Unconventional oil and gas development: Understanding and mitigating community impacts from transportation

Report for Scottish Government
Executive summary

Study aims and approach

The aims of this project are:

- To improve understanding of the scope and scale of increased traffic volumes in communities around sites, over the four stages of unconventional oil and gas development (exploration, appraisal, production and decommissioning & restoration).
- To improve understanding of the range of potential impacts (and duration of impacts) of these traffic volumes, and characterise potential impacts in sites of different types.
- To identify robust regulatory and other options that could mitigate impacts on communities and the environment.

In order to evaluate the potential impacts of traffic associated with unconventional oil and gas development in Scotland, we have firstly set out the policy and regulatory controls on road traffic associated with new development in general, and UOG in particular. We have then investigated the likely scale of material quantities and traffic changes associated with UOG activities in Scotland. We have considered evidence for the community impacts associated with road transportation, and assessed the means for avoiding or mitigating community impacts resulting from transportation due to UOG development. We have considered a number of case studies to inform the study conclusions.

Based on this analysis, we have drawn conclusions regarding the potential impacts and made recommendations for measures which would be needed to mitigate impacts.

Regulatory and planning framework

The existing regulatory and planning framework would be applicable to UOG developments. Each relevant UOG development can be required to undergo the Environmental Impact Assessment (EIA) process, in view of legal obligations for larger scale development, local authority powers to require an EIA for smaller scale developments, and industry undertakings to carry out EIAs. Mitigation measures can be implemented through planning conditions or in accordance with Section 75 of the Planning etc. (Scotland) Act 2006.

Traffic impacts of unconventional oil and gas development

The development of Scotland’s unconventional oil and gas resources would result in associated road traffic movements. Road transportation would be needed for movement of plant, equipment, materials and waste. Each shale gas well pad could require between 13,000 and 93,000 vehicle movements, spread over about a 20 year period. A coal bed methane well pad is estimated to require about 93,000 vehicle movements over about 12 years. Traffic movements would be at their highest during well pad construction and hydraulic fracturing. Traffic movements could be sustained at around 190 per week for a period of approximately 2 years during development of a pad with 15 wells. For context, typical traffic flows associated with other traffic-generating development include:

- Food superstore: Approximately 60,000 two-way vehicle trips per week
- Warehouse / distribution centre: Approximately 5,000 two-way HGV movements per week
- Windfarm at construction stage: Approximately 800-1,000 two-way movements per week

The additional traffic movements associated with onshore oil and gas resources are unlikely to be significant or detectable at a regional or national scale, in view of the much greater numbers of traffic movements resulting from other activities. The contribution of UOG development to traffic and associated impacts such as carbon emissions at a regional or national scale would be slight and comparable to many other industry sectors and activities.

Consequently, the key focus for consideration of potential community impacts of UOG development is the assessment and management of potential impacts on communities local to development sites.

Potential community impacts from transportation

Road traffic impacts would arise principally from increases in heavy goods vehicle movements on potentially unsuitable roads. These movements would take place over a relatively limited period for an individual well, but may occur over a much longer period for development of a multi-well pad, and in particular in situations where a shale gas field is being developed.
Sites with good highway links, and sites located in industrial areas are likely to have relatively low potential community impacts due to traffic. Sites in rural or urban/suburban settings would have a greater potential for community and environmental impacts. In all cases, the potential impacts should be carefully considered through the planning process. Sites with the opportunity to reduce water transport (e.g. through mains water connection; re-use of waste water on site; piped water supply and/or removal) would be more favourable.

The main potential community impacts of traffic associated with UOG development are as follows:

- **Accelerated road surface degradation.** This impact could be mitigated through cost recovery through taxes or fees; through policy measures; and/or by altering infrastructure to make it more resilient. Specific actions may include road condition surveys, specified remedial works, and/or making a payment under a Section 96 agreement to recover the cost of road repairs.

- **Risk of increased accidents.** Increased UOG traffic in areas of intensive UOG development in the USA has resulted in increased incidence of accidents in affected communities.

- **Risk of accidental release of hazardous material during transportation.** Truck accidents could potentially lead to chemical or wastewater spills. There are systems in place in the UK to manage chemical spillage in the event of a traffic accident. These controls would reduce, but not fully eliminate, such risks.

- **Air pollution impacts.** Increases in vehicle movements would result in an increase in emissions of air pollutants which would need to be considered in the planning process. In most cases, effects on local air quality are expected to be minor, but the potential for localised impacts would depend on the nature, scale and location of a proposed development.

- **Noise.** Noise associated with traffic movements to and from UOG facilities could potentially affect nearby residents. This would need to be taken into account in the planning process.

- **Nature conservation.** UOG activities can potentially affect biodiversity via a number of routes, although the likely setting of UOG development in Scotland means that impacts on remote habitats are unlikely. Nature conservation impacts would need to be taken into account in the assessment of any UOG development.

**Mitigation**

Managing the road traffic impacts of new development is a well-established discipline with project developers and regulatory authorities. To ensure that appropriate mitigation measures are identified, implemented, enforced and managed, the following is recommended.

1. National, regional and local plans should set policies to guide the development of UOG resources, in the event that the moratorium is lifted.
2. All planning applications for UOG development should be made subject to an Environmental Impact Assessment. This would include an assessment of impacts relating to traffic movements and the identification of appropriate mitigation measures, such as avoidance of transportation of water to and from the site by road, where possible.
3. A Traffic Management Plan should be required to support planning applications for UOG sites.
4. Discussions should take place between the developer and the local authority with regard to the provision of a Roads Condition Survey and provision of an appropriate financial bond to cover any required road repairs, potentially supported by planning condition.
5. At appropriate sites, an Enforcement Officer should be appointed to ensure that mitigation measures are implemented and enforced throughout the life of the project.
6. It is understood that the oil and gas industry is developing a set of key principles in relation to transportation. These should be evaluated, and, if appropriate, taken into account in the planning process.

**Residual community impacts from transportation**

Assuming that appropriate strategic policies are put in place, and appropriate mitigation is carried out, local communities would nevertheless experience an increase in traffic numbers, potentially for an extended period of a number of years. Any increase in vehicle movements could result in an increase in noise, emissions to air, road damage, or traffic accident risks, which may be identified as negligible, or may require mitigation. Provided the planning and EIA system is properly implemented, any significant impacts would be avoided through the use of appropriate mitigation measures.
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Appendix 1: Case studies
### Abbreviations

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<tbody>
<tr>
<td>AQMA</td>
<td>Air Quality Management Area</td>
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<tr>
<td>CCAN</td>
<td>Chesapeake Climate Action Network</td>
</tr>
<tr>
<td>dBA</td>
<td>Decibel, A-weighted</td>
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<tr>
<td>DEC</td>
<td>Department of Environmental Conservation</td>
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<tr>
<td>DECC</td>
<td>Department for Energy and Climate Change</td>
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<tr>
<td>DMRB</td>
<td>Design Manual for Roads and Bridges</td>
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<tr>
<td>DPMTAG</td>
<td>Development Planning and Management Transport Appraisal Guidance</td>
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<tr>
<td>EIA</td>
<td>Environmental Impact Assessment</td>
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<tr>
<td>EIASR</td>
<td>Environmental Impact Assessment (Scotland) Regulations</td>
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<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
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<tr>
<td>ES</td>
<td>Environmental Statement</td>
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<tr>
<td>EU-OSHA</td>
<td>European Union information agency for occupational safety and health</td>
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<tr>
<td>GDWTF</td>
<td>Gas Delivery and Water Treatment Facility</td>
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<tr>
<td>HGV</td>
<td>Heavy Goods Vehicle</td>
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<tr>
<td>IAQM</td>
<td>Institute for Air Quality Management</td>
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<tr>
<td>IEA</td>
<td>Institute for Environmental Assessment</td>
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<tr>
<td>IEMA</td>
<td>Institute of Environmental Management and Assessment</td>
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<tr>
<td>IHT</td>
<td>Institute of Highways and Transportation</td>
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<tr>
<td>LDP</td>
<td>Local Development Plan</td>
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<tr>
<td>LGV</td>
<td>Light Goods Vehicles</td>
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<td>m³</td>
<td>Cubic metres</td>
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<td>NORM</td>
<td>Naturally Occurring Radioactive Material</td>
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<tr>
<td>NPF</td>
<td>National Planning Framework</td>
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<tr>
<td>NYSDEC</td>
<td>New York State Department of Environmental Conservation</td>
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<tr>
<td>PAN</td>
<td>Planning Advice Note</td>
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<tr>
<td>PEDL</td>
<td>Petroleum Exploration and Development Licence</td>
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<tr>
<td>SDP</td>
<td>Strategic Development Plan</td>
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<tr>
<td>SEA</td>
<td>Strategic Environmental Assessment</td>
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<tr>
<td>SGEIS</td>
<td>Supplemental Generic Environmental Impact Statements</td>
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<tr>
<td>SPG</td>
<td>Supplementary Planning Guidance</td>
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<tr>
<td>SPP</td>
<td>Scottish Planning Policy</td>
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<tr>
<td>TA</td>
<td>Traffic Assessment or Transportation Assessment</td>
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<tr>
<td>TDT</td>
<td>Texas Department of Transportation</td>
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<tr>
<td>TMP</td>
<td>Traffic Management Plan</td>
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<td>UCG</td>
<td>Underground Coal Gasification</td>
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<tr>
<td>UK</td>
<td>United Kingdom</td>
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<tr>
<td>UKOOG</td>
<td>UK Onshore Oil and Gas</td>
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<tr>
<td>UOG</td>
<td>Unconventional Oil and Gas</td>
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<tr>
<td>US(A)</td>
<td>United States (of America)</td>
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1 Introduction

1.1 Study context

On 28 January 2015, the Scottish Government announced a moratorium on environmental and planning consents for the development of all unconventional oil and gas (UOG) extraction in Scotland, including, but not exclusively, that using hydraulic fracturing. This was extended to cover underground coal gasification (UCG) on 8 October 2015. The aim of this moratorium was to enable the Scottish Government to take a cautious, considered and evidence-based approach to the development of unconventional oil and gas in Scotland. The imposition of a temporary, open-ended moratorium gives the Scottish Government the opportunity to take a number of key steps to developing a robust policy in relation to UOG:

- Undertake a full public consultation on unconventional oil and gas extraction
- Commission a full public health impact assessment
- Conduct further work into strengthening planning guidance
- Look at further tightening of environmental regulation.

To support this programme, the Scottish Government has announced five studies to provide the required scientific and technical evidence on UOG development. These studies cover the following topics:

- Understanding and Mitigating Community Level Impacts from Transportation (this study)
- Decommissioning, Site Restoration and Aftercare – Obligations and Treatment of Financial Liabilities
- Understanding and Monitoring Induced Seismic Activity
- Economic Impacts and Scenario Development
- Climate Change Impacts

When announcing the moratorium, Fergus Ewing (Scottish Government Energy Minister) said, “We recognise that local communities are likely to bear the brunt of any unconventional oil and gas developments, particularly in terms of increased traffic and related emissions and noise impacts. These are issues that must be researched further.” This project is the cornerstone of Scottish Government’s work programme to deal with these important issues for local communities.

1.2 Project objectives

The traffic impacts of development are among the most evident for communities where widespread development of UOG resources takes place. The focus of this project was on characterising the traffic movements associated with UOG development (both in terms of volumes and vehicle types), identifying the associated environmental impacts (including emissions and noise impacts highlighted by the Minister), and outlining the regulatory and planning means by which these impacts would be dealt with, in the event of UOG development going ahead in Scotland. Underground coal gasification is not within the scope of this project.

The overall objective of this project is to better understand the potential for increases in traffic volumes in the vicinity of UOG activity during the exploration, appraisal, production, and decommissioning & restoration stages. Building on this, Scottish Government wishes to understand the link between transport impacts and the magnitude of operations, their duration, and the types of locations affected by traffic movements. This is not a straightforward issue with linear correlations between the scale and duration of operations and traffic numbers, because UOG exploration and development would typically take place at multi-well pads, and traffic movements would be strongly affected by the details of development. Traffic impacts would also be affected by the site context (e.g. proximity of sensitive locations to roads carrying additional traffic).

The Scottish Government also wishes to develop an improved understanding of the reasons for traffic movements linked to UOG development. This will enable appropriate assessments to be carried out, and in particular it will enable guidance on reducing traffic movements to a minimum, and managing
unavoidable traffic impacts to be developed, should the moratorium on UOG development be lifted. This will enable a view to be taken on the minimum likely traffic impact of UOG development scenarios, in order to assist with policy decisions in relation to the future of UOG development in Scotland.

Looking at individual sites and potential transportation-related impacts, the Scottish Government wishes to understand the magnitude of traffic flows, the likely variation in traffic flows and impacts at different locations. In the USA, where UOG development is most advanced, shale gas and similar installations have been developed in a very wide range of locations, from remote rural sites through sites located in industrial areas, sites close to residential areas, and sites in urban centres.

Hence, in summary, the project aims are:

- To improve understanding of the scope and scale of increased traffic volumes in communities around sites, over the four stages of unconventional oil and gas development (exploration, appraisal, production and decommissioning & restoration).
- To improve understanding of the range of potential impacts, and duration of impacts, of these traffic volumes, and characterise potential impacts in sites of different types.
- To identify robust regulatory and other options that could mitigate impacts on communities and the environment.

1.3 Onshore oil and gas in Scotland

Shale oil and gas reserves in Scotland are located principally across the central belt (see Figures 1 and 2). In relation to Coal Bed Methane, five site investigations had been initiated to 2014, located in historic coal mining areas in Falkirk, Dumfries & Galloway, East Fife, Lanarkshire and West Fife. Consequently, if UOG development proceeds, installations could potentially be located in a wide range of areas, including densely populated urban areas, suburban areas, remote rural areas, coastal locations and sensitive habitat zones (subject to other considerations such as the current ban on activities involving hydraulic fracturing in protected areas of the UK).

Figure 1: Area prospective for shale oil in Scotland\(^1\)

UOG development in both urban and rural areas could potentially result in traffic using unsuitable roads, and it is important for Scottish Government to understand the risk of this occurring, the mitigation measures available, and the potential environmental and community implications.

The development of an individual UOG well is characterised by an intensive phase of activity during the site preparation, well drilling, hydraulic fracturing and completion stages, with associated traffic movements. After the well is completed, it can be expected to operate with much lower levels of activity for a period of around 5 to 10 years. During this time, the hydrocarbon production rate typically drops from an early peak, until it reaches a point when the operator may opt to refracture the well. This would then result in a further phase of intensive activity and associated traffic movements. Refracturing has become less common in recent years, with recent data indicating that approximately 1% of existing wells in the US are refractured each year based on a survey of 91,000 wells. In the US, it is estimated that refracturing will account for up to 11% of horizontal well fracturing activity by 2020.

This pattern of activity may be representative for drilling of small numbers of wells during the exploration phase. However, a different pattern is likely to emerge in the event of more widespread development of a shale gas field, as discussed in our analyses for the European Commission and CCAN. The use of well pads with 10 – 20 wells would result in the initial phases of well development taking place over a longer period than would be the case for smaller well pads. Additionally, the relatively thin and fractured shale formations in Scotland compared to those in England may result in less intensive development at an individual well pad than could be expected to occur in England. These features of gas field development have been explored in the economic impact assessment, and the implications for transportation explored here. However, the transportation impacts for communities living close to any individual site would depend on the phasing of activities at that site.

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1.4 Structure of this report

The study methodology is set out in Section 2 of this report. The relevant regulatory and planning framework for Scotland is presented in Section 3. Section 4 provides data on material requirements and estimated traffic movements associated with UOG development in Scotland. Section 5 provides a discussion of potential impacts of road traffic associated with UOG development, and outlines how these impacts could be managed if UOG development is permitted to proceed. The study conclusions and recommendations are set out in Section 6.

1.5 Stakeholder engagement

The following organisations were consulted during the course of this project, and provided valuable feedback:

- Broad Alliance – “a coalition of Scottish communities opposed to onshore and near-shore unconventional oil and gas development”
- Scottish Environment Link – “the forum for Scotland’s voluntary environment organisations, with over 35 member bodies representing a range of environmental interests with the common goal of contributing to a more environmentally sustainable society”
- UK Onshore Oil and Gas – “the representative body for the UK onshore oil and gas industry including exploration and production”
2 Study methodology

2.1 Overview

The starting point for this study is the well-established understanding of the potential community impacts of road traffic. These have been evaluated and managed for many years, leading to the development of established policy and guidance for dealing with road traffic impacts in Scotland.

In order to evaluate the potential impacts of traffic associated with unconventional oil and gas development in Scotland, we have firstly set out the policy and regulatory controls on road traffic associated with new development in general, and UOG in particular. We have then investigated the likely scale of material quantities and traffic changes associated with UOG activities in Scotland. This was carried out on a site-specific basis, and then combined with scenarios for shale gas development in Scotland developed as part of the assessment of economic impacts.\(^5\) We have considered these impacts in the context of traffic statistics for Scotland, and typical traffic impacts of comparable developments.

We have considered evidence for the community impacts associated with road transportation in general, and with UOG-related traffic in particular, and assessed the extent to which the community impacts resulting from transportation due to UOG development can be avoided or mitigated.

Based on this analysis, we have drawn conclusions regarding the potential impacts and made recommendations for measures which would be needed to mitigate impacts, and areas where further research would be useful.

2.2 Material movements by process stage

The principal activities giving rise to transportation requirements (including movement of personnel) can be summarised as follows:\(^6\):

1. Well pad and road construction equipment/materials
2. Drilling rig
3. Drilling fluid and materials
4. Drilling equipment (casing, drill pipe, etc.)
5. Completion rig
6. Completion fluid and materials
7. Completion equipment (pipe, wellhead)
8. Hydraulic fracture equipment (pump trucks, tanks)
9. Hydraulic fracture water
10. Hydraulic fracture sand
11. Removal of waste water and other waste materials

In order to evaluate material movements associated with UOG development, we have used reports produced by New York State,\(^7\) the Tyndall Centre\(^6\) and the Institute of Directors\(^4\) as a starting point. These evaluations were also highlighted by consultees as key references. We have undertaken a literature review to identify any changes which may have occurred over the period since these studies and our own analyses\(^27,32\) were conducted. Information on material volumes is closely linked to information on traffic flows associated with the quantities of material moved. For example, the Tyndall Centre report provides an analysis of expected flowback fluid and produced water quantities. This is used to develop the estimates of flowback water removal shown in Table 2.

These key references are focused mainly on shale gas developments. We have also reviewed and analysed the activities associated with coal bed methane to characterise the sources of truck

\(^5\) KPMG on behalf of Scottish Government, Unconventional oil and gas development: Economic impacts, 2016


\(^7\) New York State Department of Environmental Conservation (2011) Final Supplemental Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program.
movements. In this case, the water requirement for hydraulic fracturing is likely to be significantly lower, but the requirement for treatment and potentially removal of potentially contaminated produced water can be expected to extend throughout the lifetime of the well. We have researched the published literature in relation to coal bed methane development and also consider environmental statements and Transport Assessment reports submitted in support of planning applications for coal bed methane development in Scotland.

If UOG development goes ahead, there would be variability in the plant, equipment and materials which are required to be transported to/from individual sites, and the resultant traffic movements. This variability would be related to the size and nature of a well pad site (e.g. existence of sloping terrain; previous use; number of wells), and to the extent of drilling and fracturing to be carried out. The quantity of flowback fluid and produced water would be variable and cannot be predicted with confidence. Consequently, the approach adopted in this study has been to identify a likely range of material quantities and traffic movements, based on limited experience of UOG development in Scotland and England, and more extensive experience in the USA.

The outcome of this approach was a schedule of activities associated with UOG development, covering both shale gas and coal bed methane. Each activity would have an estimated range of potential activity. The timing of each activity in the process development has been highlighted and a visual representation of this timeline developed. Each activity has been presented on the basis of “per well” or “per well pad” as appropriate, and we have also provided an indicative range for development of UOG resources in Scotland as a whole.

2.3 Likely scale of traffic changes

The likely scale of traffic changes needs to be understood for the four stages of unconventional oil and gas development: (1) exploration, (2) appraisal, (3) production and (4) decommissioning / restoration.

The scale of the impacts for an individual development can be broken down into the following characteristics which must be considered for each stage of the development:

- Total traffic volumes for each stage and broken down into activity or material to be transported (plant, aggregates, hazardous materials, construction materials, extracted products etc)
- Total HGV volumes for each stage
- Traffic (total and HGV) volumes broken down into monthly, weekly and daily movements
- Details on the types of vehicle that would be used for each task (weight, length, width etc) including details of any abnormal loads
- The typical programme for each stage of the development

The information that we have reviewed includes:

- Analyses of the road traffic impacts of UOG development including the Ricardo evaluations for the European Commission and CCAN;\(^\text{27,32}\) the Tyndall Centre report;\(^\text{6}\) the Institute of Directors report;\(^\text{4}\) the Independent Expert Scientific Panel report on Unconventional Oil and Gas;\(^\text{8}\)
- Any more recently published evidence on transportation impacts of UOG development.

