Review of National Grid Gas Transmission Gas Feeder 9 Optioneering on behalf of Ofgem

Authors:
Ju Lynne Saw
Ian Redshaw

Report Number:
RPS/18/12

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Report approved by:	Dr Mike Wardman BEng(Hons) PhD CEng MIChemE, Technical Team Lead
Report authorised for issue to Ofgem by:	Dr Stuart Hawksworth BSc(Hons) PhD Head of Centre for Energy and Major Hazards
Date of Issue:	9 July 2018
Lead Author:	Dr Ju Lynne Saw BEng(Hons) PhD CEng MIChemE, Principal Engineer
Contributing Author:	Ian Redshaw BEng CEng MIMechE, HM Inspector of Health and Safety
Customer:	Kiran Turner, Senior Manager, Systems and Networks, Ofgem
Technical Reviewer:	Jill Wilday BSc(Hons) CEng FIChemE, Technical Fellow
Editorial Reviewer:	Jill Wilday BSc (Hons) CEng FIChemE, Technical Fellow
Project number:	PE03619

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EXECUTIVE SUMMARY

In May 2018, National Grid Gas Transmission (NGGT) submitted their application to Ofgem for funding of the decommissioning of the existing Gas Feeder 9 pipeline and replacing it with a pipeline through a new tunnel under the Humber estuary. We were approached by Ofgem to review the details of the cost benefit analysis (CBA) and its assumptions, including the monetised risk of fatalities from damage to the existing pipeline. Ofgem requested HSE's views on the safety aspects of the analysis carried out by NGGT to support its needs case and CBA to build the new tunnel. The tunnel would be selected in preference to other risk reduction options including the continued use of concrete frond mattresses. Our work was divided into:

- Review of Optioneering undertaken, against the Pipeline Safety Regulations (PSR) and Gas Safety (Management) Regulations (GSMR);
- Review of QRA document written by DNV-GL, the CBA ("NGGT EVA CBA") carried out by Business Modelling Associates, and a traditional Excel-based CBA ("traditional CBA") carried out by NGGT (all three documents owned by NGGT).

In terms of compliance with Pipeline Safety Regulations (PSR) Regulation 12, the arrangements for isolating a pipeline loss of containment are satisfactory. For PSR Regulation 16, it is clear that discussions have taken place with the Port Authority and a no-anchor zone has been created to reduce the likelihood of interference damage.

For the threat of freespanning, remedial work, in the form of concrete frond mattresses and associated grout bags, have been laid to protect the pipeline. It is considered that the current inspection regime and management arrangements as described are adequate and meet the requirements to maintain the pipeline integrity. It is expected that these arrangements should remain under review and appropriate action taken based on inspection data.

In terms of risks from Third Party Interference, HSE would expect that the sources and potential risks of interference damage are identified by the operator and suitable mitigation measures undertaken as necessary. Where risks are not considered ALARP, action should be taken. This could include protection of the existing pipeline, e.g. by rock dumping; decommissioning the pipeline if no longer required; or, as proposed by NGGT, it could be relocated in a tunnel to eliminate the risk. Elimination of risk is a preferred approach in the hierarchy of controls.

The depth and degree of precaution in an ALARP assessment CBA should be proportionate to the hazards and risks. The DNV QRA indicates that these are high, especially if a passenger ferry was to be involved in a pipeline break scenario. The QRA also indicates that the risk from the pipeline is in the 'tolerable if ALARP' region.

HSE has only reviewed the inputs relevant to pipeline failure through third party interference (TPI) leading to potential loss of life and these appear reasonable, including the pipeline failure frequency, estimated consequences (loss of life), gross disproportion factor, and value of preventing a fatality. The NGGT CBA has been carried out over a 60 year period but a more realistic duration for

conducting the CBA would be 20 to 30 years. Safety benefits (prevention of loss of life) should be discounted at 1.5% but the NGGT CBA has used 3.5% for both costs and safety benefits.

