4 The proposed development

4.1 Context

1. The overall purpose of the Project is to establish whether, or not, the Bowland Shale deposits could provide a commercially viable supply of natural gas (primarily methane) . In order to do this it is necessary to drill exploratory wells into the shale to provide detailed geological data about the rock formations and measure the flow and quality of natural gas from the shale. To extract the natural gas reserves in the shale, a process called hydraulic fracturing is used to connect new and existing natural fractures in the rock to allow natural gas to flow out of the shale into the exploration well and up to the surface. Up to four wells will be drilled from the Site. The first vertical well will be drilled into the Hodder Mudstone beneath the Bowland Shale (to a depth of approximately 3,200m) to obtain detailed geological data. A horizontal well bore may then be drilled from the vertical well into the shale strata at a depth to be selected following analysis of geological information from the vertical well. Hydraulic fracturing will then occur in the vertical and/or horizontal section of the well bore within the shale formation. Flow testing of gas will follow successful completion of the hydraulic fracturing stages.

2. Depending on the well results, up to three further wells will be drilled (first vertically to the desired depth, and then horizontally), hydraulically fractured and flow tested, from the well pad. These three wells are referred to in this ES as horizontal wells. By drilling more than one well Cuadrilla will be able to hydraulically fracture the shales and test the flow of natural gas from different stratigraphic sections of the shale. This will provide data for Cuadrilla to appraise the commercial potential of the Bowland Shale for gas extraction.

3. Additionally, two seismometer arrays will be constructed (within 4km of the well pad). The first will consist of up to eight seismometers located just below the ground surface (referred to in this ES as the surface array). These seismometers will detect vibrations at ground level and will allow Cuadrilla to monitor any induced seismic effects from the hydraulic fracturing process and mitigate any potential impacts. These seismometers form a key part in the "Traffic Light System" (TLS) used to control the fracturing operation. A second set of up to 80 seismometers will be located in boreholes (up to 100m below ground level). These will be used to monitor the direction and extent of the small fractures created in the shale which, in turn, will allow Cuadrilla to monitor and optimise the hydraulic fracturing process. This array is referred to in this ES as the buried array.

4.2 Planning and permitting

4. In addition to obtaining planning permissions described earlier, other consents and permits will also be required before different operational stages of the Project can proceed (e.g. drilling and hydraulic fracturing). These are determined by regulatory regimes outside the Town & Country Planning system. However, at the time of writing the key regulators for planning and permitting of shale gas exploration projects are[29]:

- Department of Energy and Climate Change - issues Petroleum Licences, gives consent to drill under the Licence once other permissions and approvals are in place and has responsibility for assessing risk of, and monitoring, seismic activity, as well as granting consent for flaring of gas;

[29] DCLG, July 2013. Planning practice guidance for onshore oil and gas (paragraph 27).

- LCC (Mineral Planning Authority). - grants permission for the location of any wells and well pads, and imposes conditions to ensure that the impact on the use of land is acceptable;
- Environment Agency - regulates the protection of water resources (including groundwater), treatment and disposal of extractive waste, emissions to air, and accumulation, treatment and management of any naturally occurring radioactive materials (NORM), and works close to a main river; and
  Health and Safety Executive - regulates the safety aspects of all phases of gas extraction, and has regulatory responsibility for design and construction of the well casings.

4.3 Development summary

4.3.1 Overview

5. The total area of the surface works is 6.54ha, of which 1.34ha is a compacted crushed stone surfaced well pad from which the drilling, hydraulic fracturing and flow testing activities will be undertaken. A 428m access track will also be constructed (area approximately 0.5ha). 0.57ha of the application site will consist of surface water collection ditches, landscaped bunds (from topsoil and subsoil excavated during construction of the well pad) and fencing. 1.94ha of the area provides land required for the extended flow test pipeline and connection as described in Table 4.1. The remaining 2.19ha covers a Site access route through DHFCS Inskip.

6. Three pairs of groundwater monitoring wells will be installed around the perimeter of the well pad to a maximum depth of approximately 20-30m (see Appendix B for details).

7. In addition to 80 buried seismometer array points will be installed (up to 100m below ground level) and eight surface seismometer array points will also be installed in shallow pits (approximately 0.8m below ground level).

8. Up to four wells exploration will be drilled and tested from this well pad during the Project. The overall process is summarised in Table 4.1 and the activities are described in more detail in the subsequent sections of this chapter and illustrated in Figure 4.1.

9. Cuadrilla has developed several documents which describe a management framework to control operations that are safe and to minimise environmental impacts. Cuadrilla's Health, Safety, Security and Environment (HSSE) Risk Management Framework provide the framework to effectively manage operational risks. Site operational health and safety will comply with the provisions of the Borehole Sites and Operations Regulations 1995 (BSOR), and the implementation of the site health and safety procedures, record keeping, monitoring and auditing will be regulated by Health and Safety Executive (HSE). Cuadrilla has also developed Environmental Operating Standards (EOS) to outline the environmental embedded and site specific mitigation measures during site operations. These standards document Cuadrilla's commitment to safeguarding human health and the environment. A document that sets out their rationale and how they will be implemented when consent is granted can be found in Appendix E.

Table 4.1: Summary of the main elements of the Project.

Activity	Description
Install surface seismometer and buried seismometer arrays.	The surface array of eight sensitive surface seismometers and the 80 buried array seismometers and related devices will be installed, to monitor ground conditions and manage the seismic Traffic Light System (TLS) (as per section 4.4). These two arrays will be installed so that baseline data can be collected before hydraulic fracturing occurs so that any effects of the subsequent hydraulic fracturing activities can be monitored. A separate planning application has been submitted for the arrays (the Monitoring Works Application as described above in section 4.1).
Installation of the groundwater quality monitoring wells.	Three boreholes will be drilled, each installed with 2 monitoring wells, to monitor groundwater and ground gas. These also form part of the Monitoring Works Application described in section 4.1.
Construct well pad and access track.	It is anticipated that it will take up to two months to construct the exploration well pad, drilling cellars, conductor casing, access track, fencing, and installation of the mains water connection (for site staff welfare, drilling and hydraulic fracturing activities).
Drill vertical section of Well 1.	The first well to be drilled will be a vertical well to a depth of approximately 3,200m below ground level. This well will provide data on the specific geology below the Site. From this data the target zones in the shale for horizontal wells will be identified. It will take approximately 3 months to complete the vertical well (see section 4.3.2 and Figure 4.2).
Drill horizontal section of Well 1.	A horizontal well may be drilled laterally from the vertical section of Well 1 at between 1,900-2,800 m depth below the surface (the exact level to be determined). This will take approximately two months to complete, and could extend 1,000 to 2,000m horizontally from the drilling cellar.
Hydraulic fracturing.	The vertical or horizontal sections of Well 1 will be hydraulically fractured to create a network of minute cracks within the shale. Hydraulic fracturing will be carried out in a number of stages along the well. Hydraulic fracturing will occur within the horizontal sections of Wells 2, 3and 4. Hydraulic fracturing of each well is estimated to take approximately two months to complete.
Initial Flow Testing.	Natural gas and flowback fluid from the hydraulically fractured well will be tested for a period of 90 days) to establish the flow rates of gas and liquid, and confirm the chemical composition of both. The initial flow test will involve burning the gas in two flares located within the boundary of the Site. Natural gas produced during the initial flow test will be flared in accordance with the DECC consent to flare gas. Flowback fluid, separated in a closed separation system from the natural gas, will be transported off site to an Environment Agency permitted treatment centre for treatment and disposal. It is likely that flow testing and hydraulic fracturing activities will run in parallel providing sufficient gas flows from the well.
Constructing connection to the gas grid for Extended Flow Testing.	If the quantity and flow rate of natural gas from the initial flow test is sufficient, equipment required to connect the wells to the national gas grid will be constructed and installed. A gas pipeline will be constructed from the well to existing gas grid pipelines.
Extended Flow Testing (EFT).	Extended Flow Test could last between 18-24 months per well. Natural gas produced during this stage will not be flared. Instead, it would be treated and piped into the gas grid. During this period well servicing activities may occur as required to undertake maintenance activities on the wells.
Drill Horizontal Wells 2, 3 and 4. Hydraulically	The next well (2) will be drilled vertically from the surface of the well pad to a level within the shale, from where drilling would be continued horizontally. This second well will take approximately three months to

Activity	Description
fracture and flow test.	complete. This will be repeated for Horizontal Wells 3 and 4 as per the sequence described in section 4.3.2, Figure 4.2, Appendix A and Appendix B. Each of these horizontal wells will then be hydraulically fractured and flow tested (as described above for Horizontal Well 1). Likewise, if the flow of gas is sufficient the well may be subject to further Extended Flow Testing (as describe above for Horizontal Well 1), with natural gas produced being fed into the gas grid.
Decommissioning and Site restoration.	Following completion of the exploratory drilling, hydraulic fracturing and flow testing work, the Site would either be restored to its original condition (restoration) and the wells plugged and abandoned, or an application to undertake shale gas production activities prepared and submitted LCC. If the wells are no longer required they would be plugged, abandoned and monitored in accordance with the legislation applicable at the point in time.

