Appendix M3

Geotechnical Assessment of Stone Road Construction in Peat Areas

REPORT ON

CORRIB ONSHORE PIPELINE

GEOTECHNICAL ASSESSMENT OF STONE ROAD CONSTRUCTION

IN PEAT AREAS

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EXECUTIVE SUMMARY

Approximately 5.7km of the proposed Corrib onshore pipeline is to be constructed within a stone road in peat. The peat varies in depth along the route between 0.25 to 5.0m and approximately 63% of the peat area through which the proposed pipeline route passes is less than 3.0m deep.

Applied Ground Engineering Consultants Ltd (AGEC) was commissioned by Shell E & P (Ireland) Ltd (SEPIL) in November 2008 to prepare a geotechnical assessment report on the proposed use of stone road construction in areas of peat for the proposed onshore pipeline. This involved a comparison of alternative road construction methods in peat, an assessment of ground investigation data and an interpretation of ground conditions, and a quantitative stability assessment of the stone road construction method.

There are three areas where the proposed pipeline crosses over peat land and where stone road construction is proposed is Rossport (Commonage) (ch. 85,960 to ch. 88,600), South of Sruwaddacon Bay to L-1202 (ch. 89,500 to ch. 91,000), and L-1202 to Terminal Site (ch. 91,000 to 92,560).

The findings of the geotechnical assessment on the proposed use of stone road construction in areas of peat for the proposed onshore pipeline are summarised as follows:

(1) Stone road construction in peat areas is a proven method of construction in weak ground, and for many such situations is the preferred construction method. The stone road provides a dependable working platform and is a comparatively low risk construction method in peat. Furthermore, the stone road provides a stable platform in which to install the pipeline.

(2) Analyses were carried out to assess the stability of the stone road under various load cases (Table 4). The results clearly show that the stone road has adequate stability and provides a robust and stable platform for construction and long term stability.

(3) The long-term stability of the stone road in peat was examined. The installation of the stone road into the peat provides a greater degree of stability against a peat slide. This is as a result of the greater shear resistance to sliding provided by the stone fill within the road.

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1 INTRODUCTION

1.1 Background

Applied Ground Engineering Consultants Ltd (AGEC) was requested by Shell E & P (Ireland) Ltd (SEPIL) in November 2008 to prepare a geotechnical assessment report on the proposed use of stone road construction in areas of peat for the proposed Corrib onshore pipeline.

The onshore pipeline route is about 9.2km in length of which about 5.7km passes through areas of peat; it is within these peat areas that it is proposed to construct a stone road.

The construction of a road is proposed and will entail the excavation of peat, where present, along the onshore pipeline route and replacement with suitable granular fill to effectively form a stone road within the peat. It is proposed to install the onshore pipeline within the proposed stone road.

Typical details of the proposed stone road are shown in Drawing No. 864_02_001.

1.2 This Report

This report includes the following sections:

(1) Description of typical stone road details

(2) Comparison of alternative road/access construction methods in peat

(3) Assessment of onshore pipeline route and identification of peat areas

(4) Characterisation of peat conditions encountered

(5) Stability assessment of stone road with respect to:

- (a) Stability of stone road with construction loading
- (b) Effect of stone road on surrounding peat
- (c) Effect of potential impact on stone road from hypothetical peat failure

2 STONE ROAD CONSTRUCTION

2.1 Typical Stone Road Details

Stone road construction is a recognised construction method for access in peat areas and has been used for example on the Mayo-Galway gas pipeline.

The constructed stone road provides a stable platform for subsequent construction work, reducing construction impact on the surrounding peat, and provides secure ground in which to install the onshore pipeline.

A comparison with alternative construction methods in peat is given below (Section 2.3).

The proposed stone road comprises the excavation of peat and replacement with suitable 'stone' to form a road within the peat (Drawing No. 864_02_001).

2.2 Typical Proposed Sequence of Stone Road Construction

Typical proposed outline sequence and summary of stone road construction are as follow (refer to Chapter 5 of EIS for details):

(1) Peat turves will be removed in advance of the main works and stored as per details given in the Environmental Impact Statement (EIS) report. The upper (acrotelm) layer (about 0.5 to 1m thick) of peat is generally fibrous in nature and of higher strength than the lower peat layer (catotelm). It will be stockpiled and re-instated, as appropriate, after installation of the pipeline within the stone road.

(2) Following turf removal, the remaining peat (catotelm layer) will be excavated over the width of the road. The stone road will be founded on mineral soil, or other competent stratum, below the peat. Where required nominal 0.5m thickness of low permeability material (such as insitu peat) will be left insitu above the mineral soil to reduce hydraulic transmission of groundwater across the road at this interface.

(3) The extent of the excavation for the stone road will depend on the depth and condition of the peat. In shallower peat, the side slopes of the excavation may temporarily be unsupported prior to backfilling with suitable stone. In deeper peat, the side slopes of the excavation are likely to be locally unstable and construction works would need to be phased such that excavation and backfilling are co-ordinated to limit the extent and time side slopes remain exposed.

(4) Where there is deep and/or weak peat the excavation faces may not be sufficiently stable and as such may need to be supported by for example sheet piles placed in advance of the excavation works.

(5) Suitable 'stone' or granular fill will be used to construct the road and will be placed into the excavation. The stone fill material shall be capable of standing unsupported at 45 degrees or greater.

(6) The running surface of the stone road will have a minimum 9m working width. The width of the stone road will be greater at the base. The working width of the road will comprise a load bearing envelope with 45 degree side slopes (Drawing No. 864_02_001). The load bearing envelope is the boundary line outside of which no load from construction and /or maintenance traffic can be applied.

(7) As part of the stone road construction low permeability plugs, formed using a suitable low permeability soil, will be constructed across the stone road at appropriate locations. These plugs will reduce the movement of water longitudinally through the road (Drawing No. 864_02_002).

(8) The pipeline and associated pipes and cables will be installed within the stone road working width (Drawing No. 864_02_001). The minimum required cover to the top of the pipeline is 1.2m. The expected trench excavation for the pipeline will typically be 1.5 to 2m. In areas where peat thickness is greater than 2m then the pipeline will be within the stone road. In areas where peat is less than 2m thick the base of the pipeline trench will be excavated in mineral soil.

2.3 Comparison of Alternative Road/Access Construction Methods in Peat

A comparison of alternative road/access construction methods in peat has been carried out and is presented in Table 1. Many of the construction methods presented are used for permanent public trafficked roads, and are not necessarily directly applicable to the temporary road required for laying of the pipeline.

The construction methods can be divided into:

(1) *Type 1: Peat excavation (proposed method for stone road).* This is the preferred method in most cases as it greatly reduces the risk of failure due to placement of load and also eliminates subsequent settlement and maintenance. It provides a dependable working platform and be relatively costly where deep peat is to be excavated.

The proposed stone road construction is Type 1 where peat is essentially shallow. However, in areas of deeper/weaker peat where it is not practical to excavate all peat to depth then peat displacement method (Type 2) will be deployed.

(2) *Type 2: Peat displacement (proposed method for stone road in deeper peat).* Requires peat to be displaced by placement of sufficient load. Whilst used in several countries the effect of controlling the local peat displacement in the peat can be difficult. Method more applicable to high road embankments in more amorphous basin peat.

The proposed stone road construction in deeper peat will be Type 2 partial excavation method of the deeper peat. In deeper peat a larger body of more amorphous peat will be present at depth which will be suitable for localised displacement.

(3) *Type 3: Peat left insitu*. Fill is placed onto the peat surface with either reinforcing elements placed within the fill or inserted into the peat, such as piles, insitu mixing. Method represents potentially greater risk due to difficulties in safely placing load onto peat, extended construction period required to allow for sufficient strength gain and long term settlement will occur. Usually applicable to temporary conditions or where significant peat depths.

Based on the above comparison, the use of stone road construction is considered a comparatively low risk construction method for peat. Furthermore, the stone road provides a stable platform in which to install the pipeline.

Sufficient construction controls will be required to ensure that, particularly in deeper peat, that excavation in front of the stone road is carried out in a controlled manner to minimise disturbance to the adjacent peat, refer to Geotechnical Risk Register in Appendix M4 of the EIS. Notwithstanding the above, the inclusion of the stone road in close proximity to the peat excavation will provide a robust stable platform which will limit the extent of any disturbance to the surrounding peat.

The effect of the installed stone road on the stability of the peat slope is analysed in detail below.

Table 1 Comparison of Road/Access Construction Methods in Peat (based on Carlsten, 1995; Munro, 2004)

Type	Construction Method	Description of Method	Advantages	Disadvantages	Comments/Potential Risks
1	**Peat Excavation Method**	All weak material (basically peat) is excavated below the width of the road/ embankment to competent founding layer. The excavation is then backfilled with suitable fill material.	Proven technology. Should achieve a good bearing capacity using normal road embankment construction on a sound competent layer. Limited/nominal consolidation and settlement over the lifetime of the road. No additional time required for surcharge effects. Can provide additional stability to the peat.	Significant quantities of excavated materials created. Land required for formation of sideslopes in peat and disposal of excavated materials. Difficulties in excavation and placing fill below water table. Normally demands high quality stone fill material. Deep excavations may have effects on adjacent land. Unexcavated soft material below embankment may cause future settlements.	Difficulty of excavation in peatland. Effect on adjacent lands. Reduces possibility of trapped peat below embankment and hence settlement issues. Provides a dependable permanent road.
2	**Progressive Displacement Method**	Involves the construction of the road/ embankment by end-tipping fill onto the peat surface at the advancing tipping front. Usually requires embankment to be constructed several metres above the peat surface. The effect of the end-tipped fill is to cause local displacement in the peat ahead of the advancing tipping front resulting in the affected peat being displaced.	Well proven method. Should achieve a reasonable bearing capacity on the displaced peat. The displaced peat to the sides of the embankment (if placed) can enhance the embankment stability. Good method for constructing a high embankment above over peat.	Better suited to amorphous peats. Fibrous peats may prove resistant to shear failure without assistance. Requires substantial quantities of fill material for the embankment. Requires longer construction time for displacement and surcharge affects to be effective. Normally demands high quality stone fill material. Some limited consolidation and differential settlement can be expected over the lifetime of the road if peat pockets remain trapped below the embankment. The peat displaced during the procedure can cause heave effects on immediately adjacent land.	Effect on adjacent lands. Possible trapped peat below embankment. Whilst used in several countries the affect of controlling the local displacement of the peat can be difficult. Method more applicable to high road embankments in more amorphous basin peat or deeper peat.

Table 1 Comparison of Road/Access Construction Methods in Peat (based on Carlsten, 1995; Munro, 2004)

Type	Construction Method	Description of Method	Advantages	Disadvantages	Comments/Potential Risks
2	**Partial Excavation Method**	Involves the construction of the road/ embankment by end-tipping fill onto the peat surface at the advancing tipping front. Usually requires embankment to be constructed several metres above the peat surface. In this case there is partial excavation of the peat to assist displacement of the peat. The effect of the end-tipped fill is to cause local displacement in the peat ahead of the advancing tipping front resulting in the affected peat being displaced.	Well proven method. Should achieve a reasonable bearing capacity on the displaced peat. The displaced peat to the sides of the embankment can enhance the embankment stability. Good method for constructing a high embankment above over peat.	Better suited to amorphous peats. Fibrous peats may prove resistant to shear failure without assistance. Requires substantial quantities of fill material for the embankment. Requires longer construction time for displacement and surcharge affects to be effective. Normally demands high quality stone fill material. Some limited consolidation and differential settlement can be expected over the lifetime of the road if peat pockets remain trapped below the embankment. The peat displaced during the procedure can cause heave effects on immediately adjacent land. Quantities of excavated materials created.	Effect on adjacent lands. Possible trapped peat below embankment. Whilst used in several countries the effect of controlling the local displacement of the peat can be difficult. Method more applicable to high/intermediate road embankments in more amorphous basin peat or deeper peat.
3	**Strength Improvement by Stage Construction** (Also similar to pre-loading and surcharge construction. Typically used with vertical drainage)	Involves the stage construction of road/ embankment in layers. Initial layer usually less than 1m thick and normally includes a geogrid. Subsequent layers placed following sufficient consolidation and strength gain.	Produces time/load dependent gain of strength in the peat. Minimises future secondary compression settlement of the embankment. Higher embankments can be constructed without shear failure in the underlying peat. Does not require peat excavation, disposal or the need for additional land for storage of spoil	The time needed for the various stages to take effect can extend the embankment construction time. Needs to have a system in place on site for monitoring of consolidation and settlement to ensure that the required settlements are being achieved before the next layer is placed.	Difficulties in safely placing load onto peat. Extended construction period required to allow for sufficient strength gain. Long term settlement will occur.