In addition to the above, we have reviewed how traffic volumes and impacts might vary depending on location. We have reviewed case study information and published research in order to characterise the potential differences in traffic impacts depending on location.

From the information gathered, the parameters that contribute to determining the traffic impacts of Unconventional Oil and Gas developments were summarised. We have commented upon the likelihood of any strategic or local impacts, and how any such impacts would be managed, taking account of the standard of the road network and the setting of the development.

2.4 Case studies

A number of case studies were evaluated to provide information on a range of potentially relevant development types:

• Review of the traffic impact during exploratory drilling and hydraulic fracturing, Preese Hall, Weeton, Lancashire;
• Review of EIA and planning appeal information for Roseacre Wood, Lancashire;
• Review of air quality impacts of traffic resulting from proposed Roseacre Wood development;
• Review of EIA undertaken in relation to the coalbed methane site at Letham Moss Falkirk;
• Review of EIA work undertaken for Earlseat windfarm in Scotland;
• Review of EIA work undertaken for Rusha Surface Mine in West Lothian;
• Review of EIA work undertaken for Tomfyne Quarry in North Lanarkshire;
• Review of transportation impacts associated with UOG development at rural sites in Western North Dakota;9 and
• Review of transportation impacts associated with UOG development at urban sites in Tarrant and Johnson Counties, Fort Worth, Texas.10

The case studies are set out in Appendix 1.

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3 Regulatory and planning framework for transportation

3.1 Introduction

This chapter presents a strategic review of the planning and regulatory framework relating to the impact, assessment and control of transport matters as they may apply to UOG developments in Scotland.

3.2 Background

The regulatory framework for managing UOG development in Scotland was set out in guidance produced by the then Department for Energy and Climate Change (DECC) in 2013. This guidance includes the “roadmap” which is reproduced as Figure 3 below.

Figure 3: DECC Roadmap for Regulation and permitting of UOG Development in Scotland

The part that concerns transport and potential community-level impacts is controlled by the planning system which is represented by the blue coloured boxes within the roadmap figure. Additionally, other regulatory requirements may also have an indirect impact on transport and associated impacts. For example, discharge consents issued under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (more commonly known as the Controlled Activity Regulations, CAR) may require flow back or produced water to be sent off site for treatment and disposal, with associated transport requirements. Alternatively, discharge consents may provide for treatment and discharge on site, which would result in fewer movements of vehicles for removal of wastes.

On 28 January 2015, the Scottish Government announced a moratorium on environmental and planning consents for all UOG development. Given the moratorium and the relative infancy of UOG developments in Scotland there is no specific regulatory or planning framework currently in place. This strategic review therefore considers existing development planning legislation and guidance which may provide the basis for assessing traffic impacts associated with UOG development and includes the following sources:

National Planning Context

- The Town & Country Planning (Scotland) Act 1997 / Planning etc. (Scotland) Act 2006
- Scottish Government ‘National Planning Framework 3’ 2014
- Scottish Government ‘Scottish Planning Policy’ 2014

Regional and Local Planning Framework

- Strategic Development Plans
- Local Development Plans

Environmental Impact Assessment Framework

- Environmental Impact Assessment Scotland Regulation 2011
- Institute of Environmental Assessment (IEA) now the Institute of Environmental Management and Assessment, Guidance Notes No. 1: ‘Guidelines for the Environmental Assessment of Road Traffic’ 1993

Development Management and Control

- Transport Scotland ‘Development Planning and Management Transport Appraisal Guidance (DPMTAG) 2011
- Transport Scotland ‘Transport Assessment Guidance’ 2012

3.3 The Town & Country Planning Scotland (Act) 1997 / Planning etc. (Scotland) Act 2006

The Town & Country Planning Scotland (Act) is the basis for the planning system and sets out the roles of Scottish Ministers and local authorities with regard to development plans, development management and enforcements. The Act was amended by the Planning etc. (Scotland) Act 2006.

The planning system in Scotland is ‘plan-led’ and the aforementioned Acts represent the legislation that creates the planning system.

The Town & County Planning Scotland (Act) notes that

‘..“development” means the carrying out of building, engineering, mining or other operations in, on, over or under land, or the making of any material change in the use of any buildings or other land’ and that planning permission is required ‘for the carrying out of development on land’.

UOG development would therefore accord with this definition of “development” and would require planning permission. The Planning etc. (Scotland) Act 2006 extends the definition of “development” to include fish farming.

When compared with The Town & Country Planning Scotland (Act) 1997 the key changes associated with The Planning etc. (Scotland) Act include the introduction of the National Planning Framework, a greater emphasis on consultation and development plans.

Figure 4 and the following paragraphs summarise the context of the planning system and how it may apply to UOG developments.
3.4 National Planning Framework (NPF) 3

NPF 3 is the statutory spatial expression of the Scottish Government's Economic Strategy and contains plans for investment in infrastructure. NPF 3 brings together ‘plans and strategies in economic development, regeneration, energy, environment, climate change, transport and digital infrastructure to provide a coherent vision of how Scotland should evolve over the next 20 to 30 years’.

NPF 3, along with Scottish Planning Policy, applied at national, strategic and local levels provides a national vision of the expectations of the planning system and the outcomes to be delivered for Scottish people. The vision for Scotland is of:

- A successful, sustainable place;
- A low carbon place;
- A natural, resilient place; and
- A connected place.

NPF 3 identifies National Developments (decided by Scottish Ministers). National Developments are identified as they are needed to deliver the overall spatial strategy for Scotland. UOG development is not identified in NPF 3.

With regard to transport, NPF 3 sets out a spatial strategy which is intended to consider and deliver sustainable transport links and routes between key cities and rural areas while setting out a programme for investment in transport infrastructure, particularly a decarbonised transport sector. An ambitious programme for investment is proposed including the Forth Replacement Crossing, M8 / M73 / M74 upgrade schemes and freight enhancements.
The strategy, actions and developments set out in NPF 3 are expected to be considered in strategic and local development plans, which are discussed in more detail in this chapter.

3.5 Scottish Planning Policy (SPP)

SPP complements the vision for Scotland identified in NPF 3 and ‘is a statement of Scottish Government policy on how nationally important land use planning matters should be addressed across the country’.

SPP introduces a policy presumption in favour of development that contributes to sustainable development and sets out planning priorities for the operation of the planning system. SPP is part of a series of planning and architecture documents which are material considerations in the planning system. Other planning policy documents include Planning Circulars, NPF, Creating Places, Designing Streets and Planning Advice Notes. All planning policy and guidance documents with the exception of NPF 3 are non-statutory.

The planning system provides the opportunity for everyone to engage with development proposals. Local authorities should communicate and consult with communities during the preparation of development plans and developers should consult with communities during the planning application process.

Relating to UOG, SPP states:

‘...applicants should undertake a risk assessment for all proposals for shale gas and coal bed methane extraction. The assessment can, where appropriate, be undertaken as part of any environmental impact assessment and should also be developed in consultation with statutory consultees and local communities so that it informs the design of the proposal’.

In areas covered by a Petroleum Exploration and Development Licence (PEDL) issued by the Scottish Government, local development plans ‘should ensure applicants consider, where possible, transport of the end product by pipeline, rail or water rather than road’. Where numerous PEDLs are granted in overlapping areas ‘consideration should be given to the most efficient sequencing of extraction’.

With regard to the impact and assessment of development related traffic, SPP notes that development plans should appraise transport impacts using Transport Scotland’s Development Planning and Management Transport Appraisal Guidance (DPMTG). Appraisals should be carried out in sufficient time to inform local development plan spatial strategies and strategic environmental assessments. More detail relating to DPMTAG is included in section 3.12.

Where a new development is likely to generate a significant increase in the number of trips, a transport assessment should be carried out. Transport Assessment Guidance has been prepared by Transport Scotland, which is described in more detail in section 3.13.

3.6 Strategic Development Plans

Strategic Development Plans (SDPs) set out the vision for the long term development of Scotland’s city regions and again follow the overarching vision for Scotland identified in NPF 3 and SPP. There are four Scottish SDPs which replace previous Structure Plans. SDPs are formally approved by Scottish Ministers and are prepared by groups of planning authorities working together to deal with cross boundary issues such as housing and transport. SDPs are updated at least once every five years.

Within the Central Belt, Clydeplan and SESplan are the most relevant SDPs. With regard to UOG, the respective SDPs state the following:

**Proposed Clydeplan 2016**

Policy 15 of the proposed SDP for the Clyde area notes that:

- ‘Any proposals for unconventional oil and gas extraction should be considered against Scottish Planning Policy and accord with the policies of the relevant local authority. The relevant local authorities will seek to ensure a consistent approach is taken in areas where licenses extend across local authority boundaries.’
The proposed SESplan identifies the requirement for Local Development Plans to ‘identify coal, oil and gas reserves to support a diverse energy mix, giving weight to the avoidance of long term environmental impact and greenhouse gas emissions.’

A Minerals Technical Note dated July 2015 accompanies SESplan and notes the following:

- ‘For areas covered by Petroleum Exploration and Development Licence (PEDL), Local Development Plans should:
  - recognise that exploration and appraisal is likely to be the initial focus of development activity, with production probably requiring a separate decision;
  - address constraints on production and processing;
  - identify factors that will be taken into account when determining planning applications for wellhead and transmission infrastructure; and
  - provide a consistent approach to extraction where licences extend across local authority boundaries.

The SESplan area ‘contains reserves of onshore gas including coal bed methane. As required by SPP, development plans should identify the factors that will be taken into account when deciding planning applications for well heads and transmission infrastructure’.

### 3.7 Local Development Plans

Local Development Plans (LDP) provide the vision for how communities will grow and develop in the future. They provide certainty for communities and investors as to where development should take place and the supporting infrastructure required for growth. LDPs sit, where applicable, within the framework of the SDP and are process driven. The LDP process includes an evidence based approach, followed by the Main Issues Report, subsequent Proposed Plan and any following examination prior to adoption. Throughout the LDP process, stakeholders including the public, are provided with opportunities to make comment on the LDP.

Local authorities including National Park Authorities have a statutory obligation to prepare a LDP setting out specific land use allocations and strategies over a 10 year period. LDPs are updated at least once every five years.

LDPs are typically supported by a Strategic Environmental Assessment (SEA). The SEA sets out the likely impacts the plan will have on the environment and highlights ways of mitigating such impacts. The LDP should also be supported by a Transport Appraisal (DPMTAG). The Transport Appraisal typically considers the cumulative operational impacts of proposed developments and identifies mitigating measures to accommodate developments such as junction improvements. The mechanism for delivering mitigating transport measures is also identified, typically within Supplementary Guidance which may include developer contributions that may be secured through planning conditions or in accordance with Section 75 of the Planning etc. (Scotland) Act 2006.

Local authorities should also prepare a Minerals Plan or equivalent which may form part of the LDP. The Minerals Plan identifies the context and location of mineral resources within a local authority area.

The adopted Clackmannanshire Local Development Plan (August 2015) contains a Policy on the extraction of coal bed methane which states that proposals would be supported where they can demonstrate the following criteria:

- The proposal should not have significant adverse impacts on communities, the environment or the local economy;
- The proposal meets the criteria in Policy EP10 – Minerals – General Principles policy;
- The proposal would not result in a significant adverse impact on residential amenity or the built and natural environment or have an adverse effect on the integrity of the Firth of Forth SPA either alone or in combination with other projects and plans;
- The end product would be transported from the extraction point via pipeline, rail or water transport rather than by road, unless this is not practicable;
On completion of exploration and production, all plant, equipment and buildings would be removed, and high quality restoration and aftercare of the sites would be delivered."

Policy EP10 on Minerals referred to in the Coal Bed Methane Policy considers transport issues. The policy states that proposals should include “information on how any adverse impacts on settlements as a result of haulage, including road safety, environmental and amenity impacts, will be mitigated. This should include provision for routing haulage vehicles away from settlements wherever possible”.

3.8 Environmental Impact Assessment (Scotland) Regulations 2011

Environmental Impact Assessment (EIA) has been introduced in Scotland mainly as a result of Directives from the European Community (EC). The requirements of the EC Directives are transposed into Scots law by Regulations made by the Scottish Government.

The types of project which are subject to the EIA process are listed in Schedules to the Environmental Impact Assessment (Scotland) Regulations 2011 (EIASR 2011). Every project must be ‘screened’ by the approving authority to see if it should be subject to EIA procedures. All projects listed in Schedule 1 of the EIASR 2011 must be subject to EIA. Whether projects of a kind listed in Schedule 2 of the EIASR 2011 are to be subject to EIA depends on their nature, scale or location and whether they would be likely to have significant effects on the environment. Project proposers can ask competent authorities for a screening opinion, which will decide whether the project is to be subject to EIA. The Scottish Ministers also have powers to issue a screening direction.

UOG is not specifically included in Schedule 1 of EIASR 2011. However, a development for ‘extraction of petroleum and natural gas for commercial purposes where the amount extracted exceeds 500 tonnes per day in the case of petroleum and 500,000 cubic metres per day in the case of gas’ would warrant an EIA.

Schedule 2 of EIASR 2011 includes reference to a development area in excess of 0.5 hectares for ‘surface industrial installations for the extraction of coal, petroleum, natural gas and ores, as well as bituminous shale’. The majority of exploration and all production sites are likely to extend to at least 0.5 hectares in area, including any site likely to generate significant traffic movements. A planning authority should therefore consider whether a development meeting this criterion is likely to have significant effects on the environment, and if so, an EIA should be required. Additionally, the industry made a formal commitment to undertake EIAs for all exploration wells that involve hydraulic fracturing in January 2014.12 This would be linked to an individual planning application, so may potentially apply to a single well, or to a group of wells located on a single site.

On this basis, it is concluded that all UOG developments capable of generating significant traffic movements would either require an EIA as Schedule 1 development, or could be required to have an EIA as Schedule 2 development with potentially significant effects on the environment, or could be required to have an EIA on the basis of the industry commitment.12 In the unlikely event of none of these criteria applying to a future development, an applicant could be required to give detailed consideration to transportation impacts to an equivalent standard to an EIA as part of a planning application.

The application of the EIA or planning regulations would result in the application of further regulatory provisions which may be relevant to traffic impacts. For example, these may include the requirement for screening and (if necessary) appropriate assessment under the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended in Scotland).

Where a scheme warrants an EIA the developer can seek support from the planning authority to identify the parameters which determine the Environmental Statement (ES) assessment scope, including detail on the consultation process with stakeholders including the public. The ES provides the opportunity to assess the impacts and environmental effects of a proposal on traffic and transport as well as identifying any mitigating measures.

3.9 Environmental Impact Assessment Consultation

The Scottish Government is currently running a consultation (from 9th August 2016 to 31 October 2016) on Environmental Impact Assessment in relation to amending Scottish Environmental Impact Assessment Regulations to Transpose Directive 2014/52/EU. This consultation sets out the proposals for the transposition of an EU directive into Scottish Legislation. The main change associated with the stated EIA process relevant to this research is the addition of a new EIA stage entitled “monitoring / Enforcement / Penalties”. The new EU Directive states that member states should lay down penalties applicable to infringements with the penalties being effective, proportionate and dissuasive.

3.10 Guidelines for the Environmental Assessment of Road Traffic

Where EIA is applicable, an ES should be prepared which contains a chapter on Access, Traffic and Transport. The ES should be prepared in accordance with relevant guidance and for Access, Traffic and Transport the relevant guidance is provided by the Institute of Environmental Assessment (IEA) now the Institute of Environmental Management and Assessment (IEMA) in their publication entitled Guidance Notes No. 1: ‘Guidelines for the Environmental Assessment of Road Traffic’ and Institution of Highways and Transportation (IHT) publication ‘Guidelines for Traffic Impact Assessment’.

The purpose of the IEA Guidelines is to provide the basis for a systematic, consistent and comprehensive approach to the appraisal of traffic impacts for a wide range of development projects irrespective of whether the sites are to be subjected to a formal EIA. The IEA Guidelines consider the environmental effect of traffic in respect of:

- Traffic impacts;
- Noise and vibration;
- Accidents and safety;
- Driver delay;
- Fear and intimidation;
- Air pollution;
- Dust and dirt;
- Pedestrian / cycle amenity and delay; and
- Severance (the division between people and places or other people caused by a road artery).

The IEA Guidelines state that two rules can be adopted to delimit the scale and extent of the assessment.

- Rule 1: Include road links where traffic flows would increase by more than 30% (or the number of HGVs would increase by more than 30%); and
- Rule 2: Include any other specifically sensitive areas where traffic flows would increase by 10% or more.

The IEA Guidelines suggest that where the predicted increase in traffic flows is lower than the above thresholds, the significance of the impacts can be stated to be low or insignificant and further detailed assessments are not required.

The explanatory text in Paragraphs 3.16 to 3.19 of the IEA Guidelines state that ‘projected changes in traffic of less than 10% create no discernible environmental impact’. Given that daily variations in background traffic are frequently +/-10%, and other environmental impacts (e.g. pollution, ecology, etc.) are less sensitive to traffic flow changes, the Guidelines conclude that ‘a 30% change in traffic flow represents a reasonable threshold for including a highway link within the assessment’.

The impacts of development traffic are dependent on a number of factors including: volume of traffic, traffic speeds, operational characteristics and traffic composition.

The Guidelines note that the ES should identify “worst case” impacts and the frequency of this impact. The “worst case” environmental impact is likely to include the effects of “greatest change” as well as “highest impact”.

The IEA Guidelines identifies groups, locations and special interests ‘which may be sensitive to changes in traffic conditions’. The following check list identifies groups and special interests which should be considered:

- People at home;
- People in work places;
- Sensitive groups including children, elderly and disabled;
- Sensitive locations, e.g. hospitals, churches, schools, historical buildings;
- People walking or cycling;
- Open spaces, recreational sites, shopping areas; and
- Sites of ecological / nature conservation value and tourist attractions.

The Guidelines identify potential measures which could be introduced to mitigate the traffic impacts and effects of a development. These include restriction on the size of vehicles, specifying traffic routes, restricting the hours of site operation and installing traffic calming measures.

3.11 Guidelines for Traffic Impact Assessment

The IHT publication ‘Guidelines for Traffic Impact Assessment’ recommends that ESs should be assessed in accordance with the IEA Guidelines.

3.12 Development Planning and Management Transport Appraisal Guidance

DPMTAG provides guidance on the preparation of a Transport Appraisal to inform the preparation of development plans with a specific focus on the cumulative operational aspects of proposed developments on the strategic transport network. The DMPTAG process can be used to quantify impacts of land use decisions on the environment, safety, the economy and accessibility.

3.13 Transport Assessment Guidance

‘Transport Assessment Guidance’ sets out the requirements for the undertaking of Transport Assessments (TA) in Scotland. A TA is typically prepared in support of a planning application for development. TA principally relate to developments that generate significant long-term operational increases in traffic as a result of their function, such as retail parks and residential developments. The Guidance provides advice on the preparation of a TA including consideration to scoping and data collection.

In respect of environmental impacts, the Guidance notes:

‘The environmental impacts of a development proposal are generally outside the remit of the TA process, as they should be picked up through an Environmental Impact Assessment (EIA). For some types of development an EIA is always required; for others it is required if the planning authority considers that the development is likely to have significant effects on the environment’.

The screening and scoping process for a development proposal should identify if a TA is required and what the scope of the TA should be.


This planning circular provides guidance on the various stages of the planning application process. The guidance focuses on an open dialogue between a developer and the planning authority and provides guidance on the process for engaging with the public.

The circular details the type of information required to support a planning application which may include a transport assessment, EIA and design and access statement.
3.15 Summary

This chapter provides a strategic review of the planning and regulatory framework which would currently apply to UOG and UCG developments in respect of the impacts and effects of traffic. At present, there is no specific planning framework relating to UOG: applications for UOG development would be through considered through the existing regulatory and planning framework. This has an emphasis on stakeholder and public engagement throughout. Scottish Planning Policy sets principles for UOG development, including a requirement for risk assessment and establishing the principle of minimising road transportation of products. At this stage, potential development sites are not identified in NPF, SDP or LDPs. Developments which are not included in NPF, SDP or LDP are typically viewed less favourably at the planning application stage and would require an additional level of scrutiny.

Each UOG development can be required to undergo the Environmental Impact Assessment (EIA) process, in view of legal obligations for larger scale development, local authority powers to require an EIA for smaller scale developments, and industry undertakings to carry out EIAs.

