HyNet CCUS Pre-FEED

Key Knowledge Deliverable

WP4: Onshore CO_2 Pipeline Design Study Report

EXECUTIVE SUMMARY

The Onshore CO_2 Pipeline Design Study Report was generated as part of the Preliminary Front End Engineering and Design (pre-FEED) study for the HyNet Industrial CCUS Project. The HyNet CCUS pre-FEED project commenced in April 2019, and was funded under grant by the Department for Business, Energy and Industrial Strategy (BEIS) under the Carbon Capture Utilisation and Storage (CCUS) Innovation Programme.

Delivery of the project was through a consortium formed between Progressive Energy Limited, Essar Oil (UK) Limited, CF Fertilisers UK Limited, Peel Environmental Limited, University of Chester, and Cadent Gas Limited.

The main project objectives are as follows;

- To determine the technical feasibility of a full chain Industrial CCUS scheme comprising anchor loads from Stanlow Refinery and Ince Fertiliser Plant and storage in Liverpool Bay fields.
- To determine the optimised trade-off position between lowest initial cost and future scheme growth
- To determine capital and operating costs for the project to +/- 30% to support HMG development of a policy framework and support mechanism
- To undertake environmental scoping and determine a programme of work for the consent process

This document is one of a series of Key Knowledge Deliverables (KKD's) to be issued by BEIS for public information, as follows;

- HyNet CCUS Pre-FEED KKD WP1 - Basis of Design
- HyNet CCUS Pre-FEED KKD WP1 – Final Report
- HyNet CCUS Pre-FEED KKD WP2 - Essar Refinery Concept Study Report
- HyNet CCUS Pre-FEED KKD WP2 - Hydrogen Production Plant
- HyNet CCUS Pre-FEED KKD WP3 - Fertiliser Capture Report
- HyNet CCUS Pre-FEED KKD WP4 - Onshore CO2 Pipeline Design Study Report
- HyNet CCUS Pre-FEED KKD WP4 - CO2 Road Rail Transport Study Report
- HyNet CCUS Pre-FEED KKD WP5 - Flow Assurance Report
- HyNet CCUS Pre-FEED KKD WP6 - Offshore Transport and Storage
- HyNet CCUS Pre-FEED KKD WP7 - Consenting and Land Strategy

Saith Limited and RSK Environmental Limited were commissioned by Progressive Energy to undertake high level routing studies for a number of options for Phase 1 of the proposed onshore CO_2 pipeline project.

The primary focus of the pipeline work package in pre-FEED was to determine a low-cost, deliverable and consentable pipeline route from Stanlow AGI to Connah's Quay AGI, where the pipeline would connect to the existing 24” pipeline to Point of Ayr. Key routing considerations were as follows:

- Targeting existing easements as advised by Progressive Energy
- Targeting an unconstrained pipe route
- Limiting the number of potential difficulties in the pipe route
- Avoiding environmental and ecological areas of concern
- Avoiding existing major utilities

At an early stage in the pipeline routing process, an Environmental Constraints report was generated to identify areas to be avoided. Key high-level international, national and regional environmental and land use constraints datasets have been compiled for the defined Area of Search. The constraint data has been collated using readily available information held within the public domain. The data has been downloaded from web-based sources to provide project specific mapping.

In addition key local environmental and land use constraints datasets have also been compiled for the defined Area of Search. The constraint data has been collated using readily available information held within the public domain and free of charge (i.e. no consultation letters have been issued to consultees as part of this study).

Eight route options were identified with 3 of the options having small variations on their route giving a total of 14 route options contained within 3 route corridors.

Dave Parkin
HyNet Project Director

CONTENTS

1.0 INTRODUCTION

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2.0 PROJECT BACKGROUND

HyNet was first conceived in 2016 as an integrated Hydrogen and Carbon Capture, Utilisation and Storage (CCUS) project to deliver widespread decarbonisation benefits across the North West region, with a particular focus on 'hard to reach' sectors of the economy, such as heat, industry, transport and flexible power. Following two feasibility studies[1,2] published in 2017 and 2018, an industry consortium was formed to deliver a pre-FEED level study for the full chain HyNet CCUS scheme. This study was undertaken from April 2019 to May 2020 and was funded by BEIS and partner contributions. Partners were:

- Progressive Energy
- Cadent
- CF Fertilisers
- Essar Oil UK
- Peel L&P Environmental
- University of Chester

In parallel, a technically linked, but self-funded study into the offshore transport and storage elements of the scheme was undertaken by Eni, current owners and operators of the Liverpool Bay Area (LBA) oil and gas assets.