As part of this work, a "Loss of Life" Cost Analysis was carried out, for a 60-year duration, where all commercial costs were taken out of consideration, for e.g. wholesale gas price impact, constraint costs, shipping lane closures, *etc*. These costs will be considered separately by Ofgem in their evaluation of National Grid's application for funding for the Gas Feeder 9 Bored Tunnel Project. Only the costs saved through preventing fatalities from a pipeline failure scenario as a result of Third Party Interference were examined, using the appropriate discounting rates. A holistic cost benefit analysis would require both Ofgem and HSE's considerations of these relevant costs to be weighed concurrently.

The results of this analysis over 60 years, carried out by HSE, are as follows:

- The NPV of the discounted monetised cost of risk to human life from continued inspection/ mattressing (the mitigation option) is £5.79M.
- The NPV of the discounted monetised cost of risk to human life under the bored tunnel option is £0.68M.

This means that the NPV equivalent to the risk reduced by the adopting the tunnel build is £5.11M.

Therefore the risk from mitigation is ALARP if the cost of the tunnel option exceeds £5.11M (after taking account of all other business/commercial costs to National Grid, as well as other costs to consumers). For it to be a level playing field with all other companies that create major accident hazard risks in supplying products to consumers, we believe that all other reasonable business/commercial costs to National Grid, as well as other costs to consumers should be taken into account.

HSE would not normally insist on National Grid to further reduce risks, as long as it is already shown to be ALARP.

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1 INTRODUCTION AND BACKGROUND

Ofgem contacted HSE (HM Inspector of Health and Safety, Andrew Cooke) requesting support regarding "Gas Feeder 9" which is a high pressure gas pipeline operated by National Grid Gas Transmission (NGGT). The pipeline was built in 1984 and transports gas from the Easington gas terminal to the rest of the National Transportation System (NTS). The pipeline crosses the Humber estuary between Paull and Goxhill through a trench dug into the riverbed.

Around 2010, NGGT became aware that sections of the pipeline had been exposed above the riverbed due to soil erosion and movement, exposing it to the potential for damage. The exposed sections of the pipeline are in proximity to shipping traffic, including passenger ferries. Although NGGT has since carried out remedial measures (i.e. placing concrete frond mattresses and gravel bags on the exposed sections), it believes that these measures are temporary and may not be sufficient to protect the pipeline against the risk of damage. NGGT has assessed that the pipeline could, under certain circumstances, rupture with adverse consequences including the potential for fatalities. NGGT's own assessment, based on risk modelling carried out by a third party (DNV-GL) on its behalf under a number of assumptions, has concluded that the societal risk from damage to the existing pipeline is in the "tolerable if as low as reasonably practicable (ALARP)" range.

NGGT have proposed decommissioning the existing pipeline and replacing it with a pipeline through a new tunnel under the Humber estuary. At the time Ofgem approached HSE, NGGT had signalled its intention to apply to Ofgem for funding for the tunnel project. In May 2018, NGGT submitted their application to Ofgem (NGGT, 2018a). We were approached by Ofgem to review the details of NGGT's CBAs including its assumptions, specifically the monetised risk of fatalities from damage to the existing pipeline. Ofgem in essence, requested HSE's views on the safety aspects of the analysis carried out by NGGT to support its needs case and its CBAs.

Work has therefore been divided into three main streams:

- Review of optioneering undertaken, against Pipeline Safety Regulations (PSR) and Gas Safety (Management) Regulations (GSMR);
- Review of QRA document written by DNV-GL as well as the CBA ("NGGT EVA CBA") carried out by Business Modelling Associates, and a traditional Excel-based CBA ("traditional CBA") carried out by NGGT (all three documents owned by NGGT); and
- Implementation of a "Loss of Life" Cost Analysis.

2 REVIEW AGAINST PIPELINE SAFETY REGULATIONS AND GAS SAFETY (MANAGEMENT) REGULATIONS 1996

The review has focused on the two health and safety regulations most relevant to the feeder 9 replacement project, namely the Pipelines Safety Regulations 1996 (PSR) and the Gas Safety (Management) Regulations 1996 (GSMR). In essence the Regulations can be summarised as:

- PSR relates to the integrity of the pipeline; and
- GSMR relates to the safe management of gas flow through the network.

