Appendix M4

Geotechnical Risk Register

Geotechnical Risk Register

Introduction

A Geotechnical Risk Register has been compiled to show the degree of risk attached to various elements of the proposed pipeline construction and operation on a qualitative scale based on Clayton (2001)[1]. The purpose of the register is to provide and outline a description of the hazards, identify the likely cause, describe the potential impact of the hazard and identify the design and construction controls to be implemented in order to minimise the geotechnical risk.

The Geotechnical Risk Register will be actively used during the design and construction stage of the project as a guide to address geotechnical issues. The risk register will be up-dated to reflect additional data and experience as it is gained.

Whilst probability of a hazard occurring can be reduced to a minimum by geotechnical design, the impact cannot be reduced below very low. The probability and impact of a hazard have been judged on a qualitative scale as set out in Table 1.

PROBABILITY (P)		IMPACT (I)	
Description	**Score**	**Description**	**Score**
Very likely	5	Very high	5
Probable	4	High	4
Likely	3	Medium	3
Possible	2	Low	2
Negligible	1	Very low	1
Not applicable	0	-	-

Table 1 Factors used to Compile Risk Matrix

The list of hazards identified in this Geotechnical Risk Register is non-exhaustive and has been selected based on specific critical hazards that are relevant to this scheme having regard to health & safety, environmental, programme and cost considerations. However, it must be noted that this document is a Geotechnical Risk Register. It is not a Health and Safety or Environmental Risk Register. The degree of risk is determined by combining the probability and impact assessments: Risk (R) = Probability (P) x Impact (I). The the severity of the risk is as set out in Table 2.

		PROBABILITY				
		1	**2**	**3**	**4**	**5**
IMPACT	**5**	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5

Key:

- Unacceptable
- Early attention
- At least regular attention

Table 2 Risk (R) Matrix

References

[1] Clayton, C.R.I., (2001). Managing Geotechnical Risk. Thomas Telford, London.

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Notes:

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4 The risk rating values given in the register are based on engineering judgment and as such may vary between individuals depending on the perception of risk.
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January, 2009

No.	Hazard	Cause	Potential Impact		Risk Rating (Refer Table 12.1 and 12.2)			Risk Control Measure (RCM)		Risk Rating following RCM (Refer Table 12.1 and 12.2)			Contingency Measures
			Category	Specific	P	I	R	Design Control	Construction Control	P	I	R	
Pipelaying on land													
1	**Liquefaction of base of pipeline trench in tidal sand areas** **Sand mixing with water and forming liquid material.**	1. High/rising tidal waters causing liquefaction (quick conditions) of sand in excavation base 2. Inadequate site investigation information 3. Inadequate design and understanding of ground conditions 4. Improper construction	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury by drowning 2. Damage to plant 3. Loss and cessation of works	4	5	20	1. Review of previous excavations in the locality and in similar ground 2. Detailed site investigation to include trial trenches to expose soils 3. Boreholes and trial pits to be taken below base of pipeline trench 4. Specify method statement from the Contractor for working in tidal sands and check that he is fully cognisant with ground conditions 5. Check of implications of over-excavation 6. Check requirement to have ballast stone available to place in base of trench	1. Site supervision staff to inspect trench daily 2. No/limited access into trench 3. Areas of unexpectedly deep and weak ground to be reported and await further instruction 4. Works sequenced to tides and weathered conditions 5. Supervision to ensure construction carried out as detailed in the method statement 6. Limited exposure of trench base to avoid potential for base (liquefaction) failure	1	4	4	1. Stop works 2. Ballast stone to be placed in base of excavation 3. Ensure localised area made stable
2	**Escape of potential contaminated water from works into surface water channels** **Possible contaminants from leakages, spills or fines/suspended solids**	1. Extended periods of wet weather and under-design of temporary pumping 2. Over-pumping of excavation into surface water channel. 3. Potential contamination from run-off from works 4. Potential contamination from backfill material	1. Environmental	1. Risk of contamination of surface water	3	4	12	1. Walk-over survey to identify areas where greater risk of water entering works and becoming contaminated 2. Detailed site investigation to include trial trenches to expose soils and monitoring of groundwater along route 3. Spillages from plant - addressed in environmental impact statement 4. Consider limiting the extent of works/trench opened in sensitive areas 5. Specify method statement from contractor that clearly demonstrates their awareness of this issue 6. Identify any sensitive receivers along route	1. Supervision staff to be fully briefed on the ground conditions, design requirements and construction methodology 2. Supervising staff aware of weather forecasts 3. Appropriate pumping facilities to be put in place during the construction phase and silt traps/bunds constructed 4. Temporary bunds and drains to be installed as appropriate 5. Supervision to ensure construction carried out as detailed in the method statement 6. Measures to prevent contamination/clean up contamination before work continues	1	4	4	1. Stop work 2. Environmental Manager to be notified immediately. 3. Establish if contamination includes oil / diesel 4. Identify source of contamination and solve problem immediately as per EMP. 5. Oil contaminated water to be treated prior to discharge (use oil interceptors if appropriate) 6. Excess water to be diverted into drainage channels with filtration / sedimentation as required 7. Use simple and effective filtration measures to remove particle load e.g. straw bales/terram in drainage channels 8. Sedimentation tanks to be used (and cascaded if necessary) 9. Use adjacent areas within temporary working area as natural filter in agreement with NPWS e.g. for high levels of suspended peat 10. Reserve / additional pumping facilities to be available
3	**Unexpected hard obstructions in excavations, e.g. boulders, rock outcrops**	1. Ground conditions differing from those indicated from site investigation 2. Inadequate site investigation information	1. Programme 2. Cost	1. Delays to works 2. Increased noise levels due to additional rock breaking requirements	4	2	8	1. Carry out extensive site investigation. 2. Walk-over survey of route to identify areas of variable ground (e.g. shallow rock, till, peat/organic clay) 3. Selection of conservative design parameters to allow for variable conditions on site 4. Require detailed construction method statement that clearly demonstrates understanding of the ground conditions and risks involved 5. Monitoring and observation method proposed as part of construction controls	1. Construction personnel briefed on expected ground conditions 2. Reporting by site staff on change in ground conditions from that predicted 3. Advance notice of change in predicted ground condition to be fed to designers 4. Supervision to ensure construction carried out as detailed in the method statement	1	2	2	1. Stop works 2. Area to be assessed 3. Use rock breakers/non-explosive pre-splitting of rock using expansive grouts or similar
4	**Open excavations and holes filled with disturbed peat**	1. Excavation works 2. Displacements and slides 3. Improper construction methods	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of death or injury from falling into excavation 2. Damage to plant	3	5	15	1. Carry out extensive site investigation 2. Walkover survey of route to identify areas of variable ground (e.g. shallow rock, till, peat/organic clay) 3. Detailed method statement to be prepared with respect to excavation	1. Appropriate sequencing of works 2. Supervision of works by suitably qualified person 3. Tool box talks to be carried out prior to works 4. Ensure no excavations left open or unprotected 5. Backfill to be with a suitable material 6. Supervision to ensure construction carried out as detailed in the method statement	2	3	6	1. Stop work 2. Backfill open excavations with stone 3. Over excavate disturbed peat localised area and backfill with stone
5	**Unexpected soft ground in pipeline trench (outside of peat areas)**	1. Ground conditions differing from those indicated from site investigation 2. Inadequate site investigation information	1. Programme 2. Cost	1. Delays to works 2. Increased excavation and backfilling requirement	4	3	12	1. Carry out extensive site investigation. 2. Walk-over survey of route to identify areas of variable ground (e.g. shallow rock, till, peat/organic clay) 3. Selection of conservative design parameters to allow for variable conditions on site 4. Detailed method statement to be prepared 5. Monitoring and observation method proposed as part of construction controls	1. Construction personnel briefed on expected ground conditions 2. Reporting by site staff on change in ground conditions from that predicted 3. Record of change in predicted ground condition to designers 4. Supervision to ensure construction carried out as detailed in the method statement	1	3	3	1. Stop work 2. Where appropriate over excavate and backfill with stone 3. Place stone ballast to secure base of excavation
6	**Dewatering of bog-hole/ponded water in bog due to drainage (such as natural pipes, overland flow) into pipeline trench**	1. Proximity of bog-hole/ponded water to excavation 2. Inadequate site investigation information 3. Unforeseen hydraulic continuity from water source to trench	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of death or injury by drowning 2. Risk of dewatering bogland waters 3. Cross-contamination and flow velocity increase	3	5	15	1. Walk-over survey to identify areas of bog-pools and standing water within peatland 2. Detailed site investigation to include trial trenches to expose soils 3. Review of previous excavations in the locality and in similar ground 4. Measurement of groundwater from piezometers where possible 5. Consider limiting extent of works opened at any time in areas of bog-pools 6. Non-invasive monitoring of water levels in bog-pools in proximity to works 7. Detailed method statement to be prepared	1. Supervision staff to be fully briefed on the ground conditions, design requirements and construction methodology 2. No/limited access into trench 3. Monitoring of water levels in bog-pools in proximity to works 4. Appropriate pumping facilities to be put in place during the construction phase 5. Employment of contractor/personnel familiar with soft ground conditions 6. Supervision to ensure construction carried out as detailed in the method statement 7. Use of pilot holes in advance of works and limited opening up of the works	1	5	5	1. Stop works 2. Assess progress of works and alter speed of works if necessary 3. Review natural drainage encountered 4. Impede flow from local natural pools 5. Make pumps available for dewatering pipeline trench if necessary

