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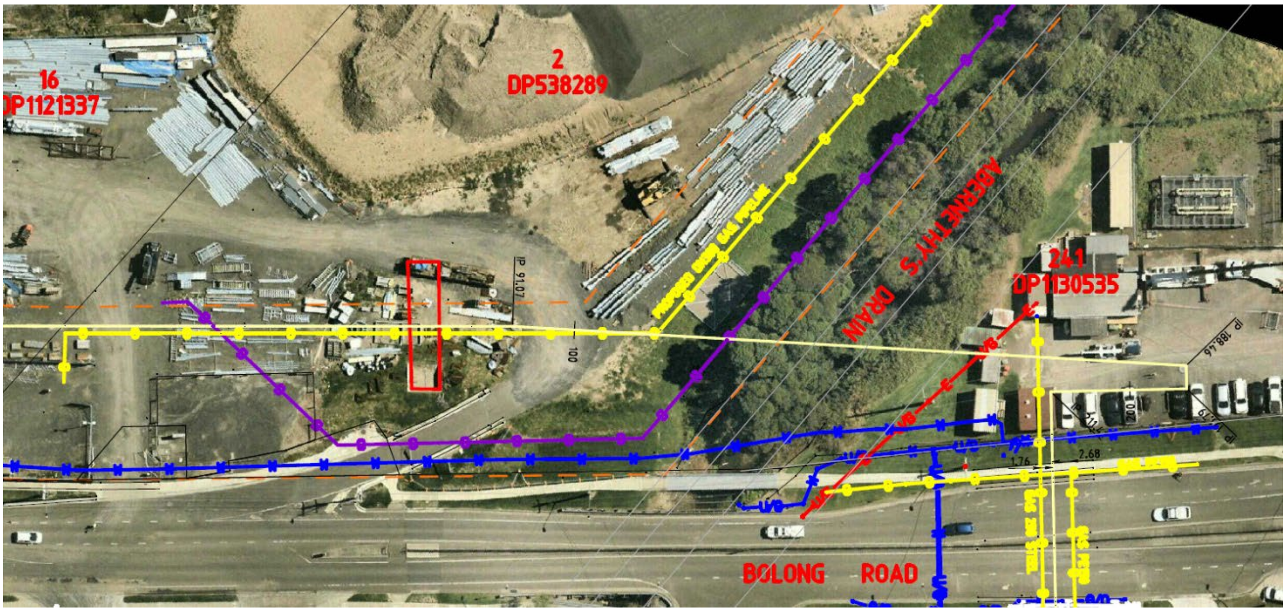
SHOALHAVEN STARCHES PTY LTD
NATURAL GAS PIPELINE AND PRESSURE REDUCTION STATIONS –
SHOALHAVEN STARCHES BOMADERRY



ABERNETHYS CREEK CROSSING – LP GAS PIPELINE – MOD 2

Work Method Statement

Document No.		NAP-SS-WMS-08		
Revision:	**Date:**	**Prepared**	**Checked**	**Approved**
Rev A	25/02/22	Mukesh Bhatia	Ajay Kesavan	Martin Moran

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1.1 INTRODUCTION

The purpose of this method statement is to provide specific instruction for the following work scope to ensure the works are adequately planned and delivered in accordance with Construction Specifications.

1.2 SCOPE

The scope of work applicable to this method statement is associated with

A) Installation of the gas pipeline under the creek/waterways by way of Horizontal Directional Drilling (HDD) as part of the Shoalhaven Starches – Natural Gas Pipeline and Pressure Reduction Stations Project.

There is a requirement to install the gas pipeline under the following creeks and waterways.

1. Abernethys Creek – Image 1

1.3 ABREVIATIONS AND DEFINITIONS

ALARP	As Low As Reasonable Practical
Checklist	A document that records or defines the actions that must be undertaken for a given task.
CEMP	Construction Environmental Management Plan
DBYD	Dial Before You Dig 1100
Hazard	Any operation or task that places personnel or equipment at risk to death, injury and or damage
HDD	Horizontal Directional Drilling
JSEA	Job Safety Environmental Analysis
NCR	Non-Conformance Report
OH&S	Occupational Health and Safety
PPE	Personal Protective Equipment
ROW	Right of Way
NAP	National Australia Pipeline Pty Ltd
Supervisor	The responsible person who oversees, or directs control of works being undertaken during the construction of the pipeline

1.4 REFERENCES

1. Project Approval (MP10_018 MOD1) SHOALHAVEN STARCHES GAS PIPELINE PROJECT - INCREASE IN PIPELINE DIAMETER AND ASSOCIATED WORKS.
2. Shoalhaven Starches Natural Gas Pipeline IFC drawings
3. Shoalhaven Starches Natural Gas Pipeline Construction Environmental Management Plan (CEMP)
4. Shoalhaven Starches Natural Gas Pipeline Construction Safety Management Plan (CSMP)
5. ESCP – APA Ref 24710
6. Geotechnical Investigation Report

1.5 PERMITS

The following approvals/permits need to be in place before commencement of site works.

1. Awaiting - Development Application Approval for Mod 2
2. NRAR Creek/Waterway Crossing Approval
3. DPIE Approval

2.0 RESPONSIBILITIES

The Project Management Team – Project Manager, Engineer, Construction Supervisor and HSE Officer – shall ensure that all project staff are adequately skilled to perform their assigned tasks and are aware of their obligations and responsibilities with regards to OH&S, Environmental Management, Quality Assurance, Industrial Relations and Administrative Functions.

The Crew Supervisor shall be responsible for the coordination of the personnel, equipment, and materials to complete the works in accordance with the relevant specifications.

2.1 JOB DESCRIPTIONS

All site personnel will have a formal job description. Detailed job descriptions for personnel have been developed and approved by the Project Manager. Please refer to the Project Execution Plan for detailed job descriptions.

To ensure that the Project is managed in accordance with the requirements of the Project and that of the contract the following key personnel have the following responsibilities.

3.0 HAZARD IDENTIFICATION AND RISK MANAGEMENT

The NAP shall, so far as reasonably practicable, ensure that any manager or supervisor is provided with such information, instruction, and training as are necessary to ensure that each employee under their management or supervision is, while at work, so far as is reasonably practicable, safe from injury and risks to health.

All personnel must be committed to achieving a safe working environment and strive to fulfill the objectives of the Project Health, Safety and Environment policy with compliance to the Safety Management Plan and the Environmental Management Plan.

3.1 MANAGEMENT CONTROLS

3.1.1 Risk Assessment

A full project risk assessment has been undertaken and the mitigation measures identified in this have been incorporated into this Work Method Statement. A JSEA will be produced by carrying out a risk assessment on this Work Method Statement and incorporating input from work crews. Each Crew member will be required to review this JSEA.

3.1.2 JSEA

The base JSEA shall be developed with input from the Project Manager, Construction Manager and HSE Advisor. The JSEA shall be reviewed and added to, as required by each crew, utilizing their experience in conducting the task. All crew personnel are to review and sign onto the JSEA before work begins.

3.1.3 Pre-Start

Supervisors shall ensure that meetings are held prior to starting each shift, and/or whenever the work scope changes. The meetings should:

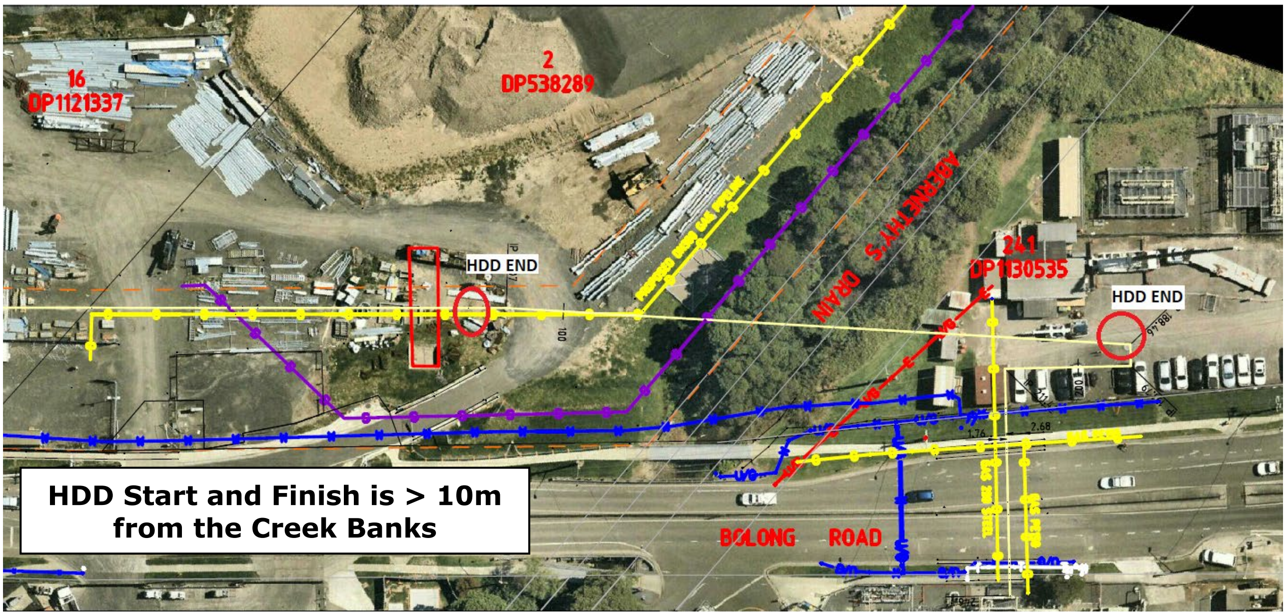
- Review the state of the works as left by the previous shift
- The target progress for the current shift
- The means of achieving the target progress
- The state of works required at the end of the shift
- Any additional safety hazards (changing conditions as work progresses)
- Any environmental hazards

3.1.4 Tool Box Meeting

Tool box meetings shall be held at regular intervals. The tool box meetings will be used to relay information such as hazard alerts between crews and make all crews aware of larger issues and general hazards.

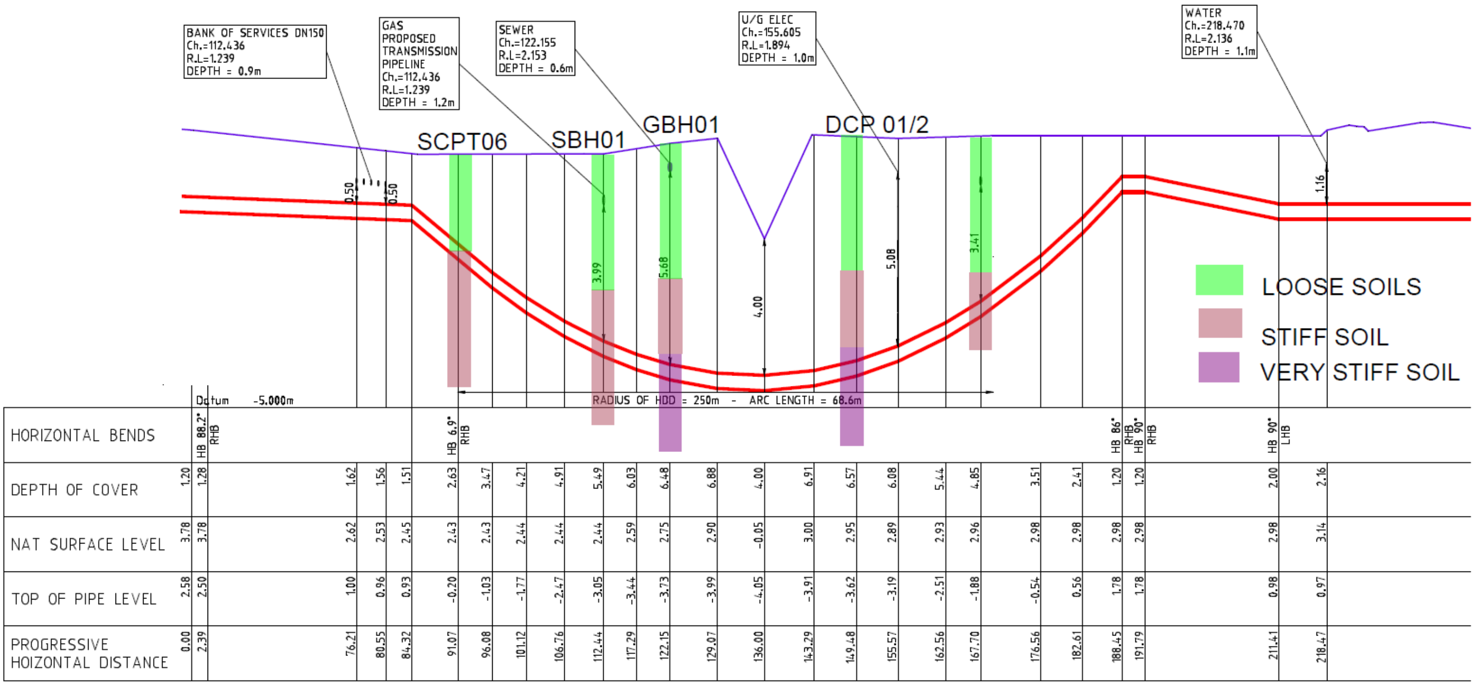
4.0 LOCATION OF WATERWAYS

ABERNETHY'S CREEK CROSSING



HDD Start and Finish is > 10m from the Creek Banks

Image 1.1 – Plan view with HDD Location and Access Track Location



HORIZONTAL BENDS		HB 88.2° RHB				HB 6.9° RHB							
DEPTH OF COVER	1.20	1.28	1.62	1.56	1.51	2.63	3.47	4.21	4.91	5.49	6.03	6.48	6.88
NAT SURFACE LEVEL	3.78	3.78	2.62	2.53	2.45	2.43	2.43	2.44	2.44	2.44	2.59	2.75	2.90
TOP OF PIPE LEVEL	2.58	2.50	1.00	0.96	0.93	-0.20	-1.03	-1.77	-2.47	-3.05	-3.44	-3.73	-3.99
PROGRESSIVE HOIZONTAL DISTANCE	0.00	2.39	76.21	80.55	84.32	91.07	96.08	101.12	106.76	112.44	117.29	122.15	129.07

HORIZONTAL BENDS									HB 86° RHB	HB 90° RHB	HB 90° LHB	
DEPTH OF COVER	4.00	6.91	6.57	6.08	5.44	4.85	3.51	2.41	1.20	1.20	2.00	2.16
NAT SURFACE LEVEL	-0.05	3.00	2.95	2.89	2.93	2.96	2.98	2.98	2.98	2.98	2.98	3.14
TOP OF PIPE LEVEL	-4.05	-3.91	-3.62	-3.19	-2.51	-1.88	-0.54	0.56	1.78	1.78	0.98	0.97
PROGRESSIVE HOIZONTAL DISTANCE	136.00	143.29	149.48	155.57	162.56	167.70	176.56	182.61	188.45	191.79	211.41	218.47

Image 1.2 – Long View of HDD Bore Profile under Creek

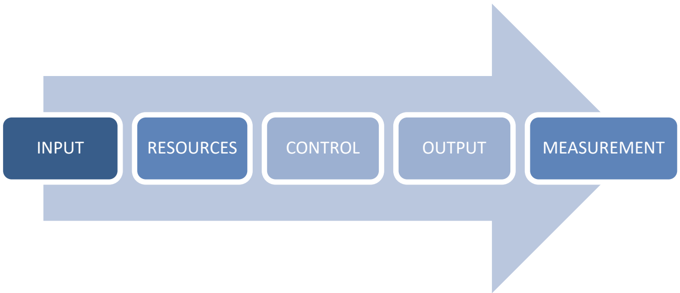
5.0 HORIZONTAL DIRECTIONAL DRILLING METHODOLOGY

5.1 PLANT/RESOURCES

The plant and equipment required for completing the water crossing is as per below.

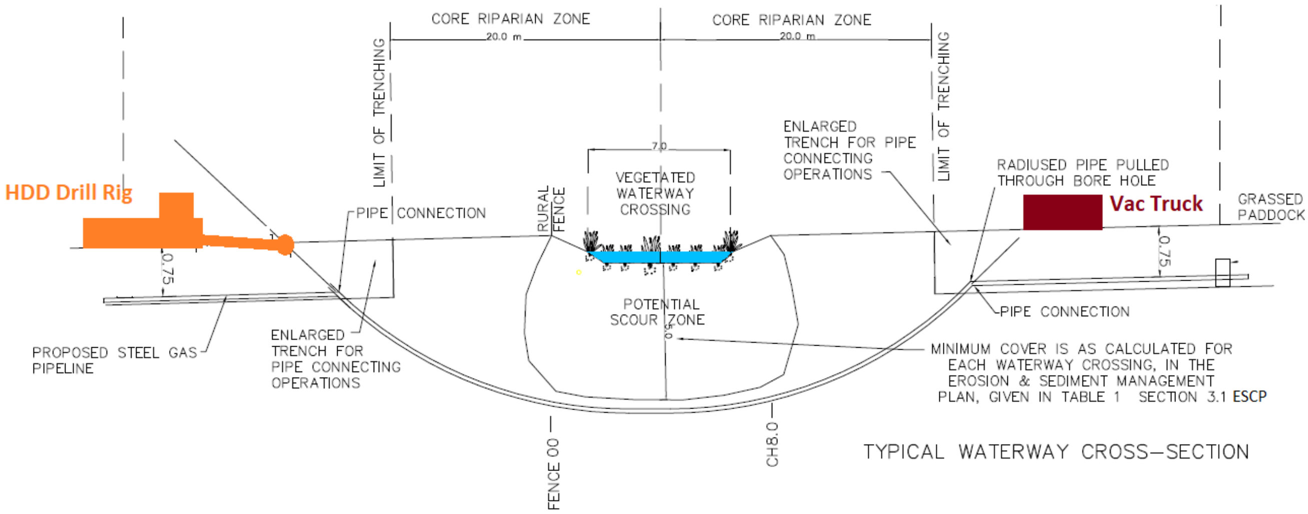
Excavator 21 ton, & bucket
Excavator 25 ton, & bucket
Loader
Utes
Welding Trucks
Tipper Truck
Water pump 2” or 3”
Spill kits
Trench Shields
HDD Drill Rig
Mud Mixing Station
Vacuum Truck
Coating Truck

5.2 PROCESS DIAGRAM



INPUT	RESOURCES	CONTROL	OUTPUT	MEASUREMENT
Pipes strung Group Other materials	Equipment Operators	Inspection Permits Surveyed Alignment Management Plans	Installed pipeline Pipeline naturally grouted Entry & Exit point reinstated As built Survey Data	QSE Key Performance Indicators No outstanding NCR’s or Client queries

5.3 HDD LAYOUT



5.4 GEOLOGY

The HDD is likely to be in Sandy Clay as per Geotechnical Investigation Report. The ground profile under the creek bed and banks is likely to be Stiff to Very Stiff Ground conditions. Accordingly, at the depth we propose to HDD we will have no issue with bore hole collapse or frac out.

For Abernethys Creek HDD

- Refer to SCPT06, SBH01 and
- GBH01, DCP 01/02

Frac calculations were completed at bed level and either side of banks for each of the above creeks, details can be found in the Appendix.

Note: For frac-out calculations, even though stiff/very stiff and hard soils were encountered at depths of 4.5m, we've used parameters of soft estuarine soils (Cohesion factor of 2, Soil Friction Angle of 25 Deg, Lower Unit Weight etc) to be on the conservative side.

In a nutshell, provided the permissible bore annulus pressures are not exceeded the chance of a frac out is remote with the creek bend or banks.

We note that several bore holes have been completed near or along the HDD path, there is a chance for drill fluid to frac at these locations. However, these locations will be pegged, and silt fencing will be installed around them.

5.5 LENGTH OF BORE AND PROFILE

Pipe Diameter – DN450 steel
Bore length – 90m
Bore profile – Refer to Section 4 above
Depth to top of pipe under creek bed – 4m

5.6 DESIGN CONSIDERATIONS

NAP has completed the following:

- Pipeline installation stress analysis has been completed
- Frac Out Management Plan
- Overbend Stress Calculations

On a general note, based on the pipeline calculations the expected pipeline stresses are well within the Specified Minimum Yield Stress with large safety margins.

Frac out risk has been minimised by:

- Ensuring that the bore is deep under creeks within Firm, Stiff or very Stiff Soils
- The drill pressures are monitored and regulated
- Appropriate mud mixes are selected
- The bore hole is reamed to at least 1.5 times the diameter of the pipeline
- Ensuring that appropriate mitigation measures are in place in the event of frac out i.e. vacuum trucks, pumps, silt fencing etc.

5.7 CONSTRUCTION STEPS

1. Existing Assets located and proved prior to bore commencing
2. Visually confirm location of services using NDD trucks
3. Re-confirm drill path based on service checks
4. Establish Drill unit
5. Entry & exit points pre excavated.
6. All previously completed bore holes to be pegged and sediment fencing to be installed creek side to prevent any fracs from these weak points.
7. Install silt controls at bore entry and exit points in order to prevent any produced drill slurry or ground water from entry to drainage systems, these fluids will be removed via Vacuum trucks for appropriate disposal to an accredited EPA site.

