to Knapton Generating Station.

Background

The NYMNPA has requested that Third Energy and Moorland Energy provide some additional information and clarification, following a review of "Additional Information following deferment of Planning Application by NYMNPA", submitted in May 2015, to enable the planning application to be reported to the Park Authority's Planning Committee. The NYMNPA's consultant Hydrogeologist, Dr Shaun Salmon of Amec Foster Wheeler, set out in an email, dated 13 May 2015, the additional information he requires to assess the cumulative impacts of the developments referred to above upon the hydrogeology of the area. Dr Salmon has raised two concerns. These can be summarised as follows:

1. Both EMA and the EMS well sites lie over the Corallian Group aquifer and secondary protection zone. Therefore, the cumulative effects of surface site works and pipelines on the aquifer and other dependent groundwater receptors such as Troutsdale Beck need to be considered. This is considered to be important in view of the high degree of sensitivity of the water environment in the area.

2. The cumulative effects of the zone of head disturbance from EMS and EMA needs to be clarified as there may be a possibility of the two zones coalescing and strengthening. This potentially could increase the risk of induced seismicity. There may also be a case for the cumulative assessment to take account of the York Potash development, given that it includes water disposal into the Sherwood Sandstone.

The documents in the appendices seek to respond to each of these concerns. The appendices are summarised below.

1. Assessment of Cumulative Effects

Chapter 11 '(Flood Risk, Hydrogeology and Drainage') of the Environmental Statement which accompanied the planning application was prepared by R Elliott Associates Ltd. Paragraphs 11.159 and 11.160 assess the cumulative effects of the EDS and the York Potash scheme respectively.

Appendix 1 comprises a letter from R Elliott Associates which considers the cumulative effects of surface site works and pipelines on the aquifer and other dependent groundwater receptors. The EMA wellsite lies outside the catchment area for the Troutsdale abstraction and therefore can be excluded from further consideration of cumulative effects. The effects upon the SPZ arising from the pipeline construction from EMA are similar to those for the EMS pipeline although there is a greater degree of mitigation owing to the greater distance of the EMA site pipeline from the abstraction point. R Elliott Associates conclude that

construction of both pipelines at the same time will not increase the risk of spillages and the residual significance of the effects of construction upon the various receptors will remain negligible. The summary of Residual Effects and Evaluation of Significance has been revised and is included in Appendix 1.

2. Risk of Induced Seismicity

2.1 Potential for Induced Seismicity Due to Injection of Produced Water in the Vale of Pickering gas Fields & Cumulative Effect of Produced Water Injection in the Ebberston Gas Fields

Introduction

Third Energy UK Gas Limited ("Third Energy") produces natural gas from the Pickering, Malton, Kirby Misperton and Marishes gas fields in the Vale of Pickering, North Yorkshire and holds interests in the undeveloped Ebberston gas fields (Ebberston South and Ebberston Moor) on the southern edge of the North York Moors; to the northeast of the Vale of Pickering.

Third Energy is planning to trial a dewatering scheme for the Pickering gas field and highly saline water will be produced (Produced Water) in conjunction with the gas from the Kirkham Abbey Formation (KAF). The scheme proposes injection of the Produced Water into the Sherwood Sandstone Formation at the Pickering-1 well (PK-1), for which a permit application was submitted to the Environment Agency in September 2014. If successful, Third Energy would look to implement similar injection schemes at Malton and Kirby Misperton, using the Malton-1 well (MN-1) and Kirby Misperton-3 well (KM-3).

The Vale of Pickering is an area of generally low seismicity, as recorded by the British Geological Survey. Third Energy (and its predecessors) has been injecting Produced Water back into the KAF via an injection well at KM-3 for many years with no adverse effects. The KM-3 well is currently permitted to allow up to 1,500m^3/day of Produced Water to be injected. Third Energy also hold a permit for the injection of up to 1,900m^3/day of Produced Water from the KAF to the Sherwood Sandstone in the Ebberston Field.

While the injection of Produced Water does **NOT** involve hydraulic fracturing, onshore injection schemes have been subject to increased scrutiny since Cuadrilla's hydraulic fracturing activity in the Preese Hall-1 well initiated seismic events that were felt by the local population.

Background

A seismic event is caused by the sudden release of energy in the Earth's crust which creates seismic waves at the surface. In order for the energy to be released movement of the earth must occur. The earth's crust is in continual movement as tectonic plates move across its surface. However, the plates move in jerks rather than smoothly and as the plates try to move, stress is built up and the stresses are reduced by the release of energy, resulting in an earthquake. As most of the movement occurs along plate boundaries, this is where the largest and most common earthquakes occur.