With regard to transport, the IEA Guidelines provide the most relevant framework for assessing the impacts and environmental effects of traffic. The IEA Guidelines detail the requirement to assess the “worst” traffic impacts and provide guidance on the mitigation of impacts. Mitigation measures can be implemented through planning conditions or in accordance with Section 75 of the Planning etc. (Scotland) Act 2006.
4 Traffic generation by onshore oil and gas activity

4.1 Material quantities for well pad activities

The construction and operation of an onshore oil and gas facility requires the movement of large quantities of equipment and materials to the location of the proposed well-head, ranging from drilling equipment to concrete and water. Once its use is completed, equipment then needs to be removed from the site along with waste materials. It is assumed that oil and gas produced at a well pad site would be transported by pipeline. Well-sites could in principle be located in a wide range of settings, including rural, industrial, urban or suburban locations. In some cases, sites may need to be accessed by newly constructed site access roads as well as the existing road network.

Various pieces of equipment and batches of materials would be delivered to the site throughout the development, with the quantity determined by the scale of the operation and the phase of the process. Due to the weight and size of these items, they would typically require the use of heavy goods vehicles in order to transport them. The details of plant, equipment and materials transportation which would be required at individual sites would result from the interaction between the activities to be carried out, regulatory requirements, and the specific circumstances and constraints of the site.

In the UK, a Heavy Goods Vehicle (HGV) is defined as a vehicle over 3,500 kg unladen weight. A Light Goods Vehicle is defined as a commercial vehicle under 3,500 kg. HGVs must not exceed 40 tonnes laden weight. Vehicles exceeding 40 tonnes laden weight are classified as Abnormal Loads and the movement of such loads requires an application process. A different definition is used in the US, with vehicles specified in eight separate classes. However, the studies reviewed as part of this project do not necessarily use the standard US definitions.

4.1.1 Hydraulic fracturing

The following is a summary of equipment used at hydraulic fracturing sites in the Marcellus Shale (eastern USA) and Eagle Ford Shale (state of Texas, USA) regions, based on observations by Rodriguez & Ouyang (2013)\(^\text{13}\). This represents a site during the hydraulic fracturing stage, and does not include the equipment used during the other phases, such as the drilling rigs, for vertical and horizontal wells, and excavation plant. It is assumed that a similar range of equipment would be required for development of a UOG site requiring hydraulic fracturing in Scotland. The traffic movements required to bring this equipment to and from a UOG site are set out in subsequent tables.

Table 1: Equipment used at hydraulic fracturing sites in the Marcellus and Eagle Ford shale regions

<table>
<thead>
<tr>
<th>Equipment type</th>
<th>Number of units</th>
<th>Equipment type</th>
<th>Number of units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracturing pump</td>
<td>14 - 16</td>
<td>Coiled tubing</td>
<td>n/a</td>
</tr>
<tr>
<td>Data monitoring and recording van</td>
<td>1</td>
<td>Wireline</td>
<td>2</td>
</tr>
<tr>
<td>Sand chief (loading/unloading proppant)</td>
<td>2</td>
<td>Wellhead</td>
<td>n/a</td>
</tr>
<tr>
<td>Boom truck (large forklift)</td>
<td>1</td>
<td>Frac tanks - stimulation fluid storage</td>
<td>10</td>
</tr>
<tr>
<td>Frac missile (low/high pressure manifold)</td>
<td>1</td>
<td>Acid tanks</td>
<td>1</td>
</tr>
<tr>
<td>Frac blender</td>
<td>1</td>
<td>Flow-back tanks</td>
<td>2</td>
</tr>
<tr>
<td>Casing pump</td>
<td>1</td>
<td>Fueling truck</td>
<td>1</td>
</tr>
<tr>
<td>Hydration unit</td>
<td>1</td>
<td>Water transfer pump</td>
<td>1</td>
</tr>
<tr>
<td>Chemical float</td>
<td>1</td>
<td>Iron truck (crane)</td>
<td>1</td>
</tr>
<tr>
<td>Gel mixer</td>
<td>1</td>
<td>Iron and hose trailer</td>
<td>1</td>
</tr>
<tr>
<td>Chemical transport</td>
<td>2</td>
<td>Parts trailer</td>
<td>1</td>
</tr>
<tr>
<td>High rate skid</td>
<td>1</td>
<td>Pumping skid</td>
<td>1</td>
</tr>
</tbody>
</table>

In addition to the equipment listed above, vehicle movements are required to bring materials to and from the site. Cuttings produced as a result of drilling must be removed from the site for disposal.

The process of hydraulic fracturing is reliant on the supply of water, as well as proppant (sand) and chemicals. The water can either be supplied through a dedicated pipeline or, as is more commonly the case, be delivered to the site by road tanker. During flow-back, the waste-water that returns to the surface would typically be temporarily stored at the site in retention ponds, before being transported to a waste-water disposal site.

In the Scottish context, it is likely that a mains water supply would be located sufficiently close to some well pad sites to enable water to be transferred to the site by pipeline. This is unlikely to be the case for all well pads, and site-specific issues such as barriers to securing the relevant access rights to install a temporary pipeline may prevent mains water being used at sites where this would otherwise be a viable option. It is anticipated that mains water could be used for hydraulic fracturing at a significant proportion of well pads in Scotland. This has been accounted for in this analysis by considering two scenarios – one scenario in which all water transferred to/from the site takes place by pipeline, or in the case of wastewater is re-used on site, and a second scenario in which all water transferred to/from the site takes place by road.

As highlighted below, a significant quantity of produced water from within the shale formation would require management. It is possible that a proportion of this produced water could be re-used for fracturing subsequent well stages. There is a limit to the extent of re-use of produced water, because of the inorganic salt content, and potential presence of Naturally Occurring Radioactive Materials (NORM). The industry view is that the salinity and NORM of produced water from shale in Scotland is likely to be lower than elsewhere, because of the conditions under which the shale was originally formed. However, this cannot be guaranteed. The potential range of re-use of wastewater in Scotland has been accounted for in this analysis within the two scenarios highlighted above – one scenario in which all water transferred to/from the site takes place by pipeline, or in the case of wastewater is re-used on site, and a second scenario in which all water transferred to/from the site takes place by road.

The following provides estimations of the quantity of materials required for the operation of a ‘typical’ hydraulic fracturing site, based on several published sources.

### Table 2: Estimations of material requirements for hydraulic fracturing

<table>
<thead>
<tr>
<th>Phase</th>
<th>Equipment / material</th>
<th>Quantity</th>
<th>Description / reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration</td>
<td>Cuttings removed</td>
<td>140 m³</td>
<td>Per well, as per Cuadrilla’s forecast development scenarios⁶</td>
</tr>
<tr>
<td>Appraisal</td>
<td>Water in during hydraulic fracturing</td>
<td>8,400 m³</td>
<td>Per well, as per Cuadrilla’s forecast development scenarios⁶</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,500 – 45,000 m³</td>
<td>Per well (King, 2012)¹⁴</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,500 – 26,000 m³</td>
<td>Per well, including initial drilling (Jiang et al., 2013)¹⁵</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,100 – 2,200 m³</td>
<td>Per stage of the fracturing operation for a single well (9,000 – 29,000 m³ per well)⁷</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 – 5 million gallons</td>
<td>Per well (United States EPA)¹⁶</td>
</tr>
</tbody>
</table>


¹⁶ Environmental Protection Agency (2010) *Scoping materials for initial design of EPA research study on potential relationships between hydraulic fracturing and drinking water resources* via [https://yosemite.epa.gov/sab/sabproduct.nsf/0/3B745430D624ED3B852576D400514B76/$File/Hydraulic+Frac+Scoping+Doc+for+SAB-3-22-10+Final.pdf](https://yosemite.epa.gov/sab/sabproduct.nsf/0/3B745430D624ED3B852576D400514B76/$File/Hydraulic+Frac+Scoping+Doc+for+SAB-3-22-10+Final.pdf)
As illustrated in Table 2, estimations on the quantity of materials required per well vary depending on the source. For the purposes of this assessment, we have assumed the values provided by Cuadrilla to be the most applicable to UK hydraulic fracturing sites. These values have therefore been used to estimate the quantity of water used per well during hydraulic fracturing, whilst the most recent data from Gallegos et al. (2016) was used to estimate the quantity of water used during refracturing. This is consistent with the data used by Broderick et al. (2011). Cuadrilla’s estimate of the rate of flow back has been applied to both hydraulic fracturing and refracturing. Similarly the estimation of the quantity of proppant and chemicals provided by Broderick et al. (2011) and Schneider (2014), respectively, have been used for both hydraulic fracturing and refracturing. This data is summarised in Table 3 below.

The material quantities in Table 3 are subject to uncertainty and variability from one well pad to another. There is reasonable consistency in the figures used for these material quantities between different studies, but the application of data from other geological formations to UOG extraction in Scotland introduces additional uncertainty which cannot be quantified.

Table 3: Materials quantities per well used for this analysis

<table>
<thead>
<tr>
<th>Phase</th>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration</td>
<td>Cuttings removed</td>
<td>140 m³ per well</td>
</tr>
<tr>
<td>Appraisal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydraulic fracturing</td>
<td>Water in</td>
<td>19,425 m³ per well,¹⁷ close to the mid-range figure identified by Broderick et al. ⁶</td>
</tr>
<tr>
<td></td>
<td>Water out</td>
<td>20 – 40% of water in (3,890 – 7,770 m³)</td>
</tr>
<tr>
<td></td>
<td>Proppant in</td>
<td>5% by volume (970 m³)</td>
</tr>
<tr>
<td></td>
<td>Chemicals in</td>
<td>&lt;1% by volume (&lt;194 m³)</td>
</tr>
<tr>
<td>Refracturing</td>
<td>Water in</td>
<td>4,500 m³</td>
</tr>
</tbody>
</table>

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4.1.2 Coal-bed methane

Data on the movements of materials and equipment to and from coal-bed methane developments are not published in the same detail as for hydraulic fracturing, however much of the same equipment is required. The majority of available data is from the US, which was assumed to be applicable to CBM resources in Scotland. A fundamental difference between CBM and extraction of other forms of UOG using hydraulic fracturing is that the extraction of coal-bed methane requires the removal of water from the coal seam, in order to release the methane from the formation. The quantity of water removed is often substantial, with some estimates putting it at approximately 17,000 gallons (approximately 64 cubic metres) per well each day\textsuperscript{20}.

Typically, this water is then removed from site using tankers to be disposed of via a number of routes (e.g. evaporation/infiltration ponds, re-injection into deeper aquifers etc.). The rate of water extracted varies throughout the life of the well, with quantities peaking during the early stages of production and gradually falling in each subsequent year, for example wells in the Warrior Basin, located in the US States of Alabama and Mississippi, have been found to show falls in water production of between 70 and 90\% after the first 1 to 2 months\textsuperscript{21}. Overall, water production at coal-bed methane wells can be expected to peak within the first year, and decline throughout the remaining lifespan (~20 years).

4.1.3 Case study evidence

A Case Study was investigated to identify the material quantities associated with exploratory drilling and hydraulic fracturing carried out in 2011 at a single well located at Preese Hall, Weeton, Lancashire (see Appendix 1). The operator, Cuadrilla, reported the following total material quantities used for fracturing of this well:

- Water: 8,399 m\textsuperscript{3}
- Sand: 463 tonnes
- Friction reducer: 3.7 m\textsuperscript{3}
- Chemical tracer: 0.004 tonnes

The water quantity reported for this well has been used in the material quantity estimates developed by Broderick et al. This seems likely to constitute a relatively low total water requirement, as hydraulic fracturing was carried out for six stages only, of which one was presumably not fully carried out. The ratio of 5\% proppant (sand) as a proportion of water used is reasonable in the light of data for Preese Hall.

The North Dakota rural UOG development case study includes an estimate of 2,300 vehicle movements associated with the development of an individual shale gas well. This was included in the analysis set out in the following section.

4.2 Traffic associated with onshore oil and gas activity

The movement of vehicles to and from onshore oil and gas sites is influenced by several factors, including the location and size of the facility, the nature of the underlying geology, and the availability

\textsuperscript{20} The Science Education Resource Centre at Carleton College (2016) Coalbed Methane via http://serc.carleton.edu/research_education/cretaceous/coalbed.html
of a local water source. Furthermore, the rate of vehicle movements fluctuates throughout the life of each well, with the intensity of vehicle numbers increasing during certain phases.

Several studies have been undertaken into the scale of vehicle movements associated with sites in both the USA and the UK, in light of the potential impact of these movements on the health and wellbeing of local communities.

The following table provides a summary of the estimated vehicle numbers occurring during the different development phases. For reference, the numbers of well pads and wells assumed in the economic scenarios are as follows:

- **Central scenario**: 20 well pads, 15 wells per pad
- **High scenario**: 31 well pads, 30 wells per pad
- **Low scenario**: 10 well pads, 10 wells per pad
- **CBM scenario**: 2 well pads, 15 wells per pad
<table>
<thead>
<tr>
<th>Table 4: Estimated vehicle numbers at onshore oil and gas sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase</td>
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<tr>
<td>---</td>
</tr>
<tr>
<td>Exploration &amp; appraisal</td>
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<tr>
<td>Phase</td>
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<tr>
<td>-----------</td>
</tr>
<tr>
<td>Completion equipment (pipes, wellhead, etc.)</td>
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<tr>
<td></td>
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<tr>
<td></td>
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<tr>
<td>Production</td>
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<tr>
<td>Phase</td>
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<tr>
<td>Decommission</td>
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<tr>
<td>and restoration</td>
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<tr>
<td>Reference</td>
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<td></td>
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</tbody>
</table>

24 Texas Department of Transportation (2012) Impact of Energy Development Activities on the Texas Transportation Infrastructure via https://www.txdot.gov/
As illustrated above, the number of vehicle movements occurring during the different stages of development varies significantly depending on the source, with estimations of heavy truck movements for single wells between well pad and road construction, and natural gas production, ranging from 719 to 3,950.

Several of the vehicle numbers provided in Table 4 have been derived from research undertaken by the New York State Department of Environmental Conservation, which has provided estimated numbers of one-way (loaded) trips per horizontal well. The NYSDEC published these estimations in a series of Draft Supplemental Generic Environmental Impact Statements (in 2009 and 2011), with the final SGEIS released in 2015. The estimated movements provided in this report are as follows:

Table 5: Estimated number of one-way (loaded) trips per well: horizontal well (Source: NYSDEC, 2015)

<table>
<thead>
<tr>
<th>Well pad Activity</th>
<th>Early Well pad Development (all water transported by truck)</th>
<th>Peak Well pad Development (pipelines may be used for water transport)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heavy truck</td>
<td>Light truck</td>
</tr>
<tr>
<td>Well pad construction</td>
<td>45</td>
<td>90</td>
</tr>
<tr>
<td>Rig mobilisation</td>
<td>95</td>
<td>140</td>
</tr>
<tr>
<td>Drilling fluids</td>
<td>45</td>
<td>140</td>
</tr>
<tr>
<td>Non-rig drilling equipment</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Drilling (rig crew, etc.)</td>
<td>50</td>
<td>140</td>
</tr>
<tr>
<td>Completion chemicals</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Completion equipment</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Hydraulic fracturing equipment (trucks and tanks)</td>
<td>175</td>
<td>326</td>
</tr>
<tr>
<td>Hydraulic fracturing water hauling</td>
<td>500</td>
<td>60</td>
</tr>
<tr>
<td>Hydraulic fracturing sand</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Produced water disposal</td>
<td>100</td>
<td>17</td>
</tr>
<tr>
<td>Final pad prep</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>-</td>
<td>85</td>
</tr>
<tr>
<td><strong>Total One-Way, Loaded Trips Per Well</strong></td>
<td><strong>1148</strong></td>
<td><strong>831</strong></td>
</tr>
</tbody>
</table>

Note: “Light” vehicles are defined in the NYSDEC study as comprising motorcycles and all two-axle, four-tyre vehicles. “Heavy” vehicles are defined as comprising all other vehicles.

The NYSDEC estimation of traffic movements forms the basis of the traffic scenarios in this report, as discussed in Section 4.3.

4.3 Traffic scenarios

4.3.1 Individual site

As illustrated in Section 4.1, estimations of the quantity of materials and the number of vehicles required per well vary depending on the source, and are likely to be affected by a number of variables, such as the size of the well, the nature of the local geology and the technology in use.

This study has based its estimations of traffic movements on data provided by the New York State Department of Environment and Conservation (NYSDEC). This approach was adopted because many other published analyses of traffic movements and impacts rely on the NYSDEC study. The NYSDEC report comprises the most reliable and comprehensive analysis of traffic movements associated with...
UOG activities. This has been supplemented with other data relevant to water quantities and coal-bed methane production. In addition, a number assumptions have also been made in order to provide projected traffic movements over the lifespans of the wells. Reliance on a single core study in this way could potentially introduce uncertainty into the analysis of traffic movements. However, the NYSDEC analysis is based on a wide range of industry sources. Where data can be cross-checked, the NYSDEC dataset is consistent with independent datasets. A more significant source of uncertainty is the application of data from the US to different shale gas formations in Scotland. This introduces an additional and non-quantifiable uncertainty into the traffic movements developed as part of this study.

The lifespan of each hydraulic fracturing site has been split into the following phases: ‘Exploration and Appraisal’, ‘Production – Hydraulic Fracturing’, ‘Production – Refracturing’ and ‘Decommissioning’, with the lifespan of coalbed methane sites split into ‘Exploration’, ‘Production and ‘Decommissioning’. The assumptions made for the activities within each phase in order to calculate vehicle movements for hydraulic fracturing and coal-bed methane are provided in Table 6 and Table 7, respectively. In these tables, for consistency with the New York State DEC study, “Light” vehicles includes motorcycles and all two-axle, four-tyre vehicles – that is, light trucks as well as cars. This contrasts with the UK definition of heavy goods vehicles, which comprises all vehicles with an unladen weight greater than 3500 kg. Hence, some vehicles in the “light” category in the tables below would be classified as “HGVs” in Scotland.

Table 6: Vehicle movement calculations at hydraulic fracturing sites, with and without water transport (Central scenario)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Activity</th>
<th>Water transport</th>
<th>Vehicle type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration &amp; appraisal</td>
<td>Well pad construction</td>
<td>With &amp; Without</td>
<td>Heavy</td>
<td>45 one-way vehicle movements per pad(^{25}), spread over 4 weeks(^{26}). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5(^{27}) to reflect increase in traffic for multi-well pad (2.4 to 3.6 hectares). Rounded up to <strong>34 vehicle movements per week</strong>, over a 4-week period.</td>
</tr>
<tr>
<td>Exploration &amp; appraisal</td>
<td>Rig mobilisation – assuming 1 vertical rig and 1 directional rig</td>
<td>With &amp; Without</td>
<td>Light</td>
<td>90 one-way vehicle movements per pad(^{25}), spread over 4 weeks(^{26}). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5(^{27}) to reflect increase in traffic to multi-well pad. Rounded up to <strong>68 vehicle movements per week</strong>, over a 4-week period.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Heavy</td>
<td>95 one-way vehicle movements per pad(^{25}), spread over 8 weeks(^{26}). Vehicle numbers multiplied by 2 to reflect total vehicle movements. Rounded up to <strong>24 vehicle movements per week</strong>, over an 8-week period.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Light</td>
<td>140 one-way vehicle movements per pad, for rig mobilisation, drilling fluids and non-rig drilling equipment(^{25}), spread over 8 weeks(^{26}). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5(^{27}) to reflect increase in traffic to multi-well pad. Rounded up to <strong>53 vehicle movements per week</strong>, over an 8-week period.</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Phase</th>
<th>Activity</th>
<th>Water transport</th>
<th>Vehicle type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilling fluids</td>
<td>With &amp; Without</td>
<td>Heavy</td>
<td>45 one-way vehicle movements per pad(^{25}), spread over 8 weeks(^{26}). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 15 to reflect the quantity required for a 15 well pad. Rounded up to <strong>169 vehicle movements per week</strong>, over an 8-week period.</td>
<td></td>
</tr>
<tr>
<td>Non-rig drilling equipment</td>
<td>With &amp; Without</td>
<td>Heavy</td>
<td>45 one-way vehicle movements per pad(^{25}), spread over 8 weeks(^{26}). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5(^{27}) to reflect increase in traffic to multi-well pad. Rounded up to <strong>17 vehicle movements per week</strong>, over an 8-week period.</td>
<td></td>
</tr>
<tr>
<td>Drilling (rig crew etc.)</td>
<td>With &amp; Without</td>
<td>Heavy</td>
<td>50 one-way vehicle movements per pad(^{25}), spread over 8 weeks(^{26}). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5(^{27}) to reflect increase in traffic to multi-well pad. Rounded up to <strong>19 vehicle movements per week</strong>, over an 8-week period.</td>
<td></td>
</tr>
<tr>
<td>Completion chemicals</td>
<td>With &amp; Without</td>
<td>Heavy</td>
<td>140 one-way vehicle movements per pad, for rig mobilisation, drilling fluids and non-rig drilling equipment(^{25}), spread over 8 weeks(^{26}). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5(^{27}) to reflect increase in traffic to multi-well pad. Rounded up to <strong>53 vehicle movements per week</strong>, over an 8-week period.</td>
<td></td>
</tr>
<tr>
<td>Completion equipment</td>
<td>With &amp; Without</td>
<td>Heavy</td>
<td>20 one-way vehicle movements per pad(^{25}), spread over 8 weeks(^{26}). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 15 to reflect the quantity required for a 15 well pad. Rounded up to <strong>75 vehicle movements per week</strong>, over an 8-week period.</td>
<td></td>
</tr>
<tr>
<td>Hydraulic fracturing</td>
<td>With &amp; Without</td>
<td>Light</td>
<td>326 one-way vehicle movements, for completion chemicals, completion equipment, hydraulic fracturing equipment (trucks and tanks), hydraulic fracturing water hauling (incl. chemicals), hydraulic fracturing sand and produced water disposal(^{25}), spread over 16 weeks(^{26}). Vehicle numbers multiplied by 2 to reflect total vehicle movements to give 41 vehicle movements per week. Figure doubled following first fracturing phase to account for water disposal, totalling <strong>82 vehicle movements per week</strong> during fracturing and waste disposal.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Heavy</td>
<td>5 one-way vehicle movements per pad(^{25}), spread over 8 weeks(^{26}). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 15 to reflect the quantity required for a 15 well pad. Rounded up to <strong>19 vehicle movements per week</strong>, over an 8-week period.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Light</td>
<td>175 one-way vehicle movements per pad(^{25}), spread over 8 weeks(^{26}). Rounded up to <strong>22 one-way vehicle movements per week</strong>, over an 8-week period.</td>
<td></td>
</tr>
</tbody>
</table>

See Rig mobilisation.

