National Grid Gas
Transmission

River Humber Gas Pipeline Replacement Project (Feeder 9)

May 2018

nationalgrid

National Grid Gas Transmission

Formal reopener submission for the River Humber gas pipeline replacement project

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I. Executive Summary

1. As the owner and operator of the Gas National Transmission System (NTS), National Grid Gas Transmission (referred to in this regulatory submission as 'National Grid') has a statutory obligation under the Gas Act 1986 to develop and maintain an efficient and economical pipeline system for the conveyance of gas.

2. A strategic component of the NTS is the Feeder 9 pipeline that crosses the Humber Estuary near Kingston Upon Hull. In 2009, underwater surveys highlighted an unprecedented amount of erosion near Feeder 9 which had exposed sections of the pipeline in the navigation channel.

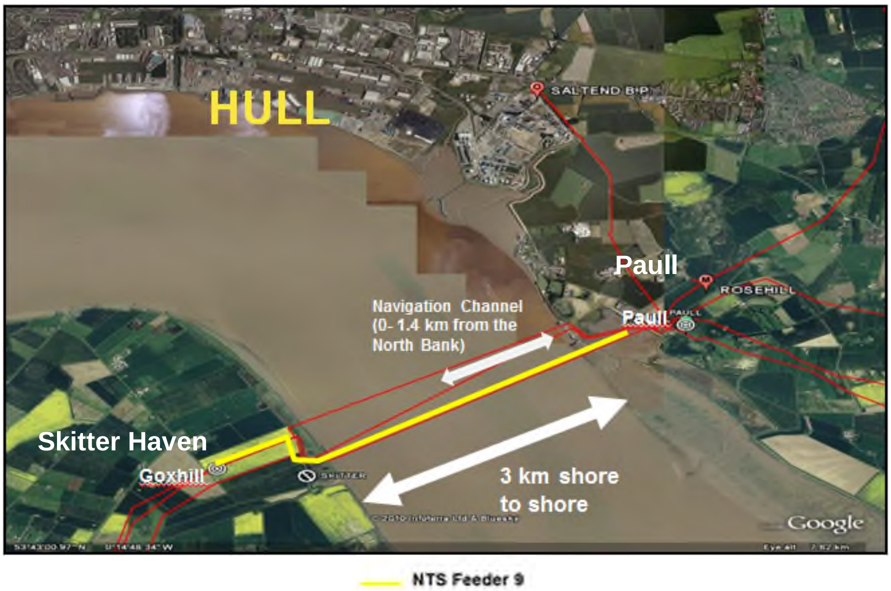

Figure 1: The River Humber where Feeder 9 crosses (yellow line)

3. After the discovery of this erosion, National Grid implemented a temporary remedial solution in 2010, which required further work in 2012. The pipeline, although currently stable, is subject to two main risks, further erosion and third party impact, both of which could result in catastrophic failure of the pipeline. In addition, the current temporary solution does not meet the requirements of the existing lease with the Port Authority and is not As Low As Reasonably Practicable (ALARP) from a safety perspective. The impact of a catastrophic failure would be significant with consequences potentially greater than any previous incident within the gas industry, both in terms of disruption to gas supplies and the physical consequences of rupture.

4. Previously, Feeder 1, which lies near Feeder 9, suffered similar erosion, which eventually required the pipeline to be isolated. However due to the reduced criticality of Feeder 1 it was possible to move the associated gas supplies to Feeder 9. Subsequently it was identified that Feeder 1 had sheared and failed.

5. The criticality and future need for Feeder 9 was assessed and it was identified that there is a long-term requirement for a section of NTS pipeline that is capable of transporting gas from the Easington Terminal and Easington entry area into the wider NTS.

6. Based on the above, it was essential to find a long-term solution for Feeder 9, whilst monitoring the existing pipeline and having all measures in place to undertake further remedial works and isolate the pipeline if necessary.

7. Strategic optioneering started in 2011 to find the best possible option to replace the pipeline. After a rigorous analysis process, a tunnelled solution was determined to be the most; economical, environmental and safe way to proceed. In 2015, the process of obtaining a Development Consent Order (DCO) was started, which concluded in August 2016, with the DCO being awarded by the Secretary of State.

8. In parallel with the DCO, a number of procurement and design activities were undertaken to mitigate the timeline risks associated with the existing pipeline, leading to the contract for the Main Works being awarded in May 2016.

9. The project delivery phase for the Feeder 9 pipeline replacement is currently in progress with several key milestones already achieved, most notable of which is the commencement of tunnelling in April 2018.

10. The Feeder 9 pipeline project, upon completion in 2021, will be the longest pipeline in a tunnel in Europe and will transport up to 20% of the UK gas supply. The new pipeline will not be subject to the uncertain conditions of the Humber Estuary and will thus ensure the reliable and safe transportation of gas for the foreseeable future.

11. This regulatory submission made under Special Condition 5E of the NTS Transmission Licence is for the design and build of the Feeder 9 replacement pipeline. The submission excludes DCO spend and any prior RIIO-T1 spend. The total funding request is for £139.9m in 09/10 prices.

12. This document explains the events around Feeder 9, starting from when issues were first observed in 2009, through the exploration of mitigation options, the process of planning permission, benchmarking, stakeholder engagement, procurement and current project delivery.

13. This reopener is being submitted in the May 2018 window as this is the first opportunity to request funding after gaining planning consent, which was a condition set out within Final Proposals.

II. Introduction

14. This document, produced by National Grid Gas Transmission (referred to in this report as 'National Grid') has been prepared as the formal reopener submission to request regulatory funding for the River Humber Gas Pipeline Replacement Project. This reopener submission is in accordance with Special Condition 5E of the NTS Transmission Licence, and with the RIIO-T1 Final Proposals for National Grid Electricity Transmission and National Grid Gas.

15. National Grid are submitting this reopener under the 'One-off asset health cost' Uncertainty Mechanism category which is defined as: 'costs *incurred, or expected to be incurred, by the Licensee in relation to any single low probability high impact event (or series of low probability high impact events with a common trigger) not explicitly included within the allowances provided for under the Special Conditions'.*

16. This chapter will be presented in the following structure:

- The regulatory background of the Feeder 9 pipeline
- The role Feeder 9 plays in the wider National Transmission System
- An introduction to the River Humber
- The potential lease issues
- The purpose of the reopener

Regulatory Background

17. The River Humber Gas Pipeline Replacement Project (hereby referred to in this report as the Feeder 9 project) relates to a replacement pipeline including a 3km underwater section of the high pressure NTS Feeder 9 pipeline that crosses the Humber Estuary near Kingston upon Hull. In 2009 underwater surveys highlighted an unprecedented amount of erosion in the vicinity of Feeder 9 which had exposed sections of the pipeline in the navigation channel leaving it susceptible to pipeline scour and potential third party interference.

18. In recognition of the need to secure the long term integrity of the pipeline, and after considerable strategic optioneering activities had been conducted, National Grid submitted a full funding request to Ofgem in the 2012 RIIO-T1 business plan outlining the needs case for the replacement of the existing Feeder 9 pipeline. The funding request was in the range of £100-£150m (2009/10 prices) to deliver a fully operational replacement pipeline.

19. The needs case and funding request were assessed by Ofgem and responded to in the July 2012 Initial Proposals[1] document. Ofgem identified that there were uncertainties over costs and timing of the project and therefore proposed to include Feeder 9 as a category in the reopener mechanism stating that National Grid could apply for appropriate funding upon approval of planning permission.

20. The funding mechanism for the project was confirmed in the December 2012 Ofgem Final Proposals[2] document where Ofgem stated:

21. "*For the Feeder 9 project we provided an ex ante allowance to enable NGGT to undertake preliminary engineering and licensing activities. Given the uncertainty and range of expected costs, we considered it appropriate that the remainder be funded (with the costs to be evaluated) via an uncertainty mechanism. The trigger for the uncertainty mechanism was NGGT being granted the appropriate planning approval'.*

22. An ex ante allowance was included as part of the RIIO-T1 plan to enable National Grid to conduct the necessary pre-works associated with obtaining the relevant planning permissions.

The Feeder 9 Pipeline and its role in the NTS

23. Feeder 9 is a high-pressure transmission pipeline constructed in 1984 which runs from the Easington Terminal on the East coast of England, towards Hatton Compressor Station in Lincolnshire and onwards to the South West.

24. The 5.4km section between Paull and Goxhill Above Ground Installations (AGIs) also includes a 3km crossing of the Humber Estuary. This section provides a critical bulk transportation route for gas from the Easington area into the wider transmission system in Lincolnshire, and the entirety of the UK market.

25. The Easington area includes the Easington terminal which connects Norwegian gas from the Ormen Lange gas field in the North Sea via the Langeled pipeline which can deliver up to 72 million cubic metres a day (mcm/d) making it the UK's primary route for Norwegian gas imports[3]. The Easington terminal currently provides approx. 20% of the UK's gas supply.

26. A large proportion of entry gas from the Easington area that must be transported to demand centres in the South and East is transported across the Humber Estuary via Feeder 9. This is the sole transportation route across the Humber

[1] Link to RIIO-T1 Initial Proposals for National Grid Electricity Transmission and National Grid Gas
[2] Link to RIIO-T1 Final Proposals for National Grid Electricity Transmission and National Grid Gas
[3] Other Norwegian pipelines to the UK are Vesterled and FLAGs. A maximum of 39 mcm/d at Vesterled and 20 mcm/d from FLAGS at St Fergus

into Feeders 9 and 22 towards Hatton Compressor Station (approximately 63 km away).

27. This underwater section of pipeline regularly transports between 70 mcm/d and 100 mcm/d, in comparison national demand on a cold winter day is 350-400 mcm, making it the highest throughput single pipeline on the NTS. This criticality means that Feeder 9 plays a pivotal role in securing the UK's energy needs and in ensuring National Grid's ability to operate the network safely and efficiently.

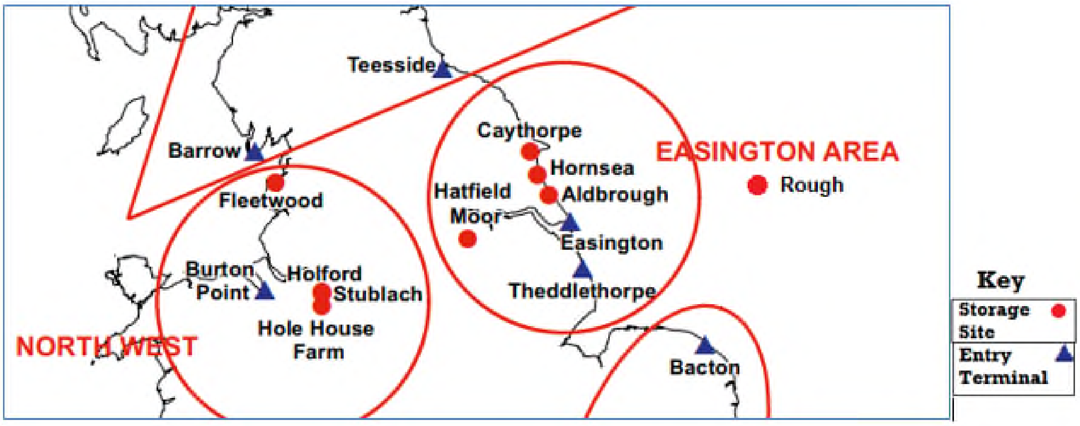

Figure 2: Map showing the onshore sites contained with the Easington Area (Rough is also included but it is a long range offshore storage site)

The Humber Estuary

28. The Feeder 9 river crossing is in the Humber Estuary which is the fourth largest estuary in Britain with a maximum tidal flow[4] of water second only to the River Severn. The river's major tributaries include the Trent, Ouse, Aire, Derwent, Don, and Wharf. These tributaries combine to drain a catchment area of approximately 24,500 square kilometres which is about 20% of England's total area.

29. Water velocities in the Humber can be extremely high and spring tide extremes can reach up to 3m/s. This velocity combined with the high concentration of suspended sediment in the river mean that the estuary bed is highly mobile and constantly changing.

30. The Humber Estuary also forms an integral part of the UK economy. It is the third largest shipping complex in Britain with almost one quarter of the UK's seaborne trade passing through the estuary.[5] It is one of the busiest and fastest growing trading areas in Europe, with four major ports (Hull, Immingham, Goole and

[4] Feeder 9 River Humber Pipeline Replacement Project – Crossing Options Report

[5] http://www.humber.com

Grimsby), over 30,000 ship movements and half a million passengers each year[6]. This commercial activity has resulted in the Humber becoming a major contributor to the UK's economy with Gross Value Added for the ports of Hull estimated to be £2.2 bn[7] per annum.

31. As well as being economically significant, the Humber Estuary and the intertidal mudflats surrounding the area are of significant ecological importance for many species including birds, mammals (seals and otters), and fish. As such it is afforded some of the highest levels of environmental protection available through International, European and National legislation. The Humber Estuary is an internationally designated RAMSAR[8] site, a European designated Special Area of Conservation (SAC), a Special Protected Area (SPA), a nationally designated Site of Special Scientific Interest (SSSI) and an Important Bird Area (IBA).

Existing Lease

32. To ensure safe passage in and out of the Humber Estuary, National Grid has a lease with the Competent Harbour Authority to lay and operate its pipelines in the Humber Estuary.

33. The lease to operate Feeder 9 in the estuary requires National Grid to keep the pipeline in good and substantial repair to prevent escape of gas or any substance. In addition, the existing lease requires the pipeline to be buried to a minimum depth below the river bed. At present, due to the estuary conditions, this depth requirement cannot always be achieved.

Purpose

34. In accordance with Licence Special Condition 5E.1 National Grid are permitted to submit a regulatory funding request in May 2015 or May 2018. After submission of the appropriate documentation required under the DCO planning process and extensive stakeholder consultation, planning permission for a tunnelled replacement pipeline solution was received from the Secretary of State in August 2016. National Grid is therefore requesting regulatory funding of £139.9m under the May 2018 reopener window.

35. The purpose of this document is to summarise the needs case information that was first presented to Ofgem in the 2012 RIIO-T1 business plan and explain the process that has been undertaken to identify the most economic and efficient solution to ensure the long-term integrity of the Feeder 9 pipeline. The document

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[6] http://www.humber.com
[7] http://www.abports.co.uk/Our_Locations/Humber/
[8] A Ramsar Site is a wetland site designated of international importance under the Ramsar Convention. The Convention on Wetlands, known as the Ramsar Convention, is an intergovernmental environmental treaty established in 1971 by UNESCO

explains the decision process in assessing the strategic options and route corridor options, and why the preferred option was selected.

36. After selection of the preferred option and route corridor the document explains the process that has been followed in order to progress from initial optioneering through to planning approval and project delivery. This includes the development of the project Front End Engineering Design (FEED), procurement, planning and consents and project delivery progress at the time of this submission.

37. National Grid expects that a determination on the reopener submission will be made in September 2018.

III. Feeder 9 Pipeline Need Case

38. This chapter shows the main drivers for the replacement of the river crossing section of the Feeder 9 pipeline in the Humber Estuary and consequently establishes the need case. The chapter will be presented in the following structure:

- The main two factors impacting the Feeder 9 pipeline, the composition of the riverbed and the volatile estuary conditions
- Significant events in the Humber Estuary that have occurred with both Feeder 1 and Feeder 9 in recent years
- Current significant risks to the Feeder 9 pipeline
- The future requirements for a pipeline in this location and the potential risks and consequences associated with not progressing a long-term alternative solution

The Humber Estuary Conditions

The Riverbed Composition

The high levels of erosion and accretion present in the Humber lead to extraordinary variation in the estuary bed. While a typical section of the channel in the pipeline vicinity would contain alternations of sand and mud resting on boulder clay, the exact composition varies greatly along the Feeder 9 route.

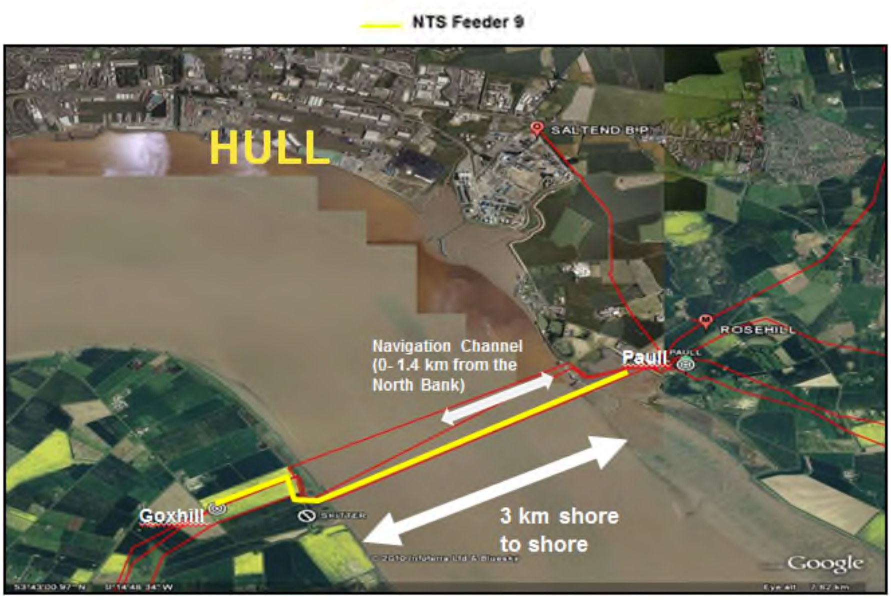

Figure 3: Location of the Feeder 9 pipeline in relation to Paull and Goxhill AGI's

39. The most significant variation is seen approximately 1km from the northeast bank (Paull AGI side) of the Humber, where Marine and Estuarian Alluvium dominate the composition. This material, which mainly consists of silt and fine sand, has

less than 15% clay content, increasing the likelihood of erosion. The section of the Feeder 9 pipeline in the navigation channel (see figure below for navigation channel) falls largely within this 1km area.

40. A further 500m away from the northeast bank, the composition changes again. In this area, the Alluvium deposit is underlain by Glacial Till, which mainly consists of boulder clay described as firm to stiff. The boulder clay is less susceptible to the forces of erosion within the estuary, although not completely impervious.

41. The Feeder 9 pipeline is buried in both the Alluvium deposits and the Glacial Till. Where the pipeline is buried solely in Alluvium and not resting in the Glacial Till, it is most vulnerable to the effects of rapid erosion.

Estuary Volatility

42. Erosion and unpredictable conditions are accelerated by the high current velocities and differing bed materials in the Humber Estuary. These conditions have caused the progressive natural extension and deepening of the navigation channel since the 1990's.

43. There are no clear trends and a high degree of uncertainty in the Humber estuary conditions making it impossible to accurately predict whether the Feeder 9 pipeline will experience further sedimentary loss and the rate at which this could happen.

44. A 2010 assessment found that depths within the navigation channel where the pipeline is laid have been shown to vary by several metres over time, with bed levels up to 4m lower during 2009/2010 than they were at the time of Feeder 9 construction. Erratic conditions were further demonstrated in the October 2015 crossing survey where over the three-day survey period the river bed level increased in depth by a metre, causing the bank to widen by 7 metres. To address the concern that patterns of erosion and accretion were being missed between the quarterly surveys, National Grid increased surveying to bi-monthly.

Feeder 1 Pipeline Erosion and Subsequent Failure

45. National Grid has previous practical experience of the estuary conditions with the Feeder 1 pipeline. The annual monitoring survey from 1999 identified that significant erosion was occurring on and around the Feeder 1 pipeline and that two sections of free-span[9] had developed.

46. Remediation work, which involved extensive rock placement, was undertaken from 2000-2002 to cover the free-spanning sections. However this was found to

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[9] A free-span on a pipeline is where the seabed sediments have been eroded, or scoured away and the pipeline is no longer supported on the seabed.

be not a long-term solution. On 19 June 2009, preliminary survey results indicated Feeder 1 had four free-spans of approximately 63m, 64m, 22m and 14m. Additionally, the conditions required for Vortex Induced Vibration (VIV) to occur existed.[10]

47. The timeline below details the erosion events that occurred at Feeder 1 between 1999-2008:

- **1999**
  - Survey reported 30-40m section of free-span
- **2000**
  - Remediation project - Extensive rock placement over pipeline to cover free-spanning section
- **2001**
  - Increased areas of free-span discovered
- **2002**
  - Remediation Project - Further rock placement works to cover free spans
- **2003**
  - Study commissioned to understand potential for Vortex Induced Vibration (VIV, a known cause of pipeline failure)
- **2004-2008**
  - Marginal increases in free-span lengths

48. Based on additional survey data and expert review of technical reports on the condition of both Feeder 1 and Feeder 9, it was determined that the only action available to safeguard the wider NTS and to remove the gas safety risk of a ruptured pipeline, was to isolate Feeder 1. From 2 to 10 July 2009, necessary actions were taken to decommission Feeder 1. The appropriate RIDDOR information was sent to the Health and Safety Executive (HSE) on the 2 August 2009.

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[10] Vortex Induced Vibration (VIV) occurs when the free-span of pipe compounds with the natural frequency of the structure to create resonant vibrations. These oscillations can rapidly increase in magnitude, leading to fatigue and failure with little to no warning..

Figure 4: Feeder 1 compressed air testing failure in July 2010

49. In July 2010, compressed air testing found the pipeline had subsequently failed and sheared. At the point of failure, the pipeline was no longer intact causing the unsupported section to collapse and come to rest on the river bed.

50. The pipeline remains in situ and is monitored in line with the Feeder 9 survey schedule. It is currently not believed to pose a threat to shipping traffic, Feeder 9 or the marine environment, but will continue to be assessed should the situation change due to the unpredictable estuary conditions.

The Impact on Feeder 9

51. In recent years, National Grid have witnessed extraordinary erosion and accretion in the estuary. As can be seen in Figure 5, at distances up to approx.1.5km from the north-east bank, Feeder 9 is partially buried in or resting on the glacial till. The Alluvium layers that previously covered the pipeline in this section of the navigation channel have been eroded to the extent that in places only the Glacial Till remains. Glacial Till erodes at a slower pace, which has helped to stem further rapid erosion and provide short term stability to the pipeline in this section.

52. Once the pipeline gets past 1.5km from the northeast bank, it then is largely buried in the softer Alluvium and is not resting on the Glacial Till. This means that when erosion events take place in this section of the channel, they are often rapid and do not have a base layer of Glacial Till to help reduce further erosion that could threaten the integrity of the pipeline. This has been seen first-hand through remediation works done on Feeder 9 and is discussed further on in this chapter.

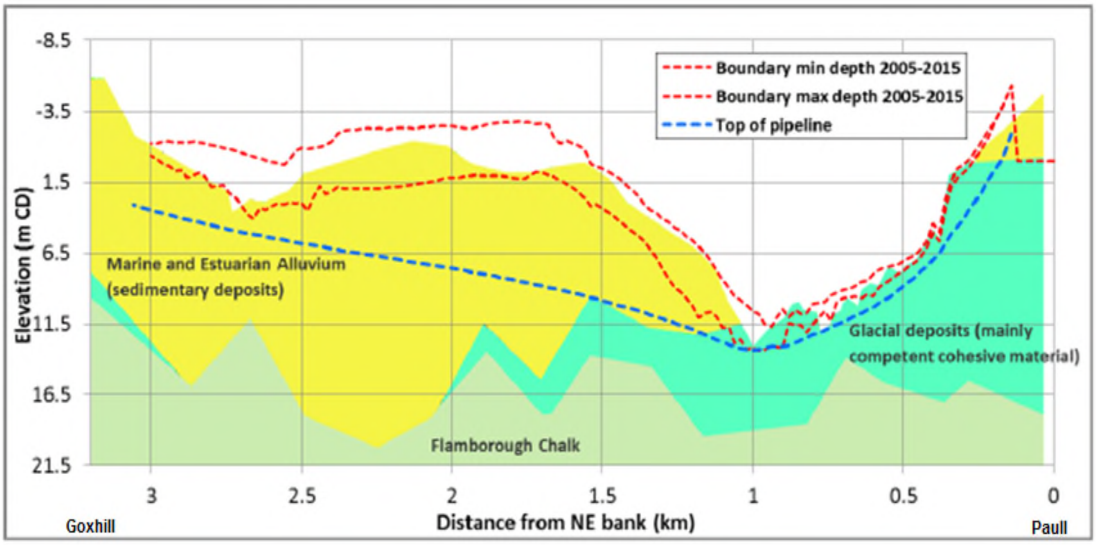


Figure 5: Graph showing the soil stratigraphy along the Feeder 9 pipeline together with pipeline position and the maximum and minimum riverbed levels measured between 2005 and 2015.

53. Figure 6 shows the depth of cover over the Feeder 9 pipeline in 2005, 2009, 2010 and 2016. The 2005 data shows that although there was significant erosion taking place, the minimum depth of cover was 0.59m, and this was located outside the navigation channel.

