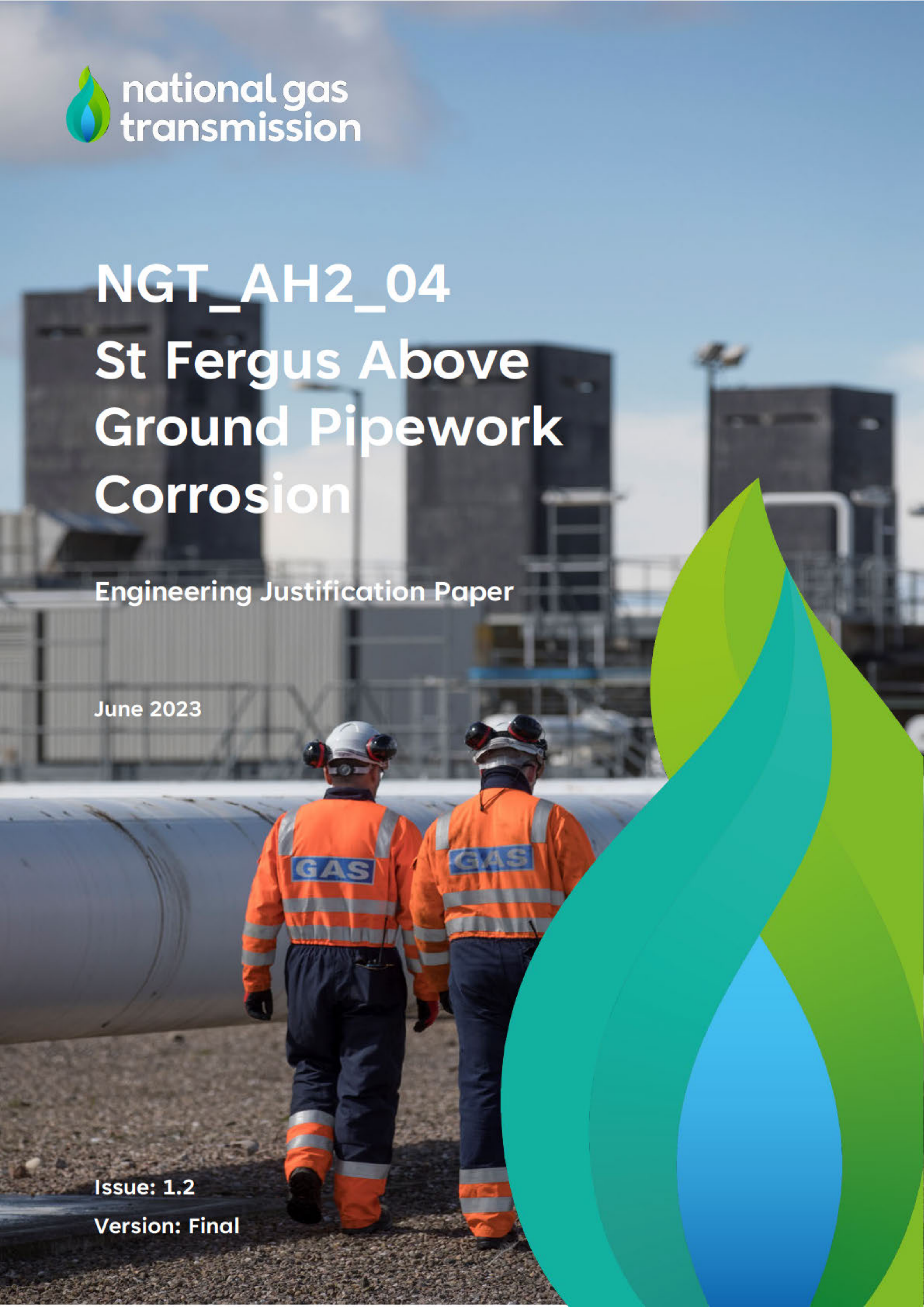

NGT_AH2_04 St Fergus Above Ground Pipework Corrosion

Engineering Justification Paper

June 2023

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Version/revision number	Date of issue	Notes
1.0	15 h Nov 2022	Superseded
1.1	18 h April 2023	Superseded
1.2	30 h June 2023	Submission to Ofgem
1.3		
1.4		
2.0		
2.1		
3.0		

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Executive summary

1. National Gas Transmission, (hereafter referred to as 'NGT'), are submitting the needs case and funding request in accordance with the RIIO-T2 Engineering Justification Paper Guidance v2 document. The purpose of this stage of the process is to justify the project need, set out the different options considered along with the preferred strategic options, and request funding for the preferred option justified within this paper.

2. This Engineering Justification Paper (EJP) details the investment for the remediation of corrosion defects on above ground pipework and implementation of a rolling site wide painting regime.

3. This is part of a suite of documents, shown in Figure 1, and should particularly be read in conjunction with the St Fergus Site Strategy and its appendices. The St Fergus Site Strategy describes the gas terminal's function, its criticality to the network and the proposed investments in line with the site strategy.

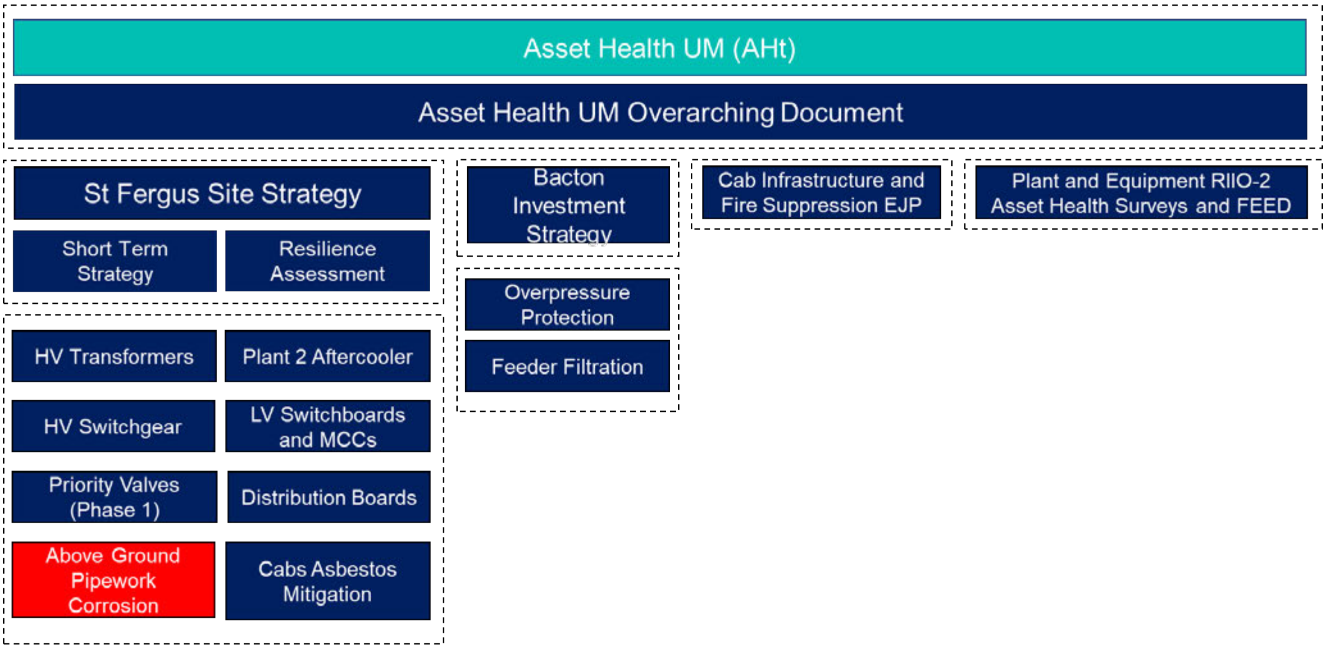

Figure 1: St Fergus Submission Documents Structure

4. The St Fergus Gas Terminal handles between 25% and 50% of the UK's gas supplies, dependent on supply and demand patterns. The site has been in continuous operation for over 45 years and is now moving beyond the design life of the critical original assets.