The Vale of Pickering lies within the Eurasian plate, some 2000 kilometres from the closest tectonic plate boundary. Within a tectonic plate, there is little or no relative motion and stress levels generally remain constant. As a consequence, there are relatively few seismic events. This doesn't mean that there are none, only that they are small and infrequent. The stresses that give rise to events in these situations may be as a result of post glaciation re- adjustment (isostatic readjustment), due to the melting of considerable ice thickness after the last ice age; the regional stress in the earth's crust created by movement elsewhere; mining; amongst other occasional small natural ground movements.

There are different ways of measuring the size or magnitude of seismic events, but one of the first methods for describing the magnitude and probably the most commonly known, was developed by Charles Richter in 1932 and is known as the Richter Scale. An important aspect of the Richter Scale is not linear; it is logarithmic therefore a magnitude 6 event is 10 times bigger than a magnitude 5 and releases 32 times more energy; 5 is 10 times bigger than 4 and releases 32 times more energy; and so on. Between 1970 and 2014 only three

seismic events have been recorded in the vicinity of the Vale of Pickering; all with a magnitude of less than or equal to 2. The two with recorded depths originated at >5km.

Within the context of recent historic observations, a period during which Produced Water has been injected into the Kirkham Abbey Formation, the Vale of Pickering has been an area of very low seismic activity with recorded activity limited to three events that would be barely perceptible by people and which were at depths and locations unconnected with the injection. Thus the injection that has been undertaken for many years has not resulted in seismic events.

Third Energy has commissioned four detailed technical reports by specialist consultants Rockflow Resources. The first set titled "Ebberston South Water Injection: Seismic Event Risk Assessment" dated July 2014 and "Ebberston Moor Water Injection: Seismic Event Risk Assessment", dated November 2014 relate to the Ebberston field. The second set titled "Pickering Water Injection: Seismic Event Risk Assessment" dated July 2014 and "Vale of Pickering Water Injection: Seismic Event Risk Assessment" dated April 2015, relate to the Vale of Pickering field. The studies were initiated to, *"investigate and, where possible, to quantify the risk that the proposed injection scheme would trigger seismic activity"*. The principal aspects of the technical reports are summarised below.

Rockflow Resources Reports

At any point in the subsurface the rocks are subjected to forces or stresses due to the weight of the overlying rock and tension in the earth's crust. In addition, the water pressure in the formations provides a counteracting force. The difference between the earth stresses together with the weight of rock, and water pressure is known as the "Effective Stress".

Water injection into a reservoir will increase fluid pressure (unless water is removed at the same time). As that fluid pressure rises, the local effective stress is reduced, such that in theory the rocks can crack or move, potentially leading to fracturing or fault movement and hence generating a seismic event.

The fluid injection at Preese Hall caused a number of events, the largest of which had a magnitude of 2.3 on the Richter scale, which (as discussed above) is a very low magnitude event. Water was injected at high pressure into Preese Hall-1 in a process that was deliberately designed to cause hydrofracturing of the impermeable shale rock. However, the water unintentionally entered a nearby pre-existing naturally occurring fault. As the fluids were unable to dissipate into the shale, pressure along the fault plane rose until the effective stress was reduced to zero and fault movement occurred, and hence the small seismic events.

In order to provide operating guidelines for future water injection schemes, DECC (the Department of Energy & Climate Change) have issued criteria that accept resultant seismic activity up to a magnitude of 0.0 on the Richter scale, and require all injection to cease if any monitored seismic event breaches a magnitude of 0.5. Such magnitudes are only detectible by sensitive instruments.

The 2014 assessment by Rockflow Resources focused on the injection of up to 556m^3/day (3,500 bpd) of Produced Water into the Sherwood Sandstone Formation via PK-1. In consideration of potential expansion of the scheme, the 2015 assessment by the same specialist considers injection of a further 874m^3/day (5,500 bpd) [giving a total of 1430m^3/day (9000 bpd)] into the Sherwood Sandstone Formation.

Unlike the shale at Preese Hall, the Sherwood Sandstone Formation is very well understood and there is a great deal of data on its porosity and permeability from gas and oil wells drilled in the North Sea, on shore in the UK and other oil and gas basins. This data shows that the Sherwood Sandstone Formation has sufficient porosity and permeability to accept injected water; and that the proposed injection rates and pressure will not induce fracturing of the rock.