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[1] *The Liverpool-Manchester Hydrogen Cluster: A Low Cost, Deliverable Project*, August 2017, Progressive Energy on behalf of Cadent (https://hynet.co.uk/app/uploads/2018/05/Liverpool-Manchester-Hydrogen-Cluster-Summary-Report-Cadent.pdf)
[2] *HyNet North West: From Vision to Reality*, May 2018, Progressive Energy on behalf of Cadent (https://hynet.co.uk/app/uploads/2018/05/14368_CADENT_PROJECT_REPORT_AMENDED_v22105.pdf)

The pre-FEED project has been delivered through seven integrated work packages, and this report constitutes the final over-arching summary report. Further details are contained within work package specific deliverables.

Work package structure for pre-FEED is as follows:

- Work Package 1 – Integration
- Work Package 2 – Refinery Capture
- Work Package 3 – Fertiliser Plant Capture
- Work Package 4 – Onshore Transport
- Work Package 5 – Flow Assurance
- Work Package 6 – Offshore Transport and Storage (undertaken by Eni outwith the BEIS funded project)
- Work Package 7 – Land and Planning

3.0 BASIS OF DESIGN

Below are the main points forming the Basis of Design document for the Onshore CO_2 Pipeline Design Study.

3.1 Legislation

During the development of the proposed scheme, cognisance should be taken of the requirements of UK legislation, such as: -

- The Pressure Systems Safety Regulations 2000 (SI 2000/128)
- The Construction (Design and Management) (CDM) Regulations 2015.
- Management of Health and Safety at Work Regulations 1999
- The Electricity at Work Regulations (EAWR) 1989.
- The Control of Noise at Work Regulations 2005
- The Pipeline Safety Regulations 1996
- The Health and Safety at Work Act (HSW) 1974.
- Dangerous Substances & Explosive Atmospheres Regulations 2002: (DSEAR)

The above is not meant to be an exhaustive list and other documents may well apply.

All principal parties should pay particular attention to the latest publication of the Construction (Design and Management) Regulations: 2015, to ensure they fully understand their latest roles, responsibilities and duties, and that they can comply with the legislation.

3.2 Design Standards and References.

3.2.1 Standards

The following are the primary design standards for this phase of the project.

- *BSI Standard Publication – PD 8010-1:2015+A1:2016, titled "Pipeline systems – Part 1 : Steel pipelines on land – Code of practice"*
- *BSI Standard Publication – BS ISO 27913:2016, titled "Carbon dioxide capture, transportation and geological storage- pipeline transportation systems"*
- *The institute of Gas Engineers and Managers (IGEM) Standard, IGEM/TD/1 Ed 5, titled "Steel pipelines and associated installations for High Pressure Gas Transmission"*

3.2.2 References

The following are the primary reference documents used for this phase of the project.

- *DNV-GL Recommended Practice – DNVGL-RP-F104 Edition November 2017, titled "Design and Operation of Carbon Dioxide Pipelines"*

3.3 Location

3.3.1 Stanlow

The proposed CO_2 Pipeline is to be routed from the CO_2 export point, which is to be constructed on a site in the Stanlow refinery industrial area, Ellesmere Port. For the purpose of this report this Tie-in point will be identified as TP1.

This location will contain a 900mm pig trap facility (PTF) for the CO_2 pipeline and is also to be shared with the proposed Hydrogen plant as the project develops. For the purpose of the CO_2 project this location is to be known as Stanlow AGI.

3.3.2 Connah`s Quay Pig Trap Facility

The end location for the CO_2 pipeline will be at a purpose-built compound near Connah's Quay, adjacent to the existing 24" Connah`s Quay to Point of Ayr pipeline. For the purpose of this report this will be identified as TP2. This compound, which will be secure against interference from third parties, will contain pig traps and associated equipment.