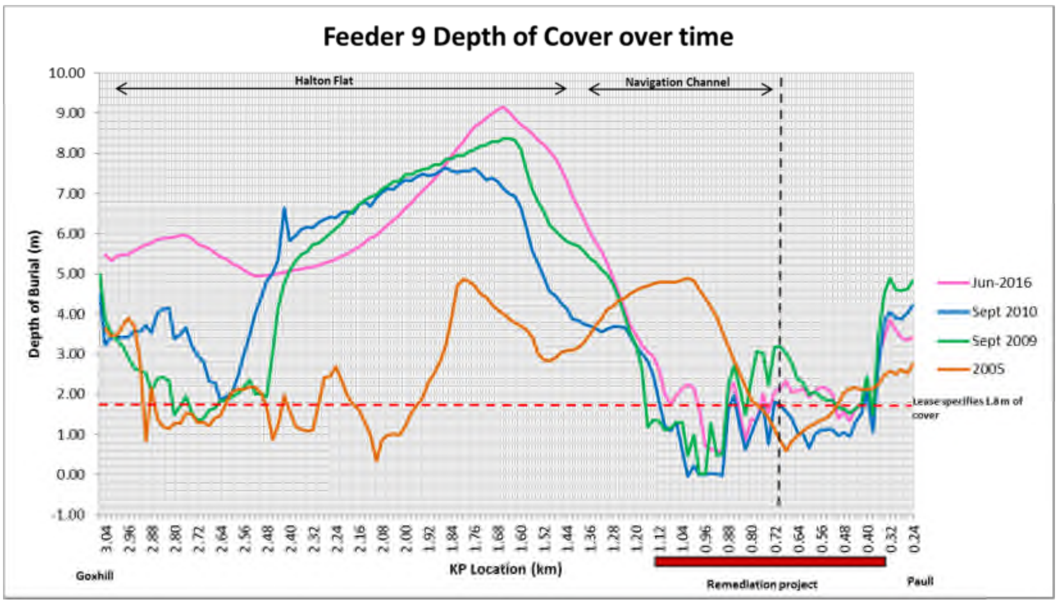


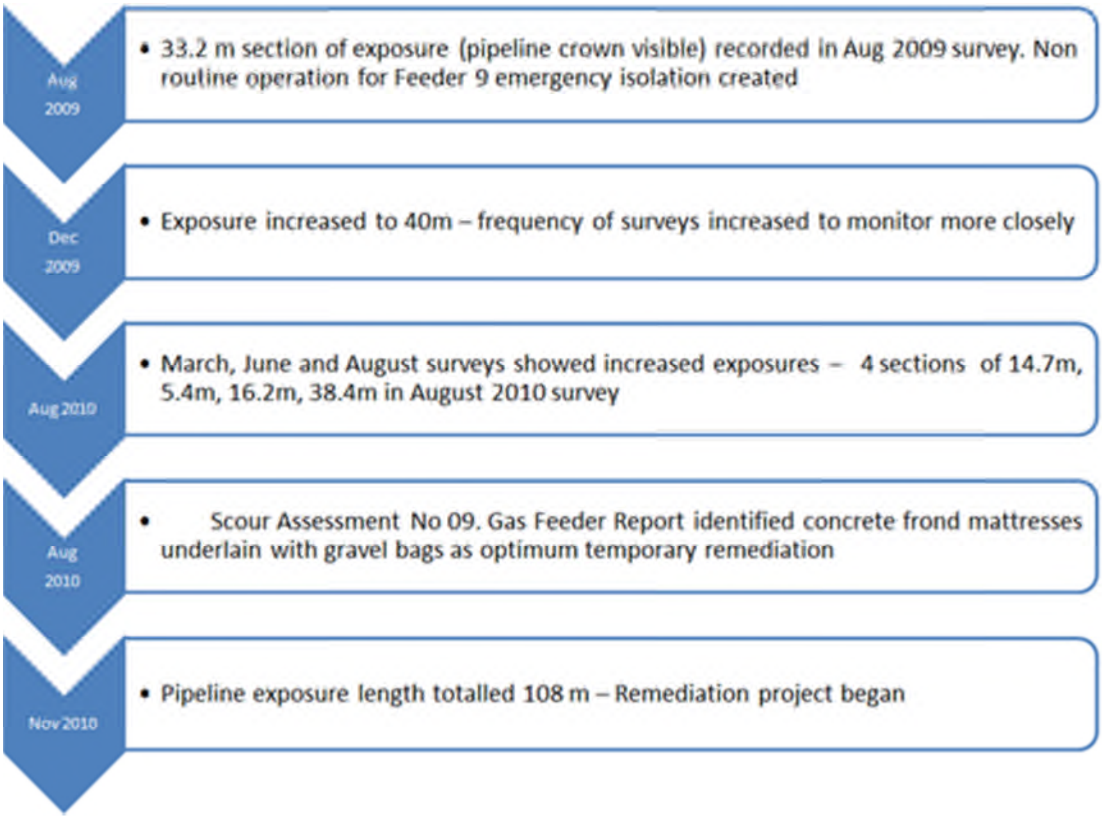
Figure 6: The depth of cover Feeder 9 over time.

54. In 2009, the erosion in the navigation channel had significantly increased with sections of the pipeline becoming exposed. This resulted in the development of a programme of short term remediation works. Before the remediation works started in 2010 another survey was conducted. The 2010 survey results identified that over the space of a year the depth of cover over the pipeline had continued to deteriorate to the extent that the exposure lengths totalled 75m and parts of the sediment in the navigation channel had decreased by approximately 1m in depth (Kilometre Point (KP) 0.84).

Feeder 9 Pipeline Erosion

55. In 2009 the survey that identified the Feeder 1 erosion also identified erosion, to a lesser extent, at Feeder 9. National Grid commissioned a survey in August 2009 to provide further detail. This survey detected an exposed section of 33.2m on the Feeder 9 pipeline where it crosses the navigation channel.

56. The timeline below details the erosion events that occurred at Feeder 9 in 2009 and 2010:



Feeder 9 Remediation Project

57. The rapidly deteriorating conditions experienced between 2009 and 2010 required National Grid to undertake remediation activities. A 'do nothing' option was not considered viable due to recent experience of the Feeder 1 pipeline

erosion and the criticality of the Feeder 9 pipeline and would have likely resulted in isolation to maintain integrity of the NTS. This would result in an unprecedented impact on UK gas supplies.

58. To secure the pipeline as expediently as possible, several long-term solutions were considered, however the timescales associated with construction options (circa three years of construction in addition to any front-end time needed for planning and design) were too great considering the immediate nature of the risk.

59. As such, National Grid developed an interim remediation project based on the recommendations of expert marine environment consultants which they outlined in their 2010 Pipeline Scour Assessment. No9 Gas Feeder Report.

60. From November 2010 to December 2011 remediation works were carried out using 300 tonnes of gravel filled bags and 760m of concrete frond mattresses laid over and alongside Feeder 9 to protect the pipeline from further seabed erosion. The concrete frond mattresses are 6m x 3m and contain 500 plastic fronds per mat which help to encourage and capture sediment cover over the mattress. Increasing the depth of cover over the pipeline helps to reduce erosion and therefore the potential for free-span and VIV to develop but it does not protect against third party interference.

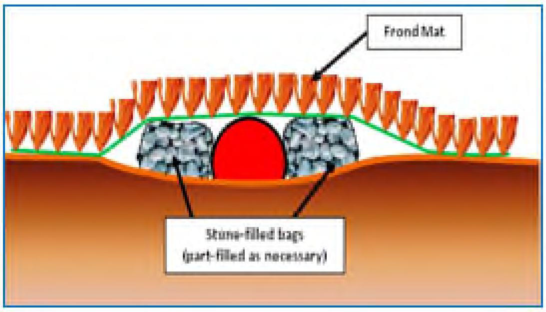


Figure 7: An illustration of the concrete frond mattresses and gravel filled bags and an image of the concrete mattresses being hoisted into the Humber estuary

61. Each gravel bag and mattress had to be installed by hand by a team of divers. Due to the fast-flowing tides, installation could only take place during a 30-60-minute period per tide known as ‘slack water’. The difficult conditions and zero visibility caused by the high level of suspended silt in the water meant that divers had to rely solely on touch to install the mattresses. Additionally, the extreme weather conditions experienced in the UK in the winter of 2010 caused further delays. This resulted in a mattress installation rate of three to four mattresses per day.

62. Although concrete frond mattresses have previously been used on subsea pipelines and the materials used have a long-term life expectancy, this form of remediation was largely untested in a tidal environment, especially one as mobile as the Humber Estuary. Independent consultants recognised this uncertainty and

the potential risk for the mattresses to become undermined by erosion. As such they predicted that the mattresses would be effective for 5-10 years and would require regular monitoring whilst this form of remediation was in use. In the November 2012 report, *Humber Pipeline Protection: Monitoring Update*, the consultants stated: “It is possible that the protection afforded by the frond mattresses in circa 50m of this section could fail within a year, however, for the rest of the pipe the protection is likely to be effective for 5 to 10 years.”

63. Following installation of the mattresses, surveys revealed that the pipeline exposures were covered and the remediation appeared to be working as intended. Subsequent surveys in 2012 identified that a 50m section of the mattresses were being scoured and undermining could occur within one year. Consequently, further remediation work took place from September to November 2013 to install 90 mattresses over the 50m at risk section.

Current Significant Risks to the Feeder 9 Pipeline

64. There are currently two significant risks to the Feeder 9 pipeline, free-span and third party interference.

Free-span

65. Free-span on a pipeline is where the seabed sediments have been eroded or scoured away and the pipeline is no longer supported on the seabed. When a pipeline becomes free-spanning, the integrity of the pipeline is compromised as it may cause it to sag, shear or lead to VIV. VIV can occur if the frequency of vortex shedding approaches the natural frequency of the structure leading to the creation of resonant vibrations (the amplitude depends on the pipeline structure and the motion of the fluid relative to it). Oscillations of increasing magnitude may then lead to fatigue and potentially rapid failure.

66. In 2003, National Grid commissioned a study to investigate the impact the Humber Estuary would have on the free-spanning of Feeder 1 including the potential for VIV. The result of this study is shown in

68. Table 1 which highlights the key parameters needed to create an environment for VIV to occur. These parameters are interdependent; therefore, if one changes, it will affect the other parameters.

69. Table 1 also shows the result of an additional study conducted on Feeder 9 which measured the same parameters. VIV did occur at Feeder 1, where these parameters were seen, which sets a precedence that parameters required for VIV are achievable at Feeder 9.

Table 1: Key parameters for VIV and reported measurements for both Feeder 1 and Feeder 9

Key parameters for VIV	Feeder 1	Feeder 9
Length of free-span	40 m	55 m
Minimum distance of 100mm between the underside of the pipeline to the sea bed?	Present	Present
Velocity of water passing the pipeline	2 m/s	2.6 m/s

Third Party Interference on pipelines

70. Areas of reduced cover over a pipeline are more vulnerable to Third Party Inference (TPI) and damage as they are no longer afforded the protection created by the cover of sedimentary deposits found in the estuary. In the case of Feeder 9, TPI could include anchor impact, vessel grounding[11] and vessel foundering. The damage caused by these incidents could range from disturbance of the pipeline protection, to loss of containment.

71. The likelihood of TPI becomes greater with increases in both volume and size of vessel traffic. Since the construction of Feeder 9 in 1984, vessel traffic in the Humber has increased substantially with estuary sea freight approx. 90% more of what it was at the time of construction (over 10,000 movements over the pipeline in a 12-month period in 2015). In addition, the size of vessel has also substantially increased, with larger vessels such as cargo, tanker and passenger ferries now representing 74% of all vessel movements over Feeder 9. These vessels have bigger drafts and larger anchors which are more capable of causing damage to the pipeline.

72. Mitigations are in place to help reduce the likelihood of TPI over the Feeder 9 pipeline including a 1 mile no anchor drop zone and detailed charts that show the location of the pipelines for Humber Estuary users.

73. Despite these mitigations, accidental and emergency anchoring still takes place. Between 2004-2014 there were five incidents near Feeder 9 that could be classed as significant[12]. Three of these events were anchors being dropped in or near to the no anchor zone either accidentally or in an emergency. The other two incidents were related to possible sinking's/groundings due to vessel collisions

[11] Grounding can be a credible cause provided that the draught of the ship is larger than the water depth plus the depth of cover. For Feeder 9 there are two identified locations where grounding could be a possibility KP 2.6 and between KP 0.35 - KP 0.65

[12] Incidents where it appears credible from the description of the event that the pipeline could have been struck as detailed in a Quantified Risk Assessment of the Underwater Section of the Feeder 9 Pipeline in the Humber Estuary

near the pipeline. Within the same timeframe there were also five incidents that were classed as being a moderate risk to the pipeline and 17 incidents that were classed as presenting a minor risk to the pipeline.

74. There are also a significant number of recorded incidents of actual anchoring damage to pipelines in the UK and globally. This includes two incidents of anchor damage in the Humber Estuary (1996 and 1997) on the Amethyst gas pipeline both of which affected production. In addition, anchor damage to the Central Area Transmission System (CATS) gas pipeline in Teesport required the shutdown of production for over two months in the summer of 2007 and saw within day gas prices rise by almost eight percent. A similar incident in Melbourne in 2008 caused an ethane pipeline to be ruptured by a vessel dragging anchor during poor weather conditions. The pipeline took four months to repair, required curtailment and cessation of production for the businesses using ethane and generated compensation claims of more than $300m AUD (circa £190m in 2010 prices).

75. The HSE published the "Guidelines for Pipeline Operators on Pipeline Anchor Hazards"[13] in 2009 which highlights the risks associated with anchor damage as well as the main protective measures and controls available to protect pipelines from anchor hazards. The document stated that the PARLOC 2001 report had identified 44 incidents involving anchoring over the 25,000km of offshore pipelines operated in the North Sea. Of these, 11 resulted in loss of containment and 22 required some form of repair.

76. The protection measures that the document recommended including trenching, rock placement, regular surveying or where the risk is unacceptably high, replacing with a re-routed or re-designed section of pipeline. Concrete mattresses are not identified as a credible form of TPI mitigation as their prime function is to prevent scour.

The Potential Risks and Consequences of Isolating Feeder 9

77. There would be severe and unprecedented consequences if Feeder 9 was to become unavailable either due to controlled isolation to mitigate a risk to the pipeline, or due to uncontrolled rupture. The severity would be influenced by variables such as the supply and demand conditions at the time of isolation and the duration of isolation. The main identified implications are:

a. Gas supply implications and network constraints
b. Impact to the wholesale gas prices (and subsequently the consumer)
c. Humber Estuary disruption
d. Impact to the UK/Norway Relationship

[13] Link to Guidelines for Pipeline Operators on Pipeline Anchor Hazards
http://www.hse.gov.uk/pipelines/pipeline-anchor-hazards.pdf

e. Potential fatalities from a Feeder 9 rupture

Gas Network and Supply

78. The loss of Feeder 9 would have both an immediate and long term impact on the NTS. These impacts can be widely categorised in two areas;

a. reduced capability of the network
b. a reduced resilience to other needs or events that may impact the NTS.

79. Depending on the nature of the loss of Feeder 9, these impacts could mean reduced capability and resilience of the NTS over a substantial period, potentially impacting UK gas supplies.

Reduced Capability: Network and Entry Capability

80. Throughout the development of the Feeder 9 project, network analysis has been conducted to understand the potential network implications of Feeder 9 isolation. This analysis has consistently shown that, the capability of the Easington area is reduced by up to 60% (to below 74.9 mcm) with the loss of Feeder 9. This relates to both the area's capability to bring gas into the UK as well as contribute to the movement of gas around the UK.

81. Easington is one of the most utilised entry points on the network, and as such sold capacity bookings exceed 74.9 mcm/d for six months of every year until 2024. It is also expected that capacity bookings from 2025 onwards would follow the same trend. This would mean that if National Grid were unable to accommodate the nominated flows at the ASEP, it would be necessary to take commercial actions to resolve the constraints. These actions include, entry capacity buyback, locational actions and forward/option contracts.

82. Additionally, the Easington area obligated capacity is 201 mcm/d, under the Uniform Network Code (UNC). A reduction in Easington Area capability to 74.9 mcm/d could result in 78 - 103 days of constraints per year.

83. Estimating buyback costs associated with constraints of this magnitude is extremely difficult as the capacity buyback incentive was not intended or designed to manage a loss of physical capability of this scale and potential variation. However, using daily buyback costs based on historic Weighted Average Price (WAP), the entry constraint management buyback costs associated with a curtailment of 78-103 days could range from £205m - £890m per year.

Reduced Resilience

84. The reduced capability in the NTS because of a loss of Feeder 9 would have a subsequent impact on the network, therefore causing a decrease in network resilience. The loss of Feeder 9 would significantly impact the capability of the

entire UK east coast, increasing reliance on the west coast and utilising more compressor hours at several compressor stations; some where there are restrictions due to emissions.

Wholesale Gas Price and Consumer Impact

85. The UK has one of the most reliable gas systems in the world with a diverse range of supply coming from both indigenous gas production and extensive import capability. Despite the considerable level of resilience created by having a broad range of supply, unplanned supply shocks have the potential to cause significant disruption, and in turn increase gas prices.

86. It can be seen from previous supply loss incidents, both within the UK and globally, that shortfalls in supply often lead to spikes in wholesale gas prices, which can also help to signal the need to balance the UK gas system. However, any maintained increase in gas price ultimately impacts the amount that consumers pay and therefore increases the cost of the consumer bill.

87. A supply loss with the potential magnitude of Feeder 9, both from a duration and criticality of asset perspective, has never been experienced in the UK. This makes it extremely challenging to predict what the market response would be. It can be assumed based on historic supply loss events that short-term price spikes would be inevitable but given the potential longevity of the incident it is also likely that longer term wholesale gas price increases would be experienced. This potential long term increase and the impact this would have on domestic bills poses one of the biggest threats to consumers should Feeder 9 require isolation.

UK/Norway Relationship

88. Norwegian gas represents a reliable and secure energy supply accounting for approx. 35% of UK supply in 2015 making it one of the key components of the UK energy mix. The Langeled pipeline was built in 2006 at a cost of £1.7bn to help provide more resilience and security to the UK gas market. This pipeline was built with the expectation there would be a continued need for, and ability to, bring Norwegian gas into the UK via the Easington terminal. The next areas of Norwegian gas field development are also likely to be connected to Langeled ensuring the continued use of the pipeline for the foreseeable future.

89. Without Feeder 9, lower volumes of Norwegian gas would be bought into the Easington area which would mean that the Langeled pipeline would not be operating as intended. This has Security of Supply (SoS) implications for the UK but also risks damaging the collaborative working relationship shared with Norway.

Humber Estuary Disruption

90. Should Feeder 9 require isolation there are potential Humber Estuary disruption consequences in the form of both commercial disruption and environmental disruption.

91. From a commercial perspective, uncontrolled rupture of the pipeline would likely result in the Harbour Master enforcing an exclusion zone around the pipeline which would close the shipping lane. Closure of the shipping lane would last for the duration that the Harbour Master determined a credible threat was posed to vessels. This would also close the two ports (out of the four on the Humber) directly upstream of Feeder 9, preventing vessels from reaching or leaving. Based on the Gross Value Added figure of £2.2bn annum for four ports, and assuming two ports would be directly impacted by the shipping lane closure, it has been estimated that shipping lane closure would cost £8.5m per day.

92. From an environmental perspective, the Humber Estuary is afforded many national and international environmental designations. There are approximately 90 species of fish identified throughout the upper middle and lower reaches of the estuary and the river is also a migratory route for protected fish species including Lamprey, Atlantic Salmon, Shad and European Eel. It is also home to and supports internationally important populations of waterfowl and waders during the winter months and migratory periods. A release of gas and any subsequent repair works could cause disruption to the fish and invertebrate species which would have a knock-on effect on the wider Humber Estuary ecosystem.

Potential Fatalities of a Feeder 9 rupture

93. If Feeder 9 were to rupture, there is a potential for the gas released to ignite and cause fatalities. As the estuary is a busy shipping area there is increased likelihood of a vessel being in in the vicinity at the time of rupture particularly if the rupture is caused by TPI.

94. In the ‘Quantified Risk Assessment of the Underwater Section of the Feeder 9 pipeline in the Humber Estuary’ document, the consequences of rupture ignition were investigated. The report identified that all onshore populations would be safe from ignition, but that vessel populations would be in danger.

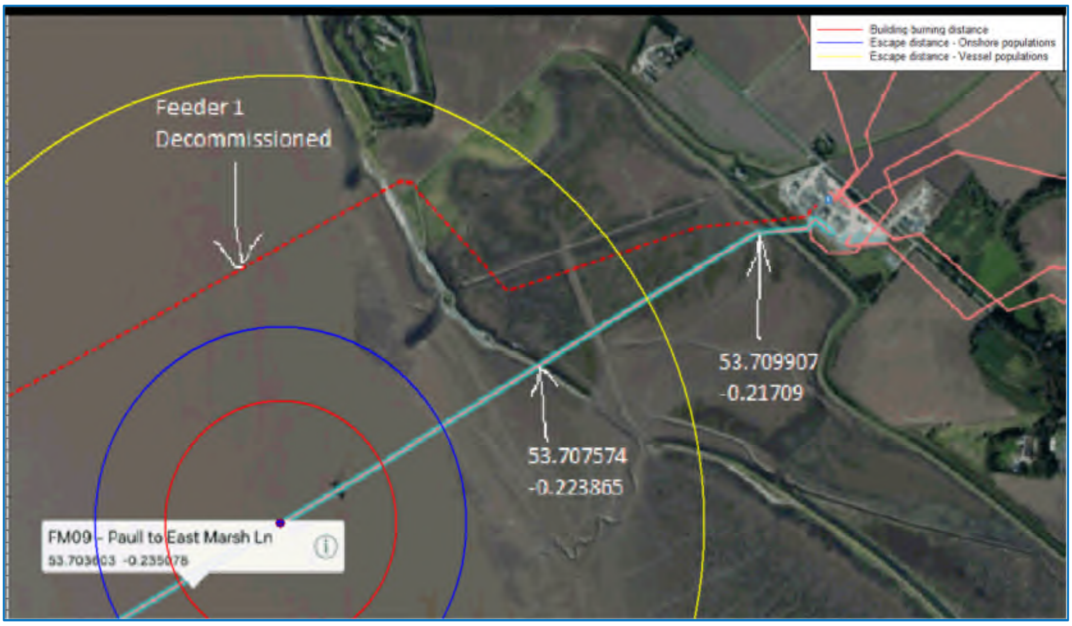


Figure 8: The maximum predicted hazard distances

95. Vessel populations on the Humber Estuary were derived from vessel traffic data to understand the potential number of fatalities. Of the approx.10,000 annual vessel movements over the pipeline (2015/16), 74% were made by the largest ship types (passenger, cargo and tanker). The passenger vessels observed in the estuary included the twice daily P&O ferries that carry up to 1,500 passenger and crew per journey.

96. TPI rupture is most likely to be caused by a larger vessel and these vessels typically carry more passengers and/or crew. In addition, one of the potential causes of TPI is vessel collision and therefore there is a risk that multiple vessels and therefore multiple vessel populations could be involved.

Conclusion

97. The high rates of erosion experienced in the Humber Estuary in recent years have caused Feeder 9, one of the most important pipelines in the NTS, to become partially exposed which has threatened the integrity of the pipeline. National Grid has undertaken remediation activities to secure the pipeline in the short-medium term. However, given the potential risks and consequences and as a prudent and responsible operator, National Grid has undertaken activities to plan and begin a long-term solution to secure the long-term integrity of the Feeder 9 pipeline, which will be discussed in subsequent chapters of this submission.

IV. Continued Use of Frond Mattresses

98. This chapter will serve to provide an understanding of why the use of frond mattresses was not a viable long term option for a pipeline of such strategic importance to the NTS. The chapter will be presented in the following structure:

- The strategy to protect Feeder 9 and a summary of the lessons learnt from mitigation efforts on Feeder 1
- The conclusion to proceed with a replacement option for the pipeline

Protecting Feeder 9 and Lessons from Feeder 1

99. To protect the Feeder 9 pipeline, National Grid has pursued both a short to medium term mitigation strategy and a long-term replacement strategy. We have undertaken numerous studies to consider the relative merits of each option and taken advice on the approaches that could be adopted, documented in independent reports issued in 2010, 2012 and 2018.

100. The mitigation techniques we have tried are rock dumping on Feeder 1 and a combination of frond mattresses and gravel bags on Feeder 9. These options were chosen based on the advice of marine specialists. In the case of Feeder 1, the rock dumping did not prove successful and in the end, we decommissioned Feeder 1 due to the risks posed by the pipeline. Upon subsequent testing of the pipeline, it was found to have failed.

101. In the case of Feeder 9, we have undertaken mitigation activities. The first attempts to mitigate the exposure of the Feeder 9 pipeline occurred in late 2010 for approximately a year, taking longer than expected due to the harsh conditions encountered. Both gravel filled bags and concrete frond mattresses were laid over and alongside the Feeder 9 pipeline to prevent further seabed erosion. In total, 760m of mattresses alongside nearly 300 tonnes of gravel filled bags were placed over the estuary.

102. Whilst every care and attention was given to ensuring diver safety, the difficult and dangerous conditions resulted in two cases of decompression sickness that required hospital treatment. The appropriate RIDDOR assessments were submitted to the HSE and a workshop was held to review diving practices to ensure there were no further actions that could be taken to mitigate the risk of decompression sickness. It was concluded that the diving operation was conducted in accordance with current best practice.