2.1 GSMR

GSMR includes the requirement to manage the safe flow of gas through the gas network including a duty to minimise the risk of a gas supply emergency. The loss of any strategic pipeline may have the potential to initiate a gas supply emergency. In the documentation provided it has been highlighted that the impact of a failure of feeder 9 in the Humber estuary and its subsequent isolation would lead to an economic impact on gas prices, due to alternative sources of gas being required, rather than to a supply emergency situation. This economic impact is not a consideration within GSMR and assuming a supply emergency situation is not credible no further consideration has been given to compliance with GSMR.

The loss of Feeder 9 may have a consequential impact on NGGT's ability to deliver requirements described in its accepted safety case (e.g. adversely affecting its obligations in relation to Operating Margins). No information on any impacts of this type has been submitted and are outside the scope of this review.

2.2 PSR

PSR covers the end to end life-cycle of a pipeline, from design and construction, through operation and finally to decommissioning. The concerns raised within the feeder 9 replacement project regarding pipeline integrity relate predominantly to the risks of damage and/or failure initiated by spanning or third party damage. PSR Regulation 13 relates to maintenance and requires that "The operator shall ensure that a pipeline is maintained in an efficient state, in efficient working order and in good repair". As with much health and safety legislation this is a goal setting rather than prescriptive requirement and therefore describes what is to be achieved rather than how it should be achieved. This requires the operator to assess the risks to achieving this goal and then ensure that suitable mitigation is in place control these risks. Operators therefore have flexibility in selecting their approach to managing risk, tailored to their specific circumstances. The following are relevant to this review.

2.2.1 Regulation 12 Arrangements for incidents and emergencies

The operator shall ensure that no fluid is conveyed in a pipeline unless adequate arrangements have been made for dealing with:

(a) an accidental loss of fluid from;

(b) discovery of a defect in or damage to; or

(c) other emergency affecting, the pipeline.

In terms of compliance with PSR Regulation 12, the arrangements for isolating a pipeline loss of containment are described in the QRA. These arrangements are in line with any other loss of containment incident elsewhere on the network and are satisfactory. Additionally criteria for isolating the crossing on identification of a span exceeding 20 m are also identified.

2.2.2 Regulation 16 Prevention of damage to pipelines

For the purpose of ensuring that no damage is caused to a pipeline, the operator shall take such steps to inform persons of its existence and whereabouts as are reasonable.

In terms of compliance with PSR Regulation 16, it is clear that discussions have taken place with the Port Authority and charts provided. A no-anchor zone has been created to reduce the likelihood of interference damage.

2.3 MAIN THREATS TO THE PIPELINE

2.3.1 Spanning

A span/ freespan on a pipeline is where the riverbed/ seabed sediments have been eroded, or scoured away and the pipeline is no longer properly supported. HSE would expect that where spanning is a threat the operator should undertake suitable inspection to establish the stability of the sea bed and quantify any spans present. Any spans should then be assessed to determine the risk to the ongoing integrity of the pipeline, and if necessary appropriate mitigation taken.

From the information provided it is noted that to date there have been no recorded spans on this pipeline, although the pipeline has been exposed in a number of locations. Remedial work, in the form of concrete frond mattresses and associated grout bags, has been provided to protect the pipeline from future exposure and spanning. Since this work has been undertaken no further exposures of the pipeline have been identified. NGGT has calculated a critical span length at which vortex induced vibration would be initiated at above 55 m. Survey frequencies have been increased such that the pipeline is now subject to inspection every 2 months which would be considered adequate given the recent survey data. Should any span(s) be identified then NGGT have clarified that, if the span exceed 20 m, the pipeline would be isolated.

It is therefore considered that the current inspection regime and management arrangements as described are adequate and meet the requirements to maintain the pipeline integrity.

It is expected that these arrangements should remain under review and appropriate action taken based on inspection data.