5. The site is one of two upper tier COMAH sites on our network and as such is a major accident hazard site, subject to regular HSE and SEPA inspections and significant health, safety, and environmental legislation.

6. Above ground assets exposed to the atmosphere at St Fergus have been experiencing and will continue to experience accelerated degradation of their protective coating and experience early onset of corrosion.

7. The painting applied to above ground pipework serves as the primary corrosion protection system. Typically, coating on aboveground pipework is designed to be effective for a period of 10 to 15 years. However, their deterioration at the terminal is accelerated by saliferous

environment which enhances the mechanical degradation of the coating system. This is evidenced from corrosion defects that have been observed on various above ground pipework across the terminal painted as recently as 6 years ago.

8. To address corrosion defects throughout the terminal, a combination of patch painting and partial painting interventions have been utilised. Regrettably, this approach is no longer sustainable given the environment in which these assets are exposed which results in an escalating number of defects observed across the terminal.

9. The number of defects on the aging plant appear to be increasing and additional resources will be needed to resolve them in a timely manner. Failure to address them promptly may result in the deterioration of these defects over time, ultimately necessitating more intrusive and costly interventions such as cut-outs and replacements. At a minimum this results in disruptions in the terminal's normal operation as outages are required to facilitate repair works, at worse, asset failure could be accelerated.

10. Given that the site will continue operating to at least 2050, remediation and prevention of corrosion defects will be required for the terminal to remain operational until at least 2050. This is because of the risk to security of supply brought about by disruptions in normal operation to facilitate remedial works.

11. The RIIO-T2 business plan included all asset health work associated with Plant 1 and Plant 2 under the Emissions Uncertainty Mechanism as the uncertainty about the future solution affected all those assets.

12. As part of the RIIO-T2 business plan, NGT requested [redacted] to remediate corrosion defects across 20% of the terminal. As part of the Asset Health UM, Ofgem granted 60% of the funding as baseline funding with the remaining 40% to be unlocked at an agreed re-opener date.

13. NGT is submitting this investment proposal in the June 2023 asset health submission window as funding is needed for the works spent at risk in remediating over 2500 corrosion defects to date and implementing an efficient approach to address corrosion for the remaining years in this regulatory period.

14. To address the risks and challenges brought about by corrosion defects the following options were assessed:

    1. Do nothing
    2. Repair on failure
    3. Remediate all inspected defects and remediate corrosion defects upon inspection (current reactive approach)
    4. Remediate all inspected defects and implement a fixed frequency painting regime (proactive approach)

15. The options above were assessed on a wide range of criteria, with the highest priority placed on managing the operational safety risk of the terminal and maximum value for the consumer by consideration of whole-life costing.

16. After careful evaluation, transitioning from a reactive maintenance approach to a proactive maintenance approach was determined to be a more efficient and cost-effective solution.

17. This proactive approach entails implementing a comprehensive rolling site wide painting program and other maintenance activities aimed at managing corrosion and mitigating accumulation of corrosion defects across the site.

18. The painting regime will encompass a thorough inspection and remedial plan based on an area. For this investment scope, only the painting of areas 3 and 6 of the terminal in the years 2024 and 2025, respectively will be considered.

19. In summary, this paper aims to define the challenges posed by corrosion on the terminal and seeks funding for the following scopes of work to transition towards a proactive maintenance approach:

    1. Costs spent at risk in remediating corrosion defects that were in scope at the start of RIIO-T2
    2. Corrosion defects at the interface of Pit Wall Transitions (PWTs)
    3. Rolling site wide paint programme commencing in RIIO-T2 in which areas 3 and 6 will be painted
    4. Remediation of forecasted corrosion defects in RIIO-T2

20. The indicative cost of this investment is [redacted] (18/19 price base). The estimated RIIO-T2 cost profile is shown in Table 1.

Table 1 Current estimated RIIO-T2 spend profile

£m 18/19	FY2022	FY2023	FY2024	FY2025	FY2026	FY2027	Total	Comments
Above ground pipework corrosion (£m)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	

21. The four scopes are in different stage of the ND500 process:

- Scope 1 is at stage 4.4: Detailed Design and Delivery with a cost accuracy of +/-10%
- Scopes (2-4) are at stage 4.2: Option Selection with a cost accuracy of +30% /-15%

22. The cost accuracies are in accordance with the Infrastructure and Projects Authority (IPA) cost estimating guidance.

23. NGT are making this funding application for the aboveground pipework corrosion Programme RIIO-T2 investment costs through the Asset Health Re-opener, in line with Special Condition 3.14, requesting an adjustment to the value of the NARMAHOt term for costs incurred in RIIO-T2.

24. This is summarised, along with other investments, within section 4 of the Asset Health Overarching Document provided as NGT_AH2_01 of the June 2023 Asset Health Re-opener Submission.

1. Introduction

25. This paper provides justification for the remediation and prevention of coating and corrosion defects identified through the routine and non-routine maintenance activities at the St Fergus Gas Terminal.

26. In developing our investment programmes at the St Fergus Gas Terminal since the RIIO-T2 Final Determinations, we have adopted a two-phase strategy to ensure clarity between short-term asset health and long-term site operating strategy.

27. Our St Fergus Short-Term Strategy provides certainty on the terminal operation requirements, including minimum compression across Plant 1 and 2, for operation out to 2030. The long-term strategy will deliver the enduring terminal solution, including compression, required for operation beyond 2030.

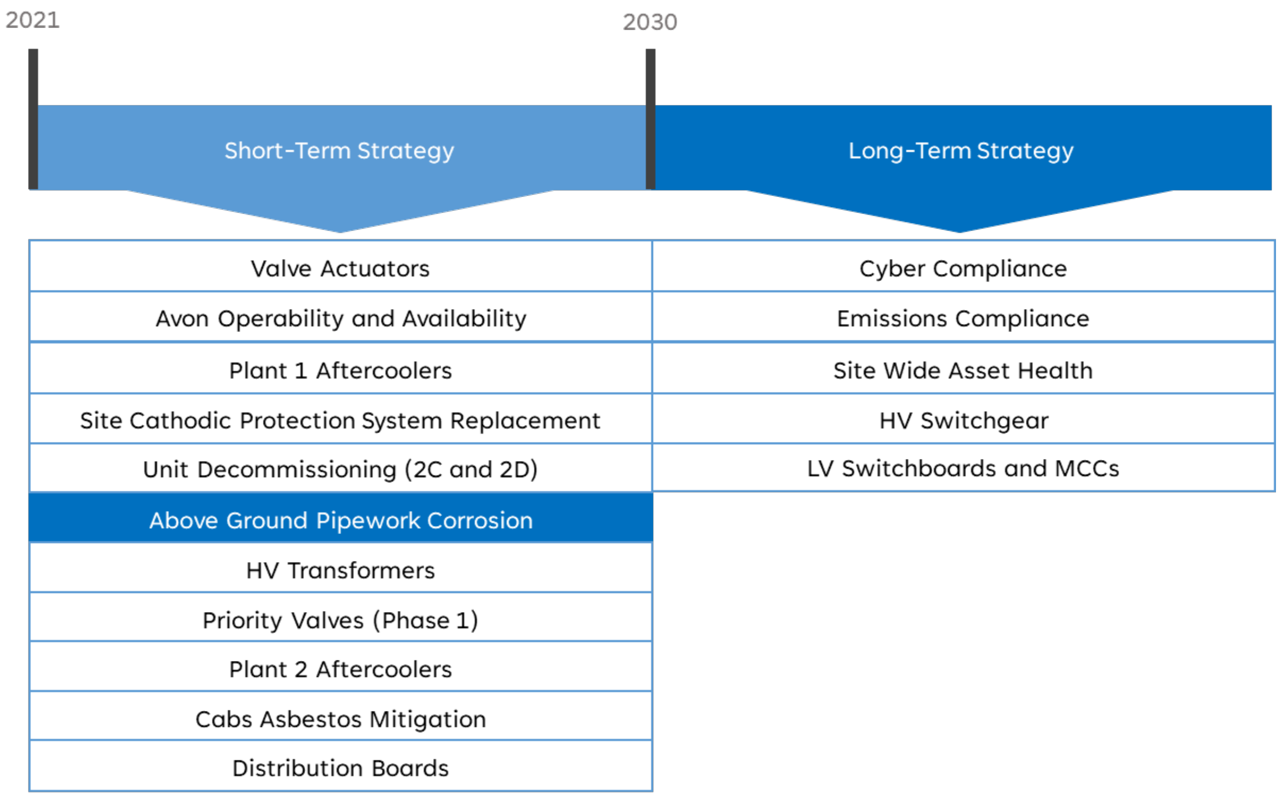

Figure 2 St Fergus Site Strategies Summary

28. As explained in the St Fergus Site Strategy, both the short and long-term strategies have confirmed the need for Plants 1 and 2. The Short-Term Strategy also recommends investing to maintain site safety and integrity to 2030. These recommendations are fundamental to the proposals in this paper which are critical to address the risk posed by corrosion. Therefore, it is important that these documents are considered in parallel.