Table 1 Comparison of Road/Access Construction Methods in Peat (based on Carlsten, 1995; Munro, 2004)

Type	Construction Method	Description of Method	Advantages	Disadvantages	Comments/Potential Risks
3	**Load Modification by Lightweight Fill**	A lightweight fill is used as a substitute for normal soil/stone fill. The lightweight fill reduces the imposed permanent stresses on the foundation	Does not require as high a bearing capacity from the peat foundation. Usually does not need the underlying peat to be strengthened. Lighter embankment construction generally means less future settlement.	High cost and transport of the specialised lightweight materials. Design and placing of lightweight materials may require special arrangements. Environmental considerations particularly with groundwater. Trafficability and bearing capacity of the lightweight embankment may be limited	Buoyancy issues with placing lightweight material below groundwater table. Lightweight fill would be susceptible to damage from high construction loading.
3	**Strengthening using Geogrid**	Involves the construction of road/ embankment using geogrid placed within the fill.	Limited site disturbance. Easy to install. Provides reinforcement effect to the base of embankment for the short to medium term. Reduces potential for localised stability and spreading. Can reduce differential settlements and lateral stresses on the peatland surface. Minimises need for embankment fill material. No excavation, disposal or need for additional land for storage of spoil.	The overall settlement of the embankment is not reduced. The geogrid can be damaged by construction equipment. Creep may affect the long term performance of the geotextile. Use of geogrid may need higher quality fill material to achieve sufficient interlock.	Difficulties in safely placing load onto peat. Extended construction period required to allow for sufficient strength gain. Long term settlement will occur.
3	**Strengthening Using Timber Raft Construction**	Involves the construction of road/ embankment using a timber raft placed onto the peat surface. The timber raft comprises typical brushwood of criss-crossing branches.	Limited site disturbance. Easy to install. Provides reinforcement effect to the base of embankment for the short to medium term. Reduces potential for localised stability and spreading. Can reduce differential settlements and lateral stresses on the peatland surface. Minimises need for embankment fill material. No excavation, disposal or need for additional land for storage of spoil.	The overall settlement of the embankment is not reduced. Can be damaged by construction equipment during placing of embankment fill. High element of manual labour required for fabrication of the raft. For longevity timber raft must be submerged.	Difficulties in safely placing load onto peat. Extended construction period required to allow for sufficient strength gain. Long term settlement will occur.

Table 1 Comparison of Road/Access Construction Methods in Peat (based on Carlsten, 1995; Munro, 2004)

Type	Construction Method	Description of Method	Advantages	Disadvantages	Comments/Potential Risks
3	**Strengthening Using Bog Mat Raft Construction**	Involves the construction of road/ embankment using a bog mat raft placed onto the peat surface. The bog mats provide a temporary road surface.	Limited site disturbance. Easy to install. Provides reinforcement effect for the short term. Reduces potential for localised stability and spreading. No need for embankment fill material. No excavation, disposal or need for additional land for storage of spoil.	Can be damaged by construction equipment during placing of embankment fill. May not provide sufficient stability for high construction loading. Used for temporary access only.	Difficulties in safely placing load onto peat. Following removal of bog mats there would be no ready access to pipeline.
3	**Strengthening Using Concrete Raft**	Involves the construction of road/ embankment using a concrete raft placed onto the peat surface. The raft may comprise cast insitu or prefabricated concrete panels.	Limited site disturbance. Easy to install. Provides long term stiff reinforcement to the base of embankment. Reduces potential for localised stability and spreading. Can reduce differential settlements and lateral stresses on the peatland surface. Minimises need for embankment fill material. No excavation, disposal or need for additional land for storage of spoil.	Overall settlement of the embankment is not reduced. Need to allow curing time for concrete. High material and manual labour cost required for fabrication of the raft.	Difficulties in safely placing load onto peat. Extended construction period required to allow for sufficient strength gain. Long term settlement will occur.
3	**Piling**	Piles are installed to end bear in competent strata under the peat. A concrete slab/geogrid load transfer platform (LTP) is then constructed over the piles.	Does not require peat excavation, disposal or the need for additional land for storage of spoil. Limited site disturbance. Minimal settlement. No additional time required for surcharge effects.	Requires a continuous concrete slab or geotextile load transfer platform (LTP). Need to construct piling platform in advance. General high cost.	Complex design with some notable recently failures of LTPs.
3	**Mass Stabilisation Method**	A binding agent (such as cement/lime) is mixed insitu with peat. The mixing is typically carried out by rotary header attached to an excavator arm.	Increases peat stiffness and strength and therefore reduces settlement and increases bearing capacity. Does not require peat excavation, disposal or the need for additional land for storage of spoil. Smaller demand of fill material compared to other preloading techniques.	Requires trials and preloading which can extend construction time. Surcharge materials may need to be brought on to site earlier than required and require double handling as a consequence. Require on-site for monitoring of consolidation and settlement to ensure that the required settlements are being achieved. General high cost.	Difficulties in safely placing load onto peat. Extended construction period required to allow for sufficient strength gain.

3 ROUTE DESCRIPTION

3.1 General

The landfall for the onshore pipeline route is at the Glengad Headland approximately 7.5km to the northwest of the Bellanaboy gas terminal site. The onshore pipeline route is about 9.2km in length of which about 5.7km passes through areas of peat; it is within these peat areas that it is proposed to construct a stone road.

For reporting purposes, the proposed route of the pipeline has been divided up into seven sections, namely;

(1) Glengad Headland, Chainage (Ch) 83,400 to Ch 84,065.

(2) Sruwaddacon Bay Lower Crossing, Ch 84,065 to Ch 84,470 (Estuary Crossing).

(3) Rossport (West), Ch 84,470 to Ch 85,960.

(4) Rossport (Commonage), Ch 85,960 to Ch 88,600.

(5) Sruwaddacon Bay Upper Crossing, Ch 88,600 to Ch 89,500 (Estuary Crossing).

(6) South of Sruwaddacon Bay Inlet to L-1202, Ch 89,500 to Ch 91,000.

(7) L-1202 to Terminal Site, Ch 91,000 to Ch 92,560.

The peat areas are sections (4), (6) and (7).

The Rossport (Commonage) section lies to the northeast of the Sruwaddacon estuary. This has a length of 2.6km. The sections from South of Sruwaddacon Bay Inlet to L-1202 and onto the Terminal Site are located south of the estuary and have a length of about 3.1km.

3.2 Rossport (Commonage), Ch 85,960 to Ch 88,600

The route passes through an area of generally open peat land which rises to a maximum elevation of 26m OD between Ch 86,950 to Ch 87,250. The route essentially follows the watershed divide (ridge line) through most of this section.

Local access tracks are encountered at Ch 86,400 and 86,830. These tracks are used to access peat cutting areas within the commonage and are areas where there is extensive peat cutting.

Public roads are encountered at Ch 87,540 and 88,350 before re-entering the Sruwaddacon estuary at Ch 88,600. Further areas of peat cuttings are located around the public roads and adjacent to the estuary.

Drawing 864_02_003 shows cross sections of the proposed pipeline and stone road within the Rossport (Commonage).

3.3 South of Sruwaddacon Bay to L-1202 to Terminal Site, Ch 89,500 to 92,560

South of the estuary the pipeline route is also within a peat area which extends from the landfall at the southern end of the estuary to the Bellanaboy terminal site. At about Ch 90,100 the route passes across a stream, where there is some reclaimed agricultural land. There is a peat cutting adjacent to the reclaimed agricultural land at Ch 90,200, which also marks the start of an area of open peat land that extends to Ch. 90,400.

From Ch 90,400 the route is essentially within forestry until the terminal site. A stream is crossed at about Ch 91,000 where a local road is crossed.

The topography initially falls from the local road to an elevation of 19m OD at about Ch 91,530 where a minor stream is encountered before rising in elevation to about 36m OD at the terminal.

Drawing 864_02_003 shows a cross section of the proposed pipeline and stone road near Leenamore Inlet on the south side of Sruwaddacon Bay.

3.4 Distribution of Peat along Route

Overall about 60% of the proposed pipeline route is within peat. The percentage of the pipeline route within ranges of peat depths is shown in Table 2. Where the route is within peat then typically peat depths will be in the range of 2 to 3m, which represents about 28% of the total proposed pipeline route.

Peat Depth Range	0m to <1m	>1m to <2m	>2m to <3m	>3m to <4m	>4m to <5.25m	Totals
Length of Route in Peat (m)	385	620	2560	1695	440	5700
% of Route Expressed as Proportion of Total Route in Peat	6.75	10.88	44.91	29.74	7.72	100
% of Route Expressed as Proportion of Total Route	4.20	6.77	27.95	18.50	4.80	62.23

Table 2 Breakdown of Proportion of Proposed Pipeline Route and Peat Depths

4 GROUND CONDITIONS

4.1 General

A review of ground conditions along the route of the pipeline was carried out to identify sections of the route where peat areas are present. Areas where peat is present are assessed for stability and suitability for the construction of the stone road.

Based on information presented in the Report on Onshore Pipeline Peat Stability Assessment (AGEC, 2009) a summary of the relevant ground conditions is given in Table 3 and a brief description of each section given below.

Section	Chainage	General Stratigraphy	Peatland	Geotechnical Properties of Soils	
				Peat	Mineral Soil
Glengad Headland	83,400 to 84,065	Mineral Soil Bedrock	No	Not considered further	
Sruwaddacon Bay Lower Crossing	84,065 to 84,470	Mineral Soil Bedrock	No	Not considered further	
Rossport (West)	84,470 to 85,960	Mineral Soil Bedrock	No	Not considered further	
Rossport (Commonage)	85,960 to 88,600	Peat Mineral Soil Bedrock	Yes	Depth: 0.25 to 5m (average 2.8m) Bulk unit weight: 10.5kPa Strength: 1 to 25kPa (see Figure 1)	Depth: not known Bulk unit weight: 19kPa Strength: 40kPa
Sruwaddacon Bay Upper Crossing	88,600 to 89,500	Mineral Soil Bedrock	No	Not considered further	
South of Sruwaddacon Bay to L-1202	89,500 to 91,000	Peat Mineral Soil Bedrock	Yes	Depth: 0 to 4m (average 2m) Bulk unit weight: 10.5kPa Strength: 1 to 19kPa (see Figure 2)	Depth: 3m to 10m Bulk unit weight: 19kPa Strength: 20kPa
L-1202 to Terminal Site	91,000 to 92,560	Peat Mineral Soil Bedrock	Yes	Depth:2.1 to 4.6m (average 3.3m) Bulk unit weight: 10.5kPa Strength: 2 to 35kPa (see Figure 3)	Depth: not known Bulk unit weight: 19kPa Strength: 40kPa

Table 3 Summary of Relevant Ground Condition for Proposed Pipeline Route

4.2 Glengad Headland Ch 83,400 to Ch 84,065

The ground conditions in this section of proposed works comprised overburden material described as generally granular deposits over bedrock. The granular deposits ranged between 3.85m and 5.0m below ground level (bgl), with exploratory holes drilled to depths of 25.1m bgl.

Peaty topsoil typically 0.5m thick was exposed along the headland cliff.

Given the absence of peat within this section it is not considered further.

4.3 Sruwaddacon Bay Lower Crossing Ch 84,065 to Ch 84,470

This section of proposed works crosses Sruwaddacon Bay between Ch 84,065 and 84,470.

The ground conditions in this section comprised overburden material described typically as a granular deposit over the bedrock.

This section is not considered further.

4.4 Rossport (West) Ch 84,470 to Ch 85,960

This section of proposed works crosses Rossport (West) between ch. 84,470 and Ch. 85,960.

The ground conditions in this section comprised overburden material described typically as granular deposits over bedrock with two exploratory holes showing cohesive deposits below the granular deposits and over the bedrock.

Topsoil comprised organic cohesive soils described as very soft to soft slightly sandy slightly gravelly clay and silt with localised areas of peat.

Most of this area is used for agricultural grazing purposes. In general, and based on limited data, the depth of peat in the area is less than 1m and comprised mostly peaty topsoil.

This section is not considered further.

4.5 Rossport (Commonage) Ch 85,960 to Ch 88,600

This section contains extensive areas of blanket peat.