2.3.2 Third Party Interference (TPI)

HSE would expect that the sources and potential risks of interference damage are identified by the operator and suitable mitigation measures undertaken as necessary. Measures can include both management and engineering controls as appropriate, for example: informing others of the location of the pipeline; controlling encroachment; and installation physical barriers.

NGGT have undertaken a QRA of the threat of third party interference (TPI) and the consequence of a loss of containment. This has highlighted the risk of both anchor damage and vessel impact. Consideration is given to the no-anchor zone, the actual historic shipping activity, anchoring and grounded vessel data, protection from grout bags, likelihood of rupture, *etc*. It is noted that no recognition is given to the protection that may be afforded by the concrete frond mattresses, and that although this assumption is conservative, the frond mattresses are not designed as an impact protection measure. Concrete mattresses are typically used for impact protection from items such as trawl boards but do not provide adequate protection from anchor damage.

It is considered that there is a credible threat of damage to the pipeline from third party interference, particularly due to anchor damage. NGGT's QRA (DNV-GL, 2016) has determined that the societal risk from interference falls above the IGEM/TD/1 criterion (IGEM, 2008). This QRA has been assessed by HSE in Section 3.1. A CBA has been developed by BMA on behalf of NGGT to determine whether the risks are ALARP and therefore tolerable.

Where risks are not considered ALARP, action should be taken. This could include protection of the existing pipeline, e.g. by rock dumping, and the QRA re-run to take account of these measures. In addition to protecting the pipeline, other measures could be considered: if the pipeline is no longer required then it could be decommissioned; or, as proposed by NGGT, it could be relocated to eliminate this risk.

Elimination of risk is a preferred approach in the hierarchy of controls.

3 REVIEW OF CBA

This section discusses our findings relating to our review of the NGGT's CBAs (BMA, 2018a and NGGT, 2018b), including inputs from the QRA (DNV-GL, 2016a). It is divided into three main areas:

- Review of the QRA and NGGT's EVA CBA (BMA, 2018a) documents;
- Review of the NGGT traditional Excel-based CBA (NGGT, 2018b); and
- Implementation of a "Loss of Life" Cost Analysis.

3.1 REVIEW OF THE QRA AND CASE STUDY 1 DOCUMENTS

3.1.1 Fraction of possible groundings resulting in pipeline break

The QRA states that only grounding of a large vessel with draught more than 5m would be a credible threat, and have assumed that only a fraction (0.05) of the possible groundings could cause a pipeline break. The basis for this fraction is not fully justified. We understand that large vessels with sufficient draught to ground comprise 32% of observed crossings. Such a vessel would also need to ground on a part of the pipeline with little cover and to be travelling at sufficient speed to damage the pipeline. The fraction used (0.05) appears to be a suitable 'cautious best estimate' for the purpose of QRA.

3.1.2 Further Hazard Identification to identify new hazards and failure modes

Section 2.7.3 of the Case Study 1 report stated that the new pipeline contained within a bored concrete tunnel would be isolated from the estuary bed and shipping, so would not be exposed to the critical failure modes (rupture from third party interference (TPI) and free spanning). A question was raised to ask whether a hazard identification exercise has been carried out to ascertain whether any other new hazards or failure modes should have been considered. NGGT responded (NGGT, 2018c) that it undertakes a series of Formal Process Safety Assessments (FPSAs) and design reviews as part of the project development, inclusive of HAZID, HAZOP and HAZCON. At the outset of each project phase a FPSA pro-forma is agreed. There are 3 significant risks identified which could impact the permanent operation and maintenance of the pipeline, namely the swan neck at Paull (the pipeline riser out of the reception pit and the associated operational stresses), the pipeline invert (how the pipeline laying on the tunnel and not on point loads) and the structures associated with the drive and reception pits if access was required in the future.