3.4 Division of Responsibility

At present there are a number of companies that are expecting to be sending their CO_2 at an agreed pressure, temperature and composition, to the export point at the Stanlow AGI in the Stanlow refinery industrial area.

The physical barrier between the companies will be the buried cathodic protection insulation joints (CPIJ) located on the security fence line of Stanlow AGI.

The CO_2 production companies will be responsible for all aspects of the design, construction and maintenance of the CO_2 pipes within their battery limits, upstream of the CPIJ. The pipelines between these CPIJ and the export point on Stanlow are outside of the scope of this document.

3.5 Units of Measurement

The units of measurement shall be the international system of units (Système international d'unités or **SI**) unless specifically noted otherwise.

Throughout the Basis of Design, and the wider project, units of mass flow rate will be both $MtCO^2$/year and kg/s. The MtCO2/year will assume a 90% availability from all sources, so the corresponding rate of instantaneous flow will be 11.1% higher, 1MtCO2/year therefore corresponds to a mass flow rate of 35.2kg/s.

3.6 Pipeline material specification (Stanlow AGI to Connah`s Quay)

Figure 3.1 below shows the proposed pipeline material specification and Norms to be used during this Pre-FEED study.

Figure 3.1: Pipeline Material Specifications and Norms

Description	Value
CO2 configuration (onshore transportation)	**Gas Phase**
Design Pressure (DP)	**49.6 barg**
Maximum Operating Pressure (MOP)	**35.0 barg**
High Level Alarm (HLA)	**TBC as a project requirement**
High High Level Alarm (HHLA)	**TBC as a project requirement**
Maximum Incidental Pressure (MIP)	**38.5 barg**
Maximum Design Temperature	**+60°C**
Minimum Design Temperature	**-20°C**
Pipeline Outside Diameter	**914.4mm**
Standard Pipe Wall Thickness	**12.7mm**
Proximity Pipe Wall Thickness	**19.1mm**
Material Grade	**L415ME (X60)**
Pipe type	**Submerged Arc Welded (Longitudinal seam)**
External Coating	**FBE**
Internal Coating	**None**
NDT Inspection Requirements	**100%**
Bend Radius	**3D min**
Building Proximity Distances (BPD) Using IGEM/TD/1 Ed 5 Fig 5 & 6	**Standard Pipe – 54m** **Proximity Pipe – 3m**
Building Proximity Distances (BPD) Using PD 8010-1 2015+A1:2016 Section 5.5.3.2	**Standard Pipe – 105m** **Proximity Pipe – 5.5m**
Population density areas	**Type R and S**

PHADI+ Inner Zone (IZ)	**TBC by HSE** [3]
PHADI+ Middle Zone (MZ)	**TBC by HSE** 3
PHADI+ Outer Zone (OZ)	**TBC by HSE** 3
Operational Design Life	**Pipeline – 40 years** **System assets – 25 years**

3.7 Routing considerations

The following list defines the main items considered in the routing of the pipeline.

- **Congested Trenchless Crossing Pits** – Some of the Thrust and Reception pits for trenchless crossings will be in congested areas. This will require concrete shafts to be sunk either side of the crossing and either a concrete sleeve installed or pipejacking method used as an alternative method to Horizontal Directional Drilling (HDD) which would require pipe stringing.
- **Pipeline Separation Distances in joint easement** – TD/1 specifies minimum separation distances for pipelines running in parallel, to prevent interaction and escalation in the event of a failure. However, this is based on an operating pressure of ≤ 80 bar. Should the use of the existing easements be granted, the space envelope available should be identified and specialist advice sought to establish if safe separation distances can be obtained at 35 bar.
- **HV Power Cables** – Although it is common practice to pass under Overhead HV Power lines (OHX) or under Below Ground HV Power lines (BGP), it should be avoided if possible.
  In particular the AGP can cause AC interference with the pipeline cathodic protection (CP) systems and cause AC corrosion. In these situations, the risks of AC interference should be assessed in accordance with the requirements of BS EN 15280 and BS EN 50443.
  Connah`s Quay Power Station is a critical passing point for option 7 but it has been identified as a potential difficulty due to the numerous AGP`s and the assumed BGP`s associated with the power station. However, it should be noted that Option 5a would avoid this complication.
- **B Class Roads** – Trenchless road crossings have generally been used on all motorways and A class roads. However, 1 or 2 instances have been identified where a B class road is in close proximity to motorways. This could cause major traffic congestion if open cut methods are used. As the design progresses, these smaller roads should be re-assessed to see if the cost of trenchless crossing methods would be more prudent.
- **HSE notification** - It is unusual to run high pressure gas mains over long distances in public roads. However, due to the considerable issues with routing the CO_2