The ground investigation along this section of proposed works included probing and hand vane testing carried out by RPS (2008). A walk over survey was also carried out by AGEC in December 2008; see Report on Onshore Pipeline Peat Stability Assessment (AGEC, 2009).

The land use in this section comprised blanket peat used for grazing and domestic peat cutting. Peat cuttings, which also comprised areas of mechanically saw cut peat, are located from about Ch. 85,960 to 87,300, Ch 878,320 to 87,850 and Ch 88,280 to 88,600.

The ground conditions within this section comprised typically peat over mineral soil and this geology was identified from walkover surveys. It should be noted that no logging of the insitu peat and underlying mineral soil was carried out by way of either trial pitting or cable percussion drilling. However, exposures were examined during the AGEC walkover survey carried out in December 2008.

Peat depth along this section of proposed stone road route varied from about 0.25m to about 5m, with an average thickness of 2.8m, as determined using peat probing typically along the pipeline route. A plot showing the relationship between depth and peat c_u determined from insitu vane testing is shown in Figure 1.

Maximum peat depths of 5m were recorded at Ch 88,093 and Ch 88,110, while minimum depths of 0.3m and 0.4m were recorded at Ch 87,504 and Ch 88,146 respectively.

Exposures of mineral soil within the area, which were limited in extent, showed firm brown/grey sandy gravelly silt with locally silty gravelly sand with gravels and cobbles.

4.6 Sruwaddacon Bay Upper Crossing Ch 88,600 to Ch 89,500

This section of proposed works crosses Sruwaddacon Bay upper between Ch 88,600 and 89,500.

The Sruwaddacon Bay upper crossing consisted of alluvium deposits which are inter-bedded layers of both granular and cohesive materials over bedrock.

Some layers of very soft brown or black organic peat/silt were encountered in several boreholes. These likely represent relict ground surfaces.

This section is not considered further.

4.7 South of Sruwaddacon Bay to L-1202 Ch 89,500 to Ch 91,000

This section contains extensive areas of blanket peat.

In situ peat probing was carried out along most of the pipeline route in this section (RPS (2008).

The land use between south of Sruwaddacon Bay and L-1202 was identified from AGEC walkover as blanket peat with several reclaimed grassland areas between Ch 89,500 and Ch 90,700. Forestry is recorded from about Ch 90,700 to 90,980.

The exploratory holes recorded peat over cohesive and granular soil over bedrock.

The peat depths along this section of proposed onshore pipeline route ranged from 0.4m to 4.2m bgl in the southeast (RPS, 2008), with the granular and cohesive soils ranging between 5.8m and 7.2m bgl.

The peat was described as very soft fibrous peat; the peat was more fibrous for approximately the upper metre. The strength descriptions of peat indicate undrained shear strengths less than 20kN/m^2.

The undrained strengths from the SL800 hand vane (RPS, 2008) ranged between 1 and 19kPa with a mean of 11kPa (Figure 2). The low strength values at shallow depth are not considered representative.

The cohesive soil was described from boreholes as very soft to soft sandy gravelly clay beneath the peat with cohesive soil recorded below the granular soil and above the bedrock described as stiff slightly sandy gravelly clay.

The bedrock was described as moderately weak to moderately strong psammite.

4.8 L-1202 to Terminal Ch 91,000 to Ch 92,560

This section contains extensive areas of blanket peat.

The overburden material between the L-1202 and the terminal site is typically peat over mineral soil.

Peat depth along the proposed onshore pipeline route, using peat probe depths typically along centre line, varied from about 2.1m to 4.6m, with an average thickness of 3.3m.

Undrained shear strength (c_u) of in situ peat was determined by IDL (Irish Drilling Ltd) using a Geonor H-10 mechanical vane (AGEC, July 2004).

Shear strength recorded from vanes ranged between 2 and 35kPa with a mean of 10kPa. A plot showing the relationship between depth and peat c_u is shown in Figure 3.

From AGEC (2004), trial pits TP-03 and 06 were taken into mineral soil below peat. From IDL (2002), trial pits TP8 to TP10 were taken into mineral soil.

In most trial pits mineral soil was not reached as sidewall collapse in peat prevented deeper excavation. Where encountered mineral soil was described as blue grey clayey gravelly fine sand with some to many cobbles.

Mineral soil comprised the following and was described (from AGEC, July 2004) as:

(1) Upper Till, which was not encountered in all trial pits and in IDL (2002) was only encountered in TP8. The Upper Till formed a relatively thin and discontinuous layer with thickness of about 0.3 to 1m.

(2) Lower Till was exposed in the bottom of trial pits over 0.35m to 1.1m thickness. The base of the Lower Till was not encountered.

In some trial pits the Lower Till was described as 'running' (TP-03 and TP-06) or 'saturated silts unstable' (TP9 and TP10) and where encountered in trial pits was saturated and sensitive to disturbance. Where there is disturbance and/or removal of confining pressure (overburden) from the Lower Till liquefaction can occur. Liquefaction is a localised effect due to removal of confining pressure.

5 ASSESSMENT OF STONE ROAD STABILITY IN PEAT

5.1 General

Stability analysis was carried out to determine the Factor of Safety (FoS) of a stone road constructed within the peat land areas with the road founded on mineral soil below the peat.

The stability analysis method used comprised a rigorous method to accurately determine the FoS. Using Talren (Terrasol, 2005) the loading and ground conditions can be realistically modelled and a rigorous stability analysis using Bishop's circular method can be carried out.

Stability was analysed using total stress condition for the soils, which applies to short-term conditions occurring during construction and for a time following construction until construction induced pore water pressures dissipate. With respect to loading of the ground, the total stress condition provides the worst case. Undrained shear strength values (c_u) for peat are used for total stress analysis.

The code of practice for earthworks BS 6031:1981 (BSI, 1981), provides advice on design of both temporary and permanent earthworks. It states that for a first time failure with a good standard of site investigation the design FoS should be greater than 1.3. This is similar to Eurocode EC7. Where temporary loading conditions apply a lower FoS may be applicable.

Where undrained parameters are used a FoS of 1.5 is preferable.

5.2 Short and Long-term Stability

The critical condition for loading cases, such as construction of the stone road, is typically the total stress condition which applies to short-term conditions occurring during construction and for a short time following construction until construction induced pore water pressures dissipate. Undrained shear strength values (c_u) for peat are used for total stress conditions.

The long-term condition occurs after construction and at a time when construction induced pore water pressures have dissipated. In the long term effective stress conditions apply. A drained analysis requires effective cohesion (c') and effective friction angle (ϕ').

For the long term analyses a comparison of a peat slope with and without a stone road was also examined.

5.3 Stability Analysis

The following were used to analyse the stability of the stone road.

(1) Stone road stability analysis was carried out where the deepest peat has been identified; this is at about ch. 88,095 in Rossport (Commonage). The peat depth at this location is 5.0m and the ground is sloping at 1 degree to the southwest. Where the peat is deepest it is also likely to be highly humified and weak.

(2) The stone road is 9m wide at the surface and widens towards the base of the peat at 45 degrees. The mix of peat and stone fill that falls outside the road construction envelope has been ignored – this is considered conservative. The height of the stone fill forming the stone road is 4.4m.

(3) Stone road stability was analysed for short-term (undrained) and long term (drained) conditions.

(4) The soil and fill material properties for the undrained analysis are as follows:

(a) Peat γ' - 10.5kN/m^3 (Table 3), c_u - see Figure 1 for strength design line

(b) Fill γ' - 21kN/m^3, ϕ' - 45 degrees

(c) Mineral soil γ' - 19kN/m^3 (Table 3), c_u - 40kPa to 70 kPa at depth (Table 3)

(5) The soil and fill material properties for the drained condition are as follows:

(a) Peat γ' - 10.5kN/m^3 (Table 3), c' - 2kPa and ϕ' - 25 degrees

(b) Fill γ' - 21kN/m^3, ϕ'- 45 degrees

(c) Mineral soil γ' - 19kN/m^3, c' - 1kPa and ϕ' - 30 degrees

(6) Applied loading on to surface of stone road as follows:

(a) No loading

(b) Uniformerly distributed load (UDL) of 20kPa

(c) Pipelaying crane/sideboom load based on typical pipelayer, such as a Caterpillar 583R. Total weight of pipelayer is 1050kN (includes maximum lifting capacity). Breakdown of loads:

Pipe	Units	Load
Pipe Weight	kN/m	3.14
Pipelaying Plant		
Weight	kN	422
Lifting Capacity	kN	628
Total	kN	1050
Pipelaying Plant Track		
Length of weight bearing track	m	3.3
Width of track	m	0.7

Based on the above total load (1050kN) applied over the area of the tracks gives a UDL of 230kPa.

(d) During pipe lifting assume a differential load distribution of the pipelayer of 67% and 33% per track to represent eccentric lifting conditions.

(7) In the short-term it is assumed that stripped peat turves from the stone road are placed on to bog mats adjacent and upslope of the stone road. The stability of the bog mats is analysed assuming two load conditions, namely UDL of 10kPa and UDL of 20kPa, which corresponds to a stacked peat height of 1m and 2 respectively.

(8) The stability of the stone road in the long term is analysed for conditions below. It is noted that as part of the reinstatement the stripped peat turves are to be placed onto the stone road following its completion.

(a) For typical peat depth of 2.5m

(b) For range of slope angles of 1 and 4 degrees in peat

(c) Comparison of the peat slope with and without a stone road

5.4 Stability Results

A summary of the various stability cases and results is given in Table 4.

The following comments are given on the stability results.

(1) Without any loading the stone road has a significant inherent stability both for circular type failure (Figure 4) and sliding failure (cases 1 and 5). This would be expected with such a gravity fill structure taking into account the higher shear resistance of the stone fill used within the road.

(2) Loading from typical construction loading (case 2) placed onto the surface of the stone road (Figure 5) gives a FoS to 2.26.

(3) The highest loading intensity on the road will be during lifting of lengths of pipeline by the pipelaying crane. Where the pipelaying crane is carrying its maximum load with the load evenly distributed (case 3) between both tracks the FoS is 1.29 (Figure 6). This will be a temporary load condition and as such a lower FoS threshold is acceptable.

(4) An analysis was carried out to assess the the stability of the pipelaying crane where the crane is carrying its maximum load with the load eccentrically distributed between the tracks (4a, 4b and 4c). Analysis of this case shows that the height of the water level within the road will effect the FoS (Figures 7 to 9).

Case 4a shows the case where there is about 1m of water within the road, which gives a FoS of 1.22.

As a check on the sensitivity of the FoS with water level in the stone road cases 4b and 4c examine different water tables within the road. The results show that the FoS during pipelaying is sensitive to an elevated water table in the stone road, as

such it is advisable that the water table is monitored in the stone road prior to and during pipelaying.

Notwithstanding the above, the load spread below the tracks will be distributed into the underlying stone road within a a 45 degree load spread envelope. Provided the tracks are not placed near the road edge or close to the pipe tench then the loading envelope would be within competent stone fill and is considered to have sufficient capacity to support the crane.

Given for example that the road edge is often poorly compacted the pipelaying plant when lifting shall be prevented from working within 1.0m of the road edge to avoid possible localised loss of support below the tracks or toppling of the crane during lifting. A safe distance must also be kept from unsupported excavations.

(5) An analysis was carried out to assess stability of the road from sliding sideways due to the weight of the peat pushing against the road (case 5). Due to the width of the stone road at its base and high shear resistance, there is a high FoS of 3.67.

(6) The placement of turves/peat onto bog mats beside the stone road was examined (cases 6a and 6b). The results show that the FoS is sensitive to the height of peat placed.

The placement of turves/peat 1.0m high (10kPa load) onto the bog mat (Figure 10) gives a FoS above the 1.3 threshold; moving the bog mat further away from the road edge has little effect on the FoS.

The placement of turves/peat 2.0m high (20kPa) onto the bog mat (Figure 11) gives a FoS below 1.0. Therefore the height of peat placed on the bog mats shall not exceed 1.0m.

(7) An analysis was carried out to assess the long term stability of the stone road within the peat slope (cases 8a and 8b). By inspection, the installation of the stone road in the slope provides an increase in shear resistance to sliding due to the higher shear resistance of the stone fill. An illustrative analysis was carried out for a peat slope with and without a stone road (Figures 12 and 13); the calculated FoS was 3.35 with stone road and 1.41 without stone road.