8. Recheck detail of all existing assets to ensure they have been proven and located prior to commencement
9. Scan bore path for interference prior to commencement
10. Entry and exit points of bore to be excavated 500mm below invert to capture and retain produced bore slurry for removal via vac unit
11. Commence pilot to designed bore plan recording invert & alignment on route – pilot process cuts the soil and utilises drill muds to carry cuttings to entry/exit points for removal via vac unit. (approx. Diameter of Drill head Cutting edge = 125mm)
12. As the bore is being piloted the tracker monitors bore alignment and invert throughout the progression of the bore in order to construct as per design – As the tracker checks this data the drill operator can see on a screen in real time – The driller and tracker are in contact via UHF Radio – specific frequency throughout the entire process.
13. Upon pilot reaching destined exit point / pipe pullback point the drill head will be removed and a reamer (approx. 300mm, followed by 450mm) will be installed, reaming of bore continues for full length of the alignment, during which drilling muds are introduced which seal the bore walls hence permitting the naturally reamed product to blend with the drilling enhancing muds which flow to the entry exit points for removal via vac unit.
14. Throughout all piloting and reaming processes the entry and exit points are monitored for adequate mud flows at each point to ensure that a pressure point does not develop in bore.
15. Throughout all piloting and reaming processes, the bore is left flooded with drill slurry which consists of naturally reamed and introduced bore enhancing products which fills void and supports the constructed bore.
16. Once the borehole is fully reamed, a pulling device is connected to the pipeline string via a swivel. The pullback then commences at a controlled speed.
17. The swivel between the pipe being installed and the drill string permits the pipe to rotate as friction requires between the drill slurry in bore and the 300NB pipe being installed.
18. The bore being full of drill slurry will be naturally displaced as the pipe is installed into the bore hole, the excess slurry transfers to both entry & exit points, which will be removed via vac units for disposal
19. As a result the annular space becomes fully grouted with naturally and introduced product resultant from the drilling process.
20. All surplus drilling slurry is removed from site and disposed of at an EPA registered disposal site

5.7.1 Risks regarding HDD process & Control Plan

Risk	**Controls**
Heave of Surface	Throughout Piloting, Reaming and pullback the entry and exit shafts as well as bore path are monitored to ensure muds are flowing and no pressure point develops within the bore. If pressure develops, work ceases and re swabbing commences to loosen up any blockage to recommence mud flows then restart the relevant process.
Frac Out	Can occur due to the geological conditions i.e. if not consistent or if geotechnical bore holes are too close to the HDD path. In the event this occurs, cease work, contain fluids, remove with vac unit, consider additional additives and action, alternatively excavate and use as a relief point for extraction of muds via a vac unit. Controls in order to eliminate this risk are by utilizing a sealing mud mix, together with at all times having a fully fluid charged bore. This risk is also mitigated due to the depth of the bore being >2m below scour depth to which the risk of Frac out or surface disruption is negligible.
Subsidence / Collapsing bore	Point 1 : the bore at all times will be fully charged with a heavy mud mix therefore a void never exists Point 2: Upon Pullback the annular space is naturally grouted with Naturally occurring spoils and Enhancing products Point 3 : at the design depths due to a fully charged bore at all times with Bore wall sealing products moisture and solids will

	remain in bore resulting in a supported bore at all times
Loss of Drill head (breakage)	Prior to commencing the bore the Drill head will be checked for fatigue to threads any cracking or distortion, If any of the above is evident the Drill head will be replaced by a conforming tool. The starter rod and hex collar to which the drill head connects to the drill rods will also be inspected for fatigue, distortion and cracks, if any of the above is evident this item of tooling will be replaced with a new unit. The hex collar (locking device between the starter rod and Drill head) will be checked for cracking, fatigue and distortion; if any of the above is evident a new unit will be supplemented. The Grub screw (hex collar retaining device) will be inspected for fatigue, thread damage, should any of the above be evident then the grub screw will be replaced by a new item. All the above ensure that the drill head and affiliated tooling are suitable to perform the required tasks. If the drill head breaks away from the drill string sub surface the drill string will be withdrawn and the drill head will remain in soil at this location. The pilot bore will be full of natural product from cuttings, this will be capped at surface to ensure no voids are present. New tooling will be installed and a

	new pilot will be performed, while abandoning the broken tooling. Should a breakage such as this occur outside the creek bed and banks the point of breakage would be excavated to retrieve the broken tooling and backfilled to standard excavation and backfilling practices. New tooling will be installed, and the bore construction will continue in the exiting pilot bore and achieve the desired pilot prior to reaming

5.7.2 Mud Mix:

- A bentonite mix of 1 bag per 1000 litres is nominated to be used
- This product ensures the bore walls are sealed retaining fluids to bore hole and to suspend the drill cuttings which is transferred to the exit point, reducing friction while ensuring good flows are maintained throughout drilling and reaming processes.
- By utilizing the nominated Mud Mix this ensures a filter cake is built to seal and support the bore, the bore retains integrity due to this filter cake and the bore full of slurry prevents any collapse of the bore hole.
- Throughout the entire process drilling fluid /slurry is always ahead of and behind the tooling, at no time does a void exist.

APPENDIX

- Fluid Management Plan
- Geotech Report
- Frac Out Calculations
- Head Tracking Tool
- Pre-Com Risk Assessment
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FLUID MANAGEMENT PLAN

NATIONAL AUSTRALIAN PIPELINES PTY. LTD.
ABN 88 005 339 211

SHOALHAVEN STARCHES

NATURAL GAS PIPELINE AND PRESSURE REDUCTION STATION

FLUID MANAGEMENT PLAN & FRAC OUT MANAGEMENT

National Australian Pipelines Pty. Ltd.

Natural Gas Pipeline and Pressure Reduction Station

Client: Shoalhaven Starches

Revision:	Issue Date:	Approved by:
Rev.0	20/01/2022	Martin J. Moran

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1 INTRODUCTION

It is recognised by National Australian Pipelines (NAP) that the consequences of any drilling fluid escaping the HDD drilling site compounds could be significant.

This Drilling Fluid Management Plan (FMP) addresses the following issues:

- The Purpose and Properties of Drilling Fluid;
- The Use of Drilling Fluid during a HDD operation;
- The Possible Paths by which Drilling Fluid could be lost to the environment;
- Safeguards the drilling contractor will put in place to minimise the chance of Drilling Fluid being lost to the environment;
- Inspection Procedures the drilling contractor will implement to ensure the safeguards are adequately maintained;
- Drilling Fluid Volume Tracking Procedures the drilling contractor will use to ensure that drilling fluid volumes are being checked;
- Drilling Fluid Loss Incident Management Procedure that will be used if Drilling Fluid Loss has been detected;
- Management of ground water ingress.

NAP believes the implementation of this Management Plan will:

- Ensure all practical safeguards are put in place to minimise the chance of Drilling Fluid being lost to the environment.
- Inspection Procedures will be in operation to maintain the integrity of the safeguards.
- Volumetric Drilling Fluid Tracking Procedures will be in operation to ensure that if Drilling Fluid is being lost or gained is detected and action taken.

2 CONTROL & DISTRIBUTION

The NAP Project Engineer controls this document. The Project Engineer shall ensure all persons named below are issued with a current copy.

REV NO.	CONTROLLED COPY ISSUED TO	ORGANISATION
Rev 0	Paul Whisson	Shoalhaven Starches
Rev 0	Colin Field	NAP (Site Copy)

3 GEOTECHNICAL AND HYDROLOGICAL ENVIRONMENT

The geotechnical investigation report indicates that majority of the borehole length shall be drilled through competent strata. This formation is inherently stable and is ideal for maintaining an open hole.

4 DRILLING FLUID

Drilling Fluid is a major factor in the success of any directional drilling program, and as such deserves careful consideration. The principal functions of the drilling fluid during a successful Directional Drilling operation are:

- ➢To drive downhole motors, drill bits and reamers.
- ➢To remove the cuttings from the bottom of the hole and carry them to the entry point.
- ➢To cool and lubricate the drill string and drill bit.
- ➢To line, support and protect the walls of the hole.

For a Horizontal Directional Drilling operation, the fluid demands are different from those required for drilling vertical wells. Hole cleaning ability or the ability of the drilling fluid to suspend cuttings is a much more critical factor for Horizontal Directional Drilling. Gel strength is the measure of this property.

For Horizontal Directional Drilling, low viscosity and high gel strength are required to ensure the cuttings are effectively suspended in the slurry and returned to the entry point. The drilling contractor is very experienced in Horizontal Directional Drilling operations and will be using some of the following products to mix the Drilling Fluid and guarantee these properties are met:

- ➢BENTONITE
- ➢KLA BORE
- ➢POLY VIS HV

- SODA ASH
- STAR GEL

These products produce a drilling fluid with low viscosity, high gel strength and sufficient Bentonite content. The Bentonite content of the drilling fluid is critical for drilling boreholes through rock. The fine particles of Bentonite form a thin, low-permeability filter cake around the walls of the borehole. This filter cake seals the pores and other openings in rock preventing the escape of drilling fluid through the rock and the inflow of formation fluids.

The Material Safety Data Sheets (MSDS's) for these products are kept on site.

5 DRILLING FLUID CIRCULATION

It is important to gain an understanding of how drilling fluid is circulated during horizontal directional drilling, to better understand the safeguards and inspection procedures drilling contractor intends to implement to manage drilling fluid during the drilling operations.

The mud gets mixed in the mixing tank. Once the mud has been mixed adequately it is transferred to the active tank. From the active tank the drilling fluid is pumped to the drilling rig, through the drill pipe, into the borehole and onto the cutting face. The drilling fluid then suspends the cuttings and travels out of the borehole and into the borehole returns pit. The borehole returns pit is positioned directly behind the hole entry point. From returns pits the excess mud is extracted using vacuum trucks and disposed offsite.

The site set up plan shown in the work method statement should be referred to for containment facilities such as the site sedimentation fencing, sumps & bunds as this plan only refers to directional drilling fluid related controls.

6 HAZARD PATH IDENTIFICATION

NAP considers any risk to the environment of the area to be unacceptable. To reduce the risk of drilling fluid escaping to the environment NAP has identified the following paths by which it is possible that drilling fluid could enter these sensitive areas.

a) Runoff or surface water could escape the drilling compound during periods of rainfall.
b) Drilling Fluid could escape the drilling compound and potentially find its way into the environment.
c) Drilling Fluid could potentially escape the borehole during drilling through inconsistencies (cracks & fissures) in the rock. This could result in drilling fluid being deposited into underground aquifers or breaking out to the surface.
d) Groundwater could seep into the borehole during the drilling operation. This ingress will result in increased drilling fluid volume and could cause drilling fluid containment facilities to become filled to capacity and possibly overloaded.

These are the only paths by which drilling fluid could be potentially lost to the environment. Therefore it is the goal of this Management Plan to minimise the chance of drilling fluid escaping via these paths through the use of safeguards and the implementation of inspection procedures.

7 SAFEGUARDS

This section deals with the safeguards that the drilling contractor will use during the execution of this project, to control the previously identified potential drilling fluid escape paths.

The following mitigation measures will be put in place to counteract the hazards identified above:

- Earth bunds and drainage channels will be placed around the upper edges of the drill site and work area, to divert natural runoff around and away from the site so that it doesn’t mix with drilling compound runoff. Necessary erosion and sedimentation control measures will be in place.

- All facilities utilised in the surface mud handling (mixing, cleaning & pumping) shall be bunded. This shall ensure natural / clean runoff contained within the compound is not mixed with drilling fluid or contaminated by oil/fuel.

- A sump pit will be constructed at the bottom of the drill site. The sump pit will be positioned (during site planning) so as all runoff from the drilling compound will flow into it. The sump pit is of such dimensions to provide a buffer for the drilling fluid returns.

- An earth bund or silt fencing will be placed on the downstream side of the bund to contain any spillage. The sump pit will be pumped out using vacuum trucks in an as required basis during the drilling operation. This will ensure that any rain event, whilst the drilling crew is not onsite, won’t lead to a sump pit overflow.

- All products used to mix the drilling fluid will be covered before they are used to mix the drilling fluid. The unmixed drilling mud shall be stored on pallets keeping them off the ground and not stored within drainage lines. This will prevent the chance of any drilling fluid components escaping the drilling compound and becoming contaminants to the environment.

- All stationery plant & equipment on site is inspected on a daily basis to ensure it is in good working order to minimise the chance of fuel/oil/grease leakage.

- Adequate spill control kits containing absorbent materials, to cleanup spills from mobile equipment outside bunds shall be on site at all times.

- All excess oils and greases shall be contained within the fuel bund in order prevent any chance of leakage. The fuel bund is a fuel tank (4500L capacity) with an inbuilt steel bund able to contain 1.5 times storage capacity of the tank.

- All used oil or grease taken from machinery during services is stored within the fuel bund. The fuel bund is regularly emptied by a licensed contractor

- By designing the drill profile using the best geotechnical information available, the drilling contractor can ensure that an adequate amount of cover can be provided beneath the surface.

- The products selected to mix the drilling fluid have been carefully selected to provide the drilling fluid with sufficient Bentonite content. The Bentonite content of the drilling fluid will ensure a thin, low-permeability filter cake forms on the walls of the borehole. This will ensure no drilling fluid is lost through the walls of the borehole.

- Chances of drilling fluid seeping in the ground through storage pits (returns pits & sump pit) are minimal. Just as the drilling fluid lines the inside of the borehole it will also line the inside pits and provides an impermeable barrier hence stopping fluid from seeping into ground.

8 INSPECTION PLAN

This section deals with the inspection procedures by which NAP intends to ensure the adequacy and integrity of the safeguard measures.

8.1 DRILLING COMPOUND RUNOFF

Earth bunds/drainage channels or silt fencing placed on the downstream side of the drilling compound will be inspected on a daily basis and/or during & after any significant rain event to ensure their adequacy and integrity.

Earth bunding placed around the sump pit will also be inspected on a daily basis and/or after any significant rain event to ensure its adequacy and integrity.

Before the commencement of drilling and at the close down each day, all components of the mud mixing system will be visually inspected to check for signs of drilling fluid loss and to ensure its adequacy for the containment of drilling fluid.

8.2 INGRESS OF GROUND WATER

The Drilling Fluid Volumetric Tracking procedure shall be utilised. This tracking procedure will be regularly updated to ensure that any ingress of groundwater into the borehole is quickly detected.

8.3 DOWNHOLE FLUID LOSS TO GROUND

The Drilling Fluid Volumetric Tracking procedure shall be utilised. This tracking procedure will be regularly updated to ensure that any ingress of groundwater into the borehole is quickly detected. Nominated cored holes will also be checked to see if there are any indicators that suggest where the fluid may be lost to.

The bore path will also be visually monitored from the surface for any signs of surface frac-out. In the event of a surface frac-out occurring, all drilling operations will cease and all efforts will be made to contain the frac-out to a localised area. Sand bags will be available on site to bund the area. Excess fluids will be removed from the area using a vacuum truck. If a vacuum truck cannot access the area of frac-out, manual pumping will be used to remediate the area surrounding the frac-out.

9 DRILLING FLUID VOLUME TRACKING PROCEDURE

The drilling fluid volume tracking procedure for the drilling operations is quick and easy. It has been designed this way so that regular and accurate checks can be made throughout each day to ensure that any groundwater ingress or downhole drilling fluid loss is detected quickly. This will minimise the volume of any drilling fluid loss from the compound due to overload of containment facilities (i.e. groundwater ingress) or drilling fluid loss to the ground through the borehole (i.e. downhole drilling fluid loss) and allow remediation activities to start promptly.

The drilling fluid tracking procedure involves a simple volumetric balance between measuring the volume of drilling fluid mixed and comparing it to the volume that the drilling fluid is occupying in the borehole and entry pit (this is dependent of the length of hole drilled and the volume in surface containment facilities). These two values can readily be measured onsite and comparison of the values will quickly determine the volume of drilling fluid gained due to groundwater ingress or lost due to downhole fluid loss.

It is true that if groundwater ingress were to equal the downhole drilling fluid loss then the drilling fluid volume tracking procedure would not detect any loss. However this situation is extremely unlikely. During normal drilling operations we expect to be pumping 19L/s to 25L/s of drilling fluid up the borehole whilst groundwater water ingress, if any, is expected to be less than 1 L/s.

The measurement of the drilling fluid volume mixed can easily be measured by making the assumption that the volume of drilling fluid produced is equal to the amount of water added to the drilling fluid tank.

The theoretical volume that the drilling fluid is occupying is also a value that can be easily calculated. Two components contribute to this value. The first is the volume of drilling fluid occupying the drilled hole and the second is the volume of drilling fluid contained within the sump pits.

The volume of drilling fluid downhole is a simple calculation knowing the diameter and the length of hole drilled. The volume of drilling fluid contained within the sump pit can also be measured easily onsite. A measurement needs to be taken of the level of drilling fluid within the drilling fluid tank. Knowing this value and knowing the dimension of the containment vessel (vacuum truck) the volume can again be calculated easily.

The drilling contractor will be making this volumetric comparison regularly each day and a minimum of three checks shall be made each shift for the duration of drilling the pilot hole.

Should inconsistent ground material be found during drilling operations (this is unlikely due to the depth of profile beneath the ground and the geotechnical information supplied) the monitoring frequency will be increased to one reading for every 10m drilled.

10 DRILLING FLUID LOSS REPORTING SYSTEM

At this stage it is important to understand that it is normal to expect some drilling fluid loss during a horizontal directional drilling operation. Some losses are expected because the fluid is filling the borehole annulus (between the pipe and the bore walls), because the fluid is lining the edges of the borehole and sump pits. Therefore, it is important that normal drilling fluid losses are taken into account in the reporting system. The reporting system proposed for this project is summarised in the following table:

Drilling Fluid Loss	Situation	Action
0-15%	Normal	Continue Drilling One Reading in 30m Drilled
15-25%	Alarm	Continue Drilling Increase Monitoring Frequency One Reading in 10m Drilled
>25%	Emergency	Cease Drilling Follow Emergency Response Plan Notify Shoalhaven Starches and DPIE before recommencing HDD

10.1 DRILLING FLUID LOSS 0-15%

The volumetric drilling fluid balance has shown 0-15% drilling fluid loss. It is normal to expect some drilling fluid loss during a horizontal directional drilling operation. The situation within this zone is quite acceptable and work should continue on as normal.

10.2 DRILLING FLUID LOSS 15-25%

The volumetric drilling fluid balance has shown 15-25% drilling fluid loss. The loss of drilling fluid has now become a concern. The volumetric balance is immediately recalculated and the drilling compound is checked to ensure there is no other reason for drilling fluid loss besides downhole loss. The drilling fluid volume tracking procedure is increased from normal (three times a day) to hourly checks until the level of drilling fluid loss exceeds 25% or decreases below 10%.

10.3 DRILLING FLUID LOSS > 25%

The drilling fluid tracking procedure has shown that drilling fluid loss has exceeded 25%. It has been checked that the only reason for this drilling fluid loss is downhole drilling fluid losses. The drilling of the borehole is immediately ceased. An incident is declared and incident response procedures implemented as described in the following section 11 . The incident response plan identifies the procedure to be used when Loss of Drilling Fluid (>25%) is experienced.

11 INCIDENT RESPONSE PLAN

Refer to the Incident Management Plan for complete details on incident response procedures. The response to loss downhole drilling fluid loss in general terms will be:

1: Cease Drilling: When downhole loss exceeds 25%

2: Notify Shoalhaven Starches immediately

3: Drilling contractor to co-ordinate sealing of the borehole.

4: Notify DPIE of issue.

5: Notify DPIE prior to recommencing HDD operations.

Possible solutions are as follows:

- Pump Extremely High Viscosity Drilling Fluid in to borehole in order to attempt to gel up the leakage.
- Utilise leak sealing mud additives into the drilling fluid in order to attempt to seal the leakage.
- Addition of loss circulation products such as rice husks, cotton or shredded paper into the drilling fluid in order to attempt to seal the leakage.
- Grouting the borehole at the leakage location and drilling through the grout and continue the hole.
- Using bentonite forms filter around the borehole walls which stops water coming in the hole due to higher annular pressure as compared to the pore pressure.

The response to containment facilities failure in general terms will be:

1: Cease Drilling: When containment failure is detected

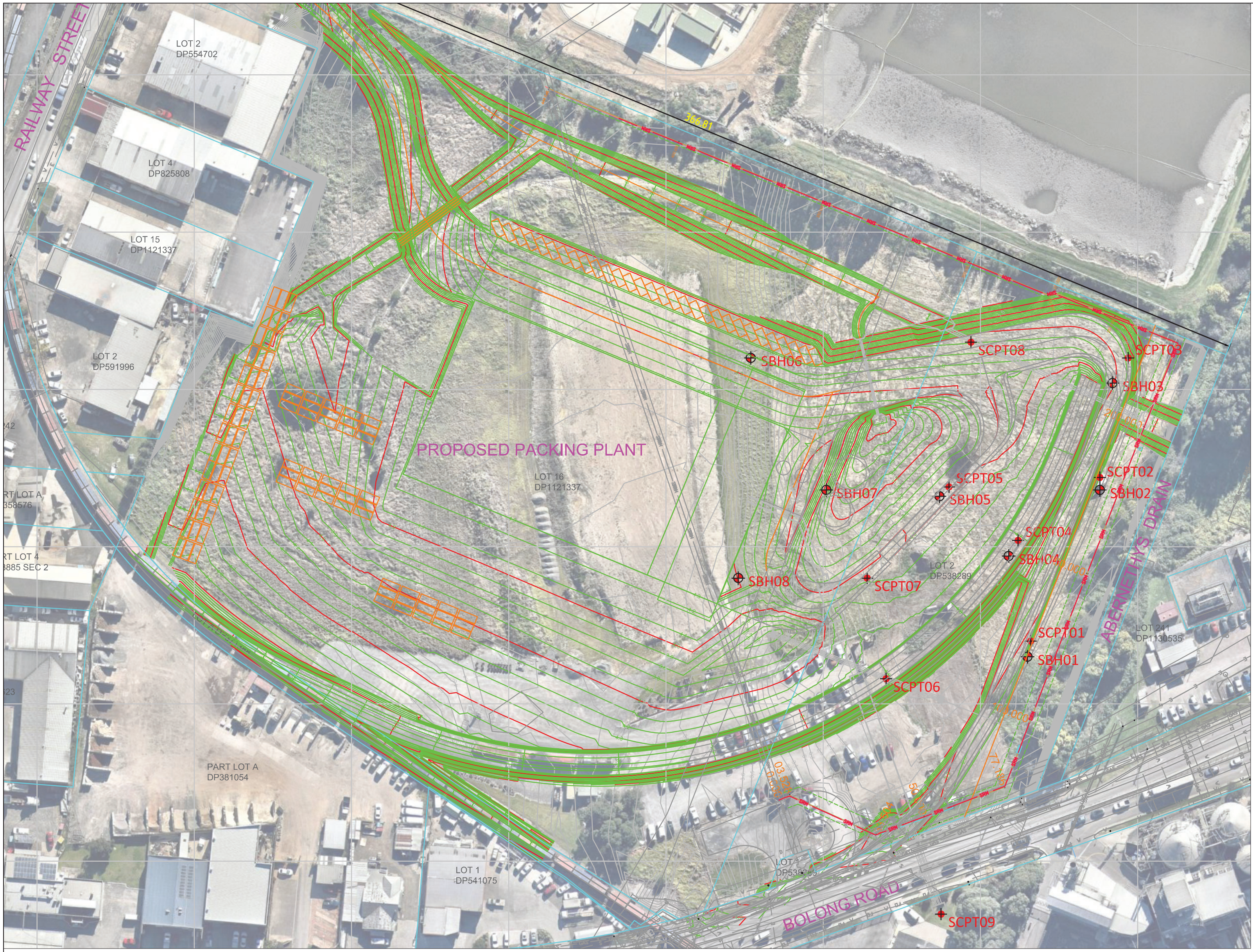
2: Notify Shoalhaven Starches immediately

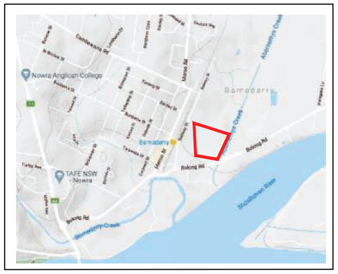
3: NAP and the drilling contractor to co-ordinate containment and cleanup of the drilling fluid leakage.

Possible solutions are as follows:

- Mobilise transportable pumps on the worksite to the location of the spill and transfer the mud to a contained area.
- Utilise the excavator on site to form windrows in order to divert the flow back into contained areas.
- Utilise the excavator on site to dig a temporary hole in order for escaping drilling fluid to gather in and mobilise transportable pumps to transfer mud to a contained area.
- Mobilise additional vacuum trucks to the worksite in case there are no more effective contained areas on the site for the mud to be stored within i.e. cannot utilise transportable pumps to transfer the mud.

GEOTECH





Site Locality

LEGEND

✦ CPT Location
⊕ Borehole Location

Design Contours

🟩 0.1 m Contours
🟥 0.5 m Contours

Existing Contours

— 0.1 m Contours

Based drawing from Allen Price & Scarratts Pty Ltd (Drawing No. 25003-300_600, updated on 18 May 2020)

Title :	**GEOTECHNICAL SITE INVESTIGATION PLAN**	CLIENT: Manilda Group Pty Ltd	DATE: 3/06/2020	DRAWN BY: GRR	REVIEWED BY: KK	PROJECT No: 3001550
Project :	**Shoalhaven Starch Plant**	0 5 10 20 30 40 50 75 100 125m 1:1250 @ A3				DRAWING No: 001
Site Location	**Shoalhaven Starches, Bolong Road, Bomaderry**					REVISION: 02

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WOLLONGONG NSW 2500

Appendix B Borehole Logs and Explanatory Notes

Explanatory Notes of Abbreviations and Terms

Used on Borehole and Excavation Logs

General

The “Geological and Engineering Log” presents data from drilling or excavation operations where material recovery is soil and or rock. Data presented is a combination of material recovered, regular sampling and in-situ testing. Excavations may present data obtained on the subsurface profile from observations of natural or man-made excavations. Logs may contain scaled graphical presentations, photography, or downhole imagery results. Logs may not contain all data types presented in these notes.