29. CM/4 defects are coating and corrosion issues and any visual mechanical interference or defects (such as gouges and dents) identified during above ground coating surveys. These are carried out on the National Transmission System (NTS) installations as required by NGT maintenance procedures.

30. Above ground corrosion is a known issue at St Fergus and the primary deterioration and failure mode for pipework coating. Severe corrosion results in expensive cut-out and replacement activities that disrupt operations due to the requirement of an outage to facilitate the works. This might lead to high constraint costs being incurred from not meeting our flow obligations and could impact security of supply for the UK.

31. Currently the approach that has been taken over the years in resolving corrosion defects on above ground pipework has been reactive. While this has managed to maintain the risk level on site to As Low As Reasonably Practicable (ALARP) and improved the condition of the site, it is not sustainable in the long term and provides lower overall value to the consumer.

32. Therefore, we propose that the Terminal move to a phased proactive paint-coating regime at the earliest opportunity. This effective management of corrosion will contribute towards achieving the following benefits:

    - Statutory compliance with Safety, Health and Environmental (SHE) policies
    - Reduction in leaks and pressure restrictions
    - Increased plant availability
    - Reduction in unplanned maintenance and deferment costs
    - Reduction in future investments for corrosion remediation
    - Proves an increased understanding of the corrosion degradation mechanisms and their rates

33. Combining this proactive approach with other planned RIIO-T2 works will deliver future efficiency savings and reduced consumer costs from current reactive programmes of work.

34. This document seeks to highlight the needs case for investment together with the benefits associated with the proposed option which supports the site's short-term strategy.

2. Equipment Summary

35. The purpose of above ground pipework is to contain natural gas flow and conduct it under pressure between process, flow-control, pressure control, gas quality, compression, metering, scrubbers, and pipework inspection equipment.

36. An illustration of the complexity of the station pipework and paint area boundaries (1-6) of the terminal is shown in Figure 3 .

[redacted]

Figure 3 - St Fergus Terminal below and above ground pipework in each area

37. Above ground pipework consists of:

- General Pipework
- Risers
- Flanges
- Pipe Supports (corrosion at interface with pipeline)
- Pit Wall Transitions (corrosion at interface with pipeline)
- Cladding
- Vent and Sealant

38. Pipework coating provides a barrier between the parent pipework and its environment to prevent corrosion from occurring. Corrosion has been highlighted as being the single biggest life limiting mechanism affecting the pipework at St Fergus.

Volume

39. There is approximately 5.5 km of above ground pipe work ranging in different diameters from 1 to 48 inches connected with 19 km of below ground pipework. The majority of the pipework was installed when the site was commissioned in 1977.

Pressure ratings

40. The pipework is subjected to a maximum operating pressure of 70 bar and the incomers 1 and 2 from the NSMP sub-terminal each carry a maximum of 36 mscmd of gas.

Managing the above ground pipework

41. The design, construction, operation and maintenance of the above ground pipework is subject to both:

    - Pressure System Safety Regulations 2000 (PSSR) – general legislation for all pressure vessels, defining the regime for setting inspection frequencies and subsequent remediation of defects.

    - The Pipeline Safety Regulations 1996 (PSR) – specific legislation for operating pipelines, placing obligations to manage the safety risks that they present to members of public and NGT staff.

42. The external inspection and subsequent remediation of pipework defects or "features" to industry standards (IGEM TD/1), supplemented by NGT policies and procedures is accepted by the Health and Safety Executive (HSE) as an appropriate way of operating a safe above ground pipework asset and complying with required legislation.

43. Assessment and management of corrosion on above ground assets is challenging as the depth and extent of any corrosion defect cannot be fully understood and assessed until an investigation has been undertaken.

44. NGT uses a defined methodology and specification for the visual inspection of paint, coating and cladding for above ground assets **T/SP/CM/4** or CM/4. The CM/4 inspections are undertaken for all above ground pipework assets every six years.

45. Each inspection result is categorised on a scale of 1 to 6 (examples of these are provided in later in this document). Figure 4 shows the risk severity of each defect category and the associated action. In the case of Vent and Sealant Lines remedial action is required from Category 3 upwards as shown in Figure 5.

CM/4 Categories 1 to 6

Category	*Monitoring Period*	*Corrosion Risk*	
1	6 Years	No Risk of Onset	No Remedial Action Required
2	6 Years	Low Risk of Onset	
3	6 Years	High Risk of Onset	
4	Risk Score <15	Corrosion Present	Remedial Action Required
5	Risk Score 15 to 20	Active Corrosion	
6	Risk Score 20 to 25	Aggressive Corrosion	

Figure 4 NGT's corrosion assessment categorisation remedial actions and risk by category

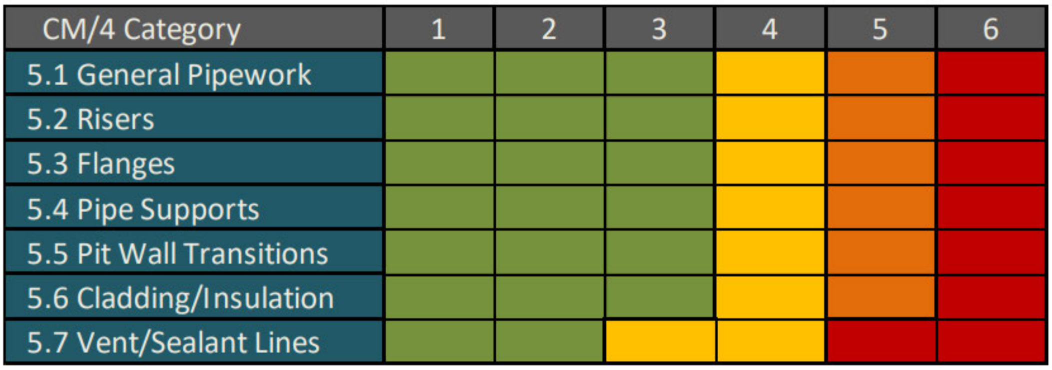

Figure 5 Corrosion Assessment Categorisation by Equipment Type

46. Following an inspection, assets in categories 4, 5 or 6 are subject to further investigation where increased inspection and monitoring requirements and a maximum intervention period is defined followed by an assessment.

47. The assessment includes non-destructive testing and/or removal of paint to assess the corrosion loss. Depending upon the asset concerned and the severity of the potential defect, this may require pressure reduction.

48. Following the assessment, a decision is then made against defined NGT policies to determine the intervention that is required which may include cut out and replace, repair, recoat, composite wrap or clamps.

49. The NGT policies used to make this decision are **T/PM/P/11** Inspection and Damage Assessment for Pipelines the Nominal Diameter greater than 150mm or **T/PM/P/20** which applies up to 150 mm nominal diameter. **T/P/PA/10** specifies procedures for painting the surfaces of all types of ferrous and non-ferrous metal engineering components

50. These policies ensure the pipework is repaired and can be operated up to its maximum operating conditions. The inspection regime, timing and defect categorisation is designed to ensure that a defect should not move more than one category between each inspection.