Light

\(^{25}\) Vehicle numbers multiplied by 2 to reflect total vehicle movements.

\(^{26}\) Vehicle numbers multiplied by 15 to reflect the quantity required for a 15 well pad.

\(^{27}\) Rounded up to the nearest whole number.
## Unconventional oil and gas development: Understanding and mitigating community impacts from transportation

### Ricardo Energy & Environment

<table>
<thead>
<tr>
<th>Phase</th>
<th>Activity</th>
<th>Water transport</th>
<th>Vehicle type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydraulic fracturing and Production</strong></td>
<td>equipment (trucks and tanks)</td>
<td>With &amp; Without</td>
<td>Heavy</td>
<td><strong>movements per week</strong>, over an 8-week period. These movements are then repeated following the completion of hydraulic fracturing.</td>
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<tr>
<td></td>
<td></td>
<td>Light</td>
<td>See Completion chemicals.</td>
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<tr>
<td></td>
<td>Hydraulic fracturing water hauling (incl. chemicals)</td>
<td>Without only</td>
<td>Heavy</td>
<td><strong>Water quantity required for a single well assumed to be 8,400 m$^3$, divided by the assumed capacity of a single haulage vehicle (28 m$^3$), multiplied by 2 to reflect total vehicle movements, spread over an 8-week period</strong>. Movements repeated for every well fractured.</td>
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<td></td>
<td></td>
<td>With &amp; Without</td>
<td>Light</td>
<td>See Completion chemicals.</td>
</tr>
<tr>
<td></td>
<td>Hydraulic fracturing sand</td>
<td>With &amp; Without</td>
<td>Heavy</td>
<td><strong>Proppant (sand) quantity based on assumed value of 5% by volume of water, which equates to 420 m$^3$, divided by the assumed capacity of a single haulage vehicle (28 m$^3$), multiplied by 2 to reflect total vehicle movements, spread over an 8-week period</strong>. Movements repeated for every well fractured.</td>
</tr>
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<td></td>
<td></td>
<td>Light</td>
<td>See Completion chemicals.</td>
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<tr>
<td></td>
<td>Flowback water removal</td>
<td>With &amp; Without</td>
<td>Heavy</td>
<td><strong>Vehicles required to remove flow-back assumed to be 40% of total fracturing fluid, equating to 120 one-way vehicle movements, spread over 8 weeks. Vehicle numbers multiplied by 2 to reflect total vehicle movements. Rounded to 30 vehicle movements per week. Assumed to take place following the initial 8 week fracturing period and repeated for each subsequent fracturing period.</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Light</td>
<td>See Completion chemicals.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Production</td>
<td>With &amp; Without</td>
<td>Heavy</td>
<td><strong>3 one-way vehicle movements per well for the removal of water during gas collection. Movements multiplied by 2 to reflect total vehicle movements and spread over a six-week period, eighteen weeks after the initial fracturing of each well</strong>. The same frequency of vehicle numbers is assumed to repeat during re-fracturing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Light</td>
<td>10 vehicle movements per wellpad per week were assumed following fracturing, to account for maintenance and on-going production, which remains constant until refracturing / decommissioning.</td>
<td></td>
</tr>
<tr>
<td><strong>Refracturing and Production</strong></td>
<td>Hydraulic fracturing equipment (trucks and tanks)</td>
<td>With &amp; Without</td>
<td>Heavy</td>
<td><strong>175 one-way vehicle movements per pad, spread over 8 weeks. Rounded up to 22 one-way vehicle movements per week</strong>, over an 8-week period. These movements are then repeated following the completion of hydraulic fracturing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Light</td>
<td>211 one-way vehicle movements, for hydraulic fracturing equipment (trucks and tanks), hydraulic fracturing water hauling (incl. chemicals), hydraulic</td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Phase</th>
<th>Activity</th>
<th>Water transport</th>
<th>Vehicle type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Fracturing sand and produced water disposal(^{25}), spread over 16 weeks(^{26}). Vehicle numbers multiplied by 2 to reflect total vehicle movements to give 26 vehicle movements per week. Figure doubled following first fracturing phase to reflect water disposal, totalling <strong>53 vehicle movements per week</strong> during fracturing and waste disposal.</td>
</tr>
<tr>
<td>Hydraulic fracturing water</td>
<td>With &amp; Without</td>
<td>Light</td>
<td></td>
<td>See Hydraulic fracturing equipment.</td>
</tr>
<tr>
<td>hauling (incl. chemicals)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Flow back</td>
<td>With &amp; Without</td>
<td>Heavy</td>
<td></td>
<td>Proppant (sand) quantity based on assumed value of 5% by volume of water(^{7}), which equates to 225 m(^3), divided by the assumed capacity of a single haulage vehicle (28 m(^3)), multiplied by 2 to reflect total vehicle movements, spread over an 8-week period(^{26}) – <strong>40 vehicle movements per week</strong>. Movements repeated for every well fractured.</td>
</tr>
<tr>
<td>Production</td>
<td>With &amp; Without</td>
<td>Heavy</td>
<td></td>
<td>The number of vehicles required to remove flowback assumed to be 40% of total fracturing fluid(^{28}), equating to 64 one-way vehicle movements, spread over 8 weeks(^{26}). Vehicle numbers multiplied by 2 to reflect total vehicle movements. Rounded to <strong>16 vehicle movements per week</strong>. Assumed to take place following the initial 8 week fracturing period and repeated for each subsequent fracturing period.</td>
</tr>
<tr>
<td>Decommission</td>
<td>With &amp; Without</td>
<td>Heavy</td>
<td></td>
<td>See Hydraulic fracturing and Production – Production.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Light</td>
<td></td>
<td>45 one-way vehicle movements per pad(^{25}), spread over 8 weeks(^{26}). Vehicle movements multiplied by 2 to reflect total vehicle movements. Rounded to <strong>11 vehicle movements per week</strong> over an 8-week period.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Light</td>
<td></td>
<td>50 one-way vehicle movements per pad(^{25}), spread over 8 weeks(^{26}). Vehicle movements multiplied by 2 to reflect total vehicle movements. Rounded to <strong>13 vehicle movements per week</strong> over an 8-week period.</td>
</tr>
<tr>
<td>Phase</td>
<td>Activity</td>
<td>Vehicle type</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>------------------------------------</td>
<td>--------------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Exploration and appraisal</td>
<td>Well pad construction</td>
<td>Heavy</td>
<td>45 one-way vehicle movements per pad$^{25}$, spread over 4 weeks.$^{26}$ Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5$^{27}$ to reflect increase in traffic to multi-well pad. Rounded up to <strong>34 vehicle movements per week</strong>, over a 4-week period.</td>
<td></td>
</tr>
<tr>
<td>Light</td>
<td></td>
<td></td>
<td>90 one-way vehicle movements per pad$^{25}$, spread over 4 weeks$^{26}$. Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5$^{27}$ to reflect increase in traffic to multi-well pad. Rounded up to <strong>68 vehicle movements per week</strong>, over a 4-week period.</td>
<td></td>
</tr>
<tr>
<td>Drilling rigs</td>
<td>Heavy</td>
<td></td>
<td>2 one-way vehicle movements per pad$^{29}$, spread over 2 weeks (assumed timeframe). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5$^{27}$ to reflect increase in traffic to multi-well pad. Rounded to <strong>2 vehicle movements per week</strong>, over a 2-week period.</td>
<td></td>
</tr>
<tr>
<td>Drilling pipe vehicles</td>
<td>Heavy</td>
<td></td>
<td>4 one-way vehicle movements per well$^{29}$, spread over 6 weeks (assumed timeframe). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 15 to reflect the quantity required for a 15 well pad. Rounded up to <strong>20 vehicle movements per week</strong>, over a 6-week period.</td>
<td></td>
</tr>
<tr>
<td>Casing vehicles</td>
<td>Heavy</td>
<td></td>
<td>5 one-way vehicle movements per well$^{29}$, spread over 6 weeks (assumed timeframe). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 15 to reflect the quantity required for a 15 well pad. Rounded up to <strong>20 vehicle movements per week</strong>, over a 6-week period.</td>
<td></td>
</tr>
<tr>
<td>Tank vehicles and other equipment</td>
<td>Heavy</td>
<td></td>
<td>5 one-way vehicle movements per pad$^{29}$, spread over 6 weeks (assumed timeframe). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5$^{27}$ to reflect increase in traffic to multi-well pad. Rounded to <strong>3 vehicle movements per week</strong>, over a 6-week period.</td>
<td></td>
</tr>
<tr>
<td>Survey equipment vehicles</td>
<td>Heavy</td>
<td></td>
<td>2 one-way vehicle movements per pad$^{29}$, spread over 6 weeks (assumed timeframe). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5$^{27}$ to reflect increase in traffic to multi-well pad. Rounded to <strong>1 vehicle movements per week</strong>, over a 6-week period.</td>
<td></td>
</tr>
<tr>
<td>Cabin vehicles</td>
<td>Heavy</td>
<td></td>
<td>5 one-way vehicle movements per pad$^{29}$, spread over 6 weeks (assumed timeframe). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5$^{27}$ to reflect increase in traffic to multi-well pad. Rounded to <strong>1 vehicle movements per week</strong>, over a 6-week period.</td>
<td></td>
</tr>
<tr>
<td>Water tankers for used water</td>
<td>Heavy</td>
<td></td>
<td>7 one-way vehicle movements per well$^{29}$, spread over 6 weeks (assumed timeframe). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 15 to reflect the quantity required for a 15 well pad. Rounded up to <strong>35 vehicle movements per week</strong>, over a 6-week period.</td>
<td></td>
</tr>
<tr>
<td>Steel lining vehicles</td>
<td>Heavy</td>
<td></td>
<td>2 one-way vehicle movements per well$^{29}$, spread over 6 weeks (assumed timeframe). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 15 to reflect the quantity required for a 15 well pad. Rounded up to <strong>1 vehicle movements per week</strong>, over a 6-week period.</td>
<td></td>
</tr>
</tbody>
</table>

### Unconventional oil and gas development: Understanding and mitigating community impacts from transportation

<table>
<thead>
<tr>
<th>Phase</th>
<th>Activity</th>
<th>Vehicle type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase</strong></td>
<td><strong>Activity</strong></td>
<td><strong>Vehicle type</strong></td>
<td><strong>Description</strong></td>
</tr>
<tr>
<td><strong>Foul sewage tanker</strong></td>
<td>Heavy</td>
<td>1 one-way vehicle movements per well[^29]²⁹, spread over 6 weeks (assumed timeframe). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 15 to reflect the quantity required for a 15 well pad. Rounded up to <strong>5 vehicle movements per week</strong>, over a 6-week period.</td>
<td></td>
</tr>
<tr>
<td><strong>Tankers to remove excess drilling fluids</strong></td>
<td>Heavy</td>
<td>3 one-way vehicle movements per well[^29]²⁹, spread over 6 weeks (assumed timeframe). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 15 to reflect the quantity required for a 15 well pad. Rounded up to <strong>9 vehicle movements per week</strong>, over a 6-week period.</td>
<td></td>
</tr>
<tr>
<td><strong>Skips</strong></td>
<td>Heavy</td>
<td>4 one-way vehicle movements per pad[^29]²⁹, spread over 6 weeks (assumed timeframe). Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5[^27]²⁷ to reflect increase in traffic to multi-well pad. Rounded up to <strong>12 vehicle movements per week</strong>, over a 6-week period.</td>
<td></td>
</tr>
<tr>
<td><strong>Drilling supplies (transit size)</strong></td>
<td>Light</td>
<td>3 one-way vehicle movements per well[^29]²⁹ per week. Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5[^27]²⁷ to reflect increase in traffic to multi-well pad. Rounded up to <strong>9 vehicle movements per week</strong>, over a 6-week period.</td>
<td></td>
</tr>
<tr>
<td><strong>Personnel vehicles (cars or vans)</strong></td>
<td>Light</td>
<td>42 one-way vehicle movements per well[^29]. Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5[^27]²⁷ to reflect increase in traffic to multi-well pad. Rounded up to <strong>126 vehicle movements per week</strong>, over a 6-week period.</td>
<td></td>
</tr>
<tr>
<td><strong>Production</strong></td>
<td><strong>Produced water disposal</strong></td>
<td>Heavy</td>
<td>Coalbed methane wells are estimated to require the removal of approximately 17,000 US gallons of water per day[^30]³⁰, at their peak, which equates to 64 cubic metres. When divided by the capacity of a single haulage vehicle (28 m³), this equates to 16 one-way vehicle movements per week. This number has been multiplied by 2 to reflect total vehicle movements, to give <strong>32 vehicle movements per week per well</strong>, which continues for a 4-week period. Following the initial 4-week period, the quantity of water removed from the initial well is assumed to fall by 80%[^41], with production at a second well occurring simultaneously, resulting in 38 vehicle movements per week, over a 4-week period. This increase in movements continues as each well is brought into production, resulting in a peak in vehicle movements of 122 per week, during water removal from the 15th well. Once all wells are in production it is assumed that water extraction reduces by 1 percentage point per year.</td>
</tr>
<tr>
<td><strong>Personnel vehicles (cars or vans)</strong></td>
<td>Light</td>
<td>42 one-way vehicle movements per well[^29]. Vehicle numbers multiplied by 2 to reflect total vehicle movements and by 1.5[^27]²⁷ to reflect increase in traffic to multi-well pad. Rounded up to <strong>126 vehicle movements per week</strong>, over a 6-week period.</td>
<td></td>
</tr>
</tbody>
</table>


Unconventional oil and gas development: Understanding and mitigating community impacts from transportation

<table>
<thead>
<tr>
<th>Phase</th>
<th>Activity</th>
<th>Vehicle type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Use of personnel vehicles assumed to be continuous during each well development stage. Once all wells are established it has been assumed the rate of vehicle movements falls in line with the rate of water extraction (i.e. a reduction of 1 percentage point per year).</td>
</tr>
<tr>
<td>Decommissioning</td>
<td>Final pad prep</td>
<td>Heavy</td>
<td>45 one-way vehicle movements per pad(^25), spread over 8 weeks(^26). Vehicle movements multiplied by 2 to reflect total vehicle movements. Rounded to <strong>11 vehicle movements per week</strong> over an 8-week period.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Light</td>
<td>50 one-way vehicle movements per pad(^25), spread over 8 weeks(^26). Vehicle movements multiplied by 2 to reflect total vehicle movements. Rounded to <strong>11 vehicle movements per week</strong> over an 8-week period.</td>
</tr>
</tbody>
</table>

This data has been used to provide an estimation of vehicle movements (moving to and from site) for a single hydraulic fracturing site and a single coal-bed methane site, under the following scenarios:

1. Hydraulic fracturing site (single pad), based on the Central, High and Low economic scenarios, including refracturing 10 years after the initial fracturing, decommissioning 20 years after construction, and the use of a dedicated pipeline delivering water to the site.
2. Hydraulic fracturing site (single pad), based on the Central, High and Low economic scenarios, excluding refracturing, with decommissioning 20 years after construction, including the use of a dedicated pipeline delivering water to the site.
3. Hydraulic fracturing site (single pad), based on the Central, High and Low economic scenarios, including refracturing after the initial fracturing, decommissioning 20 years after construction, with water delivered to the site by tanker.
4. Hydraulic fracturing site (single pad), based on the Central, High and Low economic scenarios, excluding refracturing, with decommissioning 20 years after construction, with water delivered to the site by tanker.
5. Coal-bed methane site (single pad), based on the Central economic scenario of 15 wells, excluding hydraulic fracturing, with water removed by tanker and decommissioning occurring 10 years after the establishment of each well.

The estimated traffic numbers under these Scenarios are provided below.

**Table 8: Estimated total traffic movements per well pad over well pad lifetime**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Vehicle type</th>
<th>No re-fracturing, no water transport</th>
<th>With re-fracturing, no water transport</th>
<th>No re-fracturing, with water transport</th>
<th>With re-fracturing, with water transport</th>
<th>Coal-bed methane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total over 20 year period approximately</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td>Light</td>
<td>11300</td>
<td>20400</td>
<td>14800</td>
<td>23800</td>
<td>48,800</td>
</tr>
<tr>
<td></td>
<td>Heavy</td>
<td>7300</td>
<td>9900</td>
<td>16300</td>
<td>23700</td>
<td>44,300</td>
</tr>
<tr>
<td>High</td>
<td>Light</td>
<td>21500</td>
<td>39500</td>
<td>28400</td>
<td>46400</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heavy</td>
<td>13700</td>
<td>18900</td>
<td>31900</td>
<td>46700</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Light</td>
<td>8000</td>
<td>14000</td>
<td>10300</td>
<td>16300</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heavy</td>
<td>5100</td>
<td>6900</td>
<td>11100</td>
<td>16000</td>
<td></td>
</tr>
</tbody>
</table>

Note: "Light" vehicles includes motorcycles and all two-axle, four-tyre vehicles – that is, light trucks as well as cars. The "Light" vehicle numbers include some vehicles which would be classified as HGVs in Scotland.
The following graphs illustrate the estimated vehicle movements for each of these examples, under the Central scenario.

Figure 5: Estimated traffic movements at a 15 well pad, with re-fracturing, with water transport
Figure 6: Estimated traffic movements at a 15 well pad, without refracturing, with water transport

Figure 7: Estimated traffic movements at a 15 well pad, with refracturing, without water transport
Figure 8: Estimated traffic movements at a 15 well pad, without refracturing, without water transport

Figure 9: Estimated traffic movements at a CBM well pad
Development could potentially take place in a more intensive way at individual well pads – for example, one well pad might have more than one drilling rig operational at one time, or might carry out drilling at the same time as hydraulic fracturing. If this were to take place, the associated traffic impacts would be higher than those presented above, but for a shorter duration.

### 4.3.2 National scale assessment

Estimations of the national impacts of hydraulic fracturing facilities have also been developed. The average numbers of vehicle movements forecast for the range of scenarios considered in this study across Scotland are summarised in Table 9. These movements can be expected to take place mainly in the areas shown in Figure 1 and Figure 2.