103. Unfortunately, this mitigation only lasted a year before surveys revealed further sections of pipeline that were exposed. In September 2013, further remediation work needed to be conducted to address this exposure.

104. Although we have undertaken numerous studies and have experience of different mitigation options, there is no definitive view on the effective operational life of the

frond mattresses within a fast-flowing estuary. Our best view is that they should last for 5-10 years, where currently placed. Their effectiveness at other locations where the seabed is predominantly marine and estuarian alluvium, which represents over 50% of the crossing, is unproven. In these areas the minimum depth of cover reached 0.5m, but no exposure to date has been experienced.

105. If we were to continue with frond mattresses, a further challenge would be how do we remediate an area where they already exist in 5-10 years' time. Each frond mattress weighs several tonnes, the operational window to work in the estuary is 45-60mins per day of slack water and diver visibility is close to zero. The risk to divers of such an extensive operation, on a live pipeline, in addition to the risk to the pipeline itself would be unacceptable.

The conclusion to proceed with a replacement option for Feeder 9

106. Based on the advice of these reports and the remediation experience on both Feeder 1 and Feeder 9, we concluded that remediation is only suitable to temporarily mitigate the risks of seabed erosion. The use of frond mattresses, rock dumping or other techniques does not guarantee the long-term integrity of the pipeline and, more specifically, does not protect the pipeline from third party interference or meet the requirements of the lease.

107. In terms of third party interference, the Quantified Risk Assessment conducted by an independent specialist assessed the pipeline to be outside of the societal risk criterion envelope, which means that its continued operation is only acceptable if As Low As Reasonably Practicable. As the maximum risk to life is 1506 casualties any solution that is within £1.5bn (valuation of £1m per life, no disproportion factor applied) should be considered.

V. Strategic Options Appraisal & Route Corridor Investigation Study

109. This chapter first describes the strategic options identified and the options appraisal process used to assess the environmental, socio-economic, technical and cost factors associated with each identified option. Then, the chapter discusses the process undertaken to establish the most optimal route from the strategic options given. This chapter is presented in the following structure:

- A brief overview of the Strategic Options Process as it applied to Feeder 9
- The available route options
- The appraisal of these options and the outcome of the Strategic Options phase
- A brief overview of the Route Corridor Investigation Process as it applied to Feeder 9
- The appraisal of the routing options and the outcome of the Route Corridor Investigation phase

The Strategic Options Process

110. To ensure that the most economic and efficient design solutions are identified, National Grid has published a document that outlines its approach to the design and routeing of new gas and electricity infrastructure[14]. The Options Appraisal document was developed primarily to comply with the requirements of the Planning Act 2008. It is a robust and transparent process that sets out how National Grid should identify the most appropriate method, technology and route for new gas infrastructure. The approach can then be tailored to accommodate the specific circumstances of each case.

Strategic Option Development for Feeder 9

111. The strategic optioneering work for the Feeder 9 project predominantly took place between 2011 and 2012. Extensive network analysis was carried out in 2011 to look at potential replacement and/or network reinforcement options for the Feeder 9 crossing between the Paull and Goxhill AGI's. This analysis also included a 'do nothing' option. The aim of this analysis was to ensure that all possible options were considered.

112. The initial options list created from this analysis contained 44 potential options. Rigorous internal reviews in April and May 2011 resulted in a shortlist of recommended options that could meet the entry capacity requirements of the

[14] Link to Our Approach to Options Appraisal

Easington Area and were considered in more detail in the Strategic Options Report (SOR)..

Available Route Options

113. The outcome of the initial high level assessments and challenge and review workshop was that 44 potential options were reduced to three broad route options containing a total of seven specific recommended options to be taken forward for strategic option appraisal in the SOR.

114. Based on the initial identification and assessment of options, the three broad route options identified were:

- Direct Estuary Crossing
- Onshore Pipeline
- Offshore Pipeline

115. The details of these route options and in the seven main options considered, are detailed in Table 2.

Table 2: A summary of the strategic options considered in the Strategic Options Report

Opt	Route	Length	Description	Increased Capacity?
1a	Direct Humber Estuary Crossing	6km	Tunnel	No
1b		6km	Excavated trench	No
1c		6km	Horizontal Directional Drill (HDD)	No
2	Onshore pipeline	190km	Paull to Kirmington including twin pipelines, single pipelines, tie to Feeders 9 and 22 and compression	Yes
3		250km	Pipelines routed around Hull to Asselby and Keadby and tie to Feeders 9 and 22 with no compression;	Yes
4	Offshore Pipeline	85km	Offshore pipeline between Easington and Theddlethorpe, with an onshore pipeline between Theddlethorpe to Hatton with compression	Yes
5		200km	Offshore pipeline Easington to Bacton with compression; Kings Lynn to Peterborough onshore pipeline, high flow modification and re-wheels	Yes

116. The available information regarding the highly dynamic seabed conditions and unpredictable erosion cycle combined with the criticality of the Feeder 9 pipeline and potential detrimental impacts of failure, resulted in the ‘do nothing’ option being rejected at this stage in the strategic options appraisal process.

117. National Grid considered that each of the seven identified options were able to meet the need case through the construction of single pipelines, twin pipelines or a combination of pipelines and compressor stations.

Overview of Strategic Options Costs

118. As part of the initial strategic options appraisal, indicative estimates of the capital costs were prepared to allow a high-level cost comparison of options. These were based on high level scopes of works defined for each strategic option in respect of each technology option that was feasible.

119. Figure 9 below shows the ranking of costs of the strategic options, both in terms of capital costs and of lifetime costs made with best possible assumptions at the time of optioneering in 2012. Options 1a, 1b and 1c all had the same lifetime costs, with variation on capital costs, as shown in the figure.

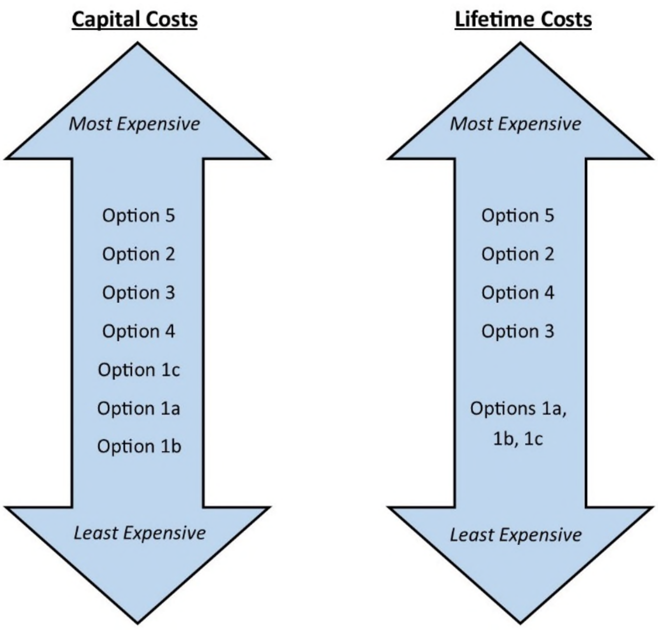


Figure 9: A summary of the costs considered for the Strategic Options, in rank of expense.

120. As these estimates were prepared before detailed design work was carried out, National Grid took account of equivalent assumptions for each option. The capital cost estimates prepared at this initial analysis stage were sufficiently detailed to allow an indicative comparison of capital costs but did not represent a forecast of actual final project cost.

121. The capital cost estimates were based on generalised unit costs for the key elements of each option. This includes the cost of compressor units and the cost of pipeline including the cost of installation of this equipment. For the tunnel element, National Grid looked at other internal tunnelling projects such as the London Power Tunnels project.

122. This initial assumption enabled a direct comparison of options to rationalise strategic options to a reasonable number of options to be taken forward for further assessment.

Option Appraisal

Assessment of the Strategic Options

123. The aim of the strategic options appraisal was to assess the relative merits and disadvantages of the seven shortlisted options and to identify which of these options should be taken forward for more detailed assessment. The information required to make comparisons between different options generally related to constraints or issues of national or international importance, which would be of sufficient importance to influence decision making at a strategic level. This information was obtained through a desktop study and a limited external consultation exercise.

124. The four topic areas in the initial strategic options appraisal were Environment, Socio-economics, Technical and Cost. These topics were identified specifically to ensure that decision making was based on a broad understanding of the implications of National Grid's project.[18]

125. An Option Appraisal Summary Table (OAST) was prepared for each strategic option, summarising the implications of that option regarding all sub-topics considered and providing a summary of the pros and cons of each strategic option.

126. The appraisal assumed that standard mitigation measures and the application of good construction practices would be implemented. Therefore, at this stage of the process only issues which would require more than standard mitigation and which would result in impacts that could differentiate factors between the options were considered.[15]

Strategic Options Appraisal Summary

127. The OAST information showed that all the options except one (Option 1c) were technically appropriate and feasible. There was a high risk of technical failure with Option 1c as it was highly complex and untested over the required length and estuary conditions. Additionally, the capital costs were 120-150% higher than the other estuary crossing options. Option 1b (excavated trench) was the least expensive option in terms of pure capital costs and Option 5 was the most expensive option.

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[15] Link to Strategic Options Report

128. The longer pipelines (options 2, 3, 4 and 5) were expected to have a greater risk of affecting more environmental features, due to the longer construction period and increased land-take. Options which included compressor stations (Options 2, 4 and 5) would potentially cause Landscape and Visual, Noise and Air Quality impacts.

129. Other considerations in the appraisal of the options included the spoil generated by the tunnel construction of option 1a and environmental and economic impacts on the Humber Estuary, flood defences and shipping from option 1b and 1c.

130. Following the appraisal, the challenge and review workshops, and consultation with statutory consultees, the project team recommended that the direct Humber Estuary crossings (options 1a and 1b) were taken forward as the preferred strategic options. Options 1c, 2, 3, 4 and 5 were discounted at this stage.

131. Options 1a and 1b complied with the over-arching guiding principles of the options appraisal. They were substantially shorter than the other options and therefore these options would result in fewer impacts overall than the longer pipelines. Although options 1a and 1b could impact upon the Humber Estuary's nature conservation importance, the estuary crossing is relatively short (3 km) and it was thought that appropriate mitigation could be implemented at the more detailed stages to ensure potential effects are minimised or avoided. The options utilised existing infrastructure, avoiding the need to construct new AGIs, and they were lower cost options.

132. In addition, options 1a and 1b did not require the installation of a compressor station, resulting in fewer impacts on noise, air quality, landscape, visual amenity and lower future operational costs.

133. Therefore, the strategic optioneering process concluded that there were two preferred options (options 1a – tunnel, and 1b – trench) to take forward to more detailed assessment in the form of the route corridor investigation. These options were supported by the responses received from statutory consultees and provided the best overall solution to the replacement of the existing Feeder 9 pipeline.

<u>The Route Corridor Investigation Study</u>

134. A Route Corridor Investigation Study (RCIS) was prepared as part of the adopted pre-application procedure for major infrastructure projects that may require an application to the Planning Inspectorate for development consent.

135. The RCIS analysed the construction techniques and route options for the preferred strategic option of a direct estuary crossing, which was used as part of the statutory consultee and public consultation process on the identified preferred route corridor.

136. The methodology adopted to identify route corridors and select the preferred route corridor was described in full in the Final Route Corridor Investigation Study report[16] which was issued in May 2013. This was the culmination of National Grid's optioneering and route corridor work, following the initial strategic optioneering process and the identification of the preferred strategic options in the Final Strategic Options Report[17] which was issued in October 2012.

137. The information required to appraise different route corridors consisted of publicly available desk top study information supplemented by a site visit by the design team. The four topic areas used for the route corridor options appraisal were the same as the strategic options topic areas; environment, socio-economic, technical and cost. These were identified specifically to ensure that decision making was based on a broad understanding of the implications of the project.

138. There were two main options from the outcome of the Strategic Options Appraisal that were considered for the Route Corridor investigation:

- Option 1a - tunnel under the Humber Estuary between Paull AGI and Goxhill AGI. The total pipeline length would be approximately 6 km (with a 3 km estuary crossing).
- Option 1b - direct estuary crossing laid in an excavated trench between Paull AGI and Goxhill AGI. The pipeline would be approximately 6 km in length (3 km estuary crossing) between the Paull AGI and Goxhill AGI.

139. Once a final preferred route corridor was identified, an initial draft pipeline alignment was developed based on information from more detailed environmental and engineering surveys.

Available Route Options

140. To identify potential route corridors an appropriate Area of Search was established. The area of search was identified as 242km^2 around the Humber Estuary between Kingston Upon Hull on the north bank and Immingham Docks on the south bank. An area of search of this size allowed all feasible routes to be identified and a robust evaluation to be made. Within this Area of Search five potential route corridor options were identified, as shown in the map in Figure 10.[18]

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[16] Final Route Corridor Investigation Study
[17] Final Strategic Options Report

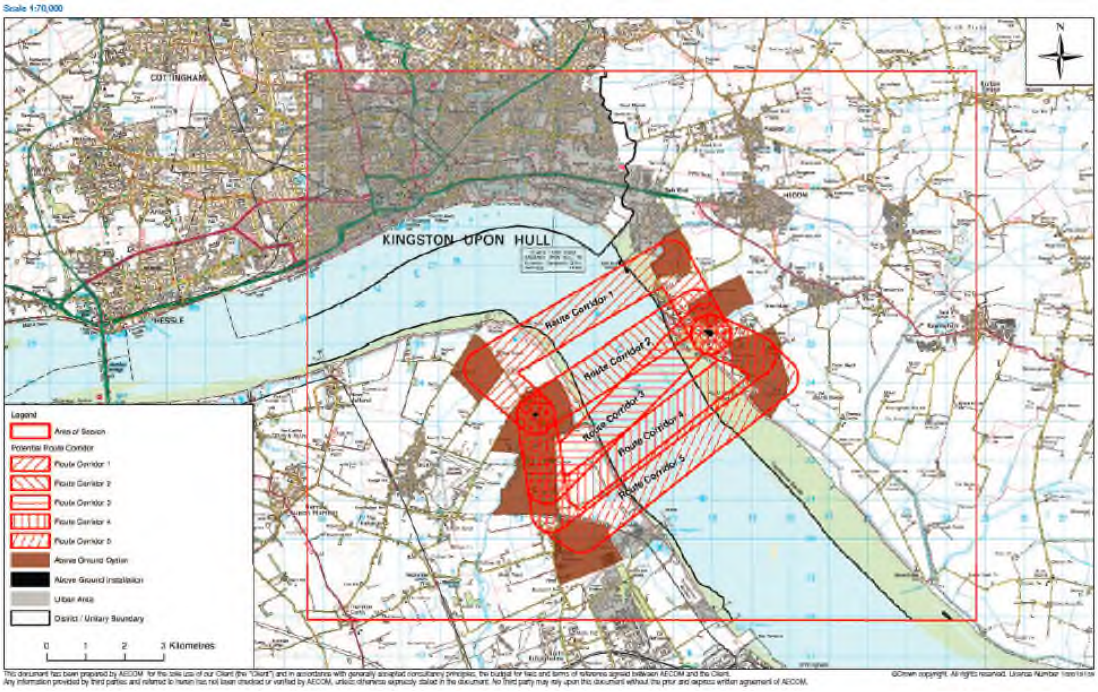

Figure 10: A map of the five route corridors considered for the Route Corridor Investigation Study

Route Corridor Appraisal

141. Full evaluation and OAST were prepared for each route corridor and construction technique, summarising the implications of that option regarding all sub-topics considered under the four main topic areas (environment, socio-economic, technical and cost). The tables provided a summary of the pros and cons of each route corridor and construction type. Additionally, constraint maps were produced that highlighted the constraints across the environmental and socio-economic sub-topics. These maps were used to identify whether an option was likely to be viable and the likely impacts of each route corridor. Further detail is available in the Final Route Corridor Investigation Study Report[18].

Route Corridor Summary

142. All trench options had less expensive capital costs than tunnelled options but compared unfavourably in environmental impacts due to their potential to have a detrimental impact on the Humber Estuary environmental receptors. The environmental importance and designations associated with the estuary meant that environmental impacts had to be included as a material consideration for the route and construction type chosen.

[18] Link to Final Route Corridor Investigation Study Report

143. Additionally, the closure of the channel would be necessary to some extent for trenching, the costs of this were not able to be entirely quantified at this stage.

144. In terms of the preferred route, corridors 3, 4 and 5 were discounted as they would impact on the proposed NSIP Able Logistics Park on the south bank and therefore it was unlikely that these routes would receive planning permission. In addition, route corridors 3, 4 and 5 offered no benefit over route corridor 2 in terms of length and cost.

145. Route corridor 2 was the shortest of all the options and was therefore likely to cause the least environmental and socio-economic disruption. Access to the construction compounds on the north bank and south bank were good and it would be the least expensive option to build. There was no perceived benefit of route corridor 1 over route corridor 2.

146. From this appraisal process, National Grid nominated route corridor 2 as the preferred route corridor to be taken forward to stakeholder consultation. The stakeholder consultation process undertaken did not change this preference and many responses received stated a preference for route corridor 2 and the tunnel construction method.

Conclusion

147. This chapter described the processes that National Grid followed to identify and assess potential options and route corridors for a replacement Feeder 9 pipeline.

148. The route corridor investigation process concluded that route corridor 2 was the most economic and efficient route to take forward to the Front End Engineering Design (FEED) and detailed design phase. This option was supported by the responses received from consultees and provided the best overall solution to the replacement of the existing Feeder 9 pipeline.

149. Although it was identified at this stage that tunnelling was the preferred construction technique as it was the least environmentally detrimental and economically disruptive option, it was still determined that both the tunnel and trench options should be taken forward to FEED. This was to check whether new trenching techniques had become available that might be less environmentally damaging and to ensure there was another viable option if FEED determined that tunnelling would not be possible.

VI. Front End Engineering Design

150. This chapter describes both the Front End Engineering Design (FEED) and design development process that took place, post completion of the route corridor investigation and in parallel with the benchmarking exercise. This chapter demonstrates the comprehensive rigour applied to ensuring that the best option for the consumer was found and moved forward into the project phase. The chapter is presented in the following structure:

- An introduction to the FEED study
- The Front-End Engineering Design Study
- The Crossing Options Report
- The aspects of the reference design

151. The FEED study, included both the technical and environmental evaluations of the crossing selection from the RCIS. This resulted in a Crossing Options Report being produced. Additional work was conducted to thoroughly understand the potential environmental impact. The FEED, considering several comprehensive elements which could materially impact the cost estimate and the programme and included;

- Design life
- Minimum tunnel diameter
- Groundwater management
- TBM selection
- Tunnel design
- Location and type of reception and drive pits
- Pipeline insertion methodology
- Cathodic protection

The Front-End Engineering Design Study

152. The objective of the FEED study was to provide sufficient information to enable a robust planning application, launch a Main Works tender event and provide a more detailed construction cost estimate and programme. Risk reduction was also an overriding objective of FEED, particularly with respect to ground and groundwater conditions, planning consent, pipeline installation and tunnel arisings, the material that is being removed to make space for the tunnel.

153. FEED was competitively tendered via an existing design framework and awarded in August 2013. The FEED process ran between August 2013 when the contract was let, to May 2015 when the procurement tender launched. The call off focussed on the capability of pipeline design as well as tunnel design. The supplier was asked to produce a Crossing Options report that investigated the

most suitable construction technique (open cut trench or trenchless) before completing the full FEED study.

154. In parallel with the FEED study, National Grid also competitively tendered the environmental consultant work package, which was awarded in July 2013. The environmental consultant was required at this stage to support the FEED Study and the development of the screening report that National Grid submitted to the Planning Inspectorate (PINS) to determine whether the scheme was considered a Nationally Significant Infrastructure Project (NSIP) and therefore required an Environmental Impact Assessment (EIA).

Crossing Options Report

155. The Route Corridor Investigation identified the preferred crossing technique as tunnelling as it was the least environmentally detrimental and economically disruptive option, which was supported by responses to the non-statutory consultation.

156. The FEED contractor undertook a Crossing Options Report which was combined with an innovation project which considered emerging crossing techniques and future development.

157. The Crossing Options Report explored four main options:

- Open cut trench excavation
- Immersed tube tunnel
- HDD
- Conventional bored tunnelling techniques

158. It describes the approach that would need to be taken if each technique was used to cross the Humber and identified potential construction issues with each technique.

159. It also considered the construction and whole life costs associated with the open cut and bored tunnel options. These costs were more refined than those developed for the SOR, however they were still purely for comparative purposes at this stage.

160. At this stage, however, several costs were not considered as part of the estimate, including:

- Cathodic protection
- Above ground works
- Land acquisition
- Licences
- National Grid or their supervising agents costs
- Costs associated with obtaining planning and consents

- Any form of compensation payment that may be deemed necessary to offset environmental or commercial damage
- Should the trenching option be taken forward, the cost of the potential closure of the shipping channel was not included, which could lead to 87-143 days of disruption.

161. Additional construction considerations with the open cut option include traversing the flood defences and localised disturbance (with associated restrictions) to wildlife, particularly on the intertidal area, between the low mean and high mean water mark.

162. The Crossing Options Report (COR) considered the technical, cost and environmental challenges to the four techniques proposed for the route. The report concluded that, due to the factors of removing both short and long term damage to the local ecosystem in comparison with the other factors of technical challenges and cost, the bored tunnel option would be the best option.

Detailed Environmental Evaluation

163. The Crossing Options Report applied both the Habitats Directive and the Habitat Regulation Assessment to the specific scenario of trenching the new pipeline to ensure a comprehensive understanding of the potential environmental impact. The Habitats Directive ensures the conservation of a wide range of rare, threatened or endemic animal and plant species. The Humber Estuary is designated as a Natura 2000 site. Under article 6(4) of the Habitats Directive, a plan or project can only proceed on a Natura 2000 site provided three sequential tests are met:

- There must be no feasible alternative solutions to the plan or project which are less damaging to the affected European site(s);
- There must be "imperative reasons of overriding public interest" (IROPI) for the plan or project to proceed;
- All necessary compensatory measures must be secured to ensure that the overall coherence of the network of European sites is protected.

164. Additionally, in applying the Habitats Directive Assessment (HDA) process on an open cut trench crossing of the estuary, and based on the known sensitive environment, it was concluded that the proposal would fail the stage 3 (Stage Three: Assessment of alternative solutions – the process which examines alternative ways of achieving the objectives of the project or plan that might avoid adverse impacts on the integrity of the Natura 2000 site). If National Grid decided to challenge this test and attempt to proceed to stage 4, there was a potential 34 month consenting period and an additional 12 months of required surveys plus the need for compensatory habitat. As a comparison, the nearby Able Logistics Park development has an additional ten-year post construction monitoring period and has had to provide 200 hectares (approximately 500 acres) of compensatory habitat.

Reference Design

165. Following confirmation that a conventional bored tunnel was the preferred crossing technique, the FEED team commenced reference design. Some of the key determinations and benefits of this work are included below.

Design Life

166. Standard design life is provided by National Grid to the FEED designer within the contract documents. The pipeline design life is 40 years, in accordance with IGEM/TD1 Edition 5. The tunnel design life is a minimum of 120 years, in accordance with Eurocode Standards. The standard civil design life provides a whole life cost opportunity to revalidate the existing pipeline beyond its mechanical design life without requiring a new crossing.

167. During FEED, consideration was given to shortening the tunnel design life to determine if this reduced the capital cost, however as tunnel segments are standardised, there was no cost benefit identified for a bespoke design life. It was also noted that there was a high probability (and precedent on the NTS) for revalidation of the pipeline beyond 40 years.

Tunnel Diameter

168. There was no fixed calculation for a tunnel diameter, as it is determined through engineering judgement based on the length between shafts, depth, curvature and activities required during and post installation.

169. At the outset of the design, the minimum recommended diameter was 3.0m (detailed in the Tunnel FEED Report (CS/064298/F9/T/RPT/013). This was based on a number of early assumptions including:

- 5km bored length and the diameter needed for rolling stock crossing points every 1-1.5km to maximise productivity in the tunnel
- Pedestrian walkway requirements in accordance with BS6164 (Code of Practice for Health and Safety in Tunnelling in the Construction Industry)
- Ventilation requirements.
- Compressed air working and air locks for TBM face interventions

170. As the tunnel design and pipeline insertion options were developed, the minimum internal diameter increased to 3.65m to balance productivity and safety. At 3.65m the emergency refuge would be sufficient for all tunnelling operators and inspectors. This minimum diameter was submitted to the HSE in a meeting in June 2015. Additionally, one of the benchmarking cases, Curtis Island, was 0.5km shorter than the Humber crossing and has a 3.65m diameter. The TBM at this diameter would have a longer stroke length (nominally 1.2m rather than 1.0m) between placing tunnel segments, reducing cycle times by 20% (approximately two months off the programme).

Ground and Groundwater

171. Ground and groundwater were the primary hazards for tunnelling activities due to the uncertainty in actual conditions encountered metre-by-metre, impacting the TBM productivity. Sufficient geotechnical site investigation was therefore paramount to the commercial tender for the main works and for developing a robust programme of works.