3.1.3 Use of Potential Loss of Life (PLL)

NGGT was asked to provide an explanation for using the 'mean' number of fatalities in the NGGT traditional CBA calculations (NGGT, 2018b), between the Base Case potential loss of life (PLL) and Worst Case PLL. NGGT's response (NGGT, 2018d) was that the traditional CBA is designed to replicate the NGGT EVA CBA (BMA, 2018a), but they have had to simplify some of the assumptions and, in addition, it does not perform a Monte Carlo analysis. The probability within the EVA model is a variable, and therefore tests the range from the Base to Worse Case. Based on a uniform distribution the average probability approximates to (0.00221+0.0155)/2, which is the value that is

used within the traditional CBA. Sensitivity to this assumption is considered at the end of Section 3.3.

3.1.4 Assumptions made in determining the PLL

HSE raised a question regarding the assumptions made in determining the potential loss of life should a major hazard scenario come to realisation. The generic methodology underpinning the Feeder 9 QRA was incorporated by DNV-GL into PIPESAFE. PIPESAFE is used by a number of international Gas Transmission companies, in addition to National Grid. As part of their response (NGGT, 2018e), NGGT provided two documents that: give an overview of the PIPESAFE model (DNV-GL-2015); and a description of the Societal Risk Model (DNV-GL, 2016b) that explains the approach to determining casualties. These seem reasonable.

3.1.5 Environmental costs for the Tunnel 2012 option

NGGT was asked to provide further corroboration for the statement made in Section 2.5 of the Case Study 1 Report, regarding the Tunnel "not having environmental costs because of minimum impact on habitat". The response from NGGT (NGGT, 2018f) was that all environmental measures are detailed within their Development Consent Order (DCO) application and within the DCO approval and local planning applications and requirements. The associated costs form part of the overall project costs and as such have already been factored into NGGT's CBAs.

3.2 REVIEW OF THE CBA

3.2.1 Requirements of an ALARP CBA

There is guidance on suitable inputs for a CBA to support an ALARP assessment (HSE, 2018b). The costs that need to be considered are only those to the organisation that is creating the risk (and paying for the risk reduction measure, the tunnel), in this case NGGT. Costs to other stakeholders are not relevant, e.g. costs to emergency services in the event of an incident. Any benefits from the risk reduction measure should be taken into account by subtracting them from its cost. It is our understanding that, as a regulated monopoly, NGGT would not benefit financially from the tunnel. However, in order to maintain a level playing field with all other companies that create major accident hazard risks in supplying products to consumers, we believe that all other reasonable benefits (avoided business/commercial costs to National Grid, as well as avoided other costs to consumers) should be taken into account in the ALARP assessment.

The depth and degree of precaution in an ALARP CBA should be proportionate to the hazards and risks. The DNV QRA (DNV-GL, 2016a) indicates that these are high. Figure 9 of the DNV QRA presents the societal risks from the existing pipeline. This figure also shows a criteria curve according to the industry standard IGEM/TD/1 (IGEM, 2008) that shows that the risk is in the 'tolerable if ALARP' region, rather than 'broadly acceptable'. HSE's Reducing Risks Protecting People (R2P2) guidance (HSE, 2001) indicates that an event that killed 50 people once in 5000 years (frequency 2E-04 per year) could be considered unacceptable. Figure 9 of the DNV QRA shows the risk as being below that level. HSE COMAH guidance (HSE, 2018g) suggests that the R2P2 point can be extrapolated by drawing a line with a slope of -1 on a log-log graph. On Figure 9 only a very small region of the worst

case curve would exceed this. It is therefore accepted that the risk from the pipeline is in the 'tolerable if ALARP' region. HSE would not insist on National Grid further reducing risks as long as it is already shown to be ALARP, e.g. by an ALARP cost benefit analysis (CBA).

3.2.2 NGGT traditional CBA

The NGGT traditional CBA (NGGT, 2018b) is not presented in the same way as is usual for an ALARP CBA. An ALARP CBA compares the cost of the risk reduction measure (the tunnel) with the benefits from the monetised lives saved plus any other benefits. The NGGT traditional CBA instead calculates total costs over a 60 year tunnel lifetime for both Option 1 (providing the tunnel) and Option 2 (continuing with the existing pipeline). The costs of each option include those of potential lives lost due to pipeline failure. Subtracting Option 2 from Option 1 provides the ALARP CBA presentation used by HSE.