51. This balances the effective monitoring of corrosion, the mitigation of risk of increasing corrosion and the costs of inspection.

3. Problem Statement

52. Above ground assets exposed to the atmosphere at St Fergus terminal have been experiencing, and will continue to experience, accelerated degradation of their protective coating and experience early onset of corrosion.

53. The painting applied to above ground pipework serves as the primary corrosion protection system. Typically, coating on above ground pipework is designed to be effective for a period of 10 to 15 years.

54. However, coating deterioration at the terminal is accelerated by saliferous environment. This is evidenced by corrosion defects that have been observed on various above ground pipework across the terminal painted as recently as 6 years ago.

55. To address corrosion defects throughout the terminal, a combination of patch painting and partial painting interventions have been utilised. Regrettably, this approach is no longer sustainable given the environment in which these assets are exposed which results in an escalating number of defects observed across the terminal.

56. Over five years, visual inspections and reporting of above ground coating surveys carried out across the site during maintenance activities have identified over 4,000 corrosion defects as shown in Figure 6.

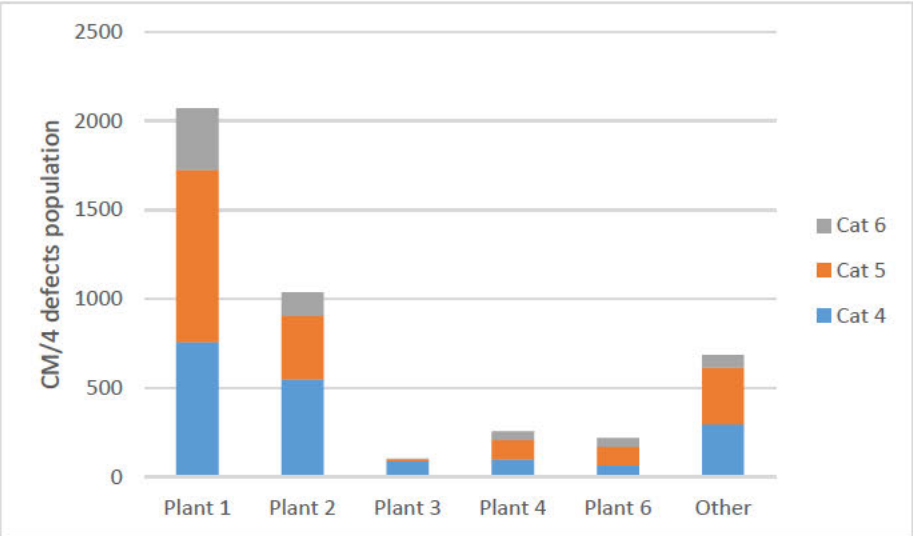

Figure 6 Defect population recorded at St Fergus as of 2021

57. Corrosion defects are more prevalent in areas such as: underneath pipe supports, at the transition from above to below ground (either at a pit wall or the wind/water line), in congested areas subject to stagnant air or on specific elements (such as flanges or small-bore pipework). This is due to accelerated corrosion mechanisms that tend to play out in these environments.

58. The HSE have recognised that managing the integrity of ageing plant and equipment is a key issue for the industry, in particular degradation due to corrosion, erosion, and fatigue.

59. Maintaining our current reactive approach will ultimately result in a growing number of corrosion defects, exceeding the capacity to address them in timely manner.

60. Consequently, certain defects will deteriorate over time, ultimately necessitating more intrusive and costly interventions such as cut-outs and replacements. This results in disruptions in the terminal's normal operation as outages are required to facilitate these repair works.

61. It is critical that an alternative approach is considered towards remediating corrosion defects to manage the costs and risks associated with operating the terminal.

62. The desired outcome for this investment is:

- Eliminate/reduce operational risks and challenges brought about by reactive corrosion remediation
- Remediate all inspected defects in the terminal and transition to a proactive approach of managing defects
- Implement a fixed frequency site wide paint programme
- Collect data to inform a future true site-specific approach asset management paint system

Drivers for Investment

63. The key drivers for investment in the above ground pipework coating and corrosion remediation are:

- Legislation
- Asset Deterioration

Legislation

66. Inspection, maintenance, and associated remediation is essential to maintaining compliance with PSSR and PSR.

Asset Deterioration

64. Pipework and its coating system is subject to several deterioration mechanisms:

- The coating deteriorates and fails to protect the pipework
- Where the coating system breaks down and has failed, external corrosion and the associated metal loss reduces wall thickness.
- This corrosion is accelerated by chloride contamination, crevice corrosion, dissimilar metal corrosion, stress corrosion cracking and erosion/fretting.

Impact of No Investment

65. Lack of investment in remediating the defects on the above ground pipework paint will result in an increasing number of corrosion defects. The existing defects will continue to get worse and new defects will arise. Lack of investment in painting will further increase the amount of corrosion and the associated defects.

66. Unmanaged corrosion and unresolved defects will ultimately lead to loss of integrity of the above ground pipework, loss of containment of high-pressure gas, unacceptable safety risks, and therefore limit the availability or performance of the terminal.

Example of the Problem

67. The photographs in Table 2 show examples of each of the CM/4 defect categories 1 to 6 together with the respective intervention.

Table 2 CM/4 defect category examples

Visual Grade	Description	Example	
1: No remedial action required	No risk of onset corrosion		Paint system in 'as new' condition with no evidence of paint degradation or algae formation
2: No remedial action required	Low risk of onset of corrosion		Paint system in good condition with only superficial coating deterioration (e.g. chalking) or algae formation. Areas may require power wash to remove algae (if present) to confirm corrosion is not being concealed.
3: No remedial action required	High risk of onset of Corrosion		General breakdown or widespread defects in the paint system (e.g. top-coat cracking or flaking) but no visible rust staining or corrosion products. Areas may require power wash to remove algae (if present) to confirm corrosion is not being concealed.
4: Remedial action required	Corrosion present Possible risk of P/11 or P/20 defects		Paint system in fair condition with some small areas of paint breakdown leading to rust staining but no other visual signs of corrosion. Patch repair techniques are likely to be cost effective.

Visual Grade	Description	Example	
5: Remedial action required	Active corrosion present Credible risk of P/11 or P/20 defects		Paint system in poor condition, with areas of brown coloured corrosion products present, often with associated rust staining. Consideration should be given for full repaint as patch repair may not be economical.
6: remedial action required	Aggressive corrosion present		Paint system in poor condition, with localised areas of black coloured corrosion products present which can result in rapid metal loss. Areas are likely to require a full repaint. Leaking damage shall be isolated and addressed immediately.

68. As will be discussed later in the document, areas 3 and 6 have been prioritised for intervention based on the poor condition of the coating and severity of corrosion. The images in Figure 7 further showcase the condition.