The “Non Core Drill Hole Engineering Log” presents data from drilling operations where a core barrel has not been used. The material is penetrated using methods other than those designed to recover core and is commonly soil or extremely to highly weathered. The “Cored Drill Hole Engineering Log” presents data from drilling operations where a core barrel has been used. The “Excavation - Geological Log” presents data obtained on the subsurface profile from observations of excavations, either natural or anthropogenic.

As far as is practicable, the data contained on the log sheet is factual. Some interpretation is inevitable with respect to the:

a. assessment of material boundaries in areas of partial sampling and recovery,

b. location of areas of core loss,

c. description and classification of material,

d. estimate of field strength, and

e. identification of drilling induced fractures.

Material description and classification is generally based on AS1726-2017 (as amended).

Drilling Method

Code	Description
ADT	Auger drilling with TC-bit
ADV	Auger drilling V-bit
AS	Auger screwing
AT	Air track
CA	Casing advancer
CC	Concrete core
CTR	Cable tool rig
DB	Wash bore drag bit
HA	Hand auger
HAND	Hand methods
HF	Hollow flight auger
HMLC	Diamond core 63.5 mm diameter
HQ / HRQ	Wire line core barrel 63.5 mm diameter
HQ3	Wire line core barrel 61.1 mm diameter
NDD	Non destructive drilling
NMLC	Diamond core 51.9 mm diameter
NQ	Wire line core barrel 47.6 mm diameter
NQ3	Wire line core barrel 45.1 mm diameter
PT	Continuous push tube
PQ	Wire line core barrel 85.0 mm diameter
RAB	Rotary air blast
RC	Reverse circulation
RD	Rotary blade or drag bit
RR	Rock roller
RT	Rotary tricone bit
SD	Sonic drilling
TBX	Tube-X
VC	Vibro-core drilling
WB	Wash bore drilling

Drilling Penetration

Ease of penetration in non-core drilling

Term	Description
VE	Very easy
E	Easy
F	Firm
H	Hard
VH	Very hard

Support and Casing

Code	Description	Code	Description
C	Casing	Hw	114.3 mm
M	Mud	Nw	88.9 mm
W	Water	PVC 150	150 mm

Core Run

Core lifts are identified by a line and depth with core loss per run as a percentage. Core loss is shown in the core run unless otherwise indicated.

Defect Spacing

The average distance between defects is measured parallel to the core axis in mm and may be expressed as a range or average.

Angle / Orientation

Angle from horizontal and orientation to magnetic north.

For inclined cored boreholes the Alpha and Beta angles are presented for orientated core. Alpha (α) is measured relative to the core axis, whilst Beta (β) is measured clockwise from the reference line looking down the core axis in the direction of drilling.

Excavation Method

Term	Definition
N	Natural exposure
X	Existing excavation
BB	Tractor mounted backhoe bucket
EX	Hydraulic excavator
EH	Hydraulic excavator with hammer
B	Bulldozer blade
R	Ripper

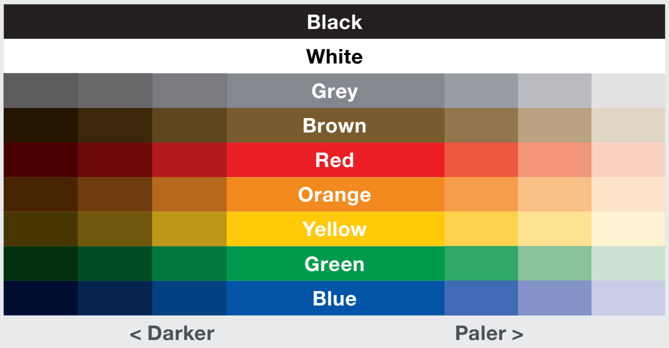
Water / Drilling Fluid

The drilling fluid used is identified and loss of return to the surface is estimated as a percentage, generally of each core lift.

Symbol	Description
►——	Water inflow
——◄	Water outflow
▽	Water level: during drilling or immediately after completion of drilling
▼	Groundwater level with date observed prior to introduction of fluids or after standpipe construction
Not observed	The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole / test pit.
Not encountered	The borehole / test pit was dry soon after excavation, however groundwater could be present in less permeable strata. Inflow may have been observed had the borehole / test pit been left open for a longer period.

Colour

The colour of a soil or rock is described in a moist/wet condition using simple terms, such as black, white, grey, red, brown, orange, yellow green or blue. These are modified as necessary by 'pale', 'dark' or 'mottled'. Borderline colours are described as a combination of these colours (e.g. orange-brown). Where a soil or rock consists of a primary colour with a secondary mottling it is described as (primary colour) mottled (first colour) and (secondary colour). Where colour is described outside of the material description it is for the interval.



Description of Soil

- **vi.** Soil name (BLOCK LETTERS)
- **vii.** Plasticity or particle size of soil
- **viii.** Colour (i.e. dominant colour of material)
- **ix.** Secondary soil components names & estimated proportions, including their plasticity / particle characteristics, colour
- **x.** Minor soil components name, estimated proportions, including their plasticity / particle characteristics, colour
- **xi.** Other minor soil components
- **xii.** Moisture condition
- **xiii.** Consistency / density
- **xiv.** Structure of soil, geological origin
- **xv.** Additional observations

Particle Size

Term		Grain Size
Clay		< 2 µm
Silt		2 – 75 µm
Sand	Fine	0.075 – 0.21 mm
	Medium	0.21 – 0.6 mm
	Coarse	0.6 – 2.36 mm
Gravel	Fine	2.36 – 6.7 mm
	Medium	6.7 – 19 mm
	Coarse	19 – 63 mm
Cobbles		63 – 200 mm
Boulders		> 200 mm

Fine Grained and Coarse Grained Soils

Term	Description
Fine Grained Soil (cohesive)	More than 35% of the material less than 63 mm is smaller than 0.075 mm (silts and clays)
Coarse Grained Soil	More than 65% of the material less than 63 mm is larger than 0.075 mm (sands, gravels and cobbles)

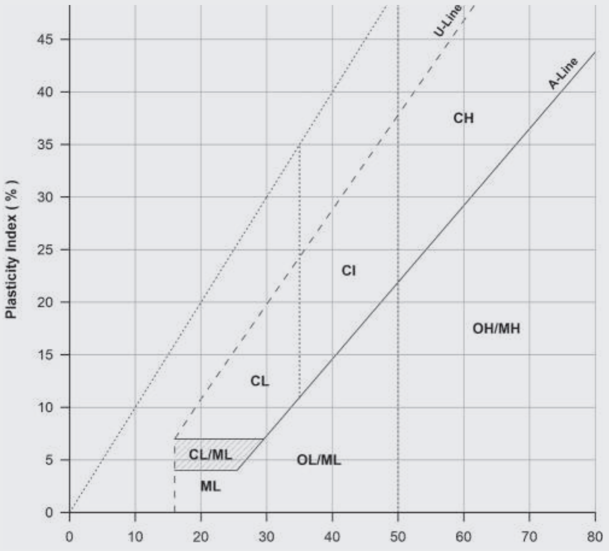
Descriptive Terms for Secondary and Minor Components

	In coarse grained soils				**In fine grained soils**	
Designation of Components	**% Fines**	**Terminology**	**% Accessory coarse fraction**	**Terminology**	**% Sand / Gravel**	**Terminology**
Minor	≤5	trace	≤ 15	trace	≤ 15	trace
	> 5, ≤ 12	with	> 15, ≤ 30	with	> 15, ≤ 30	with
Secondary	> 12	prefix	> 30	prefix	> 30	prefix

Plasticity – Fine Grained Soils

Liquid Limit (LL) %	Description
≤ 35	Low plasticity (L)
> 35 to ≤ 50	Medium plasticity (I)
> 50	High plasticity (H)

Plasticity Chart– Fine Grained Soils



Consistency Terms – Fine Grained Soils

Term	Undrained shear strength (kPa)	Indicative SPT (N) Blow Count	Field Guide to Consistency
Very Soft (VS)	< 12	0 – 2	Easily penetrated several centimetres by fist, exudes between fingers when squeezed in fist
Soft (S)	12 – 25	2 – 4	Easily penetrated several centimetres by thumb, easily moulded by light finger pressure
Firm (F)	25 – 50	4 – 8	Can be penetrated several centimetres by thumb with moderate effort, and moulded between the fingers by strong pressure
Stiff (St)	50 – 100	8 – 15	Readily indented by thumb but penetrated only with difficultly. Cannot be moulded by fingers
Very Stiff (VSt)	100 – 200	15 – 30	Readily indented by thumb nail, still very tough
Hard (H)	> 200	> 30	Indented with difficulty by thumb nail, brittle
Friable (Fr)	-		Can be easily crumbled or broken into small pieces

Density Terms – Coarse Grained Soils

Term	Density Index (%)	SPT (N) Blow Count
Very Loose (VL)	< 15	0 – 4
Loose (L)	15 – 35	4 – 10
Medium Dense (MD)	35 – 65	10 – 30
Dense (D)	65 – 85	30 – 50
Very Dense (VD)	> 85	> 50

Particle Characteristics – Coarse Grained Soils

Term	Description
Well graded	Having good representation of all particle sizes
Poorly graded	With one or more intermediate size poorly represented
Gap graded	With one or more intermediate sizes absent
Uniform	Essentially of one size

Angularity – Coarse Grained Soils

	Rounded
	Sub-rounded
	Angular
	Sub-angular

Origin of Soil

Fill	Formed by anthropogenic activity
Aeolian	Formed by wind
Alluvial	Formed by streams and rivers
Colluvial	Formed on slopes (talus)
Estuarine	Formed in marine environments
Lacustrine	Formed in lakes
Residual	Formed by weathering insitu

Soil Moisture

	Term	Code	Description
Coarse Grained	Dry	D	Looks and feels dry and free running
	Moist	M	Soil feels cool, darkened in colour, soils tend to stick together, soil grains do not run freely through fingers and no visible free water
	Wet	W	Soil feels cool, darkened in colour, soils tend to stick together, free water on remoulding
Fine Grained	Moist, Less than Plastic Limit	W < PL	Hard and friable or powdery, moisture content well below Plastic Limit
	Moist, Near Plastic Limit	W ≈ PL	Soil feels cool, darkened in colour, can be moulded, near Plastic Limit
	Moist, Wet of Plastic Limit	W > PL	Soil feels cool, dark, usually weakened, free water, moisture content well above Plastic Limit
	Wet, Near Liquid Limit	W ≈ LL	Soil exudes easily
	Wet, Wet of Liquid Limit	W > LL	Soil behaves as a liquid

Boundary Classifications

Soils possessing characteristics of two groups are designated by combinations of group symbols. For example, GW-GC, well graded gravel-sand mixture with clay binder.

Graphic Symbols

■	Asphalt	▥	MH
▥	CH	▤	ML
▨	CI	▒	OH
▤	CL	▒	OL
▦	Concrete	▒	PT
▩	Fill	▨	SC
▩	GC	▨	SM
▩	GM	░	SP
▩	GP	▤	SW
▒	GW	▒	Topsoil

Soil Classification

Soils are described in general accordance with AS1726-2017 as shown below.

<table>
<tr><th colspan="6">FIELD IDENTIFICATION PROCEDURES
(Excluding particles larger than 63 mm and basing fractions on estimated mass)</th><th>GROUP SYMBOL</th><th>PRIMARY NAME</th></tr>
<tr><td rowspan="8">COARSE GRAINED SOILS
More than 65% of the material is less than 63 mm and is larger than 0.075 mm</td><td rowspan="17">A particle size of 0.075 is about the smallest size distinguishable to the naked eye</td><td rowspan="4">GRAVELS
More than half of coarse fraction is larger than 2.36 mm</td><td rowspan="2">CLEAN GRAVELS
(Little or no fines)</td><td colspan="2">Wide range in grain size and substantial amounts of all intermediate particle sizes, not enough fines to bind coarse grains, no dry strength; ≤ 5% fines</td><td>GW</td><td>GRAVEL</td></tr>
<tr><td colspan="2">Predominantly one size or a range of sizes with more intermediate sizes missing, not enough fines to bind coarse grains, no dry strength; ≤ 5% fines</td><td>GP</td><td>GRAVEL</td></tr>
<tr><td rowspan="2">GRAVELS w/ FINES
(Appreciable amount of fines)</td><td colspan="2">‘Dirty’ materials with excess of non-plastic fines, none to medium dry strength; ≥ 12% silty fines</td><td>GM</td><td>SILTY GRAVEL</td></tr>
<tr><td colspan="2">‘Dirty’ materials with excess of plastic fines, medium to high dry strength; ≥ 12% clayey fines</td><td>GC</td><td>CLAYEY GRAVEL</td></tr>
<tr><td rowspan="4">SANDS
More than half of coarse fraction is smaller than 2.36 mm</td><td rowspan="2">CLEAN SANDS
(Little or no fines)</td><td colspan="2">Wide range in grain size and substantial amounts of all intermediate particle sizes, not enough fines to bind coarse grains, no dry strength; ≤ 5% fines</td><td>SW</td><td>SAND</td></tr>
<tr><td colspan="2">Predominantly one size or a range of sizes with more intermediate sizes missing, not enough fines to bind coarse grains, no dry strength; ≤ 5% fines</td><td>SP</td><td>SAND</td></tr>
<tr><td rowspan="2">SANDS w/ FINES
(Appreciable amount of fines)</td><td colspan="2">‘Dirty’ materials with excess of non-plastic fines, none to medium dry strength; ≥ 12% silty fines</td><td>SM</td><td>SILTY SAND</td></tr>
<tr><td colspan="2">‘Dirty’ materials with excess of plastic fines, medium to high dry strength; ≥ 12% clayey fines</td><td>SC</td><td>CLAYEY SAND</td></tr>
<tr><td rowspan="9">FINE GRAINED SOILS
More than 35% of the material less than 63 mm is less than 0.075 mm</td><td colspan="6">IDENTIFICATION PROCEDURES ON FRACTIONS < 0.075 mm</td></tr>
<tr><td rowspan="4">SILTS AND CLAYS
Liquid Limit < 50%</td><th>DRY STRENGTH</th><th>DILATANCY</th><th>TOUGHNESS</th><th>GROUP SYMBOL</th><th>PRIMARY NAME</th></tr>
<tr><td>None to low</td><td>Slow to rapid</td><td>Low</td><td>ML</td><td>SILT</td></tr>
<tr><td>Medium to high</td><td>≥ 12% clayey fines</td><td>Medium</td><td>CL, CI*</td><td>CLAY</td></tr>
<tr><td>Low to medium</td><td>Slow</td><td>Low</td><td>OL</td><td>ORGANIC SILT</td></tr>
<tr><td rowspan="3">SILTS AND CLAYS
Liquid Limit > 50%</td><td>Low to medium</td><td>None to slow</td><td>Low to medium</td><td>MH</td><td>SILT</td></tr>
<tr><td>High to very high</td><td>None</td><td>High</td><td>CH</td><td>CLAY</td></tr>
<tr><td>Medium to high</td><td>None to very slow</td><td>Low to medium</td><td>OH</td><td>ORGANIC CLAY</td></tr>
<tr><td colspan="6">HIGHLY ORGANIC SOILS: readily identified by colour, odour, spongy feel and frequently fibrous texture</td><td>PT</td><td>PEAT</td></tr>
</table>

* CL is low plasticity clay, CI is medium plasticity clay

Description of Rock

i. Rock name (BLOCK LETTERS)
ii. Grain size and mineralogy
iii. Colour (i.e. dominant colour of material)
iv. Fabric and texture
v. Features, inclusions, minor components, moisture content and durability
vi. Strength
vii. Weathering and/or alteration
viii. Rock mass properties – discontinuities and structure of rock
ix. Interpreted stratigraphic unit
x. Additional observations including geological structure

Simple rock names are used to provide a reasonable engineering description, rather than a precise geological classification. The rock name is chosen by considering the nature and shape of the grains or crystals, the texture and fabric of the rock material, the geological structure and setting, and information from the geological map of the area. Further guidance on the naming of rocks can be found in AS1726-2017, Tables 15, 16, 17 and 18. Typical rock types are described below, though subject to site specific variations.

Rock Type	Description	Example of Rock Name
Sedimentary	Formed by deposited beds of sediments, have grains that are cemented together and often rounded. Significant porosity	COMMON: Conglomerate, Breccia, Sandstone, Mudstone, Siltstone, Claystone ≥90% CARBONATE: Limestone, Dolomite, Calcirudite, Calcarenite, Calcisiltite, Calcilutite PYROCLASTIC: Agglomerate, Volcanic Breccia, Tuff
Igneous	Formed from molten rock and have a crystalline texture. Typically massive and low porosity. Rock types are from coarse to fine grained.	HIGH QUARTZ CONTENT: Granite, Microgranite, Rhyolite MODERATE QUARTZ CONTENT: Diorite, Microdiorite, Andesite LOW QUARTZ CONTENT: Gabbro, Dolerite, Basalt
Metamorphic	Formed when rocks are subject to heat and/or pressure and have typically have directional fabric. Typically have low porosity and crystalline structure. Rock types are from coarse to fine grained	FOLIATED: Gneiss, Schist, Phyllite, Slate NON-FOLIATED: Marble, Quartzite, Serpentinite, Hornfels
Duricrust	Formed as part of a weathering profile and show evidence of being cemented in situ. Cementation is typically irregular and exhibits replacement textures.	Ferricrete (Iron oxides and hydroxides) Silicrete (Silica) Calcrete (Calcium carbonate) Gypcrete (Gypsum)

Note: ( ) denotes dominant cementing mineralogy

Grain Size

Terms describing dominate grain size in sedimentary rocks.

Term	Grain size
Coarse	Mainly 0.6 mm to 2.0 mm
Medium	Mainly 0.2 mm to 0.6 mm
Fine	Mainly 0.06 mm (just visible) to 0.2 mm

Terms describing dominate grain size in igneous and metamorphic rocks

Term	Grain size
Coarse	Mainly greater than 2 mm
Medium	0.06 mm to 2 mm
Fine	Mainly less than 0.06 mm (just visible) to 0.2 mm

Texture and Fabric

Sedimentary rocks

Thickness	Bedding Term
< 6 mm	Thinly laminated
6 – 20 mm	Laminated
20 – 60 mm	Very thinly bedded
60 – 200 mm	Thinly bedded
0.2 – 0.6 m	Medium bedding
0.6 – 2 m	Thickly bedded
> 2 m	Very thickly bedded

Igneous rocks

Term	Definition
Amorphous	Indicates that the rock has no obvious crystalline structure
Crystalline	A regular molecular structure, showing crystal structure and symmetry.
Cryptocrystalline	The texture comprises crystals that are too small to recognise under an ordinary microscope. Indistinctly crystalline.
Porphyritic	Indicates the presence of phenocrysts (relatively large crystals in a fine grained ground mass) in igneous rocks.
Flow banded	Indicates visible flow lines in volcanic rocks and some intrusive rocks
Glassy	Entirely glass like. No crystalline units and without crystalline structure.
Vesicular	A texture of volcanic rocks that indicates the presence of vesicles (small gas bubbles). Where the vesicles are filled with a mineral substance they are termed Amygdales and the texture is Amygdaloidal.

Metamorphic

Term	Definition
Foliation	The parallel arrangement of minerals due to metamorphic process, which shall be defined by the terms in weak, moderate and strongly foliated.
Porphyroblastic	A texture indicating the presence of porphyroblasts (larger crystals formed by recrystallization during metamorphism, such as garnet or staurolite in a mica schist).
Cleavage	A type of foliation developed in fine grained metamorphic rocks such as slates.

Bedding and Fabric Development

Type	Definition
Massive	No obvious development of bedding – rock appears homogeneous
Poorly Developed	Bedding is barely obvious as faint mineralogical layering or grain size banding, but bedding planes are poorly defined.
Well Developed	Bedding is apparent in outcrops or drill core as distinct layers or lines marked by mineralogical or grain size layering.
Very Well Developed	Bedding is often marked by a distinct colour banding as well as by mineralogical or grain size layering.
Indistinct Fabric	There is little effect on strength properties
Distinct Fabric	The rock may break more easily parallel to the fabric

Rock Strength

Term (Code)	UCS (MPa)	$Is_{(50)}$ (MPa)	Field Guide to Strength
Very Low (VL)	0.6 - 2	> 0.03 to ≤ 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 3 cm thick can be broken by finger pressure.
Low (L)	2 - 6	> 0.1 to ≤ 0.3	Easily scored with a knife; indentations 1 mm to 3 mm show in the specimen with firm blow of the pick point; has dull sound under hammer. A piece of core 150 mm long 50 mm in diameter may be broken by hand. Sharp edges of core may be friable and break during handling.
Medium (M)	6 - 20	> 0.3 to ≤ 1.0	Readily scored with a knife; a piece of core 150 mm long by 50 mm in diameter can be broken by hand with difficulty.
High (H)	20 - 60	> 1 to ≤ 3	A piece of core 150 mm long by 50 mm in diameter cannot be broken by hand but can be broken by a pick with a single firm blow; rock rings under hammer.
Very High (VH)	60 - 200	> 3 to ≤ 10	Hand specimen breaks with pick after more than one blow; rock rings under hammer.
Extremely High (EH)	> 200	> 10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer.

Rock strength is assessed by laboratory Uniaxial Compressive Strength (UCS) testing and/or Point Load Strength Index (PLT) testing to obtain the $Is_{(50)}$ the strength table implies a 20 times correlation between $Is_{(50)}$ and UCS used for classification. Note however, multiplier may range from 4 (e.g. some carbonated and low strength rocks) to 40 (e.g. some igneous rocks and/or some high strength rocks). A site specific correlation based on testing, previous investigation or literature may be used where available. These terms refer to the strength of the rock material and not to the strength of the rock mass which may be considered weaker due to the effect of rock defects.

Visual Log

A diagrammatic plot of defects showing type, spacing and orientation in relation to the core axis.

———	Defects open in situ or clay sealed
- - - - - - - -	Defects closed in-situ
••••••••••••	Drill induced fractures or handling breaks
▬	Infilled seam

Rock Weathering and or Alteration Classification

Term (Code)		Definition	
Residual soil (RS)		Soil developed on extremely weathered rock. The rock mass structure and substance fabric are no longer evident but the soil has not been significantly transported.	
Extremely weathered (XW) Extremely altered (XA)		Rock is weathered to such an extent that it has 'soil' properties, i.e, it either disintegrates or can be remoulded in water, but the texture of original rock is still evident.	
Highly weathered (HW) Highly Altered (HA)	Distinctly weathered (DW)* Distinctly Altered (DA)	Whole rock material is discoloured usually by extent that iron staining or bleaching and other signs of chemical or physical decomposition are evident. Porosity and strength may be increased or decreased compared to the fresh rock usually as a result of iron leaching or deposition. The colour and strength of the original rock substance is no longer recognisable	*Where is it not practical to distinguish between 'HW' and MW'. Rock strength usually changed by weathering. The rock may be highly discoloured, usually by iron staining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores
Moderately weathered (MW) Moderately Altered (MA)		Whole rock material is discoloured usually by staining that original colour of the fresh rock is no longer recognisable	
Slightly weathered (SW) Slightly altered (SA)		Rock is slightly discoloured but shows little or no change of strength from fresh rock	
Fresh rock (FR)		Rock shows no sign of decomposition or staining.	