3.2.3 Key inputs to the NGGT CBA

This section considers some key inputs to the CBA (NGGT, 2018b) and whether they are justified.

For all CBAs, the inputs need to be determined as accurately as possible. For an ALARP CBA, it would be usual to use the 'cautious best estimate' principle where any uncertainty should be applied in the direction that favours safety, i.e. favours providing a tunnel.

Frequency of pipeline failure due to TPI

The prediction of pipeline failure frequency is a very specialised topic. NGGT has led the industry in having developed a fracture mechanics methodology that can take account of the specific design of a pipeline and the specific impact energy from a third party intervention such as an anchor or grounded ship (DNV-GL, 2015, 2016a,b). HSE has developed an analogous methodology that applies only to buried pipelines on land. For that case, the HSE methodology is a little more conservative (overestimates frequencies) compared with NGGT's.

The estimated pipeline failure frequencies due to TPI have therefore been obtained using the best available methodology.

For the tunnel option, from 2022, the frequency of a pipeline failure due to third party interference (TPI) that gives rise to loss of life has been reduced to zero in the NGGT CBA. This is on the basis that the construction of the bored tunnel would be to a standard where protection to the pipeline would be provided from ship collision/ grounding and anchor impact. NGGT's analysis does not include the risk of pipeline failure due to freespanning due to the isolation measures (that the HSE has found to be adequate, see Section 2 of this report).

Consequences of pipeline failure due to TPI

The measure of consequences that needs to be used in a CBA is estimated numbers of fatalities and this has been provided from the QRA (DNV, 2016a). Base case and worst case results are provided and their average used, to take account of uncertainty in the underlying assumptions.

Gross disproportion factor

In an ALARP CBA, a proposed control measure needs to be implemented if the costs are not grossly disproportionate to the benefits achieved by the measure.

A gross disproportion factor (GDF) is used in an ALARP CBA (HSE, 2018a) to ensure that the CBA is weighted towards providing increased safety. The maximum value of 10 has been used in the CBA and this is justified by the worst case (where a pipeline failure could result in over 1500 fatalities).

Value of preventing fatality (VPF)

The official values HSE uses in cost-benefit analyses of risks to workers in GB are set out at http://www.hse.gov.uk/economics/eauappraisal.htm (HSE, 2018e). The combined 'human' costs (loss of life and reduction in quality of life) and 'financial' costs (healthcare, productivity, compensation, and admin & legal costs) in 2015 prices were:

- £1.6 million for a fatality;
- £8,200 for the average non-fatal injury; and
- £18,500 for a case of (largely) short-latency ill health.

More information about these estimates can be found at http://www.hse.gov.uk/statistics/cost.htm (HSE,2018f).

NGGT has used the same VPF value as in the HSE Guidance.

Time period for comparison

The NGGT CBA uses a time period of 60 years for comparison of Option 1 (Bored Tunnel) and Option 2 (Continued Mitigation by means of concrete frond mattresses). The 60 year period is the projected lifespan of the Bored Tunnel. However, the lifespan of the Gas Feeder 9 Pipeline itself is less than this, coupled with the fact that there is uncertainty with regards to the continued use of Gas Feeder 9. A more realistic duration for conducting the CBA would be 20 to 30 years. Sensitivity to the use of different time periods is considered in Section 3.3.

Discounting

Within a safety CBA, costs should be discounted at 3.5% and safety benefits (prevention of loss of life) at 1.5% (HSE, 2018b). The NGGT CBA has used 3.5% for both standard costs and for safety benefits. This is also not in alignment with UK Treasury guidance (UK Treasury, 2018).

Discounting is used in a CBA to ensure that costs and benefits are compared in a consistent way at the same date, i.e. to compare the net present values (NPV) of the options. The review of the CBA methodology by Ritz (2018) states that all costs and benefits have been discounted to net present value (NPV) but does not comment on discounting rates. That review was of the NGGT EVA CBA methodology rather than the simplified version presented in the NGGT traditional CBA spreadsheet.