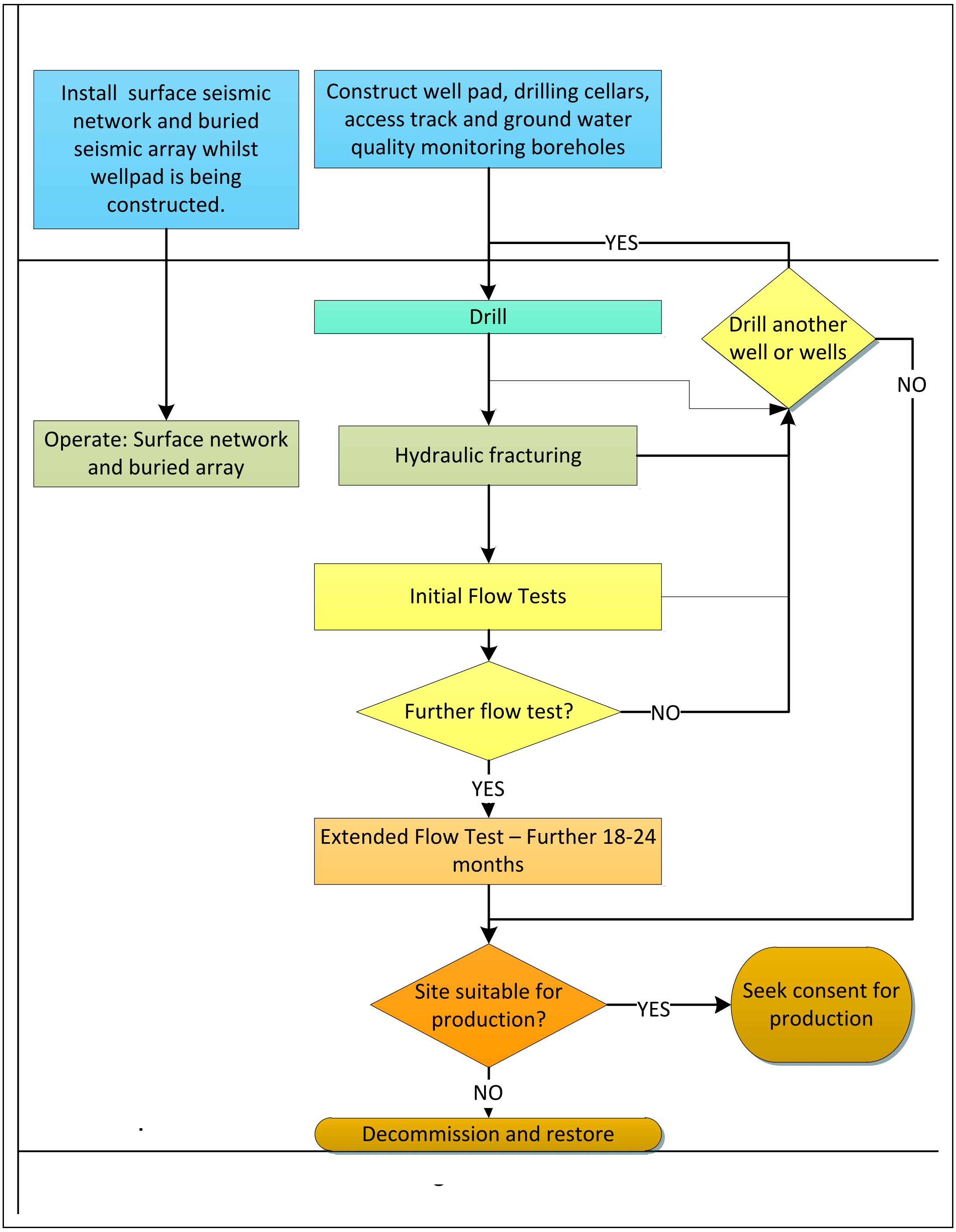

Figure 4.1: Overview of the exploration works related to the Project.

4.3.2 Sequencing

11. The sequence of activities described above, and set out in Table 4.1could occur in a variety of different orders once the well pad and access track have been constructed. For the purpose of the EIA it has been assumed that the following operational sequence will be applied:

- The drilling rig and equipment will be mobilised and used to drill the vertical and horizontal elements of Well 1. The drilling rig and equipment would be demobilised from site and replaced by hydraulic fracturing and flow testing equipment;
- Well 1 (either the horizontal or vertical section) would then be hydraulically fractured within the shale formation and initial flow testing would commence;
- Once hydraulic fracturing of Horizontal Well 1 is completed the hydraulic fracturing equipment would be demobilised and the drilling rig remobilised so that Well 2 could then be drilled. However Horizontal Well 1 would continue to be flow tested whilst Horizontal Well 2 is drilled and fractured;
- Following completion of drilling Well 2, the drilling rig and equipment would be demobilised from site and replaced by hydraulic fracturing and flow testing equipment;
- Horizontal Well 2 would then be hydraulically fractured and initial flow testing would commence;
- Horizontal Well 3 would be drilled, fractured and flow tested as described for Well 2 above; and
- Horizontal Well 4 would be drilled, fractured and flow tested as described for Well 2 above.

12. Until initial flow testing has been undertaken on the first well it will not be possible to determine when Extended Flow Testing (18-24 months per well) might begin. This is because Cuadrilla will require data on the quantity, quality and flow rate of gas to determine the details of the connection to the National Grid mains. The timing of connection into the gas grid would be subject to National Grid's processes and procedures.

13. The installation of the surface and buried arrays will be completed before any of the wells at the Site are hydraulically fractured. This is because data from the surface array is required for the Traffic Light System to establish a seismic baseline (part of the procedure to mitigate the risk of hydraulic fracturing inducing a felt seismic event). This baseline data will be collected for at least four weeks before hydraulic fracturing commences.

14. The groundwater monitoring wells will be installed and other environmental monitoring programmes commenced at the beginning of the works to establish baseline data.

15. For the purposes of the EIA the sequence illustrated in Figure 4.2 has been assessed by plotting a sequence of Site activities that would result in the maximum number of vehicle movements (see Appendix A for a more detailed Programme). The maximum duration of the various project activities are also illustrated in Figure 4.2 and Appendix B.

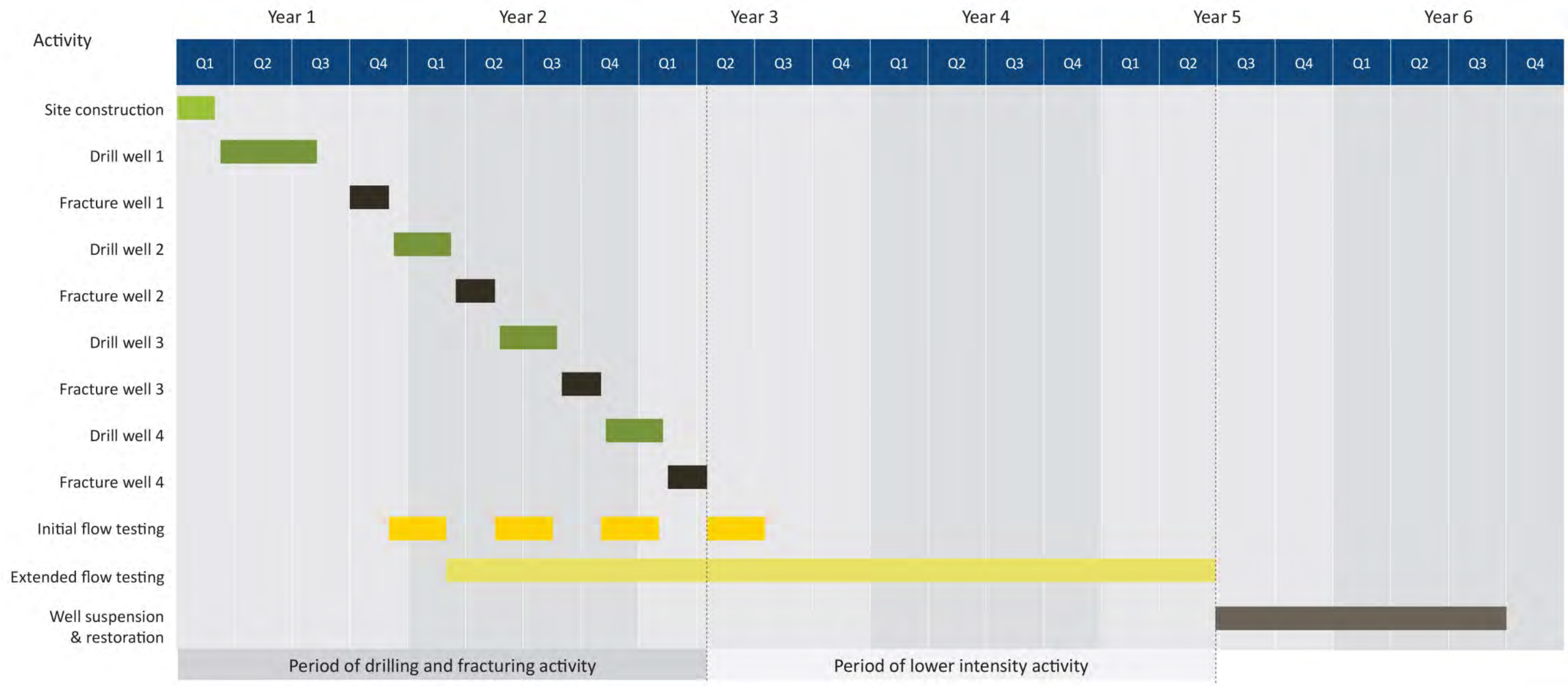

Figure 4.2: Indicative Project activity sequences.

4.3.3 Surface works and below ground works

17. The exploration activities can be split into surface works and below ground works. The surface works include construction, operation and restoration of the well pad, access track any infrastructure required to connect the Site to the gas grid during EFT and the route through DHFCS Inskip. The likely maximum extent of the surface works is illustrated in Figure 4.3.

18. The below ground works include the vertical and horizontal wells plus the extent of new fractures in the rock. At this point in time the proposed alignment of the horizontal sections of the wells is not known as this is dependent on results from geological data from vertical Well 1. Figure 4.4 shows the area in which the horizontal wells will be located and encompasses the fractures that will be created.

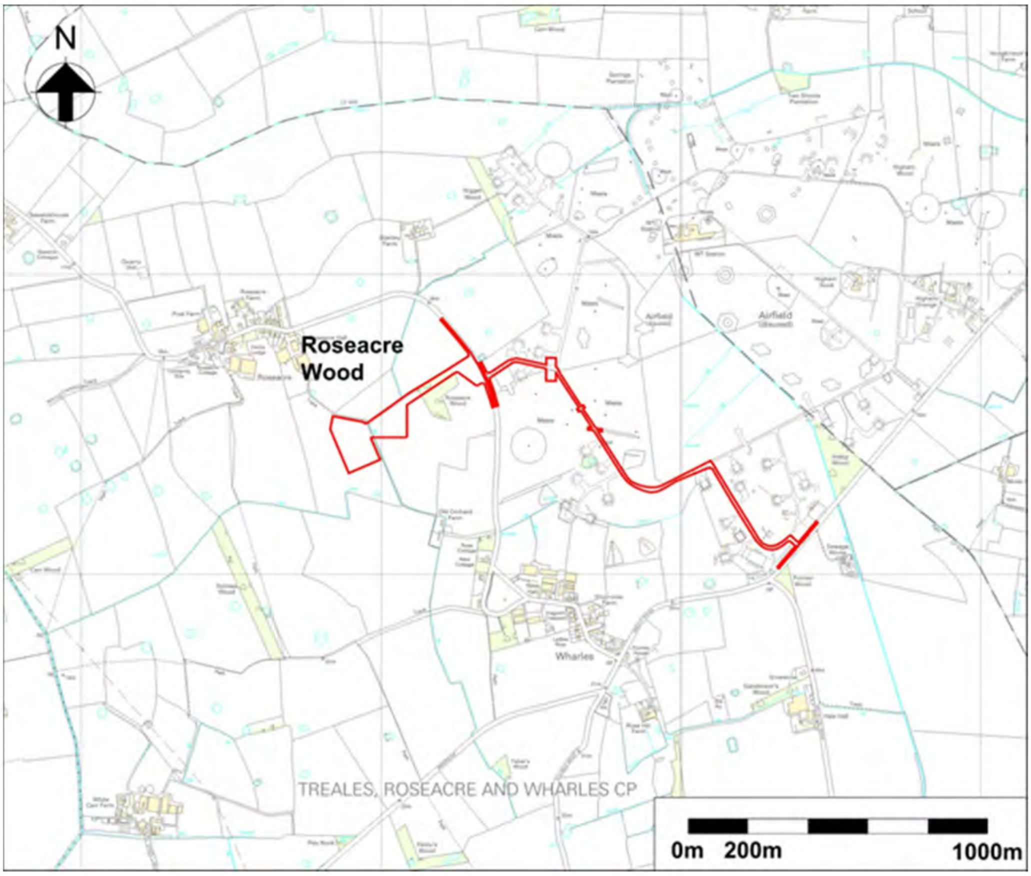

Figure 4.3: Extent of the surface works (the Site) associated with the Project (well pad, access track and areas of works for connection to the National Grid gas grid).