Rock Core Recovery

TCR = Total Core Recovery (%)

$$\frac{\textbf{Length of Core Recovered}}{\textbf{Length of Core run}} \times 100$$

SCR = Solid Core Recovery (%)

$$\frac{\textbf{Sum Length of Cylindrical Core Recovered}}{\textbf{Length of Core run}} \times 100$$

RQD = Rock Quality Designation (%)

$$\frac{\textbf{Sum Length of Sound Core Pieces > 100mm in length}}{\textbf{Length of Core run}} \times 100$$

Types of Defects

Term		Code	Description
Parting		PT	A surface or crack across which the rock has little or no tensile strength. Parallel or sub-parallel to layering (e.g. bedding) or a planar anisotropy in the rock material (i.e. cleavage). May be opened or closed.
Joint		JT	A surface or crack with no apparent shear displacement and across which the rock has little or no tensile strength, but which is not parallel or sub-parallel to layering or to planar anisotropy in the rock material. May be open or closed.
Sheared Surface		SR	A near planar, curved or undulating surface which is usually smooth, polished or slickensided and which shows evidence of shear displacement.
Sheared Zone		SZ	Zone of rock material with roughly parallel, near planar, curved, or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects. Some of the defects are usually curved and intersect to divide the mass into lenticular or wedge-shaped blocks.
Crushed Zone [a]		CZ	A zone of broken and disturbed ground containing more than one identifiable Crushed Seam.
Fracture Zone [a]		FZ	A zone of broken ground with parallel to opposing boundaries dominated by abundant, extremely closely to closely spaced defects, which may be intact or open, and planar, curved, undulating, irregular, or stepped, resulting in a dissected rock mass of angular trapezoidal, triangular or rectangular fragments.
Seam (SE)	Sheared Seam	SS	Seam of soil material with roughly parallel almost planar boundaries, composed of soil materials with roughly parallel near planar, curved or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects. Some of the defects are usually curved and intersect to divide the mass into lenticular or wedge-shaped blocks.
	Crushed Seam	CS	Seam of soil material with roughly parallel almost planar boundaries, composed of disoriented, usually angular fragments of the host rock material which may be more weathered than the host rock. The seam has soil properties.
	Infilled Seam	IS	Seam of soil material usually with distinct roughly parallel boundaries formed by the migration of soil into an open cavity or joint, infilled seams less than 1 mm thick may be described as a veneer or coating on a joint surface.
	Extremely Weathered Seam	XS	Seam of soil material, often with gradational boundaries. Formed by weathering of the rock material in place.
Fault [b]		FT	A fracture (defect) or fracture zone along which there has been an observable amount of displacement.
Vein [c]		VE	Any fracture that contains mineralized material. Veins can display either crack-normal extension or shear displacement coupled with crack-normal extension.
Vugh [a]		VG	An open void with secondary crystallisation which may be coated, partly or nearly completely filled.
Void [a]		VO	An open space created through natural or anthropogenic processes, including, but not limited to, caves, kettles, tunnels, mines, pipes, piping, landslides, faulting, shearing, dissolution, & erosion.
Mechanical Break		MB	A fracture or break induced or created by the sampling process (i.e. drilling (DB) handling (HB), drill lift (DL), excavation, or blasting).

All definitions as per AS1726-2017, except:

[a] SMEC Field Manual,
[b] British Standard BS 5930:2015, and
[c] Glossary of Geology (Fifth Edition - revised) (2011), American Geosciences Institute.

Defect Planarity

Code	Description
CR	Curved – A defect with a gradual change in orientation
IR	Irregular – A defect with many sharp changes in orientation
PL	Planar – Defect forms a continuous plane without variation in orientation
ST	Stepped – A defect with distinct sharp steps or step
UN	Undulose – A defect with undulations

Defect Roughness

Code	Description
RO	Rough – Many small surface irregularities generally related to the grain size of the parent rock
SM	Smooth – Few or no surface irregularities related to the grain size of the parent rock
PO	Polished – Planes have a distinct sheen or a smoothness
SL	Slickensided – Planes have a polished, grooved or striated surface consistent with differential movement of the parent rock along the plane
VR	Very rough – many large surface irregularities, amplitude generally more than 1mm

Type of Structures

Term	Code	Description
Bedding	BD	A layered arrangement of minerals parallel to the surface of deposition which has caused planar anisotropy in the rock substance.
Cleavage	CV	An alignment of fine grained minerals caused by deformation.
Schistosity	SH	A layered arrangement of minerals to each other
Foliation	FO	A planar alignment of minerals caused by deformation.
Void	VO	A completely empty space
Dyke	DK	Sheet-like bodies of igneous rock that cut across sedimentary bedding or foliations in rocks. They may be single or multiple in nature
Sill	SL	A sill is an intrusion of magma that spreads underground between the layers of another kind of rock
Contact	CX	A contact between intrusive and stratigraphic units.
Boundary	BN	A distinct boundary between two stratigraphic units
Vugh	VG	An open void with crystalisation

Note: Drill breaks (DB) and handling breaks (HB) are not included as natural discontinuity.

Discontinuity Spacing

Spacing (mm)	Description
> 6000	Extremely Widely Spaced
2000 - 6000	Very Widely Spaced
600 - 2000	Widely Spaced
200 - 600	Medium Spaced
60 - 200	Closely Spaced
20 - 60	Very Closely Spaced
< 20	Extremely Closely Spaced

Infill Material

Code	Name	Code	Name
Ap	Apatite	Ga	Galena
Ca	Calcite	Gp	Gypsum
Ch	Chlorite	Mn	Manganese
Cl	Clay	MnO	Manganese Oxide
Co	Coal	MS	Secondary mineral
Ep	Epidote	Py	Pyrite
Fe	Limonite/ Ironstone/ Goethite	Um	Unidentified mineral
FeO	Iron oxide	Qz	Quartz
Fs	Feldspar	X	Carbonaceous
		Ze	Zeolite

Discontinuity Observation

Term	Code	Description
Clean	CN	No visible coating or infill
Stain	SN	No visible coating or infill but surfaces are discoloured by mineral staining
Veneer < 1 mm	VN	A visible coating or soil or mineral substance but usually unable to be measured. If discontinuous over the plane, patchy veneer.
Coating > 1 mm to < 10 mm	CT	A visible coating or infilling of soil or mineral substance. Describe composition and thickness.
Filling (Filled) > 10 mm	FD	A visible filling of soil or mineral substance. Describe composition and thickness.

Discontinuity Orientation

Code	Description
VT	Vertical
HO	Horizontal
RL	Top right to bottom left
LR	Top left to bottom right

Samples and Field Tests

Code	Description
B	Bulk disturbed sample
BLK	Block sample
C	Core sample
CBR	CBR Mould Sample
CPT_u	Cone Penetration Test (with pore pressure)
DT	Dilatometer
DS	Small disturbed sample
ES	Soil sample for environmental testing
EW	Water sample for environmental testing
FP	Pressuremeter
G	Gas sample
H	Hydraulic fracturing
HP	Hand penetrometer test
I	Impression device
$Is_{(50)}$	Point Load Index
K	Permeability
LB	Large bulk disturbed sample
N	Standard penetration test result (N* denotes SPT sample recovery)
O	Core orientation
P	Piston sample
PID	Photoionisation detector reading in ppm
PP	Penetrometer
R	Hammer bouncing / refusal
SPT	Standard Penetration Test
U	Undisturbed push in sample
UCS	Uniaxial Compressive Strength
U50	Undisturbed tube sample (50 mm diameter)
U75	Undisturbed tube sample (75 mm diameter)
U100	Undisturbed tube sample (100 mm diameter)
VS	Vane shear test
● (A)	Axial Test
○ (D)	Diametral Test
☐	Irregular Lump test

Laboratory Tests

Code	Description
ACM	Asbestos Containing Material
CD	Consolidated Drained
CU	Consolidated Undrained
LL	Liquid Limit
LS	Linear Shrinkage
MC	Moisture Content
MDD	Maximum Dry Density
OMC	Optimum Moisture Content
PBT	Plate Bearing Test
PI	Plasticity Index
PL	Plastic Limit
PSD	Particle Size Distribution
ρ_b	Bulk Density
ρ_p	Particle Density
ρ_d	Dry Density
UU	Undrained Unconsolidated

Backfill / Standpipe Detail

Symbol	Description	Symbol	Description
⁙	Cement seal	░	Filter pack: sand filter
▬	Grout backfill GP -Cement BE - Bentonite Cement	∴	Filter pack: gravel filter
▯	Un-slotted pipe	■	Bentonite seal
▤	Slotted pipe	▦	Cutting – excavated material backfill
⊓	Surface Completion: Monument Above Ground	⊔	Surface Completion: Gatic Ground Monument

Completion Details

Type	Description
Collapse	Exploratory hole collapsed before reaching planned depth
Equipment Failure	Boring or excavator equipment operational failure
Flooding	Flooding of excavation
Machine Limit	Limit of machine capability reached
Obstruction	Obstruction preventing further advancement
Operator Limit	Limit of operator limit/safety reached
Possible services	Indication of possible services below
Services present	Services encountered during exploratory hole
Squeezing	Hole squeezing boring equipment
Target Depth	Depth reached as planned
Target Depth (Instrumentation Installed)	Depth reached as planned instrumentation installed
Target Depth (Standpipe Installed)	Depth reached as planned open standpipe constructed
Material Refusal	Material preventing further advancement

Status

Code	Description
-2	Historic
-1	For information
0	Preliminary
1	Checked
2	Draft
3	Final

Geological & Engineering Log

Project	Packing Plant	East	281865.0 m	Start Date	27/06/2019	Contractor	Total Drilling
Client	Manildra	North	6140465.0 m	End Date	27/06/2019	Rig Type	Hanjin 8D
Site	Bolong Road Bomaderry	Elevation	2.53 m			Mounting	Track
Job Number	3001550	Datum	MGA94 Zone 56/AHD				

Inclination 90°
Azimuth
North
Survey

Borehole Identifier: **SBH01**

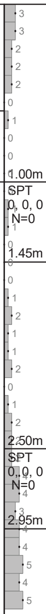
Method: ADT (0.0 – 4.0 m); WB (4.0 – 6.0 m)

Casing Support: Steel Casing - HW (114.3 mm) mm (0.0 – 4.0 m)

Water: level marked at 0.60 m

Depth (m)	Depth RL	Soil Code	Soil / Rock Material Description	Moisture Condition	Consistency Density	Origin, Stratigraphic Unit & General Observations
0.0	2.53	MI	TOPSOIL Clayey SILT trace sand: dark brown, medium plasticity, with fine to medium sand, abundant rootlets and organic matter.	W≈ PL	St	TOPSOIL
0.40	2.13	CH	Silty CLAY trace sand: high plasticity, dark grey, silt, trace fine sand and rootlets.	W>PL		ESTUARINE
0.60	1.93	CH	CLAY with silt with sand: high plasticity, dark grey, trace brown, with silt and with fine grained sand.		VS	1.00: SPT Recovery: 0.45 m; Sank 450mm 2.50: SPT Recovery: 0.45 m; Sank 450mm
2.70	-0.17	CL	Sandy CLAY with gravel: low plasticity, dark grey, fine to medium grained sand with silt, with coarse, sandstone gravel, trace sea shell and fossils. 3.80 m: Possible cobbles from 3.80m to 4.00m		S St (from 4.0 m)	4.00: SPT Recovery: 0.45 m
4.30	-1.77	CH	CLAY with silt trace sand: high plasticity, orange brown mottled red brown and pale grey, with silt and trace fine sand.			ALLUVIAL 5.50: SPT Recovery: 0.45 m

Sampling	Testing
CBR (0.60 – 1.00 m)	1.00m SPT 0, 0, 0 N=0 1.45m
	2.50m SPT 0, 0, 0 N=0 2.95m
U75 (3.50 – 4.00 m)	4.00m SPT 2, 3, 5 N=8 4.45m
	5.50m SPT 4, 5, 7 N=12 5.95m



Installation: SBH01

Observations and Comments
Backfilled on Completion

Penetrometer Notes
Type: DCP9
Blows per 100 mm

Notes
Classifications compliant with AS1726-2017: Geotechnical Site Investigations unless otherwise noted.
Defect Log Abridged. Additional detail in digital dataset. Lugeon: BS5930:1999
For Inclined Holes: Angles reported in defects are apparent dip from core horizontal unless as α or β.
Refer to explanatory notes for SMEC logs for details of abbreviations or basis of description.

Logged By	GRR	Date	27/06/2019
Approved By	SM	Date	30/08/2019
Status	Final	Page	1 of 3

Geological & Engineering Log

Project Packing Plant
Client Manildra
Site Bolong Road Bomaderry
Job Number 3001550

East 281865.0 m
North 6140465.0 m
Elevation 2.53 m
Datum MGA94 Zone 56/AHD

Start Date 27/06/2019
End Date 27/06/2019

Contractor Total Drilling
Rig Type Hanjin 8D
Mounting Track

Inclination 90°
Azimuth
North
Survey

Borehole Identifier: **SBH01**

Method	Depth (m)	Elevation	Testing: Strength SPT, DCP, Is(50) (MPa), PP (UCS kPa), SV (kPa)	Soil Code	Depth RL	Soil / Rock Material Description	Moisture Condition	Consistency Density	Origin, Stratigraphic Unit & General Observations
WB	6.0	-3.5		CH		CLAY with silt trace sand: high plasticity, orange brown mottled red brown and pale grey, with silt and trace fine sand. *(continued)*	W>PL	St	ALLUVIAL
				CI	6.40 -3.87	CLAY with gravel with sand: medium plasticity, red brown, orange brown, with highly weathered, fine to medium, sub-angular gravel, fine to medium sand (possible residual).	W≈PL	H	
	7.0	-4.5	7.00m SPT 9, 10, 14 N=24 7.45m	CH	7.00 -4.47	CLAY trace sand trace gravel: high plasticity, red brown, orange, with fine to medium grained sand, trace fine to medium, highly weathered gravel.		VSt	RESIDUAL SOIL 7.00: SPT Recovery: 0.45 m
	8.0	-5.5	8.50m SPT 8, 11, 14 N=25 8.95m						8.50: SPT Recovery: 0.45 m
	9.0	-6.5				9.10 m: Becoming pale grey below 9.10m			
	10.0	-7.5				10.50 m: With some intermittent bands of highly weathered gravel with medium sand below 10.50m			
	11.0	-8.5							
	12.0								

Observations and Comments
Backfilled on Completion

Penetrometer Notes
Type: DCP9
Blows per 100 mm

Notes
Classifications compliant with AS1726-2017: Geotechnical Site Investigations unless otherwise noted.
Defect Log Abridged. Additional detail in digital dataset. Lugeon: BS5930:1999
For Inclined Holes: Angles reported in defects are apparent dip from core horizontal unless as α or β.
Refer to explanatory notes for SMEC logs for details of abbreviations or basis of description.

Logged By GRR Date 27/06/2019
Approved By SM Date 30/08/2019
Status Final

Geological & Engineering Log

Project	Packing Plant	East	281865.0 m	Start Date	27/06/2019	Contractor	Total Drilling
Client	Manildra	North	6140465.0 m	End Date	27/06/2019	Rig Type	Hanjin 8D
Site	Bolong Road Bomaderry	Elevation	2.53 m			Mounting	Track
Job Number	3001550	Datum	MGA94 Zone 56/AHD				

Inclination 90°
Azimuth
North
Survey

Borehole Identifier: **SBH01**

Method	Casing Support	Water (Gain/Loss)	Run (TCR) RQD	Sampling	Testing: Strength SPT, DCP, Is(50) (MPa), PP (UCS kPa), SV (kPa)	Permeability, Level & Inflow	Depth (m) *Elevation*	Graphic Log	Soil Code	*Depth* RL	Soil / Rock Material Description	Moisture Condition	Consistency Density	Colour	Weathering & Alteration	Rock Strength	Inferred Rock Strength Point Load Is(50) ● - Axial ○ - Diametral (VL -0.1 L -0.3 M -1 H -3 VH -10 EH)	Relative Strength Soil-Rock	Defect Spacing (mm) (0 2 20 200 2000)	Visual	Fabric, Structure & Defect Description	Group Defects	Origin, Stratigraphic Unit & General Observations	Installation
WB							12.0 *-9.5*		CH		CLAY trace sand trace gravel: high plasticity, red brown, orange, with fine to medium grained sand, trace fine to medium, highly weathered gravel. *(continued)*	W≈PL	VSt										RESIDUAL SOIL	
							13.0 *-10.5*																	13.0
					13.20m SPT 17, 10/20 mm HB N=R 13.37m					*13.20* -10.67 *13.45*	SANDSTONE (100%): medium grained, low strength, highly weathered, pale grey, red brown, medium grained sandstone.	M	H										WEATHERED ROCK (SANDSTONE) 13.20: SPT Recovery: 0.17 m	13.5
											Hole Terminated at 13.45 m Target depth													
							14.0 *-11.5*																	14.0
							15.0 *-12.5*																	15.0
							16.0 *-13.5*																	16.0
							17.0 *-14.5*																	17.0
							18.0																	

Observations and Comments
Backfilled on Completion

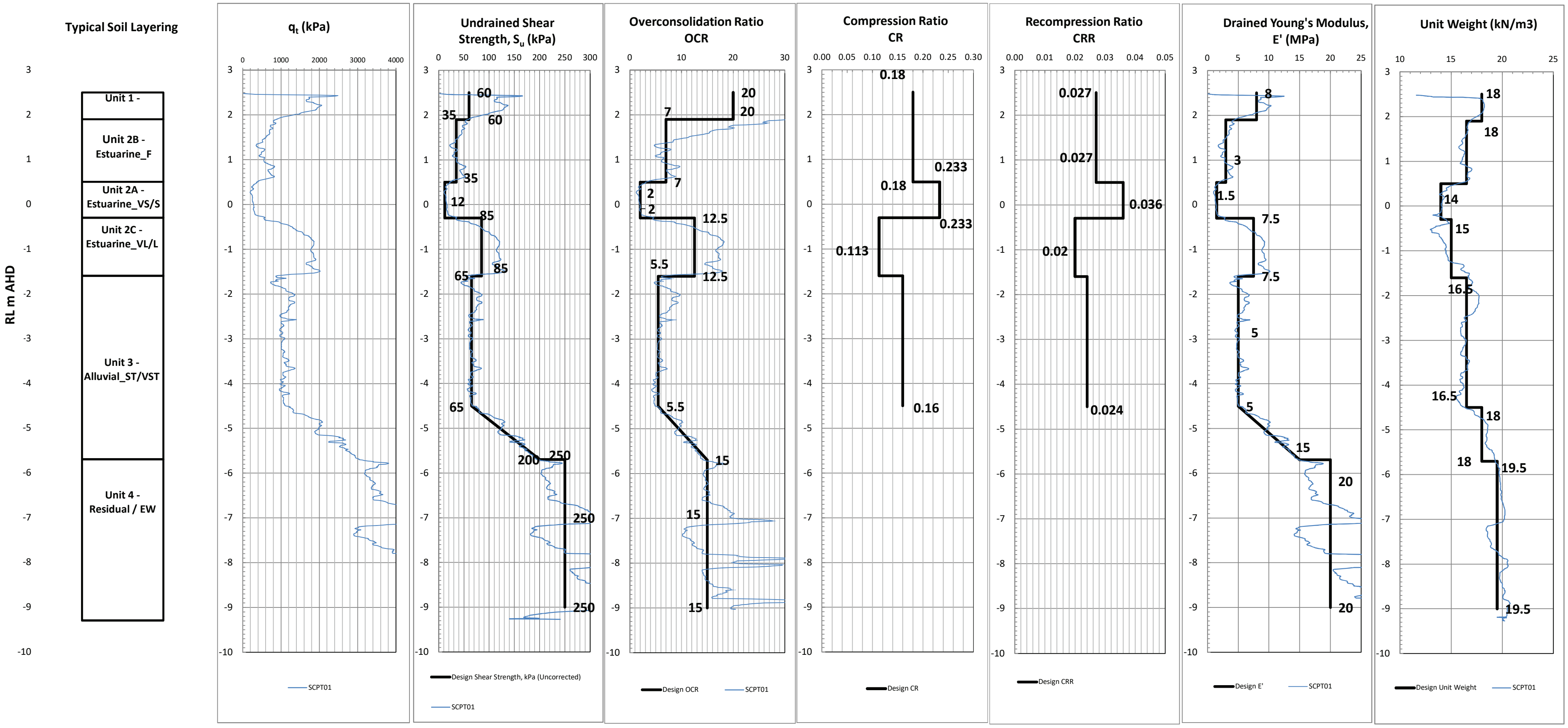
Penetrometer Notes
Type: DCP9
Blows per 100 mm

Notes
Classifications compliant with AS1726-2017: Geotechnical Site Investigations unless otherwise noted.
Defect Log Abridged. Additional detail in digital dataset. Lugeon: BS5930:1999
For Inclined Holes: Angles reported in defects are apparent dip from core horizontal unless as α or β.
Refer to explanatory notes for SMEC logs for details of abbreviations or basis of description.

Logged By	GRR	Date	27/06/2019
Approved By	SM	Date	30/08/2019
Status	Final	Page	3 of 3

Manildra - Packing Plant

Interpretation of Test Results: SCPT01



SMEC
Member of the Surbana Jurong Group

PROJECT	Manildra - Packing Plant
PROJECT NUMBER	3001550
TITLE	-
PREPARED BY	KK
CHECKED BY	KK
DATE	14/05/2020
CHAINAGE (m)	-
BH/CPT USED:	SCPT01

PROJECT:	**3001550_Manildra - Packing Plant**
Test ID:	SCPT01
Surface RL (m):	2.48
Watertable Depth (m):	1.50

Member of the Surbana Jurong Group

Top RL	**Depth (m)**			**Soil Type**	**γ**	**CR=C_{ce}**	**CRR=C_{re}**	**OCR**	**c_u**	**c'**	**ϕ'**	**c_v**	**k_v**	**E'**	**ν**
	from	**to**	**z**		**(kN/m^3)**				**(kPa)**	**(kPa)**	**(degs)**	**(m^2/yr)**	**(m/sec)**	**(MPa)**	
2.48	0.00	0.58	0.58	Unit 1 - Topsoil/Crest	18.0	0.180	0.027	20.0	60	4	27	7	1.0E-08	8.0	0.3
1.9	0.58	1.98	1.40	Unit 2B - Estuarine_F	16.5	0.180	0.027	7.0	35	4	27	7	1.0E-09	3.0	0.3
0.5	1.98	2.78	0.80	Unit 2A - Estuarine_VS/S	14.0	0.233	0.036	2.0	12	2	25	5	1.0E-09	1.5	0.3
-0.3	2.78	4.08	1.30	Unit 2C - Estuarine_VL/L	15.0	0.113	0.020	12.5	85	0	32	-	1.0E-07	7.5	0.3
-1.6	4.08	8.18	4.10	Unit 3 - Alluvial_ST/VST	16.5 - 18.0	0.160	0.024	5.5 - 15	65 - 200	5	28	8	1.0E-08	5 - 15	0.3
-5.7	8.18	11.75	3.57	Unit 4 - Esidual / EW	19.5	-	-	5.5 - 20	65 - 280	10	30	-	-	20	0.3
-9.27	Termination depth														

"Crown Tower, Level 11", 200 Crown Street
Wollongong, New South Wales 2500
Australia
www.ghd.com

Your ref: Email from S. Richardson, dated 1/2/2022, 4:15pm
Our ref: 12548413

14 February 2022

Stephen Richardson
Manildra Group
C/- Cowman Stoddart
PO Box 738
NOWRA NSW 2541

Gas Pipeline Mod 2 – Soft soil occurrence in relation to underbore below Abernethy's Creek, Bolong Road, Bomaderry, NSW

Dear Steve

1. Introduction

1.1 General

Manildra Group Pty Ltd (Manildra) was previously granted project approval for Concept Plan (MP10_0144) and Project Application (MP_10_0108) for the Shoalhaven Starches Gas Pipeline Project in 2012 by the Independent Planning Commission. Manildra submitted a Modification Application (Modification No. 1 (Mod 1)) to the NSW Department of Planning, Industry and Environment (DPIE) in March 2021 (ref: MP06_0228, dated 26 March 2021). GHD Pty Ltd (GHD) prepared a Geotechnical assessment of Riverbank Stability (Abernethy's Creek); Acid Sulfate Soil (ASS) and Contamination assessments as part of the supporting documents required for Mod 1 (report reference: 12548413-55889-10, dated 2 July 2021).