**Table 9: Forecast average weekly vehicle movements across Scotland**

<table>
<thead>
<tr>
<th>Economic scenario</th>
<th>Well pad scenario</th>
<th>Average light vehicle movements per week</th>
<th>Average heavy vehicle movements per week</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Central</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 well pads</td>
<td>No water transport, no refracturing</td>
<td>257</td>
<td>164</td>
</tr>
<tr>
<td></td>
<td>No water transport, with refracturing</td>
<td>461</td>
<td>223</td>
</tr>
<tr>
<td></td>
<td>With water transport, no refracturing</td>
<td>335</td>
<td>369</td>
</tr>
<tr>
<td></td>
<td>With water transport, with refracturing</td>
<td>539</td>
<td>537</td>
</tr>
<tr>
<td><strong>High</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31 well pads</td>
<td>No water transport, no refracturing</td>
<td>398</td>
<td>254</td>
</tr>
<tr>
<td></td>
<td>No water transport, with refracturing</td>
<td>714</td>
<td>346</td>
</tr>
<tr>
<td></td>
<td>With water transport, no refracturing</td>
<td>519</td>
<td>571</td>
</tr>
<tr>
<td></td>
<td>With water transport, with refracturing</td>
<td>835</td>
<td>832</td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 well pads</td>
<td>No water transport, no refracturing</td>
<td>128</td>
<td>82</td>
</tr>
<tr>
<td></td>
<td>No water transport, with refracturing</td>
<td>230</td>
<td>112</td>
</tr>
<tr>
<td></td>
<td>With water transport, no refracturing</td>
<td>167</td>
<td>184</td>
</tr>
<tr>
<td></td>
<td>With water transport, with refracturing</td>
<td>269</td>
<td>268</td>
</tr>
<tr>
<td><strong>CBM</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 well pads</td>
<td>No decline, no fracturing</td>
<td>52</td>
<td>47</td>
</tr>
</tbody>
</table>

This indicates that UOG development could result in 210 to 1667 traffic movements per week on average, mainly within the central belt of Scotland. CBM development could result in an estimated additional 99 traffic movements per week. For context, approximately 4.3 million trips were made by cars and goods vehicles in Scotland each weekday in 2012.\(^{31}\)

The forecast pattern of weekly average traffic movements over the period 2023 to 2055 is shown in Figure 10 for the Central scenario.

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The incremental traffic movements due to UOG activity would have no detectable effect on the overall numbers of traffic movements in Scotland. Hence, there would be no detectable impact on associated environmental issues such as national carbon dioxide emissions from road traffic.

This indicates that the key area of concern in relation to potential traffic impacts is the potential for local effects associated with vehicle movements to/from specific sites.

4.3.3 Traffic movements for associated activities

A number of activities associated with UOG development could also generate traffic. Such activities could include the following:

- Gathering and laying mains pipelines
- Constructing Compressor stations
- Gas processing and cryogenic plant for production of LNG
- Creating and utilising a water treatment infrastructure
- Building or extending road connections to gas well pads and other facilities.

The need for these associated activities would vary greatly depending on a number of factors such as location, the need to construct a facility to serve a high number of wells or the need to construct a pipeline or an access road. The traffic associated with such activities would also vary greatly as a result of many factors such as the length of road to be constructed, the length and diameter of water main to be provided, number of pipes and the size of wastewater treatment works to be constructed.

It may sometimes be possible to include some of the associated activities within the planning application for the well pads such as the construction of a new access road or a compressor station. In these circumstances, these activities would be included in the construction programme and vehicle generation numbers would be stated in the EIA. In other cases, such as the construction of a regional wastewater treatment plant, it is likely that a separate planning application would be submitted, which would identify...
vehicle generation numbers. Either way, EIAs for UOG development should consider cumulative impacts with other traffic generating development, including (but not limited to) other UOG activity. In any case, the combined traffic impacts of multiple well pad developments and associated infrastructure should be taken into account via the Strategic Environmental Assessment process for strategic and local development plans.

Mains water pipelines do not normally require planning consent as the infrastructure would generally be delivered by Scottish Water as a statutory undertaker. A pipeline would require Scottish Water Approval and an EIA may be required as a Schedule 2 development, if the total area of works exceed 1 hectare, having regard to the characteristics and location of the pipeline, and the potential impacts. In terms of traffic movements associated with the laying of a water main, there would be a limited number of heavy goods vehicles associated with the delivery of pipe and machinery to excavate and lay the pipe. However, the vehicle numbers associated with the laying of new water pipework would be negligible when compared with the vehicle numbers associated with the production stage of the well pads.

If new road connections are required, a detailed assessment of traffic and other potential impacts should be included within the EIA. The length of new road should be calculated along with the quantities of materials required to construct the road. This would then allow the associated vehicle movements to be calculated, the impacts assessed and managed, and a programme established for the delivery of materials.

The Letham Moss case study provides an indication of vehicle movements associated with the construction of a Gas Delivery and Water Treatment Facility (GDWTF) for coal bed methane development. It was anticipated that there would be a maximum of 30 two-way vehicle movements (HGV/LGV) per day during the construction phase while during operation there would be approximately 6 vehicles per day accessing the site. Construction phase traffic movements for the GDWTF were approximately 20% of the highest predicted numbers of vehicle movements. For more widespread shale gas development, it would be expected that construction of a water treatment plant would serve a number of well pads, and would represent a smaller proportion of vehicle movements.
5 Potential impacts of road traffic

5.1 Effect of onshore oil and gas development on traffic

Studies of UOG development in Scotland, the UK as a whole and elsewhere consistently find that the road traffic impacts are one of the aspects of greatest concern both to the general public and professional analysts. The Independent Expert Scientific Report (2014) commented: "It appears that for communities near unconventional oil and gas development sites, the main health impact "stressors" (i.e. areas of perceived concern, even if unproven) are "air pollutants, ground and surface water contamination, truck traffic and noise pollution, accidents and malfunctions and psychosocial stress associated with community change…” This report concluded that “Social impacts documented from shale gas and CBM developments in the US and Australia have included … increased truck traffic.” Traffic impacts were also highlighted in the preceding study carried out by the Tyndall Centre, and in the environmental risk assessment studies carried out by Ricardo for the European Commission and Chesapeake Climate Action Network.

These impacts arise principally from increases in heavy goods vehicle movements on potentially unsuitable roads. These movements would take place over a relatively limited period for an individual well, but may occur over a much longer period for development of a multi-well pad, and in particular in situations where a shale gas field is being developed. This pattern of potential effects of development on road traffic is comparable to the potential traffic effects of windfarm development, a scenario which is familiar in Scotland.

5.2 Community risks and impacts of traffic

Scottish National Indicators are set to enable progress towards the achievement of National Outcomes to be tracked. The following indicators are potentially relevant to this study:

- Reduce traffic congestion
- Reduce deaths on Scotland's roads
- Improve access to local greenspace

The indicators are useful in enabling traffic congestion, road safety and access to greenspace to be taken into account in decision-making processes.

The key starting point for identification and characterisation of environmental risks and potential impacts of traffic movements was the standard guidance for such studies in Scotland:

- Planning Advice Note 50: Controlling the environmental effects of surface mineral workings
- PAN 50 Annex C: Control of Traffic at Surface Mineral Workings
- Scottish Government “Transport Assessment Guidance”
- Transport Scotland’s economic appraisal guidance: “Development Planning and Management Transport Appraisal Guidance” (DPMTAG)
- Institute of Environmental Assessment and Management (IEAMA) – Guidelines for the Environmental Assessment of Road Traffic

These references were used to provide an overview of information on the environmental risks and impacts associated with road transportation, and in particular local increases in heavy goods traffic on existing road networks and adjacent receptors.

The community-level environmental impacts associated with traffic are identified by the IEA guidelines. These guidelines set out a list of environmental effects which should be assessed for significance which comprise:

- Noise and Vibration;

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Air pollution, dust and dirt;
- Driver delay;
- Accelerated wear and tear;
- Pedestrian severance, delay and amenity; and
- Accidents and safety.

As outlined in the legislative and regulatory review section, there are two rules within the IEA guidelines that can be adopted to delimit the scale and extent of the assessment:

- Rule 1: Include road links where traffic flows would increase by more than 30% (or the number of HGVs would increase by more than 30%); and
- Rule 2: Include any other specifically sensitive areas where traffic flows would increase by 10% or more.

5.3 Community impacts of traffic from onshore oil and gas development

5.3.1 Overview

The activities that would generate significant traffic to and from that a well pad or group of well pads are:

1. Construction and drilling— which involve the arrival of drilling equipment, drill casings and drilling water at the well pad, and the removal of bored material and drilling water from site. Variability in well depth would influence the number of vehicle movements required during this phase;
2. Hydraulic fracturing— which would require the delivery of water, proppant materials and chemicals to the well. At some locations, piped or recycled water may be available and would not require delivery;
3. Flowback removal and treatment i.e. the removal of wastewater from the well. Again, at some locations, flowback water may be recycled into the fracturing process and/or removed by pipeline;
4. All other operations, deliveries and activities associated with the well including staff movements.

The New York State DEC provided an overview of the potential effects of road traffic as follows: "The introduction of high-volume hydraulic fracturing has the potential to generate significant truck traffic during the construction and development phases of the well. These impacts would be temporary, but the cumulative impact of this truck traffic has the potential to result in significant adverse impacts on local roads and, to a lesser extent, state roads where truck traffic from this activity is concentrated."

Broderick et al. state that the data for New York combined with data in relation to exploratory drilling in the UK “…suggests a total number of truck visits of 7,000-11,000 for the construction of a single ten well pad … Local traffic impacts for construction of multiple pads in a locality are, clearly, likely to be significant, particularly in a densely populated nation…” Fry noted that noise, vibration and traffic are among the most noticeable impacts during this stage of development.

New York State DEC went on to examine some of the potential impacts of this level of transport. These include:

- Increased traffic on public roadways. This could affect traffic flows and congestion.
- Road safety impacts.
- Damage to roads, bridges and other infrastructure. This could lead to decreased road quality and increased costs associated with maintenance for roads not designed to sustain the level of traffic experienced.
- Risks of spillages and accidents involving hazardous materials.

In a review carried out for Chesapeake Climate Action Network, Ricardo-AEA commented that: “in addition to the above, the road vehicles would cause air emissions with the potential for localized air quality impacts, as well as increasing the potential for community severance (reduction in community interaction due to roads with high traffic volumes) and potentially affecting residents’ quality of life.”

Ricardo-AEA went on to summarise impacts in the context of the US state of Maryland as follows: “Even at the levels described above, the impact in traffic terms associated with an individual site would be no more than “minor” in view of the short duration, although it would potentially be noticeable by local residents. The impacts include air emissions, noise and visual impact, as well as transport system effects such as infrastructure damage, congestion and effects on road safety during the period of hydraulic fracturing.

An increase in road transportation of potentially hazardous chemicals and waste materials would result in an increased risk of environmental pollution due to accidents, although these risks cannot be quantified at present. The established controls on transportation of dangerous goods would reduce the risks posed by vehicle accidents.

If a number of well pads are developed in a given area, the potential for adverse effects would be more significant, as there would potentially be a sustained increase in numbers of goods vehicle movements in a local area. The EPA (2012a NPR p14) indicates that, if extensive refracturing is required, truck traffic associated with shale gas development in New York state could become fairly continuous. In the context of Garrett and Allegheny Counties (see Section 3.1.7), the impact of traffic associated with more widespread development, including the risks posed by traffic accidents, could be considered of “moderate” significance.”

These potential impacts are discussed in more detail in the following sections.

5.3.2 Potential for accelerated road surface degradation

A common concern regarding traffic associated with onshore oil and gas operations relates to the risk of damage caused to road surfaces and the underlying road structure through additional loading by heavy vehicles. One research paper considering transportation infrastructure impacts in Texas reported that the transportation of water can cause greater road damage than a static load; because the movement of water within the tank as the vehicle moves will constantly shift the weight borne by each axle and potentially cause greater road damage than a static load of equivalent weight.

The transportation of plant, equipment and materials to and from well sites in Scotland would most likely be via heavy goods vehicle. If transport of water to and/or from the site is required, this is likely to be by road tanker. The International Energy Agency suggested that typical articulated tankers vehicle can hold around 30 cubic metres of water, with a total laden weight of approximately 40 Tonnes. This is consistent with the figure of 26 cubic metres used to derive estimated vehicle numbers in Chapter 4. Typical rigid body tankers have a capacity of 15 cubic metres with a total laden weight of 26 Tonnes. A fully laden water tanker is close to the current limit for vehicle weight on UK roads of 40 Tonnes.

In the UK, structural wear resulting from traffic (i.e. fatigue cracking within the bound pavement layers and/or excessive subgrade deformation) is considered during the design stage of the road. The damage to roads caused by cars is very limited compared with that caused by heavy vehicles. Roads are therefore designed to support a specified number of heavy vehicle loadings over their design life.

The structural wear to a road associated with each vehicle that passes increases significantly with increasing axle load. Structural wear for pavement design purposes in the UK is taken as being proportional to the 4th power of the axle load: that is, a 50% increase in axle load would result in a five-fold increase in calculated structural wear. In the case of a 40 Tonne fully laden articulated tanker

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34 Rahm, Fields, & Farmer Journal of Rural and Community Development 10, 2(2015), 78-99
35 Naismith Engineering. (2012). Road damage cost allocation study. Corpus Christi, TX.
36 Wilson (2012) Impact of Energy Development Activities on the Texas Transportation Infrastructure. Testimony before the House Committee on Energy Resources; Phil Wilson Executive Director, Texas Department of Transportation June 26, 2012
38 Road Vehicles (Construction and Use) Regulations 1986 (SI 1986/1078), as amended
being used to transport water, with weight approximately 90% of the current UK lorry limit, the axle loading and associated structural wear is likely to be at the upper end of the range of load and wear exerted by typical HGV traffic.

UK Roads are typically built with a 20-year design capacity based on axle loading. At the design stage future structural wear is estimated using wear factors based on projected vehicle axle loads i.e. the projected HGV traffic on any given route. The future cumulative flow is calculated in terms of million standard axles (msa). Roads are therefore designed and constructed to different specifications depending on the projected loading from HGV traffic. Main routes and trunk roads are typically designed to withstand heavier loads than local or rural roadways where lower annual average traffic flows are projected at the road design stage.

Axle loading fatigue on roads is therefore likely to be accelerated by HGV movements associated with UOG development. Depending on the location of well pads, and the design specifications and current age of the road routes where a significant increase in HGV traffic would occur, there is a risk that the 20-year design capacity axle loading would be exceeded prematurely, particularly if there are multiple well pads in a small area with significant volumes of HGV traffic using the same access route. Roadways with greater annual flows of truck traffic would generally require reconstruction sooner than similar roadways with less truck traffic.

The US Federal Highway Administration has reported the cost of additional heavy truck traffic associated with Marcellus Shale natural gas developments on Pennsylvania state-maintained roadways in 2011 to be between $13,000 and $23,000 per well. In a further study by the Texas Transportation Institute, which used traffic and pavement condition data, coupled with inspection and field-collected data, to conduct a remaining pavement life analysis, it was estimated that a typical rural Texas new road would have 60% of its design life remaining after just one year with the level of traffic associated with the development of one hundred horizontal gas wells (Quiroga et al., 2012). The Texas Department of Transportation have produced the following estimated reductions in road life associated with the different phases of an onshore oil and gas development.

Table 10: Service life reductions on interstate highways, US highways, state highways and ‘farm-to-market’ highways associated with natural gas well operations (Source: TDT, 2012)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Service life reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>4% to 53%</td>
</tr>
<tr>
<td>Rig movements</td>
<td>1% to 16%</td>
</tr>
<tr>
<td>Saltwater disposal</td>
<td>1% to 34%</td>
</tr>
<tr>
<td>Average overall impact</td>
<td>30%</td>
</tr>
</tbody>
</table>

In response to this, several state governments have introduced maintenance agreements, which require drilling companies to restore the quality of roadways to pre-drilling conditions, which in some cases drilling companies have been reported to restore roads “to equal or better condition than before they were damaged” (Brasier et al., 2011).

Accelerated degradation of non-trunk roadways would lead to increased road maintenance costs. Without further intervention, these costs would fall on the relevant highway authorities. Abramzon et al. argue that in Pennsylvania, there are three broad types of policy responses which can be used to address these costs: cost recovery through taxes or fees focused on the drillers, policies designed to decrease damage to roadways such as truck weight limits, and altering infrastructure to make it more resilient to higher intensity activity.

Michaels et al. found evidence for significant road damage in Pennsylvania, and highlighted difficulties in securing payment from operators to cover road damage due to the pace of development. In the US, maintenance agreements which require UOG operators to restore roads to a minimum of pre-drilling

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41 Abramzon et. al. (2014) Estimating The Consumptive Use Costs of Shale Natural Gas Extraction on Pennsylvania Roadways
condition have been found to be an effective way of mitigating road damage impacts and preventing these additional costs being covered by the public purse.\textsuperscript{43}

This type of maintenance agreement is currently used in other parts of the United Kingdom for both developments that generate significant volumes of HGV traffic. The supplementary guidance document for onshore oil and gas published by Lancashire Council et al. specifies that pre and post commencement road surveys should be conducted to determine if any damage caused to the highway can be attributed to the development, and if so, this should be compensated by the developer. This aims to ensure that the local road network is not adversely affected and local communities are not disadvantaged.\textsuperscript{44}

Similarly, Staffordshire County Council aim to secure and maintain the structural integrity of public highways via their Supplementary Planning Guidance (SPG) for heavy commercial vehicles generated from mineral and waste developments.\textsuperscript{45} The SPG requires that the effects of a development on the structural integrity of the road are quantified to avoid unnecessary maintenance burdens falling upon the public purse. Once the extent of impact has been determined this provides a basis for determining the most appropriate form of mitigation. The guidance requires that the Transport Assessment for the development should include an assessment of the impact of heavy vehicles on the road structure. The guidance also specifies that developers may be required to provide a commuted maintenance payment, to be secured via a Section 106 Agreement planning obligation under the relevant legislation for England. An appropriate sum is calculated based on the cost of maintaining the infrastructure, which is over and above that which would have been incurred by the highway authority anyway.

There is some evidence that proactive road maintenance is more cost effective than a reactive approach. Li and Mikhail conducted a case study for a stretch of 2 lane rural road in Dimmit County, US. Their analysis demonstrated that a proactive road maintenance approach was more cost effective than a reactive approach in the long term but also noted that reactive maintenance still dominates the current practice.\textsuperscript{46}

5.3.3 Risk of increased accidents

Some research has been conducted regarding the potential for increased road traffic accidents attributable to changes in traffic volume and fleet composition e.g. increased percentage of heavy truck movements, from UOG operations. Concern has also been raised that the degradation of road surfaces from the heavy vehicle use could also impact on accident rates.\textsuperscript{26} This research was carried out mainly in countries other than Scotland, and the findings were assumed to be applicable to Scotland, with specific exceptions as identified below.

A review of accidents and injuries to road transport drivers in Europe\textsuperscript{47} reports the conclusions of a Danish analysis of road traffic accidents\textsuperscript{48} whereby the following features of heavy good vehicles were concluded to increase the accident risk of trucks in comparison with passenger cars:

- The construction/dimensions etc. of trucks can contribute to situations arising that can develop into accidents – situations that would not arise with passenger cars;
- The reduced braking and evasive abilities of trucks can contribute to situations more often developing into collisions, and the collisions occur at higher speed;
- The size and weight of trucks may mean that collisions result in more serious personal injuries than similar collisions involving passenger cars;

\textsuperscript{44} Lancashire County Council, Blackpool Council and Blackburn with Darwen Borough Council (2014) Lancashire Minerals and Waste Local Plan; Onshore Oil and Gas Exploration, Production and Distribution; Draft Supplementary Planning Document for Consultation; November 2014
\textsuperscript{45} Staffordshire County Council (2011) Supplementary Planning Guidance to the approved Staffordshire and Stoke on Trent Structure Plan 1996 – 2011; Code of Practice for Assessment of the Impact and Determination of Mitigation Measures arising from Heavy Commercial Vehicles generated from Mineral and Waste Developments
\textsuperscript{46} Li and Mikhail (2014) Impacts of energy developments on Texas Roads; Texas Department of Transportation.
\textsuperscript{47} EU-OSHA et al. (2010) European Agency for Safety and Health at Work – Working Environment Literature Review; A review of accidents and injuries to road transport drivers
Driving mistakes made by heavy goods vehicle drivers may be more serious because of the weight, size, shape, manoeuvring abilities, braking abilities, etc., of the vehicle.

The EU-OSHA report also quotes analysis prepared by the Dutch accident research board which indicates that collisions and fires involving trucks carrying dangerous substances occur fairly regularly. There is also however research which indicates that tankers carrying flammable goods have a 70-80% lower risk of crashes than heavy goods vehicles in general. This may be attributable to more stringent training of drivers of tankers carrying flammable goods, stricter standards for vehicles, and differences in the road and traffic environment in which tankers carrying flammable goods and other heavy goods vehicles travel.

A number of regions in the United States have reported increases in the rates of accidents in recent years, correlating with the expansion of the shale gas industry. For example, the Upper Great Plains Transportation Institute (2013) reported that severe injury truck crashes in North Dakota’s oil region increased by more than 1,200% between 2008 and 2012, whilst the rest of the state experienced an increase of just 147%. Similarly, in 2015 Rahm, Fields and Farmer reported that between 2009 and 2013 crash trends in the Eagle Ford Shale region of rural Texas increased by 26%, and fatalities/severe injuries by 49%, which, it is suggested, is a result of a rise in shale gas related vehicle movements.