Interpretation of seismic surveys and existing well data show that the PK-1 and KM-3 wells crossed faults within the Sherwood Sandstone Formation. In addition, there are several other local faults that cross the formation which were not intersected. Standard analysis techniques allow the strength of a rock mass and the effective stress acting on that rock mass to be evaluated. Using the known permeability, porosity,

rock strength and stress data from oil and gas exploration and production wells in the Sherwood Sandstone Formation in the UK, the risk of fault movement can be assessed. Rockflow Resources have assessed this risk based on injection in each well and the cumulative effect of injection at all the wells. This cumulative effect takes account of the injection of Produced Water over a period of 10 years.

Following detailed analysis across a range of scenarios, the Rockflow Resources report concludes that the likelihood that the injection scheme will cause a seismic event with a magnitude greater than 0.0 is assessed as less than 1 in 40,000 and water injection at the proposed rates and pressures can proceed within DECC's "Green" category.

Cumulative Effects

Third Energy holds an existing permit to discharge to the Sherwood Sandstone Formation within the Ebberston Moor field. This has also been studied in detail by Rockflow Resources. It is important that the possibility of both schemes having a combined effect be examined. The distance between the two schemes is some 10km and they are separated by the Pickering Fault. The technical assessments show that the two schemes will behave independently. If a worst case scenario is invented where the Sherwood Sandstone Formation acts as one large interconnected block and the worst case assumptions are taken for the calculations, then the resulting change in pressure would be insufficient to trigger a seismic event.

Whilst the risk of initiation of a seismic event is extremely low, mitigation can be put in place to reduce this to effectively zero by using an injection pump that produces insufficient pressure to cause a seismic event and to inject the Produced Water at a sufficient depth by proper engineering of the well.

In order to understand and monitor the pressure of the water in the formation, pressures in the injection wells should be measured at regular intervals, particularly during the initial weeks of injection.

Conclusions

In overall conclusion, due to the planned low injection pressures and injection rates, it is extremely unlikely that water injection could cause sufficient localised pressure increases to initiate fracturing of the rock or movement on existing fault planes. It is therefore extremely unlikely that the proposed water injection scheme will cause any detectable seismic events. The extremely low residual risks associated with gradual increase in formation pressure can be fully mitigated by appropriate well design and engineering. Monitoring and control systems will be used so that in the unlikely event that threshold values are approached, injection will be stopped, pressures will dissipate and this will prevent a seismic event from occurring.

The analysis of the cumulative effects clearly demonstrates that even with all the planned injection points operating over a 10 year period, that there is a very low risk of the pressure building across the formation to levels that would take the system outside the safe zone. In addition, the gradual changes in the pressures allows monitoring to take place and decisions to be made to reduce or stop injection in response to the real effects, thereby preventing seismic events and reducing the risk to effectively zero.

2.2 Potential for Induced Seismicity due to Injection of Produced Water at Ebberston South and Ebberston Moor & Cumulative effect of Produced Water Injection in the Vale of Pickering Gas Fields

Introduction

Third Energy UK Gas Limited ("Third Energy") produces natural gas from the Pickering, Malton, Kirby Misperton and Marishes gas fields in the Vale of Pickering, North Yorkshire and holds interests in the undeveloped Ebberston gas fields (Ebberston South and Ebberston Moor) on the southern edge of the North York Moors; to the northeast of the Vale of Pickering.

In a joint venture with Moorland Energy, Third Energy intends to develop natural gas reserves contained in the Kirkham Abbey Formation (KAF) by modifying the existing well at the Ebberston South wellsite (EM-S). Produced Water, which is highly saline, is obtained with the gas and it is proposed to inject this water into the Sherwood Sandstone Formation; using the same well. An environmental permit application was submitted to the Environment Agency for the proposed injection scheme in September 2014.

In May 2014, Third Energy obtained a permit for the injection of up to 1,900m^3/day of Produced Water from the KAF to the Sherwood Sandstone at the Ebberston Moor A wellsite (EB-A). The permitted injection volume is sufficient to dewater the KAF in the Ebberston fields and if successful, the proposed injection at EM-S would reduce the requirement for Produced Water injection at EB-A.