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7	**Localised Peat Displacement**	1. Unexpected weak ground conditions. 2. Intense rainfall event 3. Improper construction 4. Heave of adjacent areas due to compaction of backfill	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of death or injury by inundation 2. Environmental damage 3. Damage to plant 4. Loss and cessation of works 5. Damage to adjacent property	2	5	10	1. Carry out detailed site investigation 2. Walk-over survey of route to identify areas of potential failure 3. Obtain good understanding of stability of site and possible mechanism that might trigger ground movement 4. Assessment of potential for peat displacement 5. Design conservatively to eliminate all mechanisms likely to trigger movement 6. Detailed method statement to be prepared 7. All personnel to be fully cognisant with ground conditions expected 8. Provide sheet piling and shear keys as potential mitigation measures	1. Site supervision staff fully briefed on ground conditions 2. Provision and monitoring of instrumentation to record ground movement 3. Ensure control of all construction practices so that all works on site are within design conditions 4. Ongoing site inspection of site for evidence of ground movements 5. Have sheet piles and piling rig readily available. (refer to piling risks) 6. Divert streams and surface water away from problematic area 7. Provide suitably qualified person to monitor works	1	5	5	1. Stop works 2. Install sheetpiling to prevent ground movement using appropriate machinery 3. Monitor movements following installation of sheetpiles until movements have ceased 4. Reduce speed of works 5. Reduce excavation lengths prior to backfilling with stone 6. Install sheet piling ahead of works if possible as additional preventative measure
8	**Plant toppling or coming off access road/bog mats**	1. Local softer/weaker pockets below road 2. Excessive eccentric loading on supporting road/soft ground including transportation of materials	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury by fall/crushing plant 2. Damage to plant 3. Loss and cessation of works 4. Localised displacement of peat/ground	3	5	15	1. Carry out detailed site investigation along the route of the access roads to determine variability of the peat/soft ground strengths 2. Walk-over survey of route to identify areas of potential softer ground 3. Design temporary access roads/bog mats based on good working practice within the industry – e.g. proven practices within Bord na Mona 4. Allow for eccentric loading and additional width and passing and turning areas 5. Use conservative design parameters for ground 6. Detailed method statement to be prepared	1. Supervising staff and construction staff to be fully briefed on particular loading limitations and construction methodology 2. Supervision to ensure that the plant movement/loading is carried out as detailed in the method statement 3. Comprehensive and regular monitoring of road/bog mats and suitable markings showing edge of road 4. Installation of non-peat loading supported roads where appropriate	1	5	5	1. Stop works 2. Stabilise side slopes 3. Increase width of access roads where feasible 4. Use piled access roads
9	**Instability of peat arisings / turves due to failure of underlying ground**	1. Unexpected soft ground conditions 2. Over-loading of under-lying ground/peat	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of injury by collapse arisings 2. Damage to plant 3. Neighbouring ground affected 4. Loss and cessation of works	3	4	12	1. Carry out detailed site investigation along the route to determine variability of the peat/soft ground strengths 2. Walk-over survey of route to identify areas of potential softer ground 3. Use conservative design parameters for ground and peat 4. Specify areas where arisings can be placed and limits on arisings height 5. Detailed construction method statement to be prepared	1. Supervising staff and construction staff to be fully briefed on particular loading limitations and construction methodology for arisings 2. Employment of contractor/personnel familiar with soft ground conditions 3. Supervision to ensure that arisings placed as per method statement including a experienced geotech eng. 4. Comprehensive and regular monitoring of arisings 5. Supervision to ensure construction carried out as detailed in the method statement	1	4	4	1. Stop works 2. Use bog mats under arisings 3. Reduce height of arisings 4. Surplus arisings to be removed to another location 5. Local surplus of peat for backfilling to be stored in adjacent / nearby areas of the temporary working area
10	**Instability of peat arisings / turves due to excessive rainfall/run-off**	1. Excessive rainfall 2. Overly softened arisings 3. Concentration of water due to construction activities	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of injury by collapse arisings 2. Damage to plant 3. Neighbouring ground affected due to run-out and run-off into water courses 4. Loss and cessation of works	3	3	9	1. Carry out detailed site investigation along the route to determine variability of the peat/soft ground strengths 2. Walk-over survey of route to identify areas of potential softer ground 3. Use conservative design parameters for ground 4. Specify areas where arisings can be placed and limits on arisings height and geometry depending on condition of arisings 5. Shaping of arisings to shed water and placement of arisings away from any surface water sources and provide control to runoff. 6. Detailed construction method statement to be prepared	1. Supervising staff and construction staff to be fully briefed on particular loading limitations and construction methodology for arisings 2. Employment of contractor/personnel familiar with soft ground conditions 3. Supervision to ensure that arisings placed as per method statement 4. Inspection after any significant rainfall event 5. Preparation of areas if significant rainfall forecasted 6. Comprehensive and regular monitoring of arisings 7. Drainage ditches and water courses to be maintained.	1	3	3	1. Stop works 2. Reserve pumping facilities to be available 3. Revise drainage design 4. Reduce height of arisings
11	**Working in areas of soft ground/peat**	1. Unexpected soft ground conditions 2. Upper strong vegetated layer in peat has been broken 3. Plant too heavy 4. Existence of bog-holes 5. Excessive water logging due to rainfall	1. Health & Safety 2. Programme 3. Cost	1. Plant sinking or bogging in ground 2. Personnel falling into bogholes/soft ground areas. 3. Access for plant/personnel not possible	5	3	15	1. Detailed site investigation to include trial trenches to expose soils 2. Boreholes and trial pits to be taken at least below base of excavations/pipeline trench 3. Walkover, survey and map route to identify soft ground areas, bogholes, swallowholes, springs, streams (surface and subterrain) 4. Specify use of bogmats 5. Create safe working platforms (stone road) 6. Specify use of low pressure bearing machinery	1. Site supervision staff fully briefed on ground conditions. Geotechnial Engineer present. 2. Thorough induction of all personnel on working in soft ground with followup toolbox talks. 3. Employment of contractor/personnel familiar with soft ground conditions. 4. Site walkover at start of each day to inspect ground conditions and to alert construction personnel to ' potential risk' areas 5. Cordon-off of areas of weak/ soft ground that pose an unacceptable risk	2	3	6	1. Stop work 2. Assess situation 3. Deploy engineering solution to prevent ground movement 4. Monitor situation 5. Use additional stone to provide firm surface. Bogmats to be available also
12	**Flooding due to rainfall/surface water inflow into excavation**	1. Extended periods of wet weather 2. Reduced capacity of temporary pumping	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of death or injury by drowning 2. Risk of death or injury by collapse of trench side wall 3. Damage to plant 4. Excessive run-off into surface watercourses 5. Loss and cessation of works	3	5	15	1. Plan/program for high rainfall events 2. Use conservative design parameters for the design storm event 3. Detailed method statement to be prepared with respect to dewatering and protection of works	1. Supervising staff aware of weather forecasts 2. No/Restricted access into excavation 3. Pumping facilities to be put in place during the construction phase 4. Temporary bunds and drains to be installed where appropriate 5. Ensure construction carried out as detailed in the method statement 6. Agree unacceptable work conditions and/or temporarycessation of the work	2	5	10	1. Stop work 2. Assess situation 3. Deploy engineering solution to dewater 4. Monitor situation 5. Reserve / additional pumping facilities to be available
13	**Flooding due to groundwater inflow into excavation**	1. Extended periods of wet weather leading to build-up in groundwater 2. Interception of water-bearing soils 3. Unexpected ground conditions	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of death or injury by drowning 2. Risk of death or injury by collapse of excavation side wall 3. Damage to plant 4. Excessive run-off into surface watercourses 5. Loss and cessation of works	3	5	15	1. Review of previous excavations in the locality and in similar ground 2. Walkover, survey and map route to identify soft ground areas, bogholes, swallowholes, springs, streams (surface and subterrain) 3. Detailed site investigation to include trial trenches to expose soils 4. Measurement of groundwater from piezometers where possible 5. Detailed method statement to be prepared with respect to dewatering and protection of works. 6. Installation of low permeability plugs in stone road	1. No/Restricted access into excavation 2. Appropriate pumping/dewatering facilities to be put in place during the construction phase. 3. Employment of contractor/personnel familiar with soft ground conditions 4. Supervision to ensure construction carried out as detailed in the method statement	1	5	5	1. Stop work 2. Assess situation 3. Deploy engineering solution to dewater 4. Install low permeability plugs in or in close proximity to areas where there is water ingress 5. Monitor situation 6. Reserve / additional pumping facilities to be available