	Stability Case No./Description	Analysis type	Water Condition	Comment	FoS	Figure
1	Stone road with no load	Undrained analysis	Fill partly saturated: r_u =0.24	No loading	3.67	4
2	Stone road with UDL of 20kPa applied	Undrained analysis	Fill partly saturated: r_u =0.24	UDL represents heavy construction traffic	2.26	5
3	Stone road with uniform loading from pipelayer carrying maximum lift	Undrained analysis	Fill partly saturated: r_u =0.24	Load spread evenly between both tracks	1.29	6
4a	Stone road with eccentric loading from pipelayer carrying maximum lift	Undrained analysis	Water level at 3.4m below stone road surface.	Load spread 67% and 33% per track due to eccentric pipe load	1.22	7
4b	Stone road with eccentric loading from pipelayer carrying maximum lift	Undrained analysis	Water level at 1.5m below stone road i.e. at base of trench for pipe.	Load spread 67% and 33% per track due to eccentric pipe load Water level in road at base of pipeline trench	1.13	8
4c	Stone road with eccentric loading from pipelayer carrying maximum lift	Undrained analysis	Water level at surface of stone road	Load spread 67% and 33% per track due to eccentric pipe load	1.04	9
5	FoS for stone road against sliding	-	Water table at peat surface	Force equilibrium hand calculation based on stone road in 5m depth of peat	3.67	-
6a	Turves/peat 1m high (10kPa) on bog mat at 2m from edge of road	Undrained analysis	Not applicable	10kPa loading i.e. 1m height of peat	1.40	10
6b	Turves/peat 2m high (20kPa) on bog mat at 2m from edge of road	Undrained analysis	Not applicable	20kPa loading i.e. 2m height of peat	0.78	11
7a	Long term stability of peat with stone road	Drained analysis	Water table at peat surface	Drained analysis, peat depth of 2.5m, 4° slope	3.35	12
7b	Long term stability of peat with stone road	Drained analysis	Water table at peat surface	Drained analysis, peat depth of 2.5m, 4° slope	1.41	13

Table 4 Summary of Stability Cases and Results

5.5 Effect on Stone Road due to Potential Impact from Peat Slide

The effect on the stone road due to a potential impact from a peat slide is considered as follows:

(1) The inclusion of the stone road within the peat slope provides an increase in the stability of the peat slope due to the increase in shear resistance to sliding provided by the higher shear resistance of the stone fill. As such, in the unlikely case where a peat slide occurred the stone road would provide greater resistance to peat movement than the peat itself.

(2) A review of methods to retain potential peat slides shows that stone barrages, comprising essentially stone fill with similar geometry to the proposed stone road, have been used to contain peat slides.

(3) The proposed alignment of the stone road for a significant proportion of the route is within shallow slopes close to the watershed divide or is aligned normal to the slope contours, that is aligned to pass up/down a slope.

    This alignment reduces the potential of a peat slide impacting on the stone road.

(4) In the unlikely event of a peat slide affecting the road, the loading of the peat slide against the stone road is considered to be akin to the passive pressure exerted by the peat. The upper limits of passive pressure are controlled by the undrained strength of the peat. Given the low strength of the peat the pressure exerted onto the stone road by a potential peat slide are considered to be relatively low compared to a slide in mineral soil.

Based on the above, the likely effects of a potential peat slide on the stone road are considered to be limited. Furthermore, installing the pipeline within the stone road will provide a significant degree of protection for the pipeline, in the unlikely event of a peat slide, compared to installing the pipeline within the peat.

6 CONSTRUCTION PRACTICE IN PEAT AREAS

Following recent peat failures (AGEC, 2004), the following general recommendations are given for construction practices in order to reduce the likelihood of peat instability (for details refer to Geotechnical Risk Register, Appendix M4 of EIS). Construction practices and management of the stone road works should take into general consideration, but not be limited to the following:

- Avoidance of placing arisings from excavations and local concentrated loads on peat slope. Where arisings from excavations and/or concentrated load are to be placed onto the peat surface the adequacy of the ground to support the load shall be determined. The stability and adequacy of the ground shall be determined by suitably qualified geotechnical personnel and may involve simple insitu testing, knowledge of previous similar load being placed, or monitoring of a load test to verify that ground can adequately support the load.

- Avoidance of uncontrolled concentrated water flow. All water discharged from excavations during work shall be directed into suitably designed drainage lines or natural drains. No concentrated discharge of water onto slope surface shall be allowed. All release of water should be into a formalised drainage path which shall form part of a site-wide drainage network. Positive drainage measures shall be provided to prevent potential build-up of water in the temporary and permanent condition.

- Avoidance of unstable excavations. All excavation shall be suitably controlled or supported as appropriate to prevent collapse and development of tension cracks.

- Avoidance of placing fill and excavations in the vicinity of steeper peat slopes.

- Areas of machine saw cut peat (also referred to as ‘ploughed’ or ‘sausage’) should be inspected by suitable experienced personnel prior to works commencing in these areas. Where possible, suitable measures taken in advance to provide sufficient side-support for excavations. Given the inherent weakness of cut peat no concentrated loads should be placed onto the peat.

- Geotechnical supervision during works by suitably qualified and experienced personnel. Supervision shall be on a full-time basis for the duration of the construction works.

- On-going and confirmatory ground investigation. As construction progresses, on-going assessment of ground conditions shall be carried out to confirm the findings with respect to stability contained within this report. The results of on-going ground investigation are to be assessed by suitably qualified geotechnical personnel.

- Installation and monitoring of geotechnical instrumentation, as appropriate, in areas of possible poor ground, as indicated from stability assessment for example by collapsed v-ditches, continued and accelerated settlement of floating roads, sidewall instability at shallow inclinations of excavations, wet ground areas, machine saw cut areas. Monitoring works shall include periodic monitoring of piezometers where installed.

- A formalised reporting procedure shall be adopted on site that records site workings, monitoring results and any observations that may be pertinent to the stability of the works.

- Contingency plan to detail level of response to observed poor ground conditions. The performance of the ground shall be assessed against design assumptions. Where the works perform better than expected or as expected there will be no need for contingencies to be implemented. Where findings indicate that the ground is performing outside the expected limits, then a potentially adverse situation might develop, and corrective actions shall be implemented in accordance with the contingency plan.

- Routine inspection of stone road site by maintenance personnel to include an assessment of ground stability conditions. This is to comprise a non-technical assessment based on observation. Maintenance personnel shall be briefed and made aware of key observations that can be carried out in the normal course of their work that may indicate potentially unstable ground conditions.

- Periodic inspection of the route following completion of works by suitably experienced and qualified geotechnical personnel. The site shall be inspected on initially a yearly basis to assess the stability condition. This inspection shall include a walkover inspection of the site with a report produced.

- A Geotechnical Risk Register has been compiled to identify the risks associated with the proposed construction works in peat areas and includes recommended mitigation measures (refer Appendix M4 of the EIS).

7 SUMMARY OF FINDINGS

The findings of the geotechnical assessment of the proposed use of stone road construction in areas of peat for the proposed onshore pipeline from the Glengad Headland to the Bellanaboy gas terminal site are as follows.

(1) An assessment of the use of stone road construction in areas of peat along the proposed onshore pipeline route was carried out and included the following: comparison of alternative road construction methods in peat, assessment of ground investigation data and interpretation of ground conditions, and stability analysis of stone road.

(2) A comparison of alternative road construction methods in peat was carried out (Table 1). Based on this comparison, the stone road construction would be considered the preferred solution as it greatly reduces the risk of peat failure associated with placement of load onto the peat surface. The stone road provides a dependable working platform and is a comparatively low risk construction method in peat.

(3) The proposed onshore pipeline route is some 9.2km long, from the landfall at Glengad Headland to the terminal, and passes through approximately 5.7km of deeper peat areas with depths ranging from 0.25 to 5m. About 63% of the peat area is less than 3m deep.

(4) There are three sections where the proposed pipeline crosses over peat areas and where stone road construction is envisaged, namely: Rossport (Commonage) (ch. 85,960 to ch. 88,600), South of Sruwaddacon Bay to L-1202 (ch. 89,500 to ch. 91,000), and L-1202 to Terminal Site (ch. 91,000 to 92,560).

(5) The walkover survey (Report on Onshore Pipeline Peat Stability Assessment. AGEC, 2009) of the proposed route identified several features which should be taken into consideration when constructing the proposed pipeline:

   (a) Areas of machine cut peat within the commonage. There are extensive areas of machine cut peat (for example ch 86,250 to 86,600, ch 87,300 to 87,450). Machine cuts can weaken the peat and cause excavation side faces to readily collapse. Possible temporary excavation support may be required in these areas.

   (b) Areas of wet/weak peat. There is a series of shallow bog pools within an area of relatively intact peat (ch 87,200 to 87,300). The bog pools possibly indicate wetter/weaker peat at depth and excavation works would need to allow for measures to support excavation faces.

   (c) Areas of deep peat. Around ch 88,100 there is an area of significantly deep peat (up to 5m deep). Possible temporary excavation support may be required

in these areas or partial excavation and displacement method adopted in placing the stone fill.

(d) Areas of weak peat. Several areas of potentially weaker peat have been identified (for example at about ch 87,220, 89,960). Whilst areas of weak peat will be investigated prior to construction nevertheless excavation works would again need to allow for measures to support excavation faces where weaker peat is encountered.

(6) The geotechnical risk register in Appendix M4 of the EIS details mitigation measures to reduce the potential risk associated with construction work in deep/weak peat.

(7) Stability analysis was carried out to examine various stability cases with respect to the stone road (Table 4). The results of the stability analyses are as follows:

(a) Without any construction loading the stone road has a significant inherent stability both for circular type failure (Figure 4) and sliding failure. This would be expected with such a gravity fill structure.

(b) Loading from typical construction works placed onto the surface of the stone road (Figure 5) gives a satisfactory Factor of Safety (FoS). The highest loading intensity on the road will be during lifting of lengths of pipeline by the pipelaying crane.

The results show that the FoS during pipelaying is sensitive to an elevated water table in the stone road; as such it is advisable that the water table is monitored in the stone road prior to and during pipelaying.

The stability risk associated with pipelaying is associated with possible localised loss of support below the crane tracks or toppling of the crane during lifting. The pipelaying contractor shall ensure that adverse eccentric loading of the pipelaying crane is avoided.

Given that the road edge is often poorly compacted the pipelaying plant when lifting shall be prevented from working within 1.0m of the road edge. A safe distance must also be kept from unsupported excavations.

(c) The placement of turves/peat onto bog mats beside the stone road was examined (Figures 10 and 11). The placement of turves/peat 1.0m high (10kPa load) onto the bog mat gives a FoS above the 1.3 threshold whilst the placement of turves/peat 2.0m high (20kPa) gives a FoS below 1.0.

The height of peat placed on the bog mats shall not exceed 1.0m.

(d) The long term stability of the the peat slope with a stone road will have an increased degree of stability as the stone road provides an increase in shear resistance to sliding due to the higher shear resistance of the stone fill. An

illustrative analysis was carried out for a peat slope with and without a stone road (Figures 12 and 13) which shows a marked increase in the FoS with the stone road in the peat slope.

(8) A review of the ground investigations carried out along the route indicates that investigations have been limited in some areas due to access difficulties. It is recommended that confirmatory geotechnical investigation work is carried out prior to any construction in areas where there is limited data, refer to Report on Onshore Pipeline Peat Stability Assessment (AGEC, 2009).

(9) In conclusion

(a) Stone road construction in peat areas is a proven method of construction in weak ground, and for many such situations is the preferred construction method.

(b) Analyses were carried out to assess the stability of the stone road under various load cases. The results clearly show that the stone road has adequate stability and provides a robust and stable platform for construction and long term stability, as would be expected from such a large gravity fill structure.

(c) The long-term stability of the stone road in the peat was examined. The installation of the stone road into the peat provides a greater degree of stability against a peat slide. This is as a result of the greater shear resistance to sliding provided by the stone fill within the road.