172. Lessons learnt from prior tunnel collapse from a waste water tunnel in Hull were considered in the design of the geotechnical site investigation.

173. In accordance with BS5930:2015, "Code of practice for site investigations", a geotechnical desktop study was commissioned followed by site investigations. The recommendations within BS5930 and Eurocode 7 are to have ground information every 200m.

174. An initial 16 overwater boreholes and 11 onshore boreholes were completed to depth of up to 55m. Upon review of the factual reports, an additional six were completed, including below the High Mean Water Mark, with the assent of Natural England and the consent of the Marine Management Organisation (MMO).

175. To support and mitigate the ground riskthere was a review of the cores taken and an additional report produced (CS/064298/F9/GEO/RPT/102). The report compared borehole logs with the core photographs to check the lithostratigraphy, fracturing and the CIRIA chalk description and classification grade which helped to reduce risk in the tender bids (cost and time).

176. Ground water and in particular, saline intrusion (pulling salt water into fresh water areas) from tunnelling activities was also a primary concern for the Environment Agency. To mitigate this potential environmental and consenting risk, an innovative pump test arrangement was designed using the existing boreholes with the Environment Agency invited to witness the testing and results. This solution resulted in a significant cost savings. Subsequently the Environment Agency were satisfied that the risks of saline intrusion had been mitigated and could support the consent application.

TBM Selection

177. Post completion of the geotechnical desk top study and noting the hydrostatic head (water pressure) from groundwater, there were two potential types of TBM considered; Slurry Pressure Balance Machine (SPBM) and Earth Pressure Balance Machine (EPBM). The EPBM typically had a lower capital cost than the SPBM, however it was more susceptible to damage from flint and interventions, therefore not necessarily the lowest whole life cost.

178. As there were potential advantages and disadvantages of both types of machine, a preferred TBM was not chosen at FEED and reference design. By not

specifying the TBM type National Grid didn't restrict competition or attract unnecessary liability. Each supplier was responsible for assessing and submitting their TBM proposal taking full cognisance of the whole life cost in the given ground conditions.

Tunnel Design Alignment

179. Before this phase, the FEED process did not overly stipulate the precise location of the tunnel, but stated minimum depths of cover under key features such as the flood defence and the shipping channel[19]. These limits were mirrored in the vertical limits of deviation stated in the DCO.

180. Through lessons learnt from Corrib, Ems and Curtis Island (see [Benchmarking and Best Practice]) and design development, a traditional tunnel with deep shafts and near horizontal drive was discounted for Feeder 9. The pipeline engineers worked collaboratively with the tunnel engineers and developed a "vertical curve" profile under the estuary as the preferred alignment solution. Designing the tunnel curvature not to exceed the natural bend radius of the pipeline (1:4700) would reduce the stress and strain on the pipeline during installation and operation. A vertical curve also permitted longer strings of pipeline to be welded on the surface, reducing the installation time significantly.

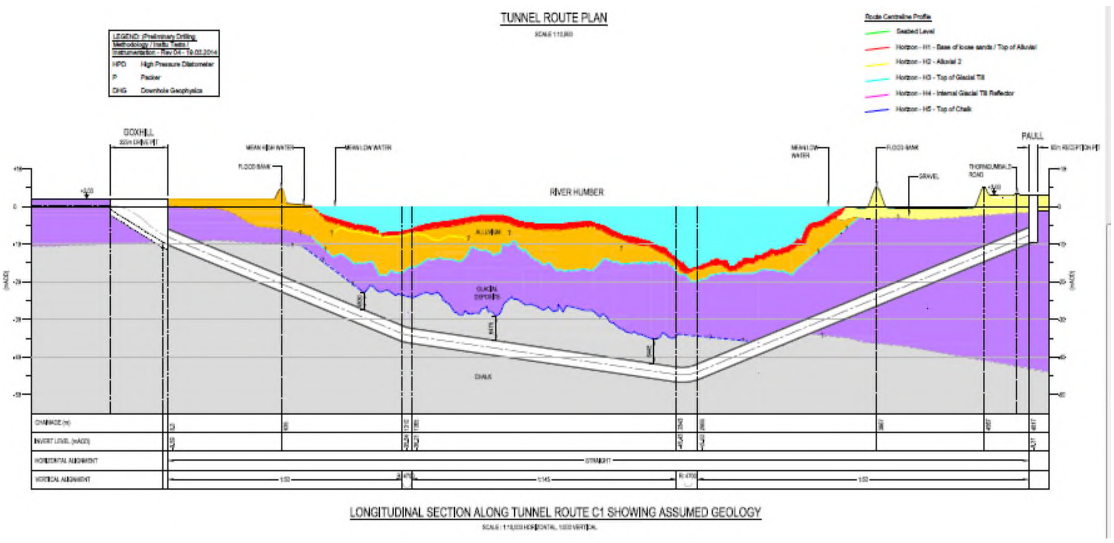

Figure 11: Shows the preferred tunnel alignment developed during FEED

181. There were also considerable safety benefits in this approach as there was no requirement for excessive lifting operations into a deep shaft and no requirement for welding in a confined space.

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[19] For the offshore pipeline design standards require that the pipeline should be located at such a depth as to give a depth of cover of not less than 7m from the true bed of the watercourse, after the removal of any silting, to the top of the tunnel

Drive and Reception Pits

182. Due to ground conditions, environmental sensitivity and availability of land to string pipe ready for insertion, it was deemed preferable to launch from the southern (Goxhill) side of the estuary. If the northern side was selected as the main site establishment there was a risk of working hours, lighting and noise emissions being restricted, extending the programme and associated costs.

183. The preferred location of the drive pit minimised the number of pipeline and road crossings required, plus from desk top studies had the least potential for archaeological impact (and associated potential programme impacts). There was negligible difference in crossing length on the preferred launch location.

184. The preferred design option identified during FEED was a drive shaft that was 60m long x 10m wide x 13m deep. This would be further developed with the pipeline insertion method during the Main Works tender.

Pipeline Insertion Methodology

185. There were no standards or specifications for inserting a 5km pipeline into a concrete tunnel. This was recognised at the outset of the design and resulted in early engagement with the few comparable schemes available to discuss lessons learnt. It was decided that the pipeline insertion methodology should be an area of focus in the procurement event with suppliers being specifically asked to provide alternative bids to identify potential opportunities with the pipeline insertion method.

Cathodic Protection Design

186. During FEED, it was recognised that the cathodic protection design would be challenging due to the limited comparable schemes and the global experience of onshore/offshore solutions. During an early engineering challenge and review, it was apparent that the cathodic protection design would need detailed analysis once the successful main works contractor had finalised the tunnel lining design and installation methodology.

187. In parallel to this, in 2015 National Grid initiated an NIA project to investigate and develop options for CP for pipelines within a tunnel, with particular focus on CP for a flooded tunnel. The project aimed to identify the most appropriate option but also targeted a reduction in procurement and construction costs for CP systems and greater integrity for pipelines within a tunnel.

Tunnel Outline Programme and Budget

188. An outline programme and approximate budget were created as part of FEED. It was estimated that the tunnel drive would take approximately 10 months but the

overall duration from issue of the tunnel tender document to handing over the tunnel for pipeline installation would be in the region of 32 months.

The budget estimate did not include for public road access improvements, pipe supports, pipes, pipeline installation, backfilling of the tunnel or pits or site reinstatement.
Independent Design Check

189. National Grid require designs to be approved and appraised prior to build (T/PM/G35). This process is robust and mature for gas transmission assets, but the civil approval and appraisal does not traditionally include large diameter segmental tunnels.

190. To provide assurance on the tunnel reference design, a CAT III registered design house was engaged to complete an Independent Design Appraisal of the FEED. This review investigated the tunnel design decisions, ground conditions (and associated risk) and contract strategy. Early contractor involvement was reaffirmed as a good contract strategy practice (see Procurement Chapter). The vertical curve solution was accepted by the potential suppliers as a buildable option given ground and groundwater conditions, taking note of the pipeline installation process.

Conclusion

191. The FEED study considered the technical and environmental challenges of the different crossing methods to the route decided from the RCIS. The Crossing Options Report is the result of this consideration and concluded that a bored tunnel was the preferred option, given the parameters considered. Further environmental analysis was also undertaken, which confirmed the significant environmental challenges that would be faced with a trench option.

192. After the FEED study was concluded, the reference design considered many practical elements of the project in detail; from design life to the pipeline insertion methodology to cathodic protection. The analysis and understanding produced from this part of the project were invaluable in moving forward to gain the necessary planning permission and to launch a Main Works Contractor tender event.

VII. Benchmarking and Best Practice

193. This chapter describes the benchmarking and best practices captured by National Grid through engagement with comparable schemes worldwide. The Feeder 9 pipeline, when complete will be the longest pipeline in a tunnel in Europe and the longest pipeline in a tunnel under an estuary in the world. It was therefore necessary to seek out relevant lessons learnt and best practices have contributed to the development of the Feeder 9 project.

194. The chapter is presented in the following structure:

- Introduction of benchmarking to the Feeder 9 project
- Projects explored:
  1. The Corrib Bay Onshore Pipeline Project (Ireland)
  2. The Emstunnel Project (Dutch/German border)
  3. Curtis Island Project (Western Australia)
  4. London Power Tunnels
- Embedding lessons learnt and best practices

Benchmarking and Best Practice for Feeder 9

195. Due to the unique nature and scale of the project there were very few comparable schemes in the world to Feeder 9 for threading a steel pipeline through a 5km tunnel. The project team identified three recent projects, Corrib Bay Onshore Pipeline Project (Ireland), Emstunnel Project (Dutch/German border) and Curtis Island Project (Western Australia), with tunnel lengths between 4km and 4.9km and internal diameters between 3.0m and 3.65m; housing a steel, high pressure pipeline. Contacts were established with all three projects and lessons learnt and best practices captured in parallel to the development of the Front End Engineering Design (FEED) process which started in August 2013. Engagement with comparable projects was also utilised to gain further confidence in the early design principles employed on Feeder 9.

Corrib, Ireland

196. The onshore pipeline element of the Corrib gas project commenced in 2005 and involved a 4.9 km tunnelled section with an internal diameter of 3.0m. A site visit was organised by the National Grid project team and FEED designer to capture best practice and lessons learnt from the Corrib project team. For the most part, the tunnel was driven in a vertical curve alignment through weak rock and granular soils below the water table under Sruwaddacon Bay in Co. Mayo, Ireland.

Figure 12: Successful breakthrough of the Herrenkneckt SPB into a shallow piled reception pit – Corrib, Ireland

197. Following the site visit and a series of discussions, the primary lessons learnt from Corrib were;

- Stakeholder engagement - The project had suffered severe delays (years) due to community and Non-Governmental Organisation (NGO) opposition to the scheme. The associated planning enquiries resulted in years of delays and the operator accepting numerous design constraints. The Corrib experience reinforced the need for early engagement with local communities, as well as council and government bodies.

- Appropriate land-take - Temporary land-take restrictions in the planning conditions restricted pipeline strings to only 72m, hampering the pipeline installation programme by months and increasing costs.

- Tunnel backfill material - Tunnel backfill was explicitly stated as grout in the planning conditions, adding to the project cost.

- The hydro-test of the pipeline created an elastic extension of circa 5m. This could impact the pipeline installation technique and restraint on the pipeline as well as the size and therefore cost of the drive and reception shaft.

- Environmental considerations - Restrictions on environmental noise meant there were times when site operations had to cease, delaying the programme.

- Contract strategy - The tunnel route incorporated several changes of direction in line and level, requiring some pipeline welding in a confined space.

198. A best practice was:

- Rehearsal tunnel - The pipeline contractor had developed a short, above ground section of tunnel for rehearsing the auxiliary utility installation, to drive efficiencies and safety.

199. The Feeder 9 project team shared the early indicative site layout with the Corrib team who were supportive of the land-take identified. At the time, the Feeder 9 project had a limit of 12 pipe sections (circa 144m) welded together which the Corrib team challenged. With up to 700m of space available the recommendation was to develop a Technical Query to the pre-testing limits specified within IGEM/TD/1 Edition 5. With improvements in welding, quality assurance and Non Destructive Testing (NDT), this Technical Query was subsequently developed and approved by National Grid. This reduced the pipeline installation time by an estimated 20-30 days (welding, coating, testing time saved for 18 pipeline welds on the critical path).

200. For the pipeline installation, the Corrib team identified a further option, to create a concrete invert in the tunnel to act as an anchor for the pipeline to then enable a flooded solution, eliminating the need for a grouted annulus. This option was added to the existing pipeline installation options for further development.

River Ems, Dutch/German Border

201. The Emstunnel Project was built in 2009/10 and until Corrib and latterly the Curtis Island projects, it was considered the largest pipeline river crossing in the world. The tunnel was designed to carry a 48” high-pressure gas transmission pipeline between Holland and Germany, and crossed a long stretch of the River Ems.

202. A site visit was organised with Gasunie to discuss the recent River Ems scheme (4.0km crossing, 3.0m internal diameter) as well as a site visit to the River Elber tunnel and pipeline crossing (1.5km crossing, 3.0m internal diameter).

Figure 13: The 48” gas pipe emerging at reception – Ems tunnel

203. The primary lessons learnt from Gasunie were:

- Crossing Option – Horizontal Directional Drill was considered, however when all risks were considered, a tunnel was the preferred solution

- Land-take - Post contract award the new project manager instructed more land-take to process tunnel arisings and prepare the pipeline strings, 90% reuse of arisings, 10% to landfill. This was an amendment to planning.

- Ground conditions (Elber) - Drive shaft experienced delays due to very soft ground conditions. Additional temporary works were required to anchor the shaft to offset the thrust force from the tunnelling activity. The key lesson learnt was to focus on the temporary works of the draft shaft as part of the tender evaluation to mitigate this risk

- Pipeline installation method - Pipeline installation used a rail system, however frequent rails and bogey failures lost weeks on the construction programme. If rail solution is proposed, ensure it is designed as permanent works due to the frequency of loading

The National Grid project team shared the evolving indicative site layout with the Gasunie team who were supportive of the land-take identified.

Curtis Island, Australia

204. The Curtis Island project in Australia was the most similar to the proposed Feeder 9 project. Curtis Island was a 4.3km, 3.65m internal diameter tunnel to facilitate a 1220mm diameter high pressure gas pipeline off the coast of Queensland, Australia. The contract arrangement recognised the pipeline as the primary asset and awarded the main works to a pipeline led contractor. The pipeline contractor,

sub contracted to the tunnelling contractor. This strategy resulted in greater design focus on the pipe installation process at the outset.

Figure 14: Pipeline threading using long pipe strings and Herrenkneckt Thruster Rig – Curtis Island, Australia

205. The additional best practices gleaned from the Curtis Island project were:

- TBM construction - Use of a drive shaft for optimising tunnelling and then modified for long strings of pipeline (circa 360m). This enabled the TBM to be fully constructed (140m) in the drive shaft, reducing the construction programme.

- Pipeline insertion method - A combination of pushing (using a pipe thruster and braking arrangement) and pulling (winch) to install the pipeline. This reduces the potential for stress and strain and aids the guidance through the tunnel

- Pipeline insertion method - Pipeline insertion using a flooded tunnel was recommended to reduce pulling/pushing forces through negative buoyancy

206. Due to the distance of this project from the UK, engagement was conducted via remote communication. However, the project team invited a senior pipeline inspector from the Curtis Island project to attend the Feeder 9 HAZCON (hazard in construction study) to share further knowledge of the pipeline preparation and installation process. A discussion was held over the pipeline coating system and the quality assurance challenges associated with three layer systems, in conjunction with the pipeline installation process.

London Power Tunnels

207. The project team also engaged with the London Power Tunnel project team to discuss key lessons learnt and best practices. This included a small number of site visits to the 3m and 4m diameter tunnels.

208. In terms of the client role the requirement for and application of, a robust Geotechnical Baseline Report (GBR) was reinforced. This contractual document is the most important mitigation measure for ground risk, post geotechnical investigation. The importance of a credible GBR was also highlighted. A GBR that is overly defensive would not drive a robust target price nor be an effective contract document as all risk would be assigned to and therefore explicitly priced by the supplier.

209. Settlement monitoring and equipment was also highlighted as a key contractual requirement to mitigate risk and consequential risk to third party assets.

210. The project team also shared the indicative layout which was confirmed as suitable for use on a major tunnel infrastructure project.

Embedding Lessons Learnt & Best Practices

211. The project team considered all learning against the Feeder 9 criteria and made the following decisions and changes:

Vertical Alignment

212. A primary lesson learnt from the three comparable projects was the "vertical curve" solution for the tunnel profile as opposed to the traditional tunnel construction with deep shafts and near horizontal drive. The vertical curve is essential for the efficient and safe installation of the pipeline. The Feeder 9 solution also reflects this vertical curve principle and is reflected in the DCO vertical limits of deviation. The vertical curve does not exceed 1:4700 (the natural bend radius of the pipeline) to minimise stresses in installation and operation. A vertical curve does require the TBM to handle different strata (predominantly Flamborough and Burnham chalk, then glacial deposits). The TBM specification and the Geotechnical Baseline Report reflect this in the main works contract. The vertical curve also takes cognisance of the depth of cover required under key features (flood defences, pipelines, estuarine alluvium).

213. The drive shaft principle was also reinforced through the engagement with similar projects. The ability to construct a full TBM at the outset of construction, rather than lowering the individual TBM sections and having restricted operation of the TBM until fully constructed, would have a benefit to the programme. From a safety perspective, there are also far less lifting operations required. The temporary works modifications to enable the pipeline installation were also

identified as a primary requirement and therefore specific client requirement in the Main Works contract.

Stakeholder Engagement

214. The importance of effective stakeholder consultation was emphasised from the sharing exercises. Throughout all stages of the development and delivery of the Feeder 9 project, National Grid has undertaken engagement with a wide range of statutory stakeholders and community groups.

215. National Grid also prepared several stakeholder documents as part of the DCO which was approved by the Secretary of State in August 2016. Because of the comprehensive stakeholder engagement that was done early in the process, there was no requirement for additional public hearings and no formal objections sustained. This has helped to ensure that the project timeline and hence cost has not been adversely impacted by stakeholder opposition to the project.

Temporary Land-take

216. Sufficient temporary land-take was another consistent lesson learnt. The National Grid project team had tested the proposed footprint with all four projects.

217. As part of the land-take, environmental sensitivity should be considered. The environmental designation for Corrib was similar to Feeder 9. The EIA Consultant reviewed the Feeder 9 environmental surveys for potential receptors which concluded a risk for lighting and noise restrictions if the main construction compound was on the north side of the river. This was utilised as part of the crossing options and contributed to the southern side of the estuary being selected as the preferred launch location in addition to the preference to drive through the harder Burnham chalk first.

218. By consciously not specifying the TBM type, the project tested the land-take for both Slurry Pressure Balance Machine (SPBM - additional filtration and presses) and Earth Pressure Balance Machine (EPBM - additional land-take for managing tunnel arisings with greater water content). 4D modelling (3D model linked to the programme showing the virtual build sequence) was utilised to test the temporary land-take requirements as well as the hazards during construction. This process also underpinned the planning consent (works plans and land plans).

219. Land-take was also tested for the various pipeline installation options, including the pushing and pulling options.

Pipeline Installation Methodology

220. Noting the range of potential pipeline installation methods dependent on the preference and experience of differing contractors, the project team requested compliant and alternative submissions as part of the Main Works tender event. (A compliant bid aligns to project specifications while an alternative bid explores

other methods to achieve the same deliverable). A compliant bid was provided against the anchored roller design with alternative bids comprising of concrete coating and floatation and rail systems being received.

221. After engagement with the comparable projects, National Grid included a specific requirement in the contract for an above ground section of tunnel to rehearse the auxiliary installation process. The cost benefit is approximately only four hours of tunnelling downtime across a 10 month construction period. This not only provided an opportunity to drive efficiencies, it could also be utilised for inductions and emergency planning purposes.

Contract Strategy

222. The project team decided to include commercial stress and financial stability tests at the earliest (pre-qualification) stage of the procurement process.

223. The lessons learnt reinforced the FEED and main works contract position to ensure tunnel and pipeline are considered and developed in parallel, with the pipeline being the primary asset. There were no restrictions on contract entities, however the pre-qualification and tender process required demonstrable competence and capability in both tunnelling and pipeline construction.

224. The commercial/non-commercial scoring ratio for the tender event was also discussed with the three projects, which highlighted a need to balance the high contract value against the technical difficulty of the scheme.

225. A robust TBM specification was developed for inclusion in the contract (albeit not stipulating the TBM type). Prior to inclusion, the content was discussed with TBM suppliers to ensure the requirements could be achieved on a 3.65m minimum internal diameter machine, ensuring bespoke costs were avoided.

226. A robust GBR was completed and peer reviewed as part of the learning from the London Power Tunnel team.

Conclusion

227. By engaging with project teams from three comparable schemes early on, National Grid ensured that valuable best practice and lessons learnt could be incorporated into the Feeder 9 scheme at an early stage.

228. Benchmarking and best practice from these projects helped to inform FEED and reference design, in particular, the vertical alignment of the pipeline, pipeline insertion methodology, temporary land-take and contract strategy. This has provided cost, safety and programme opportunities as the project developed.

229. Benchmarking reduced costs through avoidance of pre-testing shorter pipeline strings and contributed to the reduction in DCO hearings and associated risk.

VIII. Cost Benefit Analysis

230. National Grid recognised the need for additional rigour in the assessment of the options for Feeder 9. In the context of an NIA (Network Innovation Allowance) project, Business Modelling Associates (BMA) were asked to explore the challenges associated with quantifying the risks of high impact low probability events. BMA would utilise a leading-edge business analytics software in an innovative use case and, coupled with their risk analytics consultancy expertise, analyse the many and disparate data sources associated with this type of investment appraisal.

231. This chapter serves to discuss this project and the value it adds to the Feeder 9 project. The structure of this chapter is:

- Presentation of the innovative CBA (Cost Benefit Analysis) methodology that was applied to the strategic options for Feeder 9.
- Discussion of the results of the integrated model of possible decision routes to mitigate the risk of Feeder 9. This includes the consideration of failure consequences, how key input metrics were varied in stress testing, and the allowance of uncertainty in input data.

The CBA Methodology

232. Two fully integrated decision tree-based models of the investment options were built in the River Logic's proprietary 'Enterprise Optimiser' (EO) platform. They incorporated probability weighted consequences of failure of Feeder 9 valued from a safety, environmental, social, commercial, and reputational perspective. The capital costs of new investments were amortised using a customer bill impact method per National Grid's regulatory settlement. The timescale applied to the analysis was 60 years to capture the full extent of the forecast impact on customer bills of the intervention options. A Monte Carlo simulation was used to investigate uncertainty. Microsoft Power BI data visualisation was used to assimilate results.

233. The project addressed two challenges of cost benefit analysis, namely;

- how to accurately consider the volume and diversity of data generated by impact assessments in a single decision making framework
- how to address the fact that common approaches to cost benefit and net present value analysis tend to emphasise mean or expected values while undervaluing extreme value risks and ignoring uncertainty.

234. The solution developed and tested in this project addressed both challenges. The project developed, tested, and implemented a methodology and business modelling platform that encompassed financial, asset and operational modelling to address extreme value events (low probability, high impact asset failures). The methodology followed a real options analysis approach. The solution developed

using this methodology supported rapid ‘what-if’ scenario analysis, this allowed users to quickly test different assumptions and decision criteria.

235. The approach taken was to model the range of investment choices, consequential decisions, and consequences thereof, as a decision tree. Where multiple decision options or outcomes occurred, the probability of each occurring, or their frequencies, were assigned and determined from expert elicitation or from historic data where possible (for example in assigning probabilities to the early, on-time or late completion of Feeder 9 replacement). Where there was uncertainty in the probabilities or consequences of decisions or outcomes these were modelled as probability density functions. This minimised the use of average values which underestimate extreme risk (tail end risks). Multiple nested decision trees were built, with the final branch being the assignation of costs arising from each decision consequence.

236. There were five scenarios considered:

Scenario	Modelled Scenario Details
Stop Tunnel in 2016 and Mitigate	• MWC not awarded in 2016 • DCO aborted, investment decision made to continue to use current Feeder 9 pipeline • mitigating the risk of pipeline failure due to TPI and free spanning using inspection and concrete frond mattresses. • There remains a risk of critical failure (rupture) of the pipeline due to TPI or free spanning.
Stop Tunnel in 2017 and Mitigate (Mitigate 2017)	• Same as above except that MWC was awarded, and then cancelled in 2017
Tunnel Replacement start in 2012 (Referred to as Tunnel (2012))	• Decision made to replace Feeder 9 with a new pipeline within a concrete tunnel bored underneath the Humber Estuary • This new pipeline is not exposed to the two critical failure modes of the current pipeline (TPI or free-span) • Current pipeline is decommissioned
Trench Replacement start in 2012 (Trench (2012))	• Decision made to progress trenching option. • DCO takes until early 2018 due to increased environmental constraints • Construction finishes in 2019 • Same failure modes as for existing pipeline, but probability of reduction of these risks is extended for 20 years after construction.
Stop Tunnel in 2016 and build Trench (Trench (2016))	• Tunnel DCO is applied, but the decision is made to not continue as NG leadership then decide to go with trench option. • Trench DCO awarded in April 2019, construction begins in May 2019 and finishes early 2021.