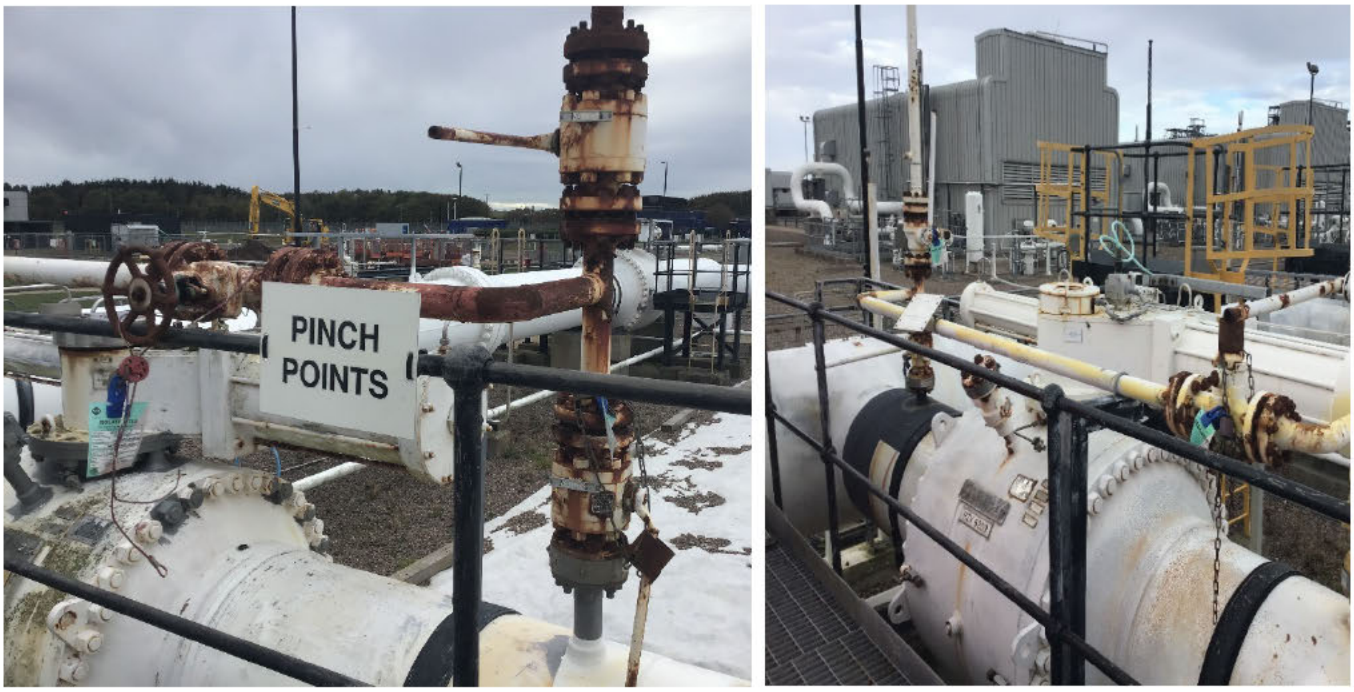

Figure 7 Category 6 corrosion defects on above ground pipework in the mixing area (located in area 6) of the terminal

Spend Boundaries

69. This investment is limited to corrosion remediation and coating of the above ground pipework across the terminal. It also covers pit wall transitions which are not protected by the cathodic protection system.

70. Corrosion associated with below ground pipework is out of scope and is captured in the Cathodic Protection EJP which was submitted in January 2023.

4. Probability of Failure

71. Coating failure occurs when coatings no longer perform their designed function. This failure often takes place when the bond between the coating and the substrate weakens or ceases.

72. Given that the coating protecting the assets has broken down and corrosion is fully visible, the protection system is considered to have already failed.

73. There are various failure modes associated with pipework coating such as:

- **Adhesion Failure:** The coating fails to adhere properly to the pipe's surface, resulting in peeling, blistering, or flaking.
- **Corrosion Underneath Coating:** The coating may appear intact, but corrosion can occur beneath the coating due to inadequate surface preparation or coating application.
- **Coating Disbondment:** The coating separates from the pipe surface, leaving the metal exposed to corrosion and other environmental factors.
- **Cracking or Crazing:** The coating develops cracks or fine lines, which can allow moisture or chemicals to penetrate and cause damage.
- **Delamination:** Layers of the coating separate from each other, leading to the loss of protective properties and potential corrosion issues.
- **Pinholes or Holidays:** Small gaps or voids in the coating that expose the underlying pipe material to the environment, making it susceptible to corrosion.
- **Mechanical Damage:** The coating gets damaged during transportation, installation, or operation, compromising its protective capabilities.
- **Environmental Degradation:** Exposure to extreme temperatures, UV radiation, biological, chemicals, or harsh weather conditions can degrade the coating's performance over time.

74. The main failure mode of pipework coating at the St Fergus terminal is due to mechanical damage and the wearing of the surface coating over time when subjected to the corrosive/harsh environment.

75. For this paper, historic data from site inspections is used to calculate the failure rate of pipework coating by taking the average number of defects in each category recorded from the year 2015 to 2023 (see Appendix D: Forecasted defects model).

Table 3 Defect volume per year. Data from the years 2015-2023.

Timeframe	Cat. 4 (defects/year)	Cat. 5 (defects/year)	Cat. 6 (defects/year)
2015 - 2023	1000	238	89

76. The data in Table 3 showcases the expected growing number of defects if we maintain our current reactive approach to managing defects. It is evident that re-instating the primary protection system of above ground pipework through painting (discussed later in the document) will significantly curb the growth of new defects thus allowing for the current population of

defects to be remediated without the increased risk of them developing in severity (e.g., from a Category 5 to Category 6 defect).

5. Consequence of Failure

77. Pipework coating in numerous areas of the terminal is considered to have failed or in in the process of failing. This is evidenced by an increasing population of defects identified through site inspections. Low risk defects (e.g. Category 1-3) have very little consequence on the operation of the terminal.

78. However, high risk defects (e.g. Category 4-6) can have significant implications on operation of the terminal if, upon reinspection, they are determined to be severely corroded and in need for intervention.

79. The contribution of individual service risk measures towards the overall risk for Above Ground Pipework and Coating can be explained as follows, in order of significance at St Fergus:

80. Safety impact:

- Category 6 corrosion defects present the highest safety risk due to their potential to severely degrade the pipe wall thickness and cause a loss of containment of high-pressure gas.
- In the event of a loss of containment, site operations respond by reducing the gas pressure followed by isolation of the area/pipeline. This is done to eliminate the risk of injury to site personnel or damage to assets from ignition.
- Additionally, corrosion could also impact the functionality of other assets such as:
  - Vent and sealant lines which might affect the provision of valve isolations
  - Fire water main system of which the internal corrosion cannot be mitigated by the CP system

81. Security of supply:

- Unavailability of key assets, because of outages required to facilitate corrosion remediation works, will have an impact on security of supply. For example, the Plant 1 aftercoolers have been on prolonged outage to address corrosion issues on associated pipework. This limited the flow capability of the terminal and could have resulted in NGT not meeting its flow obligations to NSMP.

82. Environmental impact:

- This is caused by the loss of gas through corrosion and joint leaks.
- Gas is vented to the atmosphere when de-pressurising and isolating an area for corrosion remediation. If a proactive maintenance approach is not taken to addressing corrosion the occurrence of venting to the atmosphere to remediate defects will increase.

83. Financial impact:

- Remediation of severely corroded pipework requiring mechanical intervention is an expensive scope of work due to the requirement of cut-out and replacement activities.
- If an outage is required to facilitate corrosion remedial works this can impact the flow capability in the terminal which puts NGT at risk of not being able meet North Sea Midstream Partners (NSMP), Shell and Ancala flow obligations.
- As an example, at a gas price of [redacted] the cost of the gas impacted would be roughly [redacted] per mscm, this is consistent with the constraint cost assumptions used in the Final Option selection Report (FOSR) in January 2023 and is a conservative estimate of the costs we would expect to see in the event of a constraint (see St Fergus resilience assessment)

6. Options Considered

84. In total, four high-level options are considered here for management of the condition issues and associated risks as outlined in previous sections. Of these four options, three are discounted as they are not viable for compliance reasons, which are outlined below.

Options discounted

85. **Option 1**: Do nothing: Continue to operate without resolving the defect risk

- This option is not viable due to requirements to operate safe plant in compliance with PSSR, COMAH and other safety regulations.
- This option would not meet expectations set out by the HSE.
- Coating has an effective design life of 10-15 years; this is further shortened as a result of the harsh coastal conditions at St Fergus. The growing number of defects is a strong indication that the coating in place in no longer effective.
- The current approach to remediating reported defects through patch/partial interventions is no longer sustainable because of the growing number of defects across the terminal.
- Failure to control the degradation process of severely corroded assets in an effective or timely manner may affect the asset's operability and will eventually result in it reaching its final corrosion limit state leading to a loss of containment.
- Consequently, unplanned outages required to facilitate remediation works could impact security of supply.