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FIGURES

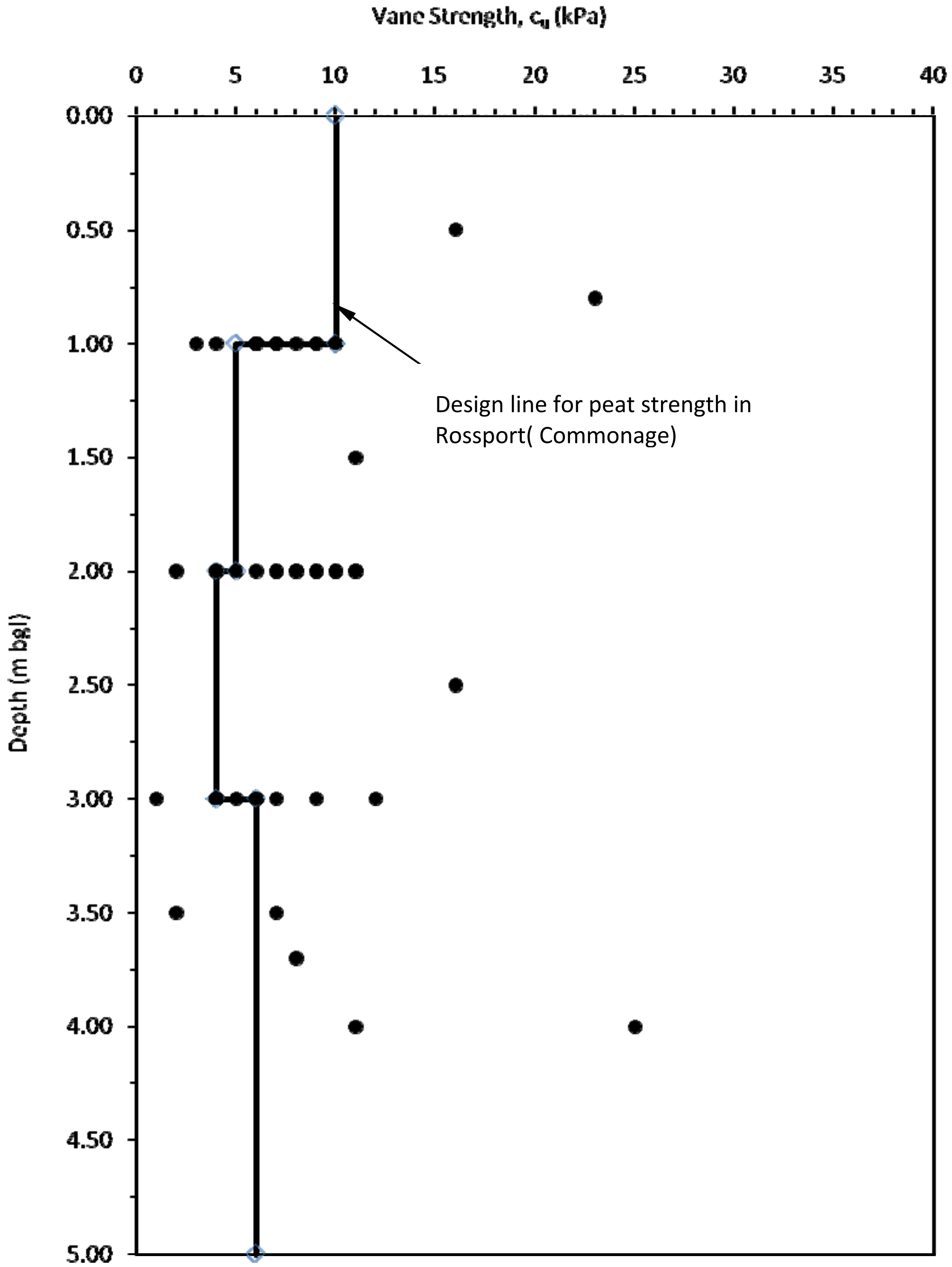


Figure 1 Shear Vane Strength (c_u) for Peat with Depth showing Design Line, Rossport (Commonage)

Note
(1) Results based on insitu tests using SL810 hand vane with 33mm diameter vane
(2) Vane results are not corrected for plasticity.

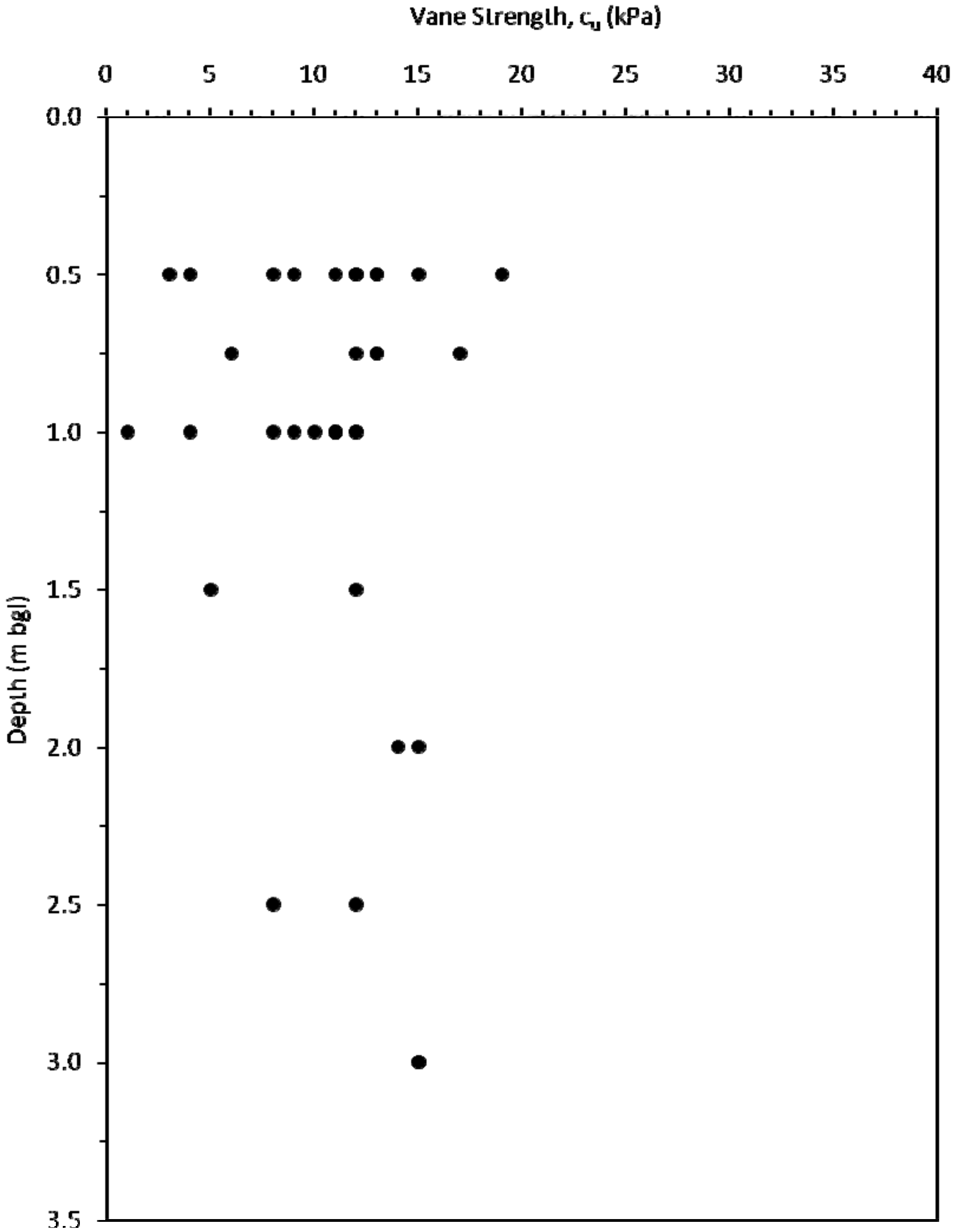


Figure 2 Shear Vane Strength (c_u) for Peat with Depth, South of Sruwaddacon Bay to L-1202

Note
(1) Results based on insitu tests using SL810 hand vane with 33mm diameter vane
(2) Vane results are not corrected for plasticity.

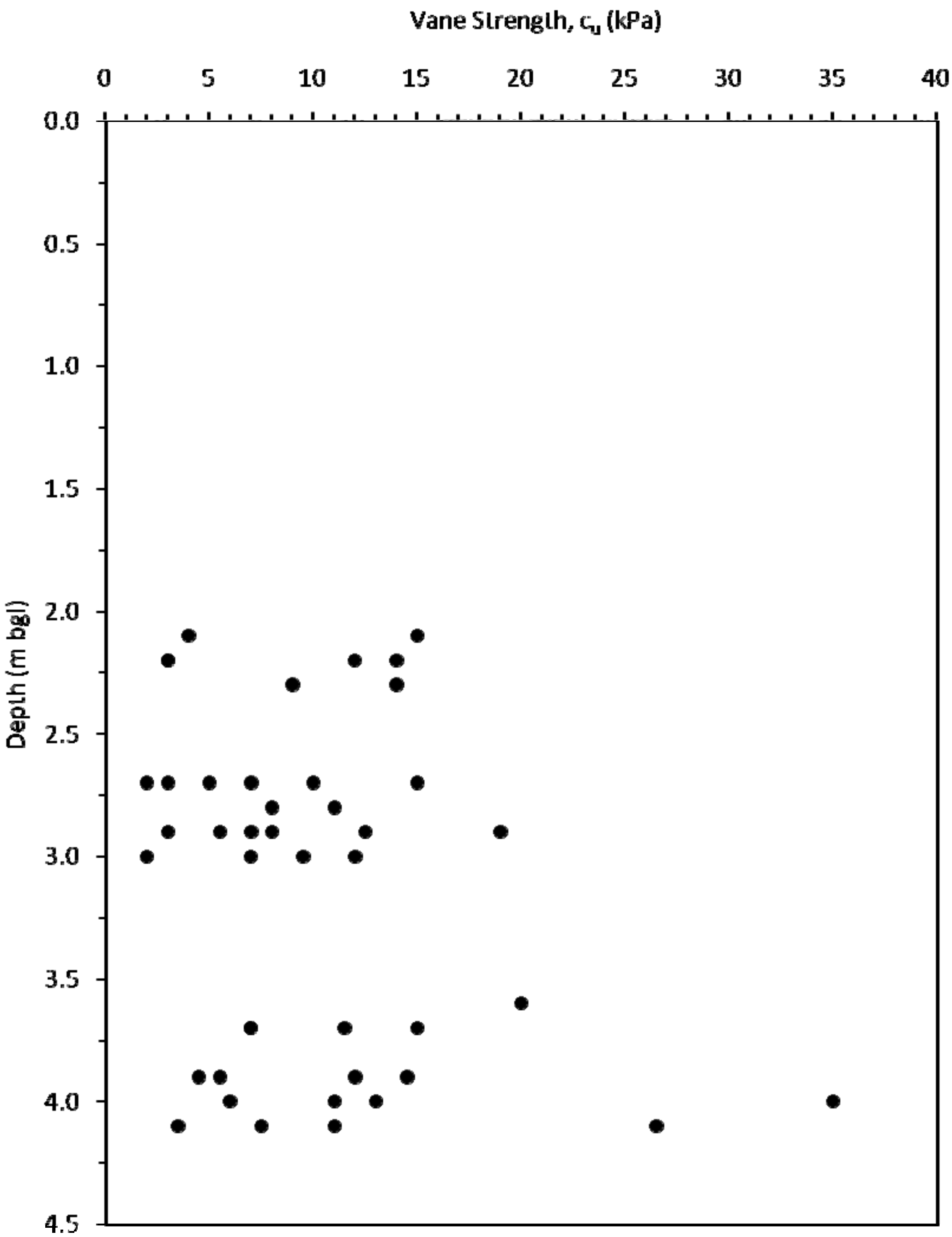


Figure 3 Shear Vane Strength (c_u) for Peat with Depth, L-1202 to Terminal Site

Note
(1) Results based on tests using Geonor H-10 mechanical vane with 65mm diameter
(2) Vane results are not corrected for plasticity.