Manildra is seeking a second modification (Mod 2) changing the alignment of the gas pipeline due to constraints posed to the Mod 1 alignment by existing underground services and infrastructure. The proposed new alignment extends east from the Gas Pressure Reduction Facility (GPRF), passing under Abernethy's Creek, then continuing south across Bolong Road terminating near Fermenter No. 2. GHD prepared a Geotechnical assessment of Riverbank Stability (Abernethy's Creek); ASS and Contamination assessments as part of the supporting documents required for Mod 2 (report reference: 12548413-12952-22, dated 24 December 2021).

Based on the limited available subsurface information, soft to very soft soils are expected to occur in the vicinity of the watercourse crossing. GHD's assessment of the proposed underboring (Horizontal Directional Drill (HDD)) for the gas pipeline below Abernethy's Creek raised concerns in regard to the pipe installation and possible frac-out through the soft soils into the watercourse. The potential for excessive settlement of the pipe following installation was also raised as a concern (GHD, 2021b). In order to provide additional information on the subsurface conditions either side of the creek to inform the HDD design and methodology, Manildra requested GHD carry out geotechnical boreholes on the eastern and western sides of Abernethy's Creek. Based on subsurface conditions encountered during the intrusive investigation, GHD will review and where applicable update our advice concerning the underbore.

1.2 Purpose of this report

The purpose of this report is to provide Manildra with additional information in relation to the subsurface conditions on the eastern and western sides of Abernethy's Creek for the HDD Contractor to consider in their underbore design and drilling methodology.

1.3 Limitations

This report: has been prepared by GHD for Manildra Group and may only be used and relied on by Manildra Group for the purpose agreed between GHD and Manildra Group as set out in Section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than Manildra Group arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring after the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

This report was prepared for Manildra Group based on the objectives and scope of work listed in Sections 1.1,1.2 and 2. No warranty, expressed or implied, is made as to the information and professional advice included in this report. Anyone using this document does so at their own risk and should satisfy themselves concerning its applicability and, where necessary, should seek expert advice in relation to the particular situation.

This report is to be read in conjunction with document titled "General Notes" (Ref: DS5.5.1 Issue 0 Date: 05/10/2018), in of this report.

2. Scope of work

Therefore, the following scope of work was carried out to provide Manildra with additional information on the subsurface conditions for the proposed underbore (HDD):

- Site walkover to assess drilling rig access and service location. Service location was undertaken by an accredited service locator.
- One borehole drilled on the western side of Abernethy's Creek to a maximum depth of 11 m below ground level (bgl) with Standard Penetration Tests (SPTs) carried out at 1 m intervals.
- Two Dynamic Cone Penetrometer (DCP) tests were carried out on the eastern side of Abernethy's Creek to depths of 3.9 m and 4.8 m bgl.
- Preparation of this letter report summarising the results of fieldwork and discuss findings of subsurface conditions in relation underboring activities, and review, and where applicable, update our advice concerning the underbore.

3. Fieldwork

Fieldwork was undertaken on 6, 7 and 11 February 2022, managed by a geo-environmental scientist from GHD.

One borehole location, GBH01, was drilled using a track mounted drilling rig equipped with 100 mm solid flight augers fitted with a tungsten carbide (TC) bit to a maximum depth of 11 m bgl. SPTs were carried out at 1 m intervals to assess density and consistency of the soil profile. Borehole location GBH01 was drilled at approximately 3 m offset from the proposed HDD alignment and approximately 20m south-west of the SMEC borehole location SBH01. Upon removal of the augers, the borehole collapsed to approximately 1 m bgl. The upper 1 m was reinstated with bentonite to 0.5 m bgl followed by concrete for the remaining 0.5 m.

Due to access constraints on the eastern side of Abernethy's Creek, two DCP tests were carried out, DCP01 and DCP02, to depths of 3.9 m and 4.8 m bgl, respectively. DCP01 was positioned close to the proposed underbore alignment and DCP02 was approximately 15 m north-east of the alignment. DCP test results are included in Attachment 3.

The logging of the borehole was carried out according to Australian Standard AS1726-2017 and GHD's standard operating procedures. Engineering logs for borehole locations GBH01 and SBH01 are included in Attachment 2. The approximate location of boreholes and DCPs are shown in Figure 1 below. We understand that Manildra will arrange for a surveyor to record the spatial position and elevation of GBH01, as this is required by the HDD contractor to manage frac-out. GHD has recorded the approximate location with a handheld GPS with coordinates shown on the borehole log for GBH01 and have marked the actual position of the borehole on-site with a wooden stake.

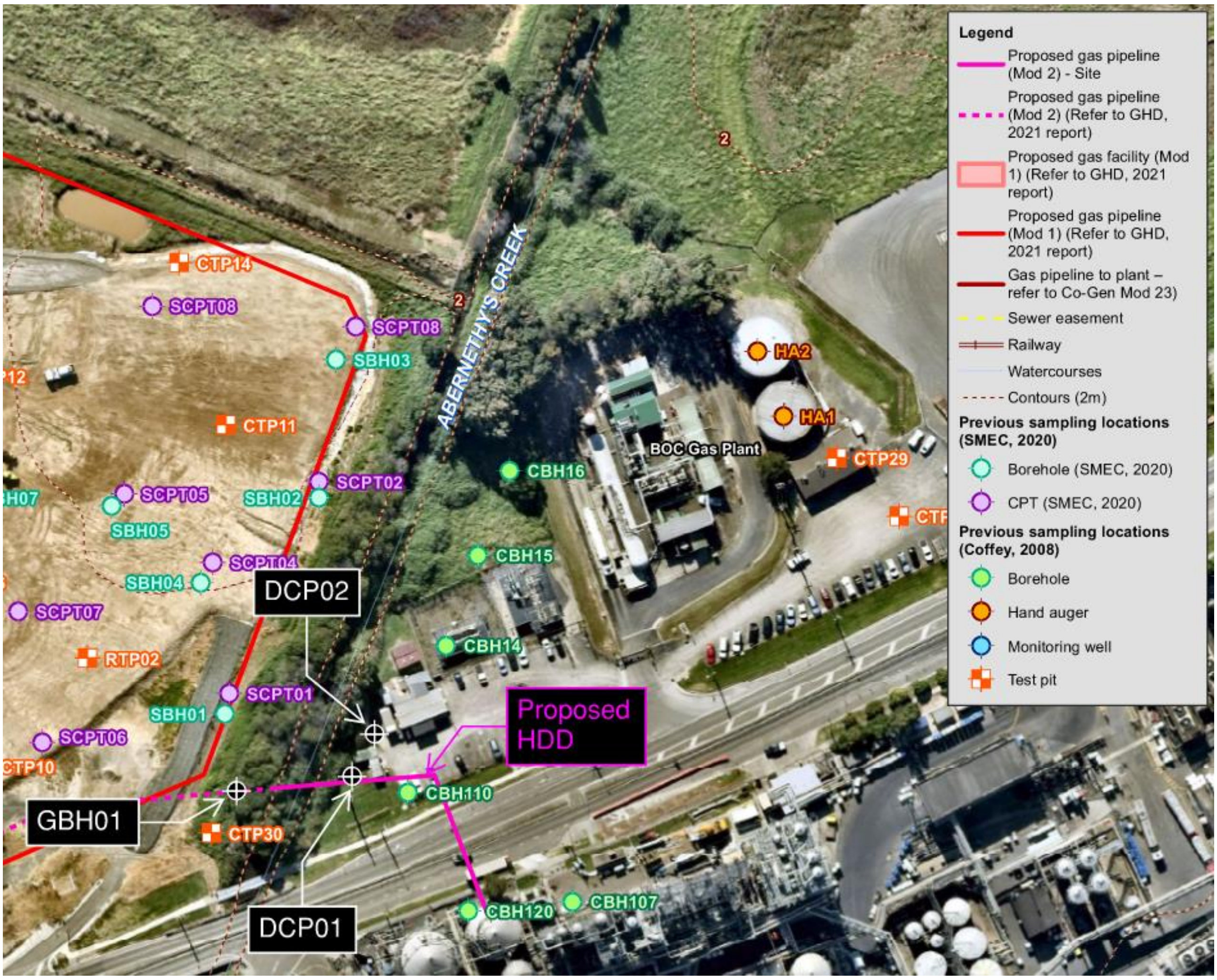


Figure 1 *Site layout plan showing approximate borehole and DCP locations*

4. Results

4.1 Subsurface conditions

4.1.1 Western side of Abernethy's Creek

Soft and very soft clay soils were encountered at borehole location SBH01 to a depth of 4 m bgl, west of Abernethy's Creek and approximately 20 m north of the proposed HDD alignment. The clays were estuarine and described as dark grey high plasticity with silts, sands and shell fragments. No anthropogenic materials were noted (SMEC, 2020). Stiff alluvial soil described as clay, with silt and trace sand, high plasticity, orange-brown mottled red-brown, becoming very stiff to hard residual clay with gravel from 6.4 m bgl. Highly weathered sandstone was encountered from 13.2 m bgl.

The subsurface conditions encountered at borehole location GBH01 differed from those at SBH01, however the consistency was similar where soft to very soft clayey silt was encountered between 0.1 m and 2.8 m bgl, overlying loose clayey sands from 2.8 m to 3.5 m bgl. Stiff sandy clays were encountered below 3.5 m, becoming very stiff from 5.9 m bgl. Dark grey estuarine clays with shell fragments were not encountered at GBH01. The lithology comprised alluvium overlying residual/extremely weathered rock. SBH01 appears to be situated in a transition zone for an alluvial plain deposit and an associated ASS occurrence within 1 m of the ground surface. The mapped depth to ASS increases towards Bolong Road to between 1 m and 3 m below ground surface, at the position of GBH01. This may account for the differences in lithology observed between the two boreholes.

Groundwater inflow occurred in GBH01 at 2.7 m which was deeper than the groundwater inflow observed at SBH01 which was recorded at 0.6 m bgl. The water level in Abernethy's Creek measured from the underside of the pedestrian footbridge adjacent to Bolong Road, was approximately 3.2 m. The base of the creek bed was approximately 3.45 m from the underside of the footbridge.

4.1.2 Eastern side of Abernethy's Creek

DCP results for DCP01, close to the HDD alignment, indicate soft soils occur between 0.9 m and 1.9 m bgl, with soft to firm soils from 1.9 m to 2.5 m. DCP results for DCP02 were similar to DCP01 where soft soils occurred between 0.9 m and 2.1 m bgl. Deeper soft soils are known to occur further to the east within the BOC gas plant and on the eastern side of the plant.

5. Conclusions

The additional borehole drilled on the western side of Abernethy's Creek and two DCP tests on the eastern side of the creek confirm the presence of soft alluvium (estuarine) soils overlying stiff alluvial clays. The HDD under Abernethy's Creek will pass through soft to very soft soils on both sides of the creek before encountering stiff clay soils at depths of approximately 3.5 m on the western side and to about 2.1 m on the eastern side. It is anticipated that the HDD will be embedded in stiff clay soils once it passes through the soft soil zone.

The HDD design and construction methodology will need to consider the presence of the soft soil zone and potential for collapse of these soils as well as the potential for frac-out to the surface on the approaches to the creek. The embedment depth into the stiff clays and depth below creek bed level will also need to be considered in the design to minimise the risk of frac-out occurring into the creek.

It is noted that the presence and depth of soft or very soft soils can vary significantly within the alluvial plain area within and around the Manildra Plant due to the presence of paleochannels (ancient infill channels).

6. References

GHD. (2021a). *Gas Pipeline Mod 1 - Geotechnical assessment of Riverbank Stability (Abernethy's Creek); Acid Sulfate Soil (ASS) and Contamination assessments (report reference: 12548413-55889-10, dated 2 July 2021).* GHD Pty Ltd.

GHD. (2021b). *Gas Pipeline Mod 2 - Geotechnical assessment of Riverbank Stability (Abernethy's Creek); Acid Sulfate Soil (ASS) and Contamination assessments (report reference: 12548413-12952-22, dated 24 December 2021).* GHD Pty Ltd.

SMEC. (2020). *Report - Manildra Design and Construction Services - Packing Plant Soft Soil Improvement Design.* Ref: 3001550, dated 4 June 2020.

Standards Australia. (2017). *AS1726-2017 Geotechnical Site Investigations.*

* * *

We trust the information is suitable for your current needs. If you require further information, please do not hesitate to contact the undersigned.

Regards

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Attachments:
Attachment 1: General notes
Attachment 2: Borehole log with explanation sheets
Attachment 3: DCP test results

Attachments

Attachment 1

General notes

GENERAL NOTES

The report contains the results of a geotechnical investigation or study conducted for a specific purpose and client. The results may not be used or relied on by other parties, or used for other purposes, as they may contain neither adequate nor appropriate information. In particular, the investigation does not cover contamination issues unless specifically required to do so by the client.

To the maximum extent permitted by law, all implied warranties and conditions in relation to the services provided by GHD and the report are excluded unless they are expressly stated to apply in the report.

TEST HOLE LOGGING

The information on the test hole logs (boreholes, test pits, exposures etc.) is based on a visual and tactile assessment, except at the discrete locations where test information is available (field and/or laboratory results). The test hole logs include both factual data and inferred information. Moreover, the location of test holes should be considered approximate, unless noted otherwise (refer report). Reference should also be made to the relevant standard sheets for the explanation of logging procedures (Soil and Rock Descriptions, Core Log Sheet Notes etc.).

GROUNDWATER

Unless otherwise indicated, the water depths presented on the test hole logs are the depths of free water or seepage in the test hole recorded at the given time of measuring. The actual groundwater depth may differ from this recorded depth depending on material permeabilities (i.e. depending on response time of the measuring instrument). Further, variations of this depth could occur with time due to such effects as seasonal, environmental and tidal fluctuations or construction activities such as a change is ground surface level. Confirmation of groundwater levels, phreatic surfaces or piezometric pressures can only be made by appropriate surveys, instrumentation techniques and monitoring programmes.

INTERPRETATION OF RESULTS

The discussion or recommendations contained within this report normally are based on a site evaluation from discrete test hole data, often with only approximate locations (e.g. GPS). Generalised, idealised or inferred subsurface conditions (including any geotechnical cross-sections) have been assumed or prepared by interpolation and/or extrapolation of these data. As such these conditions are an interpretation and must be considered as a guide only.

CHANGE IN CONDITIONS

Local variations or anomalies in ground conditions do occur in the natural environment, particularly between discrete test hole locations or available observation sites. Additionally, certain design or construction procedures may have been assumed in assessing the soil-structure interaction behaviour of the site. Furthermore, conditions may change at the site from those encountered at the time of the geotechnical investigation through construction activities and constantly changing natural processes.

Any change in design, in construction methods, or in ground conditions as noted during construction, from those assumed or reported should be referred to GHD for appropriate assessment and comment.

GEOTECHNICAL VERIFICATION

Verification of the geotechnical assumptions and/or model is an integral part of the design process - investigation, construction verification, and performance monitoring. Variability is a feature of the natural environment and, in many instances, verification of soil or rock quality, or foundation levels, is required. There may be a requirement to extend foundation depths, to modify a foundation system and/or to conduct monitoring as a result of this natural variability. Allowance for verification by appropriate geotechnical personnel must be recognised and programmed for construction.

FOUNDATIONS

Where referred to in the report, the soil or rock quality, or the recommended depth of any foundation (piles, caissons, footings etc.) is an engineering estimate. The estimate is influenced, and perhaps limited, by the fieldwork method and testing carried out in connection with the site investigation, and other pertinent information as has been made available. The material quality and/or foundation depth remains, however, an estimate and therefore liable to variation. Foundation drawings, designs and specifications should provide for variations in the final depth, depending upon the ground conditions at each point of support, and allow for geotechnical verification.

REPRODUCTION OF REPORTS

Where it is desired to reproduce the information contained in our geotechnical report, or other technical information, for the inclusion in contract documents or engineering specification of the subject development, such reproductions must include at least all of the relevant test hole and test data, together with the appropriate Standard Description sheets and remarks made in the written report of a factual or descriptive nature.

Reports are the subject of copyright and shall not be reproduced either totally or in part without the prior written consent of GHD. GHD expressly disclaims responsibility to any person other than the client arising from or in connection with this report.

Ref: DS5.5.1 Issue 0 Date: 05/10/2018

Attachment 2

Borehole log with explanation sheets

GLOSSARY OF SYMBOLS

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This standard sheet should be read in conjunction with all test hole log sheets and any idealised geological sections prepared for the investigation report.

GENERAL

Symbol	Description	Symbol	Description
D	Disturbed Sample	**R**	Rising Head Permeability Test
B	Bulk Sample	**F**	Falling Head Permeability Test
U(50)	Undisturbed Sampled (suffixed by sample size or tube diameter in mm if applicable)	**PBT**	Plate Bearing Test
CS	Core Sample (suffixed by diameter in mm)	▶—	Water Inflow (make)
ES	Soil sample for environmental sampling	—◀	Water Outflow (loss)
PID	Photoionisation Detector	▽	Temporary Water Level
SPT	Standard Penetration Test (with blows per 0.15m)	▼	Final Water Level
N	SPT Value	●	Point Load Test (axial)
HB/HW	SPT Hammer Bouncing/Hammer Weight	○	Point Load Test (diametric)
PP/HP	Pocket/Hand Penetrometer (suffixed by value kPa)	**PL**	Point Load (kPa)
PK	Packer Test (kPa)	**IMP**	Impression Device Test
PZ	Piezometer Installation	**PM**	Pressuremeter Test
SV/VS	Shear Vane Test (suffixed by value in kPa)		

SOIL SYMBOLS

Main Components				Minor Components			
▨	SAND	▨	FILL	▨	sandy	▨	vegetation, roots
▨	GRAVEL	▨	SILT	▨	gravelly	▨	silty
▨	CLAY	▨	TOPSOIL	▨	clayey	*Note: Natural soils are generally a combination of constituents, e.g. sandy CLAY*	▨

ROCK SYMBOLS

Sedimentary						Igneous			
▨	SANDSTONE	▨	SILTSTONE	▨	CONGLOMERATE	▨	GRANITIC ROCK	▨	IGNEOUS DYKE
▨	CLAYSTONE	▨	SHALE	■	COAL	▨	BASALTIC ROCK		

Note: Additional rock symbols may be allocated for a particular project

NATURAL DEFECTS *(Coding)*

Defect Type		Orientation					
Jt	Joint	For vertical non-oriented core ... “Dip” angle (eg. 5°) measured relative to horizontal.					
Pt	Parting	For inclined non-oriented core ... “Angle” measured relative to core axis.					
SS	Sheared Surface	For inclined oriented core ... “Dip” angle and “Dip Direction” angle (eg. 45°/225° mag.).					
WSm	Weathered Seam	**Orientation (con’t)**		**Roughness**		**Coating**	
SSm	Sheared Seam	**VT**	Vertical	**Pol**	Polished	**Cn**	Clean
CSm	Crushed Seam	**HZ or 0°**	Horizontal	**So**	Smooth	**Sn**	Stained
ISm	Infilled Seam	**d / °**	Degrees	**Rf**	Rough	**Ve**	Veneer
SZ	Sheared Zone			**VR**	Very Rough	**Co**	Coating
VN	Vein			**Slk**	Slickensided		

Shape			
Pln	Planar	**St**	Stepped
Cu	Curved	**Ir**	Irregular
Un	Undulating	**Dis**	Discontinuous

Others					
OP	Open	**CL**	Closed	**Ti**	Tight

Infilling / Common Materials			
CLAY	Clay	**Mi**	Micaceous
Ca	Calcite	**Mn**	Manganese
X	Carbonaceous	**Py**	Pyrite
Kt	Chlorite	**Qz**	Quartz
Fe	Iron Oxide	**MU**	Unidentified Mineral

SOIL DESCRIPTION AND CLASSIFICATION

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Soil is described in general accordance with Australian Standard AS 1726-2017 (Geotechnical Site Investigations) in terms of visual and tactile properties, with potential refinement by laboratory testing. AS 1726 defines soil as particulate materials that occur in the ground and can be disaggregated or remoulded by hand in air or water without prior soaking. Classification of the soil is undertaken following description.

SOIL DESCRIPTION

The soil description includes a) Composition, b) Condition, c) Structure, d) Origin and e) Additional observations. 'FILL', 'TOPSOIL' or a 'MIXTURE OF SOIL AND COBBLES / BOULDERS' (with dominant fraction first) is denoted at the start of a soil description where applicable.

a) Soil Composition (soil name, colour, plasticity or particle characteristics, secondary and then minor components)

Soil Name: A soil is termed a *coarse grained soil* where the dry mass of sand and gravel particles exceeds 65% of the total. Soils with more than 35% fines (silt or clay particles) are termed *fine grained soils*. The soil name is made up of the primary soil component (in BLOCK letters), prefixed by applicable secondary component qualifiers. Minor components are applied as a qualifiers to the soil name (using the words 'with' or 'trace').

Particles are differentiated on the basis of size. 'Boulders' and 'cobbles' are outside the soil particle range, though their presence (and proportions) is noted. While individual particles may be designated as silt or clay based on grain size, fine grained soils are characterised as silt or clay based on tactile behaviour or Atterberg Limits, and not the relative composition of silt or clay sized particles.

Colour: The prominent colour is noted, followed by (spotted, mottled, streaked etc.) then secondary colours as applicable. Roughly equally proportioned colours are prefixed by (spotted, mottled, streaked etc.). Colour is described in its moist condition, though both wet and dry colours may also be provided if appropriate.

Plasticity: Fine grained soils are designated within standard ranges of plasticity based on tactile assessment or laboratory assessment of the Liquid Limit.

Particle Characteristics: The particle shape, particle distribution and particle size range within a coarse grained soil is described using standard terms. Particle composition may be described using rock or mineral names, with specific terms for carbonate soils.

Secondary and Minor Components: The primary soil is described and modified by secondary and minor components, with assessed ranges as tabulated.

Carbonate Soils: Carbonate content can be assessed by use of dilute '10%' HCl solution. Resulting clear sustained effervescence is interpreted as a *Carbonate soil* (approximately >50% carbonate), while weak or sporadic effervescence indicates *Calcareous soil* (< 50% carbonate). No effervescence is interpreted as a non-calcareous soil.

Organic and Peat Soils: Where identified, organic content is noted. *Organic soil* (2% to 25% organic matter) is usually identified by colour (usually dark grey/black) and odour (i.e. 'mouldy' or hydrogen sulphide odour). *Peat* (>25% organic matter) is identified by a spongy feel and fibrous texture. Peat soils' decomposition may be described as '*fibrous*' (little / no decomposition), '*pseudo-fibrous*' (moderate decomposition) or '*amorphous*' (full decomposition).