86. **Option 2**: Repair on failure: Repair assets once they have failed (i.e., a category 6 defect is identified)

- This option is not viable due to requirements to operate safe plant in compliance with PSSR, COMAH and other safety regulations.
- This option would not meet expectations set out by the HSE.
- Coating has an effective design life of 10-15 years; this is further shortened because of the harsh coastal conditions at St Fergus.
- The harsh conditions coupled with the fact that the terminal has not undergone a site wide paint programme in more than 15 years makes the assets very prone to failure as coating degradation will continue to occur at an increased rate to a critical point which will result in a loss of containment event.
- This makes the site susceptible to increased outages which would result in NGT paying constraint costs from not meeting its flow obligation and lead to a shortfall of supply to the network.
- The option is not economical as replacing pipework during reactive maintenance is very costly due to the need for extensive scopes to facilitate works.

- Failure to address other category defects i.e., Category 4 and 5's will result in inefficiencies as the defects will increase in severity and number over time requiring an increased cost to remediate.
- There is also a risk to personnel and property in the event of a catastrophic failure.

Options progressed

87. The options progressed are those that maintain the safety level of operating the terminal to ALARP and comply with safety regulations.

88. Progressed options **must include** the remediation of inspected defects identified across the terminal with emphasis on corrosion defects in pit wall transitions which require expensive scope of works to remediate due to challenges with access (discussed later in the document).

Table 4 Activity under each option

Activity	Option 3: Reactive management of corrosion	Option 4: Reactive management in RIIO-T2 and proactive management in RIIO-T3	Option 5: Proactive management of corrosion commencing RIIO-T2
Patch painting	✓	✓	✓
Full site re-paint	✗	✓	✓
Corrosion remediation	✓	✓	✓

89. **Option 3**: Remediate inspected defects and remediate corrosion defects upon inspection:
    - This option involves remediating all outstanding inspected Category 4, 5 and 6 defects and continue remediating new Category 3 and 4 defects upon inspection across the entire site though patch painting.
    - This option complies with PSSR, COMAH and other safety regulations.
    - This option minimises the number of expensive reactive maintenance works required to facilitate works as the defects have not developed to the highest-risk category.
    - This option however does not address the root cause of corrosion as there will be a growing number of low-risk defects across the terminal over time as the coating system is no longer effective.
    - This option is highly reliant on inspections to identify and plan remediation which might take longer than expected, leading to defects developing to higher risk categories.
    - This will eventually result in a back log of defects to remediate over time.

90. **Option 4**: Remediate inspected defects and implement a painting regime in RIIO-T3:
    - This option involves remediating all outstanding inspected Category 4, 5 and 6 defects. After which new Category 3 or 4 defects will be remediated through patch painting. A phased proactive painting regime will be implemented in RIIO-T3 (2026 onwards).
    - This option complies with PSSR, COMAH and other safety regulations.

- This option addresses the root cause of the issue as it puts in place a protection system against corrosion. However, delaying the painting programme to the start of RIIO-T3 is less effective from a whole life cost perspective as the terminal is still exposed to the operational risks and challenges brought about reactive maintenance.

91. **Option 5:** Remediate inspected defects and implement a painting regime commencing in RIIO-T2:

- This option involves remediating all outstanding inspected Category 4, 5 and 6 defects. A phased, proactive painting regime will be implemented in this regulatory period (2024 - onwards).
- This option also includes regular power washing of pipework to prevent microbial degradation of coating.
- This option complies with PSSR, COMAH and other safety regulations.
- This option addresses the root cause of the issue as it puts in place a protection system against corrosion for a long duration and prevents expensive reactive maintenance.
- This reduces the number of growing defects over time hence reducing the overall costs required to remediate inspected defects over time.
- This option greatly minimises the requirement for outages and expensive cut outs due to the reduced number of Category 6 defects.
- This option delivers the most value to consumers as a result of the long-term cost savings achieved.

Options Cost Details

92. A whole life cost (WLC) approach is utilised to demonstrate the cost differences between the options discussed in the previous section. This approach ensures the option that delivers the most value to consumers is chosen. (See Appendix D: Forecasted defects model)

93. The following assumptions have been made while developing the **theoretical model:**

- All areas of the terminal start with the same defect population
- Linear yearly growth of defect population of 17% in each category. The CM/4 inspections are undertaken for all above ground pipework assets across the NTS every six years. It is therefore assumed defects will grow by the same rate (~0.166) which is a conservative growth rate for St Fergus terminal given the Saliferous environment.
- Intervention (painting or corrosion remediation) is limited to one area every year
- 17% of the average defect population is expected 6 years after re-instating painting system through grit-blast and paint compared to 3 years after maintenance painting.
- 12-year frequency period for grit blast and paint and a 6-year frequency period for maintenance painting

94. Model limitations:

- Fixed frequency intervention is the only solution applied for the proactive approach. More data (area specific corrosion deterioration rates) is needed to implement a true site-specific approach asset management paint system which would be even more cost effective.
- No inclusion for contractor fee, inspection testing, prelims, excavations and setting out work area

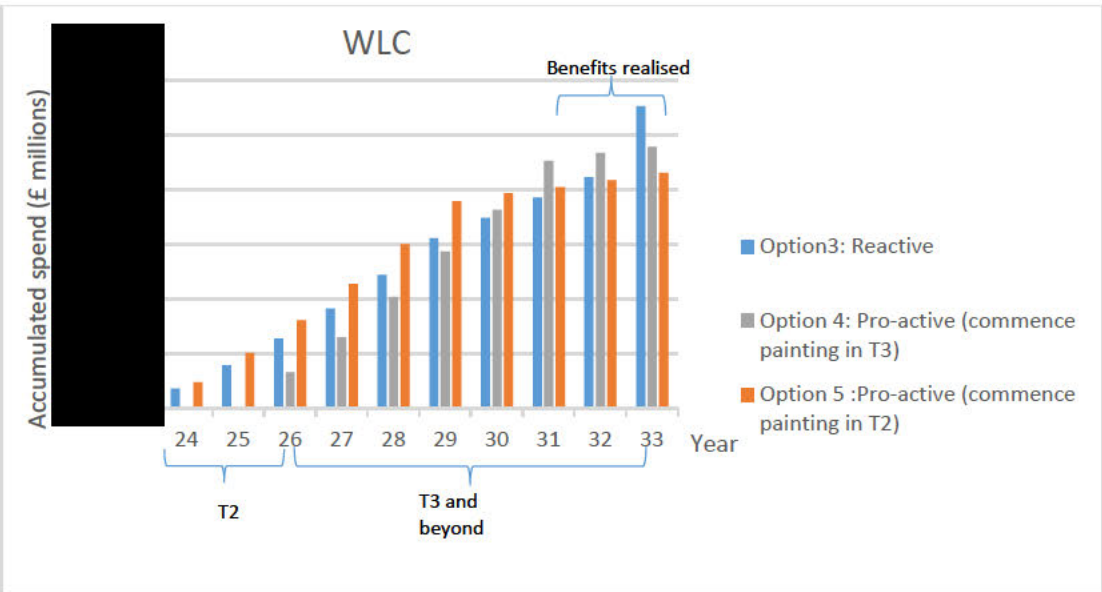

Figure 8 WLC analysis of options

95. From a WLC perspective, a proactive approach to maintaining the integrity of the coating system and managing corrosion defects proves considerably more cost effective compared to the reactive approach, as illustrated in Figure 8.

96. By re-instating the primary protection system of the pipework, the proactive approach effectively reduces and avoids the accumulation of defects, thereby minimising the associated costs of remediation.

97. It is worth noting that the cost differences between the two approaches are expected to be even greater, as the analysis does not account for the additional expenses required for invasive works and the operational risks and challenges from a reactive management approach.

98. A sensitivity analysis of the defect growth rate showed that even halving the rate only delayed benefits being realised by a year.

99. Moreover, the WLC analysis also highlights the cost savings derived from implementing a site-wide paint programme at the earliest opportunity, as it is expected to prevent the occurrence of numerous defects.