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14	**Failure of base of excavation (piping/heave)**	1. Unexpected weak ground conditions below excavation 2. Temporary localised head pressure present due to the elevation differences between trench and surrounding ground 3. Over-excavation in weak ground	1. Health & Safety 2. Programme 3. Cost	1. Risk of injury 2. Damage to plant 3. Excessive deformation of base of excavation 4. Settlement of surrounding ground and possible failure of excavation sides 5. Loss and cessation of works	2	5	10	1. Review of previous excavations in the locality and in similar ground 2. Detailed site investigation to include trial trenches to expose soils 3. Boreholes and trial pits to be taken below base of excavations 4. Measurement of groundwater from piezometers where possible 5. Detailed method statement to be prepared in accordance with ground conditions anticipated	1. Site supervision staff to inspect trench 2. No/Restricted access into excavation 3. Areas of heave and/or piping to be reported 4. Employment of contractor/personnel familiar with soft ground conditions 5. Engineering supervision to ensure construction carried out as detailed in the method statement 6. Limited exposure of excavation base and sides to avoid potential for failure	1	4	4	1. Stop work 2. Ballast stone to be placed at base of excavation 3. Reserve pumping facilities to be available 4. Use of settlement tanks 5. Divert water from settlement tanks into drainage channels/onto bog surface where appropriate 6. Use straw bales/terram in drainage channels
15	**Presence of sensitive clay/silt below peat**	1. Unexpected loss of strength 2. Loading/vibration/excavation	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury 2. Damage to plant 3. Loss and cessation of works 4. Collapse of excavation sides 5. Peat slide	2	5	10	1. Review of previous excavations in the locality and in similar ground 2. Detailed site investigation to include trial trenches to expose sensitive soils 3. Boreholes and trial pits to be taken below base of excavations 4. Avoidance of excessive loading and/or excessive vibration 5. Detailed method statement to be prepared in accordance with ground conditions anticipated	1. Site supervision staff to inspect trench 2. No/Restricted access into excavation 3. Employment of contractor/personnel familiar with soft ground conditions 4. Engineering supervision to ensure construction carried out as detailed in the method statement 5. Limited exposure of excavation base and sides to avoid potential for failure 6. Avoid excessive loading and/or vibration	1	5	5	1. Stop work 2. Ballast stone to be placed at base of excavation 3. Stone to be placed downslope of any potential peat movement 4. Remove excess loads 5. Avoid excessive vibrations
16	**Failure of pipeline trench support**	1. Unexpected ground conditions - weaker and deeper 2. Embedment of sheet piles not sufficient 3. Failure of trench box/shoring	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury by collapse of trench side wall 2. Damage to plant 3. Loss and cessation of works 4. Collapse of excavation sides	4	5	20	1. Detailed site investigation to include trial trenches to expose soils 2. Boreholes and trial pits to be taken below base of pipeline trench 3. Use of conservative soil parameters for temporary design 4. Conservative design of propping system, where used 5. Check of implications of over-excavation 6. Specify method statement from the Contractor on trench support	1. Site supervision staff to inspect temporary retaining structure on daily basis 2. No/Limited access into trench 3. Monitoring of sheet pile movements during construction where appropriate 4. Provision of additional temporary propping systems to be available on site during excavation phase 5. Supervision to ensure installation of support carried out as detailed in the method statement 6. Buddy system for people working in trench, never alone onsite or in the trench	1	4	4	1. Stop work 2. Install additional lateral supports 3. Use longer / larger sheet piles 4. Use stone road approach
17	**Failure of pipeline trench slopes during installation of pipe**	1. Unexpected weak ground 2. Localised slope failure 3. Water ingress 4. Plant too close to excavation 5. Slopes too steep	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury by collapse of trench side wall 2. Damage to plant 3. Loss and cessation of works	4	5	20	1. Detailed site investigation to include trial trenches to expose soils 2. Boreholes and trial pits to be taken below base of pipeline trench 3. Use of conservative soil parameters for temporary design 4. Conservative design of propping system, where used 5. Detailed method statement for the works	1. No/Restricted access into excavation 2. Employment of contractor/personnel familiar with soft ground conditions 3. Geotechnical supervision to ensure slope batter appropriate to soil conditions 4. Supervision to ensure construction is carried out as detailed in the method statement	1	4	4	1. Stop work 2. Remove failed material 3. Batter back to safe angle OR install temporary support 4. Review pipe installation procedure
18	**excavation in stone road**	1. Localised slope failure 2. Water ingress 3. Plant too close to excavation 4. Slopes too steep	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury by collapse of trench side wall 2. Damage to plant 3. Loss and cessation of works	2	5	10	1. Excavation slopes to be specified 2. Detailed method statement to be prepared to include Health and Safety requirements for open excavations 3. Use of conservative design parameters	1. Appropriate sequencing of works 2. Geotechnical supervision of works 3. Tool box talks to be carried out prior to works 4. Use shoring or trench boxes if sloped sides are not possible 5. Supervision to ensure construction carried out as detailed in the method statement	1	5	5	1. Stop work 2. Review cause of failure 3. Ensure safe distance of plant 4. Review pipe installation procedure
19	**Peat slide**	1. Unexpected weak ground conditions. 2. Intense rainfall event 3. Improper construction	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of death or injury by inundation 2. Environmental damage 3. Damage to persons, plant, property and livestock 4. Loss and cessation of works 5. Adjacent land affected due to peat/ground movement	2	5	10	1. Carry out detailed site investigation 2. Walkover survey of route to identify areas of potential failure 3. Obtain good understanding of stability of site and possible mechanism that might trigger ground movement 4. Assessment of potential for peat failure 5. Design conservatively to eliminate all mechanisms likely to trigger movement 6. Detailed method statement to be prepared	1. Site supervision staff fully briefed on ground conditions 2. Provision and monitoring of geotechnical instrumentation to record ground movement and groundwater pressures where appropriate 3. Control of all construction practices so that all works on site are within design conditions 4. Continual site inspection of site for evidence of ground movements 5. Sheet piles readily available 6. Impede surface water's access to failed area 7.Provide suitably qualified person to supervise/monitor remedial works 8. Supervision to ensure construction carried out as detailed in the method statement	1	5	5	1. Stop works 2. Use sheetpiling to stop ground movements 3. Monitor movements following installation of sheetpiles until movements have ceased 4. Reduce speed of works 5. Reduce excavation lengths prior to backfilling with stone