Graham et al. examined records of motor vehicle accidents and drilling activity in Pennsylvania from 2005 to 2012. Data on the number of traffic accidents (total vehicle accidents, heavy-truck, fatal, and major-injury accidents) per county and month were reviewed. They compared records from counties where drilling was occurring with equivalent control counties where there was no drilling activity. For counties in north Pennsylvania, their results indicated that overall vehicle crash rates were 15-23% higher during the years 2010–2012 and heavy truck crash rates were 61–65% higher during 2011–2012 than the control counties. In southwest Pennsylvania rates of fatal and major injury crash rates were 45 – 47% higher during 2012.

Graham et al. also investigated whether there was a relationship between number of new wells and crash rate. In the northern drilling comparison group, each increase of 10 wells was associated with a 3% increase in vehicle crash rate and a 9% increase in heavy-truck crash rate. The statistical model also suggested that there was a statistically significant 5% increase in fatal crash rate for each 10 additional wells drilled in the northern counties. In the southwestern drilling comparison group, the only significant finding was a 10% increase in heavy-truck crash rate associated with each 10 additional wells.

Research conducted in Texas indicated that the most likely time period for crashes was between 17.00 and 18.00, with the majority of crashes during this period involving employees’ personal vehicles. Only 10% of the crashes overall involved commercial vehicles. The authors concluded that this may be caused by employee traffic at rush hour having an impact on road crashes in regions where energy industries were present.

Another analysis of road traffic accident records has shown that workers in the US oil and gas extraction industry experience 8.5 times the rate of work-related motor vehicle-related deaths compared to all other workers in the United States. It also reports that half of the workers who died were either not wearing a safety belt or were ejected from the vehicle and presumably, not wearing a safety belt. This research highlighted that low levels of seat belt use in the oil and gas extraction industry may be in part related to the culture of the work environment, consistent with the sociological profile of the workforce.

There are significant differences between seat belt legislation in Scotland and in the relevant states of the US which would be expected to result in increased seatbelt use for commercial vehicle operators in Scotland compared to the US.

51 Texas Department of Transportation. (2012). Task force on Texas’ energy sector roadway needs: Report to the Texas transportation commission. Austin, TX.
52 Retzer et al. (2013) Motor vehicle fatalities among oil and gas extraction workers; Accident Analysis and Prevention 51 (2013) 168– 174
5.3.4 Risk of accidental release of hazardous material during transportation

There is a risk that truck accidents could lead to chemical or wastewater spills. This could include fracturing fluid, additives, flowback water, and produced water. In the event of an accidental release, fluids can run off into surface water and/or seep into groundwater.

One example of this occurring has been found in our review, in December 2011, a truck accident in Mifflin Township, Pennsylvania released fracking wastewater into a nearby creek.\(^{54}\)

An increase in road transportation of potentially hazardous chemicals and waste materials would result in an increased risk of environmental pollution due to accidents. The established controls on transportation of dangerous goods would reduce the risks posed by vehicle accidents, but not fully eliminate such risks.\(^{32}\)

5.3.5 Air pollution impacts

The increases in heavy vehicle numbers is also likely to result in an increase in emissions of air pollutants. The New York State Department of Environmental Conservation estimates the following increases in state-wide emissions from additional vehicle miles travelled associated with gas drilling:

- Oxides of nitrogen – 686.7 tons per year
- Volatile organic compounds – 70 tons per year
- Sulphur dioxide – 2.5 tons per year
- Particulate matter (<10 micrometres) – 34.4 tons per year
- Particulate matter (<2.5 micrometres) – 33.3 tons per year
- Carbon monoxide – 668.6 tons per year

These impacts are relatively minor in the context of state-wide emissions to air of these substances, consistent with the assessment of regional/national traffic impacts in Section 4.3.2. However, the potential for localised impacts would need to be taken into account in the environmental assessment of any UOG development. The vehicle movements for individual well pads identified in Section 4.3.1 are sufficient that long-term and short-term air quality impacts would be scoped in for consideration through the planning process. Consideration should be given to appropriate sources of data on baseline air quality, and an air quality monitoring survey may be appropriate in some circumstances.

A study by Goodman et al. (2016) estimated that a single well can result in “substantial increases in local air quality pollutants during key activity periods, primarily involving the delivery of water and materials for fracking to the site”. Heavy truck movements are known to increase the levels of particulate matter and exhaust fumes in close proximity to road networks, as has been found in Garfield County, Colorado, which has experienced increased levels of PM\(_{2.5}\) concentrations, which are thought to be the result of nearby tight-gas developments.\(^{28}\) It would be important for any assessment of traffic impacts to consider dust resuspension in situations where vehicle movements would take place on unmade surfaces.

Air quality management areas (AQMAs) exist in many parts of Scotland within which UOG development may take place. The presence of an AQMA would highlight the potential significance of air quality impacts, which would need to be given careful attention in the planning process. While an AQMA does not in principle present a bar to traffic-generating development, it may place an additional constraint on the development, which would influence the mitigation that would need to be provided to ensure that the development would have no significant effects on the AQMA or on measures being implemented by a local authority to improve air quality.

5.3.6 Noise

There have been several other reported impacts on local communities associated with increased traffic movements to and from UOG facilities, such as noise, which can result from heavy vehicle movements as well as drilling and completion operations, and flaring.\(^{55}\)

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A survey of interested and affected parties in the United States highlighted concerns about the by-products of the UOG operations. Noise from both site operations and transportation was highlighted as one of the most prevalent concerns. The noise levels generated by vehicles depend on a number of variables, such as vehicle type, load and speed, type of road surface, road grade, distance from the road to sensitive receptor, road gradient, ground condition, and atmospheric conditions.

A single passing of a HGV is a short duration noise event. However, multiple truck trips result in higher hourly average noise levels and impacts on noise receptors close to affected routes. Other factors being equal, the noise impact of truck traffic would be greater for travel along roads that do not normally have a large volume of traffic, especially HGV traffic.

Goodman et al. calculated estimated excess noise emissions from onshore UOG transportation and concluded that they appear negligible (< 1 dBA) when normalised over the duration of the well operation, but may be considerable (+3.4 dBA) in particular hours. The impacts of peak traffic flows could be greater if they occur during night-time periods.

As such any Environmental Impact Assessment for UOG operations should consider noise as with any other development where an increase in traffic is forecast to occur.

5.3.7 Nature conservation

Gas extraction can affect biodiversity via a number of routes (Entrekin et al. 2011). These include:

- Removal of habitat;
- Degradation of habitat (e.g. as a result of excessive water abstraction); or fragmentation (e.g. as a result of fencing, road construction);
- Introduction of invasive species;
- Noise and other disturbance;
- Water and land pollution.

New York State DEC highlights the potential effects on biodiversity due to invasive species as a potential concern. Entrekin et al describe the risks to wildlife posed by sediment runoff into streams, reductions in streamflow, contamination of streams from accidental spills, and inadequate treatment practices for recovered wastewaters as “realistic threats”. Entrekin et al. conclude that there are preliminary indications of detectable effects of sedimentation of watercourses due to shale gas development, and consider that scientific data are needed to ensure protection of water resources.

Farwell et al. (2016) considered the impacts of unconventional gas development on forest habitat and breeding songbirds at a predominantly forested site in the central Appalachians from 2008 to 2015. The results of the study indicated that “shale gas development has the potential to fragment regional forests and alter avian communities”. Traffic movements would be one component of this potential effect. The likely setting of shale gas development in Scotland means that impacts on remote habitats are unlikely. However, there would be a risk of harm to habitats which may be valuable in their local setting. Any such effects would need to be considered during the planning and EIA process.

5.3.8 Site grouping

All of the above impacts could be compounded if UOG developments are grouped in a relatively small area. This could potentially result in an intensification or an extended duration of impacts for local communities. This would need to be addressed through the strategic and local planning process.
5.4 Case studies

The case studies were reviewed to identify the likely community-level impacts that would need to be considered when appraising UOG applications, and the mitigation that could be provided to alleviate these impacts. The case studies included consideration of a wind farm site and a quarry site, because some of the features of these sites are comparable with UOG sites.

The case studies are set out in Appendix 1. The windfarm, opencast mining and quarry case studies all resulted in comparable maximum numbers of HGV movements. For example, the windfarm case study resulted in a maximum of 92 two-way HGV movements and 40 two-way worker vehicle movements per day during the construction period. This would be a relatively short period compared to the operational lifetime of a UOG site during which vehicle movements could be taking place. Conversely, HGV movements associated with opencast mining and quarrying would continue throughout the site operational lifetime.

These HGV movement numbers are higher than those which would be associated with a shale gas well pad for the Central scenario during hydraulic fracturing – 322 movements per week (about 64 per day) for an 8-week period, followed by 115 movements per week (about 23 per day) for approximately two years. Light vehicle movements for the Central UOG scenario would be similar to the windfarm scenario.

Measures to mitigate transportation impacts were proposed for each of the case study developments. These were typically to be implemented by means of a Traffic Management Plan. With this mitigation in place, traffic was found to have negligible, minor or (in some aspects) moderate impacts. It is reasonable to expect that mitigation for transportation impacts associated with UOG development, provided it takes account of the specific factors relevant to UOG development, would be effective in reducing and minimising transportation impacts to a low level. As with any comparable development, traffic impacts could not be completely eliminated, but could be reduced to a level which would be considered negligible or minor. The case studies illustrate how this would need to be evaluated on a case by case basis, and appropriate mitigation designed and implemented.

5.5 Management and mitigation measures

5.5.1 Scottish Planning System

If the current moratorium on UOG development in Scotland is lifted, the Scottish planning system would play a key role in ensuring that appropriate mitigation measures are implemented at a UOG site. The planning system is used to guide decisions about the future development and use of land and identifies the locations and conditions under which development should and should not happen.

The planning system is “plan-led” and is divided into three key parts which include:

1. Development plans which set out how places should change in the future;
2. Development management which is the process for making decisions on planning applications. Planning legislation requires that decisions on applications are guided by policies in the development plan; and
3. Enforcement, which makes sure development is carried out correctly.

The Government published the Scottish Planning Policy (SPP) in 2014 which sets out the national planning policies which reflect Scottish Ministers’ priorities for operation of the planning system and for the development and use of land. Transport forms a key role within SPP and is supported by the supplementary planning guidance (SPG) document, Planning Advice Note (PAN) 75, “Planning for Transport”.

PAN 75 provides good practice guidance which planning authorities, developers and others should carry out in their policy development, proposal assessment and project delivery. In principle, UOG project developers should expect to carry out similar levels of assessment of traffic impacts and provide appropriate mitigation, similar to other comparable developments and in accordance with PAN 75.

There is an opportunity to develop supplementary guidance associated with assessing the merits of UOG sites and ensuring the appropriate management of development. This could be in the form of a PAN or a planning circular, or could be developed as Supplementary Planning Guidance by individual authorities. Specific transport guidelines could be developed to provide local authorities with a means
to assess the traffic and transport impacts of a UOG application, and to identify appropriate mitigation. This would also assist developers in the preparation of associated documents including Environmental Statements, Traffic Management Plans etc. Local communities could refer to this guidance to identify what level of assessment, management and mitigation of transportation impacts they can expect. This would ensure that there is consistency across all planning applications coming forward for UOG sites in Scotland.

5.5.2 The EIA process

As set out in Section 3.8, any planning application for UOG development with the potential for generating significant traffic movements could be made subject to an Environmental Impact Assessment (EIA), in view of legal obligations for larger scale development, local authority powers to require an EIA for smaller scale developments, and industry undertakings to carry out EIAs. This would include a requirement for assessment of impacts relating to traffic movements.

Traffic modelling studies are likely to be needed in support of an EIA for UOG development. The exception would be cases where the potential traffic impact is too low to warrant such a study. The starting point for traffic modelling studies is to understand the existing, or baseline, traffic flows on the road network. This information can be obtained from traffic count data, and/or from modelling and interpolation of traffic counts. Modelling analyses can then be carried out to determine the additional flows which are expected to result from the planned activity, and to identify the routes that these vehicles can be expected to follow to and from the site. Based on this data, an assessment of environmental impacts due to traffic movements can be carried out. These impacts may include noise and emissions to air, as well as risks which are not specifically environmental, such as traffic accidents. If required, appropriate mitigation can then be devised and residual impacts assessed. Mitigation measures then need to be confirmed, implemented and monitored, as described below.

5.5.3 Identifying the need for mitigation

Following the application of Rules 1 and 2 in the IEA Guidelines, a detailed assessment of a particular road link(s) may be required. The assessment (if required) should consider the following potential environmental impacts as discussed in Section 5.2:

- Noise and Vibration;
- Air pollution, dust and dirt;
- Driver delay;
- Accelerated wear and tear;
- Pedestrian severance, delay and amenity; and
- Accidents and safety.

The assessment must determine if the proposed development has a significant detrimental impact on any of the above and identify if any mitigation measures are required. Specific measures may be identified to address one or more of the aspects above. Examples of mitigation measures include the provision of a pedestrian crossing facility to address pedestrian severance, or wheel washing facilities to minimise dust and dirt.

However, it may also be possible to provide mitigation measures which reduce the traffic impact of the proposed development to an extent that traffic impact is reduced to below the levels identified in IES Rule 1 and Rule 2. Such measures would typically be set out in a Traffic Management Plan.

These measures are likely to vary with each planning application that comes forward and would be dependent on a number of factors including (but not restricted to):

- The location of the UOG site e.g. rural, urban and the location of the site in relation to the road network;
- The number and location of sensitive receptors relative to the site such as settlements, schools, hospitals etc
- Variations across local / transport authorities with regards to approach and judgement;
- The extent of the proposals coming forward which would in turn influence the volume of traffic; and
- The standard of the road network and the existing volume of traffic carried by these roads.
Any mitigation measures require to be identified during the planning application stage and should be clearly defined in the ES.

The following sections provide a guide to the transport-related mitigation measures which may be appropriate for UOG sites based on the review of UOG sites and published research. Specific measures can be expected to vary with each application that comes forward.

5.5.4 Mitigation by Design

Site selection could form a key role in reducing the traffic impacts associated with a proposed UOG site. A site with access directly onto the strategic road network would have much less of a traffic impact than a site accessed via a network of rural roads because the development traffic would not use routes of an inadequate standard, and traffic movements associated with the development would be diluted by the existing traffic.

If the construction of new roads is required, selecting sites that have an opportunity to locally source road construction material (from on-site borrow pits for example) would significantly reduce the wider traffic impacts.

A key design element for reducing the volume of traffic generated is the avoidance of road transportation of water. This could be achieved by mains supply of water, and/or re-use of flowback water from preceding hydraulic fracturing at the same site. In the Scottish context, the oil and gas industry considers that shales are less saline and are likely to contain less Naturally Occurring Radioactive Material than shale formations in England or the US. If this is the case, this would facilitate re-use of waste-water. Road movements could also be reduced by providing for removal of any produced water or flowback water which cannot be recycled by pipeline, or by on-site treatment. On-site treatment is less likely to be a cost-effective option for a single well pad. The preparation of guidelines identifying the use of such design features would allow local authorities and developers alike to narrow their area of search and to give priority to sites where these features can be achieved.

The Letham Moss case study indicated that with water delivered by mains supply, the remaining traffic levels were predicted to be below the thresholds for further assessment of detailed environmental effects. The Clackmannanshire Local Development Plan makes specific reference to transportation of water for hydraulic fracturing, and indicates that preference would be given to sites that could import water by pipeline.

Traffic impacts can also be mitigated by effective material and logistics planning. This may include the use of central warehousing, communications with suppliers, and contractual arrangements which encourage safe and considerate driving.

5.5.5 Traffic Management Plan

The primary purpose of a Traffic Management Plan (TMP) is to minimise traffic impact associated with a proposed development. A TMP can be implemented during the construction stage, operational stage and/or decommissioning stages of a development. TMPs may not be required for all sites given that each site would vary considerably. However, in view of the nature of UOG sites, a TMP is likely to be appropriate at all stages. The TMP is an evolving document and should be updated at appropriate stages or when planned changes to the development would directly influence vehicle movements and therefore environmental impacts associated with traffic.

TMPs are often requested by local authorities at the planning consent stage by means of a prescriptive condition attached to the issued consent. There is variability between local authorities in their approach to requiring TMPs for different types of development. There is a lack of consistency with regard to the requirement to produce the TMP and with regard to the measures that should be included within a TMP.

Developers should produce TMPs with a range of measures identified within the TMP to minimise and control traffic movements and associated environmental impacts. During project development, some sections of the TMP are likely to be provisional, and would not be able to be finalised until the finer details of the development are known. Many of these measures can be readily implemented and checked, but there is in some cases a lack of enforcement from local authorities with regard to the full implementation of the TMP and its measures.

Whilst the content of a TMP varies depending on the project, the following elements should be included as standard.
Table 11: Typical contents of a Traffic Management Plan

<table>
<thead>
<tr>
<th>TMP Element</th>
<th>Effect / Comment</th>
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<tbody>
<tr>
<td>Identify designated routes for HGVs and general construction traffic</td>
<td>This is particularly important for HGVs in order to ensure that the road network is suitable to accommodate the vehicles and that traffic impacts are minimised, particularly in sensitive areas such as rural villages, schools etc. The TMP should specify any junctions or road links that require to be avoided during busy periods and would require discussions with local authorities and Transport Scotland (if applicable). It may be appropriate to identify multiple routes to / from site so that the impact of HGVs is spread out and not restricted to the same sections of road. It is likely that these routes would have been identified in the ES. However, the TMP would consider routes in more detail. As a TMP is an evolving document, it is prudent to reassess these routes after a designated period of time to ensure that they remain appropriate and that the contractor is adhering to the routeing specified in the TMP. A mechanism for surveys or independent checks should be included.</td>
</tr>
<tr>
<td>Access arrangements</td>
<td>The TMP should detail the access arrangements to the site both for staff and construction traffic / HGVs. Certain sites may have multiple access points and all relevant parties should be fully aware of the purpose of each access. For example, there may be a dedicated access for staff and another for HGVs. In addition, it may be appropriate to restrict the use of certain access points / sections of the road network at specific times of the day. This would usually be during the weekday AM and PM commuter periods. This would normally be identified in the ES, however, this should form a key part of the TMP.</td>
</tr>
<tr>
<td>Designation of working hours</td>
<td>The TMP should specify the working hours of staff and routeing / access arrangements to site should be specified taking cognisance of these working hours. It may be necessary to designate working hours in such a way that staff would not be travelling to site during the weekday AM and PM commuter peaks. This would limit the traffic impact of the development during these busy periods. As with general construction sites, HGV access to UOG sites should normally be limited to weekdays and a half day on a Saturday.</td>
</tr>
<tr>
<td>Staff travel arrangements / parking</td>
<td>The TMP should detail travel arrangements for staff. This would include working hours (as specified above) and also parking arrangements including the location of the car park(s) within the site. A Travel Plan (TP) can also be prepared which could form an Appendix or dedicated chapter of the TMP. The purpose of the TP is to encourage trips to / from the site by sustainable modes and discourage single-occupancy private car trips. For urban sites, this would include encouraging trips on-foot, by bicycle, by public transport and by car sharing. For more rural sites, a TP would be likely to focus on encouraging car sharing. A Travel Plan Coordinator would be appointed to raise awareness of the plan and to ensure that the measures contained within the plan are implemented effectively. The Coordinator would be responsible</td>
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### Appointment of community liaison officer

In view of the ongoing requirement for traffic access to UOG sites and potential for use of unsuitable roads, it may be appropriate to appoint a community liaison officer who would be responsible for ensuring members of the public and local businesses are kept up-to-date with the current status of the development and highlighting what measures the developer / contractor is putting in place to ensure impacts on the local community are minimised. The developer / contractor would therefore have a responsibility to disseminate this information and ensure the officer has all the necessary information.

### Co-ordination with other sites

The TMP should provide details of any committed or planned development sites in the vicinity, particularly if the construction stages coincide. Discussions between developers / contractors should take place at the earliest opportunity so that travel arrangements, HGV routeing etc can be co-ordinated in order to minimise traffic impact. A summary of discussions should form part of the TMP.

In addition, a co-ordinated approach with regards to mitigation measures can also be developed between developers and should be included within the TMP.

### Speed limits / signage arrangements

Any amendments to speed limits in the vicinity of the site should be stated and described in detail within the TMP. This should include the location of the speed limit change, the timescales and detail any associated signage.

Furthermore, any other signage proposed should be clearly stated within the TMP.

### Traffic arrangements monitoring

It may be prudent to monitor the volume of traffic associated with the proposed development to ensure that the actual volume of traffic is in line with the calculations outlined in the ES. This is to ensure that the mitigation measures (if any) continue to be appropriate for the volume of traffic associated with the development.

The TMP should clearly indicate the arrangements for these monitoring surveys, and should specify the location of the counters. This would require to be agreed with the local authority and / Transport Scotland.