Fraction	Components		Particle Size (mm)
Oversize	BOULDERS		> 200
	COBBLES		63 - 200
Coarse grained soil particles	GRAVEL	Coarse	19 - 63
		Medium	6.7 -19
		Fine	2.36 - 6.7
	SAND	Coarse	0.6 - 2.36
		Medium	0.21 - 0.6
		Fine	0.075 - 0.21
Fine grained soil particles	SILT		0.002 - 0.075
	CLAY		< 0.002

Plasticity Terms (Fine Grained Soils)		Laboratory Liquid Limit Range
Silt	**Clay**	
N/A	N/A	(Non Plastic)
Low Plasticity	*Low Plasticity*	≤ 35%
	Medium Plasticity	> 35% and ≤ 50%
High Plasticity	*High Plasticity*	> 50%

Particle Distribution Terms (Coarse Grained Soils)	
Well graded	good representation of all particle sizes
Poorly graded	one or more intermediate sizes poorly represented
Gap graded	one or more intermediate sizes absent
Uniform	essentially of one size

Particle Shape Terms (Coarse Grained Soils)		
Rounded	*Sub-angular*	*Flaky or Platy*
Sub-rounded	*Angular*	*Elongated*

Secondary and Minor Components for Coarse Grained Soils			
Fines (%)	**Modifier** (as applicable)	**Accessory coarse (%)**	**Modifier** (as applicable)
≤ 5	*'trace silt / clay'*	≤ 15	*'trace sand / gravel'*
> 5, ≤ 12	*'with clay / silt'*	> 15, ≤ 30	*'with sand / gravel'*
> 12	*prefix 'silty / clayey'*	> 30	*prefix 'gravelly / sandy'*

Secondary and Minor Components for Fine Grained Soils	
% Coarse	**Modifier** (as applicable)
≤ 15	add *"trace sand / gravel"*
> 15, ≤ 30	add *"with sand / gravel"*
> 30	prefix soil *"sandy / gravelly"*

SOIL DESCRIPTION AND CLASSIFICATION

b) Soil Condition (moisture, relative density or consistency)

Moisture: Fine grained soils are described relative to plastic or liquid limits, while coarse grained soils are assessed based on appearance and feel. The observation of seepage or free water is noted on the test hole logs.

Moisture - Coarse Grained Soils		
Term		**Tactile Properties**
Dry	*('D')*	Non-cohesive, free running
Moist	*('M')*	Feels cool, darkened colour, tends to stick together
Wet	*('W')*	Feels cool, darkened colour, tends to stick together, free water forms when handling

Moisture - Fine Grained Soils		
Term		**Tactile Properties**
Moist, dry of plastic limit	('$w < PL$')	Hard and friable or powdery
Moist, near plastic limit	('$w \approx PL$')	Can be moulded
Moist, wet of plastic limit	('$w > PL$')	Weakened, free water forms on hands with handling
Wet, near liquid limit	('$w \approx LL$')	Highly weakened, tends to flow when tapped
Wet, wet of liquid limit	('$w > LL$')	Liquid consistency, soil flows

Relative Density (Non Cohesive Soils): The Density Index is inherently difficult to assess by visual or tactile means, and is normally assessed by penetration testing (e.g. SPT, DCP, PSP or CPT) with published correlations. Assessment may be affected by moisture and *in situ* stress conditions. Density Index assessment may be refined by combination of *in situ* density testing and laboratory reference maximum and minimum density ranges.

Consistency (Cohesive Soils): May be assessed by direct measurement (shear vane, CPT etc.), or approximate tactile correlations. Cohesive soils include fine grained soils, and coarse grained soils with sufficient fine grained components to induce cohesive behaviour. A 'design shear strength' must consider the mode of testing, the *in situ* moisture content and potential for variations of moisture which may affect the shear strength.

Relative Density (Non-Cohesive Soils)		
Term and (Symbol)		**Density Index (%)**
Very Loose	*(VL)*	≤ 15
Loose	*(L)*	> 15 and ≤ 35
Medium Dense	*(MD)*	> 35 and ≤ 65
Dense	*(D)*	> 65 and ≤ 85
Very Dense	*(VD)*	> 85

Consistency assessment can be influenced by moisture variation.

Consistency (Cohesive Soils)			
Term and (Symbol)		**Tactile Properties**	**Undrained Shear Strength**
Very Soft	*(VS)*	Extrudes between fingers when squeezed	< 12 kPa
Soft	*(S)*	Can be moulded by light finger pressure	12 - 25 kPa
Firm	*(F)*	Can be moulded by strong finger pressure	25 - 50 kPa
Stiff	*(St)*	Cannot be moulded by fingers	50 - 100 kPa
Very Stiff	*(VSt)*	Can be indented by thumb nail	100 - 200 kPa
Hard	*(H)*	Can be indented with difficulty by thumb nail	> 200 kPa
Friable	*(Fr)*	Easily crumbled or broken into small pieces by hand	-

c) Structure (zoning, defects, cementing)

Zoning: The *in situ* zoning is described using the terms below. *'Intermixed'* may be used for an irregular arrangement.

'layer' (a continuous zone across the exposed sample)

'lens' (a discontinuous layer with lenticular shape)

'pocket' (an irregular inclusion of different material).

'interbedded' or *"interlaminated'* (alternating soil types)

Defects: Described using terms below, with dimension orientation and spacing described where practical.

'parting' (an open or closed surface or crack sub parallel to layering with little / no tensile strength - open or closed)

'fissure' (as per a parting, though not parallel or sub parallel to layering – may include desiccation cracks)

'sheared seam' (zone of sub parallel near planar closely spaced intersecting smooth or slickensided fissures dividing the mass into lenticular or wedge shaped blocks)

'sheared surface' (a near planar, curved or undulating smooth, polished or slickensided surface, indicative of displacement)

'softened zone' (in clayey soils, usually adjacent to a defect with associated higher moisture content)

'tube' (tubular cavity, singly or one of a large number, often formed from root holes, animal burrows or tunnel erosion)

'tube cast' (an infilled tube – infill may vary from uncemented through to cemented or have rock properties)

'infilled seam' (sheet like soil body cutting through the soil mass, formed by infilling of open defects)

Cementation: Soils may be cemented by various substances (e.g. iron oxides and hydroxides, silica, calcium carbonate, gypsum), and the cementing agent shall be identified if practical. Cemented soils are described as:

'weakly cemented'	easily disaggregated by hand in air or water
'moderately cemented'	effort required to disaggregate the soil by hand in air or water

Materials extending beyond '*moderately cemented'* are encompassed within the rock strength range. Where consistent cementation throughout a soil mass is identified as a duricrust, it is described in accordance with duricrust rock descriptors. Where alternate descriptors of cementation development are applied for consistency with regional practices or geology, or client requirements, these are outlined separately.

d) Origin

An interpretation is provided based on observations of landform, geology and fabric, and may further include assignment of a stratigraphic unit. The use of terms ‘possibly’ or ‘probably’ indicates a higher degree of uncertainty regarding the assessed origin or stratigraphic unit. Typical origin descriptors include:

Residual	Formed directly from in situ weathering with no visible structure or fabric of the parent soil or rock.
Extremely weathered	Formed directly from in situ weathering, with remnant and/or fabric from the parent rock.
Alluvial	Deposited by streams and rivers (may be applied more generically as transported by water).
Estuarine	Deposited in coastal estuaries, including sediments from inflowing rivers, streams, and tidal currents.
Marine	Deposited in a marine environment.
Lacustrine	Deposited in freshwater lakes.
Aeolian	Transported by wind.
Colluvial and Slopewash	Soil and rock debris transported down slopes by gravity (with or without assistance of water). Colluvium is typically applied to thicker / localised deposits, and slopewash for thinner / widespread deposits.
TOPSOIL	Surficial soil, typically with high levels of organic material. Topsoils buried by other transported soils are termed *‘remnant topsoil’*. Tree roots within otherwise unaltered soil does not characterise topsoil.
FILL	Any material which has been placed by anthropogenic processes (i.e. human activity).

e) Additional Observations

Additional observations may be included to supplement the soil description. Additional observations may consist of notations relating to soil characteristics (odour, contamination, colour changes with time), inferred geology (with delineation of soil horizons or geological time scale) or notes on sampling and testing application (including the reliability, recovery, representativeness, or condition of samples or test conditions and limitations). If the material is assessed to be not representative, terms such as ‘poor recovery’, ‘non-intact’, ‘recovered as’ or ‘probably’ are applied.

SOIL CLASSIFICATION

Classification allocates the material within distinct soil groups assigned a two character Group Symbol:

Coarse Grained Soils
(sand and gravel: more than 65% of soil coarser than 0.075 mm)

Major Division	Group Symbol	Soil Group
GRAVEL (more than half of the coarse fraction is > 2.36 mm)	GW	GRAVEL, well graded
	GP	GRAVEL, poorly graded
	GM	Silty GRAVEL
	GC	Clayey GRAVEL
SAND (more than half of the coarse fraction is < 2.36 mm)	SW	SAND, well graded
	SP	SAND, poorly graded
	SM	Silty SAND
	SC	Clayey SAND

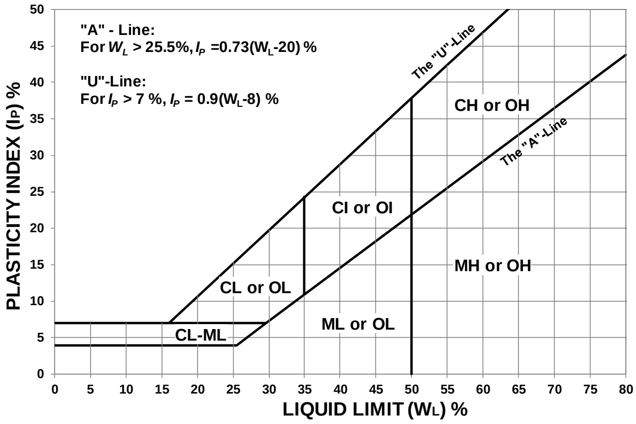
Fine Grained Soils
(silt and clay: more than 35% of soil finer than 0.075 mm)

Major division	Group Symbol	Soil Group
SILT and CLAY (low to medium plasticity)	ML	SILT, low plasticity
	CL	CLAY, low plasticity
	CI	CLAY, medium plasticity
	OL	Organic SILT
SILT and CLAY (high plasticity)	MH	SILT, high plasticity
	CH	CLAY, high plasticity
	OH	Organic CLAY / SILT
Highly Organic	Pt	PEAT

Coarse grained soils with fines contents between 5% and 12% are provided a dual classification comprising the two group symbols separated by a dash, e.g. for a poorly graded gravel with between 5% and 12% silt fines (poorly graded ‘GRAVEL with silt’), the classification is GP-GM.

For the purpose of classification, *poorly graded, uniform,* or *gap graded* soils are all designated as poorly graded. Soils that are dominated by boulders or cobbles are described separately and are not classified.

Classification is routinely undertaken based on tactile assessment with the soil description. Refinement of soil classification may be applied using laboratory assessment, including particle size distribution and Atterberg Limits. Atterberg Limits testing is applied to the sample portion finer than 0.425 mm. Fine grained soil components are assessed on the basis of regions defined within the Modified Casagrande Chart.



ROCK DESCRIPTION AND CLASSIFICATION

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Rock is described in general accordance with Australian Standard AS 1726-2017 (Geotechnical site investigations) in terms of visual and tactile properties, with potential refinement by laboratory testing. AS 1726 defines rock as any aggregate of minerals and/or organic materials that cannot be disaggregated by hand in air or water without prior soaking. The rock description and classification distinguishes between rock material, defects, structure and rock mass.

ROCK DESCRIPTION AND CLASSIFICATION

a) Description of rock material (rock name, grain size and type, colour, texture and fabric, inclusions or minor components, moisture content and durability)

Rock Name: Simple rock names are used to provide a reasonable engineering description rather than a precise geological classification. The rock name is chosen on the basis of origin, with common types summarised below. Additional, non-exhaustive, terminology is included in AS 1726. Rock names not described within AS 1726 may be adopted, with geological characteristics typically noted within accompanying text.

Grain Size (mm)	Sedimentary					Metamorphic		Igneous		
	Clastic or Detrital		Carbonate		Pyroclastic	Foliated	Non-Foliated	Felsic	↔	Mafic
			Low Porosity	Porous						
>2.0	CONGLOMERATE (rounded grains in a finer matrix) BRECCIA (angular or irregular fragments in a finer matrix)		LIMESTONE (Predominantly $CaCO_3$) or DOLOMITE (Predominantly $CaMgCO_3$)	CALCIRUDITE	AGGLOMERATE (rounded grains in a finer matrix) VOLCANIC BRECCIA (angular fragments in a finer matrix)	GNEISS	MARBLE (carbonate) QUARTZITE	GRANITE	DIORITE	GABBRO
2.0-0.06	SANDSTONE			CALCARENITE	TUFF	SCHIST	SERPENTINITE	MICRO-GRANITE	MICRO-DIORITE	DOLERITE
0.06-0.002	MUDSTONE (silt and clay)	SILTSTONE (mostly silt)		CALCISILTITE	Fine grained TUFF	PHYLLITE or SLATE	HORNFELS	RHYOLITE	ANDESITE	BASALT
<0.002		CLAYSTONE (mostly clay)		CALCILUTITE						

Reproduced with modification from Tables 15, 16 and 17, Clause 6.2.3.1, AS 1726-2017, Geotechnical site investigations.

Grain size: For rocks with predominantly sand sized grains the dominant or average grain size is described as follows:

Rock type	Coarse grained	Medium grained	Fine grained
Sedimentary rocks	Mainly 0.6 mm to 2 mm	Mainly 0.2 mm to 0.6 mm	Mainly 0.06 mm (just visible) to 0.2 mm
Igneous and metamorphic rocks	Mainly >2 mm	Mainly 0.06 mm to 2 mm	Mainly <0.6 mm (just visible)

Colour assists in rock identification and interpolation. Rock colour is generally described in a *"moist"* condition, using simple terms (e.g. grey, brown, etc.) and modified as necessary by *"pale"*, *"dark"*, or *"mottled"*. Borderline colours may be described as a combination of these colours (e.g. red-brown).

Texture refers to the arrangement of, or the relationship between, the component grains or crystals (e.g. porphyritic, crystalline or amorphous).

Fabric refers to visible grain arrangement along a preferential orientation or a layering. Fabric may be noted as *"indistinct"* (little effect on strength) or *"distinct"* (rock breaks more easily parallel to the fabric). Common terms include *"massive"* or *"flow banding"* (igneous), *"foliation"* or *"cleavage"* (metamorphic). Sedimentary layering is described as *"bedding"* or (where thickness < 20 mm) *"lamination"*. The typical orientation, spacing or thickness of these structural features can be described directly in millimetres and metres. Further quantification of bedding thickness applied by GHD is as follows:

Bedding Term	Thickness
Very thickly bedded	>2 m
Thickly bedded	0.6 to 2 m
Medium bedded	0.2 to 0.6 m
Thinly bedded	60 to 200 mm
Very thinly bedded	20 to 60 mm
Laminated	6 to 20 mm
Thinly laminated	<6 mm

Features, Inclusions and Minor Components are typically only described when those features could influence the engineering behaviour of the rock. Described features may include: gas bubbles in igneous rocks; veins of quartz, calcite or other minerals; pyrite crystals and nodules or bands of ironstone or carbonate; cross bedding in sandstone; clast or matrix support in conglomerates and breccia.

Moisture content may be described by the feel and appearance of the rock, as follows: *"dry"* (looks and feels dry), *"moist"* (feels cool, darkened in colour, but no water is visible on the surface), or *"wet"* (feels cool, darkened in colour, water film or droplets visible on the surface). The moisture content of rock cored with water may not represent in situ conditions.

Durability of rock samples is noted where there is an observed tendency of samples to crack, breakdown in water or otherwise deteriorate with exposure.

b) Classification of the rock material condition (strength, weathering and/or alteration)

Estimated Strength refers to the rock material and not the rock mass. The strength is defined in terms of uniaxial compressive strength (UCS), though is typically estimated by either tactile assessment or Point Load Strength Index ($Is_{(50)}$) (measured perpendicular to planar anisotropy). A correlation between $Is_{(50)}$ and UCS is adopted for classification, though is not intended for design purposes without appropriate supporting assessment. A field guide follows:

Term and (Symbol)		UCS (MPa)	$Is_{(50)}$ (MPa)	Field Guide
Very Low	*(VL)*	0.6 – 2	0.03 - 0.1	Material crumbles under firm blows with sharp end of geological pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 30 mm thick can be broken by finger pressure.
Low	*(L)*	2 - 6	0.1 - 0.3	Easily scored with knife; indentations 1 to 3 mm show in the specimen with firm blows of a geological pick point; has dull sound under hammer. A piece of core 150 mm long by 50 mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.
Medium	*(M)*	6 - 20	0.3 - 1.0	Readily scored with a knife; a piece of core 150 mm long by 50 mm diameter can be broken by hand with difficulty.
High	*(H)*	20 - 60	1 - 3	A piece of core 150 mm long by 50 mm diameter cannot be broken by hand but can be broken by a geological pick with a single firm blow; rock rings under hammer.
Very High	*(VH)*	60 - 200	3 -10	Hand specimen breaks with geological pick after more than one blow; rock rings under hammer.
Extremely High	*(EH)*	>200	>10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer.

Based on Table 19, Clause 6.2.4.1, AS 1726-2017, Geotechnical site investigations. Refer to source document for further detail.

Material with strength less than *"very low"* is described using soil characteristics, with the presence of an original rock texture or fabric noted if relevant.

Weathering and Alteration: The process of weathering involves physical and chemical changes to the rock resulting from exposure near the earth's surface. A subjective scale for weathering is applied as follows:

Weathering Term and (Symbol)		Description
Residual Soil	*(RS)*	Material has weathered to such an extent that it has soil properties. Mass structure and material texture and fabric of original rock are no longer visible, but the soil has not been significantly transported.
Extremely Weathered	*(XW)*	Material has weathered to such an extent that it has soil properties. Mass structure, material texture and fabric of original rock are still visible.
Highly Weathered	*(HW)*	The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable. Rock strength is significantly changed by weathering. Some primary minerals have weathered to clay minerals. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Moderately Weathered	*(MW)*	The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable, but shows little or no change of strength from fresh rock.
Slightly Weathered	*(SW)*	Rock is partially discoloured with staining or bleaching along joints but shows little or no change of strength from fresh rock.
Fresh	*(Fr)*	Rock shows no sign of decomposition of individual minerals or colour changes.

Modified based on Table 20, Clause 6.2.4.2, AS 1726-2017, Geotechnical site investigations. Refer to source document for further detail.

Where physical and chemical changes to the rock are caused by hot gases or liquids at depth, the process is called alteration. Unlike weathering, the distribution of altered material may occur at any depth and show no relationship to topography. Where alteration minerals are identified the terms *"extremely altered" (XA)*, *"highly altered" (HA)*, *"moderately altered" (MA)* and *"slightly altered" (SA)* can be used to describe the physical and chemical changes described above.

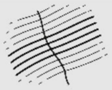
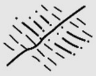
c) Description of defects (defect type, orientation, roughness and shape, coatings and composition of seams, spacing, length, openness and thickness, block shape)

Defects often control the overall engineering behaviour of a rock mass. AS 1726 defines a defect as “a discontinuity, fracture, break or void in the material or materials across which there is little or no tensile strength”. Describing the type, character and distribution of natural defects is an essential part of the description of many rock masses.

Commonly described characteristics of defects within a rock mass include type, orientation, roughness and shape, coatings and composition of seams, aperture, persistence, spacing and block shape.

The degree of detail required for defect descriptions depends on project requirements. All defects judged of engineering significance for the site and project are described individually. Where appropriate, generalised descriptions for less significant, or multiple similar, defects can be provided for delineated parts of rock core or exposures. A general description of delineated defect sets is provided when sufficient orientation data is available.

Defect Type is described using the terms summarised below. On core logs, only natural defects across which the core is discontinuous are described (i.e. inferred artificial fractures such as drill breaks are excluded). Incipient defects are described using the relevant texture or fabric terms. Healed defects (those that have been re-cemented by minerals such as chlorite or calcite) are described using the prefix “healed” (e.g. healed joint).

Type and (Symbol)		Description	Diagram
Parting	(Pt)	A surface or crack across which the rock has little or no tensile strength. Parallel or sub-parallel to layering (e.g. bedding) or a planar anisotropy in the rock material (e.g. cleavage). May be open or closed.	
Joint	(Jt)	A surface or crack with no apparent shear displacement and across which the rock has little or no tensile strength, but which is not parallel or subparallel to layering or to planar anisotropy in the rock material. May be open or closed.	
Sheared Surface	(SS)	A near planar, curved or undulating surface which is usually smooth, polished or slickensided and which shows evidence of shear displacement.	
Sheared Zone	(SZ)	Zone of rock material with roughly parallel near planar, curved or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects. Some of the defects are usually curved and intersect to divide the mass into lenticular or wedge-shaped blocks.	
Sheared Seam	(SSm)	Seam of soil material with roughly parallel almost planar boundaries, composed of soil materials with roughly parallel near planar, curved or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects. Some of the defects are usually curved and intersect to divide the mass into lenticular or wedge-shaped blocks.	
Crushed Seam	(CSm)	Seam of soil material with roughly parallel almost planar boundaries, composed of disoriented, usually angular fragments of the host rock material which may be more weathered than the host rock. The seam has soil properties.	
Infilled Seam	(ISm)	Seam of soil material usually with distinct roughly parallel boundaries formed by the migration of soil into an open cavity or joint, infilled seams less than 1 mm thick may be described as a veneer or coating on a joint surface.	
Extremely Weathered Seam	(WSm)	Seam of soil material, often with gradational boundaries. Formed by weathering of the rock material in place.	

Modified based on Table 22, Clause 6.2.5.2, AS 1726-2017, Geotechnical site investigations. Refer to source document for further detail.

Defect Orientation is recorded as the “dip” (maximum angle of the mean plane, measured from horizontal) and the “dip direction” (azimuth of the dip, measured clockwise from true north). Dip and dip direction is expressed in degrees, with two-digit and three-digit numbers respectively, separated by a slash (e.g. 45/090). For vertical boreholes, the defect dip is measured as the acute angle from horizontal. Rock core extracted from vertical boreholes is generally not oriented, so the dip direction cannot be directly measured. For non-oriented inclined boreholes, a defect “alpha” (α) angle is measured as the acute angle from the core axis. For vertical and non-oriented inclined boreholes, the dip direction can sometimes be estimated from the relationship of the defect to a well-defined site structure such as fabric. For oriented inclined boreholes, the measurement of the defect orientation is carried out and recorded in a form suited to the particular device being used and later processed to report true dip and dip direction.

ROCK DESCRIPTION AND CLASSIFICATION

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Roughness and Shape of the defect surface combine to have significant influence on shear strength. Standard descriptions and abbreviations include:

Roughness and (Symbol)		Description
Very Rough	(VR)	Many large surface irregularities (amplitude generally more than 1 mm). Feels like, or coarser than very coarse sand paper.
Rough	(Rf)	Many small surface irregularities (amplitude generally less than 1 mm). Feels like fine to coarse sand paper.
Smooth	(So)	Smooth to touch. Few or no surface irregularities.
Polished	(Pol)	Shiny smooth surface.
Slickensided	(Slk)	Grooved or striated surface, usually polished.