(Contains Ordnance Survey data © Crown copyright and database right 2013) (Not to scale).

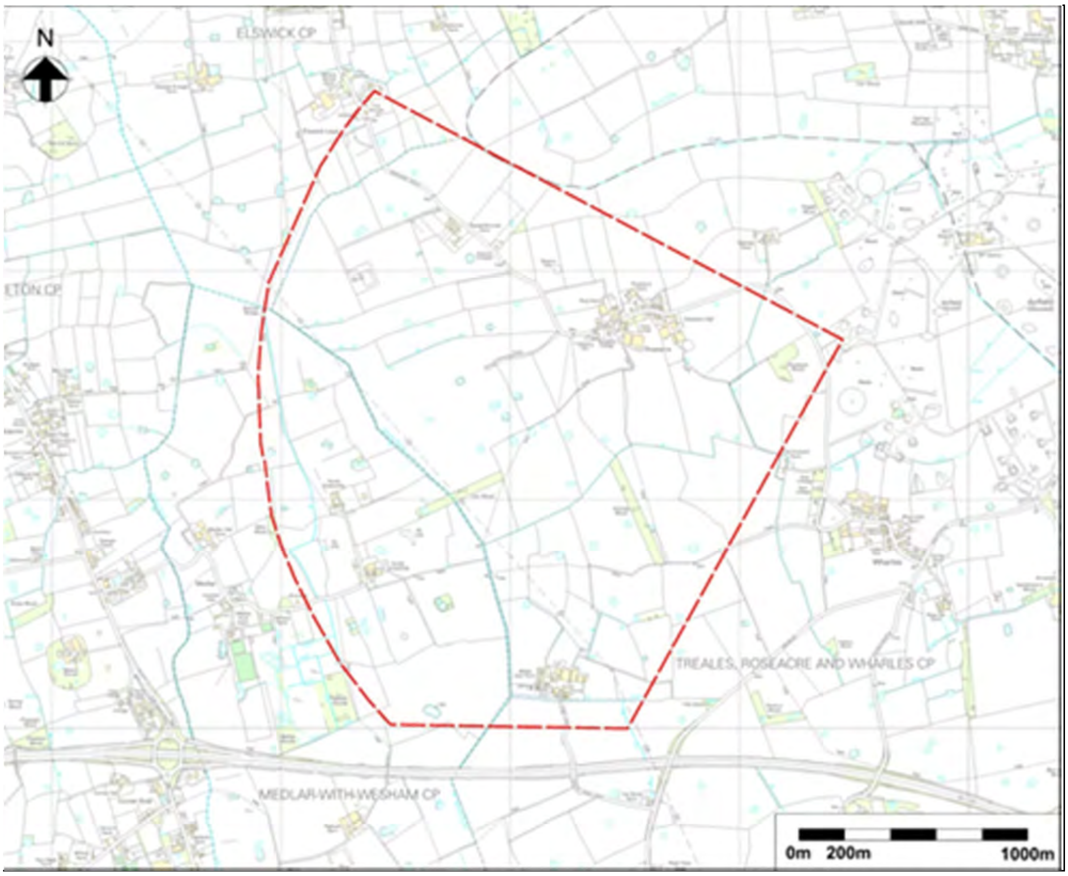

Figure 4.4: Maximum extent of the below ground works.

(Contains Ordnance Survey data © Crown copyright and database right 2014) (Not to scale).

4.4 Installation of the surface and buried seismic monitoring arrays

21. As noted in section 4.1, two seismic monitoring arrays will be implemented as part of the Project. The seismic events induced by hydraulic fracturing do not typically exceed magnitude 0 M_L and very rarely exceed 0.5 M_L. Data from the surface array will be used to mitigated the level of induced seismicity from hydraulic fracturing operations so that they are below 1.5M_L (this a level of magnitude that will not damage buildings or infrastructure and are unlikely to be felt by people)[30]. The buried array will provide data on the location, extent and direction of the fractures that occur within the shale rock during hydraulic fracturing. This will allow the hydraulic fracturing process to be refined throughout the hydraulic fracturing activities.

4.4.1 Surface Array

22. The surface array is a network of shallow buried seismic monitoring stations that will monitor the hydraulic fracturing process in real-time. It will detect vibrations and movement that might occur at the surface due to the creation of fractures at depth, in the

[30] The Royal Society and the Royal Academy of Engineering. (2012)
Shale gas extraction in the UK: a review of hydraulic fracturing.
http://royalsociety.org/policy/projects/shale-gasextraction

shale rock. The surface array will comprise eight shallow pits (to a depth of approximately 0.8m below ground level) within which sensitive seismometers will be located (illustrations of what these look like can be seen in Figure 4.5 and Figure 4.6). The installation of each surface array station will also include small junction boxes to house batteries, data logging equipment, modem and GPS units. This equipment will be located in a small kiosk (approximately 1.1m high and located between 1 to 3m from the seismometer).

23. DECC has developed a Traffic Light System (TLS) that monitors against values measured using the earthquake magnitude scale (M_L). In the event of surface vibrations caused by the below ground fracturing operations exceeding threshold values[31] whilst pumping fracturing fluid into the well hydraulic fracturing injection pressures will be monitored and flowback rates adjusted (amber status) or fracturing will be suspended (red status) pending analysis of data.

24. It will take between 1-2 days to install each array point. Once installed the array will record background seismic data to provide baseline seismic data. The TLS system will be operated during hydraulic fracturing operations and will require personnel to visit each site to change the batteries used to power the seismometer, data recording and communications equipment that feed data back to operators at the well pad in real time.

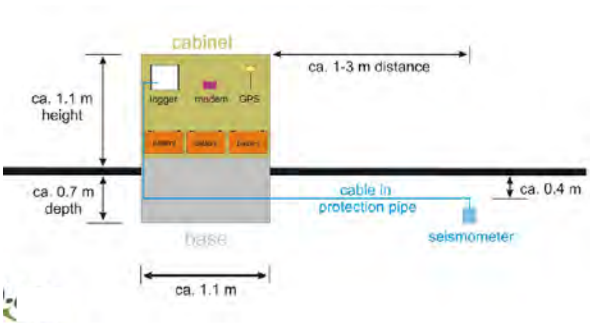

Figure 4.5: Schematic of Traffic light monitoring equipment

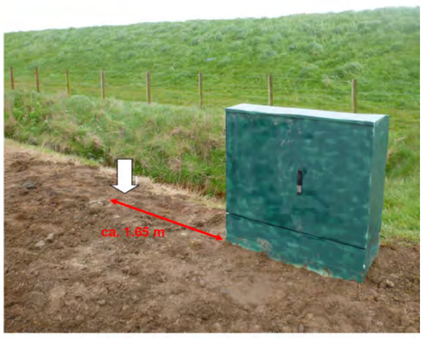

Figure 4.6: Indicative illustration of Traffic light monitoring equipment

4.4.2 Buried Array

25. In addition to the surface array described above, the buried array will comprise deep buried seismic monitoring stations (at a depth of approximately 100m below ground level) that will be installed to measure the extent and rate of fracture propagation within the shale rock. The array stations will be drilled by a truck mounted drilling rig, such as that used to drill water wells. These stations will provide data on the direction and extent of the small fractures that are opened up in the underground shale. This array will comprise 80 boreholes containing seismometers.

26. The surface treatment of the buried array stations will comprise a concrete pad or collar with an inspection cover mounted flush with the ground surface (see Figure 4.7 for reference). They will be located at sites away from buildings, roads and other potential sources of interference. They will also be enclosed by fencing to prevent damage by

[31] Up to value of $0.0M_L$ operations can proceed as planned; $0.0\text{-}<0.5M_L$ operations can proceed but with caution, possibly with reduced volumes of water, at different locations or with longer monitoring and analysis periods; if vibrations exceed $0.5M_L$ hydraulic fracturing will be suspended and pressures immediately reduced.

livestock or farm machinery. The surface and buried arrays will be installed at locations shown in Figure 4.8.

Figure 4.7. Typical surface treatment for the buried array points.

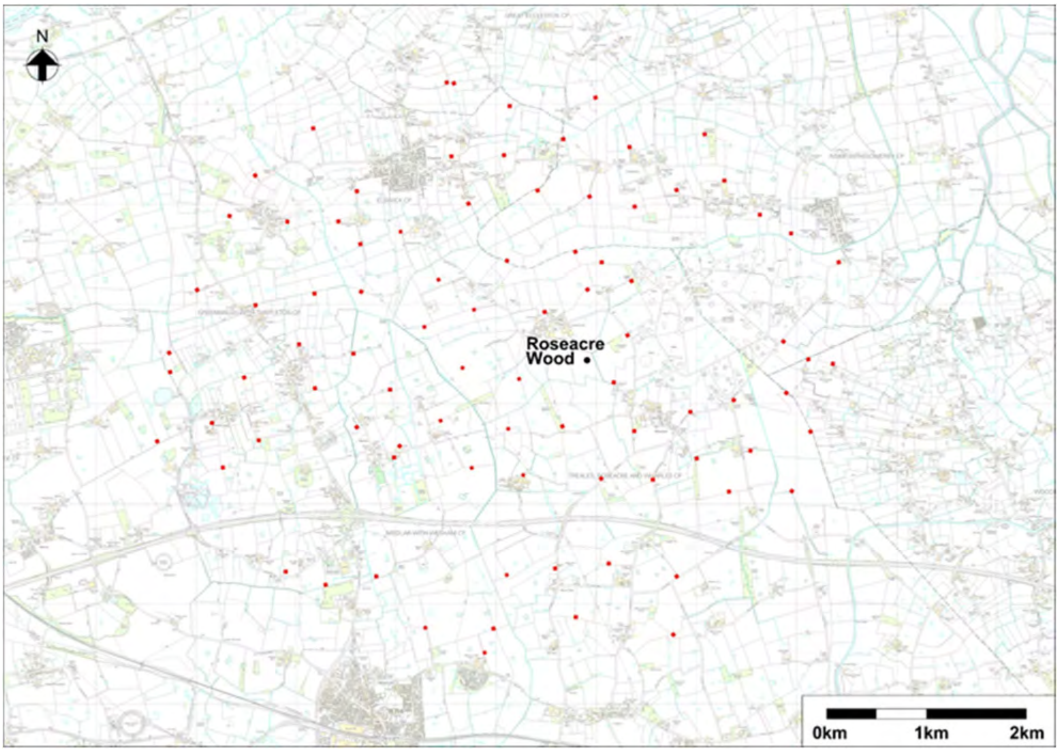

Figure 4.8. Location of the surface and buried seismometer arrays. (Not to scale).

4.4.3 Operation of the surface and buried array

30. During hydraulic fracturing operations, data will have to be downloaded from the buried array points after each time a well undergoes hydraulic fracturing. This will be done remotely via the mobile phone network. As a result operatives will only need to visit the array sites approximately once a week to change the batteries used to power the seismometers. When hydraulic fracturing operations are not occurring the array points will require less frequent visits.

4.5 Construction of the well pad and access track

4.5.1 Equipment

31. To construct the well pad general earth working equipment will be used. In addition to this the following equipment will be present:

- Truck mounted drilling rig to drill the shallow section of the conductor casing;
- Well drilling rig (for groundwater monitoring wells); and
- Site welfare facilities for construction staff.