Transport management plans should be circulated to all suppliers for distribution to drivers.

In the past, TMPs have proven to be a very effective way of reducing the traffic impact associated with the development and they are often used as a “catch-all” with regard to the mitigation of traffic and associated environmental impacts. However, their success relies on a number of factors including:

- Local authorities actively monitoring the implementation of TMPs;

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<td>for monitoring the success of the plan against agreed targets and would be the key point of contact for staff. The staff induction process provides an opportunity to disseminate travel arrangements. Staff should be clear with regards to their travel arrangements and should be encouraged to travel to site, where possible, by sustainable modes (including car sharing). Staff should also be clear about where to park on-site and whether there are any restrictions associated with access locations.</td>
</tr>
<tr>
<td>Appointment of community liaison officer</td>
<td>In view of the ongoing requirement for traffic access to UOG sites and potential for use of unsuitable roads, it may be appropriate to appoint a community liaison officer who would be responsible for ensuring members of the public and local businesses are kept up-to-date with the current status of the development and highlighting what measures the developer / contractor is putting in place to ensure impacts on the local community are minimised. The developer / contractor would therefore have a responsibility to disseminate this information and ensure the officer has all the necessary information.</td>
</tr>
<tr>
<td>Co-ordination with other sites</td>
<td>The TMP should provide details of any committed or planned development sites in the vicinity, particularly if the construction stages coincide. Discussions between developers / contractors should take place at the earliest opportunity so that travel arrangements, HGV routeing etc can be co-ordinated in order to minimise traffic impact. A summary of discussions should form part of the TMP. In addition, a co-ordinated approach with regards to mitigation measures can also be developed between developers and should be included within the TMP.</td>
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<td>Speed limits / signage arrangements</td>
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</tr>
<tr>
<td>Traffic arrangements monitoring</td>
<td>It may be prudent to monitor the volume of traffic associated with the proposed development to ensure that the actual volume of traffic is in line with the calculations outlined in the ES. This is to ensure that the mitigation measures (if any) continue to be appropriate for the volume of traffic associated with the development. The TMP should clearly indicate the arrangements for these monitoring surveys, and should specify the location of the counters. This would require to be agreed with the local authority and / Transport Scotland.</td>
</tr>
</tbody>
</table>
Developers and contractors being proactive at implementing TMPs (also in a situation where they are not being pursued by the local authority / Transport Scotland);

- Effective communication between the contractor so that they are aware of the requirement to prepare a TMP; and

- TMPs being subject to a planning condition / Section 75 Agreement rather than a voluntary undertaking.

5.5.6 Road Condition Survey and maintenance

A Road Condition Survey (sometime called a Dilapidation Survey) can be an appropriate mitigation measure for proposed UOG sites where there is likely to be accelerated wear and tear on the road network as a result of increased heavy goods vehicles. This survey is most likely to be required when the UOG site is situated in a rural location meaning that HGVs and general construction traffic are required to use C-class roads or unclassified roads. These may be single track and are not designed to carry large volumes of heavy goods vehicles. A significant increase in heavy vehicle traffic is likely to have a detrimental impact on road surfacing and could potentially affect the full road construction.

With regard to timescales for the survey, there are a number of options including:

- Upgrade the road to a specification identified by the local authority prior to construction on-site;
- Undertake regular Road Condition Surveys throughout the lifespan of the project to ensure that the road is not deteriorating to a level where improvements are required. When the survey indicates issues, the developer / contractor would be responsible for implementing improvements or paying for mitigation to be undertaken.

In order to minimise the risk of disagreements regarding the timing and extent of improvement works, a financial agreement in line with Section 96 of the Roads (Scotland) Act 1984 could be put in place from the outset. A legal mechanism is put in place to allow the Council to recover the cost of road repairs and the mechanism would identify an extent for the surveys and potentially a limit of the value of repairs. A financial bond can be put in place by the developer which the Council can draw down against as necessary.

At this stage, there would be an opportunity to integrate the expected arrangements for road condition surveys and maintenance arrangements into specific planning policy/guidelines for UOG development.

5.5.7 Traffic Monitoring

It is recommended that traffic levels associated with the development are monitored to check that they are in line with the levels predicted in the ES. This is to ensure that any mitigation measures that were identified in the ES remain appropriate for the volume of development traffic. If this process identifies higher than anticipated traffic volumes, the outcome of this process could potentially be that additional mitigation measures require to be identified. Traffic monitoring at an appropriate frequency could form part of the TMP. However, if the local authority determine that a TMP is not required, traffic monitoring could be undertaken as a stand-alone exercise with a planning condition used to ensure its implementation.

5.5.8 Managing and enforcing mitigation measures

It is important to ensure that careful consideration is given to identifying appropriate measures to mitigate the impact of the proposed development. While these measures would differ depending on the proposal, there is a clear opportunity at this stage to develop a consistent approach with regards to identifying appropriate measures and more importantly, ensuring that these measures are managed / enforced throughout the life of the project.

In principle, the approach to identifying mitigation measures for traffic associated with a UOG site should not be any different to other environmentally sensitive applications (that require the preparation of an ES) such as windfarms, quarries, overhead transmission lines etc. However, there is a lack of consistency in implementation and management of traffic management measures across the industry. In some cases, mitigation measures are identified in the ES and may be backed up by planning condition, but are not always fully implemented in practice. This is largely due to:

- Difficulties experienced by the relevant authorities in monitoring whether or not these measures have been implemented – for example, as a result of cost / resourcing issues;
Lack of effective communication between the planning team and the appointed contractor; and
Lack of a constructive or pro-active approach from developers, resulting in measures not being implemented unless prompted

The “tools” needed to mitigate the traffic impacts of UOG sites are available, and a well-established mechanism for identifying the need for mitigation is already in place. However, ensuring that appropriate arrangements are in place for specifying, managing and enforcing these measures is an area that should be addressed ahead of the implementation of UOG activity in Scotland.

One effective way of ensuring the measures are implemented is to appoint an independent Compliance Officer (CO) who would be paid for by the developer. The CO would be responsible for ensuring that the developer / contractor is satisfying planning conditions and other legal agreements (such as Section 75 Agreements or Section 96 Agreements). This should include any measures that have been identified through the ES including TMPs, Road Condition Surveys and Traffic Monitoring as well as any other measures identified in the ES to address driver delay, pedestrian delay etc which may have been subject to stand-alone planning conditions.

Planning policy for UOG sites could ensure that there is a requirement to appoint a CO post planning agreement. This could be subject to specified thresholds (e.g. maximum forecast daily traffic flow above an identified level). This would provide confidence that mitigation measures would be implemented and managed throughout the life of the project. It may potentially be possible to link the Compliance Officer role with a liaison officer, if appointed (see Table 11).
6 Conclusions and recommendations

6.1 Traffic impacts of unconventional oil and gas development

The development of Scotland’s unconventional oil and gas resources would result in associated road traffic movements. Road transportation would be needed for movement of plant, equipment, materials and waste.

Estimates were made of potential traffic movements per well pad, as follows:

Table 12: Estimated traffic movements for individual well pads over the well lifetime

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Vehicle type</th>
<th>No re-fracturing, no water transport</th>
<th>With re-fracturing, no water transport</th>
<th>No re-fracturing, with water transport</th>
<th>With re-fracturing, with water transport</th>
<th>Coal-bed methane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Central</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light</td>
<td>Light</td>
<td>11300</td>
<td>20400</td>
<td>14800</td>
<td>23800</td>
<td>48,800</td>
</tr>
<tr>
<td></td>
<td>Heavy</td>
<td>7300</td>
<td>9900</td>
<td>16300</td>
<td>23700</td>
<td>44,300</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light</td>
<td></td>
<td>21500</td>
<td>39500</td>
<td>28400</td>
<td>46400</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heavy</td>
<td>13700</td>
<td>18900</td>
<td>31900</td>
<td>46700</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light</td>
<td></td>
<td>8000</td>
<td>14000</td>
<td>10300</td>
<td>16300</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heavy</td>
<td>5100</td>
<td>6900</td>
<td>11100</td>
<td>16000</td>
<td></td>
</tr>
</tbody>
</table>

Note: "Light" vehicles include motorcycles and all two-axle, four-tyre vehicles – that is, light trucks as well as cars.

The peak traffic movements were estimated to be up to 430 movements per week, and traffic movements at an individual site could be sustained at around 190 per week for a period of approximately 2 years under the Central scenario. For context, typical traffic flows associated with other traffic-generating development include:

- Food superstore: Approximately 60,000 two-way vehicle trips per week (most would be light vehicles)
- Warehouse / distribution centre: Approximately 5,000 two-way HGV movements per week
- Windfarm at construction stage: Approximately 800-1,000 two-way movements per week

The potential impact of wide-scale development of unconventional oil and gas resources in Scotland was considered. At a regional or national scale, traffic movements would have effects on aspects such as vehicle exhaust emissions, highway damage and accident risk, as with any other industry sector.

It was found that the range of UOG development scenarios considered could give rise to between 210 and 1,670 traffic movements per week on average across the country as a whole, with a further 99 movements associated with the coal bed methane scenario. For context, approximately 4.3 million trips were made by cars and goods vehicles in Scotland each weekday in 2012.

It is concluded that, if the moratorium on UGO development in Scotland is lifted, the additional traffic movements associated with onshore oil and gas resources would be unlikely to be significant or detectable at a regional or national scale, in view of the much greater numbers of traffic movements resulting from other activities. Hence, as with any comparable industry sector, traffic associated with UOG development would have a slight adverse influence on some Scottish National Indicators, principally the following:

- Reduce traffic congestion
- Reduce deaths on Scotland's roads
- Improve access to local greenspace
It is concluded that the contribution of UOG development to these indicators would be slight and comparable to many other industry sectors and activities. Hence, it is considered that no significant weight should be given to the impacts of traffic associated with UOG at a national or regional level. Consequently, the key focus for consideration of potential community impacts of UOG development should be the assessment and management of potential impacts on communities local to development sites. The main factor affecting traffic flows to and from a well pad site is the requirement for transportation of clean and waste water. If the transportation of water by road can be avoided (e.g. by use of pipelines and/or by re-using wastewater), traffic impacts can be significantly reduced.

6.2 Potential community impacts from transportation

Road traffic impacts are one of the aspects of UOG development of greatest concern both to the general public and professional analysts. These impacts arise principally from increases in heavy goods vehicle movements on potentially unsuitable roads. These movements would take place over a relatively limited period for an individual well, but may occur over a much longer period for development of a multi-well pad, and in particular in situations where a shale gas field is being developed.

Managing the road traffic impacts of new development is a well-established discipline with project developers and regulatory authorities. UOG development is different from other more familiar activities, in that development would take place at locations which would be determined by a broad range of factors, including, but not limited to, the desirability of minimising traffic impacts. The areas potentially prospective for UOG development include much of the Central Belt of Scotland, and cover rural, suburban and urban areas (see Figure 1 and Figure 2).

Consequently, UOG development could potentially take place in rural, suburban or urban settings. These would pose different challenges in respect of the management of transportation impacts. These challenges would focus on the potential for traffic movements to take place along potentially unsuitable routes.

6.2.1 Site typology

A UOG site may comprise a well pad, compressor station, water treatment works, or other infrastructure. An outline site typology is provided below, which may assist in identifying and managing potential impacts at a strategic or site-specific level.

- **Site with good highway links**: It may be possible to locate a UOG site at a point with good connections to the main road network. In this case, there are unlikely to be significant community impacts from road traffic, although it would be important to ensure that this is given full consideration through the planning process.

- **Industrial site**: A UOG site in an industrial setting is likely to have good connections to the main road network. Additionally, neighbouring land uses are likely to be industrial in nature, and hence would typically have low sensitivity to traffic impacts. In this case, there are unlikely to be significant community impacts from road traffic, although it would be important to ensure that this is given full consideration through the planning process.

- **Rural site**: A rural UOG site could potentially be located at some distance from the main road network. This could potentially require vehicles accessing the site to use unclassified roads which may be unsuitable in view of the proximity to sensitive properties, road surface, road width, poor visibility, or potential for effects on natural ecosystems. Such impacts should be carefully considered through the planning process.

- **Urban/suburban site**: An urban or suburban UOG site could potentially be located at some distance from the main road network. This could potentially require vehicles accessing the site to use roads which may be unsuitable in view of the proximity to sensitive properties which may be numerous; presence of pedestrians/cyclists; road surface; road width; or poor visibility. Such impacts should be carefully considered through the planning process.

Additionally, a subcategory of each of the above site categories may be considered:

- **Subcategory: Site with reduced water transport requirement**: Water transportation accounts for a substantial proportion of heavy goods vehicle movements to and from a well pad site. A site in any of the above categories with the opportunity to reduce water transport would
be more favourable from the perspective of managing transportation impacts. This could be achieved in a number of ways:

- Mains water connection
- Piped supply of fresh water and/or removal of waste water
- Complete or partial re-use of waste water on site

The following sections summarise the potential community impacts of traffic associated with UOG development, and outline how these potential impacts would be managed.

### 6.2.2 Potential for accelerated road surface degradation

UOG development presents a risk of damage to road surfaces and the underlying road structure through additional loading by heavy vehicle movements. This impact can be mitigated through cost recovery through taxes or fees; through policies designed to decrease damage to roadways such as truck weight limits; and/or altering infrastructure to make it more resilient. Maintenance agreements are currently used in the United Kingdom for both UOG and other types of process that generate significant volumes of HGV traffic, and may involve before and after condition surveys, the carrying out of specified remedial works, and/or making a payment under a Section 96 agreement to recover the cost of road repairs.

### 6.2.3 Risk of increased accidents

The evidence indicates that increased UOG traffic in areas of intensive UOG development in the USA has resulted in increased incidence of accidents in affected communities.

### 6.2.4 Risk of accidental release of hazardous material during transportation

There is a risk that truck accidents could lead to chemical or wastewater spills. This could include fracturing fluid, chemical additives, flowback water, or produced water. There are systems in place in the UK to manage the impact of chemical spillage in the event of a traffic accident. These controls would reduce, but not fully eliminate, such risks.

### 6.2.5 Air pollution impacts

The increases in vehicle movements would result in an increase in emissions of air pollutants. The Roseacre Wood case study suggests that road traffic flows associated with an individual development are not likely to result in significant air quality impacts. However, the potential for localised impacts would depend on the nature, scale and location of a proposed development. The potential for localised impacts on air quality would need to be taken into account in the environmental assessment of any UOG development.

### 6.2.6 Noise

Noise associated with traffic movements to and from UOG facilities could potentially affect nearby residents. Noise impacts would be determined by factors such as vehicle type, load and speed, type of road surface, road grade, distance from the road to sensitive receptor, road gradient, ground condition, and atmospheric conditions. Any Environmental Impact Assessment for UOG operations should consider noise as with any other development where an increase in traffic is forecast to occur.

### 6.2.7 Nature conservation

UOG activities can potentially affect biodiversity via a number of routes. In relation to traffic, the impacts potentially relate to accidental spills, sediment run-off and possibly new road construction or increased traffic movements in sensitive areas. The likely setting of shale gas development in Scotland means that impacts on remote habitats are unlikely. However, there would be a risk of harm to habitats which may be valuable in their local setting. Any such effects would need to be considered during the planning and EIA process.

### 6.3 Mitigation measures

Mitigation of potential community impacts from road traffic associated with UOG development should take place via the strategic and land-use planning processes.
6.3.1 Strategic planning

The Scottish planning system is used to guide decisions about the future development and use of land and identifies the locations and conditions under which development should and should not happen. Scottish Planning Policy (SPP) in 2014 which sets out the national planning policies which reflect Scottish Ministers’ priorities for operation of the planning system and for the development and use of land. Transport forms a key role within SPP and is supported by Planning Advice Note (PAN) 75, “Planning for Transport”.

PAN 75 provides good practice guidance which planning authorities, developers and others should carry out in their policy development, proposal assessment and project delivery. As with any other traffic-generating development, UOG project developers should expect to carry out assessment and mitigation of traffic impacts in accordance with PAN 75.

Strategic Development Plans set out the vision for the long term development of Scotland’s city regions and follow the overarching vision for Scotland identified in NPF 3 and SPP. Clydeplan and SESplan make reference to UOG development, and mandate the setting of appropriate policies in local development plans.

Local Development Plans provide the vision for how communities will grow and develop in the future. A local development plan could include specific policies relating to the transportation impacts of UOG development. For example, the Clackmannanshire Local Development Plan makes specific reference to transportation of water for hydraulic fracturing, and indicates that preference would be given to sites that could import water by pipeline.

As set out in Section 5.5, supplementary guidance for assessing the merits of UOG sites and ensuring the appropriate management of development could be developed. This could be in the form of a PAN or a planning circular, or could be developed as Supplementary Planning Guidance by individual authorities. This would assist planners and developers in narrowing and prioritising their areas of search for appropriate sites. Specific guidance would also assist in the preparation and evaluation of documents including Environmental Statements, Traffic Management Plans etc. Local communities could refer to this guidance to identify what level of assessment, management and mitigation of transportation impacts they can expect.

6.3.2 Land-use planning

Any planning application for UOG development which would generate significant traffic movements should be made subject to an Environmental Impact Assessment (EIA), using the powers available to planning authorities if necessary. An EIA would include a requirement for assessment of impacts relating to traffic movements. The assessment must determine if the proposed development would have a significant detrimental impact, and identify if any mitigation measures are required. Any mitigation measures should be clearly defined in the Environmental Statement. These may include measures for mitigation of traffic impacts by design, following the principles set out in Section 5.5. One of the key design measures is likely to include avoidance of transportation of water to and from the site by road, where possible.

The most appropriate means of implementing a range of mitigation measures is through a Traffic Management Plan (TMP). This enables a flexible approach to be taken to managing traffic impacts. TMPs are often requested by local authorities at the planning consent stage by means of a prescriptive condition attached to the issued consent.

6.3.3 Recommendations for mitigation

To ensure that appropriate mitigation measures are identified, implemented, enforced and managed, the following is recommended.

1. National, regional and local plans should set policies to guide the development of UOG resources, in the event that the moratorium is lifted. The Strategic Environmental Assessment which informs the strategic planning process should include consideration of multiple UOG developments in a locality and outline how the potential cumulative impacts of such development should be managed. For example, SEA could consider potential for effects on regional air quality due to traffic associated with multiple sites, or potential cumulative impacts of traffic noise from multiple sites. SEA could also be used to assess and manage the potential effects of development of multiple sites on protected natural habitats and species.
2. All planning applications for UOG development should be made subject to an Environmental Impact Assessment as discussed above.

3. A “Framework Traffic Management Plan” should be required to support all planning applications for UOG sites. The purpose of the document would be to demonstrate how traffic impact would be minimised and would clearly state what measures would be put in place. A full TMP should then be prepared post-planning and should be subject of a planning condition. This should include arrangements for traffic monitoring.

4. Discussions should take place between the developer and the local authority at the planning application stage with regards to the provision of a Roads Condition Survey and provision of an appropriate financial bond to cover any required road repairs. If required, this should be subject of a planning condition.

5. At appropriate sites, the developer should be required to appoint an Enforcement Officer post planning agreement to ensure that mitigation measures are implemented and enforced throughout the life of the project. This requirement may be subject to minimum thresholds associated with the forecast traffic impact of the proposed development.

6. It is understood that UK Onshore Oil and Gas is working with the industry, the Road Haulage Association and Fleet Operator Recognition Scheme on a set of key principles in considering transportation for onshore oil and gas. When published, these can be evaluated by planning authorities and, if appropriate, taken into account in considering and determining planning applications for UOG development, and identifying appropriate mitigation.

6.4 Residual community impacts from transportation

Assuming that appropriate strategic development policies are put in place, and appropriate mitigation is carried out, some residual community impacts due to transportation can be expected to remain. Local communities would experience an increase in traffic numbers, potentially for an extended period of a number of years. This might be experienced as an increase in HGV movements on local roads, together with associated road improvements such as junction improvements or passing places.

Any increase in vehicle movements could result in an increase in noise, vehicle exhaust emissions, road damage, or traffic accident risks, which may be identified as negligible, or may require mitigation. Mitigation of such traffic impacts would require specific management and financial resources which would need to be secured through the planning process. Provided the planning and EIA system is properly implemented, any significant impacts would be avoided through the use of appropriate mitigation measures.
Appendices

Appendix 1: Case studies
Appendix 1: Case studies

Exploratory drilling and hydraulic fracturing, Preese Hall, Weeton, Lancashire

A case study was carried out to investigate the traffic impacts associated with exploratory drilling and hydraulic fracturing carried out in 2011 at Preese Hall, Weeton, Lancashire. A single well (referred as PH1) was fractured in six stages, of which five used significant quantities of material. Planning permission for this exploratory well test was granted before significant attention was paid to shale gas activity in the UK. The limited information submitted with the planning application indicated that there would be up to 220 truck movements associated with the well test. These movements took place along a B class road past scattered dwellings for a distance of about 4 km, followed by an unclassified road for a distance of about 1 km, and finally a newly constructed site access road for a distance of about 400 metres.