Results

237. In summary, the models developed were successfully able to compare the risk adjusted NPV of constructing a new pipeline (via both a tunnelled and trenched construction method) with an enduring maintenance regime of the existing Feeder 9 (Mitigate 2016 and Mitigate 2017 scenarios). The model integrated a broad range of costs and risks to provide a robust analysis drawing on a wide body of data. Risk was represented both as probability and frequency to capture both low probability and high frequency risk events, including extreme risks (low probability, high impact risks). The risk to safety, environmental, social, commercial, and reputational outcomes were effectively considered in the model. Where input data was uncertain, that uncertainty was directly represented in the model.

238. In addition to successfully delivering an extreme risk-adjusted analysis of the NPV of the main options to manage the risk associated with Feeder 9, the solution also demonstrated some of the core modelling capabilities the wider NIA project is to develop with the additional case studies.

239. Model results showed a significant cost benefit of the tunnel solution over the next best option. , Key cost drivers are the potential impact on consumer bills of Feeder 9 isolation (minimised in the case where pipeline replacement has already been consented and planned) arising from capacity buy-back costs, the risk of loss of life due to a catastrophic failure, and the impact on the wholesale price of natural gas owing to reduced supply availability in the Easington area. Across the full range of stress test scenarios, the tunnel-based pipeline replacement project remains the highest value (lowest cost) solution, indicating that the tunnel option is robust and is therefore the preferred approach.

IX. Planning, Consents and Stakeholders

240. The purpose of this chapter is to describe the consenting process undertaken by National Grid for the Feeder 9 project and the stakeholder management that took place alongside. The structure of this chapter is:

- The Development Consent Order (DCO) Process and conditions, other planning requirements and outcome
- Stakeholder engagement

The DCO Process

241. A DCO is the means of obtaining consent for developments categorised as Nationally Significant Infrastructure projects (NSIPs) under the Planning Act 2008. The DCO process for NSIPs consists of six main stages:

1. Pre-application
2. Acceptance
3. Pre-examination
4. Examination
5. Recommendation and Decision
6. Post Decision

242. As part of this process, National Grid sought determination from the Secretary of State on the type of planning requirements necessary for the project. Due to the project scale and the considerable environmental designations afforded to the Humber location, it was determined that National Grid's normal permitted development rights that exist for such projects were not applicable due to a positive screening determination from the Planning Inspectorate (PINS) that an Environmental Impact Assessment (EIA) for the project needed to be carried out. Therefore, the DCO process had to be followed.

DCO Summary

243. National Grid was granted DCO planning permission for a tunnelled replacement of the Feeder 9 pipeline in August 2016. The decision made by the Secretary of state was received one month ahead of the allowed deadline.

244. The project scale and considerable environmental designations afforded to the Humber location meant that National Grid had been unable to progress the project under its normal permitted development rights. The screening decision from the Secretary of State concluded that the project would require an EIA and would therefore need to follow the DCO planning process presented significant risks that could have led to potential delays to the programme.

245. Through a proportional and well-planned approach, National Grid mitigated these risks by working with statutory and non-statutory stakeholders to address concerns early in the DCO process. This continued stakeholder engagement led to a reduction

of three planning hearings, which reduced the risks associated with consenting delays and delivered a cost saving. A further amount assigned to consenting risk was also retired due to lower than expected clarifications from the Planning Inspectorate.

246. As part of the DCO approval National Grid were given several DCO conditions that need to be discharged as the project progress. The project is continuing to discharge these DCO conditions successfully with all milestones achieved to date and no increase in costs nor time.

DCO Conditions

247. Post approval of the DCO, the project team commenced agreeing the stages of authorised works that would facilitate the programme of works and agree which documentation, outside of the core requirements, would be submitted at each stage of the project to satisfy the 19 requirements stipulated. This key activity was required to mitigate risk of the DCO conditions impacting the programme.

248. The project team initially agreed this with the contractor, then invited the representatives of both local councils to discuss in advance of submission to gain an approval in principal of how the DCO would be managed, both in respect of which documentation would be required at each stage and the logistics of submission.

249. Seven stages of project development were laid out, currently Stages 1-5 have been accepted, Stage 6 has been completed and Stage 7 (reinstatement) is due to be submitted at the end of the calendar year 2018.

Other Planning Requirements

250. In parallel to the DCO process, local planning applications for enabling works in advance of the DCO determination (traffic management, demarcation of land-take and topsoil stripping) were applied for with North Lincolnshire District Council, to reduce risk to the overall programme (ahead of possible conflicts of working under the DCO parameters during the first winter of the scheme). **Stakeholder Engagement**

251. Throughout all stages of the development and delivery of the Feeder 9 project, National Grid has aspired to engage positively with stakeholders that could be impacted by the scheme. These stakeholders include local communities, utility companies, government bodies, NGO's and landowners.

National Grid's Approach to Consultation

252. When engaging with affected communities, National Grid has built upon its knowledge and experience to develop a multi-stage approach to DCO pre-application consultation. This provides consultees with opportunities at formative stages of the project to comment on, and influence the design. In developing the approach to consultation, National Grid has considered the specific requirements set out in the

relevant legislation and in internal guidance documents such as the 'Stakeholder, Community and Amenity Policy'[20].

253. By building on previous knowledge and expertise in consultations for infrastructure projects (most recently and particularly the carbon capture pipelines), completing thorough engagement with the affected local planning authorities on approach to engagement; and by having regard to accessibility, National Grid conducted meaningful and effective stakeholder engagement on the Feeder 9 project.

Identification of Stakeholders

254. Under the Planning Act 2008, there are two separate formal stages of pre-application consultation: Section 42 with prescribed consultees (e.g. Natural England, Environment Agency, English Heritage), local authorities, landowners and others with interests in land; and Section 47 consultation with the local community in accordance with the Statement of Community Consultation[21].

Stakeholder Engagement during Strategic Option Appraisal

255. A draft Strategic Options Report (SOR) was issued to statutory consultees and key stakeholders for comment, in May 2012. Responses received identified options 1a (tunnel), 1b (trench) and 1c (HDD) as the most favourable options to take forward primarily due to their lower cost and reduced environmental impact. Any comments received from consultees were documented and used to inform the final recommendations of the strategic options appraisal.

DCO Stakeholder Engagement

256. Proportionate pre-application consultation is required under the Planning Act 2008 for a NSIP such as the Feeder 9 project and is critical to the success of the DCO application.

257. Consultation on the Feeder 9 project was undertaken at a series of stages to help manage the balance between consulting early and having the necessary details for consultees to provide meaningful feedback. At each stage of the consultation process, clear parameters were set out to explain to consultees what decision(s) the specific stage of consultation was designed to inform. Where necessary National Grid undertook supplementary consultation to ensure that local communities and stakeholders were consulted on changes made throughout the project development.

258. The pre-application consultation on the project commenced in 2012 and comprised two main stages, the non-statutory (Stage 1) and statutory (Stage 2) consultation. These activities are outlined in the April 2015 Consultation Report.[28]

[20] Link to Stakeholder, Community and Amenity Policy
[21] Link to Statement of Community Consultation

Stakeholder Satisfaction

259. To support National Grid's drive for successful and long lasting stakeholder relationships, and in line with the RIIO stakeholder satisfaction incentive, satisfaction surveys are carried out with stakeholders impacted by major works at key stages throughout the project lifecycle.

260. Ten stakeholders from the Feeder 9 project met the criteria for the satisfaction survey and agreed to be interviewed. These stakeholders gave the project an overall score of 8.3 with three respondents scoring ten out of ten. Respondents gave particularly high scores for National Grid demonstrating the right behaviours (score of 9.67 achieved) and for ensuring National Grid were available to discuss issues in relation to the project (score of 8.7 achieved).

261. All scores received were above the incentive target of 7.4, but the key areas of improvement highlighted by the respondents included ensuring that the provision of information met their needs (score of 7.6 achieved) and ensuring that National Grid had taken account of environment and sustainability issues in the design of the project (score of 7.89 achieved). The comments received from the survey helped to shape the engagement Action Plan that was developed to improve the way in which National Grid engaged with stakeholders on the Feeder 9 project.

DCO Stakeholder Engagement Summary

262. All representations received during the non-statutory and statutory pre-application consultation stages were considered in the development and refinement of the project. National Grid took great care to analyse and consider all feedback received and published a feedback report ahead of the statutory consultation. Details of all the consultees and their responses can be found in the Consultation Report[22].

263. In general, consultees supported National Grid's preferred option, route corridor and construction technique. Thus, the main decisions made based on the feedback received included; taking the preferred route corridor forward to Stage 2 (route corridor 2); adopting a tunnel approach and building a short temporary private road to divert construction traffic away from South End, which has also improved the image of National Grid in the community. Where changes were not made National Grid clearly articulated to consultees the reasons why and published information which fully explained these reasons.

264. The stakeholder engagement conducted during pre-application was in accordance with the published SOCC and the requirements of the Planning Act and therefore the DCO was granted in August 2016. The engagement undertaken at this stage has helped to support further engagement as the project has progressed into project delivery.

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[22] Link to Consultation Report

Stakeholder Conclusion

265. Throughout all stages of the development and delivery of the Feeder 9 project, National Grid has undertaken engagement with a wide range of statutory stakeholders and community groups.

266. The statutory and non-statutory consultation that took place during strategic optioneering and route corridor investigation helped to shape the decision to select the tunnel replacement pipeline as the preferred solution. Stakeholders were particularly concerned with the potential traffic issues associated with the project so National Grid worked alongside them to answer their queries and listen to their concerns. Thus, National Grid could alter the traffic management plan to better suit the needs of local communities. This helped to reduce the number of objections and issues raised during the DCO process.

267. The positive score of 8.3 received for the Stakeholder Satisfaction Survey in 2015 further supports the work that National Grid has been doing in this area to ensure that stakeholders feel engaged in the project. This contributed to the Secretary Of State's decision to grant the DCO in August 2016.

268. National Grid will endeavour to maintain and improve upon this level of engagement to ensure that stakeholders remain engaged and positive about National Grid's presence in their community.

X. Procurement

269. The purpose of this chapter is to introduce the comprehensive procurement process that was used for the Feeder 9 main works contractor and the outcome of the stages along the process. The chapter will focus primarily on the procurement process followed for the Main Works Contract (MWC) as this was the highest value contract let for the Feeder 9 project. The structure of this chapter is:

- The procurement process for the main works contractor
- The results of the stage gates along the way
- Other contracts issued over £1m

Introduction

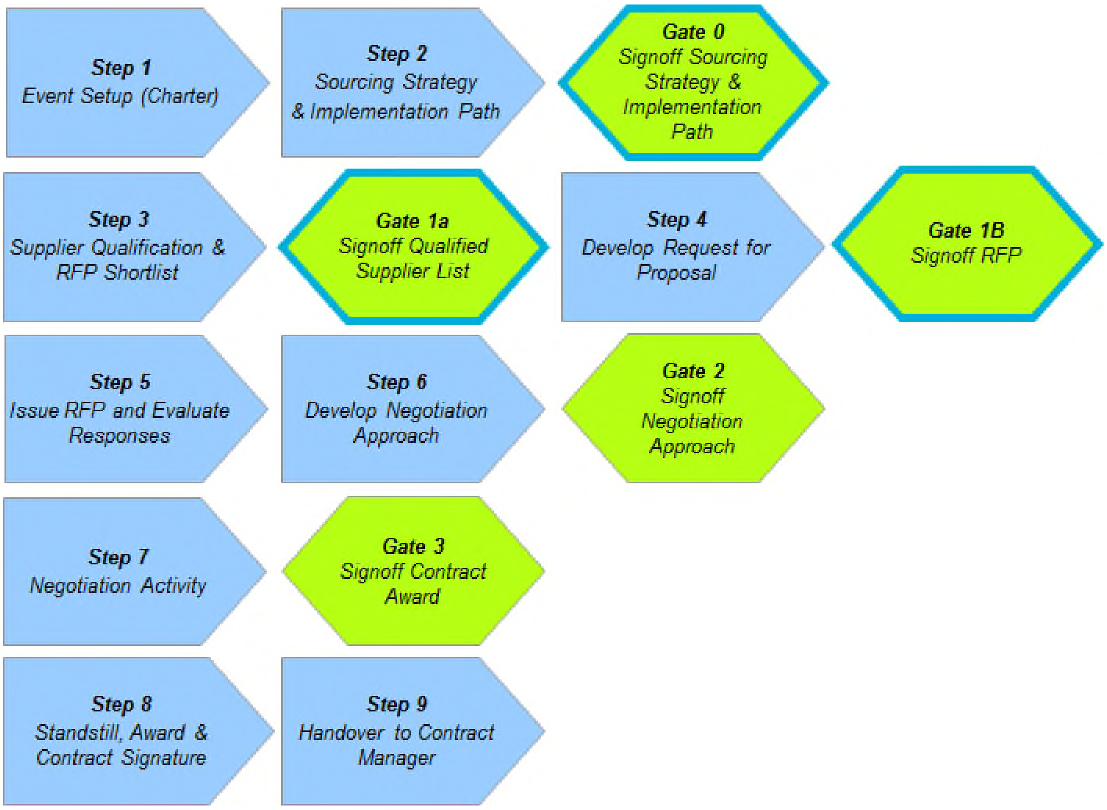
270. The right procurement strategy was essential to the efficient delivery of the project and commenced early in the design, once the preferred crossing option had been established. Noting the unique nature of the project with high risks of ground conditions and the pipeline interface with the tunnel it was key to develop a contract strategy that would balance risk and reward to achieve the most economic price.

271. The procurement strategy was both iterative and competitive to allow National Grid to appoint a competent contractor to deliver the preferred replacement project. Additionally, the retention of project costs and risks until suitable design development had been completed ensured a truly competitive tender was completed, avoiding the potential for uncertainty to be priced into the baseline tender evaluation.

Procurement Process for the MWC

272. To ensure that the Feeder 9 Project was delivered efficiently and cost effectively, National Grid developed a procurement strategy to support the project delivery plan. National Grid utilised its existing Strategic Sourcing Process (SSP) comprising five gateways and nine steps through the project life cycle to reach the appointment of a competent and capable supplier through a competitive tender process. The steps and

gateways were broken down into the following process:



273. The procurement process was supported by a multi-discipline team of National Grid employees (hereby referred to as the 'contract team'). This team was responsible for approving the project through the stage gates.

Steps 1, 2 and Gate 0
Sign Off: July 2014

274. Steps 1 and 2 involved the establishment of the procurement event and the development of the procurement strategy. This culminated in the Gate 0 sign off where the "Heads of" contract team approved the scope of the event, detailed business requirement, resource commitment, roles and responsibilities and timelines. Key activities that took place in Steps 1 and 2 were the development of the contract and lotting strategies.

Steps 1 and 2 - Contract Strategy

275. Noting the challenging nature of a tunnel and pipeline project, significant emphasis was placed on the contract strategy. The contract strategy was developed through late 2013 and into the spring of 2014, based on the preferred crossing technique established through route corridor investigation and FEED. A Request for Information (RFI) was also issued prior to the contract strategy to gain a market insight into potential contract options as well as for feedback on key project challenges.

276. In developing the contract strategy, National Grid took full cognisance of lessons learnt from the few comparable projects to Feeder 9

277. The FEED Consultant was also asked to independently identify appropriate forms of contract for the project. They engaged with tunnelling subcontractors who identified NEC and IChemE burgundy book as the industry standard for tunnelling. This was consistent with the output of the RFI.

278. National Grid evaluated the types of contract considering comparable projects and further engaging with industry experts. The tunnelling industry preference appeared to be for NEC target cost due to balancing scope flexibility (the supplier's proposal would be based on in house experience and available equipment, which precedes detailed design), risk appetite (particularly ground conditions affecting TBM drive rates) and opportunity (incentivised gain share) but there was not one consistent approach that was applied to all projects. The IChemE burgundy book was predominantly used in the water Industry for tunnelling projects and National Grid Gas had limited experience of this contract type. The NEC contract had been used by National Grid for the River Exe tunnelled pipeline project and all high-pressure pipeline contracts in the past 10 years, therefore there was recent experience within National Grid of applying this contract type.

279. Based on the information obtained from industry experts, the experience of National Grid in the application of NEC contracts, and the learning gained from similar projects, it was determined that a NEC contract would be preferable for the Feeder 9 project.

280. National Grid decided to progress with a NEC C contract, with well-defined pain/gain share parameters to allow for the right levels of incentives and shared risk.

Early Contractor Involvement

281. Through the contract strategy development and benchmarking exercises the opportunity for Early Contractor Involvement (ECI) was considered and included in the procurement scope. In essence, ECI provides a grant (under OJEU rules) to down-selected suppliers with an objective to reduce programme, costs and risk. A particular advantage of ECI for target cost (NEC Option C) contract is all savings are to the benefit of the client, the gain mechanism does not commence until contract award.

Steps 1 and 2 - Lotting Strategy

282. It was also important to select an optimum lotting strategy and contract entity that could help to mitigate risks associated with the complex nature of the project. There were three options considered for the lotting of the tunnel and pipe works:

- Single Lot (tunnel and pipeline joint bid)
- Separate Lots (tunnel or pipeline bid)
- Choice of either/or (option to bid for either one lot or both lots)

283. A single lot joint venture approach would benefit National Grid as it would give greater visibility and direct interface over two specialist contractors under one contract. This would mean that National Grid had greater programme integration and reduced interface management. The joint venture approach would also avoid paying fee-on-fee and attract more contract players.

284. Separate lots would allow suppliers to focus on their specific area of expertise. It would also ensure suppliers capable of only part of the scope were not excluded. Separate lots would mean that there was a risk of compensation events caused by delays by “others” with the varying suppliers, creating a “lose lose” scenario for the client. National Grid would also have to manage procurement, Construction Design and management (CDM), programme and contract interfaces. It would also mean that there would need to be multiple tender events which could prolong the length of the procurement phase.

285. Allowing bidders to choose an either/or scenario would ensure full market coverage and give bidders the option to join up with their preferred partners, however it would complicate and lengthen the evaluation process. The inherent link between the pipeline installation, tunnel lining and cathodic protection system would increase the contract interfaces if separate lots were pursued.

286. Based on the advantages and disadvantages of each approach and the responses received from suppliers during the RFI phase, it was determined that a single lot was the most economic and expedient option.

Gate 0

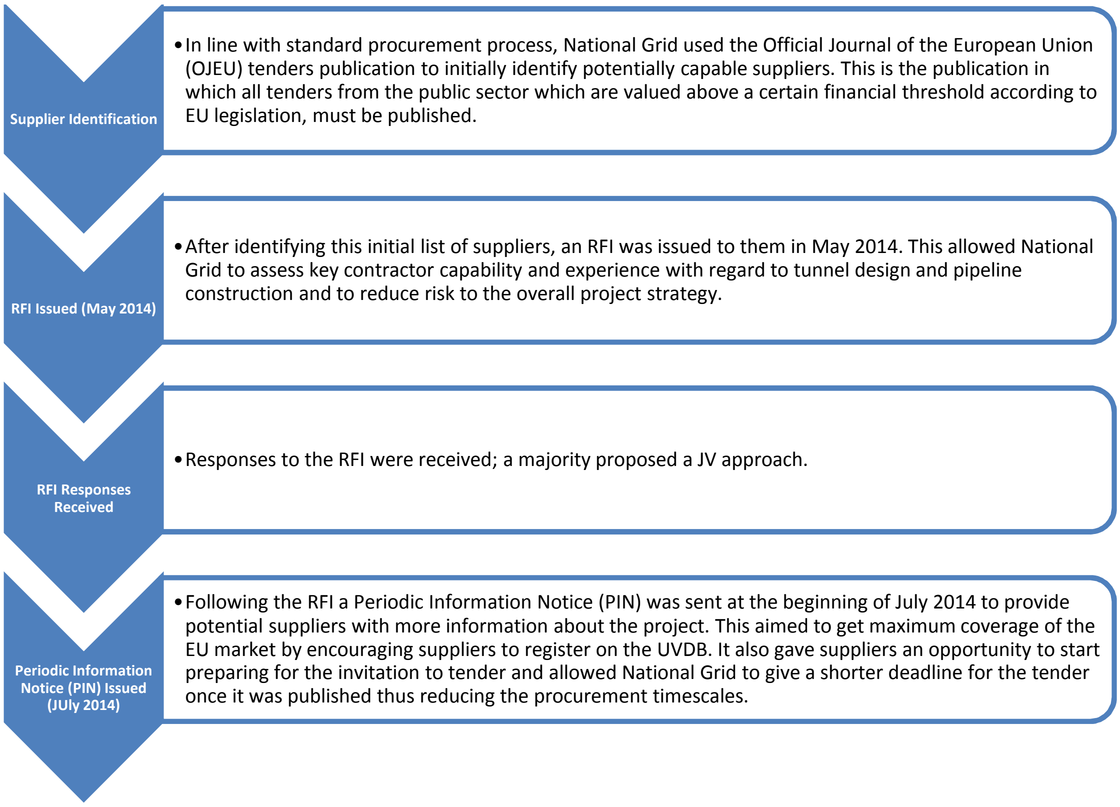
287. Gate 0 was signed off by the contract team in July 2014. It approved the contract and lotting strategy developed during Steps 1 and 2.

Step 3 and Gate 1a
Sign Off: November 2014

288. Step 3 was used to gather information on supplier capability and experience in order to identify a shortlist of potential suppliers to take forward. During this stage, suppliers were initially identified which were then down selected to potential tenderers. This culminated in the Gate 1a sign off confirming that the down selected tenderers identified were capable and competent of delivering the project.

Step 3

289. National Grid followed the below process for early identification and selection of suppliers:



290. After the initial supplier identification, National Grid conducted an Additional Questions (AQ) process that was launched 21 July 2014. The AQs were sent to suppliers that were identified as having a sufficient turnover to undertake the project as well as the relevant UVDB codes (an online system for pre-qualification of health, safety, environment and quality management systems as well as compliance with EU procurement regulations). They were asked questions on financial stability, insurance, health and safety, environment, quality assurance and design and construction experience. These criteria helped National Grid to establish the capability, experience and suitability of suppliers and helped to do an initial filtering out of suppliers who were not capable of delivering the project.

291. National Grid also ran a Detailed Additional Qualification (DAQ) process in parallel with the AQ process. The DAQ process aimed to gather further information and was part of the down selection process aimed at finding the most capable supplier. The process was launched in July 2014 and concluded in September 2014. By running the supplier identification, AQ and DAQ process the initial list of suppliers was down selected to take forward to the Request For Proposal (RFP) process and supplier engagement days.

Gate 1a

292. For the Gate 1a sign off, the contract team were asked to approve the list of tenderers to be taken forward to RFP and Gate 1b. **Step 4 and Gate 1b**
Sign Off: March 2015

293. Step 4 was used to develop the RFP that would be sent to the down selected suppliers inviting them to tender for the Feeder 9 project. This culminated in the Gate 1b sign off confirming which tenderers would be invited to submit a tender, the detail of the requirement they were tendering for, and how the tenders would be evaluated.

Step 4

294. Before the RFP was sent out, National Grid contacted the down selected suppliers to organise technical supplier days. The technical supplier days involved National Grid inviting each of the suppliers to individually meet to discuss the project in greater detail and to provide feedback on their DAQ responses.

295. All suppliers were provided with identical, general information and were given heatmap feedback on their AQ and DAQ submissions. The supplier days helped to further inform them of the project, provide updates on the project status and timeline, provide geotechnical site information, access to the borehole cores, and provide the draft TBM specification; this helped to reduce the risk of suppliers needing an extension of time during the tender and increase cost certainty in the bids.

296. The RFP tender evaluation criteria focussed on commercial and non-commercial capability. It utilised three key pieces of source data to inform the commercial and non-commercial evaluation; the project risk register, the CDM risk register and the outputs from the pre-qualification stage. This ensured that only the high priority and differentiating elements of the project were included in the evaluation which helped to streamline the process.

297. At this stage suppliers were invited to submit both compliant and alternative bids. They had to submit the compliant bid that met the minimum threshold for commercial and non-commercial criteria. Alternative bids were invited to ensure that tenderers were allowed to propose genuine opportunities for innovation and commercial efficiencies, including those outside the base scope.

298. The pain/gain mechanism to be applied to the successful supplier was also developed during Step 4. This was to be directly linked to the supplier's performance against 5 Key Performance Indicators (KPI) in design and 8 KPI's in the construction phase. The KPIs focussed on safety, risk assessment and method statements (timeliness due to programme impact) and environmental performance.

Gate 1b

299. The evaluation team evaluated all of the proposals put forward in Gate 1b and reviewed the project charter to ensure that the business requirements were still being accurately reflected. The RFP documentation and control and governance were approved in March 2015.

Step 5, 6 and Gate 2
Sign Off: October 2015

300. Step 5 involved issuing the agreed RFP to the down selected suppliers and evaluating the responses received. Responses were received from suppliers and National Grid undertook a number of clarifications with these suppliers to ensure that information was complete and anomalies resolved. One of the bids received failed the RFP. In Step 6, the negotiation strategy that would be used with the remaining down selected suppliers was developed. This process concluded with the Gate 2 sign off of the negotiation approach.