4.5.2 Groundwater monitoring wells

32. Groundwater monitoring wells will be constructed within the Site fence line but outside of the impermeable liner and drainage ditches. The boreholes will allow groundwater quality and ground gas data to be collected prior to, during, and post-exploration.

33. The three pairs of monitoring wells would be installed around the well pad to a maximum depth of approximately 30m, using a small drilling rig, typically used for site investigation or water well drilling purposes. The first borehole would be drilled to prove the top of the Mercia Mudstone and to understand the superficial geological sequence. The monitoring installations will comprise, in each borehole, one standpipe in the deeper granular glacial deposits and a second in the shallower superficial deposits.

34. The detailed monitoring scope and reporting procedures would be agreed with the regulators in advance. It would comprise a period of baseline monitoring prior to drilling the shale gas exploratory wells, as well as monitoring throughout drilling, fracturing and flow testing and for an agreed period following abandonment. Continuous monitoring devices that record groundwater quality and gas concentrations in the monitoring wells regularly (e.g. hourly) are likely to be deployed, with periodic sampling and laboratory analysis. Monitoring would be undertaken by a specialist contractor for Cuadrilla.

4.5.3 Site preparation

35. Vegetation and topsoil will be stripped from the entire area of the well pad and access track, and will be stockpiled in contoured bunds surrounding the Site. The soil stockpile will be graded, roughly cultivated and seeded to prevent erosion and sediment-laden run-off. It will be maintained in a tidy and weed-free condition throughout the operational life of the well pad and Defra soil management guidelines will be implemented to ensure maintenance of soil quality.

36. Reprofiling of the sub-soil will be undertaken to create a level platform for the well pad and a sloped embankment for the access to the highway.

4.5.4 Well pad construction

4.5.4.1 Security

37. The Site and access road will be secured by a 4m high welded mesh security fence. Additional fencing will be installed within the well pad area to help demarcate areas. Security lighting will be installed, and access to the Site will be controlled via a gated entrance onto Roseacre Road. A small cabin will be provided on the well pad for security

personnel who will actively patrol the Site. CCTV will also be installed at strategic points of the Site.

4.5.4.2 Well pad construction

38. The well pad will be constructed with a minimum depth of 300mm clean, compacted aggregate laid on an impermeable membrane and geotextile layer with protective felt inter-layers, or similar impervious profile.

39. Four drilling cellars will be constructed at between 5 and 25m spacings (see Drawing RW_EW_100 in Appendix A). These will comprise voids of about 3 metres in width and depth, with concrete walls and floor. Each exploration well will be drilled from the base of an individual drilling cellar.

40. Surface water run-off drainage and attenuation will be provided by a perimeter ditch system, a pollution interceptor and an isolation valve so that the well pad can be isolated from the adjacent surface water ditches (see Figure 4.9 to Figure 4.11).

41. Figure 4.9 shows the layout of the prepared site before any operation activity commences and Figure 4.10-Figure 4.11 relate to sections showing boundary treatment.

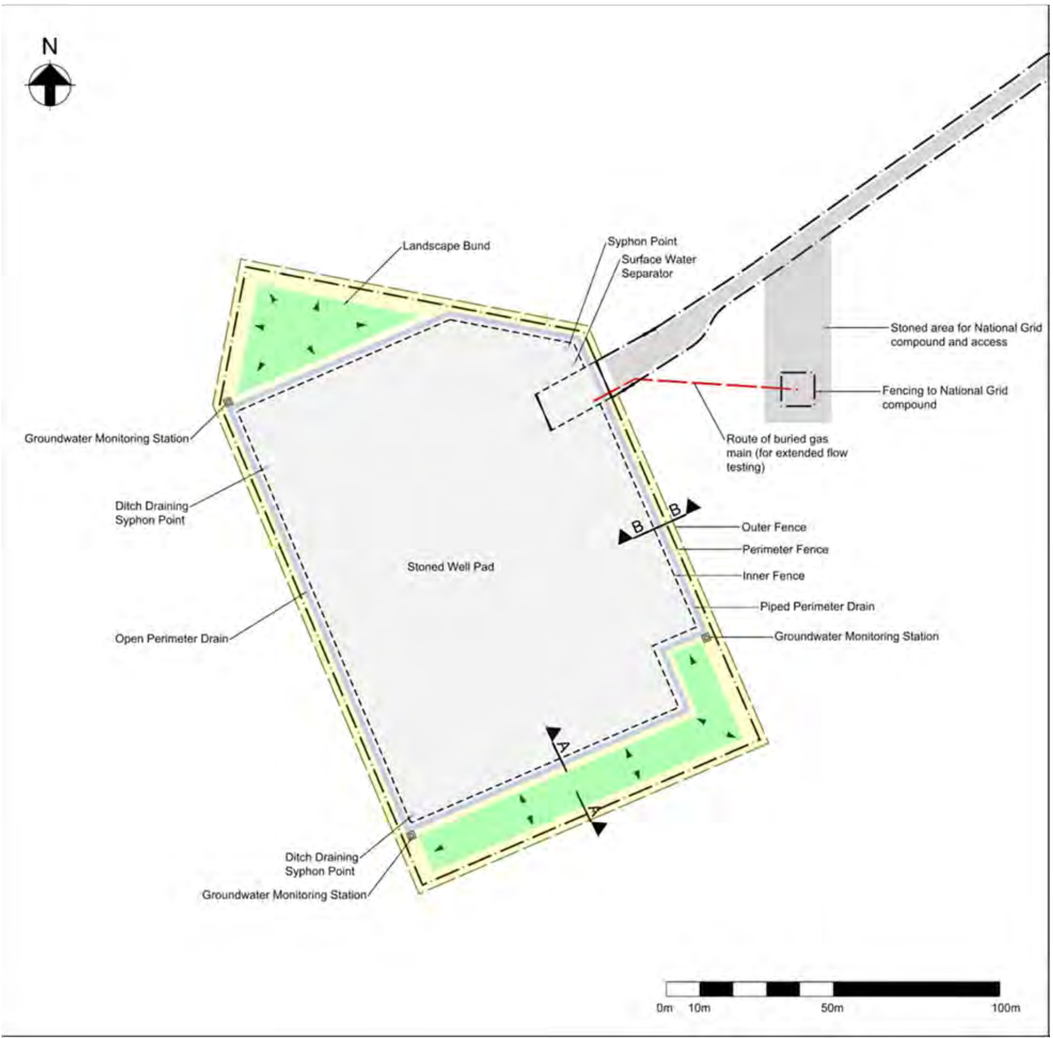

Figure 4.9: Well pad design

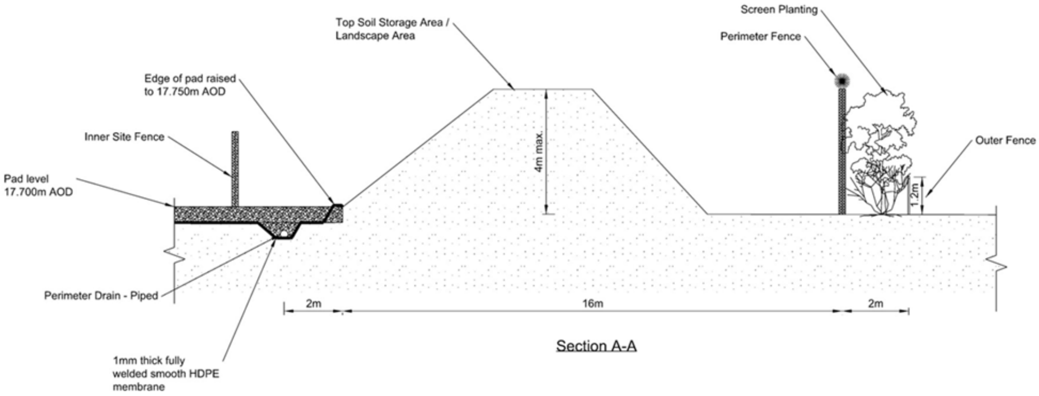

Figure 4.10: Well pad design (cross section A-A)

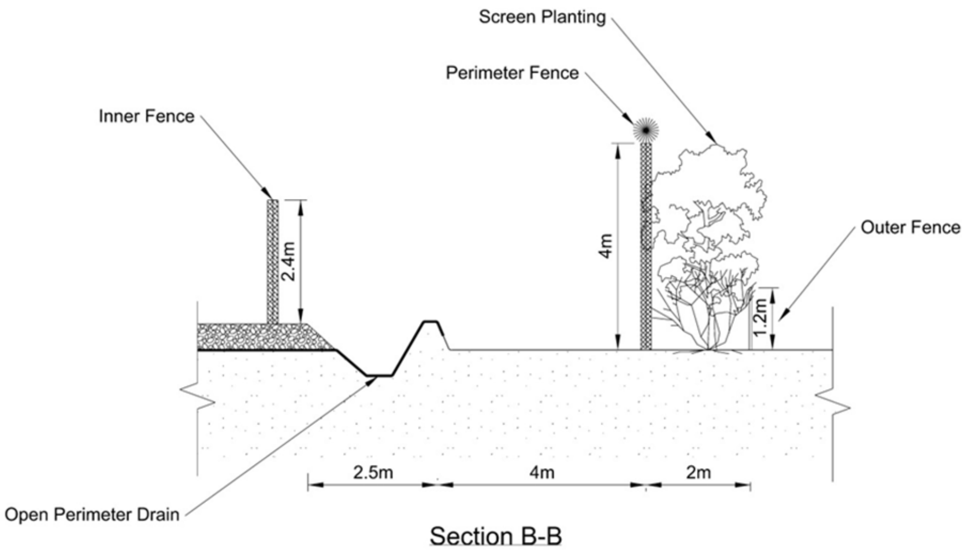

Figure 4.11: Well pad design (cross section B-B) Update with latest design.

4.5.5 Utility connections

45. Mains water required by the Project will be drawn via a 150mm diameter pipe from a United Utilities mains located in Roseacre Road. All foul sewage will be collected and contained on the Site, in pre-fabricated toilet and mess room facilities. Foul sewage will be removed from the Site by tanker by registered waste contractors. Electricity requirements will be provided by on-site diesel-powered generators. Small power (mains electricity) and telecommunication connections may also be provided to the offices and welfare facilities at the Site.

4.6 Access

46. The main transport impacts arising due to the proposed development are associated with the size of vehicles that require access to the site. Having assessed a number of alternatives, the preferred route for Heavy Goods Vehicles (HGVs) follows the existing public road network from Junction 4 of the M55 passing along the A585 (Kirkham Bypass), Salwick Road, Dagger Road, Inskip Road and Roseacre Road. This is termed the "Wharles Route".

47. As a partial variant on this route, and subject to agreement being reached with the landowner, permission is also being sought for access to the site following the same route up to Inskip Road and then passing through the Ministry of Defence's (MoD) Defence High Frequency Communications Site (DHFCS) Inskip facility. This is termed the "DHFCS Inskip" route. This would have the benefit of allowing HGV traffic to bypass Wharles. Both routes are illustrated in Figure 4.12.

48. Subject to restrictions imposed by the landowner and/or site operator the DHFCS Inskip Route would be used for HGV traffic for the majority of the construction period and for the drilling, hydraulic fracturing and initial flow testing stages of the development.