There would be additional movements for construction, drilling and restoration activities, removal of drilling waste and waste water, etc. No specific information on vehicle numbers was available.

The operator, Cuadrilla, reported the following total material quantities used for fracturing of this well:
- Water: 8,399 m$^3$
- Sand: 463 tonnes
- Friction reducer: 3.7 m$^3$
- Chemical tracer: 0.004 tonnes

These material quantities would have resulted in approximately 300 two-way truck movements for water transport to the site, and approximately 17 two-way truck movements for transport of sand to the site. Most wells would require more than 5 stages of hydraulic fracturing, and these estimated vehicle numbers are consistent with the estimated “high scenario” vehicle movements associated with hydraulic fracturing of 814 heavy vehicles per well.

Shale gas application at Roseacre Wood, Lancashire

An application was made to Lancashire County Council to carry out exploratory drilling and hydraulic fracturing at a site at Roseacre Wood, Lancashire. A further application was made for a similar development at a nearby site. The applications were refused by Lancashire County Council in 2015, and were the subject of planning appeals in 2016. The Department for Communities and Local Government announced that the planning inquiry would be re-opened in October 2016.

This case study focuses on the potential air quality impacts of traffic movements resulting from the proposed Roseacre Wood development during the planning application stage. Preston City Council raised concerns about the potential impacts on air quality in a nearby Air Quality Management Area (AQMA). A Council officers’ report to a Planning Committee meeting in June 2015 commented that “...the consequences of routeing HGV construction traffic from the A6 via Broughton and the B5269 would have unacceptable adverse traffic and air pollution impacts conflicting with the requirements of APLP Policy T19 and PPLP Policy ST2, Core Strategy Policies 2, 3 and 30 and the Framework.” Specifically, the report drew attention to potential air quality impacts on an Air Quality Management Area (AQMA) designated by Preston City Council which covers the A6 Garstang Road in Broughton, referred to as “AQMA 3”. AQMA 3 was designated on the basis of high measured levels of nitrogen dioxide.

This was considered by Ricardo Energy & Environment on behalf of Lancaster County Council. The forecast traffic and associated air quality impact was assessed in the context of guidance published by the Institute of Air Quality Management (IAQM). This indicates that a development can be considered as having an insignificant impact on air quality if it is forecast to result in:

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• A change of light duty vehicle flows of less than 100 vehicles per day (annual average) within or adjacent to an AQMA
• A change of heavy duty vehicle flows of less than 25 vehicles per day (annual average) within or adjacent to an AQMA

If these criteria are exceeded, the IAQM guidance advises that an Air Quality Assessment should be carried out. In the case of the proposed development, it was found that these criteria would not be exceeded, and on the basis of the IAQM guidance, the impacts can be considered as having an insignificant effect. This preliminary evaluation was checked using the Department of Transport Design Manual for Roads and Bridges (DMRB) screening methodology. This demonstrated that the proposed development would result in an increase of 0.12% in levels of nitrogen dioxide. Such a change is below the range of impacts considered in the IAQM guidance, and would not be significant in the context of other influences on air quality, or detectable by any practicable means. For example, the change is about one hundredth of the variability in measured nitrogen dioxide levels within AQMA 3 from year to year. It was concluded that the proposed development would have an insignificant effect on air quality in Preston City Council’s Air Quality Management Area 3 at Broughton.

Letham Moss Coalbed Methane Sites

This case study concerns a 14 well coal bed methane production development at Letham Moss Falkirk. The development, which was initially refused approval (and is now subject to a sisted appeal), had proposed to undertake drilling, well site establishment at 14 locations, inter-site connection services, site access tracks, a gas delivery and water treatment facility, ancillary facilities, infrastructure and associated water outfall point. It is important to note that the inter-site connection services would remove the need for water to be transported to the site on road once it is operational.

The Traffic and Transport chapter of the submitted ES states that the site preparation phase would generate the highest number of traffic movements and that site preparation activities would not occur at all 14 sites simultaneously. Instead it was assumed that drilling works would be undertaken at two sites at a time while site preparation works would be ongoing at a couple of nearby sites. It is also assumed for the worst case scenario that the construction of the Gas Delivery and Water Treatment Facility (GDWTF) would be on-going at the site.

The ES predicts a worst case total of around 158 vehicle movements per day (HGV and construction worker transport). Of this total, 68 movements would be HGVs associated with site preparation, 60 HGVs/LGVs associated with drilling operations and 30 HGVs/LGVs associated with the construction of the GDWTF.

These predicted traffic movements were then used to assess the level of impact that the proposed development would have on the local road network. The assessment found that on all the assessed roads the percentage increase was lower than 30% and therefore lower than the threshold stated in Rule 1 of the IEA guidelines. It also found that once the site preparation and drilling is complete, the number of movements would reduce to approximately 6 vehicle movements per day. Hence, the higher level of impact predicted was considered to be only a temporary and not a permanent effect.

In addition, the access routes to the site were not considered to be ‘specifically sensitive areas’ and therefore the temporary increase in traffic was not predicted to cause a significant effect when tested against Rule 2 of the IEA’s document. Therefore, no further detailed assessment of environmental effects associated with increased traffic was considered to be warranted in line with the available guidance.

Although the traffic effects of the proposed development were not predicted to cause any significant environmental effects, a number of mitigation measures were proposed within the ES:

• Construction of accesses to each site that respect prevailing roads standards and ensure adequate visibility and turning areas;
• Extension of the Traffic Management Plan (TMP) in operation at the existing well sites to encompass the new sites thus ensuring that robust procedures are in place to manage traffic to and from the new sites.

The ES does however consider the predicted effects of the development on public access. The ES provides a list of core paths in the area which will be affected by the proposed development and to what
degree the development will affect them. The ES does however state that no permanent well sites or the GDWT will physically encroach on any core paths. In terms of recreational access elsewhere around the development the ES states that apart from the areas taken up by permanent well sites and the GDWT, there will be no loss of land for recreational use.

In its assessment of significance of the impact on public access, the ES states that prior to any mitigation, assuming a high user sensitivity and a moderate magnitude of effect during construction, the significance would be moderate to high in the short term period due to conflicts with users of the core paths. In the longer term, when vehicle access to the sites is much lower, the magnitude of effect would reduce to low, resulting in a slight or negligible adverse significance.

With regards to mitigation for public access, the ES states that the TMP would require site traffic to give priority to any recreational users of the core paths or users of access tracks or other land under the Land Reform Act. For example, horse riders, cyclists or pedestrians using any access track or the road network would be considered as a priority user, and would be provided with sufficient room by any overtaking Dart vehicles, or allowed to pass before a Dart vehicle if overtaking was not possible.

The ES also states that where possible, a standoff between any developed access track and field boundaries, or other “informal” tracks will be maintained so they will remain available for use during construction and avoid conflict with vehicle use. The ES then states that with these mitigation measures in place, the short term significance (during drilling) would reduce from “moderate to high”, to “minor to moderate” (high user sensitivity but minor impact magnitude).

The ES does not consider the noise and vibration impact of traffic generated by the development but does consider the air quality and dust impact.

This assessment takes into consideration the emissions created by site generated traffic as well as the nuisance dust effects from vehicles. With regards to emissions, the ES states that the air quality impact of NOx and other combustible emissions produced by vehicles servicing the sites during construction is considered negligible. With regards to nuisance dust effects, the effect is also considered slight or negligible. However, some mitigation measures for dust are proposed. These include:

- All vehicles to switch off engines – no idling vehicles;
- Effective vehicle cleaning and specific fixed wheel washing on leaving site and dampening down of haul routes;
- All loads entering and leaving site to be covered;
- No site runoff of water or mud;
- On-road vehicles to comply with set emission standards; and
- All non-road mobile machinery to use ultra-low sulphur tax exempt diesel where available and be fitted with appropriate exhaust after treatment.

On review of the ES, it was clear that the proposed development generated a modest volume of traffic which only had a very localised impact which did not trigger a detailed assessment of environmental effects associated with increased traffic. It would appear that the key mitigation on this project was the commitment to deliver water to the site by means of mains connections which meant that there would be no requirement for water deliveries by road.

Consent was not granted for this development but Stirling Council recommended that the following conditions should be attached to any consent issued:

- Provision of a road traffic management plan
- Undertaking of a road condition survey and undertaking of repair work should deterioration occur as a result of increased traffic
- Enter into a legal agreement (as per Section 96 of the Roads (Scotland) Act 1984) to allow the Council to recover the cost of repairing roads.

**Earlseat Windfarm**

This case study is a 9 turbine windfarm, located at Earlseat Farm, Kirkcaldy (Planning No. 10/03539/EIA), which was consented in 2012 and constructed in 2014. No post development data is available, and consequently this case study reviews the information provided as part of the EIA Process.
The ES breaks down the traffic impact into three sections, construction effects, operational effects and decommissioning effects.

The ES estimated that the windfarm would increase traffic flows (up to 92 two-way HGVs per day) during the construction phase and this was identified as the worst-case scenario. The ES also considered site construction worker movements and identified that there would be up to 40 two-way construction worker movements per day during the construction stage of the development.

The assessment of the environmental effects associated with construction traffic concluded that the impacts on the road network would be “negligible” in terms of significance and would have no effect on the operation of the local road network. The ES also undertook a sensitivity test to identify the cumulative impact should the operations at a nearby mining operation (‘Wellsgreen OCCS’ which was at planning application stage at the time the ES was written) occur at the same time as the construction of the windfarm. The ES found that for this worst case scenario, the impact at all assessment points would be less than 1% of baseline traffic flows. The predicted levels of trip generation were therefore below the threshold of both Rule 1 and Rule 2 of the IEA guidelines and therefore no further assessment under either of the IEA documents rules is warranted.

During the operational phase of the development, the ES did not envisage that there would be any permanent staff on the site and that any traffic movements would be related to maintenance. The ES states that these movements would have a “negligible” effect on the local highway network. The ES therefore concluded that it was not necessary to assess the environmental impacts of traffic generated by the operational phase of the windfarm.

The ES states that the levels of traffic associated with decommissioning are anticipated to be lower than those required during construction and that traffic management procedures would be agreed with Fife Council at the appropriate time. No further assessment of decommissioning effects was therefore undertaken.

With regard to the mitigation of traffic and abnormal load impacts, a Traffic Management Plan was proposed which would include the following:

- Approved access routes and any necessary restrictions including left turn only restrictions for HGVs at the site access;
- Temporary signage in the vicinity of the site warning of construction traffic;
- Temporary signage warning other users of abnormal load turbine movements;
- Arrangements with Police for escort of abnormal loads from the Port of Entry;
- A warning system to identify the site entrance on Standing Stane Road will be established;
- Ground preparation including protection of services and lowering of pavements;
- Arrangements for road maintenance and cleaning;
- Timing of deliveries – construction hours will be outwith peak traffic hours, subject to agreement with Fife Council;
- Arrangements for parking restrictions along access route if required; and
- Wheel cleaning arrangements.

The ES carried out an assessment of the impact of the construction traffic on noise which found that the largest predicted increase would be 0.2 dB which was deemed to be insignificant. The ES also states that traffic noise associated with the proposed Wellsgreen OCCS, at the same time as Earlseat construction will result in a negligible increase in noise levels, as a result of traffic from the two developments.

There is no assessment of air quality, but it would have been reasonable for any assessment of air quality to have been scoped out during the preliminary stages of the EIS process.

The following conditions relevant to road transportation were attached to the consent by Fife Council:

- Preparation of a Traffic Management Plan
- Creation of a turning area at the site to ensure that vehicles accessing and egressing the site do so in forward gear
- Off-street parking to be provided on site to prevent overspill onto surrounding road network
- Wheel cleaning to be provided at site entrance to prevent mud and debris from being deposited onto road network
- Core paths crossing the site to be maintained

The windfarm case study is similar to the Coal Bed Methane development in terms of traffic generation and the type of mitigation required.

**Rusha Surface Mine**

This case study is a 154ha open cast coal mine at Rusha Farm, West Lothian (Planning No. LiVE/1199/M/07), which was consented in 2010 and began extraction in 2012. No post development data is available, and consequently this case study reviews the information provided as part of the EIA Process. This development was chosen for comparison in view of the nature of the development and the Central Scotland location.

The Traffic and Transport section of the ES states that for assessment purposes, a maximum output of 10,000 tonnes per week (126 HGV movements per day) is assumed. However, the average production is likely to be 6000 tonnes per week (resulting in 76 vehicle movements per day). The ES references the TA which was produced to support the development which concludes that the 12 vehicles per hour generated by the site will give rise to increases of traffic flows between 1.2% and 9.8% of baseline flows.

The predicted levels of trip generation for the mine were therefore below the thresholds of both Rule 1 and Rule 2 (albeit marginally) of the IEA guidelines and therefore no further assessment under either of the IEA document rules is warranted.

The ES suggests that the scale of additional traffic would not be expected to have an adverse effect on road safety for the following reasons:

- Road accidents are multifactorial events in which vehicle condition, driver experience and behaviour, road conditions, weather and lighting all contribute;
- Heavy vehicles are not involved disproportionally in accidents on the routes examined;
- The characteristics of heavy vehicles make them less likely to be involved in accidents than other vehicle categories.

The ES also notes that the Environmental Management Plan (EMP) will be adhered to and site specific instructions will be applied to drivers and HGV routes in order to minimise impacts in built up areas that vehicles would pass through in order to access the site.

The ES does not discuss the impact of noise, air quality or dust relating to traffic. However, the EMP does provide some commentary on dust mitigation, which is particularly relevant for a mining activity. The EMP states that the access road at the site entrance will be provided with a tarmac surface which will be regularly cleaned to ensure that dust and mud do not accumulate. The EMP also states that a wheel wash will be provided at the site which all HGVs will be instructed to use before leaving the site.

The following conditions relevant to road transportation were attached to the planning consent issued by West Lothian Council:

- Measures to be taken to prevent material being deposited on external road network by transport vehicles
- Wheel cleaning to be provided at site entrance to prevent mud and debris from being deposited onto road network
- First part of site access road to be finished in tarmac to prevent mud and debris being deposited onto local road network
- Preparation of an Environmental Management Plan
Tomfyne Quarry

This case study is a 350,000 tonnes per annum quarry at Tomfyne Farm, North Lanarkshire (Planning No. 12/00729/FUL). The application is “minded to grant” subject to the signing of a Section 75 agreement. This case study reviews the information provided as part of the EIA Process.

The Traffic and Transport section of the ES states that following characteristics are associated with the proposed development at Tomfyne:

- The removal of material from the site will generally be via 20 tonne tipper lorries;
- Operations at the site would be Monday to Saturday;
- Working hours would likely be 0700-1900 Monday to Friday and 0700-1200 on Saturdays;

The Traffic and Transport section also sets out the trip generation potential of the proposed development. It is anticipated that the development would generate approximately 13 two-way HGV movements per hour with an additional 10 two-way staff vehicle movements in the AM and PM peak periods. The traffic impacts assessment which was carried out in the ES indicates that the impact of development generated traffic will be less than 5% at all remote junctions and as such no further capacity or operational assessments have been undertaken in line with Rule 1 and Rule 2 of the IEA guidelines.

The ES provides a list of potential measures to reduce the traffic related impacts of the proposed development which include:

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| Measures to Reduce Dust and Dirt on External Road Network | - A 567m section of the site access road from the site entrance to the wheel wash facility will be surfaced with asphalt.  
- A wheel washing facility will be installed on site, used to clean the wheels of vehicles as and when required to prevent dirt / mud from being dragged out onto the external road network.  
- All vehicles exiting the site will have loads covered with sheeting to ensure that dust is kept to a minimum.  
- The access road to the site shall be kept free of dust and dirt by means of a mechanical sweeper which shall be deployed as and when necessary. |
| Measures to Reduce Traffic Impact          | Designated HGV routes to the site will also be established so that heavy vehicles travelling to and from the site are kept to main routes. This will ensure that HGVs are kept away from sensitive areas and the impact on the general public is minimised. |
| Speed Limit                                | It is proposed to impose a 20mph reduced speed limit for all traffic on the access road which will be reinforced by speed limit signs along the length of the route. |
| External Signage                           | External signage will be erected on the local road network in the vicinity of the development site to warn people of quarry activities and associated vehicles turning at the access. The purpose of such signage is to provide driver information and to maintain road safety in the proximity of the site access. |
| Workforce Travel                           | The operator of the site will seek to minimise workforce traffic movements through the promotion of shared transport arrangements for site operatives.  
Car parking for the workforce will be provided entirely within the confines of the site boundary so that there is no impact on existing road users. |
| Staff Induction                            | All permanent site staff will be informed about traffic management arrangements and procedures via site induction literature |
The Noise Chapter of the ES states that the change in road traffic noise level would be regarded as negligible and that any corresponding change in airborne variation would be negligible.

North Lanarkshire Council proposed a number of conditions relating to traffic and transport as part of their Committee Report. These conditions relate to the following:

- The provision of a Transport Management Plan which will include: HGV routes, speed limits and drivers code of conduct;
- Wheel washing equipment / monitoring of site access to prevent damage to the public road;

UOG development at rural sites in Western North Dakota

A review of transportation impacts associated with UOG development at rural sites in Western North Dakota was carried out by the Upper Great Plains Transportation Institute at North Dakota State University. North Dakota experienced a seven-fold increase in oil and gas production between 2004 and 2011. This was achieved partly by more than doubling the average daily production per well over this period.

It was estimated that each well resulted in approximately 2,300 drilling-related truck trips, broken down as follows:

- Water (Fresh)  450 loaded  900 total
- Water (Waste)  225 loaded  450 total
- Frac Tanks  115 loaded  230 total
- Sand  100 loaded  200 total
- Scoria/Gravel  80 loaded  160 total
- Rig Equipment  65 loaded  130 total
- Drilling Mud  50 loaded  100 total
- Cement  20 loaded  40 total
- Pipe  15 loaded  30 total
- Other  30 loaded  60 total

A key source of traffic movements has been the requirement for collection of oil by truck to pipeline or rail transfer location. Oil pipeline connections are available for wells in part of the state where hydrocarbon production is well established, but trucks are needed for collection of oil in the majority of the state.

The State legislature has identified that ongoing truck movements could potentially result in significant highway damage, and has set studies in motion to understand the traffic movements associated with UOG development in North Dakota and the associated highway maintenance costs. It is also important to consider safety issues, emergency response, road design and capacity, and ensuring proper enforcement.

UOG development at urban sites in Tarrant and Johnson Counties, Fort Worth, Texas

The United States Extractive Industries Transparency Initiative has published a short case study describing UOG production in Tarrant and Johnson Counties, Fort Worth, Texas. The case study is a multi-stakeholder initiative, designed to illustrate how mineral resources are managed in practice. Tarrant County covers the majority of Fort Worth, a city with a population of approximately 800,000. Johnson County covers the southern part of Fort Worth, and extends southwards to include the smaller cities of Cleburne and Alvarado.

The case study highlights that the benefits of extraction comes with associated costs for governmental institutions, and states:

“During well construction and drilling, heavy truck traffic causes wear on roads and bridges that can significantly reduce their service life. This problem is particularly pronounced on roadways
that were not originally designed to support industrial traffic. According to the Texas Department of Transportation (DOT), the volume of truck traffic required to bring one gas well into production is equivalent to the impact of approximately eight million cars; truck traffic required to maintain that well is equivalent to another two million cars. Constructing such a well reduces highway service life by as much as 53%."

The equivalence figures referred to are the estimated numbers of cars which would have an equivalent impact on highway damage to the calculated truck movements. The case study did not go beyond this to consider other community impacts.

The main type of road damage was found to be rutting. Rig traffic, construction traffic, and removal of wastewater were estimated to result in a reduction in road service life of approximately 5.6%, 29%, and 16% respectively. A separate study highlighted four potential means of managing highway maintenance issues in Texas:

- A proactive, performance-based approach whereby roads are strengthened prior to energy development.
- A reactive, performance-based approach whereby a fee for road maintenance costs is estimated after damage has been caused.
- A fee-based structure which is not linked to specific roadway deterioration.
- A policy approach, in which counties are empowered to promote transportation infrastructure projects in areas affected by oil and gas production activities.

A task force is being convened by The Academy of Medicine, Engineering and Science of Texas (TAMEST) to examine the environmental and community impacts of shale oil and gas development in Texas. The group will review existing scientific research and findings regarding the effects of shale oil and gas development in Texas, focusing on seismicity, land resources, water, air, transportation and community impacts. This initiative is due to be launched on 6 October 2016.

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