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Tunnelling													
20	**Subsidence/loss of ground at ground surface due to tunnelling** **Sinking/excessive settling of ground.**	1. Variable ground conditions on tunnel line with zones of weaker ground 2. Weathered rock, areas of fractured rock such as at fault/shear zones 3. Flushing out of weak material in cavities or fractures from tunnelling	1. Health & Safety 2. Programme 3. Cost	1. Subsidence at ground level 2. Risk of accident or injury 3. Damage to neighbouring property 4. Loss and cessation of works	3	4	12	1. Carry out detailed site investigation along the route to determine ground conditions particularly variable ground, zones of weaker ground 2. Walk-over of accessible parts of route to map rock exposures and general ground conditions 3. Carry out geophysical surveying and tie-in of survey with borehole information 4. In particular determine rockhead profile where tunnelling is to below/above rockhead 5. Review of detailed site investigation and re-evaluate areas of unusual ground or where highly variable 6. Produce ground model along tunnel corridor 7. Revise tunnel route to suit ground conditions and to minimise risk due to subsidence and difficult ground 8. Use of conservative design parameters for ground 9. Selection of tunnelling methodology (use of full bore sleeving pipe)	1. Supervising staff and construction staff to be fully briefed on particular ground conditions 2. Employment of contractor/personnel familiar with tunnelling in such ground conditions 3. Tunnell designers risk assessment and method statement for construction 4. Comprehensive and regular monitoring of tunnel works to provide advance notice of potential problems	1	4	4	1. Stop works 2. Assess ground movements 3. Adjust parameters of drilling fluid operating system (flow rate, composition, pressure) 4. Adjust rate of progress
21	**Unexpected obstructions in tunnel excavation e.g. hard strata, boulders, rock outcrops or man made objects**	1. Ground conditions differing from those indicated from site investigation 2. Presence of boulders/ bedrock 3. Presence of difficult to drill natural/man-made object	1. Programme 2. Cost	1. Delay due to reduced tunnelling rate 2. Possible cost of surface recovery of tunnel machine 3. Cost of excessive wear on tunnel cutters 4. Cost due to reduced tunnelling	2	4	8	1. Carry out detailed site investigation along the route to determine ground conditions particularly variable ground, zones of weaker ground 2. Walk-over of accessible parts of route to map rock exposures and general ground conditions 3. Carry out geophysical surveying and tie-in of survey with borehole information 4. In particular determine rockhead profile where tunnelling is below/above rockhead 5. Review of detailed site investigation and re-evaluate areas of unusual ground or where highly variable 6. Produce ground model along tunnel corridor 7. Revise tunnel route to suit ground conditions and to minimise risk due to subsidence and difficult ground 8. Use of conservative design parameters for ground 9. Conservative tunnel performance specification to allow for possibility of hard obstructions 10. Conservative tunnel performance specification based on ground model to allow for durable and robust tunnel boring machine and reserve critical plant	1. Supervising staff and construction staff to be fully briefed on particular ground conditions 2. Employment of contractor/personnel familiar with tunnelling in such ground conditions 3. Detailed method statement and specific tunnel risk assessment 4. Comprehensive and regular monitoring of tunnel works to provide advance notice of potential problems 5. Check cutting returns, type, shape, mass balances 6. Check data collected by instrumentation in TBM (pressure, flow, temp, video, torque of cutting wheel, speed etc) 7. Check data collected from the thruster/jacking station 8. Check thrust force versus geology and profile 9. Check if rotational direction of cutting wheel can be changed. 10. Man entry for inspection or repair of TBM 11. Man entry in front of the TBM 12. Man entry to break an obstacle 13. External access / intervention pit	1	4	4	1. Attempt to be undertaken to fix/secure/break the object from within the TBM or from outside, then to drill through the obstacle. 2. Change teeth in cutting head (potentially from within Sleeve Pipe) 3. Develop pipe entry procedures for removal of obstruction from inside installed sleeving pipe 4. Pull back pipe string and adjust trajectory. 5. If all remedial options do not work, consider removal of obstruction from surface (intervention pit within inter-tidal area). 6. Construct additional pits in inter-tidal area / extend pit to complete crossing in open cut
22	**Loss of bentonite slurry from tunnel face due to unexpected variable ground conditions** **Bentonite escaping through fissures/openings at bore depth**	1. Ground conditions differing from those indicated from site investigation 2. Zones of higher permeability soils	1. Environmental 2. Programme 3. Cost	1. Delay due to reduced tunnelling rate 2. Excessive leakage of bentonite into ground with possible environmental concerns 3. Cost of excessive wear on tunnel cutters 4. Cost due to reduced tunnelling rate 5. Cost of clean up due to bentonite breakout	2	5	10	1. Carry out detailed site investigation along the route to determine ground conditions particularly variable ground, zones of weaker ground 2. Walk-over of accessible parts of route to map rock exposures and general ground conditions 3. Carry out geophysical surveying and tie-in of survey with borehole information 4. In particular determine rockhead profile where tunnelling is below/above rockhead 5. Review of detailed site investigation and re-evaluate areas of unusual ground or where highly variable 6. Produce ground model along tunnel corridor 7. Revise tunnel route to suit ground conditions and to minimise risk due to subsidence and difficult ground 8. Use of conservative design parameters for ground 9. Conservative tunnel performance specification to allow for possibility of loss in bentonite/alternative face support	1. Monitor bentonite mass balance (2 circuits; to support cutting face and reduce friction) 2. Monitor bentonite system operating pressures 3. Modify bentonite composition 4. Surface inspection/monitoring 5. Alter drilling fluid	1	5	5	1. Stop work 2. Adjust bentonite mix 3. Adjust trajectory 4. Develop fall back construction method, sheetpiling in sections, surface excavation
23	**Slow or no drilling progress**	1. Worn Cutting elements	1. Programme 2. Cost	1. Delay due to reduced tunnelling rate 2. Possible cost of surface recovery of tunnel machine 3. Cost of excessive wear on tunnel cutters 4. Cost due to reduced tunnelling	3	3	9	1. Carry out detailed site investigation along the route to determine ground conditions particularly variable ground, zones of weaker ground 2. Walk-over of accessible parts of route to map rock exposures and general ground conditions 3. Carry out geophysical surveying and tie-in of survey with borehole information 4. In particular determine rockhead profile where tunnelling is below/above rockhead 5. Review of detailed site investigation and re-evaluate areas of unusual ground or where highly variable 6. Produce ground model along tunnel corridor 7. Revise tunnel route to suit ground conditions and to minimise risk due to subsidence and difficult ground 8. Use of conservative design parameters for ground 9. Conservative tunnel performance specification to allow for durable and robust tunnel boring machine and reserve critical plant	1. Check cutting returns, type, shape, mass balances on continuous basis 2. Check data collected by instrumentation in TBM (pressure, flow, temp, video, torque of cutting wheel, speed etc) 3. Check data collected from the thruster/jacking station 4. Check thrust force records versus geology and profile on continuous basis 5. Pull back of a steel pipe string to launch pit 6. Man entry for inspection or repair of TBM 7. Man entry for replacement cutting elements in shield	2	3	6	1. Withdraw TBM with pipe string (steel pipe string) to replace the key cutting tools in shield. 2. Check if man entry for replacement cutting elements in shield is feasible