49. To implement these routes, works are required to formalise passing places and to improve/create junctions as described below (see also the Transport Assessment in Appendix R1).

4.6.1 Passing places

50. Some localised highway improvements will also be required to create passing places along sections of the proposed route. The detailed proposals are set out in Appendix R1 but in summary comprise five passing places along Dagger Road with a further four passing places created along Roseacre Road. In some places, creation of these passing places formalises existing arrangements where rutting of verges has occurred.

4.6.2 Junction Works - Wharles Route

51. For the Wharles Route (without the DHFCS Inskip Route in place) the Site would be entered via the existing junction off Roseacre Road onto a farm track leading through Roseacre Wood. This junction would be widened and improved requiring partial removal and lowering of sections of existing hedgerow. A wide entrance will be created to allow for the passing of two heavy goods vehicles (HGVs) to avoid waiting and blocking of the main highway. A new track will be constructed to the Site which will be surfaced appropriately to withstand HGV traffic.

4.6.3 Junction Works – DHFCS Inskip Route

52. Should the use of the DHFCS Inskip route be agreed,, the existing junction between the farm track and Roseacre Road would not be improved. Instead, existing accesses from Inskip Road and Roseacre Road to the DHFCS site would be widened and improved and a new junction would be made from Roseacre Road through to the farm track to allow vehicles to cross Roseacre Road in one “straight ahead” movement. This junction would also require partial removal and lowering of sections of existing hedgerow. A wide entrance will be created to allow for the passing of two heavy goods vehicles (HGVs) to avoid waiting and blocking of the main highway. A new track will be constructed to the site which will be surfaced appropriately to withstand HGV traffic.

53. In addition, highway works (as described in further detail in the Transport Assessment) would also be undertaken under separate agreement with the Local Highway Authority to improve the existing gated access to DHFCS Inskip from Inskip Road and to widen and improve the existing gated access to DHFCS Inskip from Roseacre Road.

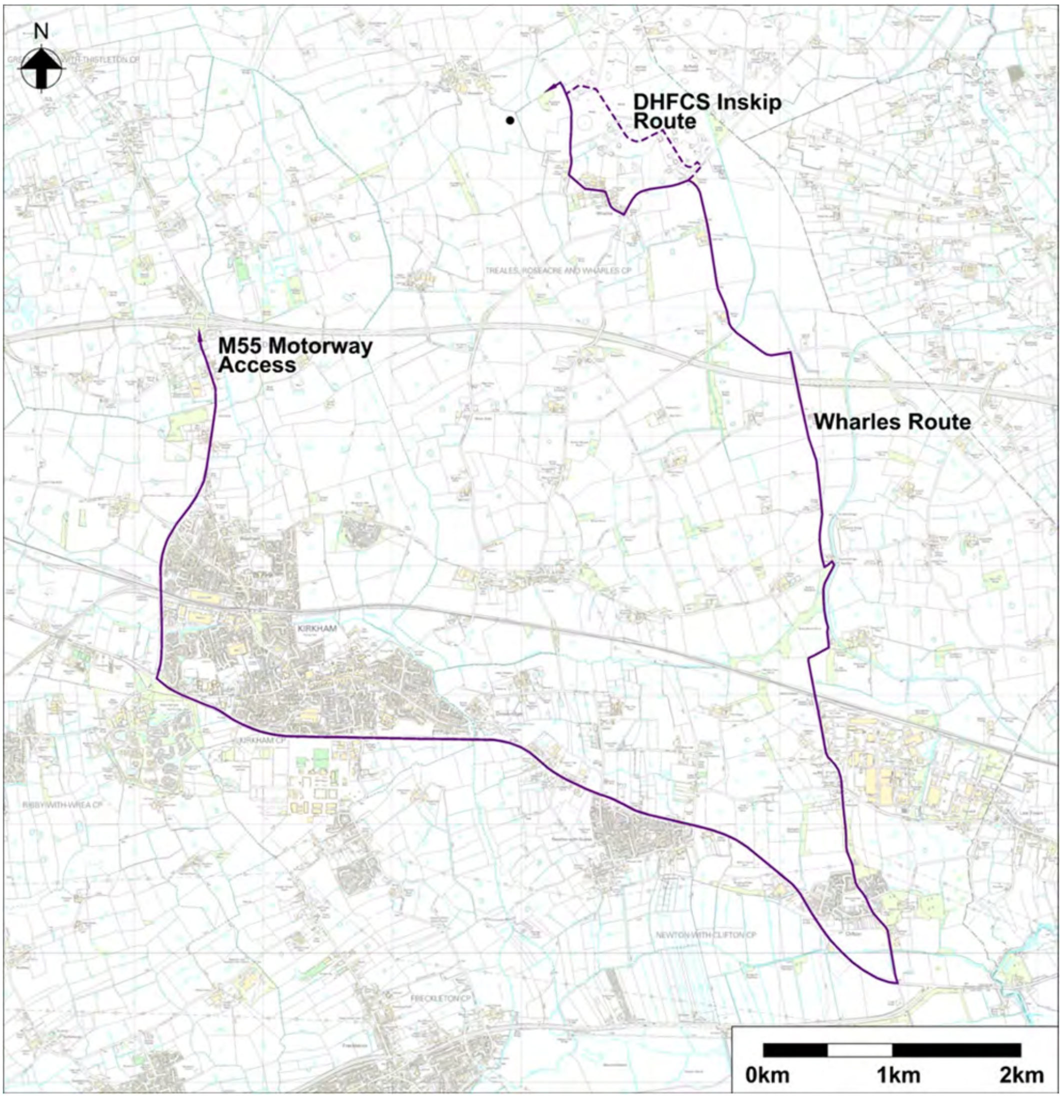

Figure 4.12. Proposed routes from the Site to the M55.

4.6.4 Works within the DHFCS Inskip Facility

54. The route through the DHFCS Inskip facility follows and existing estate road. In order to use this route for HGV traffic the following works are described (see drawing RW-EW-101) for further details. These comprise:

- Raising of overhead cables;
- Improvement of the existing roadway in places;
- Construction of timber stock fencing; and
- Installation of gates and fencing.

55. The potential effects of allowing traffic to use the DHFCS Inskip route have been considered in Table 4.2. Table 4.2 highlights the chapters of this ES where the potential significant effects of the DHFCS Inskip route have been assessed.

Table 4.2. Topics scoped in/out from the assessment of effects associated with the use of the DHFCS Inskip Route.

Topic	Justification
Air Quality	The route does not increase vehicle numbers or affect emissions to air are not altered. Junction works on Roseacre Road and Inskip Road will not result in additional or greater magnitude dust impacts. The measures used to control fugitive dust emissions set out in Chapter 6 will also be applied for these works. Therefore, no further assessment is required.
Cultural Heritage and Archaeology.	The route does not affect any designated heritage features. Likewise the works to raise cables and construct the two junctions do not occur within any areas of known archaeological finds as identified in the Historic Environment Record. Therefore, no further assessment is required.
Greenhouse Gas Emissions.	The route is of similar length to the Wharles Route and therefore the impact on greenhouse gas emissions from vehicles is negligible. The area of works to construct and improve the junctions with Roseacre Road and Inskip Road are minimal and therefore it is concluded that the impact on greenhouse gas emission associated with the use of materials is also negligible. Therefore, no further assessment is required.
Community and Socio-Economics	The use of the DHFCS Inskip Route will not impact on any of the community or socio-economic factors assessed in the ES as it will not generate additional employment. Likewise, it would not alter the demands on existing community or social infrastructure. Therefore, no further assessment is required.
Ecology.	The use of the DHFCS Inskip Route would require the removal of vegetation (e.g. hedgerow) to improve access. As a consequence the effects of implementing this route area assessed further within Chapter 10 of this ES. Therefore further assessment is required.
Hydrogeology and ground gas	The use of the DHFCS Inskip Route would not create any additional potential pollutant pathways (to those assessed in Chapter 11. Therefore, no further assessment is required.
Induced Seismicity	The use of the DHFCS Inskip Route would not involve any activities that could induce a seismic event such as those associated with hydraulic fracturing. Therefore, no further assessment is required.
Land Use	Other than the small areas of land that would be required to improve access through DHFCS Inskip no other works would be required. The day to day operation of the facility and the grazing of cattle in the fields adjacent to the estate road through DHFCS would also not be affected. Therefore, no further assessment is required.
Landscape and visual amenity	Although some sections of hedgerow will have to be removed and others lowered to allow access and improve visibility for HGVs turning out of the DHFCS Inskip facility the magnitude of the impact will be very localised and will not open up views of the Site to a greater number of visual receptors. Therefore, no further assessment is required.
Lighting	It is not anticipated that any additional lighting would be required for the DHFCS Inskip Route. Therefore, no further assessment is required.
Noise	The DHFCS Inskip Route would not direct HGVs past a greater number of residential properties or create additional sources of noise. Therefore, no further assessment is required.
Resources and Waste	The construction and use of the DHFCS Inskip Route would not generate additional waste streams or greater quantities of waste beyond those already assessed in the ES. Therefore, no further assessment is required.

Topic	Justification
Transport	The DHFCS Inskip Route does not generate additional vehicle movements However the effects on transport receptors within Wharles have been assessed (Chapter 18).
Water Resources	The junction works required for the DHFCS Inskip Route will only use negligible quantities of water. Once in use there will be not be any requirement for water use. The route also lies within an area at very low risk from river flooding (this area has a chance of flooding of less than 1 in 1,000 (0.1%)). Therefore, no further assessment is required.

4.7 Drilling

4.7.1 Equipment

56. The equipment required to undertake drilling will be brought to the Site by HGVs, and will include:

- Plant and equipment specific to the drilling unit used, including a mast with an erected height of between 30m and 53m[32];
- 40ft 'shipping containers' for storage of equipment, workshops, and modules for office, welfare and onsite accommodation (single storey height; shipping containers not stacked double height);
- Cranes to assemble the drilling rig and other equipment;
- Drilling mud logging equipment;
- Well cementing equipment;
- Wireline logging equipment;
- Drilling materials and fluids; and
- Casings and tubulars.

57. The equipment mobilisation period for the drilling stage will typically last for two weeks. The approach to assessing traffic impacts from the equipment mobilisation is discussed in Chapter 18. An illustration of the types of drilling rig that may be used during exploration works is provided in Figure 4.13. The indicative layout for these activities is illustrated in Appendix A - Drilling stage layout (Drawing RW_EW_102) and Figure 4.14 provides an illustration of the equipment likely to be used during drilling.

Figure 4.13: Illustrations of potential drilling rigs to be used during the Project.

4.7.2 Drilling

58. Up to four exploration wells will be drilled at the Site, as summarised in section 4.3.2. The first well will be drilled vertically through the geological profile to a maximum depth of c. 3,200m. The geological information from this first vertical well will provide data on the characteristics of the shale. From this data, the depths and orientation within the shale at which the horizontal wells will be drilled will be selected.

[32] For the purposes of the EIA the larger drilling rig has been assessed to ensure that the worst case visual effects have been assessed.