Shape and (Symbol)		Description
Planar	(Pln	The defect does not vary in orientation.
Curved	(Cu)	The defect has a gradual change in orientation.
Undulating	(Un)	The defect has a wavy surface.
Stepped	(St)	The defect has one or more well defined steps.
Irregular	(Ir)	The defect has many sharp changes of orientation.

Although the surface roughness of defects can be described at small (10-100 mm) scales of observation, the overall shape of the defect surface can usually be observed only at medium (0.1-1 m) and large (>1 m) scale.

Where it is necessary to assess the shear strength of a defect, observations are generally made at multiple scales. Surface roughness may also be characterised by using the joint roughness coefficient (JRC) profiles established by Barton and Choubey (1977). Where large-scale observations are possible, further measurement of defect "waviness" (angle of the asperities relative to the overall dip angle of the plane) is made.

Coatings and Composition of Seams: Many defects have surface coatings, which can affect their shear strength. Standard descriptions include:

Coating and (Symbol)		Description
Clean	(Cn)	No visible coating.
Stained	(Sn)	No visible coating but surfaces are discoloured.
Veneer	(Ve)	A visible coating of soil or mineral substance, but too thin to be measured may be patchy.
Coating	(Co)	A visible coating up to 1 mm thick. Soil material greater than 1 mm thick is described using defect terms (e.g. infilled seam). Rock material greater than 1 mm thick is described as a vein (Vn).

The composition of seams are described using soil description terms as given on the SOIL DESCRIPTION AND CLASSIFICATION Standard Sheet. Where possible the mineralogy of coatings is identified. Common mineral coatings include:

Common Minerals and (Symbol)	
Clay	(CLAY)
Calcite	(Ca)
Carbonaceous	(X)
Chlorite	(Kt)
Iron Oxide	(Fe)
Micaceous	(Mi)
Manganese	(Mn)
Pyrite	(Py)
Quartz	(Qz)

Aperture: Defects across which there is little or no tensile strength can be either *"open"* (*Op*) or *"closed"* (*Cl*). For rock core, the width of the "open" defect is measured whilst still in the core barrel splits. The descriptor *"tight"* (*Ti*) can only apply to healed or incipient defects (i.e. veins, foliation, etc.).

Persistence and Spacing of defects is described directly in millimetres and metres. If the measurement of defect persistence is limited by the extent of the exposure, the end conditions are noted (i.e. 0, 1 or 2 defect ends observed). The spacing between defects of similar orientation (i.e. within a specific defect set) is recorded when possible.

The frequency of defects within rock core can be measured as either: the spacing between successive defects; or the "Fracture Index", which is the number of defects per metre of core.

Spacing Term	Thickness
Very wide	>2 m
Wide	0.6 to 2 m
Medium	0.2 to 0.6 m
Closely	60 to 200 mm
Very closely	20 to 60 mm
Extremely closely	6 to 20 mm

Block Shape: Where it is considered significant, block shape can be described using the subjective terms as follows:

Block Shape	Description
Polyhedral	Irregular discontinuities without arrangement into distinct sets, and of small persistence.
Tabular	One dominant set of parallel discontinuities, for example bedding planes, with other non-continuous joints; thickness of blocks much less than length or width.
Prismatic	Two dominant sets of discontinuities, approximately orthogonal and parallel, with a third irregular set; thickness of blocks much less than length or width.
Equidimensional	Three dominant sets of discontinuities, approximately orthogonal, with occasional irregular joints, giving equidimensional blocks.
Rhomboidal	Three (or more) dominant, mutually oblique, sets of joints giving oblique-shaped, equidimensional blocks.
Columnar	Several, usually more than three sets of continuous, parallel joints usually crossed by irregular joints; lengths much greater than other dimensions.

Modified based on Table 23, Clause 6.2.5.7, AS 1726-2017, Geotechnical site investigations. Refer to source document for further detail.

d) Interpreted stratigraphic unit

Stratigraphic units may be interpreted and reported, in accordance with The Australian Stratigraphic Units Database (ASUD). The terms *"possibly"* or *"probably"* indicate increased uncertainty in this interpretation.

e) Geological structure

After describing the rock material and defects, an interpretation of the nature and configuration of rock mass defects may be presented in logs, charts, 2D sections and 3D models (e.g. dipping strata, folds, unconformities, weathering profiles, defect sets, geological faults, etc.).

PARAMETERS RELATED TO CORE DRILLING

Drill Depth and Core Loss: Drilling intervals are shown on GHD Core Log Sheets by depth increments and horizontal marker lines.

"Core loss", or its inverse "total core recovery" (TCR), is measured as a percentage of the core run. If the location of the core loss is known, or strongly suspected, it is shown in a region of the column bounded by dashed horizontal lines. If unknown, core loss is assigned to the bottom of a core run.

Rock Quality Designation (RQD), described by Deere et al. (1989), may be recorded on GHD Core Log Sheets.

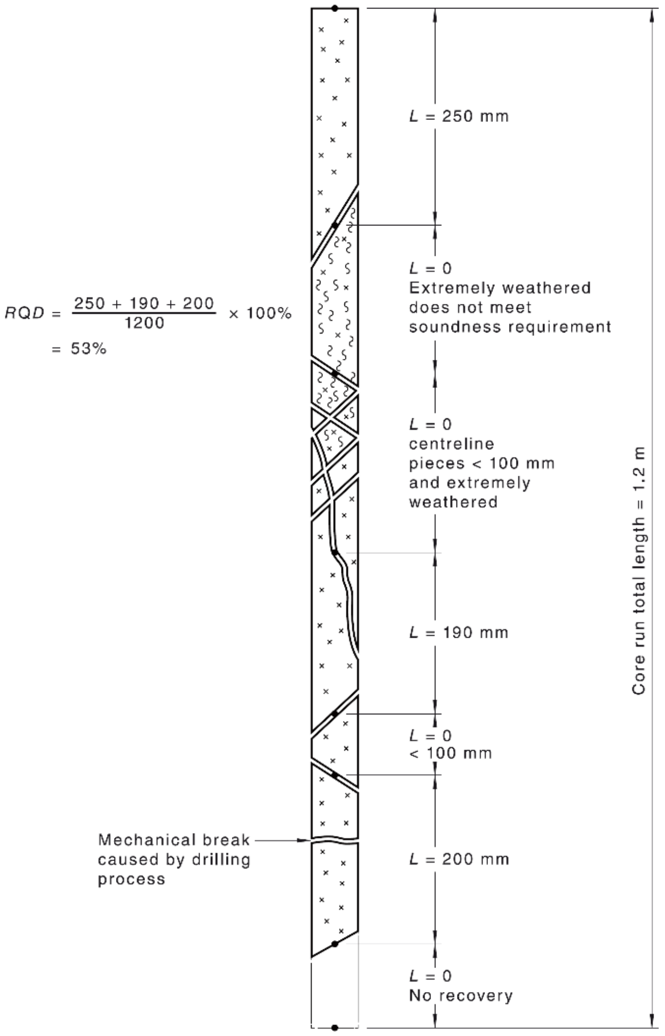
For certain projects, such as tunnelling or underground mining investigations, rock mass ratings or classifications can be required as part of the design process. The RQD forms a component of these rock mass ratings and provides a quantitative estimate of rock mass quality from rock core logs.

The rock core must be "N" sized (nominally 50 mm) or greater for derivation of RQD. The RQD is expressed as a percentage of intact rock core (excluding residual soil and extremely weathered rock) greater than 100 mm in length over the total selected core length.

Deere et al. (1989) recommends measuring lengths of core along the centreline, as shown right.

RQD is expressed as:

$$RQD = \frac{\sum Length\ of\ sound\ core\ pieces > 100\ mm\ in\ length}{Length\ of\ core\ run}\ x\ 100\%$$



RQD measurement procedure
(reproduced from Figure 13, Clause 6.2.9.4, AS 1726-2017, Geotechnical site investigations)

ROCK MASS CLASSIFICATION

Rock mass classification schemes may be used to represent the engineering characteristics of a rock mass. A large variety of classification schemes have been developed by various authors, ranging from simple to complex. All of the schemes are limited in their application and many rock mass classification systems assume that the rock mass is isotropic, which is rarely the case.

References

STANDARDS AUSTRALIA (2017). AS 1726-2017. GEOTECHNICAL SITE INVESTIGATIONS.
BARTON, N. AND CHOUBEY, V. (1977). THE SHEAR STRENGTH OF ROCK JOINTS IN THEORY AND PRACTICE. ROCK MECHANICS 10, 1-54. SPRINGER.
DEERE, D.U. AND DEERE, D.W. (1989). ROCK QUALITY DESIGNATION (RQD) AFTER TWENTY YEARS. CONTRACT REPORT GL-89-1. ARMY CORPS OF ENGINEERS. WASHINGTON DC, 1989.

DYNAMIC CONE PENETROMETER (DCP) TESTING

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SCOPE

The Dynamic Cone Penetrometer (DCP) test comprises the measurement of the soil resistance to a steel rod driven into the ground by a dropped weight.

The DCP test is a simple manual test used in both sandy and clayey soils. The test is a measure of the shear strength of the soil at relatively shallow depth.

EQUIPMENT AND METHOD

A general description of the dynamic penetrometer apparatus used by our firm is presented in Australian Standard AS 1289.6.3.2. The equipment utilises a 9 kg sliding weight with a drop height of 510 mm. It is fitted with a conical tip. The equipment can be adjusted for a fall of 600 mm and use of a blunt tip in accordance with AS 1289.6.3.3.

The test data are generally recorded as the number of blows (n) per 50 mm of penetration. For specific applications (such as pavement investigations), the data may be collected in the reverse form, i.e. as mm per blow. The results are presented either in tabular or graphic form for reporting purposes.

INTERPRETATION

The interpretation of the DCP results is generally based on the assumption that the measured resistance is a function of soil strength. A profile of soil strength (cohesive soils) or density index (cohesionless soils) can thus be established. The test often can be used to qualitatively indicate the presence of soft or loose zones within a soil profile.

The energy of the system per unit area is similar to that of the larger Standard Penetration Test (SPT). Thus, the common relationships of SPT and other parameters can be used as a means of estimating soil properties, after appropriate site specific consideration. The interpretations from the test are approximate only, and this is particularly pertinent to sand profiles where the magnitude of confinement stress is important in the assessment of the results.

Interpretation of the DCP penetration rate at depth must be conducted with due regard to rod friction effects. In particular, care must be exercised with soft clay profiles where rod resistance may have an unconservative impact on the results. Care must also be exercised with soil profiles containing larger particles such as gravels and cobbles where penetration rate can be affected if the DCP tip strikes or glances off such particles.

In-situ California Bearing Ratio (CBR) values of clay soil subgrades are sometimes interpreted directly from DCP test results for use in road pavement design. In this case, the correlation between DCP and CBR based on that published in AUSTROADS Pavement Structural Design guide (AGPT02-17 Part 2) may be applied. This correlation should be verified by site specific laboratory testing, where appropriate. In addition, the effects of moisture content variations (in-situ versus design conditions) must be considered, as the DCP test only reflects the shear strength of the soil at the time of testing. Further information can be found in AUSTROADS Geotechnical Investigation and Design guide (AGRD07-08 Part 7).

Ref: DS5.4.3 Rev 0 Date: 05/10/2018

GEO_BOREHOLE_AS1726 2017 12548413 SEP PIPELINE.GPJ GHD_GEO_TEMPLATE 2.00.GDT 11/2/22

BOREHOLE LOG SHEET

Client : Manildra Group
Project : Starches Expansion Project - Gas Pipeline Mod 2
Location : Lot 2 DP538289, Bolong Road Bomaderry NSW, (western side of Abernathy's Creek)

HOLE No. GBH01

SHEET 1 OF 3

Position : 281863.0 E 6140447.0 N GDA2020/ 56 **Surface RL:** Not measured **Angle from Horiz. :** 90° **Processed :** AJET
Rig Type : Hanjin 88D **Mounting:** Track **Contractor :** South Coast Drilling **Driller :** CM **Checked :** MW/CQ
Date Started : 4/2/2022 **Date Completed :** 4/2/2022 **Logged by :** MW **Date:** 11/2/2022

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
	Solid Flight Auger	Nil			0.10			[TOPSOIL/FILL]: Silty SAND: fine to medium grained, brown, low plasticity silt, trace clay.	SM	L	
							ML	Clayey SILT: low to medium plasticity, brown, trace sand (alluvium).	w < PL	S	
				D							
1				SPT 1/2/1 N=3							1.0m, PP=40-60kPa
2				SPT 0/0/0 N=0				2.0m, becoming brown with trace orange-brown.	w = PL	VS	SPT sunk under own weight 2.0m, PP=40-60kPa
			▶								2.7m, inflow observed during drilling
					2.80		SC	Clayey SAND: fine to medium grained, pale brown to brown, low to medium plasticity clay, trace fine, sub-angular to sub-rounded gravel (alluvium).	W	L	
3				SPT 0/1/3 N=4							3.0m, PP=60-80kPa
					3.50		CI	Sandy CLAY: medium plasticity, orange brown-red, fine to medium grained sand, trace gravel (alluvium).	w > PL	St	
4				SPT 4/4/6 N=10							4.0m, PP=140-180kPa
					4.70		CI-CH	Silty CLAY: medium to high plasticity, pale grey, trace fine grained sand (alluvium).	w = PL	St	
5											

See standard sheets for details of abbreviations & basis of descriptions

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CONSULTING GEOTECHNICAL ENGINEERS AND GEOLOGISTS

Job No.
12567208

BOREHOLE LOG SHEET

Client : Manildra Group
Project : Starches Expansion Project - Gas Pipeline Mod 2
Location : Lot 2 DP538289, Bolong Road Bomaderry NSW, (western side of Abernathy's Creek)

HOLE No. GBH01

SHEET 2 OF 3

Position : 281863.0 E 6140447.0 N GDA2020/ 56
Surface RL: Not Measured
Angle from Horiz. : 90°
Processed : AJET
Rig Type : Hanjin 88D
Mounting: Track
Contractor : South Coast Drilling
Driller : CM
Checked : MW/CQ
Date Started : 4/2/2022
Date Completed : 4/2/2022
Logged by : MW
Date: 11/2/2022

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
	Solid Flight Auger	Nil		SPT 3/5/8 N=13		▨	CI-CH	Silty CLAY: as previous.	w = PL	St	5.0m, PP=140-150kPa
6				SPT 2/7/10 N=17	5.90	▨	CI	Silty CLAY: medium plasticity, mottled red/brown, orange/brown, trace fine to medium grained sand (residual).	w = PL	VSt	6.0m, PP=340-450kPa
7				SPT 3/4/7 N=11		▨					7.0m, PP=220-270kPa
					7.60	▨	CI-CH	Silty CLAY: medium to high plasticity, red/brown, orange/brown, trace fine to medium grained sand (extremely weathered).	w < PL	VSt/ H	
8				SPT 7/11/17 N=28		▨					8.0m, PP=180-260kPa
9						▨					
10											

See standard sheets for details of abbreviations & basis of descriptions

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Job No.
12567208

BOREHOLE LOG SHEET

Client : Manildra Group
Project : Starches Expansion Project - Gas Pipeline Mod 2
Location : Lot 2 DP538289, Bolong Road Bomaderry NSW, (western side of Abernathy's Creek)

HOLE No. GBH01

SHEET 3 OF 3

Position : 281863.0 E 6140447.0 N GDA2020/ 56 **Surface RL:** Not Measured **Angle from Horiz. :** 90°
Rig Type : Hanjin 88D **Mounting:** Track **Contractor :** South Coast Drilling **Driller :** CM
Date Started : 4/2/2022 **Date Completed :** 4/2/2022 **Logged by :** MW

Processed : AJET
Checked : MW/CQ
Date: 11/2/2022
Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
	Solid Flight Auger	Nil			11.00	▨	CI-CH	Silty CLAY: as previous.	w < PL	VSt/ H	
11								End of borehole at 11.00 metres.			
12											
13											
14											
15											

Geological & Engineering Log

Project	Packing Plant	East	281865.0 m	Start Date	27/06/2019	Contractor	Total Drilling	Inclination	90°
Client	Manildra	North	6140465.0 m	End Date	27/06/2019	Rig Type	Hanjin 8D	Azimuth	
Site	Bolong Road Bomaderry	Elevation	2.53 m			Mounting	Track	North	
Job Number	3001550	Datum	MGA94 Zone 56/AHD					Survey	

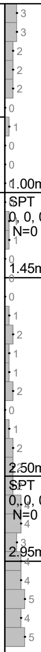
Borehole Identifier: **SBH01**

Method: ADT (0.0–4.0 m); WB (4.0–6.0 m)

Casing Support: Steel Casing - HW (114.3 mm) mm (0.0–4.0 m)

Water Level & Inflow: ▶ 0.60 m

Sampling	Testing (Strength: SPT, DCP, Is(50) (MPa), PP (UCS kPa), SV (kPa))
CBR (0.60–1.00 m)	
	1.00m SPT 0, 0, 0 N=0 1.45m
	2.50m SPT 0, 0, 0 N=0 2.95m
U75 (3.50–4.00 m)	
	4.00m SPT 2, 3, 5 N=8 4.45m
	5.50m SPT 4, 5, 7 N=12 5.95m



Depth (m)	RL	Soil Code	Soil / Rock Material Description	Moisture Condition	Consistency Density	Origin, Stratigraphic Unit & General Observations
0.00	2.53	MI	TOPSOIL Clayey SILT trace sand: dark brown, medium plasticity, with fine to medium sand, abundant rootlets and organic matter.	W≈ PL	St	TOPSOIL
0.40	2.13	CH	Silty CLAY trace sand: high plasticity, dark grey, silt, trace fine sand and rootlets.	W>PL		ESTUARINE
0.60	1.93	CH	CLAY with silt with sand: high plasticity, dark grey, trace brown, with silt and with fine grained sand.		VS	1.00: SPT Recovery: 0.45 m; Sank 450mm 2.50: SPT Recovery: 0.45 m; Sank 450mm
2.70	-0.17	CL	Sandy CLAY with gravel: low plasticity, dark grey, fine to medium grained sand with silt, with coarse, sandstone gravel, trace sea shell and fossils. 3.80 m: Possible cobbles from 3.80m to 4.00m		S (2.70–4.00) St (4.00–4.30)	4.00: SPT Recovery: 0.45 m
4.30	-1.77	CH	CLAY with silt trace fine sand: high plasticity, orange brown mottled red brown and pale grey, with silt and trace fine sand.			ALLUVIAL 5.50: SPT Recovery: 0.45 m

Installation: SBH01

Observations and Comments
Backfilled on Completion

Penetrometer Notes
Type: DCP9
Blows per 100 mm

Notes
Classifications compliant with AS1726-2017: Geotechnical Site Investigations unless otherwise noted.
Defect Log Abridged. Additional detail in digital dataset. Lugeon: BS5930:1999
For Inclined Holes: Angles reported in defects are apparent dip from core horizontal unless as α or β.
Refer to explanatory notes for SMEC logs for details of abbreviations or basis of description.

Logged By	GRR	Date	27/06/2019
Approved By	SM	Date	30/08/2019
Status	Final	Page	1 of 3

Geological & Engineering Log

Project	Packing Plant	East	281865.0 m	Start Date	27/06/2019	Contractor	Total Drilling
Client	Manildra	North	6140465.0 m	End Date	27/06/2019	Rig Type	Hanjin 8D
Site	Bolong Road Bomaderry	Elevation	2.53 m			Mounting	Track
Job Number	3001550	Datum	MGA94 Zone 56/AHD				

Inclination 90°
Azimuth
North
Survey

SMEC

Borehole Identifier: **SBH01**

Method	Casing Support	Water (Gain/Loss)	Run (TCR) RQD	Sampling	Testing: Strength SPT, DCP, Is(50) (MPa), PP (UCS kPa), SV (kPa)	Testing: Permeability, Level & Inflow	Depth (m) *Elevation*	Graphic Log	Soil Code	*Depth* RL	Soil / Rock Material Description	Moisture Condition	Consistency Density	Colour	Weathering & Alteration	Rock Strength	Inferred Rock Strength Point Load Is(50) ● - Axial ○ - Diametral VL -0.1 L -0.3 M -1 H -3 VH -10 EH	Relative Strength Soil-Rock	Defect Spacing (mm) 0 2 20 200 2000	Visual	Fabric, Structure & Defect Description	Group Defects	Origin, Stratigraphic Unit & General Observations	Installation
							6.0 *-3.5*		CH	*6.40*	CLAY with silt trace sand: high plasticity, orange brown mottled red brown and pale grey, with silt and trace fine sand. *(continued)*	W>PL	St										ALLUVIAL	
									CI	-3.87 *7.00*	CLAY with gravel with sand: medium plasticity, red brown, orange brown, with highly weathered, fine to medium, sub-angular gravel, fine to medium sand (possible residual).	W≈PL	H											
					7.00m SPT 9, 10, 14 N=24 7.45m		7.0 *-4.5*			-4.47	CLAY trace sand trace gravel: high plasticity, red brown, orange, with fine to medium grained sand, trace fine to medium, highly weathered gravel.		VSt										RESIDUAL SOIL 7.00: SPT Recovery: 0.45 m	7.0
							8.0 *-5.5*																	8.0
					8.50m SPT 8, 11, 14 N=25 8.95m																		8.50: SPT Recovery: 0.45 m	
WB							9.0 *-6.5*				9.10 m: Becoming pale grey below 9.10m													9.0
									CH															
							10.0 *-7.5*																	10.0
											10.50 m: With some intermittent bands of highly weathered gravel with medium sand below 10.50m													
							11.0 *-8.5*																	11.0
							12.0																	

Observations and Comments
Backfilled on Completion

Penetrometer Notes
Type: DCP9
Blows per 100 mm

Notes
Classifications compliant with AS1726-2017: Geotechnical Site Investigations unless otherwise noted.
Defect Log Abridged. Additional detail in digital dataset. Lugeon: BS5930:1999
For Inclined Holes: Angles reported in defects are apparent dip from core horizontal unless as α or β.
Refer to explanatory notes for SMEC logs for details of abbreviations or basis of description.

Logged By	GRR	Date	27/06/2019
Approved By	SM	Date	30/08/2019
Status	Final	Page	2 of 3

Geological & Engineering Log

Project	Packing Plant	East	281865.0 m	Start Date	27/06/2019	Contractor	Total Drilling	Inclination	90°
Client	Manildra	North	6140465.0 m	End Date	27/06/2019	Rig Type	Hanjin 8D	Azimuth	
Site	Bolong Road Bomaderry	Elevation	2.53 m			Mounting	Track	North	
Job Number	3001550	Datum	MGA94 Zone 56/AHD					Survey	

Borehole Identifier: **SBH01**

Method	Casing Support Water (Gain/Loss)	Run (TCR) RQD	Sampling	Testing: Strength SPT, DCP, Is(50) (MPa), PP (UCS kPa), SV (kPa)	Testing: Permeability, Level & Inflow	Depth (m) *Elevation*	Graphic Log	Soil Code	*Depth* RL	Soil / Rock Material Description	Moisture Condition	Consistency Density	Colour	Weathering & Alteration	Rock Strength	Inferred Rock Strength Point Load Is(50) ● - Axial ○ - Diametral VL L M H VH EH (-0.1 -0.3 -1 -3 -10)	Relative Strength Soil-Rock	Defect Spacing (mm) 0 2 20 200 2000	Visual	Fabric, Structure & Defect Description	Group Defects	Origin, Stratigraphic Unit & General Observations	Installation
WB						12.0 *-9.5* 13.0 *-10.5*		CH		CLAY trace sand trace gravel: high plasticity, red brown, orange, with fine to medium grained sand, trace fine to medium, highly weathered gravel. *(continued)*	W≈ PL	VSt										RESIDUAL SOIL	13.0
				13.20m SPT 17, 10/20 mm HB N=R 13.37m					*13.20* -10.67 *13.45*	SANDSTONE (100%): medium grained, low strength, highly weathered, pale grey, red brown, medium grained sandstone.	M	H										WEATHERED ROCK (SANDSTONE) 13.20: SPT Recovery: 0.17 m	13.5
						14.0 *-11.5* 15.0 *-12.5* 16.0 *-13.5* 17.0 *-14.5* 18.0				Hole Terminated at 13.45 m Target depth													14.0 15.0 16.0 17.0

Observations and Comments
Backfilled on Completion

Penetrometer Notes
Type: DCP9
Blows per 100 mm

Notes
Classifications compliant with AS1726-2017: Geotechnical Site Investigations unless otherwise noted.
Defect Log Abridged. Additional detail in digital dataset. Lugeon: BS5930:1999
For Inclined Holes: Angles reported in defects are apparent dip from core horizontal unless as α or β.
Refer to explanatory notes for SMEC logs for details of abbreviations or basis of description.