Annex 6 of The Green Book (UK Treasury, 2018), "The standard STPR of 3.5% applied in appraisal should decline over the long term due to uncertainty about future values of its components". The declining rates are shown in Table 8 of Annex 6, and if the comparison duration exceeds 30 years, should decrease to 3% for years 31 to 75. The discount rate for safety benefits should decrease to 1.29%.

3.3 "LOSS OF LIFE" COST ANALYSIS

We carried out a "Loss of Life" Cost Analysis, where all commercial costs (e.g. whole gas price impact, constraint costs, shipping lane closures, *etc*.) were not included. These commercial costs will

be considered separately by Ofgem in their evaluation of NGGT's application for funding for the Gas Feeder 9 Bored Tunnel Project.

Only the costs saved through preventing fatalities from a pipeline failure scenario as a result of Third Party Interference were examined, using the appropriate discounting rates. A holistic cost benefit analysis would require both Ofgem and HSE's considerations of these relevant costs to be weighed concurrently.

We have produced a version of the spreadsheet (HSE, 2018h), using an asset life of 60 years, as per NGGT's assumptions, and that:

- Removes all capital, operational and maintenance costs as well as potential investment/ business/ economical costs (these are marked as needing to be supplied by Ofgem);
- Uses the health and safety discount rate of 1.5%, reducing this to 1.29% after 30 years. Discount rates therefore follow UK Treasury and HSE CBA guidance;
- Uses a GDF of 10 (as was used by NGGT).

For a Cost Analysis that is conducted over 60 years, the NPV of the discounted monetised cost of risk to human life from continued inspection/ mattressing (the mitigation option) is £5.79M. The NPV of the discounted monetised cost of risk to human life under the bored tunnel option is £0.68M and is due to the risk of loss of life from the pipeline before the tunnel is completed.

This means the NPV equivalent to the reduced risk of loss of life from adopting the tunnel build over 60 years is £5.11M. Therefore the risk from mitigation is ALARP if the net cost of the tunnel option exceeds £5.11M (after taking account of all other business/commercial costs to National Grid, as well as other costs to consumers).

3.3.1 Sensitivity to time period of cost analysis

The sensitivity to the time period used for comparison (as discussed in Section 3.2.3) for the cost analysis is as shown in Table 1.

Table 1: NPV for loss of life for different time periods

Time period (years)	NPV cost for tunnel (Option 1)	NPV cost for status quo (Option 2)	NPV of net benefit of tunnel
60	£0.68M	£5.79M	£5.11M
30	£0.68M	£3.40M	£2.72M
20	£0.68M	£2.43M	£1.75M

3.3.2 Sensitivity to Potential Loss of Life (PLL) value used in the Cost Analysis

In addition, Section 3.1.3 discussed that the traditional CBA used a 'mean' PLL value derived from the Base Case and Worst Case PLLs. From a sensitivity perspective, if the Base Case PLL is used rather than the average applied, the 60-year NPV of the discounted monetised cost of risk to human life from continued inspection/ mattressing (the mitigation option, i.e. Option 2) is £1.44M. The NPV

of the discounted monetised cost of risk to human life under the bored tunnel option (Option 1) is £0.17M. The NPV equivalent to the reduced risk of loss of life from adopting the tunnel build over 60 years is thus £1.27M. Therefore, using the Base Case PLL in HSE's Loss of Life Cost Analysis model with appropriate discount factors, the risk from mitigation is considered ALARP if the net cost of the tunnel option exceeds £1.27M (after taking account of all other business/commercial costs to National Grid, as well as other costs to consumers). The NPVs for the different time periods using the Base Case PLL instead of the average value calculated from the Base Case and Worst Case PLLs is summarised in Table 2.