59. The lower section of the vertical well (Vertical Well 1) may be plugged with cement to the selected depth for initiating the drilling of the first horizontal (Horizontal Well 1), which would then be drilled to its anticipated lateral extent (see Figure 4.14).

60. Horizontal Wells 2, 3 and 4 will be drilled from the surface to depths determined by geological information derived from Vertical Well 1.

61. Once commenced, drilling works must take place 24-hours per day, 7 days per week. This is in order to maintain the stability of the borehole and to avoid the drill bit and equipment becoming obstructed in the hole.

62. Low intensity security lighting will be used as well as focussed task lighting around the base of the drilling rig to allow works to be undertaken during hours of darkness).

63. Drilling of the well includes the following elements: drilling mud engineering, casing running and cementing, data acquisition via coring and wireline logging, and directional drilling. Licensed, sealed radiological sources are commonly used for measurement purposes in wireline logging and logging while drilling.

64. The likely waste products from this stage of the Project are outlined in Chapter 17.

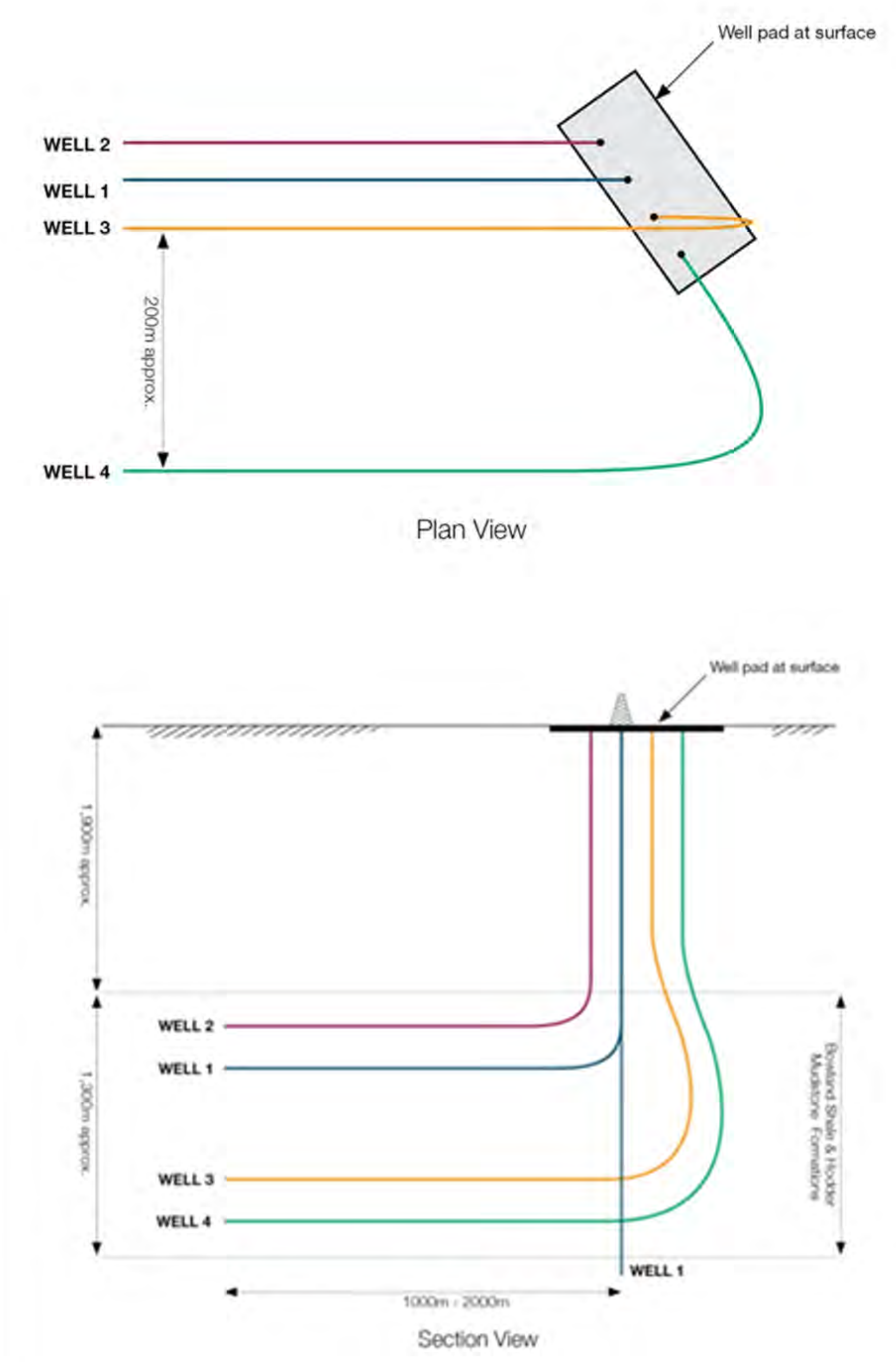

Figure 4.14: Illustrative schematic showing the potential arrangement of vertical and horizontal wells below ground. (Not to scale).

4.7.3 Well design

66. The overall well construction will be designed to provide multiple barriers between the groundwater and deep underlying production zones and will be constructed in accordance with Oil & Gas UK Well Integrity Guidelines, UKOOG UK Onshore Shale Gas Well Guidelines (2013), Borehole Sites and Operations Regulations 1995 (BSOR) and Offshore Installations and Wells (Design and Construction Etc) Regulations 1996 (DCR), The well design and installation will be submitted for review by an independent well-examiner, and notified to the Health and Safety Executive.

67. Three types of well have been designed for the Project (see Chapter 11 and Appendix K for further details). The vertical section of Well 1; the horizontal section of Well 1; and the subsequent three combined vertical and horizontal wells (Horizontal Wells 2, 3 and 4). Although the specific design of these wells may differ, they will all comprise a series of steel casings. The functions of these casings are summarised below; sizes and depths are indicative and are subject to modification according to final geological and operational conditions at and underneath the Site:

- *Shallow conductors* - a series of steel casings ranging from 42 inch (1067mm) to 30 inch (762mm) in diameter. These typically extend down to 60m below ground level depending on shallow soil and geological conditions. These steel casings are driven or fixed in place to provide a stable surface platform from which to drill subsequent sections of the well-bore. The conductor casings are designed to isolate any shallow groundwater, and isolate any shallow unstable sands. Shallow conductors are installed as part of civil site works;
- *Deep conductor*- Nominally 18 5/8 inch (473mm) to 20 inch (508mm) diameter steel casing extending from the surface to a depth of approximately 300m below ground level and terminating within the lower section of the Mercia Mudstone. This conductor may be installed either prior to mobilisation of the main drilling unit, using a smaller specialised conductor setting rig, or by the main drilling unit itself;
- *Surface casing* - Nominally 13 3/8 inch (340mm) diameter steel casing extending from surface to a depth of approximately 1,300m below ground level terminating within the upper section of the Manchester Marl;
- Intermediate casing - Nominally 9 5/8 inch (245mm) diameter steel casing extending from surface to a depth of approximately 2,000m below ground level, targeting the Upper Bowland Shale;
- *Drilling liner and tie back* - Nominally 7 inch (178mm) diameter steel casing extending from inside the 9 5/8 inch (245mm) casing to a depth ranging from 2,300m to 3,200m below ground level and depending on the departure depth from the vertical well. The 7 inch liner will be tied back to surface with 7 inch production casing; and
- *Production Liner* - Nominally 4 ½ inch (114mm) diameter steel casing extending from inside the 7 inch liner to the final depth of the well, which will be determined once data from Vertical Well 1 has been analysed.

68. Casings and liners will generally be cemented in place to seal off the various subsurface formations through which they extend. However for the 7 inch tie back and intermediate casing, the upper portion of the annulus will be left uncemented to allow for pressure monitoring. It should however be noted that uncemented sections will only be present in sections of the well where there will always be at least one further layer of casing between well and adjacent rock. Each string (section of casing) will be pressure tested and subjected to quality assurance procedures to ensure its integrity. The depths, diameters and specifications of each casing will be dependent on the depth at which the

different geological formations are encountered. For this reason all of the values described above are indicative.

69. A high-pressure wellhead will be installed onto the surface casing. A blow out preventer (BOP) will be installed onto the wellhead to provide secondary well control when drilling the remainder of each well. A BOP is not required for drilling to shallower depths because ground gas has not been encountered whilst drilling in these geological formations in other wells in the Fylde.

4.7.4 Drilling operations

70. When drilling wells, drilling fluids or "muds" are used to:

- Facilitate the removal of drill cuttings (i.e. the fragments of rock created by the drill);
- Manage the hydrostatic pressure within the well as it is deepened for primary control of subsurface pressures to prevent the release of fluids or gas during drilling;
- Stabilise the borehole and the drilled cuttings;
- Lubricate the drill string when drilling the vertical and horizontal wells;
- Cool the drill bit; and
- Allow use of bridging agents in the drilling fluid to minimise any loss of drill cuttings or fluids to permeable formations, where these exist.

71. Two types of drilling mud are proposed, water based muds (primarily polymer drilling) or low toxicity oil-based emulsion mud (LTOBM). In all instances water based muds will be used when drilling through the shallow formations and the permeable Sherwood Sandstone formation. Where borehole stability is problematic and/or maximum lubrication is required during directional drilling and to reach the intended target distance, low toxicity oil-based muds (LTOBMs) offer improved performance over water-based fluids. LTOBM would not be used prior to casing and cementing off all potentially sensitive groundwater receptors in order to provide isolation from the base oil used in deeper sections. This means using LTOBM only after the surface casing has been set and cemented to isolate the Sherwood Sandstone. In addition, LTOBM can be reconditioned for use at other locations, thus minimizing waste generation. Further details are provided in Appendix K

72. The EA will review and assess all drilling fluids and components.

73. Further details about well design and drilling operations can be found in Appendix B and Appendix K.

4.8 Hydraulic Fracturing

4.8.1 Equipment

74. The hydraulic fracturing equipment, accommodation and ancillary equipment will be brought onto the Site in a pre-planned sequence, over a period of approximately two weeks. HGVs and other commercial vehicles will deliver the following (indicative description):

- Storage units (steel containers for additive storage);
- Steel water tanks (for freshwater and flowback storage);
- Sand storage/delivery units;
- Two enclosed gas flare stacks (up to 10m high);

- High volume separator ;
- Work-over rig (up to 36m high);
- Up to 6 hydraulic fracture pumps;
- Blender unit;
- Manifold unit;
- Coiled tubing unit;
- Coiled tubing support tower (up to 36m high); and
- Monitoring cabin

75. The indicative layout for these activities is illustrated in Appendix A (Drawing RW_EW_104 Hydraulic fracturing layout) and Figure 4.15 which provides an illustration of the equipment likely to be used during hydraulic fracturing.

Figure 4.15: Example of Hydraulic Fracturing equipment.

4.8.2 Overview of process

77. Hydraulic fracturing (commonly referred to as "frac'ing" or "fracking") is a process which is undertaken to enable the flow of liquids and gases through relatively impermeable underground rocks (i.e. to increase permeability). It is used in situations where, under natural permeability conditions, fluids or gases will not flow freely, for example in shale or in rocks such as granite. It has been frequently carried out offshore and onshore in the UK on oil and gas wells in low-permeability reservoirs to increase well productivity. Hydraulic fracturing is also used, in geothermal energy developments to create fractures for water to flow through crystalline rocks such as granite.