Name	γ(kN/m3)	φ(°)	c(kPa)
Peat 1	10.5	0.0	10.0
Upper Till	19	0.0	40.0
Granular Fill	21	45.0	0.0
Peat 2	10.5	0.0	5.0
Peat 3	10.5	0.0	4.0
Peat 4	10.5	0.0	6.0
Lower Till	19	0.0	75.0

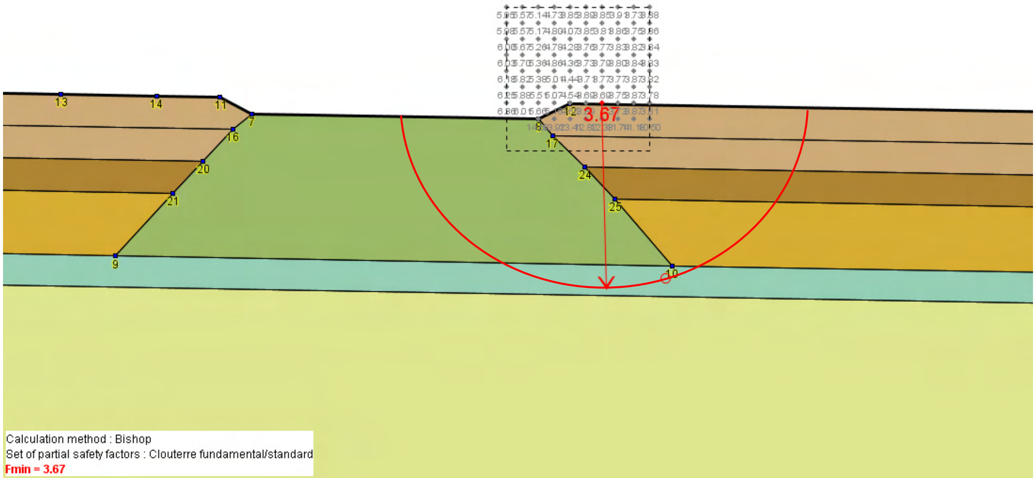


Figure 4 Stability Analysis with No Load on Stone Road

Name	γ(kN/m3)	φ(°)	c(kPa)
Peat 1	10.5	0.0	10.0
Upper Till	19	0.0	40.0
Granular Fill	21	45.0	0.0
Peat 2	10.5	0.0	5.0
Peat 3	10.5	0.0	4.0
Peat 4	10.5	0.0	6.0
Lower Till	19	0.0	75.0

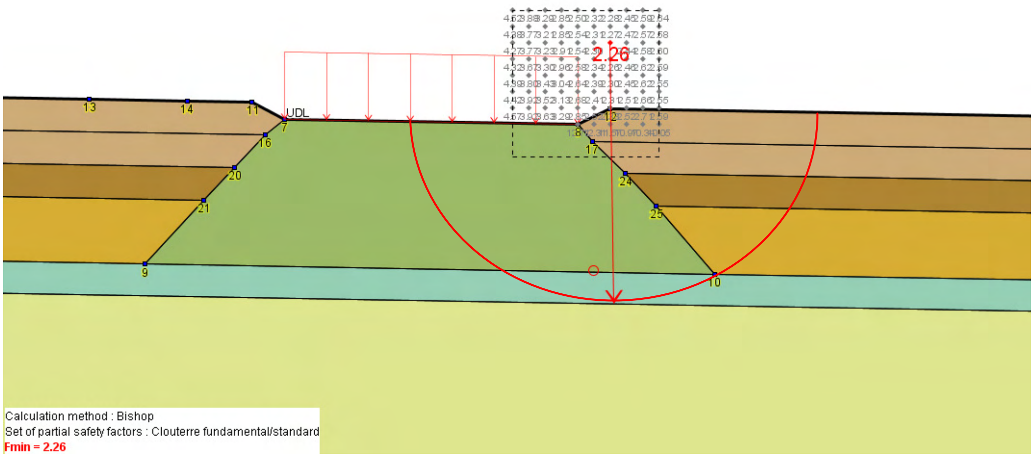


Figure 5 Stability Analysis with UDL of 20kPa on Stone Road

Name	γ(kN/m3)	φ(°)	c(kPa)
Peat 1	10.5	0.0	10.0
Upper Till	19	0.0	40.0
Granular Fill	21	45.0	0.0
Peat 2	10.5	0.0	5.0
Peat 3	10.5	0.0	4.0
Peat 4	10.5	0.0	6.0
Lower Till	19	0.0	75.0

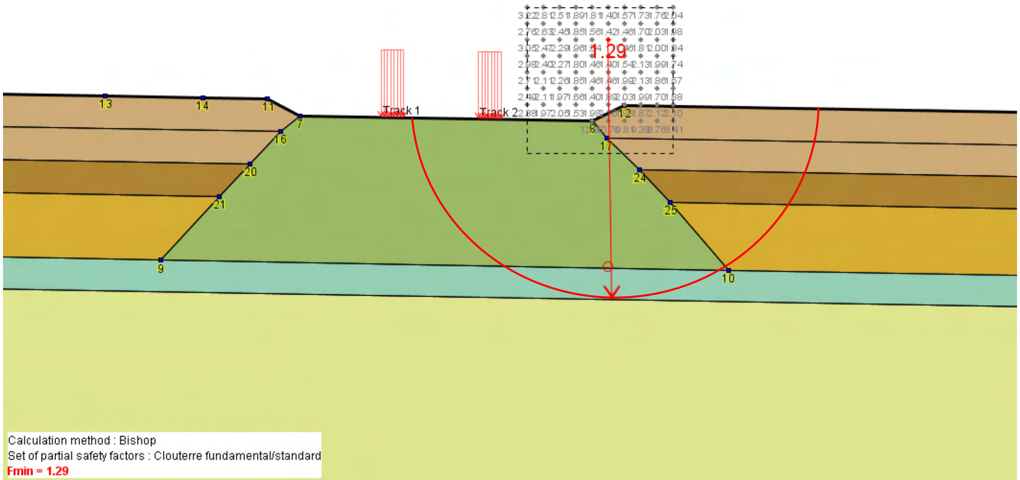


Figure 6 Stability Analysis with Uniform Loading from Pipelayer with Maximum Lift on Stone Road

Name	γ(kN/m3)	φ(°)	c(kPa)
Peat 1	10.5	0.0	10.0
Upper Till	19	0.0	40.0
Granular Fill	21	45.0	0.0
Peat 2	10.5	0.0	5.0
Peat 3	10.5	0.0	4.0
Peat 4	10.5	0.0	6.0
Lower Till	19	0.0	75.0

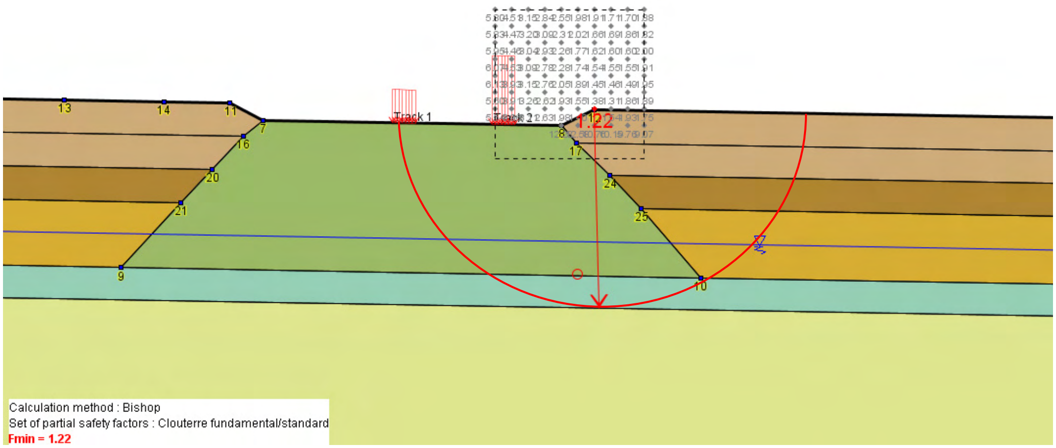


Figure 7 Stability Analysis with Eccentric Loading from Pipelayer with Maximum Lift on Stone Road (Water level at 3.4m below surface of stone road)

Name	γ(kN/m3)	φ(°)	c(kPa)
Peat 1	10.5	0.0	10.0
Upper Till	19	0.0	40.0
Granular Fill	21	45.0	0.0
Peat 2	10.5	0.0	5.0
Peat 3	10.5	0.0	4.0
Peat 4	10.5	0.0	6.0
Lower Till	19	0.0	75.0

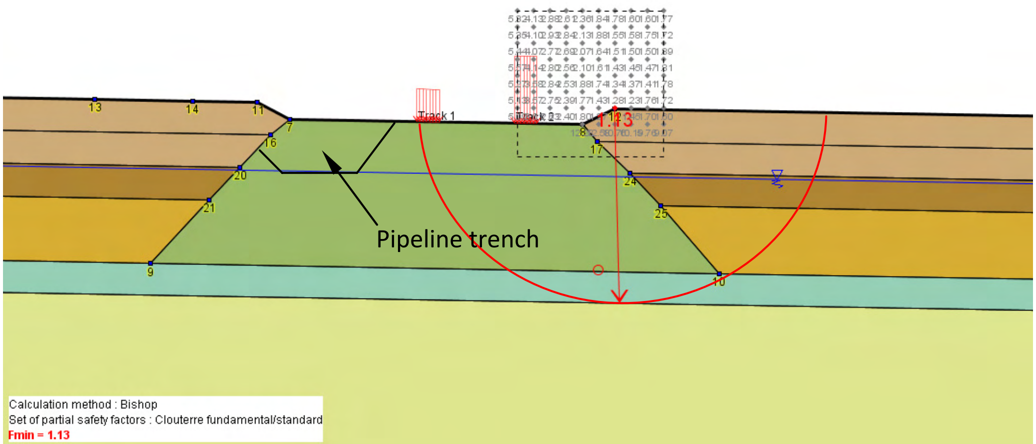


Figure 8 Stability Analysis with Eccentric Loading from Pipelayer with Maximum Lift on Stone Road (Water level at 1.5m below road surface)

Name	γ(kN/m3)	φ(°)	c(kPa)
Peat 1	10.5	0.0	10.0
Upper Till	19	0.0	40.0
Granular Fill	21	45.0	0.0
Peat 2	10.5	0.0	5.0
Peat 3	10.5	0.0	4.0
Peat 4	10.5	0.0	6.0
Lower Till	19	0.0	75.0