Step 5

301. During the challenge and review stage the evaluation team initially read through bids looking for missing documents and anomalies. Over this two-week tender review period the evaluation team raised over 600 clarifications with the suppliers. These clarifications helped to ensure that all necessary content was available before moving on to the full evaluation. It also helped to drive robust pricing as any ambiguity could be addressed at this stage ensuring like-for-like cost comparisons.

302. After the challenge and review, National Grid carried out the full evaluation and gave each of the supplier's initial rankings based on the commercial elements of their bids.

303. The non-commercial evaluation (Heath & Safety, Technical, Environment and Quality) took place in parallel with the commercial evaluation. The contract team challenged and reviewed the questions that were answered as part of the non-commercial bid.

304. To ensure that the bids being submitted were an accurate reflection of market prices, National Grid's internal estimating hub (ehub) also created an estimate for the works, based on the reference design. This provided a useful benchmark when evaluating the bids submitted by the suppliers, particularly where genuine efficiencies were proposed between the reference design and submitted bids as well as areas whereby costs were particularly high or low, enabling clarifications to be raised. *Step 6*

305. Throughout the evaluation process a number of common areas of risk were identified including the pipeline insertion methodology, geotechnical site investigation at Paull mudflats, TBM delivery plan, spoil treatment and the shaft and tunnel alignment design.

306. It was therefore proposed that the biggest risks to the project be addressed through an Early Contractor Involvement (ECI) process as part of the negotiation strategy. This would allow National Grid to work with each supplier to further reduce cost and mitigate programme risk.

Gate 2

307. Based on the RFP evaluation it was recommended that the contract team take forward the compliant suppliers to ECI and the negotiation stage of the procurement. Having multiple suppliers for the negotiation stages provided a greater opportunity to

capture innovation opportunities and also reduced National Grid's exposure if one of the bidders decided to drop out.

308. To ensure impartiality of all the bids, each supplier was provided an anonymous name.

Step 7 and Gate 3
Sign Off: March 2016

309. Step 7 covered the negotiation activity that took place with the down selected suppliers post RFP. Completion of this step was followed by Gate 3 sign off which confirmed that the contract team approved the contract award recommendation.

Step 7

310. To further reduce cost and programme risk, ECI was approved by the contract team at Gate 2 and was undertaken in parallel with the negotiation strategy. Through a review of the capital cost estimate, the critical path and the project risk register, a number of deliverables were identified to reduce cost and programme uncertainty. These included the drive/launch pit design and location, the tunnel alignment (including location of the curve transitions), ground conditions under the Paull mudflats and developing the tendered TBM specification into a procurement ready TBM specification. This activity reduced the overall prices by a significant amount.

311. Negotiations with the down selected bidders took place between November 2015 and January 2016 with final bid submissions in January 2016.

Gate 3

312. The contract team approved this approach in March 2016 and a NEC C contract was awarded in May 2016.

Additional Contracts Awarded

313. As well as the MWC, a number of other smaller value contracts were also let to support the Feeder 9 project. Contracts over £1m in value are summarised in the table below:

	Service Provided		Date of Contract Let	Date of Contract end	Contract Type	Procurement Process Followed
	Detailed and Conceptual Design		Aug 2013	Dec 2019	NEC Professional Services (E)	Full tender event – Design Services Framework
	Project Services		Apr 2017	Jul 2019	NEC Professional Services (E)	Full tender event – Project Services Framework
	Material Purchases (free issue linepipe)		Jan 2017	Feb 2018	Line pipe sourcing agent	Framework supplier
	EIA		Jul 2013	Dec 2019	NEC Professional Services (E)	Full tender event – Environmental Services Framework
	Inspection Services		Oct 2017	Jan 2020	NEC Professional Services (E)	Inspection Services Framework

314. The FEED contract was a competitive tender from the Design Services Framework and awarded on an Option E basis. The scope included intrusive site surveys (onshore and offshore) to further develop the project to inform the cost estimate, risk register and tender event

315. Key FEED deliverables included the crossings option report, the FEED report and reference design for the pipeline and tunnel. All of which fed into the main works tender event. The scope is described in the Front-End Engineering Design and Reference Design chapter.

316. A significant proportion of the contract value related to intrusive onshore and offshore ground investigation. Ground and groundwater conditions are the primary risk on a tunnelling project, therefore appropriate and proportionate geotechnical site investigation is critical to the success of the project. In accordance with BS5930 Code of Practice for Site Investigations, the FEED designer completed a geotechnical desktop study to inform the scope of geotechnical site investigation (specification) covering both onshore and offshore (overwater) works.

317. After the main works tender event, the FEED supplier has been retained as the pipeline designer, to ensure design liability for the primary asset is maintained.

318. A supplier for project services was competitively tendered from the project services framework to support the Project Manager in delivering the project and administer the contract for the duration of the design and build. This includes the site duties of a client under the CDM Regulations, discharge of DCO conditions, inclusive of the third-party engagement and commercial assessments of contractual claims. Roles include, planning, commercial, document control and site assurance.

319. National Grid has an established materials framework to source and quality assure bulk volumes of materials (such as linepipe to the required specification) with a dedicated supplier. This framework is nationwide and delivers volume discounts. The line-pipe for the crossing and associated pipework tie-ins at the Above Ground Installations was procured by National Grid through this framework and free issued to the main works contractor.

320. The environmental services contract was awarded through a competitive process via the Environmental Services Framework on an Option E contract (time reimbursable).

321. In terms of core scope, due to the potential adverse impacts on a Natura 2000 site an Environmental Screening Report was required to determine whether the project would require an Environmental Statement in accordance with the EIA Regulations. A positive screening report resulted in the compilation of the Environmental Impact Assessment, in support of the DCO.

322. The inspection service supplier was selected from a mini competitive tender from the Inspection Services Framework. The independent inspection assures the integrity of the tunnel and pipeline assets. Inspection activities include the factory and site acceptance testing, assuring the offloading of pipe and transfer of liability to the main works contractor, the welding, coating and testing requirements for the pipeline and the reinstatement of the land to minimise compensation claims from tenants and landowners.

Conclusion

323. National Grid followed a structured, competitive tender approach for the award of the MWC and all procurement activities were completed as early as reasonably practicable to reduce the overall project programme.

324. The evaluation team comprised National Grid employees and where appropriate, external, subject matter experts with relevant experience and expertise. This ensured that the right skill sets were available to evaluate bids and that primary risks were continually mitigated. A robust and iterative approach to the evaluation process meant that non-compliant, high risk proposals were eliminated.

325. National Grid worked with potential suppliers to ensure that all relevant information was shared equally and that feedback to tender responses was sent promptly and was clearly articulated. Where possible design and site data was issued early to the potential suppliers, reducing the risk of an extended procurement timeline but most importantly to reduce the uncertainty in the tendered prices.

326. The contract type chosen was NEC C target cost which was beneficial as it does not require absolute certainty in scope (not to restrict opportunities and efficiencies) and promotes innovation and is appropriate for the nature and risks (particularly ground conditions) of this project. A robust pain/gain mechanism was agreed that was directly linked to the suppliers KPI performance. This ensures poor performance or good performance is addressed appropriately.

327. ECI was used to allow National Grid to work with each supplier to further reduce cost and mitigate programme risk ahead of submission of their final bids. This resulted in a net reduction in overall prices. Furthermore, this method has been shared as best practice across National Grid to help improve the procurement process for major projects across the company.

The main works contract was awarded in May 2016 to a JV comprising Skanska, A.hak and PORR. Skanska are the major civils contractor, A.hak brings expertise in pipeline testing and insertion and PORR brings significant experience and expertise in tunnelling activities.

XI. Project Delivery

328. The purpose of this chapter is to present the project delivery from main works contract award in April 2016 up to the start of tunnel boring in April 2018. The structure of this chapter is:

- The project scope and description
- The project timeline
- The detailed design
- Construction progress

Introduction

329. The project involves replacing the National Grid Feeder 9 crossing of the Humber estuary with a new 1050mm diameter pipeline inserted into the 4.86km long 3.65m internal diameter segmental tunnel. Once constructed, this project shall be the longest pipeline in a tunnel in Europe and the longest tunnelled, pipeline crossing of an estuary in the world.

330. A project of this magnitude faces many challenges. The key engineering challenge (as with any segmental tunnelling project) is ground and ground water conditions. Additionally, the unique challenge to a pipeline in a tunnel is the interface between the pipeline installation, cathodic protection and tunnel lining.

331. As part of the contract strategy it was recognised that the pipeline installation, cathodic protection design and tunnel lining contained uncertainty and was reliant upon the successful bidder's proposals prior to resolution.

332. The project is driven by a timeline with several key milestones, distributed across four distinct phases: detailed design, enabling works at the two construction sites, Goxhill and Paull, tunnelling and pipeline works. At the time of this submission, the tunnelling and pipeline phases have commenced.

Project Scope and Description

333. This project entails the construction of a tunnel up to 30m below the Humber for nearly 5km, the installation of the pipeline, the connection of the new pipeline to the existing connections in the NTS and the decommissioning (make safe) of the original Feeder 9 that is trenched in the River Humber. The enduring solution for the existing pipeline is outside the scope of this project.

334. There are two construction sites, Goxhill and Paull, that will be connected by the tunnel. The enabling works at Goxhill commenced in September 2016 and the construction phase commenced in March 2017. The enabling works at Paull commenced August 2017, with the construction phase commencing May 2018. Core working hours will be between 0700 -1900 hours Monday to Friday and 0800 -1600 on Saturdays with tunnelling activities undertaken seven days a week, 24 hours a day. There may be a requirement to undertake other construction activities on a Sunday. However, HGV movements would be restricted at the weekends.

335. The permanent works comprise of:

- The buried pipeline
- The tunnel
- Nitrogen monitoring for the existing pipeline
- The cathodic protection equipment.

336. The land use would be returned to its existing use and all hedges and vegetation loss reinstated. An easement agreement with the landowners would allow access for future inspection and maintenance. At Goxhill, there will be a small area of permanent landtake to the north-eastern side of the AGI for the nitrogen monitoring kiosk for the existing crossing and the stopple and bypass fittings for the new crossing tie-in. At Paull, the only additional, permanent land take will be a cathodic protection kiosks, nitrogen monitoring kiosk, cables and the marker posts.

337. The existing pipeline will be filled with low pressure (<2barg) nitrogen to mitigate internal corrosion whilst the permanent intervention is determined and monitored from these kiosks. This area will be post and rail fenced. There will also be a cathodic protection kiosk for the new pipeline and marker posts that will typically be 2m high and positioned every 500m with smaller marker posts positioned at each field boundary.

The Pipeline and Tunnel

338. The activities undertaken during FEED, EIA and the tender process were used to develop a schedule of works for project delivery, which included approximately 6km (now 5.5km through detailed design development) of pipeline of up to 1050mm diameter with a maximum operating pressure of 70barg from Goxhill AGI to Paull AGI. This pipeline is comprised of:

- 5.03km of concrete lined tunnel under the Humber Estuary with a minimum internal diameter of 3.65m and a maximum internal diameter of 4m (reduced to 4.86km through detailed design development);
- 120m of pipeline laid onshore at Goxhill and 400m at Paull for the connections to each AGI;
- Cathodic protection facilities;
- Connection works and minor modifications to the Paull AGI;
- Connection works to the existing pipeline at the Goxhill AGI;

339. For the offshore pipeline under the Humber Estuary, it was established that the pipeline should be located at such a depth as to give sufficient cover from the true bed of the watercourse, after the removal of any silting, to the top of the tunnel.

340. The onshore installation of the pipeline will be laid to a contour at a depth of cover of not less than 1.2m (in accordance with National Grid Specification T/SP/ P/10) from the original surface to the top of the pipe. The trench will be excavated so that pipes are evenly bedded throughout their length. Minor variations in contour will be excavated to minimise field bending.

341. The minimum depth of cover for the onshore section of the pipeline in relation to a public highway is 2m (in accordance with T/SP/P/10). The depths of highway

crossings are also influenced by third party services and the depth of adjacent ditches.

342. The pipeline is designed to have a minimum operation life of 40 years and the tunnel a minimum design life of 120 years.

Construction Works on the Goxhill Side

343. The main construction work, including the launching of the TBM, is being carried out from the southern side (Goxhill). The tie-in works at Goxhill will be outside the boundary of the existing AGI. The compound and site area includes several temporary construction areas, including the following:

Site area	Description
Site Establishment, Administration and Welfare Compound	• Hardstanding, temporary cabins (temporary administration and welfare cabins), including car parking spaces • Topsoil storage bunds (3m in height to assist with screening, however no higher to mitigate compaction and damage to the topsoil) • Waste compound and laydown areas • Generator compound • Foul water system
Tunnelling Compound	This area is set around the drive pit and includes: • A crane pad • Tunnel segment storage • Excavated spoil treatment plant • Generator compound • Laydown areas • Subsoil and topsoil storage bunds (3m in height for topsoil, 4m in height for subsoil) • Surface water and dewatering management • A working width for pipeline trenching
Pipe Storage and Stringing Site	This area is surrounded by 3m high topsoil storage bunds and is set out immediately behind and in line with the drive pit to allow as much of the gas pipeline to be fabricated and Non-Destructively Tested (NDT) prior to its installation within the tunnel, including: • Pipe storage to receive, inspect and store pipe prior to its fabrication along the pipeline alignment and stringing site • Pipeline fabrication laydown area for materials and equipment • Pipe stringing area for the fabrication of seven pipe strings for insertion into the tunnel.
Stopple and Bypass at Existing Feeder 9 Crossing	A work area for the new Feeder 9 pipeline and tie-in to the existing crossing
Surface Water and Dewatering	This area is required to both manage water generated within the site and for the testing of the pipeline and includes:

Management Area	• Hydrostatic test water to prove the integrity of the fabricated pipe • Groundwater management area to control the quality of discharged water • Dewatering management area to control the quality of discharged water • Topsoil storage bunds (of 3m in height)
Spoil Management Area	The excavated spoil from tunnelling will all be processed at the Goxhill site, for storage, possible re-use or disposal. Prior to removal from site, spoil will be stored in bunds of a maximum height of 3m
Temporary Access Works and Passing Places	This includes a series of road widening and road improvements that have been undertaken at key locations along the access routes to facilitate the safe movement of construction traffic. This included the timely diversion of an Overhead Power Line.

Construction Works on the Paull Side

344. The replacement pipeline will be accepted at the reception shaft via the concrete segmentally lined tunnel that will be installed under the Humber Estuary. A section of standard pipeline will connect the new crossing into the existing AGI at Paull. The temporary compound and site area includes a number of areas, as outlined below:

Site area	Description
Site Establishment, Administration and Welfare, Pipeline Compound	• Access track • Temporary administration and welfare cabins including car parking spaces • Waste area • Laydown area for pipeline and AGI works • Trenchless crossing launch • Reception work areas for pipeline crossings • Work area for pipeline trenching • Topsoil bunds (3m in height)
Tunnelling Compound	This area is set around the reception shaft and will include: • A crane pad • Tunnel work areas including workshops and stores • Generator compound • Laydown areas • Subsoil and topsoil storage bunds (3m in height); • Surface water and dewatering management • A working width for pipeline trenching to existing AGI
Stopple Pit on Existing Feeder 9	A work area is required on the south west edge of Paull AGI in order to decommission the existing Feeder 9 crossing

Crossing	
Settlement Monitoring Area	Required to monitor settlement associated with the construction works
Temporary Access Works and Passing Places	An existing private track will be the main construction access route and this has been subject to localised improvement and widening, as well as other road improvements at key locations to facilitate the safe movement of construction traffic.

Ground Conditions and Weather Challenges

345. The ground conditions that the tunnel must go through, in addition to issues with flooding and weather in the areas around the construction sites, pose significant challenges to the project.

346. Specifically, the tunnel will pass through Burnham and Flamborough chalk for approximately 4km, then cross into glacial till. Glacial till contains a mixture of clays and boulders of varying size. Flint boulders and voids are the key risks with chalk, leading to interventions for changing cutter discs more frequently, or injecting grout to fill voids. A functional Tunnel Boring Machine (TBM) specification was issued as part of the tender and explicitly required the suppliers to demonstrate how the nominated TBM would manage the differing strata.

347. In the early stages of the project, an onshore and offshore geotechnical site investigation was completed to inform the delivery and to mitigate ground risk. Additionally, an independent review of the borehole cores was conducted. A Geotechnical Baseline Report (GBR) was issued to capture and apportion ground risk within the contract.

348. Due to the open nature and location next to the estuary, weather is also a risk, particularly wind. To mitigate this, the site has been constructed to minimise the number of lifting operations.

Feeder 9 Project Delivery

349. The project is broken down into four distinct phases; detailed design, enabling works, tunnelling and pipeline works.

Detailed Design

350. The detailed design is on the critical path and must be completed in advance of tunnel launch and to gain acceptance from third parties.

351. The key components of the detailed design package are;

a. TBM specification and design
b. Slurry treatment plant (STP) design
c. Cathodic protection detailed design

d. Pipeline installation design
e. The tunnel lining design
f. The tunnel alignment

Tunnel Boring Machine design

352. The MWC opted for a new slurry TBM, specific for the project. As part of the Early Contractor Involvement, the MWC developed the TBM delivery plan. These proactive measures assisted in the timely design, manufacture and Factory Acceptance Testing (FAT) of the TBM prior to shipping to the project.

Slurry Treatment Plant Design

353. The MWC developed and designed an STP to fulfil the requirements and predicted ground conditions. The STP is inherently linked to the operation and performance (it is essential to process the arisings) of the TBM insofar as throughput of arisings impacts the productivity of the tunnelling closed loop system. The STP is also designed to reduce the moisture content in the arisings to potentially enable reuse as opposed to landfill. Regardless of the STP design, the risk of the alkalinity of the arisings remain, with associated risks of the arisings being treated as a waste by the EA. Additional boreholes and leachate tests are being completed to refine the probability and cost impact of this risk.

Cathodic Protection

354. In this phase of detailed design, the long term cathodic protection for a pipeline in a segmental tunnel and the inherent linkage to the tunnel lining design and pipeline insertion methodology was a key pipeline integrity concern. With the reliance on a completion of the detailed design solution, this risk and opportunity was owned by National Grid at tender awardA detailed challenge and review was completed, identifying six options. A risk assessment was completed as part of the workshop and the six options were reduced to two. Both options were acceptable, therefore a cost benefit approach was required.

355. Based on the conclusions of the challenge and review, supplemented by internal and external subject matter experts, the optimum design was selected as the final solution.

Pipeline Installation

356. At the tender stage, contractors were asked to provide alternative bids to identify potential opportunities with the pipeline insertion method compared to the designed roller method. *Tunnel lining design*

357. The MWC carried out a detailed review of the existing ground investigation data and carried out some supplementary geotechnical site investigations to develop a tunnel lining design with a 120-year design life as required by the Eurocode Civil design codes.

358. This design was developed in conjunction with several other design disciplines including the TBM, pipeline insertion and cathodic protection designers. One key risk associated with the tunnel lining was the potential degradation over time due the operation of the pipeline cathodic protection system. This relatively new and uncodified phenomenon was investigated by the contractor using specialist academic support and a model developed to predict the levels of degradation. The tunnel lining along with the launch pit and reception shafts were independently checked by suitably competent and independent designers (known as a category III check) to provide independent assurance of their suitability.

Tunnel Alignment

359. The revised tunnel alignment, ground investigation results and associated tunnel lining were reviewed and assured by a tunnelling specialist.

Enabling Works

360. Due to the timings of the DCO determination there was a risk of up to a 6-month delay and MWC standing costs to the project as mobilisation would be coinciding with the winter of 2016. To mitigate this, a local planning application was pursued for early enabling works.

361. The local authority planners advised this would be an acceptable approach and advised that the conditions in the DCO would be mirrored to the enabling works.

362. The enabling works included topsoil strip, creation of the internal haul roads, placement of passing places along the traffic management route, placement of crossings on site, early completion of archaeological works, diversion of an Overhead Power Line (OHPL), water vole works and badger protection works.

363. The project already had an accepted vole licence and submitted the badger works licence in tandem with developing reduced documentation in line with the 19 DCO requirements for the works.

364. The local planning application was submitted and signed off to schedule, allowing the project to commence in September 2016 rather than March 2017.

365. Other smaller planning applications have subsequently been submitted during the project; two additional passing places in response to local resident requests and the raising of the amendment of silo numbers and heights as the detailed design has progressed.

Tunnelling

366. The tunnelling element of the project represents the highest risk activity during delivery. This is due primarily to the risk of ground conditions that could lead to potential TBM issues.

367. To mitigate the tunnelling programme and risks, a short section of above ground tunnel was constructed at Goxhill. This permits the rehearsal of installing auxiliary

equipment, interventions to the TBM cutter as well as rehearsals for emergency planning.

368. The tunnel boring machine was designed, constructed and passed factory acceptance tests prior to a successful delivery to site throughout December 2017. Due to the size and weight of the TBM sections, an abnormal load order was required. This included utilising a Network Rail bridge which required third party approvals. Post assembly of the TBM, it has been subject to Site Acceptance Tests prior to tunnelling.

369. The dewatering system and secant piles (overlapping concrete piles drilled into the ground for moderately deep excavations, typically up to 30m)was part of the DCO conditions. . Once the base was cured, the system was modified to a passive system, in accordance with the DCO. Tunnelling commenced on the 5th April 2018.

Paull (northern side)

370. The tunnel reception area has been topsoil stripped and the pipe delivered to site to connect the tunnel swan neck through to Paull AGI. Piling has commenced on the reception shaft. The settlement monitoring array has been established on the approach to the reception shaft.

Pipeline Works

371. The pipeline stringing area, capable of fabricating multiple pipe lengths of up to 700m has also been completed. Appropriate inspection and quality controls were put in place due to the substantial loading from the concrete coated pipes, once in situ.

372. The pipe has been manufactured and shipped in preparation for the coating to be applied. Integrity checks have been successfully completed.

373. The pipeline will arrive and quality assurance checks completed on the coating, ovality and bevel ends, in preparation for welding. Noting the poor ground conditions underneath the highway, laser scanning is being completed to monitor for any dilapidation and appropriate remediation action required. The highway condition is captured on the project risk register.

Conclusion

374. The project delivery phase for the Feeder 9 pipeline replacement, which will be the longest pipeline in a tunnel in Europe, is well underway and several key milestones have been reached:

- The detailed design is approaching completion, with uncertainty of the permanent design resolved on key aspects including the TBM, STP, pipeline installation and cathodic protection design. The final steps are design approval and appraisal.
- The TBM passed the Factory Acceptance Testing and was successfully delivered to site on time, in preparation for Site Acceptance Testing and launch.

- The launch pit has been successfully constructed, in particular the dewatering system has been completed and operational in “passive” mode as per the DCO condition and to the acceptance of the EA.
- The STP has been designed and constructed with supplementary leachate and ground testing completed to refine the risk range of the arisings being treated as an inert or active waste.
- The pipeline has been delivered and testing successfully completed.

375. Tunnelling is now underway and the next phases of the project will be progressed in the coming months, with a planned project completion date in early 2021.

XII. Governance

376. The purpose of this chapter is to provide an overview of the governance process followed by National Grid to approve the Feeder 9 project investment decision and manage delivery. The structure of this chapter is:

- Governance Code and Network Development Process
- Project Governance
- Feeder 9 Sanction Stages, including Optioneering, FEED and Contract Award

Introduction

377. All Capex projects over £50k within National Grid follow the Gas Transmission Owner Governance Code to sanction and monitor investments. Its purpose is to ensure there is appropriate accountability for investments and to make sure necessary changes in sanctioned costs, timescales and project scope are managed.

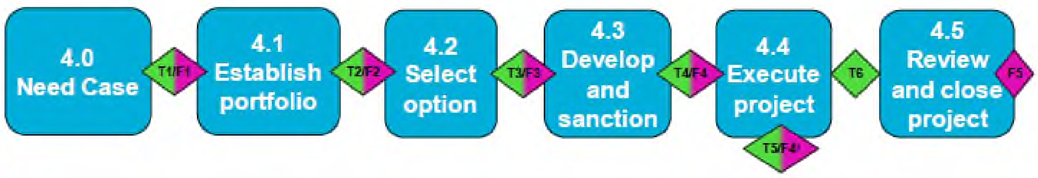
Governance Code and Network Development Process

378. All National Grid investments in the regulated business follow the rules set out in the Governance Code. The rules set out in this code are mandatory for all transmission investments following the Network Development Process (ND500 process). The NDP process was introduced in April 2014 and the Feeder 9 project transitioned to the new process in November 2014 at stage 3 (equivalent to conceptual design and planning submission) of the sanction process.

379. The Governance code covers the process and requirements for the technical and financial decision points within the ND500 process. The financial decisions points are required to approve the future spend for the first and next phase of investment and to ensure that the solution selected is still the right decision for the business.