[3] *The informal advice from HSE on PADHI Zones is to assume CO_2 for CCS applications to be a Category E fluid (ref. Table 1 from BS PD8010-1), which is the same as for Natural Gas, and, given that this has the most severe requirements, the same PADHI distances have been assumed for the purposes of this exercise.*

pipeline, a few public and private roads are being considered. The opinion of the HSE specialist pipeline inspectors should be sought on this subject at the earliest possible time.

- **New Roads and Street Works Act (NRSWA)** –If the HSE are satisfied with the CO_2 pipeline running in the public roads, the cost of overcoming 3rd party services would be offset with not having to purchase easement rights.
- **Traffic Management** – Some of the routes are along major arterial roads. The construction of a pipeline along these routes would cause major traffic congestion at peak times.
- **Historic Woods and Tree Preservation Orders (TPOs)** – Where possible wooded areas have been avoided but, in some instances, it will be necessary to route the CO_2 pipeline through wooded areas. With the information available all historical woods have been avoided or mitigated.
- **SSSI, Ecological and Environmental** – The ecological and environmental impact of such a long pipeline system may give rise to many mitigation methods being required. An ecological and environmental study has been carried out and cognisance of these studies has been taken during this pre-feed routing study.
- **Flora & Fauna** – As with the impact on the area's ecology and environment. A pipeline of this size may have an impact on the flora & fauna in the area. Therefore, a study of the flora & fauna study should be sought when the CO_2 pipeline route is more defined.
- **Flood plains** - The flood risks along the CO_2 route vary from Very Low Risk to High Risk. This will be unavoidable because of the natural lay of the land in the Cheshire plains and crossing major rivers. However, the risks can be mitigated with longer HDDs and, if required, pipeline buoyancy solutions. This could add to the overall costs of the project if required.
- **Working next to waterways** - There will be sections of the route that will require the construction to be performed next to or under waterways. This is an obvious construction safety issue but could lead to expensive mitigations.
- **Landfill / Gowy local wildlife site (GWLS)**– Some of the CO_2 pipeline route options pass close to a Landfill site. As the project progresses, the land fill site owners should be contacted to establish if they have any intentions to operate closer to the proposed route. However, it should be noted that this same area is designated as part of the GWLS although the pipeline would cross the area at its narrowest point.
- **Rail Crossing Permission** – As with all trenchless rail crossings for pipelines, Railtrack will need to be contacted at the earliest possible time during the detail design stage, due to the stringent procedures and lengthy time scales required before approval would be granted. This procedure could take up to 12 months for one rail crossing, therefore with multiple rail crossings required, a significant design period would be required.
- **High Density Traffic Route Crossing Permission** – As with rail crossings, high density traffic routes have stringent procedures and lengthy time scales required before approval would be granted. This would apply to all motorway & dual carriageway trenchless crossings, where calculations would be required for each

location to show maximum settlement calculations relevant to the specific ground conditions. Again, a significant design period would be required.

- **Borehole and Ground Investigation Surveys (GIS)** – To enable trenchless crossing calculations to be completed for the relevant authorities. There will be a requirement for Boreholes and GIS to be conducted. This information will also take a lengthy period from when the data is gathered to interpretive reports being issued for use at detail design.