Corrib Onshore Pipeline

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			Category	Specific	P	I	R	Design Control	Construction Control	P	I	R	
24	**Unexpected variable ground conditions (hard/soft) in tunnel excavations**	1. Unexpected change in geology / ground conditions 2. Ground conditions differing from those indicated from site investigation 3. Combination of alternating hard/soft ground conditions 4. Variable weathered rock conditions	1. Programme 2. Cost	1. Delay due to reduced tunnelling rate 2. Possible cost of surface recovery of tunnel machine 3. Cost of excessive wear on tunnel cutters 4. Cost due to reduced tunnelling rate	3	2	6	1. Carry out detailed site investigation along the route to determine ground conditions particularly variable ground, zones of weaker ground 2. Walk-over of accessible parts of route to map rock exposures and general ground conditions 3. Carry out geophysical surveying and tie-in of survey with borehole information 4. In particular determine rockhead profile where tunnelling is below/above rockhead 5. Review of detailed site investigation and re-evaluate areas of unusual ground or where highly variable 6. Produce ground model along tunnel corridor 7. Revise tunnel route to suit ground conditions and to minimise risk due to subsidence and difficult ground 8. Use of conservative design parameters for ground 9. Conservative tunnel performance specification based on ground model to allow for durable and robust tunnel boring machine and reserve critical plant	1. Supervising staff and construction staff to be fully briefed on particular ground conditions 2. Employment of contractor/personnel familiar with tunnelling in such ground conditions 3. Detailed method statement and specific tunnel risk assessment 4. Comprehensive and regular monitoring of tunnel works to provide advance notice of potential problems 5. Check on continuous basis cutting returns, type, shape, mass balances 6. Check data collected by instrumentation in TBM (pressure, flow, temp, video, torque of cutting wheel, speed etc) 7. Check position/positioning system (do we follow the design trajectory/alignment) 8. Check data collected from the thruster/jacking station 9. Check thrust force records versus geology and profile on continuous basis 10. Drilling progress 11. Man entry for inspection or repair of TBM (consider airlock)	1	2	2	1. Pull back cutter head 2. Intervention pit within inter-tidal area 3. Sheetpiling in sections / surface excavation 4. Extend tunnel in open cut
25	**Mechanical System Failure (bentonite handling)**	1. Failure of the bentonite injection	1. Programme 2. Cost	1. Delay due to reduced tunnelling rate 2. Possible cost of surface recovery of tunnel machine 3. Cost of repairs to bentonite handling system 4. Cost due to reduced tunnelling rate	2	3	6	1. Appoint experienced contractor with fit for purpose plant and equipment 2. Pre-construction system checks to be outlined.	1. Check bentonite generation at plant 2. Check cutting returns, type, shape, mass balances 3. Check data collected by instrumentation in TBM (pressure, flow, temp, video, torque of cutting wheel, speed etc) 4. Entry of sleeving pipe/concrete jacking pipe for inspection 5. Survey route/bay for potential loss of drilling fluid	1	3	3	1. Repair mechanical components in-situ if possible 2. Remove and repair mechanical components. 3. Replace mechanical components where necessary 4. Tools, equipment, parts and necessary skilled operatives to be available to deal with mechanical problems with bentonite handling system.
26	**Unexpected high thrust force**	1. Change geology 2. Worn out cutting tools 3. Failure of the bentonite system	1. Health & Safety 2. Programme 3. Cost	1. Risk to personnel and equipment from possible failures 2. Loss and cessation of works 3. Delay due to reduced tunnelling rate 4. Cost of excessive wear on plant, machinery and tunnel cutters 5. Cost due to reduced tunnelling rate	2	3	6	1. Carry out detailed site investigation at site of thruster location along the route to determine ground conditions particularly variable ground, zones of weaker ground 2. Walk-over of accessible parts of route to map rock exposures and general ground conditions 3. Review of detailed site investigation (determined based on preferred tunnel route) 4. Use of conservative design parameters for ground	1. Check cutting returns, type, shape, mass balances 2. Check data collected from the thruster/jacking station 3. Check thrust force versus geology and profile 4. Man entry for inspection or repair of TBM 5. Man entry in front of the TBM 6. Man entry to break an obstacle 7. External access / intervention pit 8.Check possibility to run cutting wheel in opposite direction	1	3	3	1. Stop work 2. Reduce thrust 3. Reduce rate of progress 4. Use Intermittent jacking stations. 5. Increase use of/ number of foreseen and planned bentonite injection points into annulus.
27	**Failure of Pipe Thruster/jacking station (Mechanical)**	1. Wear and tear. 2. Human error, design errors, 3rd party interference etc.	1. Health & Safety 2. Programme 3. Cost	1. Risk to personnel and equipment from unstable ground following failure 2. Loss and cessation of works 3. Delay due to reduced tunnelling rate 4. Cost due to reduced tunnelling rate 5. Cost of repairs to thruster / jacking station	2	4	8	1. Carry out detailed site investigation at thruster location to determine ground conditions particularly variable ground, zones of weaker ground 2. Use of conservative design parameters for thruster unit 3. Independent design & procedure verification by specialist	1. Carry out load test and check safety devices 2. Check data collected from the thruster/jacking station 3. Check thrust force versus geology and profile 4. Security and adequate fencing	1	5	5	1. Availability of spare parts on site (including spare hydraulic cylinder) 2. High level of expertise on site (Herrenknecht technicians) 3. Possibly spare thruster /jacking station
28	**Pipe thruster /jacking station foundation damage / failure/ Water logging.**	1. Design error (wrong interpretation of geotechnical data) 2. Greater than expected thrust from equipment during tunnelling 3. Construction error 4. Failure of anchors 5. Unexpected zone of weak ground within influence of anchors	1. Health & Safety 2. Programme 3. Cost	1. Risk to personnel and equipment from unstable ground following failure / flooding 2. Loss and cessation of works 3. Delay due to reduced tunnelling rate 4. Cost due to reduced tunnelling rate 5. Cost of repairs to thruster / jacking station	3	4	12	1. Carry out detailed site investigation at site of thruster location along the route to determine ground conditions particularly variable ground, zones of weaker ground conditions 3. In particular determine rockhead profile and rock condition where anchors/support piles to be located in rock 4. Review of detailed site investigation (determined based on preferred tunnel route) 5. Produce ground model at thruster site 6. Use of conservative design parameters for ground 7. Independent design verification 8. Capable contractor with proven track record in complex foundation construction 9. Load testing of piles 10. Outstanding geotech boreholes at entrance pits essential	1. Check data collected from the thruster/jacking station 2. Check thrust force versus geology and profile 3. Supervising staff and construction staff to be fully briefed on particular ground conditions 4. Employment of contractor/personnel familiar with tunnelling in such ground conditions 5. Detailed method statement and specific tunnel risk assessment notice of potential problems 7. Pumping of water from pit. 8. Carry out load test	1	4	4	1. Stop work 2. Reduce thrust 3. Reduce rate of progress 4. Install additional anchor supports 5. Establish alternative drilling location.
29	**TBM runs off the design alignment. Vertical and or horizontal**	1. Unforeseen ground conditions 2. Steering fault	1. Environmental 2. Programme 3. Cost	1. Loss and cessation of works 2. Delay due to reduced tunnelling rate 3. Cost due to reduced tunnelling rate 4. TBM breaks surface with consequent environmental impact. 5. Deviation towards unknown ground conditions	2	4	8	1. Carry out detailed site investigation along the route to determine ground conditions particularly variable ground, zones of weaker ground conditions 3. Carry out geophysical surveying and tie-in of survey with borehole information 4. In particular determine rockhead profile where tunnelling is below/above rockhead 5. Review of detailed site investigation and re-evaluate areas of unusual ground or where highly variable 6. Produce ground model along tunnel corridor 7. Revise tunnel route to suit ground conditions and to minimise risk due to subsidence and difficult ground 8. Use of conservative design parameters for ground 9. Conservative tunnel performance specification to allow for durable and robust tunnel boring machine and reserve critical plant	1. Check cutting returns, type, shape, mass balances 2. Check data collected by instrumentation in TBM (pressure, flow, temp, video, torque of cutting wheel, speed etc) 3. Check position/positioning system (do we follow the design trajectory/alignment) 4. Check thrust force versus geology and profile	1	4	4	1. Detailed geological cross section together with further geological information to be collected. 2. Check possible pull back for a steel pipe string for a new trajectory through detailed steering of a new trajectory with finer spaced data collection positioning of the pipe string and TBM.