Table 5 Estimated cost savings from implementing a rolling site wide paint programme in RIIO-T2

Options	Estimated total cost till 2033	Estimated Cost Increase compared to option 5
Option 5: Remediate all defects and start painting in RIIO-T2	[redacted]	[redacted]
Option 4: Remediate all defects and start painting in RIIO-T3	[redacted]	[redacted]
Option 3: Reactive management of defects	[redacted]	[redacted]

7. Option Analysis and Selection

Solution considerations		Option 1	Option 2	Option 3	Option 4	Option 5
		Do nothing	Repair on failure	Remediate upon inspection	Proactive painting regime in RIIO-T3	Proactive painting regime in RIIO-T2
Meeting HSE Requirements		Non-complaint	Non-complaint	Compliant	Compliant	Compliant
Cost		**No initial cost. Will result in higher overall costs from an increased volume of high-risk defects that require expensive SOW. Incur expensive constraint costs because of increased outages**	**Low initial cost. Will result in higher overall costs from an increased volume of high-risk defects that require expensive SOW. Incur expensive constraint costs because of increased outages**	**Medium cost.** Will result Increased number of defects that will need intervention. Potential to incur higher costs due to increasing back log of developing defects	**Medium cost.** Will result Increased number of defects that will need intervention in the short term before moving to a proactive approach in T3.	**High initial cost** **Low costs overall** due to addressing root cause of the problem which results in a reducing number of defects over time.
Compliance	PSSR	Non-compliant	Non-complaint	Compliant	Compliant	Compliant
	PSR	Non-compliant	Non-compliant	Compliant	Compliant	Compliant
Environmental Impact		High impact from corrosion leaks	High impact from corrosion leaks	Medium impact. Reduced number of defects with leaks	Low impact	Low impact.
Maintenance	Ongoing OPEX	High OPEX resulting from increased number of defects to remediate and malfunctioning assets that will require repair to continue operation	High OPEX resulting from increased number of defects to remediate and malfunctioning assets that will require repair to continue of operation	Medium- Back log of defects might cause a strain on operations to remediate and outages will be required to facilitate works	Low- Increased number of defects to remediate in the short term before moving to a paint regime which will significantly reduce number of defects	Low Number of defects significantly reduced over time. Reduced number simplifies planning of defect remediation
	Risk	High risk to site personnel from operating in a hazardous environment	High risk to site personnel from operating in a hazardous environment	Low risk as defect number is kept low and at an allowable level of risk	Low risk as defect number is kept low and at an allowable level of risk	Low Population of defects significantly reduced

Solution considerations	Option 1 Do nothing	Option 2 Repair on failure	Option 3 Remediate upon inspection	Option 4 Proactive painting regime in RIIO-T3	Option 5 Proactive painting regime in RIIO-T2
Security of Supply	High risk due to increased number of unplanned outages to facilitate remediation works. High likelihood of not meeting flow obligation	High risk due to increased number of unplanned outages to facilitate remediation works. High likelihood of not meeting flow obligation	Medium- Long duration outages will be required to facilitate growing backlog of defects	Low Increase number of defects in the short term however number of defects significantly reduces in the long term due to implementation of painting. Outages will be planned therefore reducing the risk from asset availability	Low – Number of high-risk defects will have significantly reduced. Outages will be planned therefore reducing the risk from asset availability
Overall viability	Not viable	Not viable	Viable	Viable	Viable

8. Preferred Option Scope and Project Plan

100. The assessments outlined in this paper and the associated discounting and costing of options demonstrates there is only one cost effective option to take forwards: Option 5 – Remediate defects and implement a phased proactive painting regime commencing in RIIO-T2.

101. The focus is therefore on ensuring this is delivered at the overall cost thereby lowering risk and achieving compliance. The following factors support this:

- The St Fergus Site Strategy confirms the need for corrosion remediation and prevention on aging above ground pipework.
- The option suggests a painting programme which prolongs the life of assets thus providing the most value to the business and consumers.
- The competitive tender process undertaken for the Main Works Contractor (MWC) provides assurance that a competitive market rate is paid for the programme

Project scope

102. Remediation of CM/4 defects is required to enable the safe operation of the site and a painting regime to maintain the condition of the assets thereby maximising their useful life.

103. The following table shows the population of CM/4 defects identified through inspection surveys at the start of the RIIO-T2 regulatory period.

Table 6 Defects population at the start of 2021

Status	Category 4	Category 5	Category 6
Defects Start of 2021	1643	1821	610

104. It should be noted that inspections across the terminal process pipework system are continuously carried out, leading to additional defects being found on a regular basis. High risk category defects if left un-intervened also progress in severity over time.

105. This engineering justification paper seeks to request funding for:

1. Costs spent at risk in remediating corrosion defects in scope at the start of RIIO-T2
2. Remediation of corrosion defects in pit wall transitions
3. Rolling site wide paint programme commencing in RIIO-T2 in which areas 3 and 6 will be painted in the years 2024 and 2025 respectively
4. Remediation of forecasted corrosion defects in RIIO-T2 and yearly power washing of aboveground pipework across the terminal

1) Costs spent at risk in remediating corrosion defects in scope at the start of RIIO-T2 (PAC3419)

106. Originally in the RIIO-T2 business plan, the full funding request for remediating corrosion defects across the terminal was [redacted].

107. However due to the uncertainty of the terminal's final option selection at the time, NGT included all asset health work associated with Plant 1 and Plant 2 under the Emissions Uncertainty Mechanism as the uncertainty about the future solution affected all those assets.

108. Therefore, NGT requested [redacted] to remediate corrosion defects across 20% of the terminal. However, as part of the UM, Ofgem granted 60% of the funding as baseline with the remaining 40% to be unlocked at an agreed re-opener date.

109. The main works contractor (MWC) was awarded the contract to remediate the inspected CM/4 defects and the additional scope to remediate high risk Category 5 and 6 defects which was required to maintain the terminal's risk level to ALARP.

110. Various deliverability challenges have manifested since the work was first scoped and presented in the RIIO-T2 business plan and have had an upwards pressure on costs (challenges covered later in this document). The following are the key deliverability challenges:

- being able to achieve isolations on site and arrange outages with customers, whilst also maintaining a gas path through the terminal
- Outputs of condition-based assessments resulting in scope adjustments and culminating in cost variances
- additional scope required, which was not foreseen before detailed design had commenced e.g., a cut out and pipe replacement can be recommended after carrying out an inspection on a Category 5 defect

111. The benefits from the project are:

- the reduced operational risk from corrosion induced failures and
- the increased visibility of the scope requirements to deliver remediation of CM/4 defects. Learnings over the delivery of CM/4 defects remediation will impact the programme and/or costs and used to determine more efficient ways of delivering.

112. Delivery of works covering corrosion defects within the original scope are in flight see Table 7

Table 7 Outstanding defects within MWC scope

Status	Category 4	Category 5	Category 6
Defects Start of RIIO-T2	1221	955	348
Outstanding defects from original scope	0	366	71

113. The baseline funding provided for remediating corrosion defects has been utilised and an additional funding request of [redacted] is being made for remediating the outstanding corrosion defects within the MWC's scope.

2) Corrosion defects at the interface of Pit wall transitions

114. Pit wall transitions are features at most compressor stations, terminals and some block valve and off-take sites. Some involve transition of the carrier pipe through the pit wall between pits (atmospheric zone to atmospheric zone); others involve the transition through the pit wall into the ground (atmospheric zone to buried zone).

115. The pit wall transitions are expected to attract the most commercial risk for this scope. This is in part due access challenges. Pits are classed as confined spaces and will require construction of scaffold to facilitate entry. Excavation may also be required to access.

116. 32 pit wall transitions have been identified with severe corrosion problems. Pit wall transitions are challenging to inspect using non-intrusive methods. Defect reports request further investigation within the transitions which requires more invasive inspection techniques.

117. Scope definition:

- Inspect the area using NDT such as short-range ultrasonic testing to determine whether excavation is necessary
- Further inspection, blasting, cleaning etc may determine that patch painting is not the most appropriate remedial action and line replacement, or rerouting, is required.