4.0 ENVIRONMENTAL CONSTRAINTS

At an early stage in the pipeline routing process, an Environmental Constraints report was generated to identify areas to be avoided. Key high-level international, national and regional environmental and land use constraints datasets have been compiled for the defined Area of Search. The constraint data has been collated using readily available information held within the public domain. The data has been downloaded from web-based sources to provide project specific mapping. The following constraints formed the basis of this stage of the study:

- Special Area of Conservation (International)
- Special Protection Area (International)
- World Heritage Sites (International)
- Ramsar sites (International)
- Site of Special Scientific Interest (National)
- National Nature Reserve (National)
- Local Nature Reserves
- Registered Parks and Gardens (National)
- Scheduled Monuments (National)
- Grade I, Grade II and Grade II* Listed buildings (National)
- Ancient Woodland (National)
- National Parks (National)
- Areas of Outstanding Natural Beauty (National)
- Landscape Character Areas (National)
- National Trails and Long Distance Footpaths
- RSPB Reserves
- Flood Zones
- Heritage Coast
- Country Parks
- National Trust Land
- Open Access/Common Land
- Agricultural Land Classification
- National Cycle Route
- National Cycle Network Link Cycle Route
- Regional Cycle Route

- MOD Establishments (over 1ha)
- Regionally Important Geological and Geomorphological Sites
- Countryside and Rights of Way Act 2000 (CRoW) Section 15 Land
- CRoW Access Land

In addition key local environmental and land use constraints datasets have also been compiled for the defined Area of Search. The constraint data has been collated using readily available information held within the public domain and free of charge (i.e. no consultation letters have been issued to consultees as part of this study). The following constraints formed the basis of this stage of the study:

- Public Rights of Way
- Local Geology Sites
- Local Wildlife Sites (note data limitations below)
- Conservation Areas
- Historic Landfill Sites
- Planning/Housing Allocations (from Local Plans)
- Green Belt

Illustrative examples of output constraint mapping are shown in Figure 4.1 and Figure 4.2 below for two out of three route corridors:

Figure 4.1: Environmental Constraints Mapping

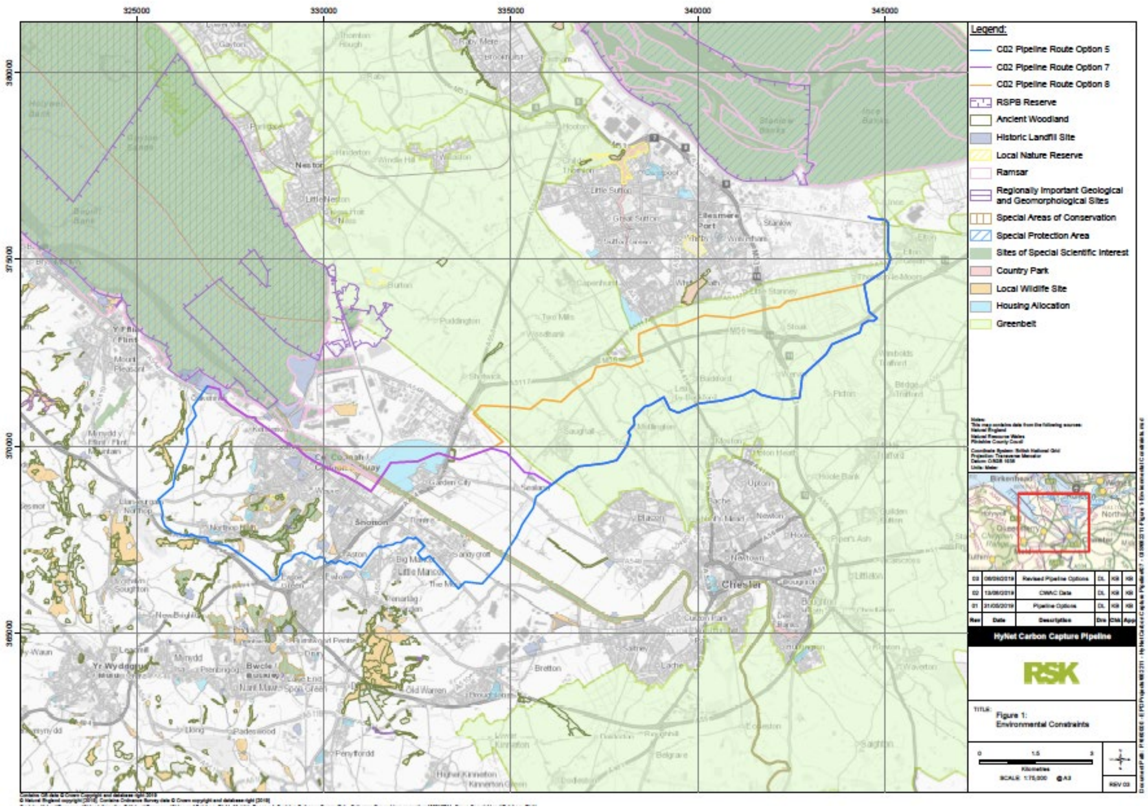
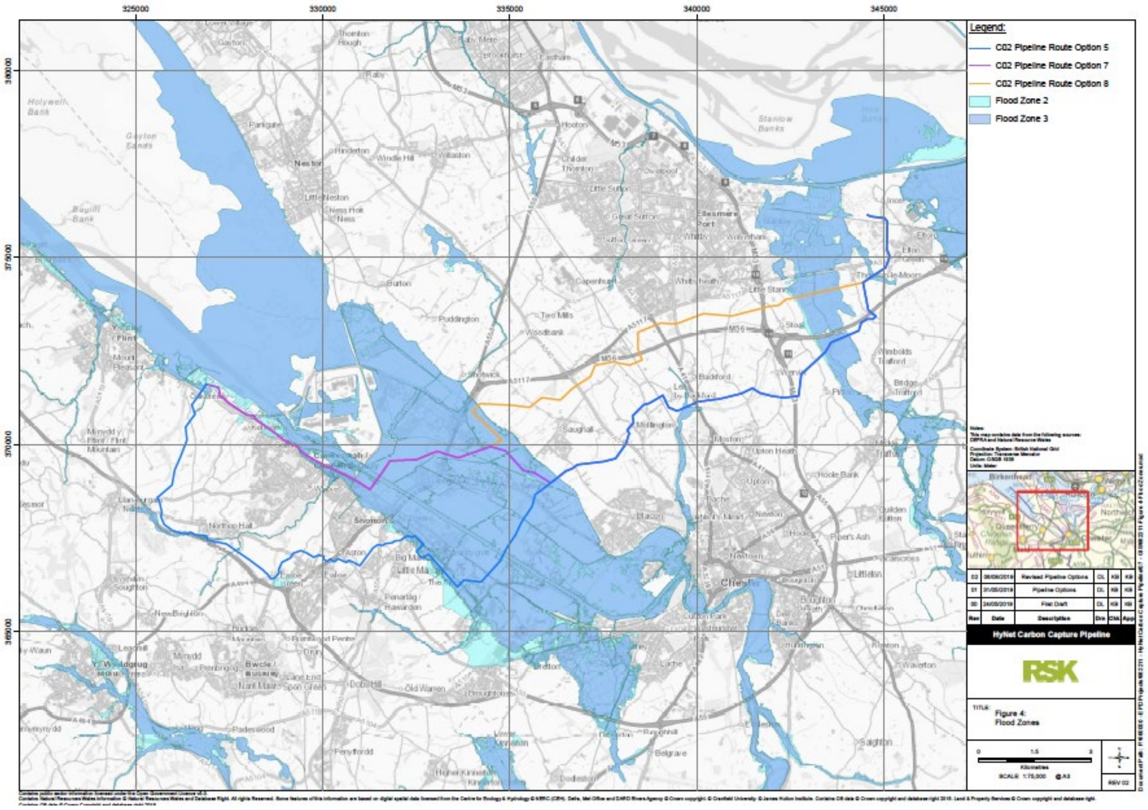