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			Category	Specific	P	I	R	Design Control	Construction Control	P	I	R	
30	**TBM and or Pipe Thruster are too weak to cope with the ground conditions**	1. TBM runs off the design alignment, vertical and or horizontal. 2. Too long stretch in unstable geological strata due to not sufficient geological data. 3. Steering fault	1. Environmental 2. Programme 3. Cost	1. Loss and cessation of works 2. Delay due to reduced tunnelling rate 3. Cost due to reduced tunnelling rate 4. Cost of mobilising higher specification equipment 5. TBM breaks surface with consequent environmental impact.	2	5	10	1. Carry out detailed site investigation along the route to determine ground conditions particularly variable ground, zones of weaker ground 2. Walk-over of accessible parts of route to map rock exposures and general ground conditions 3. Carry out geophysical surveying and tie-in of survey with borehole information 4. In particular determine rockhead profile where tunnelling is below/above rockhead 5. Review of detailed site investigation and re-evaluate areas of unusual ground or where highly variable 6. Produce ground model along tunnel corridor 7. Revise tunnel route to suit ground conditions and to minimise risk due to subsidence and difficult ground 8. Use of conservative design parameters for ground 9. Conservative tunnel performance specification to allow for durable and robust tunnel boring machine and reserve critical plant	1. Check cutting returns, type, shape, mass balances 2. Check data collected by instrumentation in TBM (pressure, flow, temp, video, torque of cutting wheel, speed etc) 3. Check position/positioning system (do we follow the design trajectory/alignment) 4. Check thrust force versus geology and profile	1	5	5	1. Detailed geological cross section together with further geological information to be collected. 2. Check possibility of pull back for a steel pipe string for a new trajectory through detailed steering 3. Use foreseen and planned intermediate jacking stations. 4. Use of foreseen and planned number of bentonite injection points into annulus. 5. Use possible additional spare Pipe Thruster/jacking station
31	**High friction when pulling back steel string or no progress**	1. Collapse of hole on top of pipe causing high friction. 2. Accumulation of debris behind TBM in the annulus when pilling back steel pipe 3. Management of bentonite (backfilling)	1. Environmental 2. Programme 3. Cost	1. Subsidence in surface of crossing 2. Potential for escape of bentonite 3. Remediation works may be required	3	3	9	1. Design of bentonite handling system by experienced personnel 2. Carry out detailed site investigation along the route to determine ground conditions particularly variable ground, zones of weaker ground 3. Carry out geophysical surveying and tie-in of survey with borehole information 4. Review of detailed site investigation and re-evaluate areas of unusual ground or where highly variable 5. Produce ground model along tunnel corridor 6. Revise tunnel route to suit ground conditions and to minimise risk due to subsidence and difficult ground 7. Use of conservative design parameters for ground 8. Conservative tunnel performance specification to allow for durable and robust tunnel boring machine and reserve critical plant	1. Check cutting returns, type, shape, mass balances 2. Check data collected from the thruster/jacking station 3. Foreseen and planned intermediate bentonite injection 4. Bentonite injection in front of shield 5. Foreseen and planned intermediate jacking stations	1	3	3	1. Possible bentonite injection (high pressure jetting) at the back of the TBM into the anulus. 2. Injection of bentonite in front of shield to create additional push force against the shield. 3. Use planned and foreseen intermediate jacking stations to pull back. 4. Use possible spare Pipe Thruster /jacking station. 5. Construct Intervention pit in inter-tidal area 6. Construct additional pits in inter-tidal area 7. Extend pit to complete crossing in open cut 8. Use TBM and sleeving pipe of same diameter
32	**Failure of TBM equipment**	1. Adverse ground conditions causing excessive mechanical wear 2. Mechanical/electrical break-down	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Delay due to repairs 2. Possible cost of surface recovery of tunnel machine 3. Cost due to repairs	2	5	10	1. Carry out detailed site investigation along the route to determine ground conditions particularly variable ground, zones of weaker ground 2. Walk-over of accessible parts of route to map rock exposures and general ground conditions 3. Carry out geophysical surveying and tie-in of survey with borehole information 4. In particular determine rockhead profile where tunnelling is below/above rockhead 5. Review of detailed site investigation and re-evaluate areas of unusual ground or where highly variable 6. Produce ground model along tunnel corridor 7. Revise tunnel route to suit ground conditions and to minimise risk due to subsidence and difficult ground 8. Use of conservative design parameters for ground 9. Conservative tunnel performance specification to allow for durable and robust tunnel boring machine and reserve critical plant	1. Supervising staff and construction staff to be fully briefed on particular ground conditions 2. Employment of contractor/personnel familiar with tunnelling in similar ground conditions. Herrenknecht technicians to be present on-site. 3. Detailed method statement and specific tunnelling risk assessment 4. Comprehensive and regular monitoring of tunnel works to provide advance notice of potential problems *5*. Check cutting returns, type, shape, mass balances 6. Check data collected by instrumentation in TBM (pressure, flow, temp, video, torque of cutting wheel, speed etc) 7. Check thrust force versus geology and profile 8. Drilling progress 9. Man entry for inspection or repair of TBM	1	5	5	1. Pull back cutter head 2. Removal of cutter head from surface (intervention pit within inter-tidal area) 3. Develop pipe entry procedures for repair of TBM (permit to work system to be in place) 4. Inventory of spare parts to be present on-site 5. Construct additional pits in inter-tidal area 6. Extend pit to complete crossing in open cut