380. The overview below summarises Level 2 of the ND500 process; it shows the six stages of the process and how the process stage gates are arranged to control the movement of investments from stages 4.0 to 4.5. The process stage gates are differentiated between Technical Stage Gates T1 to T6 ('green diamonds') and Financial Stage Gates F1 to F5 ('pink diamonds')

Figure X – Network Development process – Level 2 Overview



381. For ND500 projects the applicable Financial Stage Gate checklist is required to be passed before a sanction paper can be submitted for approval. The 'Responsible Owner' who will provide the information required for a successful pass of the financial stage gate is the sanction paper author..

Project Governance

382. Within the project structure there are three levels of delegations of authority (DoA).

383. Whereby the estimated cost to complete exceeds the upper sanction (P80) or the completion date is exceeded, the project is returned to the Investment Committee, with a challenge and review of the business case and an evaluation of alternate and mitigating options. At this stage a re-sanction may be required if the project still forecasts outside of governance, even after post mitigation actions, yet the business case remains valid.

Feeder 9 Sanction for Initial Optioneering

Sanction PAC 2260 – June 2010

384. In June 2010, after completing a number of emergency remediation activities, National Grid approved the first sanction paper to explore alternative solutions for the existing Feeder 9 crossing. This pre-works sanction paper (PAC 2260) approved spend to progress the initial development of alternative investment solutions that could mitigate the risks associated with estuary sediment erosion of the Feeder 9 pipeline. The spend was required to enable initial optioneering work from June 2010 to August 2010 that would derive the range of potential options to be taken forward to consultation and development in line with the Planning Act 2008. At this early stage, three alternative solutions were identified:

- New tunnelled crossing of the Humber[23]
- Onshore pipeline and compression solution
- Offshore pipeline and compressions solution

Sanction PAC 2260 – October 2010

385. In order to enable progression of preliminary studies, in October 2010 a re-sanction of PAC 2260 was submitted. This sanction paper included a competitive tender to revisit the Environmental Impact Assessment (EIA) for a new tunnelled crossing of Feeder 9 which was previously undertaken as part of the Fleetwood storage facility entry capacity signal work in 2007. Revisiting the Fleetwood storage facility EIA would help to inform the scope of a new Feeder 9 specific EIA should it be determined by PINS that the project was EIA development.

386. In addition, in anticipation of future stakeholder consultation requirements it was decided that the tendering exercise for the EIA should also include an option to undertake route corridor investigation and site selection. **Feeder 9 Sanction for Strategic Optioneering and Route Corridor Investigation**

[23] The tunnelled crossing was based on experience at London Power Tunnels and a 2.44m internal diameter in clay.

Sanction PAC 2260 – September 2011

387. In September 2011, an updated sanction PAC 2260 was submitted to progress to the next phase of pre-works sanction investment. The sanction request was driven by the need to progress strategic optioneering to a point where an appropriate enduring Feeder 9 solution could be identified.

388. The full strategic optioneering process associated with the project took place in 2011 and 2012. Through network analysis, the initial options list contained 44 potential options that fell under three broad categories; direct estuary crossing, onshore pipeline and offshore pipeline. This list went through significant internal challenge and review in order to down select this to the seven most viable options that could be taken forward to the SOR (this is covered further in Chapter IV – Strategic Options Appraisal).

389. Following the appraisal Options 1a (tunnel replacement) and 1b (trench replacement) were identified as the preferred strategic options to be taken forward to route corridor investigation. All other onshore and offshore pipeline replacement options were discounted at this stage.

390. National Grid used the optioneering work studies to inform its RIIO-T1 submission where the potential options and costs were outlined. Ofgem determined that at this stage in the replacement development, there was too much uncertainty over costs and timing of the project to provide full ex-ante funding. Ofgem therefore proposed to provide an allowance to undertake preliminary engineering and licensing activities and included an additional uncertainty mechanism for ‘one off asset health shock’ stating that: ‘NGGT can apply for the appropriate funding upon granting of planning permissions’. This funding arrangement was confirmed in the December 2012 Final Proposals document.

391. The Route Corridor Investigation Study (RCIS) published in May 2013 further appraised the preferred direct crossing construction options (tunnel and trench) and identified potential route corridors. Costs were further refined at this stage based on more detailed information on the route length and potential constraints. The trenched options were cheaperbut had significant environmental constraints associated with the technique (see Chapter V – Route Corridor Investigation for further details). As a result of the study, and the subsequent stakeholder consultation, the preferred solution to take forward to FEED was the tunnel option. However, due to the tunnel complexity and potential for new and emerging trench techniques to develop, the trenched option was also carried forward to the initial stage of FEED for further investigation.

Feeder 9 Sanction for FEED

392. During FEED the preferred replacement solution for the Feeder 9 pipeline was identified as a conventional bored tunnel. The information collected through FEED and reference design allowed for more detailed cost estimates to be developed.

Sanction PAC 2260 – February 2013

393. Following the strategic optioneering process a Stage 2 sanction PAC 2260 was submitted in February 2013. This was to complete the construction FEED study, the EIA and second stage public consultation on the preferred direct crossing solution up to planning permission submission.

The reduction in the cost estimate range was due to greater certainty in activities and deliverables, post challenge and review against DCO and tender requirements. It was highlighted at this stage that a re-sanction in the form of a Stage 3 sanction would be required after the FEED study to complete detailed design, DCO preparation and submission once costs were more fully understood. *Sanction PAC 2260 – November 2014*

A Stage 3 sanction PAC 2260 was submitted in November 2014 and was required to further extend the scope of works to deliver the DCO and achieve the critical path. This was the first time National Grid Gas Transmission had delivered a project under the DCO process and there were only two National Grid Electricity Transmission projects that had secured DCO approvals at this time and National Grid Carbon submitted one for Humber Carbon Capture and Storage, which some members of the project team had experience of.

394. The higher percentage of project management costs (project services and NG staff costs) were reflective of the positive decision to compile the DCO related deliverables in house, with support from the EIA consultant, rather than through supplementary legal support at greater cost.

Feeder 9 Sanction for Contract Award

Sanction PAC 2260 – April 2016

395. The Stage 4 sanction PAC 2260 was approved in April 2016. The sanction stages associated with PAC 2260 prior to Stage 4 had focussed on the approval of the investment for the preliminary works to achieve the appropriate design and planning permissions for the chosen replacement option. At this point, the need case was challenged and it was reconfirmed that it was necessary to replace.

396. The Stage 4 sanction was based on the unpredictable nature of the Humber estuary and the potential rapid failure mode (which had already broken the adjacent Feeder 1); and the criticality of Feeder 9 to gas supplies for the UK. The Stage 4 sanction sought approval for the full investment with a closure date of 2021.

397. The approval of this sanction paper allowed for the MWC award to be progressed in May 2016 and mobilisation works began on site in September 2016.

Feeder 9 Re-Sanction

398. The investment has been re-sanctioned in April 2018 to reflect the latest estimated cost to complete and the extension of time required.

399. Key activities such as completing the enabling works (avoiding winterisation and MWC standing time costs) establishing the drive shaft with a passive dewatering

system; the delivery and site acceptance of the TBM have been completed and the costs captured into the base. Risk has been retired associated with the TBM delivery, third party crossing agreements and dewatering drawdown on East Halton Beck. The DCO conditions have been successfully discharged with only the reinstatement condition to be submitted by the end of the calendar year 2018.

Conclusion

400. The Feeder 9 project has followed a prescriptive governance and sanction process since 2009, which has ensured that robust investment decisions were taken at every stage in the project's development.

401. The appropriate Delegates of Authority and sanction committees scrutinised and approved the sanction papers submitted and in April 2016 made the decision to progress with a tunnelled replacement of the Feeder 9 pipeline.

XIII. Risk Mitigation and Opportunity Realisation

402. The purpose of this chapter is to present the risk process that is used to dynamically consider risk for the Feeder 9 project and to discuss the top, current risks to the project. The structure of this chapter is:

- Risk Management Approach
- Previous significant Feeder 9 risks
- Current major risks to the project

Introduction

403. Hazard identification and the management of risk to ensure their reduction to a level 'as low as reasonably practicable' is integral to the considerations in the planning, design, procurement and construction of tunnel and pipeline works. This chapter describes the risk management process undertaken to identify and mitigate uncertainty and risk inherent in the delivery of the Feeder 9 project. A description of the top risks that were present at the time of full project sanction in April 2016 through to this reopener submission is included. The risk information used to inform the April 2016 sanction was taken from the December 2015 risk register. The risk information used to inform the April 2018 re-sanction on time was taken from the March 2018 risk register, which is summarised in the Appendix.

Risk Management Approach

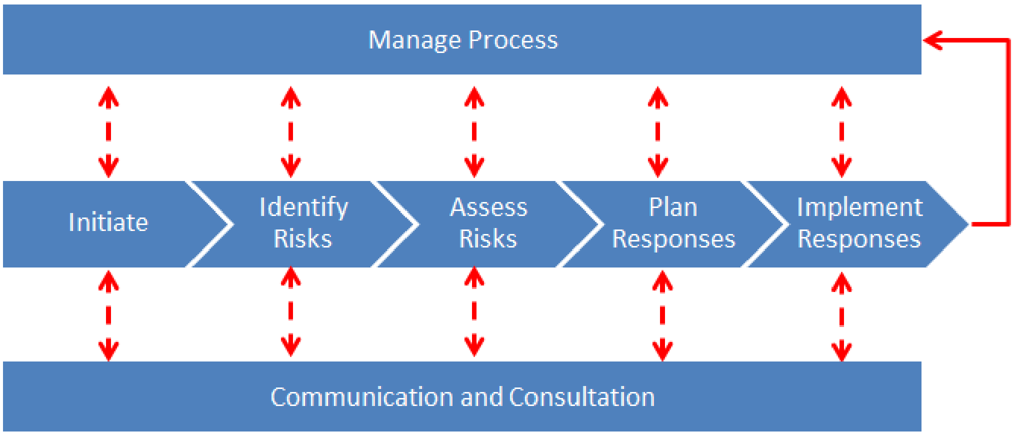
404. The processes for managing threats and opportunities in delivering projects and programmes are set out in the National Grid Project Risk Management Construction Phase Gas (NSBP181G). The risk procedure is consistent with the processes mandated in National Grid's Corporate Risk Policy as well as reflecting industry best practice. This procedure sets out a framework to manage reasonably foreseeable risks in a manner which is proactive, effective and appropriate. The objective is to maximise the likelihood of the project achieving its expected outcomes whilst maintaining risk exposure at an acceptable level.

405. Noting the tunnelling nature of the project, the risk management process also took cognisance of the requirements of "A Code of Practice for Risk Management of Tunnel Works, January 2006", developed by the International Tunnelling Insurance Group. The particular objective of this code is to promote and secure best practice for the minimisation and management of risks associated with the design and construction of tunnels, caverns, shafts and associated underground structures including the renovation of existing underground structures. It sets out practice for the identification of risks, their allocation between the parties to a contract and insurers, and the management and control of risks through the use of risk assessments and risk registers.

406. This Code of Practice was developed because of tunnel failures. Of note, a tunnel collapse occurred in Hull during 1999 with an additional cost impact of £55m. The collapse caused a surface depression some 60m in diameter and up to 2.6m deep.

The estimated volume loss was 2600 cubic metres, filling some 400m of tunnel and the recovery of the tunnel required freezing of the ground.

407. The risk process is summarised below and is broadly based on ISO 31000:2009, Risk management – Principles and Guidelines:



408. It covers all activities undertaken during the lifetime of a project or programme from inception, through design, development and implementation and including transition to operations and project close down defined in National Grid's Investment Process (Network Development Process or ND500 process). Throughout the Front End Engineering Design a monthly risk workshop was held, reviewing the sanctioned stage. Confidential construction risk workshops were completed through FEED, in preparation for the main works contract.

Risk Identification Process

409. The aim of the risk identification process is to identify all risks that might affect the project objective over its lifetime. This includes the following risk types:

- Risks intrinsic to the nature of the work being undertaken;
- Risks associated with the management environment;
- External risks that could affect the project or the assumptions on which the project is based;
- Risks associated with the implementation approach being proposed; and
- Risks associated with the contractual relationship with stakeholders, suppliers and other parties

Preliminary Hazard Analysis and Safety Review

410. Noting the complex nature of the project, a Preliminary Hazard Analysis and Safety Review (PHASR) was conducted during FEED to inform the project and CDM risk registers.

411. A PHASR is a study that examines the causes and consequences of perceived issues in determining the true significant hazards and the acceptable level of risk. It

enables the early identification of hazards and major hazard potentials as well as the evaluation of accident scenarios and critical deviations in operation and construction that may result in an unwanted consequence.

412. A PHASR is the initial identifier of significant hazards and risks, and engineering challenges that must flow through the project lifecycle to a fully considered engineering system and safe solution.

413. The three unacceptable items identified at the PHASR were, dewatering (launch pit and flooding of the tunnel), planning conditions and the tunnel closure process. The following actions were taken in order to mitigate these risks:

- To reduce dewatering activities to an acceptable level of risk, a hydrological impact assessment and consequently pump tests were completed to inform the temporary works launch pit design
- A dedicated DCO coordinator was brought into the project team to align all FEED and EIA activities for the planning consent
- A series of tunnel acceptance certificates were developed and included in the contract to demonstrate the acceptance of the tunnel pre-and post-installation.

414. These actions significantly contributed to the reduction in DCO and enabling works costs and risks

Qualitative Risk Assessment

Once identified, risks were assessed for probability and impact against the project objectives using a standard set of qualitative criteria.

415. Risks were assessed to evaluate both the current and target ratings and mitigation actions.

416. Probability assessments were based on objective information where this was available or on professional judgements based on experience of similar activities within National Grid or within the wider construction industry. Cost and schedule impacts were supported by assessments of the actual costs and durations based on rates and quantities where possible or by professional judgements and benchmarking data where available.

417. The qualitative risk is derived from multiplying the likelihood by impact.

418. The colour coding of the grid indicates the risk category and the numbers in each cell indicate the relative ranking of each risk. This matrix reflects National Grid's current risk tolerance and prioritisation criteria.

Likelihood	5	Probable	5	10	15	20	25
	4	Likely	4	8	12	16	20
	3	Possible	3	6	9	12	15
	2	Unlikely	2	4	6	8	10
	1	Very Unlikely	1	2	3	4	5
			Very Low	Low	Medium	High	Very High
			1	2	3	4	5
			Impact				

Quantitative Risk Assessment

419. Upon sufficient definition of the project and majority of uncertainty in scope removed, the risk register matures from a qualitative approach to quantitative.

420. Quantitative risk data in the form of percentage probability was captured and recorded in the risk register against the commercial and schedule quantitative impact. Monte Carlo risk analysis (industry recognised tool for complex projects) was utilised and completed on a monthly cycle. Risk reports were produced to inform the project manager of the appropriate focus activities, mitigation ownership and actions.

421. The quantitative risk register produced a probability curve, in particular the P20, P50 and P80 value to incorporate the appropriate risk contingency for monthly forecasting, sanction processes and investment lifecycle milestones. A P50 probability has a 50-50 chance of defining the actual outturn cost.

422. A simple calculation for P50 is;

(1 x lowest cost + 4 x average cost + 1 x highest cost) / 6

423. This simple technique is limited to P50 values only and therefore probabilistic tools such as Monte Carlo are required to determine the full risk range.

Estimating Bias

424. To mitigate the potential for probability estimating bias, a number of additional steps have been completed as part of the risk management process.

425. The extent to which an individual or project team has previously encountered the situation drives whether risk probability is perceived as high or low. Where there is little or no previous relevant experience, skill or knowledge, the degree of uncertainty is perceived as higher than is the case when it is assessed by individuals or groups who have come across the situation before. To mitigate the lack of "familiarity" with the risks, representatives from internal tunnelling specialists have attended risk workshops.

426. To aid those probability assessments based on professional judgement, the value orientated approach has also been utilised. Risks with an objective based probability

can be used to benchmark the relativity of the probability of the risk, in essence a test of "more than likely" or "less than likely" to occur.

Risk Mitigation Strategies

427. Risk mitigation is formally reviewed monthly throughout the project life cycle, aligned to the commercial reporting cycles. Additional risk workshops are held at key project milestones, for example as part of the contract strategy development.

428. The six key strategies (eliminate, reduce, mitigate, accept, share, transfer) for risk mitigation are applied to each of the entries on the project risk register and any new entries.

429. A full breakdown of previous, current and potential risks have been detailed to Ofgem in relation to this project.

Feeder 9 Opportunities

430. National Grid has sought out efficiency opportunities throughout the duration of the project. At the time of the April 2016 sanction there were 12 active opportunities being explored and tracked alongside the risk register.

431. The top three opportunities identified are detailed in brief below.

MWC Negotiation

432. When the opportunity tracker information was compiled, the MWC procurement event was in the negotiation phase with three suppliers. National Grid conducted Early Contractor Involvement (ECI) with each of the remaining three bidders to develop the tendered proposals further. Through a review of the capital cost estimate, the critical path and the project risk register, a number of deliverables were identified to reduce cost and programme uncertainty. These included the drive/launch pit design and location, the tunnel alignment (including location of the curve transitions), ground conditions under the Paull mudflats and developing the tendered TBM specification into a procurement ready TBM specification.

433. This opportunity was realised between January - May 2016 once all tenderers had submitted their final bids and the MWC was awarded.

Spoil Disposal

434. During the FEED stage, there was an opportunity explored to potentially dispose of the arisings by spreading thinly and widely across the adjacent land; however, this was not feasible after the contract phase because it was highly unlikely that the necessary permits would have been granted by the Environment Agency for this method of disposal. Additionally, other issues because apparent, namely;

- Landowner agreement would be an issue (tenant farmer's opinion may not be that of the landowner).
- Site overlays a sensitive aquifer that the Environment Agency are very strict on and they would almost certainly deny a permit application on this basis.
- Arisings have elevated levels of nitrogen and chlorides, also potentially high pH, all of which would make spreading to land highly undesirable.

Spoil disposal remains an ongoing risk and opportunity within the project. *Installing Swan Neck in Reception Pit* An opportunity was identified to reduce the temporary works complexity and cost by installing a 'swan neck' in the reception pit. This would mean the reception shaft could be made shorter which would reduce costs.

435. This opportunity was realised and was included in the overarching ECI efficiency.

Feeder 9 Risks Retired

436. There are a number of risks that have been retired since April 2016, either moving to the base cost (in full, or part), or have not crystallised.

437. Those risks which have not crystallised by managing and implementing mitigating measures include the delivery of the TBM , through engaging a specialist subcontractor and regular dialogue with the local authorities to ensure safe and successful delivery. Other notable successes include the avoidance of any structural support / bailey bridge over a Network Rail crossing.

438. The risk of third party crossing agreements impacting tunnelling were mitigated through continual and proactive engagement through the DCO process and post determination meetings,.

439. The dewatering associated with the drive shaft establishment was also successfully retired with no risk crystallising. The project engaged specialist support to advise given the sensitive dewatering system required due to close proximity of the estuary and East Halton Beck. This resulted in a successful dewatering system which was a key risk in terms of engineering integrity as well as alleviating any consenting risk and concerns from the Environment Agency. This enables risk to be retired to cover the mitigation for a sheet pile wall between the drive shaft and East Halton Beck.

Conclusion

440. A robust risk management process is being followed to enable National Grid to identify, manage and mitigate key project risks in a dynamic way with appropriate mitigation plans in place.

441. In addition, several risks associated with the enabling phase of works have been retired, as well as several project opportunities realised.

XIV. Innovation

442. The purpose of this chapter is to discuss the use of innovation throughout the project. The structure of this chapter is;

- Introduction of the National Grid Innovation Culture
- The specific innovative aspects of the project:
- Alternate Crossing Techniques
- Cathodic Protection
- Building Information Modelling
- Pump Tests
- Contract Strategy- Early Contractor Involvement (ECI)
- Extreme Value Analysis- Project EVA

Introduction

443. Across National Grid, a culture of innovation has been nurtured to promote improvement in business processes, stakeholder engagement and technology application to deliver value to stakeholders. As part of National Grid's enduring commitment to innovation, all projects and employees are encouraged to find a better way of working through the development and application of innovative ideas and approaches. Where appropriate, National Grid uses innovation stimuli such as the Network Innovation Allowance (NIA) to provide funding to further promote efficiencies.

444. This chapter highlights some of the tangible examples of how National Grid has incorporated innovation into the development of the Feeder 9 project to reduce cost, risk and time for completion. Where opportunities for innovation were identified that carried additional risk or uncertainty, the NIA innovation stimulus was utilised. The alternate crossing technology applied research and the cathodic protection specification for a tunnel, were both examples of innovation identified as a result of high risks and opportunities to the project. As such, these two packages of work were developed and funded through the NIA process.

445. In addition to the development of new innovative approaches through NIA, National Grid also looks for opportunities to share innovation learning across projects. Through evaluation of the Feeder 9 project requirements and deliverables, an opportunity was identified to utilise the 2014 NIA Building Information Modelling (BIM) project to mitigate Feeder 9 planning consent and construction risk. This meant that Feeder 9 was the first project to apply the BIM approach outside of a case study environment.

446. Feeder 9 was also used as a case study for the Extreme Value Analysis (Project EVA) innovation project which was initiated to support the cost-benefit analysis of high impact low probability events associated with the existing Feeder 9. The project has provided an extreme value analysis support tool and methodology for the Feeder 9 project that enables robust assessment of the cost and benefits of investments that involve extreme risks and extreme uncertainty.

447. Looking at innovation and best practice outside of National Grid has also provided opportunities. Innovation was applied to the contract strategy with Early Contractor Involvement (ECI) being utilised for the first time within National Grid (November 2015 – January 2016) to mitigate project risk and reduce costs.

Alternate Crossing Techniques

448. By evaluating the project risk register a potential opportunity was identified related to the crossing option considered for the Feeder 9 project. To support understanding and look for new and emerging technologies, in 2015 National Grid commissioned an independent study (AFAA-R0267-15-Rev 01) using NIA funding to review worldwide crossing option techniques. The NIA cost to develop the new specification was £15k.

449. The report primarily focussed on identifying potential and forecast advances in trenchless technology across the life of the Feeder 9 project. It looked at seven different technologies and assessed their strengths and weaknesses relating to safety, likelihood of success, time taken to complete, impact on the environment and cost. National Grid was particularly interested in understanding the further potential for use of Horizontal Directional Drill (HDD) and Direct Pipe techniques as these were emerging and developing technologies with increased distances being achieved.

450. HDD is an established technique for reaming an open bore of increasing diameter until large enough for the host pipe to be pulled in. The applied research concluded that the longest, single HDD in the world at the time was a project crossing the river Yangtze, China at 3.3km. This was considerably shorter than the length required for the Feeder 9 crossing. Although HDD was also a lower capital cost option than conventional tunnelling, two inherent risks were identified with this technique; collapse of the open bore and bentonite breakout (bentonite slurry is used as the lubricant within the open bore). Noting the ground conditions present at the Humber (fractured chalk) there was a very high potential for bentonite loss and breakout into the environmentally sensitive estuary. Bentonite is a very fine clay which can collect in the gills of fish, starving them of oxygen.

451. With respect to Feeder 9, saline intrusion is a significant and inherent risk to the HDD technique. By the very nature of an open bore, crossing through freshwater to saline water boundaries would produce a conduit and have an unacceptable adverse impact on groundwater; the primary concern of the Environment Agency.

452. National Grid’s own experience with HDD was that any single crossing above 1km in length significantly increased the risk of failure which could result in alternative options having to be employed. Having to use an alternative option after a failed HDD attempt would prolong the programme and increase costs. It was therefore determined that the significant risk of HDD failure excluded this option.

453. The only new technology identified was Direct Pipe, a hybrid technique of HDD and micro-tunnelling. Whilst there were potential benefits in terms of no/shallow shafts required, the longest crossing at that time was only 1.4km. After engagement with the equipment manufacturer this option was discounted in this instance as there was limited experience and knowledge in this technology due to it being a new innovation.

454. Segmental bored tunnelling was also reviewed. It was determined that the greatest advantage of this technology was its proven experience over long distances. In addition, with sufficient planning and methods, this technique could be carried out through almost all soil types meaning it could be used to cross the chalk and glacial till found around the Humber. Its main disadvantage was need for highly specialised planning and coordination which would lead to higher capital costs than the HDD technique.

455. Despite the costs associated with tunnelling, the report concluded that for crossing lengths in excess of 1km, tunnelling would be the preferred technique due to its proven success and reliability over long distances. This reaffirmed the tunnel solution as the only technically feasible non-dig crossing technique for the Humber Estuary.

Cathodic Protection

456. During the Feeder 9 project development it was observed that there was no standard which covered the application of Cathodic Protection[24] (CP) on a pipeline within a tunnel. In addition, there were a number of known and managed CP challenges encountered on other, smaller National Grid tunnel projects particularly during the detailed design phase. Initial investigation and cost estimates suggested that a flooded tunnel technique instead of a grout filled annulus between the tunnel and the pipeline may be the most cost efficient option. This presented a level of risk and uncertainty for National Grid and it was therefore necessary to further understand the appropriate CP technique.