78. The Bowland Shale Formation was originally deposited as a mixture of organic-rich siliciclastic and carbonate mudrocks. These deposits accumulated in a deep marine

environment, in an ocean basin in which the prevailing conditions were periodically oxygen deprived. This resulted in the accumulation of abundant organic material and therefore the deposits are characterized by relatively high total organic content (TOC). During subsequent shallow burial and compaction of the sediment to form shale, organic matter was converted to kerogen (an insoluble organic compound). During deeper burial (increasing temperature) and greater compaction, the kerogen generated liquid hydrocarbons and natural gas (primarily methane). At the present day this gas is adsorbed onto the remaining organic material and is trapped in the microscopic pore spaces in the Bowland Basin target formations. Because the gas-saturated shales are hard, fine grained, and with very low permeability, they need to be hydraulically fractured to produce the natural gas.

79. Pore spaces within the shales are very small (in the range of 5 to 100 nanometres) and have very limited connectivity. This means gas present in kerogen and pore spaces is trapped in the formation and cannot freely flow. In order to release the gas, and allow it to flow towards a well bore, the process of hydraulic fracturing must be undertaken. Hydraulic fracturing is the process of injecting fluids at high pressure to overcome rock strength and pressures acting on the rock at depth in order to develop a network of small fractures in the rock. As the overall goal is to maximize the surface area of the rock accessible by the well, the fracture sizes are designed to be root-like networks of minute fractures. Proppant (generally sand grains) that is part of the hydraulic fracturing fluid holds open the induced and pre-existing fractures so that pore spaces can be connected to the well.

80. The hydraulic fracturing fluid will consist of the following:

- **Water** is the predominant constituent in the fluid. It is intended that the water will be sourced from the mains water supply and by reusing the hydraulic fracturing fluid that returns to the surface between hydraulic fracturing stages as a closed loop system. This has the combined benefit of reducing both the consumption of mains water and the quantity of flowback fluid that has to be removed for treatment and disposal offsite. Clean rainwater collected in the perimeter ditches could also be used to make up the fracturing fluid. This would further reduce mains water consumption and the quantity of waste water transported from the Site;
- **Proppant** (Silica sand) is mixed in with the fracturing fluid at specific stages during a fracturing event to keep the fractures created in the shale wedged open after the hydraulic pressure has been released; and
- **Friction reducer** is added to the water to minimise the pressure losses incurred due to friction between the water and the well casings as the water travels several kilometres from surface through the well to the shale formation. The proposed friction reducer is polyacrylamide which is non-toxic classified as non-hazardous to groundwater by the Environment Agency.

81. There is the potential that the flowback fluid which is re-used for subsequent hydraulic fracturing stages could contain bacteria. If some circumstances these bacteria can restrict the flow of gas. To kill this bacteria UV treatment will be used. This would also be used to treat rainwater if it were also to be used to make up the hydraulic fracturing fluid.

82. As a contingency, dilute hydrochloric acid may be used to facilitate entry of the fracturing fluid from openings in the production casing to the body of shale. Hydrochloric acid would be used to reduce fracturing pressure requirements and improve treatment effectiveness. The hydrochloric acid will be stored at a strength of no greater than 10% in

solution. However, it has not been necessary to use it at other wells drilled in the licence area to date and it is thus included as a contingency.

83. Cuadrilla proposes to use a fracturing fluid with a composition comprising of at least 99.95% water and sand, and less than 0.05% friction reducer, by volume.

4.8.3 Steps in the hydraulic fracturing process.

Consent for Hydraulic Fracturing

84. A Hydraulic Fracturing Programme (HFP) will be submitted to DECC for review and approval after drilling is completed and before any fracturing starts. The HFP will identify how risks associated with hydraulic fracturing operations will be managed. Like all other activities prior to undertaking hydraulic fracturing activities, all other relevant consents will be obtained. DECC require[33] the HFP to include:

- *A map showing faults near the well and along the well path, with a summary assessment of faulting and formation stresses in the area and the risk that the operations could reactivate existing faults;*
- *Information on the local background seismicity and assessment of the risk of induced seismicity;*
- *Summary of the planned operations, including stages, pumping pressures and volumes;*
- *A comparison of proposed activity to any previous operations and relationship to historical seismicity;*
- *Proposed measures to mitigate the risk of inducing an earthquake and monitoring of local seismicity during the operations; and*
- *For shale gas fracs, a description of proposed real-time traffic light scheme for seismicity, and proposed method for fracture height monitoring.*

Well preparation

85. Prior to hydraulic fracturing, a “Frac Tree” will be installed on the wellhead. The purpose of the Frac Tree is to provide a seal and prevent release of gas and liquids at the surface. The valves within the tree have been specified to withstand the maximum hydraulic fracture pressure. Secondary valves in the tree are used as a contingency in the event that the primary valve (master valve) fails.

86. Following installation, the assembly will be tested to the maximum planned operational pressure. Once the test pressure has been set, operational activities cannot exceed the test pressure. The installation and testing is generally performed prior to mobilisation of hydraulic fracturing equipment to the Site.

Perforation of well-bore casing

87. In order to control where fractures are created, the well casing must be perforated at target locations. These perforations will be pre-set into the well casing by installing sleeves (known as “frac sleeves”) during well construction, which can be later mechanically opened.

88. In the event that any of the frac-sleeves fail to open satisfactorily, the casing will be perforated using either an abrasive jetting technique or asmall shaped explosive charge.

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33 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/79173/Extended_well_tests_and_Frac_Plan.docx

If jetting is used, coiled tubing is placed into the well and a jetting fluid is injected through the tubing under pressure. The jetting fluid, similar to the hydraulic fracturing fluid, contains water, sand, and a friction reducer. Following perforation, the jetting fluid can be recovered as very little will have been released into the surrounding formation. During recovery, the sand will settle in the bottom of surface collection tanks and separated from the fluid. The recovered jetting liquid can be reused. However the sand generally cannot be reused as it returns in a damaged form unsuitable for reuse. Explosive charges have the benefit of providing calibration data for the buried array, and as such, may be used on initial perforations.

Mini-fracture testing

89. Before undertaking the main hydraulic fracturing stage, a pilot hydraulic fracturing stage or "mini-fracture" will be performed. This involves pumping small volumes of fracturing fluid (without any proppant) into the well. The purpose of the mini-fracture is both to evaluate the injection pressure required to generate fractures in the rock during the subsequent main hydraulic fracturing stage as well as to calibrate the micro-seismic monitoring network. The fracturing schedule may then be modified subject to the data gathered in the mini fracture. Mini-fracture testing may also be performed at various times during the hydraulic fracturing.

Hydraulic fracturing

90. Hydraulic fracturing will be performed over 30 to 45 stages per well at intervals of 30 to 50m per stage. The exact interval for each stage will depend on a variety of factors including extent of induced fracture networks on preceding stages. The initial stage will be at the end of the horizontal section of the well, furthest from the well pad, with successive stages working backwards along the well length towards the vertical section of the well. In order to induce fractures, pressure will be applied to the target interval. The applied pressure during each stage will be within the maximum operational pressure of the equipment. Within each stage several steps will be performed where the type and quantity of the sand proppant will be adjusted to optimize the fracturing process. Each stage is anticipated to last up to three hours. The entire hydraulic fracturing programme, per well, is anticipated to be less than two months per well.

91. Initial fracturing events will be conservative with respect to fluid and proppant volumes in order to analyse fracture development and potential seismicity.

Flowback fluid

92. Once a hydraulic fracturing stage is complete, the pressure at surface may be reduced, and a portion of the water which was injected into the well, allowed to return to the surface. This water is termed “flowback fluid” and will comprise a mixture of the injected hydraulic fracture fluids, sand, waters naturally occurring within the shale, dissolved minerals and released hydrocarbons. Naturally occurring radioactive materials (NORM) are anticipated to be present in flowback fluid. This is because soluble NORM is naturally present in shale. In addition, if LTOBM is used during drilling, the flowback fluid may also contain small amounts of LTOBM constituents. Sampling and analysis will be performed on flowback fluid in order to ensure appropriate waste classification and adequate handling and disposal. It is anticipated that the flowback fluid will be classified as radioactive waste with non-hazardous composition.

93. On reaching the surface flowback fluid will be passed through a four phase separator that allows solids, water, condensate and gases to be separated for optimal waste recovery and management. This process will separate-out residual sand (by allowing it to settle out at

the bottom of the collection tanks), a portion of the NORM (in solid form) and flowback fluid. These materials will be stored temporarily on site in enclosed tanks and then will be subsequently removed to an appropriate waste treatment facility permitted by the Environment Agency (including being licensed to receive NORM). The flowback fluid will then be reused, along with mains water, to create more hydraulic fracturing fluid for the next hydraulic fracturing stage

94. Produced natural gas will be separated, measured and sent to two enclosed flare stacks where it will be combusted to form carbon dioxide and water vapour. More detailed information on flare stack emissions are contained in Chapter 6 of this ES.

Management of Hydraulic fracturing operations

95. After hydraulic fracturing operations have been authorised by the relevant regulatory authorities, hydraulic fracturing will commence. It will generally comprise the stages illustrated in Figure 4.16.

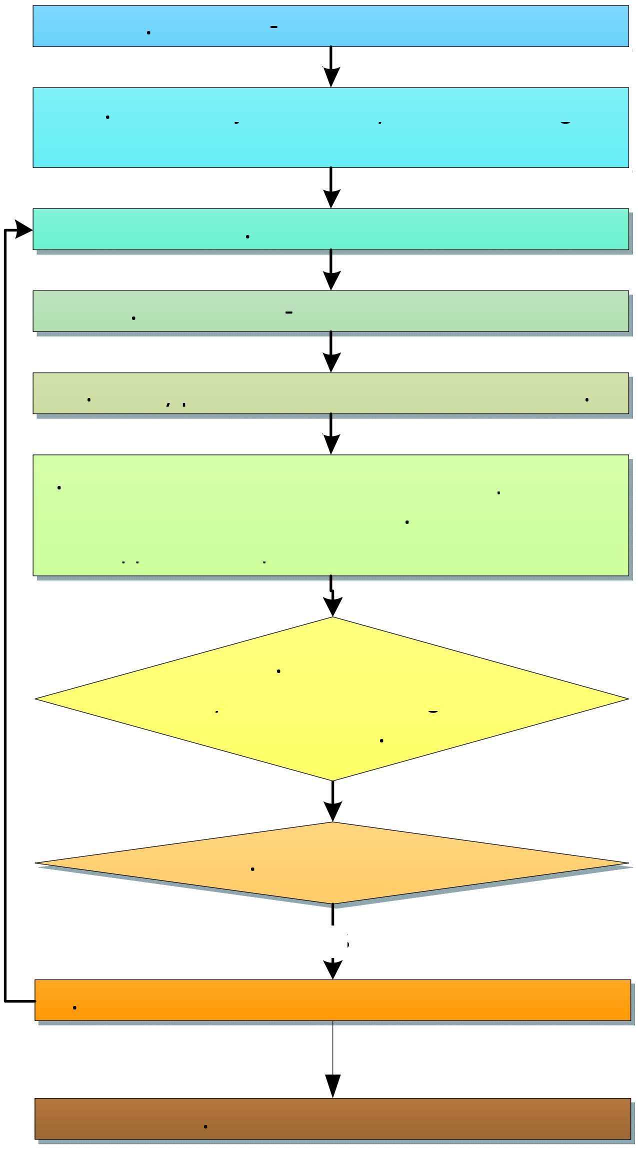

Figure 4.16: Hydraulic fracturing process.