118. The funding request for this scope is [redacted] to remediate the pit wall transitions in this regulatory period.

3) Rolling site wide paint programme commencing in RIIO-T2 in which areas 3 and 6 will be painted

119. The painting regime will consider a full site wide paint with an area-based inspection and remedial plan. This rolling strategy aims to inspect an area of the plant in one year, with areas identified for follow up action/remediation planned to be completed in the following year as shown in Table 6.

Table 8 Area inspection plan

Area	Planned remediation year
6	2024
3	2025

120. Within this regulatory period only areas 6 and 3 will be painted. These areas were prioritised based on the severity of corrosion defects identified in the area and outage availability to carry out works. Funding for the remaining areas will be requested in the next regulatory period.

121. Scope definition:

- Erection of habitat scaffolds with working platforms around pipework in accordance with NGT standards.
- Preparation of the work zone, cleaning of the pipework and coating application in accordance with T/SP/PA/10

- All work carried out on the site shall comply with good safe working practice and the specific conditions of a Permit to Work where issued on an operational site.

122. Power washing of all site pipework on an annual basis to remove any algae growth which affects pipe coating integrity due to microbial corrosion. Carrying out this activity further reduces the risk of the coating system degrading to a point where onset corrosion is possible.

123. The funding request to implement this scope of work is [redacted]

4) Remediation of forecasted corrosion defects in RIIO-T2

124. These are the expected or forecasted defects to be found in rolling yearly CM/4 inspections per area.

Table 9 Forecasted Corrosion defects per area per year

Category 4 defects	Category 5 defects	Category 6 defects
219	40	15

125. The volumes were determined based on-site inspections that took place between 2015-2023. It is not possible to ascertain the extent and nature of the Category 6 defects that will be found in future inspections.

126. The funding request to remediated forecasted defects found in this regulatory period is [redacted].

Final cost and programme

127. Table 10 provides a breakdown of the final costs for the project split by several cost categories.

Table 10 Project Cost Breakdown

	Cost Category	Outturn Costs (£m)	Costs (£m) 2018/19 Price Base
	OEM costs	[redacted]	[redacted]
Direct	EPC Estimate	[redacted]	[redacted]
Indirect	EPC PM	[redacted]	[redacted]
Direct	EPC Site Estab ishment	[redacted]	[redacted]
Direct	NGGT Direct Company Costs	[redacted]	[redacted]
Indirect	NGGT Indirect Company Costs	[redacted]	[redacted]
	Contractor Risk	[redacted]	[redacted]
Direct	NGGT Project Risk	[redacted]	[redacted]
	FEED	[redacted]	[redacted]
	Deve opment / Optioneering	[redacted]	[redacted]
	Land / Easements	[redacted]	[redacted]
	TOTAL	[redacted]	[redacted]
	Base ine funding	[redacted]	[redacted]
	Net tota		[redacted]

128. Table 11 shows the spend profile for our preferred option in 2018/19 pricing.

Table 11 Spend profile

£m 18/19	FY 2022 (£m)	FY2023 (£m)	FY2024 (£m)	FY2025 (£m)	FY2026 (£m)	FY2027 (£m)	Total (£m)
Corrosion (PAC3419)	[redacted]						
Total cost	[redacted]						
Baseline	[redacted]						
Funding request	[redacted]						
Corrosion defects in Pit wall transitions	[redacted]						
Total cost	[redacted]						
Baseline	[redacted]						
Funding request	[redacted]						
Site wide painting and power washing	[redacted]						
Total cost	[redacted]						
Baseline	[redacted]						
Funding request	[redacted]						
CAT 4/5/6 Forecasted Defects	[redacted]						
Total cost	[redacted]						
Baseline	[redacted]						
Funding request	[redacted]						

RIIO-T2 Volume UIDs

129. Costs associated with this project have been assigned against the RIIO-T2 Unique Identifier A22.22.5.2 & 4 **(UID) - ST. FERGUS TERMINAL.**

130. Table 12 provides a summary of the UIDs and associated funding for the scope of works proposed in this paper.

Table 12 UID Details

Scope	UID	Base ine vo ume of Intervention (By PP) (by unit of measure)	Base ine tota funding avai ab e (£m 18/19)	ECC unit cost (£m 18/19)	Current vo ume of intervention (by unit of measure)	ECC tota funding required (£m 18/19)	Output Year	UID funding requested through UM (£m)
Corrosion (PAC3419)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	FY2025	[redacted]
Pit wa transitions	[redacted]	-		[redacted]	-	[redacted]	FY2026	[redacted]
Site wide painting and power washing	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	FY2026	[redacted]
Category 4, 5, & 6 CM/4 Defects forecast	[redacted]	[redacted]		[redacted]	[redacted]	[redacted]	FY2026	[redacted]
Tota s								[redacted]

NARMs Benefit

131. Following discussions with Ofgem in the NARM Development Monthly Meetings, it is proposed that for simplicity all the investments that arise from the UMs are collated and one NARMs update is provided after the Plant & Equipment submission in January 2024.

132. For further details and a summary of UIDs please see Section 4 and Appendix 2 of the Asset Health Overarching Document.

9. Conclusion

139. This report has explained the safety concerns NGT has regarding the CM/4 defects at St Fergus and their implications to the safe and reliable operation of the terminal. As detailed in this justification paper, it is of paramount importance to secure the necessary investment to address the highlighted investment drivers.

140. Remediation of above ground pipework corrosion and implementation of a rolling site wide painting regime will total [redacted] (18/19 prices). The cost accuracy of investments in delivery is +/-5% and for those in development it is estimated at +30/-15% in accordance with the Infrastructure and Projects Authority (IPA) cost estimating guidance.

10. Appendices

Appendix A: Project summary table

Table 13 Project summary table

Name of project	T2_St Fergus_2021_St Fergus RIIO-2 Asset Health Programme		
Scheme reference	[redacted]		
Primary investment driver	Asset Deterioration/Legislation		
Project initiation year	2023		
Project close out year	2026		
Total installed cost estimate (£)	[redacted]		
Cost Estimate accuracy (%)	+30/-15		
Project spend to date (£)	[redacted] (all St Fergus RIIO-T2 AH UM development)		
Current project stage gate	F2		
Reporting table ref	RRP Table 6.3 (Asset Health) and Table 6.4 (Asset Health Projects)		
Outputs included in RIIO-T1 business plan	No		
Spend apportionment	T1	T2	T3
	[redacted]	[redacted]	[redacted]

Appendix B: [redacted] asset condition report

File: 5210385-001-MD-REP, 15- Category 4, 5 & 6 CM/4 Defects & Painting, [redacted] Rev 03, 2023

Appendix C: Corrosion defects interventions

CM/4 investigations and assessments could result in any of the following interventions. The decision on the intervention to be undertaken is specific to the nature and location of the defect together with the type and volume of the adjacent defects and site.

- Patch Paint - removal of coating, pipework preparation and repainting of small individual sections of pipework. Defects of category 3 and above will require some level of coating repairs to prevent the defect from deteriorating to a level where physical intervention and non-destructive testing (NDT) will be required by the next inspection.
- Partial Site Repaint - removal of coating, grit blasting of the pipework and repainting of whole sections of pipework.
- Full Site Repaint - removal of coating, preparation of the pipework (including grit blasting) dressing and repainting of all the pipework on a site

- Pipework Repair - for external corrosion of the pipework and external interference damage:
    - minor redressing of the large diameter pipework and reinstatement of the coating.
    - replacement of small sections of small diameter pipework
- Pipework Refurbishment - for external corrosion of the pipework and external interference damage more significant issues can be resolved by:
    - for large diameter pipework the installation of a shell or clamp over the pipework and the reinstatement of the coating.
    - replacement of full sections of small diameter pipework • the use of composite repair techniques
- Pipework Replacement - for significant external corrosion, external interference damage or internal corrosion then a section of the pipework can be replaced which consists of pipework isolation and shutdown, vent inventory, purge, cut out affected section and weld in replacement, reinstate coating and recommission.

Appendix D: Forecasted defects model

File: St Fergus site wide paint Justification.xlsx