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			Category	Specific	P	I	R	Design Control	Construction Control	P	I	R	
Temporary Works													
33	**Failure of bog mat access road**	1. Overloading of the underlying soft peat soils. 2. Insufficient understanding of the variability of the strength within the peat. 3.Localised softer/weaker pockets within the peat. 4. incorrect use of bog mats and bog mat road	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury by fall/crushing plant. 2. Damage to plant 3. Loss and cessation of works	3	5	15	1. Carry out detailed site investigation along the route of the access road to determine variability of the peat/soft ground strengths 2. Walkover survey of route to identify areas of potential softer ground 3. Determine areas suitable for bog mats 4. Require contractor to provide detailed construction method statement 5. Undertake supervision and monitoring regime on site works	1. Supervising staff and construction staff to be fully briefed on the ground conditions, temporary works design requirements (in particular loading limitations) and construction methodology 2. Supervision to ensure that the construction is carried out as detailed in the method statement 3. Comprehensive and regular monitoring and comparison of predicted ground behaviour with observed ground behaviour 4. Inspection after significant rainfall event 5. Preparation of areas if significant rainfall forecasted	1	5	5	1. Stop works 2. Use additional bog mats. 3. Install stone road
34	**Failure of granular stone/geogrid reinforced access road**	1. Overloading of the underlying soft peat soils. of the strength within the peat. 3.Local softer/weaker pockets of underlying material 4. incorrect installation of geogrids	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury by fall/crushing plant 2. Damage to plant 3. Loss of works	3	5	15	1. Carry out detailed site investigation along the route of the proposed road to determine variability of the peat/soft ground strengths 2. Walkover survey of route to identify areas of potential softer ground 3. Design temporary access roads based on good working practice within the industry – e.g. proven practices within Bord na Móna 4. Determine areas suitable for temporary access roads 5. Require contractor to provide detailed construction method statement 6.Undertake supervision and monitoring regime on all site works.	1. Supervising staff and construction staff to be fully briefed on the ground conditions, design requirements (in particular loading limitations) and construction methodology 2. Supervision to ensure that the construction is carried out as detailed in the method statement 3. Comprehensive and regular monitoring and comparison of observations with predicted ground behaviour. 4. Inspection after significant rainfall event 5. Preparation of areas if significant rainfall forecasted	1	5	5	1. Stop works 2. Install stone road/bog mats 3. Install stone road
35	**Installation of temporary sheet piles**	1. Unexpected ground conditions. 2. Slope angle steeper than expected 3. Excessive groundwater inflow 4. Declutching of sheets	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of injury during installation 2. Damage to plant 3. Change of hydrology 4. Loss and cessation of works	2	4	8	1. Carry out detailed site investigation along the route of the proposed road 2. Walkover survey of route 3. Appropriate pile type to be selected 4. Detailed method statement to be prepared for sheet pile installation 5. Hydrology of area to be considered during sheet pile design	1. Installation of sheet piles to be supervised by appropriately experienced personnel 2. Use appropriate equipment and sheets 3. Installation to be carried out by competent contractor 4. Installation to be stand-alone task and should not interfere with other works 5. Supervision to ensure construction carried out as detailed in the method statement	1	4	4	1. Stop works 2. Record and report problem 3. Install stone road where appropriate
36	**Failure of temporary sheet piles**	1. Unexpected soft ground conditions. 2. Excessive groundwater inflow 3. Mechanical failure of pile 4. Insufficient embedment depth	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of injury or death by failure of piles or associated ground movement 2. Damage to plant movement 4. Trigger major slide with damage to property, persons, livestock	3	5	15	1. Carry out detailed site investigation along the route 2. Walkover survey of route 3. Undertake test pile to determine suitability of installation 4. Monitoring of installation 5. Detailed method statement to be prepared	1. Competent person to install piles with suitable equipment 2. Piles damaged during installation to be replaced. 3. Provide adequate working platform (refer to bog mat risks) 4. Regular inspection and monitoring of piles and supported ground/peat. 5. Drainage ditches and water courses to be monitored and maintained. 6. Supervision to ensure construction carried out as detailed in the method statement	1	5	5	1. Stop works 2. Record and report problem 3. Install stone road
37	**Recovery of plant and equipment**	1. Plant stuck in bogholes 2. Plant sliding off haul roads or bog mats 3. Plant caught in displaced peat 4. Localised slip failure of stone road	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of injury or death to personnel 2. Damage or loss of plant 3. Spillage of fuel and oil	3	5	15	1. Working area extents to be pegged 2. Use of appropriate plant 3. Design to consider abnormal loading 4. Detailed method statement to be prepared for the works 5. Temporary recovery access to be designed specifically for recovery works	1. Spill kits around plant and involvement of environmental expert to ensure containment of spillages 2. Removal of potential and actual contaminants as required. 3. Develop clear plan of action prior to recovery operation 4. Works supervised by experienced personnel 5. Use of correct lifting equipment, slings and recovery/winch cables 6. Damaged plant to be removed to safe area 7. Supervision to ensure recovery carried out as detailed in the method statement	1	5	5	1. Stop works 2. Use alternative plant for works 3. Increase width of access roads where feasible and appropriate