96. Once all hydraulic fracturing activities are completed on a single or multiple wells, fracturing equipment will be removed from the Site and initial flow testing of the well will commence (see below). The duration of hydraulic fracturing activities for each well will vary according to the total number of hydraulic fracture stages undertaken in each well. However, it is not expected to last more than 2 months per well. Staff will be present on Site 24 hours a day, 7 days a week. However the pumps used to pressurise the well to create the fractures will not be operated at night[34].

97. Further details about hydraulic fracturing operations can be found in Appendix B.

[34] Night time is taken to be the time between the hours of 2300 and 0700 (as defined by BS5228).

4.9 Initial flow testing

98. Although initial flow testing is described below as a standalone stage there is potential for some initial flow testing to be undertaken while hydraulic fracturing is also being implemented (i.e. in between fracturing stages).

4.9.1 Equipment

99. Following completion of hydraulic fracturing activities on a well, the equipment listed below will remain on Site for initial flow testing (see Appendix A, Drawings RW_EW_103 and RW_EW_104):

- Site staff offices, welfare facilities and storage containers;
- Coiled tubing rig (up to 36m high);
- Service rig to install/remove tubing up to 36m high);
- 2 enclosed gas flares (10m high) (an indicative illustration of the flare is included in Figure 4.17);
- Flowback separator with line heater and associated equipment;
- Enclosed flow-back tanks; and
- Water storage tasks.

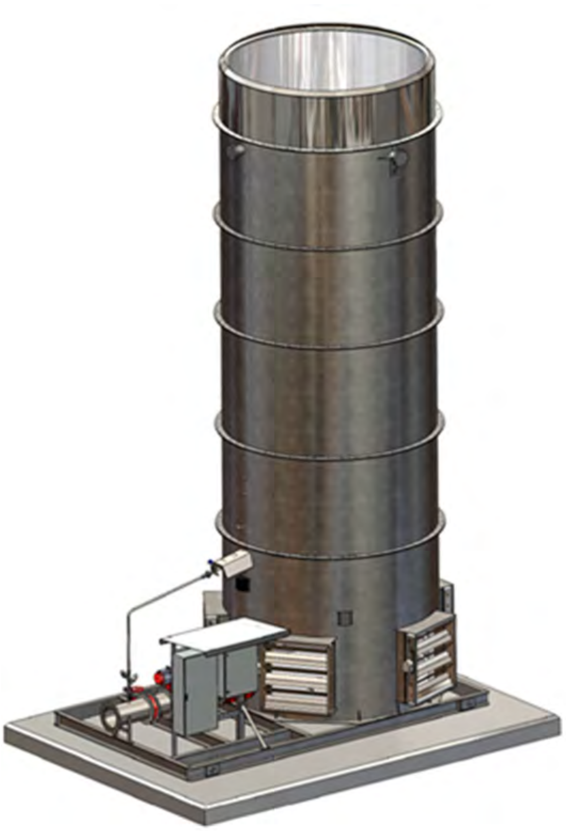

Figure 4.17: Indicative enclosed flare stack to be used during initial flow testing (not to scale).

4.9.2 Initial flow testing operation

101. Following the hydraulic fracturing injection period, the well will be opened at the surface to reverse the flow of the fracturing fluid. The purpose of this operation is to remove a portion of the injected hydraulic fracturing fluid from the reservoir to enable natural gas flow into the well.

102. To maintain full pressure control during the flowback process, and to prevent excessively high flowback velocities through the surface production equipment, the flow coming out of the well is passed through a device called a “choke manifold”, which reduces the pressure downstream of the frac head to a safe operating level as fluid is removed from the well. After the pressure reduction the flow stream enters a high-volume test separator, the purpose of which is to separate the water from the natural gas, and also to remove small amounts of sand, solids and condensate that may be produced during the flowback. The water and natural gas flow rates are measured and recorded. Samples of each are periodically taken so that a full compositional analysis of the water and hydrocarbons can be obtained.

103. At some point the well will start to produce mainly natural gas, and diminishing volumes of flowback fluid. It is at this point when the initial flow test begins. This test will run for up to 90 days by burning the gas in the flare system to establish an initial production rate or “IP”. If the findings are favourable, it may be followed by an extended flow test (as described below).

104. Natural gas produced during the initial flow test (but not extended flow test) will be burned via the two on-site enclosed flare stacks. Flaring of natural gas would only occur during this relatively short initial flow test period. Any further flowback fluid produced during this stage would be stored in tanks and periodically removed from Site for disposal at an Environment Agency approved permitted waste treatment facility.

4.10 Extended Flow Testing (EFT)

105. If flow rates indicate potentially viable flows and quantities of natural gas, a subsequent EFT period of between 18-24 months could be implemented.

106. The purpose of the extended flow test is to produce gas from the well for a longer period to gather data on the relationship between flow rates and well pressures, measure decline rates, and determine how much flowback fluid will be produced over time. This extended flow test data will contribute to an understanding of the reservoir and the predictability of the production performance. This data will also allow future well performance to be predicted, and this may be scaled up to estimate performance of a group of shale gas wells during any subsequent development phase.

107. In the event of EFT being undertaken, the resultant gas would be piped into the gas grid via a connection to the nearest main of appropriate size and pressure. This would eliminate the need for gas flaring. Additional equipment would be required to treat and regulate the pressure of the gas prior to connection to the gas grid, subject to the quality of gas produced.

4.10.1 Equipment for the EFT

108. At the Site the separation, dehydration and filtration plant and associated storage vessels will be located in the open areas of the well pad. The area required for this equipment will be approximately 25m x 17m. There will be a kiosk of size 6m x 3.5m which will house

gas quality monitoring, pressure control and energy measurement equipment. The process required to treat the gas before it enters the high pressure gas grid is described in Table 4.3.

Table 4.3. Treatment and monitoring processes required to connect to the gas grid.

Process	Description
Separation	Volumes of sand and liquids will normally be produced from the well along with natural gas. Separation equipment will be used to separate out the gas, with sand, water and condensate being retained in separate vessels. These tanks will be emptied on a regular basis and the materials disposed of at an appropriately permitted facility via tanker transport.
Drying	After separation the gas will still be too wet for gas grid injection and, a dehydration process will be used to remove the remaining water from the gas.
Filtration	Subject to gas quality (determined in the initial flow test), the separated natural gas may need to be passed through an active carbon filter to remove impurities. The activated carbon material would be periodically replaced, typically twice a year dependent on the level of components being removed and size of activated carbon beds.
Gas Quality Monitoring	Measurements will be made to determine water and hydrocarbon dew points and other components (such as nitrogen) in order to comply with National Grid entry quality standards.
Energy Measurement	The natural gas will be continuously measured for flow rate and calorific value, together with gas quality monitoring, and pressure control. A meter will be installed at the boundary of the well pad to measure the flow and quantity of gas produced at the Site.
Pressure Regulation	The pressure of the gas at the well head is estimated to be in excess of 75bar. Therefore a regulator will be installed to limit the pressure of the gas to 75bar prior to injection into the transmission network. After the pressure control there will be a Remotely Operable Valve (ROV) that will mark the boundary between the Cuadrilla system and the National Grid infrastructure.
Ancillary Equipment	A small flare will be fitted as part of the installation in order to enable safe operation of the facility in accordance with standard procedures. This flare would only be used in emergency conditions in order to avoid pressure build up above design conditions. It is noted that the gas well can be shut off at surface to control gas flow should this be required, therefore the flare is unlikely to be used.

4.10.2 Layout and connection to the gas grid

109. To allow connection to the gas grid a buried pipeline (depth of 1.2m and 6 inch diameter), will be laid. It will run eastwards for 55m from the well pad and connect to the gas grid pipeline running in a north to south direction to the east. At the connection point to the gas grid National Grid would require separate fenced area off areas of approximately 8m x 9m. This will contain a small kiosk (approximately 4m x 2m) containing telemetry and gas quality monitoring equipment. (See Appendix A Drawings RW_EW_103, RW_EW_104 and RW_EW_105).

4.11 Well servicing

110. During the initial flow testing and extended flow testing stages there may be need for occasional servicing of the well [well servicing]. A service rig, coil tubing unit and other equipment would be brought to Site to undertake this procedure. The well servicing visits are unlikely to last more than a week and will only occur occasionally (see Appendix B for details).

4.12 Decommissioning and restoration

111. Once the exploration activities, described above (sections 4.3 to 4.11), have been completed, the well pad and associated surface works will either be taken on into production, subject to further consents and EIA, or decommissioned and restored to its current agricultural use.

112. Decommissioning and restoration would include the following activities:

- The well will be suspended, plugged and abandoned, the wellhead removed and the casing cut of at least 2 m below ground in accordance with regulatory requirements[35];
- Monitoring of the groundwater monitoring wells will continue following exploration well abandonment for a period agreed with the regulators, and subsequent decommissioning of the groundwater monitoring wells;
- Removal of remaining plant, equipment and temporary buildings;
- Removal of the surface array;
- Removal of the buried array surface features;
- The ditches would be emptied;
- All utilities would be disconnected and the layers of aggregate, high density poly ethylene membrane, geotextile and felt would be removed;
- If a connection to the gas grid has been constructed this would be removed up to the connection point to the gas grid and capped in accordance with any requirements from National Grid;
- Sub-soil stored on Site would be treated with selective herbicides, as appropriate, prior to placement on the site sub-grade;
- Topsoil stored on Site would be treated with selective herbicides, as appropriate, prior to placement on the replaced subsoils;
- Removal of Site boundary fencing; and
- Reinstatement of fences, gates and field drains.

4.13 Environmental management

4.13.1 Environmental Operating Standard (EOS)

113. Cuadrilla has produced an Environmental Operating Standard (EOS) document which will establish a framework to enable environmental impacts, risks and compliance arrangements for operational activities to be effectively managed (see Appendix E).

114. A 'Structure and Rationale' version of the EOS has been prepared to accompany this ES which sets out the purpose and structure of the EOS. The EOS will be updated with specific measures required to meet the conditions of the various permits and the planning conditions.

4.13.2 Environmental monitoring

115. During the Project Cuadrilla will monitor a range of environmental parameters to allow them the effectively manage their operations. The following provides an overview of the aspects of the Project that that may be monitored:

- Seismicity (using the surface and buried arrays);

[35] Offshore Installations and Wells (Design and Construction Etc) Regulations 1996 (DCR). Regulation 15.

- Ambient air quality around the Site;
- Noise levels;
- Flowback fluid composition;
- Surface water and groundwater composition and concentrations;
- Ground gas composition and concentrations; and
- Fugitive gas emissions.

116. The monitoring parameters, frequency of sampling and dissemination of the data during operations will be confirmed once the planning and environmental consents are in place and agreed with the appropriate authorities.