Figure 4.2: Flood Zones Mapping



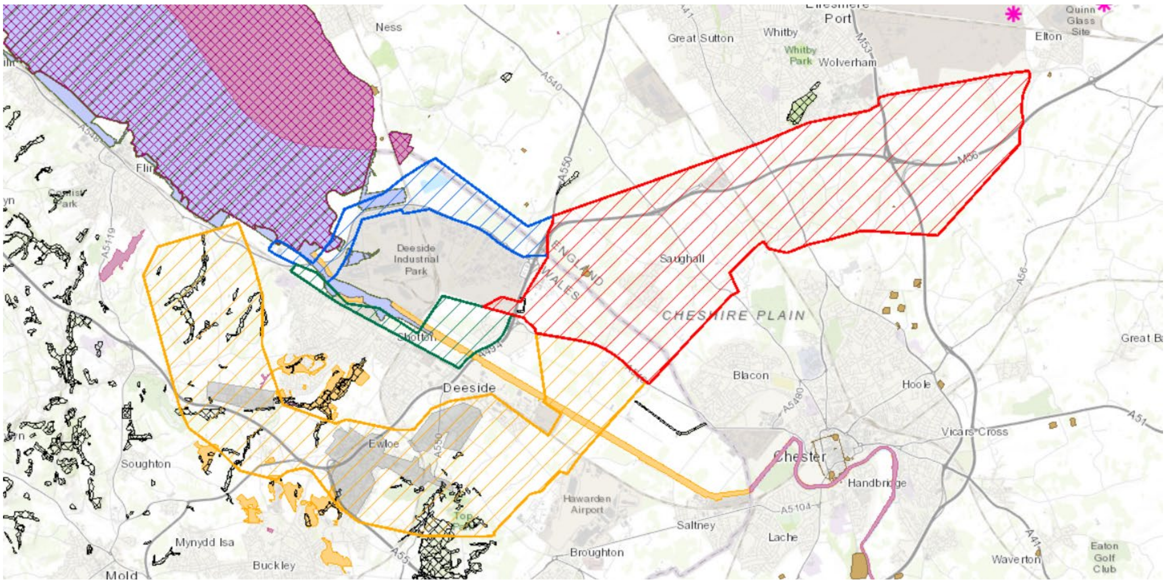
5.0 DESIGN OPTIONS

Key routing considerations were as follows:

- Targeting existing easements as advised by Progressive Energy
- Targeting an unconstrained pipe route
- Limiting the number of potential difficulties in the pipe route
- Avoiding environmental and ecological areas of concern
- Avoiding existing major utilities

Eight route options were identified with 3 of the options having small variations on their route giving a total of 14 route options contained within 3 corridors, as defined by Figure 5.1 below.

Figure 5.1 Pipeline routing corridors



5.1 Routing Selection

To enable a comparative overview of all the route options, an assessment was undertaken to downselect to a shortlist against the following parameters:

- Red identifies one of the following:
  - High cost compared to other options
  - Longer length compared to other options
  - More potential difficult than other options
- Amber identifies ones of the following:
  - Similar cost compared to other options
  - Similar length compared to other options
  - Similar potential difficulties compared to other options
- Green identifies one of the following:
  - Lower cost compared to other options
  - Shorter length compared to other options
  - Fewer potential difficulties compared to other options

Considering the assessment above, and, in conjunction with the consultants involved in the pre-FEED activity. An option ranking was derived to form the basis of further route appraisal work in FEED.

5.2 Cost Estimates

A cost estimate for each option was undertaken to support decision making between routes. These cost estimates were not undertaken to a specified AACE Class Estimate, but, given the level of engineering undertaken in pre-FEED, are considered to be commensurate with an AACE Level 4 +/- 30%.

An illustrative midpoint cost summary is set out in Figure 5.2 below:

Figure 5.2: Construction Cost Estimate for Pipeline (£)

Description	Quantity	Total Cost
Open cut road crossings	26	780,000
Trenchless road crossings	22	6,600,000
Trenchless river crossing	3	2,250,000
Trenchless canal crossing	1	300,000
Junction / Pig Trap Facilities	3	225,000
Existing Utilities	1	30,000
Trenchless rail crossing	4	1,400,000
Forged bends	300	3,600,000
Pipework laid in rural areas	28350m	49,612,500
Pipework laid in built up areas	5000m	12,500,000
	Total Estimate	**77,297,500**

An estimate has not been developed for the section of 12" pipeline from Grinsome Road AGI to Stanlow AGI. The capital cost estimate for the main section of pipeline from Stanlow AGI to Connah's Quay AGI is £2.3m/km. Given that the section from Grinsome Road to Stanlow is smaller diameter, and of considerably lower engineering complexity, a parametric estimate of £1.5m/km has been used to generate a capital cost estimate of £3.75m for this section over its 2.5km length. A further 20% allowance has been included for contingency, giving a total cost estimate as follows:

- Grinsome Road to Stanlow AGI - £3.75m
- Stanlow AGI to Connah's Quay - £77.30m
- Contingency @ 20% - £16.21m
- Total Cost Estimate - £97.26m

6.0 REPURPOSING OF CONNAH`S QUAY TO POINT OF AYR PIPELINE FOR CO_2 USE.

Once the CO_2 is compressed to the desired pressure it will be transported via a new 900mm pipeline to a purpose-built compound near Connah's Quay known as CQPTF.