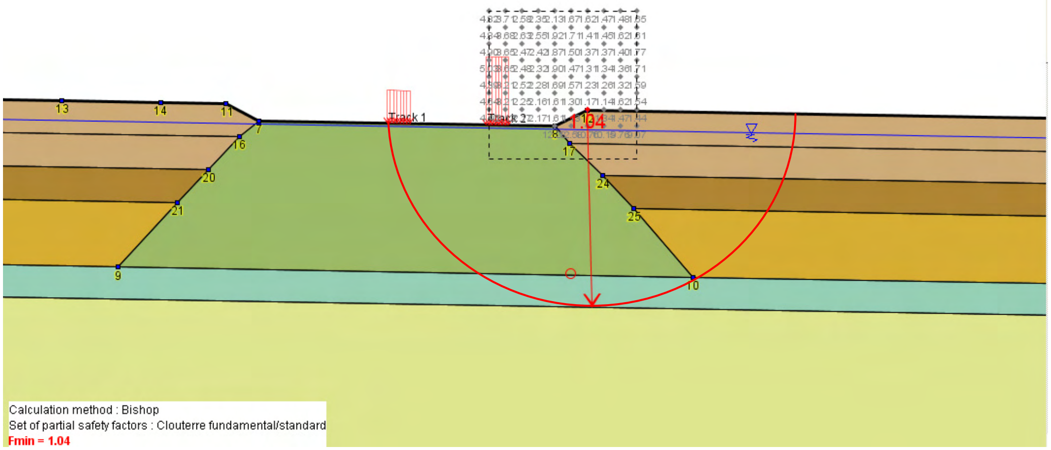
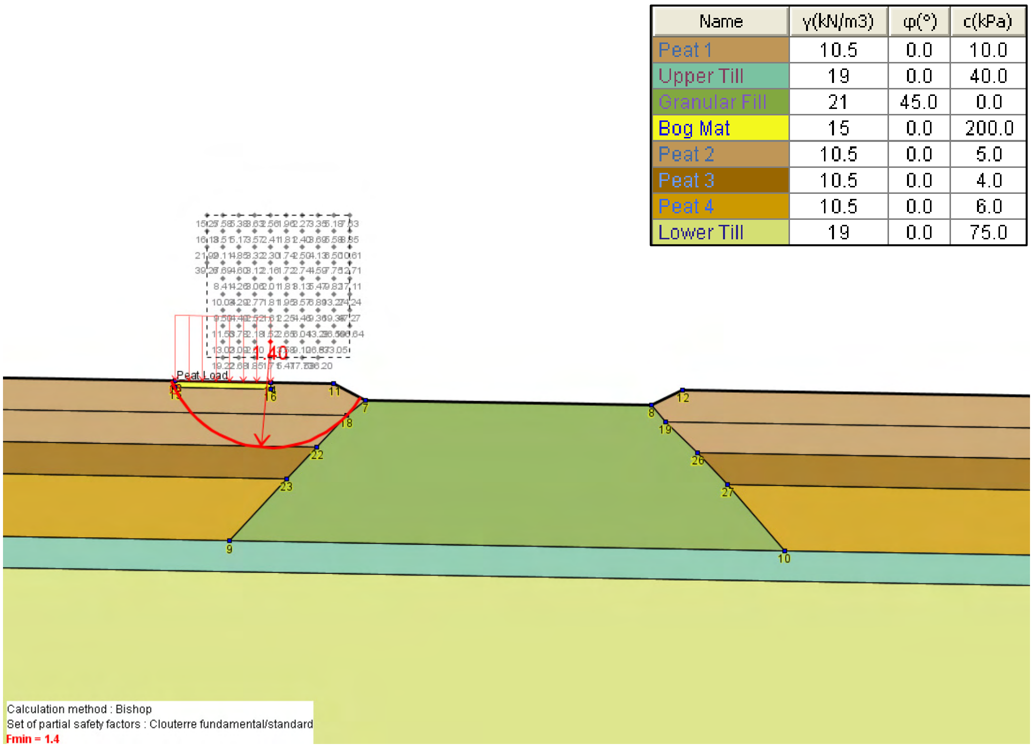
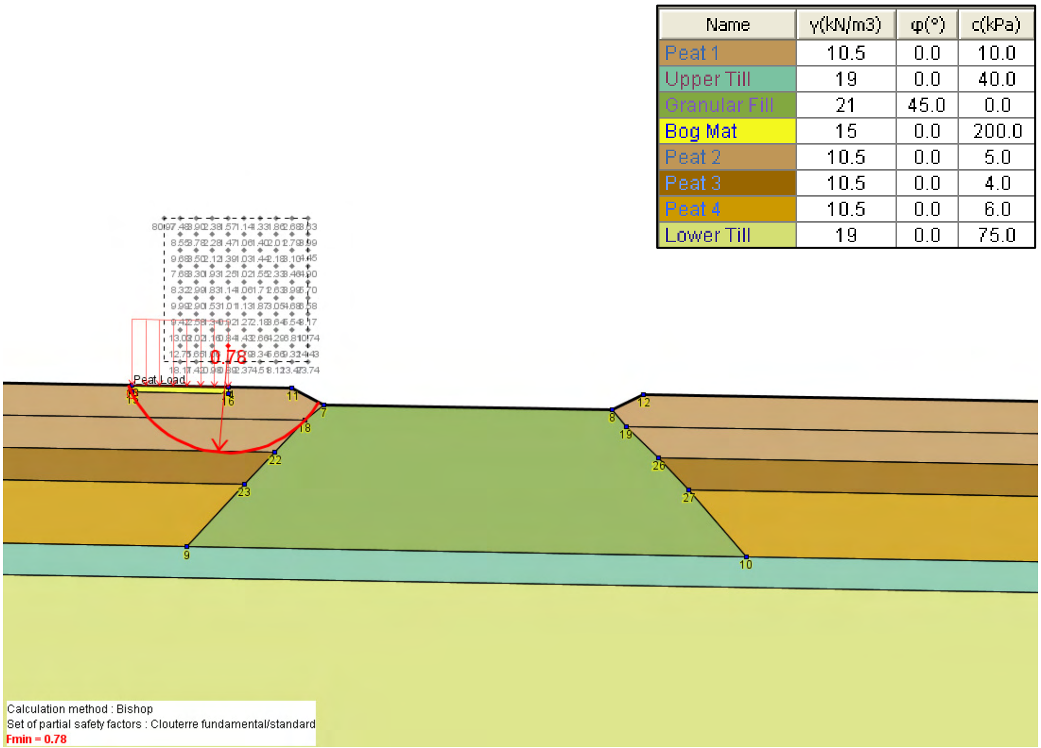


Figure 9 Stability Analysis with Eccentric Loading from Pipelayer with Maximum Lift on Stone Road (Water level at top surface of stone road)



Name	γ(kN/m3)	φ(°)	c(kPa)
Peat 1	10.5	0.0	10.0
Upper Till	19	0.0	40.0
Granular Fill	21	45.0	0.0
Bog Mat	15	0.0	200.0
Peat 2	10.5	0.0	5.0
Peat 3	10.5	0.0	4.0
Peat 4	10.5	0.0	6.0
Lower Till	19	0.0	75.0

Figure 10 Stability Analysis with 10kPa Uniform Loading on Bog Mats at 2m from Road Edge



Name	γ(kN/m3)	φ(°)	c(kPa)
Peat 1	10.5	0.0	10.0
Upper Till	19	0.0	40.0
Granular Fill	21	45.0	0.0
Bog Mat	15	0.0	200.0
Peat 2	10.5	0.0	5.0
Peat 3	10.5	0.0	4.0
Peat 4	10.5	0.0	6.0
Lower Till	19	0.0	75.0

Figure 11 Stability Analysis with 20kPa Uniform Loading on Bog Mats at 2m from Road Edge

Name	γ(kN/m3)	φ(°)	c(kPa)
Peat	10.5	25.0	2.0
Underlying Till	19	30.0	1.0
Granular Fill	21	45.0	0.0

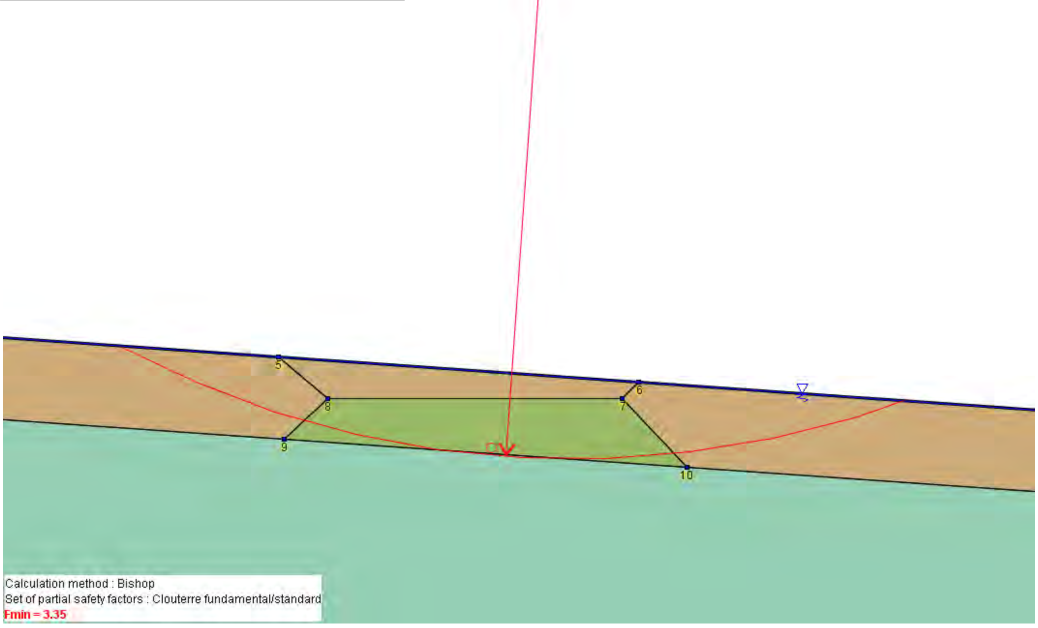


Figure 12 Long-term Stability of Peat with Stone Road (Peat depth 2.5m and 4 degree peat slope)

Name	γ(kN/m3)	φ(°)	c(kPa)
Peat	10.5	25.0	2.0
Underlying Till	19	30.0	1.0
Granular Fill	21	45.0	0.0

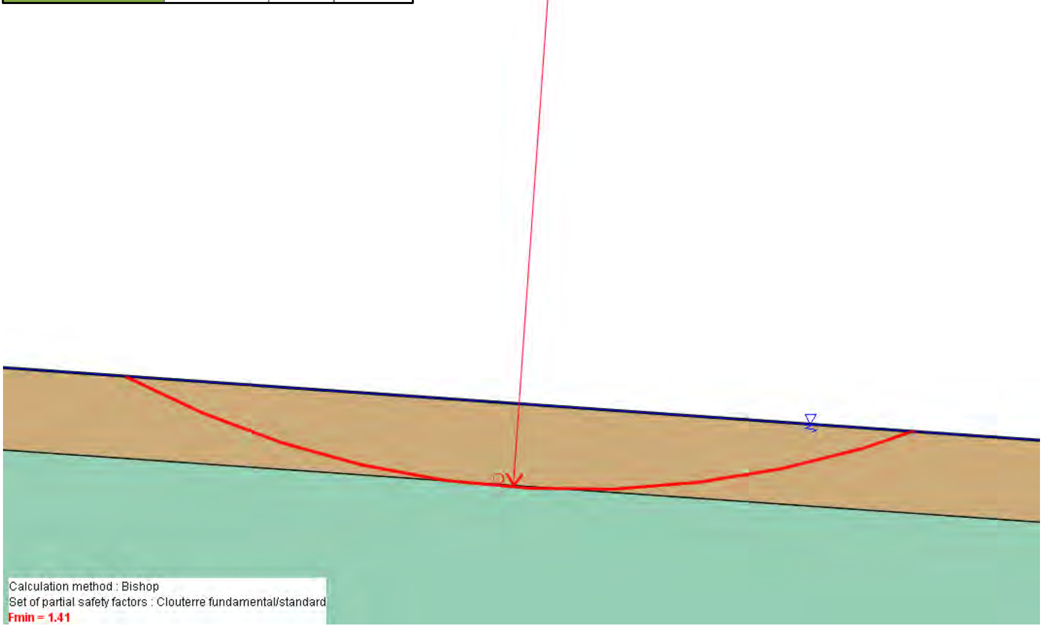
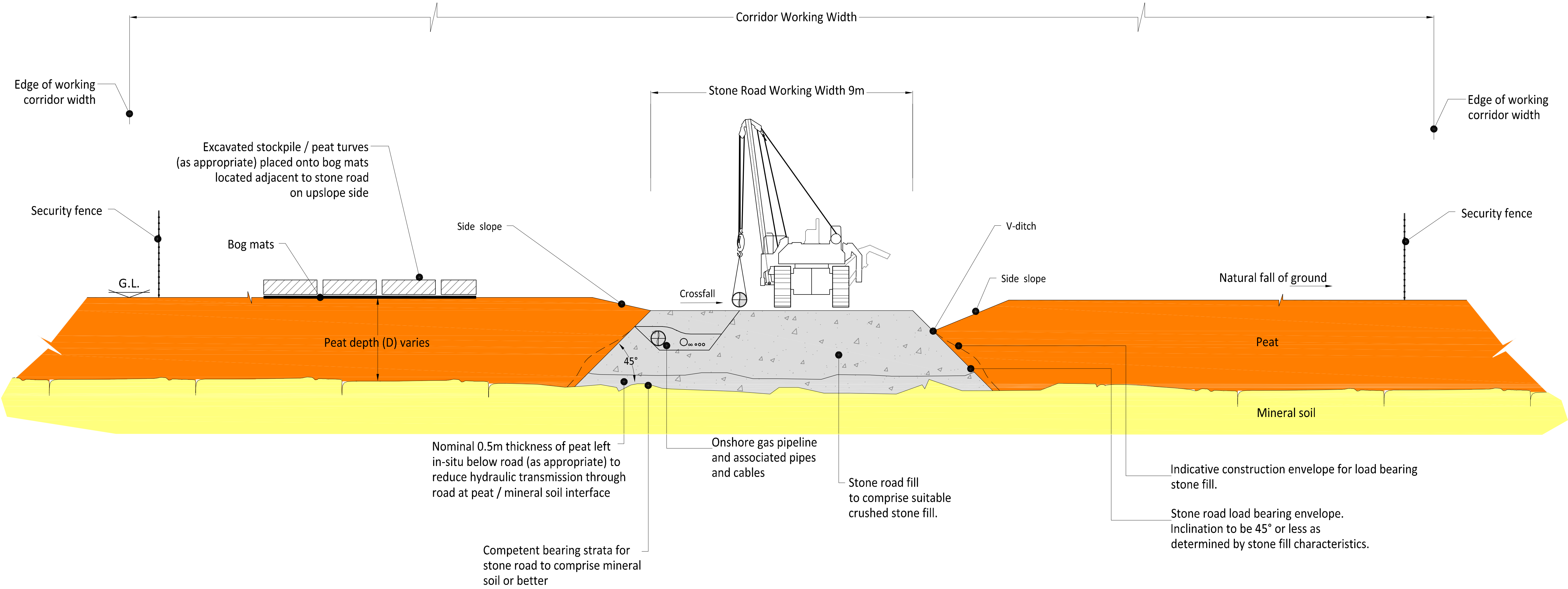