Third Energy also proposes to develop a similar dewatering scheme in the Vale of Pickering and the results of a trial dewatering scheme for the injection of Produced Water into the Sherwood Sandstone Formation at the Pickering-1 well (PK-1), is critical to the development of the proposed scheme at Ebberston South.

Ebberston South and Ebberston Moor is an area of generally low seismicity, as recorded by the British Geological Survey. Third Energy (and its predecessors) has been injecting Produced Water back into the KAF via an injection well at KM-3 in the Vale of Pickering for many years with no adverse effects. The KM-3 well is currently permitted to allow up to1,500m^3/day of Produced Water to be injected.

While the injection of Produced Water does **NOT** involve hydraulic fracturing, onshore injection schemes have been subject to increased scrutiny since Cuadrilla's hydraulic fracturing activity in the Preese Hall-1 well initiated seismic events that were felt by the local population.

Background

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Within the context of recent historic observations, a period during which Produced Water has been injected into the KAF in the Vale of Pickering; Ebberston South and Ebberston Moor have been an area of very low seismic activity with recorded activity limited to three events that would be barely perceptible by people and which were at depths and locations unconnected with the injection. Thus the injection that has been undertaken nearby for many years has not resulted in seismic events.

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Unlike the shale at Preese Hall, the Sherwood Sandstone Formation is very well understood and there is a great deal of data on its porosity and permeability from gas and oil wells drilled in the North Sea, on shore in the UK and other oil and gas basins. This data shows that the Sherwood Sandstone Formation has sufficient porosity and permeability to accept injected water; and that the proposed injection rates and pressure will not induce fracturing of the rock.

Interpretation of seismic surveys and existing well data show that the EM-S and EM-A wells do not cross any geological faults within the Sherwood Sandstone Formation. The closest fault structure is the Helmsley-Filey Fault located some
4km south of EM-S; 6.5km south of EB-A. Standard analysis techniques allow the strength of a rock mass and the effective stress acting on that rock mass to be evaluated. Using the known permeability, porosity, rock strength and stress data from oil and gas exploration and production wells in the Sherwood Sandstone Formation in the UK, the risk of fault movement can be assessed. Rockflow Resources have assessed this risk based on injection in each well and the cumulative effect of injection at all the wells. This cumulative effect takes account of the injection of Produced Water over a period of 10 years.

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assessed as less than 1 in 50,000 and water injection at the proposed rates and pressures can proceed within DECC's "Green" category.

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Third Energy is also proposing to develop a similar Produced Water injection scheme in the Vale of Pickering. This has also been studied in detail by Rockflow Resources. It is important that the possibility of both schemes having a combined effect be examined. The distance between the two schemes is some 10km and they are separated by the Pickering Fault. The technical assessments show that the two schemes will behave independently. If a worst case scenario is invented where the Sherwood Sandstone Formation acts as one large interconnected block, and the worst case assumptions are taken for the calculations, then the resulting change in pressure would be insufficient to trigger a seismic event.

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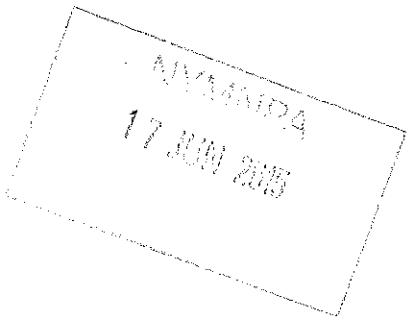


3. Influence of the York Potash Scheme – Water Reinjection

York Potash Limited (YPL) has proposed to construct and operate a potash mine in the Whitby area of North Yorkshire, and as part of the project, YPL intend to inject waste water for disposal into the Sherwood formation. This has the potential to overlap with the waste water injection schemes that Third Energy is proposing for the Ebberston Moor and Vale of Pickering dewatering schemes. As the schemes intend to inject water into the Sherwood formation, the impact of the combined schemes should be considered.

YPL propose to inject waste water into the Sherwood formation at a site on Dove's Nest Farm, south of Whitby; this is approximately 15km north of Third Energy's proposed Ebberston Moor injection wells, and a further 10km from the Vale of Pickering injection sites. The available documents do not provide comprehensive details regarding the scheme, but indicate that, in the worst case scenario, up to 1100m^3/d (~7000bbl/d) of water will be injected during the construction phase (approximately 24 months), falling to 600m^3/d (~4000bbl/d) of water for the following 24 months. The documents do not indicate:

1. whether injection would continue beyond this date
2. what the base case injection rates are
3. what the cumulative injection volumes are expected to be.