At present natural gas is supplied from the Liverpool bay gas fields to the Point of Ayr (PoA) processing terminal, from the PoA processing terminal there is an existing 24" pipeline that feeds natural gas to Connah`s Quay power station. The intention of this project is to repurpose the existing 24” gas pipeline to feed the CO_2 from the purpose-built compound near Connah’s Quay.

Modifications to the existing 600mm pipeline at CQPTF will bring the existing pipeline above ground and tie-in to a new 600mm Pig trap which will be installed at CQPTF along with valves, reducers and interconnecting pipework to the new 900mm pigtrap arrangement, allowing CO_2 to flow from the new 900mm pipeline to the existing repurposed 600mm pipeline.

Figure 6.1 below shows the existing parameters of the pipeline from Connah`s Quay to Point of Ayr and the required repurposed parameters.

Figure 6.1: Existing & Repurposed parameters of 24” pipeline to POA

Description	Existing Parameters	Repurposed Parameters
Fluid being carried	Natural Gas	CO_2 in Gas Phase
Design Pressure (DP)	99 barg	49.6 barg
Maximum Operating Pressure (MOP)	70.0 barg 45.0 barg (current)	35.0 barg
Maximum Incidental Pressure (MIP)	77 barg	38.5 barg
Maximum Design Temperature	+60°C	+60°C
Minimum Design Temperature	-20°C	-20°C
Pipeline Outside Diameter	610mm	610mm
Standard Pipe Wall Thickness	11.1mm	9.5mm
Proximity Pipe Wall Thickness	22.2mm	19.1mm
Pipe type	Submerged Arc Welded Seam type TBC	HFW / L / H
External Coating	FBE	FBE
Internal Coating	None TBC	None
NDT Inspection Requirements	100%	100%
Bend Radius	3D min	3D min
Building Proximity Distances (BPD) Using IGEM/TD/1 Ed 5 Fig 5 & 6	Standard Pipe – 28m Proximity Pipe – 3m	Standard Pipe – 33m Proximity Pipe – 3m
Building Proximity Distances (BPD) Using PD 8010-1 2015+A1:2016 Section 5.5.3.2	N/A	Standard Pipe – 65m Proximity Pipe – 5.5m
Population density areas	Type R and S	Type R and S
PHADI+ Inner Zone (IZ)	TBC by HSE	TBC by HSE
PHADI+ Middle Zone (MZ)	TBC by HSE	TBC by HSE
PHADI+ Outer Zone (OZ)	TBC by HSE	TBC by HSE
Operational Design Life	TBC	25 years

As can be seen from Figure 6.1, the operational parameters for the existing 24” pipeline from Connah`s Quay to Point of Ayr exceed the required parameters for the transportation of CO_2 from CQJ to PoACS.

However, two points of concern should be noted: -

- The internal coating of the existing pipeline is unknown. It is very likely that the pipeline was installed with an internal coating but its structure and condition is unknown. The main concern that needs to be considered relates to detachment of the internal coating in a pressure reduction situation, due to diffusion of CO_2 into the space between the coating and steel pipe during normal operation or due to low temperature during depressurization. It should be noted that the decompression effects may be gradual, i.e. start as blistering and ultimately cause full detachment.
- Damaged coating may be transported to the receiving facilities causing process upsets, plugging of injection wells or preventing positive valve isolation of the CO_2. Using IGEM/TD/1 a reference for the building proximity distances, it should be noted that the BPD calculated using Table 5 of IGEM/TD/1 was more onerous than the method used in PD 8010-1. Therefore, it is assumed there are potential infringements of the BPD if the original pipeline BPD was calculated using PD 8010-1.