Figure 13 Long-term Stability of Peat with No Stone Road (Peat depth 2.5m and 4 degree peat slope)

DRAWINGS



TYPICAL PEATLAND STONE ROAD CROSS SECTION

SCALE NTS

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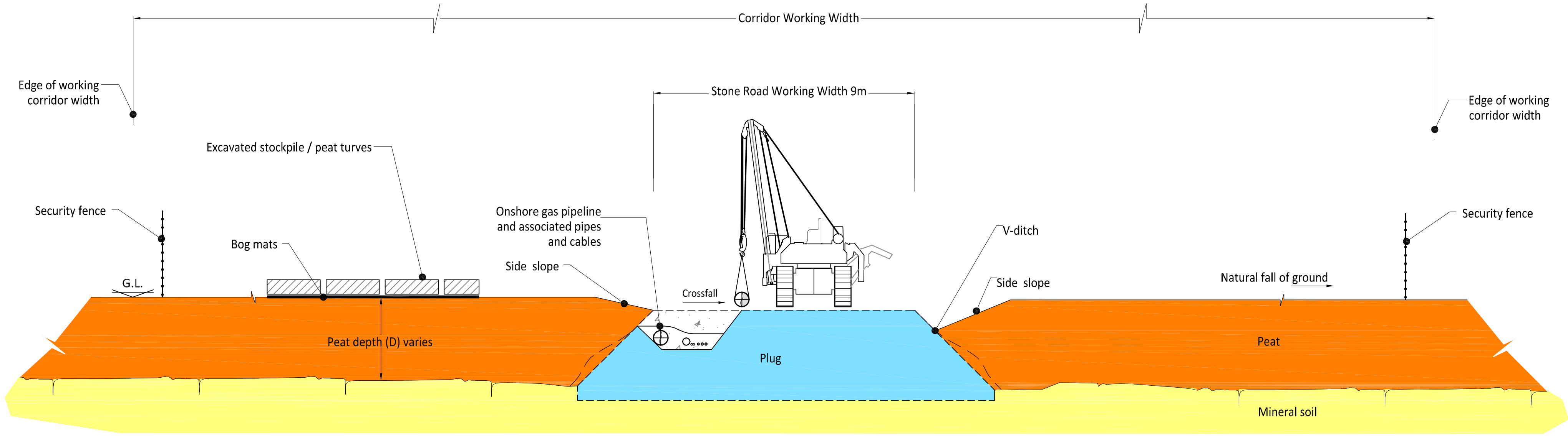
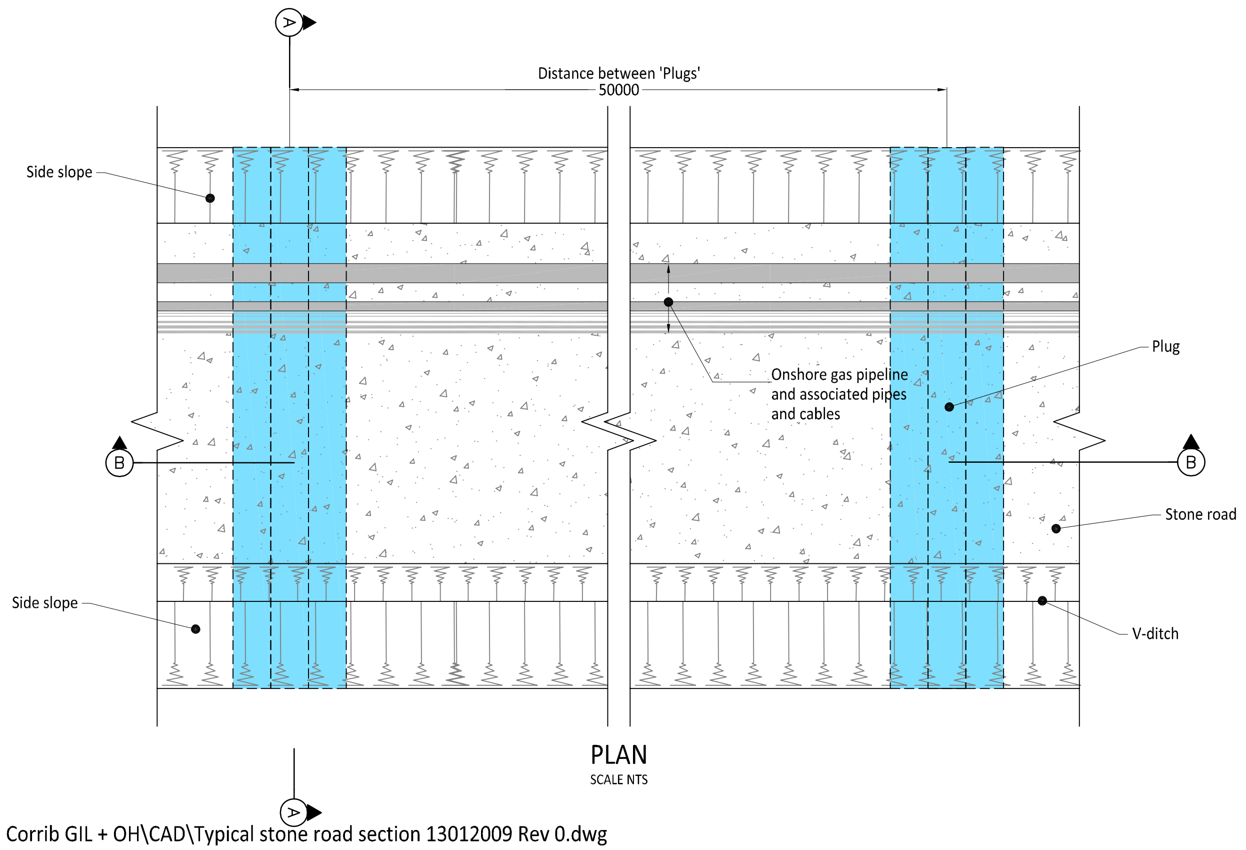
Notes: Minor Amendments		Client: Shell E&P Ireland Ltd.	Job: Corrib Onshore Pipeline.	Drg. No. - 864_02_001 Title: Typical Details of Stone Road in Peat Aeas	AGEC Ltd The Grainstore Singletons Lane Bagenalstown Carlow Ireland Tel: +353 59 972 3800 Fax: +353 59 972 3793 www.agec.ie info@agec.ie
Scale: NTS	Checked: PJ				
Date: 13/01/2009	Revision: 0				
Drawn: O.B.	Based on:				



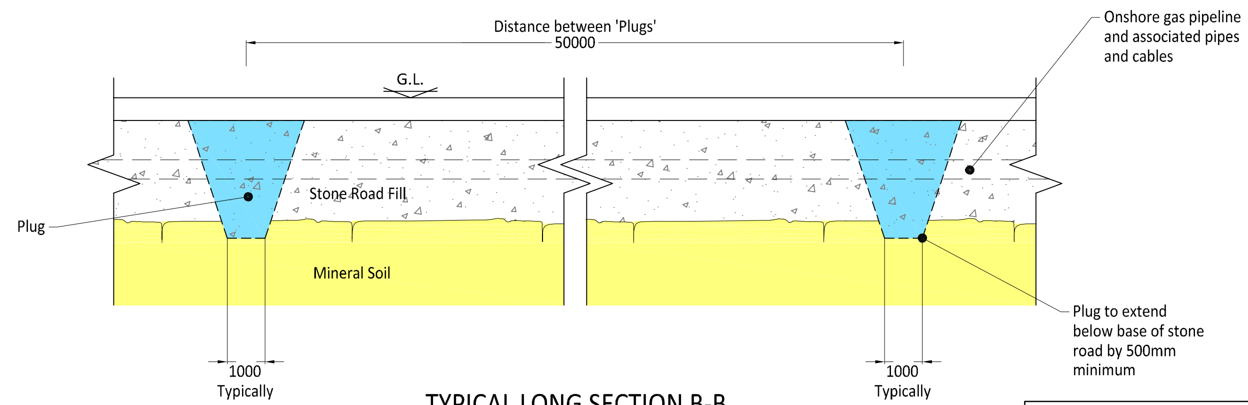
TYPICAL SECTION A-A PEATLAND STONE ROAD CROSS SECTION SHOWING TRANSVERSE 'PLUGS'

SCALE NTS



PLAN

SCALE NTS



TYPICAL LONG SECTION B-B

SCALE NTS

Note:
1. Plugs shall consist of suitable low permeability material or other isolation technique subject to detailed design

2. Plugs to be constructed during / following completion of stone road and prior to installation of onshore gas pipeline

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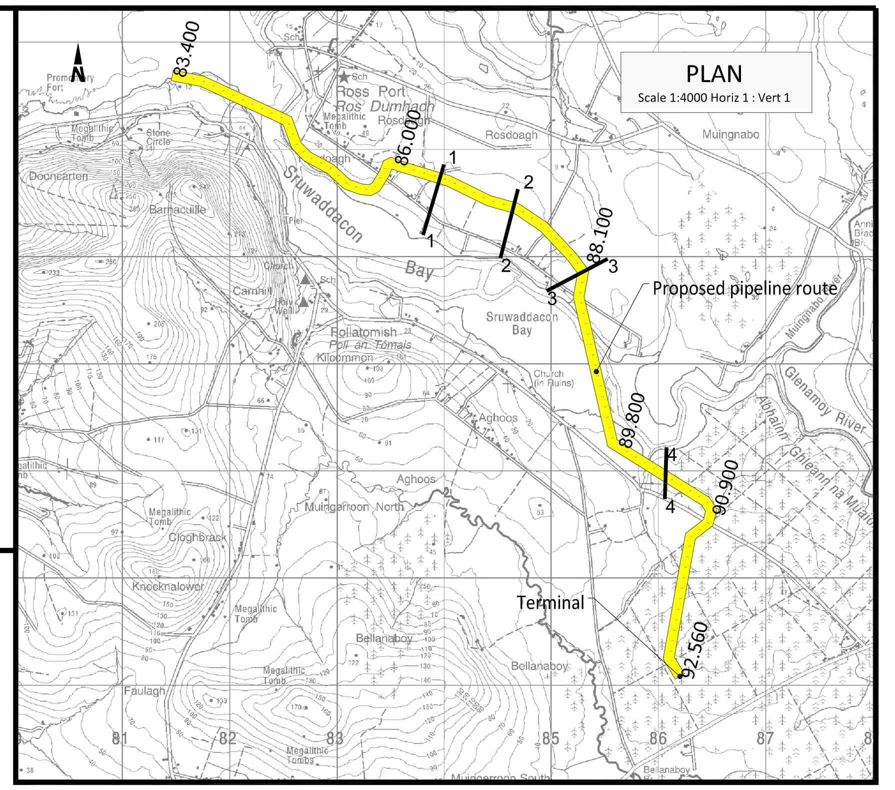
Notes: Minor Amendments		Client: Shell E&P Ireland Ltd.	Job: Corrib Onshore Pipeline.	Drg. No. - 864_02_002 Title: Typical Details of Stone Road in Peat Aeas -Transverse Plugs	AGEC Ltd The Grainstore Singletons Lane Bagenalstown Carlow Ireland Tel: +353 59 972 3800 Fax: +353 59 972 3793 www.agec.ie info@agec.ie
Scale: NTS	Checked: PJ				
Date: 13/01/2009	Revision: 0				
Drawn: O.B.	Based on:				

Geological Profile Legend

- Peat
- Mineral Soil
- Bedrock
- Geological Boundary

Note

Geological interpretation is based on the available site investigation information. The interpretated geological boundaries are not necessarily an accurate indication of ground conditions. Actual ground conditions may vary from that shown on the drawing.



Typical Cross Sections

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Further notes:

Notes:		Client: Shell E&P Ireland Ltd.	Job: Corrib Onshore Pipeline.
Scale: As shown	Checked: PJ		
Date: January 2009	Revision: 0		
Drawn: OB	Based on:		

Drg. No. - 864_02_003

Title: Typical Cross Sections

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