Table 2: NPV for loss of life using the 'Base Case PLL' for 60, 30 and 20 years

Time period (years)	NPV cost for tunnel (Option 1)	NPV cost for status quo (Option 2)	NPV of net benefit of tunnel build
60	£0.17M	£1.44M	£1.27M
30	£0.17M	£0.85M	£0.68M
20	£0.17M	£0.61M	£0.44M

4 CONCLUSIONS

In terms of compliance with Pipeline Safety Regulations (PSR) Regulation 12, the arrangements for isolating a pipeline loss of containment are satisfactory. For PSR Regulation 16, it is clear that discussions have taken place with the Port Authority and a no-anchor zone has been created to reduce the likelihood of interference damage.

For the threat of freespanning, remedial work in the form of concrete frond mattresses and associated grout bags have been provided to protect the pipeline. It is considered that the current inspection regime and management arrangements as described are adequate and meet the requirements to maintain the pipeline integrity. It is expected that these arrangements should remain under review and appropriate action taken based on inspection data.

In terms of risks from Third Party Interference, HSE would expect that the sources and potential risks of interference damage are identified by the operator and suitable mitigation measures undertaken as necessary. Where risks are not considered ALARP, action should be taken. This could include protection of the existing pipeline, e.g. by rock dumping; decommissioning the pipeline if no longer required; or as proposed by NGGT it could be relocated in a tunnel to eliminate the risk. Elimination of risk is a preferred approach in the hierarchy of controls.

The depth and degree of precaution in an ALARP CBA should be proportionate to the hazards and risks. The DNV QRA indicates that these are high, especially if a passenger ferry was to be involved in a pipeline break scenario. The QRA also indicates that the risk from the pipeline is in the 'tolerable if ALARP' region.

HSE has only reviewed the inputs relevant to pipeline failure through third party interference (TPI) leading to potential loss of life and these appear reasonable, including the pipeline failure frequency, estimated consequences (loss of life), gross disproportion factor, and value of preventing a fatality.

The NGGT CBA has been carried out over a 60 year period, i.e. the projected lifespan of the Bored Tunnel. However, the lifespan of the Gas Feeder 9 Pipeline itself is less than this. A more realistic duration for conducting the CBA would be 20 to 30 years.

Discounting of standard costs at 3.5% is in line with HSE and Treasury guidance. However, safety benefits (prevention of loss of life) should be discounted at 1.5%. The NGGT CBA has used 3.5% for both costs and safety benefits.

As part of this work, a "Loss of Life" Cost Analysis was carried out, for a 60-year duration, where all commercial costs were taken out of consideration, for e.g. whole gas price impact, constraint costs, shipping lane closures, *etc*. These costs will be considered separately by Ofgem in their evaluation of National Grid's application for funding for the Gas Feeder 9 Bored Tunnel Project. Only the costs saved through preventing fatalities from a pipeline failure scenario as a result of Third Party Interference were examined, using appropriate the discounting rates. A holistic cost benefit analysis would require both Ofgem and HSE's considerations of these relevant costs to be weighed concurrently.

The results of this analysis over 60 years, carried out by HSE, are as follows:

- The NPV of the discounted monetised cost of risk to human life from continued inspection/ mattressing (the mitigation option) is £5.79M.
- The NPV of the discounted monetised cost of risk to human life under the bored tunnel option is £0.68M.

This means that the NPV equivalent to the risk reduced by the adopting the tunnel build is £5.11M.

Therefore the risk from mitigation is ALARP if the cost of the tunnel option exceeds £5.11M (after taking account of all other business/commercial costs to National Grid, as well as other costs to consumers). For it to be a level playing field with all other companies that create major accident hazard risks in supplying products to consumers, we believe that all other reasonable business/commercial costs to National Grid, as well as other costs to consumers should be taken into account.

HSE would not normally insist on National Grid to further reduce risks, as long as it is already shown to be ALARP.

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HSE's Buxton operations are certified to:
ISO 9001 OHSAS 18001

Health and Safety Executive
Science Division

Harpur Hill
Buxton
Derbyshire
SK17 9JN
UK

1.2 Redgrave Court
Merton Road
Bootle
L20 7HS

www.hsl.gov.uk
www.hse.gov.uk/research

T: +44 (0)20 3028 2000
E: hslinfo@hsl.gsi.gov.uk