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In Operation													
38	**Corrosion of pipe due to aggressive ground conditions**	1. Insufficient understanding of corrosion mechanism 2. Inadequate site investigation information 3. Inadequate design.	1. Health & Safety 2. Environmental 3. Cost	1. Potential leakage from pipe with risk of injury or death and damage to property 2. Damage to facility 3. Cost due to shut-down and repair	2	5	10	1. Carry out detailed site investigation along the route to determine ground conditions particularly chemical testing of ground aggressivity, electrical resistivity 2. Provide results of chemical testing to pipeline designers 3. Robust pipeline specification - by pipeline designers	1. Carry out detailed site investigation along the route to determine ground conditions/aggressivity. 2 Check performance of CP system after commissioning	1	5	5	1. Cathodic protection measures to be explored.
39	**Settlement/soft ground in pipe trench backfill**	1. Poorly compacted backfill 2. Inadequate backfilling 3. Inadequate soil strength at base of trench	1. Health & Safety 2. Cost	1. Risk of injury by tripping/ bogging of plant 2. Damage to farm plant and land 3. Surface depressions manifested	3	4	12	1. Consider alternatives for the backfilling of the trench (introduction of brushwood, geogrid) that will not alter the hydrogeology of that area of the site long term 2. Highlight on drawings the need to cordon off the trench post construction and also the need to provide discrete crossing points for plant and personnel to facilitate safe movement around the site 3. Detailed method statement to be prepared 4. Mounding of backfill where appropriate to accomodate subsequent consolidation 5. Determine likely time for backfill to consolidate and ground to become stable 6. Specify re-inspection of re-instated areas and follow-up work as necessary	1. Supervision staff to be fully briefed on the ground conditions, design requirements and construction methodology 2. Cordon off of areas of weak/soft ground 3. Supervision to ensure reinstatement/backfilling carried out as detailed in the method statement 4. Re-inspection of reinstated areas post consolidation period	1	4	4	1. Dig out material around pipe and replace and recompact 2. Import approved material to re-grade if necessary
40	**Erosion of overburden cover to buried pipe in river/stream crossings (eg 2003 rainfall event)**	1. Intense rainfall and associated run-off conditions 2. Over-digging during ditch clearance	1. Health & Safety 2 Environmental 3. Cost	1. Potential leakage from pipe with risk of injury or death and damage to property 2. Damage to facility 3. Cost due to shut-down and repair	2	5	10	1. Specify as-built records to provide details of actual level/line of pipe in ground 2. Walk-over survey to identify river/stream crossings and depth of alluvial sediments 3. Adequate protection measures/ burial depths identified based on conservative values 4. Burial depth to consider significant stream bed erosion due to extreme rainfall events 5. Detailed method statement to be prepared 6. Specification for robust pipeline wall - by pipeline designers 7. Installation of concrete slabs above pipeline where the bottom of the drain/ditch may be lowered (as per IS 328)	1. Supervision staff to be fully briefed on the ground conditions, design requirements and construction methodology 2. Supervision to ensure construction carried out as detailed in the method statement 3. Control of line and level of pipe in ground	1	5	5	1. Divert river/stream 2. Backfill and strengthen backfill material 3. Increase depth of concrete slab above pipeline
41	**Erosion of seaward cliff at landfall facility**	1. Unexpected storm conditions 2. Unexpected freak wave	1. Health & Safety 2 Environmental 3. Cost	1. Coastal erosion and loss of natural environment 2. Potential injury due to falling material	3	4	12	1. Walk-over of cliff line to identify extent of erosion and soils/rock within cliff 2. Use of conservative design parameters for design of sea cliff 3. Use of conservative erosion/wave action 4. Re-instated sea cliff to be robust and also to be sympathetic to existing natural cliffs 5. Detailed construction method statement to be prepared	1. Site supervision staff fully briefed on ground conditions and tidal working 2. Re-use of acceptable as-dug materials to re-construct cliff is sympathetic to existing sea cliffs 4. Regular inspections of the cliff face (especially after storms)	1	4	4	1. Place erosion control measure on cliff e.g. rip-rap
42	**Peat slide**	1. Unexpected weak ground conditions. 2. Intense rainfall event 3. Peat movement from outside site	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of death or injury by inundation 2. Environmental damage 3. Damage to plant 4. Cost due to shut-down and repair	2	5	10	1. Carry out detailed site investigation 2. Walk-over survey of route to identify areas of potential failure 3. Obtain good understanding of stability of site and possible mechanism that might trigger ground movement 4. Assessment of potential for peat failure 5. Design conservatively to eliminate all mechanisms likely to trigger movement 6. Carry out sensitivity test to show performance of pipe with different failure scenarios 7. Specify robust pipe construction 8. Assess stability of stone road under flooded conditions	1. Maintenance requirement to include regular walkover inspection of pipeline route 2. Walkover inspection to be carried out by suitably qualified persons 3. Report of walkover inspection to determine existing stability of peat and any works required and to recommend time period for next walkover 4. Long term monitoring using GPS plates if possible	1	5	5	1. Install sheetpiling to stop ground movements 2. Monitor movements following installation of sheetpiles 3. Maintain drains and ditches locally
43	**Striking and damaging of buried pipe (following completion) by others**	1. Insufficient burial depth 2. Reduction in overburden cover with time due to erosion/ inadvertent removal/ settlement 3. Pipe placed too high	1. Health & Safety 2 Environmental 3. Cost	1. Potential leakage from pipe with risk of injury or death and damage to property 2. Damage to facility 3. Cost due to shut-down and repair	2	5	10	1. Specify as-built records to providing details of actual level/line of pipe in ground 2. Walkover/review to identify areas along route where there is any potential for disturbance of ground over pipe (peat cuttings, excavation, stream beds, tidal scour) 3. Adequate protection measures/burial depths are identified in areas of potential ground disturbance 4. Detailed method statement to be prepared, including sequence of excavation, storage and backfilling (separate layers) 5. Use of appropriate signage	1. Supervision staff to be fully briefed on the ground conditions, design requirements and construction methodology 2. Supervision to ensure re-instatement/backfilling carried out as detailed in the method statement 3. Detailed and accurate as-built records to be generated during construction and furnished for maintenance file 4. Ensure the trench is deep enough and pipeline is installed at correct depth 5. Installation of Marker Tape (approximately 300mm above buried pipeline)	1	5	5	1. Shut off supply of gas to pipe 2. Repair pipe in accordance with relevant codes and standards 3. Install protective cover and increase signage where appropriate to prevent recurrence
44	**Creep movement/ settlement of pipe due to movement of soil**	1. Insufficient understanding deformation properties of surrounding soil 2. Inadequate site investigation information 3. Inadequate design.	1. Health & Safety 2 Environmental 3. Cost	1. Damage to facility 2. Potential leakage from pipe with risk of injury or death and damage to property	2	5	10	1. Detailed site investigation to include trial trenches to expose and record soils 2. Boreholes and trial pits to be taken below base of pipeline trench 3. Pipeline designers to include for potential creep movement 4. Pipeline to be laid onto competent bedding 5. Tolerances for movement to be specified 6. Detailed method statement to be prepared	1. Site supervision staff fully briefed on ground conditions 2. Employment of contractor/personnel familiar with soft ground conditions 5. Long term monitoring using GPS plates if possible	1	5	5	1. Install measures to prevent excess movements e.g. sheetpiles/extend stone road