457. In 2015 National Grid initiated an NIA project to investigate and develop options for CP for pipelines within a tunnel. The project aimed to identify the most appropriate option but also targeted a reduction in procurement and construction costs for CP systems and greater integrity for pipelines within a tunnel. The NIA cost to develop the new specification T/SP/ECP/9 was £28k.

458. The new specification detailed the requirements for the design, materials specification, construction, installation, operation, maintenance and decommissioning of CP systems for carrier pipes installed in tunnels and sleeves, where there is considered to be a risk that the carrier pipeline could be shielded from the flow of CP current from any CP system installed outside the tunnel.

459. As well as supporting the Feeder 9 project, the specification developed new learning in a specialist and complex work area that looks at combining existing onshore and offshore techniques in a hybrid scenario to provide reduced cost with an appropriate integrity solution. The project set a benchmark for which future tunnel projects could follow and develop their project specific requirements with regards to pipeline CP in tunnels.

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[24] CP is provided by impressed current and sacrificial anode techniques. This protects the pipeline by allowing current to flow through the pipeline and to and from the ground bed to ensure that material is not lost in corrosion products

460. The cathodic protection design being used for Feeder 9 is in line with the specification developed through the innovation project. Through detailed design further reductions were identified in the reduction of vehicle movements and a reduction in installation time.

Building Information Modelling

461. Throughout FEED, Building Information Modelling (BIM) processes developed through the 2014 NIA project were employed by the FEED designer to identify potential project cost savings and to promote effective engagement with stakeholders.

462. Laser scanning (following the NIA Laser Scanning Standard) was utilised to capture the true “as is” status during the Feeder 9 project design phase particularly on the existing Paull AGI. This highlighted a lack of space (via clash detection) for a new pig trap connection and drove further optioneering. Through collaborative working with an existing live project (Paull Rationalisation), an option to permit an in line tie in to the existing Feeder 9 pig trap was identified. This has reduced costs through the reduction in materials and associated resources and equipment.

463. BIM was used extensively with stakeholders throughout the design development process. It was used to address concerns raised by statutory consultee Natural England by exporting the 3D model to a lighting package, demonstrating Lux (lighting) levels across the temporary working area and alleviating the concerns of the stakeholder. It was also used for public consultations to enable the local community to visualise the temporary scale of the project enabling more robust feedback.

464. The pipeline insertion technique initially had no specification, therefore BIM was used to undertake a constructability study using 4D modelling (linking the 3D model to the programme). This formed part of the tender return from the MWC suppliers, focussing on the pipeline insertion technique. Visualisation of the proposed methods enabled clarifications to be raised and risks removed from the project. 4D modelling was also utilised to provide robustness to the construction programme and to reduce risk to the Works Plans and Land Plans needed as part of the Development Consent Order.

465. Building Information Modelling was also included in the scope of the Main Works contract to ensure benefits continued to be realised.

Pump Tests

466. To address the concerns and potential DCO consent objections from the Environment Agency (EA), a hydrological risk assessment was completed, concluding the need for pump tests to establish the permeability of the chalk. Due to the high-water volumes, traditional pump tests would have produced significant quantities of water, greater than the predicted drawdown to establish the launch pit and at significant cost Therefore, a hydro-geological consultant was engaged to find an innovative solution and to alleviate the EA’s concerns. Using the existing boreholes and water sampling points, the consultant developed a series of mini pump tests, sufficient to give the EA confidence in the behaviour of the groundwater.

Contract Strategy – Early Contractor Involvement (ECI)

467. In May 2014 as part of the MWC procurement process, an early Request for Information (RFI) was sent to potential suppliers. This process identified that ECI could be beneficial to the Feeder 9 project. ECI is the process of engaging with suppliers prior to contract, reducing cost and programme risk. The ECI was broken down into five main areas; pipeline insertion methodology, additional ground survey, TBM delivery plan, spoil treatment and arisings management plan and shaft and tunnel design.

468. The ECI process was an innovative approach for National Grid that helped to deliver significant cost savings and risk reduction. As a result, it is now a standardised option within major project procurement strategies across National Grid.

Extreme Value Analysis – Project EVA

469. Investment decisions within National Grid can involve evaluating extreme value risks, which are low probability, high impact events. The nature of these events makes it difficult to accurately quantify the risks associated with them. Consequently, there is a danger that a higher decision threshold is placed on investments that mitigate extreme risk events, increasing the vulnerability of asset infrastructure, and therefore of society and the environment, to such events.

470. National Grid identified two key challenges associated with the quantification of extreme value risks:

    - The volume and diversity of data generated by impact assessments makes the incorporation of quantitative risk assessments and scenario analysis within a single decision making framework challenging.
    - The common approaches to cost benefit and net present value analysis tend to emphasise mean or expected values while undervaluing extreme value risks (low probability, high impact) and ignore uncertainty.

471. In order to address these issues and to assure the original final investment decision making, National Grid applied for NIA funding to develop an innovative business modelling platform that would help to quantify the value of investments that involved mitigating extreme value risks. The data and analysis associated with the Feeder 9 investment decision was used as a case study to test the model. The model developed encompasses financial, asset connectivity and operational risk modelling to support investment decision making and includes an extreme risk weighted Net Present Value (NPV) calculation.

472. The project has provided an extreme value analysis support tool and methodology for the Feeder 9 project that enables robust assessment of the cost and benefits of investments that involve extreme risks and extreme uncertainty. This helps to provide more confidence that investments being made are achieving the best possible trade-off between cost and risk.

473. The results of this work demonstrated that the tunnel option had the most advantageous average net present value compared to trenching and continued mitigation options. This supports the investment decision made to progress with a tunnel replacement option (further detail of the Project EVA results is available in Chapter VIII Cost Benefit Analysis).

Conclusion

474. Throughout the development and delivery of the Feeder 9 project National Grid has looked for opportunities to explore innovative techniques and solutions that aim to drive efficiency and reduce risk.

475. Through the identification and implementation of innovation opportunities, significant cost savings have been realised on the Feeder 9 project. In addition, many of the opportunities identified can be used as best practice and applied to future projects to ensure that benefits continue to be realised.

XV. Financial Summary

476. The purpose of this chapter is to provide a summary of the Feeder 9 actual spend to date, the forecast spend for the remainder of the project, the commercial changes and efficiencies achieved. The structure of this chapter is;

- Ex-Ante Allowance
- Feeder 9 Project Expenditure and Forecast
- Commercial Movements
- Project Manager's Instructions and Compensation Events
- FEED, DCO, Tender and Delivery Efficiencies
- Final Funding Request

Introduction

477. In recognition of the need to secure the long-term integrity of the pipeline, and after considerable strategic optioneering activities had been conducted, National Grid submitted a full funding request to Ofgem in the 2012 RIIO-T1 business plan outlining the needs case for the replacement of the existing Feeder 9 pipeline. The funding request was in the range of £100-£150m (2009/10 prices) to deliver a fully operational replacement pipeline.

478. The funding mechanism for the project was confirmed in the December 2012 Ofgem Final Proposals[25] document where Ofgem stated:

479. "*For the Feeder 9 project we provided an ex ante allowance to enable NGGT to undertake preliminary engineering and licensing activities. Given the uncertainty and range of expected costs, we considered it appropriate that the remainder be funded (with the costs to be evaluated) via an uncertainty mechanism. The trigger for the uncertainty mechanism was NGGT being granted the appropriate planning approval'.*

480. An ex ante allowance was included as part of the RIIO-T1 plan to enable National Grid to conduct the necessary pre-works associated with obtaining the relevant planning permissions.

DCO Activities (Ex Ante Allowance)

The consenting related activities up to DCO determination in September 2016 are excluded from the re-opener funding request. **Commercial Movements**

481. Whilst the estimated cost to complete the project was within the original Financial Investment Decision (FID) sanctioned range), the P50 has increased

482. In accordance with ISO31001, the project team utilise a quantitative risk register (QRA) to manage and mitigate the risk throughout the life of the project. As a

[25] Link to RIIO-T1 Final Proposals for National Grid Electricity Transmission and National Grid Gas

minimum, the risk register is reviewed on a monthly basis, with a focus on mitigation planning and then subject to a Monte Carlo analysis.

Project Manager's Instructions and Compensation Events

483. Prior to tender launch, National Grid reviewed the opportunities, risks and areas of uncertainty which would be best managed by National Grid at contract award and assessed as the detailed design, temporary works and construction progressed. This would ensure competitive and lowest cost tenders were submitted, removing the potential for uncertainty to be priced..

484. The project manager would subsequently use Project Manager Instructions (PMI's) to instruct changes to the prices and assess Compensation Events (CE's) submitted by the contractor, both of which could adjust the target cost and programme.

485. Compensation events (CE) are events which are not the contractors risk and are identified as a compensation event within Clause 60 of the NEC C contract. CE's impact upon both time (completion date) and target value. As a result, the prices, key dates or the completion date of the project may need to be reassessed, and in many cases the contractor will be entitled to more time or money.

Efficiencies

486. Throughout each stage of the project there has been a specific focus on embedding innovation, good decision making, risk mitigation and implementing efficiencies. An efficiency tracker is in place). The project has followed a typical efficiency profile insofar as the greatest opportunity to drive efficiencies at the lowest cost are in the early stages of design development.

FEED Efficiencies

487. The FEED Consultant was instructed by the project team to generate and maintain a whole life cost report demonstrating the quantitative decision making for key activities.

488. The traditional approach for pipelines inserted in concrete sleeves is to grout the annulus to ensure the cathodic protection system operates correctly. The challenge with Feeder 9 is the volume of grout required and with the associated cost and carbon impact. The ability to inject grout over such a distance also posed constructability and quality assurance challenges.

489. The power supply of the TBM was also evaluated as part of the whole life cost report and subject to a Best Available Technique (BAT) assessment. This considered the lead time for power availability, the emissions and the whole life costs. Diesel generation was deemed" BAT," at significantly less than the second-best option.

490. Building Information Modelling (intelligent 3D modelling) learning from a NIA project was applied to Feeder 9. A benefit was realised at Paull AGI whereby combining the laser scan with the proposed tie in location demonstrated insufficient space for a new

pig trap. Through spatial tests, 3D clash detection and engaging with the Paull rationalisation project it was possible to tie into the existing pig trap, reducing all the materials, equipment and labour costs.

491. Lessons learnt from the Corrib project regarding the efficiency for longer pipe strings generated a technical query to extend the permissible length of pre-tested pipe to 700m, to align to the available space behind the tunnel. The technical query evolved to ultimately negate the requirement for pre-testing; due to advances in non-destructive testing and quality assurance of the pipe.

492. Through the development of the groundwater model and engagement with the Environment Agency there was a clear requirement to gain confidence with in situ testing of the permeability of the chalk and tidal influences due to the risk of saline intrusion into fresh water zones. The project team engaged an independent hydrology consultant who typically was engaged by main works contractors. An innovative design using the existing boreholes was proposed and accepted by the project team and the Environment Agency. The cost saving of the “mini pump test” versus the FEED consultant proposal was significant.

493. During the consultation process, most feedback from the local community was concerned with traffic movements and impacts. On the northern side of the estuary, the project team negotiated the use of a private, highway standard track with a local landowner, negating the requirement for construction traffic through the villages of Paull and Thorngumbald. The width and condition of the existing highway would have required additional works, the result being cost savings plus the benefit of addressing the concerns of the local residents and reducing the risk associated with the planning consent and additional representations at the DCO hearings.

494. As a result of the consultation on the southern side of the estuary an accident black spot was identified. A targeted consultation was held with residents of South End. The parish council feedback was to build a temporary bypass to the subsequent main road, a distance of 1.8km. The project team pursued an alternate option at a distance of 0.6km and a third of the cost through negotiation with Persons with an Interest in Land (PIL’s) for a short private track, connecting back to the highway, avoiding costs. This option was submitted as part of the DCO and ultimately accepted by the Planning Inspectorate.

DCO Efficiencies

495. Lessons learnt and project team member’s experience of the DCO process identified efficiencies in the collation and quality assurance of the DCO submission. To date, DCO’s had been led by a legal team, however noting the strength of the needs case and moderate nature of the scale of the project, this was rationalised under the project manager with support from the EIA Consultant. Rather than engaging a DCO manager, a DCO coordinator (post graduate) was hired resulting cost savings.

496. This efficient and effective approach to the DCO enabled a reduction of 2 hearings , avoided a public hearing and retired a significant amount of risk associated with the DCO process up to determination. The benefits have continued through to delivery

with 6 of the 7 stages of the DCO accepted. The approach taken on Feeder 9 has been shared as best practice with the wider National Grid consenting team.

497. The project team were focussed on the project objective, to replace the existing pipeline as expediently and efficiently as possible. With the tender evaluation and DCO determination being completed in parallel, the project team applied the same practice witnessed for power station developments, insofar as entering a local planning application for enabling works, ahead of the DCO determination. This was required to ensure site works (topsoil stripping in particular) was completed ahead of the winter 2016. The extent of the enabling works was specifically limited to those activities which could be readily reversible if the DCO was rejected thus minimising cost exposure.

Tender Efficiencies

498. Early contractor involvement (ECI) was embedded into the tender process, focussing on areas of high risk and opportunity to reduce the overall price of the contract.

499. There were five areas of ECI, pipeline insertion methodology, geotechnical site investigation at Paull, TBM procurement and delivery, spoil treatment and arisings; and shaft and tunnel design.

The ECI process generated significant savings . *Delivery Efficiencies*

500. National Grid established a nationwide materials framework to maximise the volume discounts for materials and fittings across the National Transmission System. The project team utilised this framework to procure the line pipe with a view to “free issue” to the main works contractor. With respect to the construction programme the risk of late delivery and impacting the critical path was low and therefore an acceptable risk for the project team.

501. If the line pipe procurement been the responsibility of the main works contractor, this would have attracted a sub contract fee.

Funding Request

502. The funding request of £139.9m is for the P50 to complete the project with deductions made for the DCO spend and any prior RIIO-T1 spend.

Consumer Bill Impact

503. In 2016/17 approximately £16.29 of an average domestic consumer bill related to the gas transmission services we provide; this equates to 2.7% of a typical gas bill of £604.

504. The expected maximum impact of this project on customer bills in any year is approximately 45p in 16/17 price base.

Conclusion

505. The Feeder 9 pipeline project, upon completion in 2021, will be the longest pipeline in a tunnel in Europe and will continue to facilitate the transmission of up to 20% of the UK gas supply. The new pipeline will not be subject to the uncertain conditions of the Humber Estuary and will thus ensure the reliable and safe transportation of the UK gas supplies for the foreseeable future.

506. Throughout each stage of the project there has been a specific focus on embedding innovation, good decision making, risk mitigation and implementing efficiencies.

507. The funding request for this project is set at a P50 value of £139.9m in 09/10 price base.

XVI. Glossary

ABP – Association of British Ports

ASEP – Aggregated Supply Entry Point

AGI – Above Ground Installation: Above ground gas assets (including, but not limited to; pipework, valves, pigtraps, meters and regulators) located within a fence line for the safe operation and maintenance of the National Transmission System

ALARP – As Low As Reasonably Practicable - Reasonably practicable involves weighing a risk against the trouble, time and money needed to control it.

Alluvium – Material transported by rivers and deposited along its course.

Annulus – The circumferential space between the gas pipeline and the inner tunnel wall.

AQ – Additional Questionnaire

Aquifer - A body of permeable rock that is capable of storing significant quantities of water; through which groundwater moves.

Arisings - materials forming the secondary or waste products of industrial operations, such as tunnelling activities.

Bentonite - Bentonite is clay used in tunnelling / drilling fluids to lubricate and cool the cutting tools, to remove cuttings, and to help prevent blowouts.

BIM – Building Information Modelling - is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.

BS5930 - BS 5930:2015 deals with the geotechnical investigation of sites in order to assess their suitability for construction and to identify the characteristics of a site that affect the design and construction of the project. It also considers related issues including the environment and the security of adjacent land and property.

CAT III check - A Cat III check involves taking the final detail design drawings and functional specification, and developing independent load cases, calculations and analysis. By utilising an independent party to carry out a check allows the client to be confident that the design is suitable for its intended purpose, and also viable for construction.

CP - Cathodic Protection: Is a technique used to control the corrosion of a metal surface by making it the cathode of an electrochemical cell. A simple method of protection connects the metal to be protected to a more easily corroded "sacrificial metal" to act as the anode.

CDM – Construction Design Management Regulations 2015 - The Construction Design and Management Regulations 2015, also known as CDM Regulations or CDM 2015, which came into force on 6 April 2015, are regulations governing the way construction projects of all sizes and types are planned.

CIRIA grade - The description of chalk for engineering purposes is reviewed and recommendations are made for a refined method for the field determination of chalk strength, hardness and density.

CE– Compensation Event

DAQ – Detailed Additional Questionnaire

DCO – Development Consent Order - is a statutory instrument granted by the Secretary of State to authorise the construction and development of a Nationally Significant Infrastructure Project. The nature of these projects are defined by ss. 14-30 of the Planning Act 2008.

DCMA Assessment - The DCMA Assessment is a set of schedule checks that DCMA (the Defense Contract Management Agency) established to assess the quality of a schedule's critical path. This assessment is frequently used in tender evaluations and post contract award to establish the quality of a submitted programme.

Direct Pipe – is a combination of micro-tunnelling and HDD methods for pipeline crossings. A steel pipe is completely prefabricated before pipe-laying begins and is laid out in its full length behind the pipe thruster.

Drift shaft – An elongated shaft to enable the full establishment of the tunnel boring machine to advance the start-up and commencing of tunnelling activities. The drift shaft also enables the installation of the gas pipeline.

EA – Environment Agency - is a non-departmental public body, established in 1995 and sponsored by the United Kingdom government's Department for Environment, Food and Rural Affairs (DEFRA), with responsibilities relating to the protection and enhancement of the environment in England (and until 2013 also Wales).

ECC – Estimated Cost to Complete

ECI – Early Contractor Involvement - is an approach to contracting that supports improved team working, innovation and planning to deliver value for money. It involves an integrated contractor and designer team, appointed under an incentivised, two-stage contract.

EIA – Environmental Impact Assessment - The process by which the impacts of a proposed development upon all aspects of the receiving environment are identified and analysed.

ES – Environmental Statement - Document that reports the findings of an Environmental Impact Assessment.

EPBM – Earth Pressure Balance Machine - EPB technology uses mechanical pressure at the face of the tunnel to counterbalance earth and groundwater pressures. This negates the need for compressed air to control subsidence of the tunnel face. It is predominantly used in soft ground conditions. A screw conveyor transports the cut material out of the tunnel without the need for slurry.

Eurocode 7 – In the Eurocode series of European Standards (EN), related to construction, Eurocode 7. Geotechnical design (abbreviated EN 1997 or, informally EC 7) describes how to design geotechnical structures, using the limit state design philosophy. It is published in two parts; “General rules” and “ground investigation and testing.”

EVA – Extreme Value Analysis

FEED – Front End Engineering Design – Provides sufficient engineering and technical detail to achieve a desired level of certainty with respect to the cost estimate, risk register and project programme.

FES – Future Energy Scenario

GBR – Geotechnical Baseline Report - A contract document containing measurable contractual descriptions of the geotechnical conditions to be anticipated or to be assumed to be anticipated during construction.

GIS - Geographical Information System

HDD – Horizontal Directional Drill - Directional boring, commonly called horizontal directional drilling or HDD, is a steerable, trenchless method of installing underground pipe, conduit, or cables in a shallow arc along a prescribed bore path by using a surface-launched drilling rig, with minimal impact on the surrounding area.

HGV – Heavy Goods Vehicle

Hydrological Risk Assessment - The hydrogeological risk assessment fulfils the 'prior investigation' requirement of the Groundwater Regulations, 2009.

IROPI - Imperative Reasons of Overriding Public Interest **-** where, in spite of a negative habitat assessment (as defined in the Habitats Directive), a potentially damaging project may proceed provided that there are 'Imperative Reasons of Overriding Public Interest' (IROPI) that outweigh the potentially damaging impacts that the project may have on a European site such as a Special Conservation Area (SAC) or Special Protection Area (SPA) and there are no 'alternative solutions'.

JV –Joint venture - a business arrangement in which two or more parties agree to pool their resources for the purpose of accomplishing a specific task. This task can be a new project or any other business activity.

Lithostratigraphy - a sub-discipline of stratigraphy, the geological science associated with the study of strata or rock layers. Major focuses include geochronology, comparative geology, and petrology.

Lux Levels - The *lux* (symbol: lx) is the SI derived unit of illuminance and luminous emittance, measuring luminous flux per unit area. It is equal to one lumen per square metre.

MMO – Marine Management Organisation - The Marine Management Organisation is an executive non-departmental public body in the United Kingdom established under the Marine and Coastal Access Act 2009

Monte Carlo Analysis – produces distributions of possible outcome values. By using probability distributions, variables can have different probabilities of different outcomes occurring. Probability distributions are a much more realistic way of describing uncertainty in variables of a risk analysis

MWC – Main Works Contractor - A Main Works Contractor is responsible for providing all of the material, labour, equipment (such as engineering vehicles and tools) and services necessary for the construction of the project. The MWC hires specialised subcontractors to perform all or portions of the construction work

Natura 2000 – Natura 2000 is a network of nature protection areas in the territory of the European Union. It is made up of Special Areas of Conservation and Special Protection Areas designated respectively under the Habitats Directive and Birds Directive

NEC – New Engineering Contract - NEC is a family of contracts that facilitates the implementation of sound project management principles and practices as well as defining legal relationships. It is suitable for procuring a diverse range of works, services and supply, spanning major framework projects through to minor works and purchasing of supplies and goods.

NGO – Non-Governmental Organisation - Non-governmental organisations, commonly referred to as NGO's are international organizations and generally non-profit organisations independent of specific governments (though often funded by governments) that are active in humanitarian, educational, healthcare, public policy, social, human rights, environmental, and other areas to effect changes according to their objectives.

NIA – Network Innovation Allowance

NPV – Net Present Value

NSIP –Nationally Significant Infrastructure Project

OAST – Options Appraisal Summary Table

OJEU – Official Journal of the European Union - The Official Journal of the European Union is the gazette of record for the European Union. Around 2500 new notices are advertised every week - these include invitations to tender, prior information notices, qualification systems and contract award notices.

Paramoudra - A large flint, pear-shaped, barrel-shaped, or cylindrical and often with a central cavity, found (typically upright) in chalk strata.

PHASR – Preliminary Hazard Analysis and Safety Review – is a qualitative technique for the early identification of potential hazards and threats effecting people, the environment, assets or reputation.

PINS - Planning Inspectorate - On 1 April 2012, under the Localism Act 2011, the Planning Inspectorate became the agency responsible for operating the planning process for Nationally Significant Infrastructure Projects (NSIPs). The Planning Inspectorate examines the application and will make a recommendation to the relevant Secretary of State, who will make the decision on whether to grant or to refuse development consent.

Pump test - A pumping test is a field experiment in which a well / borehole is pumped at a controlled rate and water-level response (drawdown) is measured in one or more surrounding observation wells.

RAMS – Risk Assessment and Method Statement – A written procedure covering the safe system of work for a given activity.

RAMSAR – A site as set out in the Ramsar Convention (Convention on Wetlands of International Importance, especially as Waterfowl Habitats) (1971).

RCIS – Route Corridor Investigation Study - An appraisal of the high-level planning and environmental constraints to identify potential Route Corridor options within a defined Area of Search.

Reaming - to enlarge to desired size (a previously bored hole) by means of a reamer.

RFP – Request for Proposal - is a document that solicits a proposal, made through a bidding process, by an agency or company interested in procurement of a commodity, service, or valuable asset, to potential suppliers to submit business proposals.

RFI – Request for Information - is a standard business process whose purpose is to collect written information about the capabilities of various suppliers.

SAC – Special Area of Conservation - Protected sites designated under the EC Habitats Directive. The listed habitat types and species are those considered to be most in need of conservation at a European level (excluding birds).

SoS – Security of Supply

SPA – Special Protection Area - Areas selected by the national government on the advice of English Nature, designated for the protection of particularly sensitive bird species, or for regularly migrating birds.

SPBM – Slurry Pressure Balance Machine – A SPBM is a closed-face type shield tunnelling machine, meaning the "head" part of machine is "closed" and separated from the rear part of machine. The "head" has a working chamber filled with soil or slurry between the cutting face and bulkhead to stabilise the cutting face under soil pressure. The SPBM uses the external pressurised slurry to stabilise the cutting face. The slurry is circulated to transport the excavated soil by fluid conveyance.

SSP – Strategic Sourcing Process

SSSI – Site of Special Scientific Interest - An area of land of special interest by reason of its flora, fauna, geology or physiographical features notified under section 28 of the Wildlife and Countryside Act 1981.

SOCC – Statement of Community Consultation

SoCG - Statements of Common Ground

SOR - Strategic Options Report

TBM – Tunnel Boring Machine - A machine used to excavate tunnels with a circular cross section through a variety of soil and rock strata.

TPI – Third Party Interference

T/PM/G35 – National Grid management procedure for the approval and appraisal of modifications to the National Transmission System.

UKCS – United Kingdom Continental Shelf

UNC - Uniform Network Code

VIV – Vortex Induced Vibration

Winterisation – The process of preparing for winter, such protecting soil structure on temporary working areas.