For the purposes of the current analysis, continued injection at a rate of to 600m^3/d (~3800bbl/d) is assumed for the 10 years period that has been considered previously for the Third Energy injection schemes. This would imply a maximum cumulative injection volume of 16 million barrels (MMbbl) of water in YPL's worst case scenario. The corresponding volumes for Third Energy's schemes are 19.6 MMbbl in the Vale of Pickering and 23.1 MMbbl at Ebberston Moor.

If all three areas are hydraulically connected area (i.e. in the same pressure compartment), implied aquifer size covers an area in excess of 3800km^2. Based on the analysis undertaken previously, using the worst case subsurface parameters, a cumulative injection volume of 58.7 MMbbl from the three schemes would raise the regional aquifer pressure by less than 260 psi. This is approximately half the minimum trap integrity and would be at the upper end of the "safe" category, or the lower end of the "Monitor" category, that were defined in the previous analysis. Consequently, the resulting increase in formation pressure would be extremely unlikely to trigger a seismic event, but should be measured regularly to ensure that it does not rise unexpectedly.

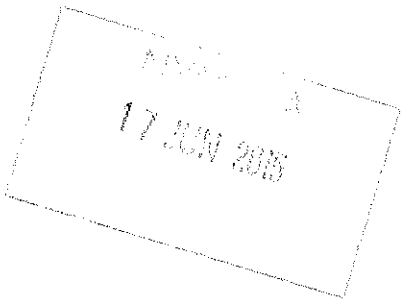
During the previous analysis, several other scenarios considered smaller pressure compartment sizes. The distance of Dove's Nest Farm from Ebberston Moor means that the only other scenario that should be considered is the one where the Vale of Pickering Faults is sealing, but the aquifer is continuous otherwise. This would isolate the Vale of Pickering injection volumes, but would allow the Ebberston Moor and YPL schemes to communicate. In such a scenario, the maximum cumulative injected volume would be 40 MMbbl injected into an aquifer that extended over at least 300km^2. In this configuration, it is possible for the aquifer pressure to rise to levels that would be categorised as "Unsafe" or "Very Risky". These pressures would not be impose immediately, but would develop over the 10-year period under consideration.

Consequently, although the circumstances that would allow these pressures to develop are extremely unlikely, it would be advisable to implement a regular pressure measurement scheme during the early years of the injection operations. A monitoring program will be able to measure any pressure increase, allowing

the compartment size to be extrapolated and injection policy adjusted accordingly.

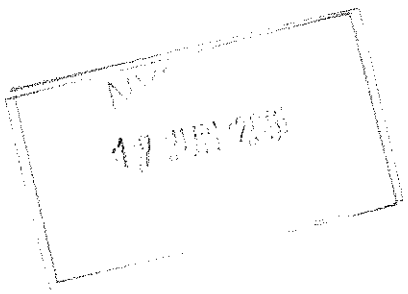
There is also an effective feedback mechanism. Under fixed injection conditions, the tubing head pressure (THP) on an injection well is constant, so as the formation pressure rises, the pressure excess presented by the well will fall. As a result, the injection rate will slow and eventually cease once the formation pressure matches the pressure in the well. So, as long as the THP is set at a level that such that the static water column pressure does not exceed the fracture gradient, the only consequence will be curtailment of the injection.

In conclusion, it is extremely unlikely that the combined effect of the proposed injection schemes will increase the fluid pressure within the Sherwood Formation to a level sufficient to cause rock failure. Additionally, a regular pressure measurement program should ensure that the effects of extreme scenarios are detected sufficiently early to allow intervention that would prevent pressures rising to dangerous levels.



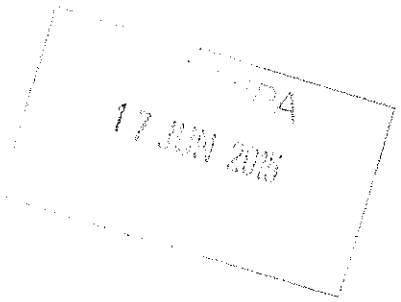
Appendix 1 Assessment of Cumulative Effects

- Letter from R Elliott Associates



Appendix 2 Potential for Induced Seismicity – Vale of Pickering

- Rockflow Report – Seismic Event Risk Assessment



Appendix 3 Potential for Induced Seismicity – Ebberston Moor

- Rockflow Report – Seismic Event Risk Assessment 20th November 2015