Logged By	GRR	Date	27/06/2019
Approved By	SM	Date	30/08/2019
Status	Final	Page	3 of 3

Attachment 3

DCP test results

REACTIVE SOILS SITE MANAGEMENT PRECAUTIONS

GHD
Specialist Services in Geotechnical Engineering,
Geology, Field/Laboratory Testing and Hydrogeology
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These precautions are considered supplementary to any structural and/or foundation design measures for the subject building, and are intended for distribution to the prospective building owner / occupier.

Reactive clays are prone to heave/shrink movements with changes in soil moisture content due to natural or artificial means. The basic design philosophy employed for the building is to provide a foundation/superstructure adequate to accommodate ground movements due to extreme seasonal moisture changes only. The possibility of other abnormal and/or localised moisture changes (the cause of most building distress) has been assumed to be controlled by the following site management procedures.

In particular, leaking plumbing or blocked drains should be repaired promptly and site grading maintained to prevent ponding near foundations. Garden watering, particularly by fixed systems, should be controlled carefully to avoid gross over-watering. On the other hand, proper garden maintenance should produce year round uniform moisture conditions.

Trees and shrubs can cause a substantial drying of the clay soil profile and associated shrinking of reactive clays. This effect is most likely to result in damage when added to the drying from a drought or a long dry spell. The problem can be avoided by planting trees at substantial distances from the building. The distance depends upon the species, soil conditions, and site classification.

Problems during droughts can be minimised by extensive pruning (thus reducing water demand) and/or providing trees with adequate water. This watering can be achieved by boreholes or trenches dug well into the clay between the tree and the footing. To avoid settlement problems, the holes or trenches should not be too close to the footing and should be filled with compacted screenings. The installation of root barriers is another option. Frequent moderate watering during dry periods also should assist in minimising the extraction of excessive moisture from beneath the foundation of the building by trees and other vegetation as well as the environmental effects.

This action should also be immediately undertaken by the owner / occupier if brickwork cracking due to tree drying is noticed. Most reactive clay failures can be avoided or the effects minimised by controlling the combined drying effects of trees and drought.

The owner / occupier should also appreciate that on reactive clays it is virtually impossible to design an economic foundation system which will totally prevent movement. Some minor aesthetic cracking, while undesirable, will occur in a significant proportion of houses. In addition, some minor problems should be expected with jamming of windows and doors, especially during the settling-in period or following a major drought, and such repairs should be regarded as part of normal building maintenance. Even significant masonry cracking with widths over 5mm usually has little influence on the function of the wall and presents an aesthetic problem. Just as it is difficult to design an immovable footing system, it is almost impossible to provide remedial measures that will prevent further movements if distress does occur. Consequently, extreme remedial measures should not be undertaken for minor problems.

Advice on these matters is addressed in Australian Standard AS2870 “Residential slabs and footings”. In particular the designer, owner and occupier are referred to Appendix B “Foundation Performance and Maintenance” in AS2870.

Useful information for homeowners can also be found in CSIRO Building Technology File BTF 18-2011 “Foundation Maintenance and Footing Performance: A Homeowner’s Guide”, available through CSIRO Publishing.

Ref: DS5.4.1 Rev 0 Date: 04/10/2018

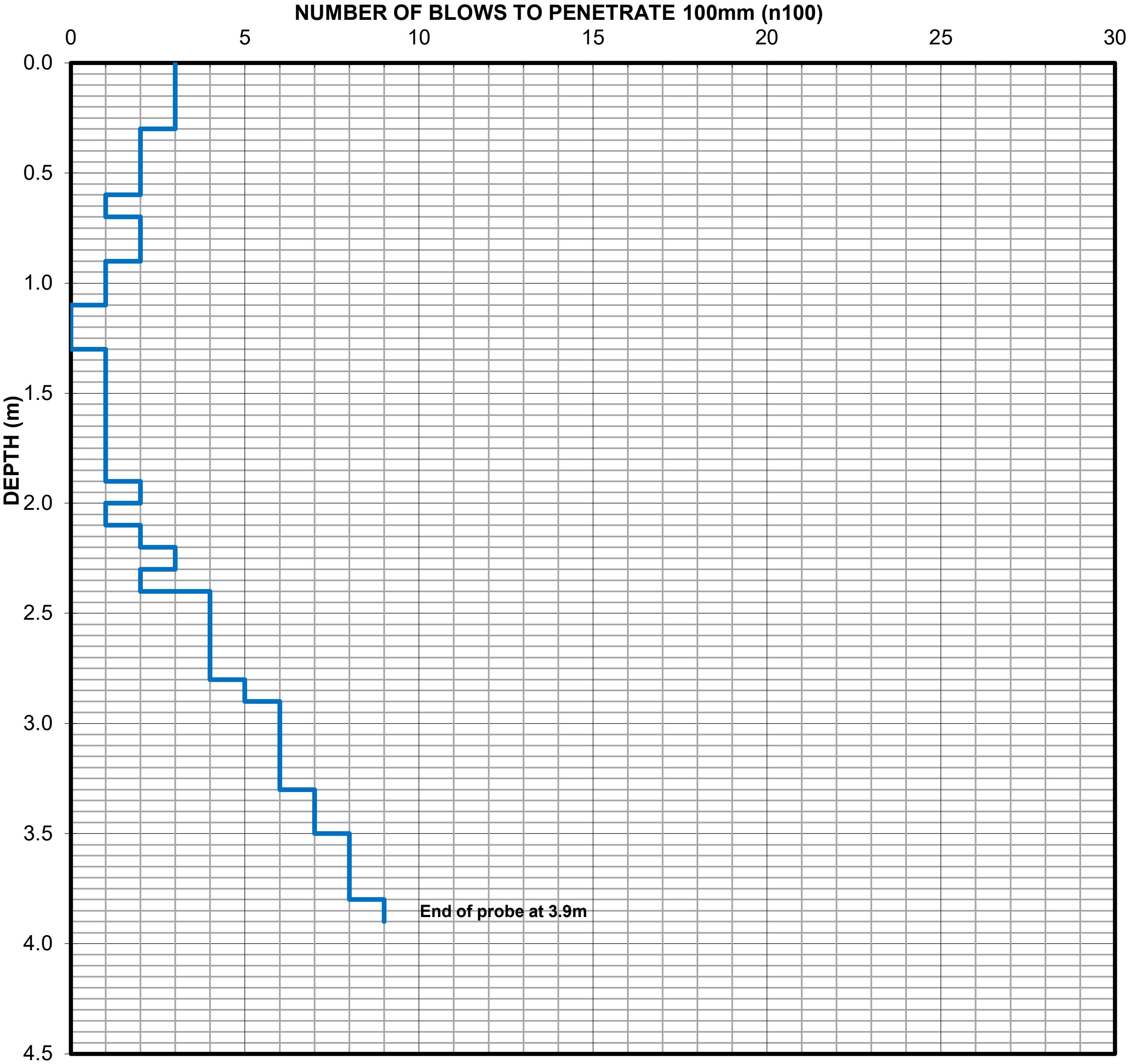
DYNAMIC CONE PENETROMETER LOG SHEET

Client: Manildra Group
Project: Shoalhaven Starches Expansion Project
Location: Abernathy's Creek, Bolong Road, Bomaderry

PROBE: DCP01

AS 1289.6.3.2-1997 (Cone Tip) 510 mm drop height.

Position:	281894 E; 6140452 N	**Chainage:**	N/A	**Operator:**	M. Wright
Elevation:	Not measured	**Offset:**	N/A	**Date:**	11/02/2022
Adjacent Test Hole / Pit:	N/A			**Checked:**	C. Quayle
Position Relative to Test Hole / Pit:	N/A			**Date:**	14/02/2022



Comments:

CONSULTING GEOTECHNICAL ENGINEERS AND GEOLOGISTS
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GHD GEOTECHNICS

Job No.
12548413

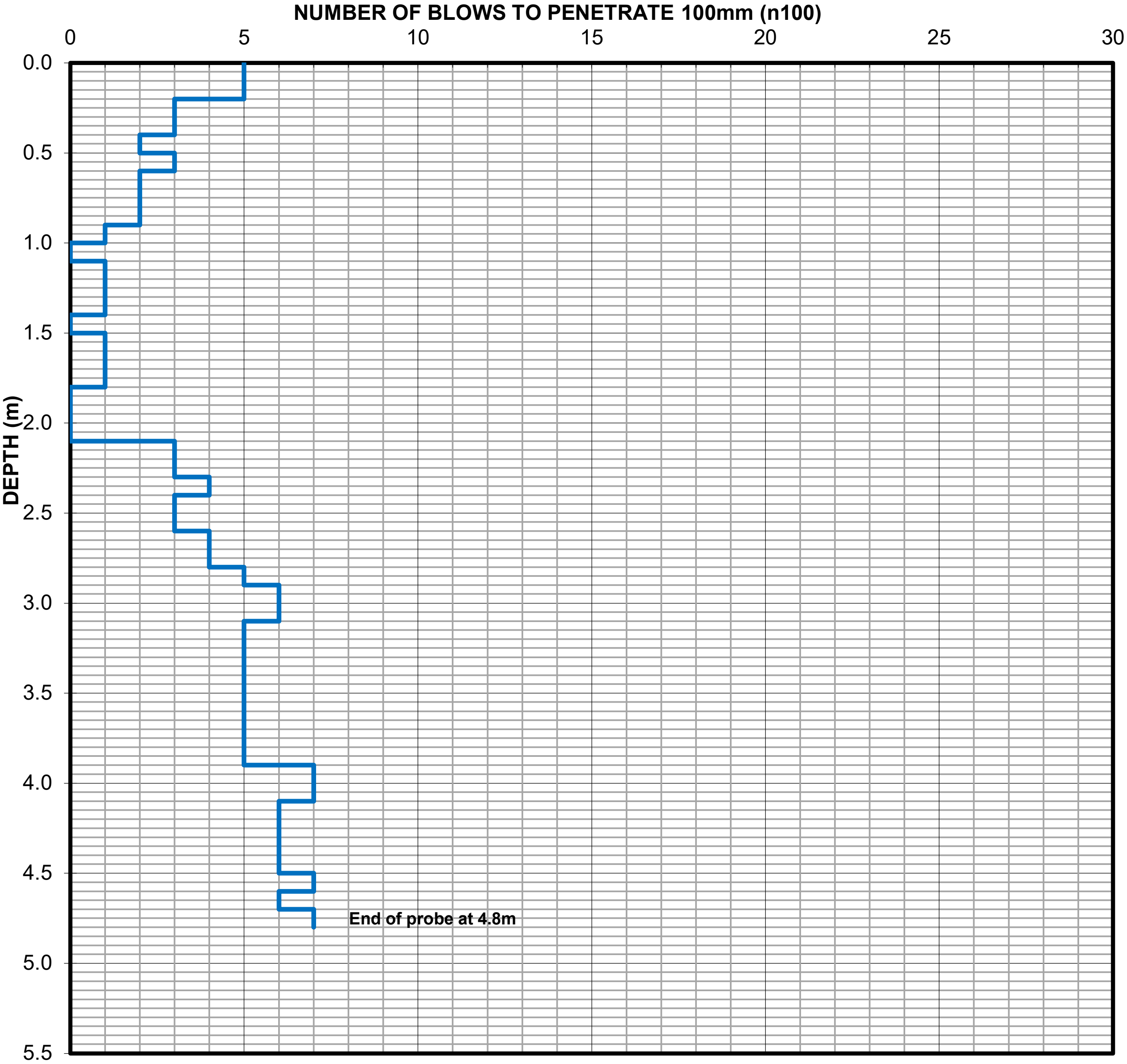
DYNAMIC CONE PENETROMETER LOG SHEET

Client: Manildra Group
Project: Shoalhaven Starches Expansion Project
Location: Abernathy's Creek, Bolong Road, Bomaderry

PROBE: DCP02

AS 1289.6.3.2-1997 (Cone Tip) 510 mm drop height.

Position: 281900 E; 6140464 N
Chainage: N/A
Operator: M. Wright
Elevation: Not measured
Offset: N/A
Date: 11/02/2022
Adjacent Test Hole / Pit: N/A
Checked: C. Quayle
Position Relative to Test Hole / Pit: N/A
Date: 14/02/2022



Comments:
At 1.8 m DCP rods sunk after one blow to 2.1 m

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Job No.
12548413

FRAC

CALCS

Natural Gas Pipeline and Pressure Reduction Station
FRAC OUT ANALYSIS

HDD NAME **ABERNETHYS CREEK - DN450 BORE** 23/02/2022 REV 1

CAVITY EXPANSION THEORY WAS USED TO DETERMINE MAX BORE HOLE PRESSURE

The model is developed to establish the maximum allowable pressure that can be applied to a given soil without hydrofacture occuring, expressed as follows

$$p_{max} = u + [\sigma_0' \cdot (1+\sin\varphi) + c\cdot\cos\varphi + c\cdot\cot\varphi]\cdot\left(\left(\frac{R_0}{R_{pmax}}\right)^2 + \frac{\sigma_0'\cdot\sin\varphi + c\cdot\cos\varphi}{G}\right)^{\frac{-\sin\varphi}{1+\sin\varphi}} - c\cdot\cot\varphi \quad [1]$$

Where

pMax is the max allowable mud pressure in bore hole in kPa

Ro Initial Bore Radius (For Pilot Hole) 4.25 inch 0.05 m
Rpmax Radius of Plastic Zone 0.32 m Borehole Size 0.10795 m
Rmax Generally 3 times the bore hole size

Soil Variables (In accordance with Geotech Report Ref 3001550, Packing Plant - Soft Soil Improvement Design) - SCPT06, SBH01
& In accordance with 12548413-LET-1_GP-MOD2 GHD REPORT - GBH01, DCP 01/02

$\varphi =$ Soil Friction Angle [°] 25.00 Deg Worst case scenario value

$c =$ cohesion 2.00 kPa Worst case scenario value

$\gamma =$ Unit weight of soil above the groundwater 15 kN 1529.05 kg/m3 Worst case scenario value

$\gamma' =$ Unit weight of soil below the groundwater 1529.05 kg/m3

E = Youngs Modulus 7.50 Mpa Average Value (Refer to SCPT01)

v = Poissons Ratio 0.30

G = Shear Modulus G = E / (2(1+v)) 2.88 Mpa 2,884.62 kPa

Variables Dependent on Bore Geometry at **Under Creek Bed** **Deepest Point - Bore Mid Point** Ch 136

$h_s =$ Depth of the Bore below Ground Surface 4.00 m

$h_w =$ Height of groundwater over the bore -4.00 m

$u =$ Groundwater Pressure 39.24 kPa

$\sigma' =$ Effective Stress $= \gamma\cdot(h_s - h_w) + \gamma'(h_w)$ 6,116.21 kg/m2 60.00 kPa

sinQ	0.422618262
cosQ	0.906307787
tanQ	0.466307658
cotQ	2.144506921

$[\sigma_0' \cdot (1+\sin\varphi) + c\cdot\cos\varphi + c\cdot\cot\varphi]$ = 91.45873

$\frac{-\sin\varphi}{1+\sin\varphi}$ = -0.2971

$\left(\left(\frac{R_0}{R_{pmax}}\right)^2 + \frac{\sigma_0'\cdot\sin\varphi + c\cdot\cos\varphi}{G}\right)$ = 0.04

$\left(\left(\frac{R_0}{R_{pmax}}\right)^2 + \frac{\sigma_0'\cdot\sin\varphi + c\cdot\cos\varphi}{G}\right)^{\frac{-\sin\varphi}{1+\sin\varphi}}$ = 2.66

$$p_{max} = u + [\sigma_0' \cdot (1+\sin\varphi) + c\cdot\cos\varphi + c\cdot\cot\varphi]\cdot\left(\left(\frac{R_0}{R_{pmax}}\right)^2 + \frac{\sigma_0'\cdot\sin\varphi + c\cdot\cos\varphi}{G}\right)^{\frac{-\sin\varphi}{1+\sin\varphi}} - c\cdot\cot\varphi \quad [1]$$

Borehole pressure to be less than this
= 278.11 kPa 40.33 psi

Variables Dependent on Bore Geometry at **At 4m Cover** **1/3 into the bore** Outside Creek Bank Ch 112

$h_s =$ Depth of the Bore below Ground Surface 5.49 m

$h_w =$ Height of groundwater over the bore -3.00 m

$u =$ Groundwater Pressure 29.43 kPa

$\sigma' =$ Effective Stress $= \gamma\cdot(h_s - h_w) + \gamma'(h_w)$ 8,394.50 kg/m2 82.35 kPa

sinQ	0.422618262
cosQ	0.906307787
tanQ	0.466307658
cotQ	2.144506921

$[\sigma_0' \cdot (1+\sin\varphi) + c\cdot\cos\varphi + c\cdot\cot\varphi]$ = 123.2542

$\frac{-\sin\varphi}{1+\sin\varphi}$ = -0.2971

$\left(\left(\frac{R_0}{R_{pmax}}\right)^2 + \frac{\sigma_0'\cdot\sin\varphi + c\cdot\cos\varphi}{G}\right)$ = 0.04

$\left(\left(\frac{R_0}{R_{pmax}}\right)^2 + \frac{\sigma_0'\cdot\sin\varphi + c\cdot\cos\varphi}{G}\right)^{\frac{-\sin\varphi}{1+\sin\varphi}}$ = 2.59

$$p_{max} = u + [\sigma_0' \cdot (1+\sin\varphi) + c\cdot\cos\varphi + c\cdot\cot\varphi]\cdot\left(\left(\frac{R_0}{R_{pmax}}\right)^2 + \frac{\sigma_0'\cdot\sin\varphi + c\cdot\cos\varphi}{G}\right)^{\frac{-\sin\varphi}{1+\sin\varphi}} - c\cdot\cot\varphi \quad [1]$$

Borehole pressure to be less than this
= 344.72 kPa 49.98 psi

Variables Dependent on Bore Geometry at **At 2.63m Cover** Near car park **Ch 91**

$h_s =$ Depth of the Bore below Ground Surface 2.63 m

$h_w =$ Height of groundwater over the bore 0.00 m

$u =$ Groundwater Pressure 0.00 kPa

$\sigma' =$ Effective Stress $= \gamma \cdot (h_s - h_w) + \gamma'(h_w)$ 4,021.41 kg/m2 39.45 kPa

sinQ	0.422618262
cosQ	0.906307787
tanQ	0.466307658
cotQ	2.144506921

$[\sigma_0' \cdot (1 + \sin\varphi) + c \cdot \cos\varphi + c \cdot \cot\varphi]$ = 62.22392

$\frac{-\sin\varphi}{1+\sin\varphi}$ = -0.2971

$\left(\left(\frac{R_0}{R_{pmax}}\right)^2 + \frac{\sigma_0' \cdot \sin\varphi + c \cdot \cos\varphi}{G}\right)$ = 0.03

$\left(\left(\frac{R_0}{R_{pmax}}\right)^2 + \frac{\sigma_0' \cdot \sin\varphi + c \cdot \cos\varphi}{G}\right)^{\frac{-\sin\varphi}{1+\sin\varphi}}$ = 2.73

$$p_{max} = u + [\sigma_0' \cdot (1 + \sin\varphi) + c \cdot \cos\varphi + c \cdot \cot\varphi] \cdot \left(\left(\frac{R_0}{R_{pmax}}\right)^2 + \frac{\sigma_0' \cdot \sin\varphi + c \cdot \cos\varphi}{G}\right)^{\frac{-\sin\varphi}{1+\sin\varphi}} - c \cdot \cot\varphi \quad [1]$$

Borehole pressure to be less than this
165.34 kPa 23.97 psi

Variables Dependent on Bore Geometry at **2/3 into the bore** Outside Creek Bank **Ch 162**

$h_s =$ Depth of the Bore below Ground Surface 5.44 m

$h_w =$ Height of groundwater over the bore -3.44 m

$u =$ Groundwater Pressure 33.75 kPa

$\sigma' =$ Effective Stress $= \gamma \cdot (h_s - h_w) + \gamma'(h_w)$ 8,318.04 kg/m2 81.60 kPa

sinQ	0.422618262
cosQ	0.906307787
tanQ	0.466307658
cotQ	2.144506921

$[\sigma_0' \cdot (1 + \sin\varphi) + c \cdot \cos\varphi + c \cdot \cot\varphi]$ = 122.1873

$\frac{-\sin\varphi}{1+\sin\varphi}$ = -0.2971

$\left(\left(\frac{R_0}{R_{pmax}}\right)^2 + \frac{\sigma_0' \cdot \sin\varphi + c \cdot \cos\varphi}{G}\right)$ = 0.04

$\left(\left(\frac{R_0}{R_{pmax}}\right)^2 + \frac{\sigma_0' \cdot \sin\varphi + c \cdot \cos\varphi}{G}\right)^{\frac{-\sin\varphi}{1+\sin\varphi}}$ = 2.59

$$p_{max} = u + [\sigma_0' \cdot (1 + \sin\varphi) + c \cdot \cos\varphi + c \cdot \cot\varphi] \cdot \left(\left(\frac{R_0}{R_{pmax}}\right)^2 + \frac{\sigma_0' \cdot \sin\varphi + c \cdot \cos\varphi}{G}\right)^{\frac{-\sin\varphi}{1+\sin\varphi}} - c \cdot \cot\varphi \quad [1]$$

Borehole pressure to be less than this
346.53 kPa 50.25 psi

Check - Internal Pressure within Borehole

Annular Pressure (Pd) of Drill Fluid exerted by a mid sized HDD rig ranges from 10kPa to 52kPa for a 100 to 120m HDD

Hydrostatic pressure of the Drill Fluid is $P_{\text{drill fluid hydrostatic}} = h_{\text{drill fluid}} \times 9.81 \times \rho_{\text{drill fluid}}$

Where,

Height of drill fluid column $h_{\text{drill fluid}}$

Mud Weight $\rho_{\text{drill fluid}} = 1.20$ kg/l

(mud weight of 1.20 kg/l used due to cuttings suspended in the hole)

Accordingly for various locations along the HDD path the internal pressures are as per below.

		Ph	*Location of Drill Head*	*Expected Pd*	Total Expected Internal Pressure
Pdrill fluid Hydrostatic	at 2.63m head (h)	30.96 kPa	Ch 91	20 kPa	51.0 kPa
	at 5.49m head (h)	64.63 kPa	Ch 112	27 kPa	91.6 kPa
	at 4m head (h)	47.09 kPa	Ch 136	34 kPa	81.1 kPa
	at 5.44m head (h)	64.04 kPa	Ch 162	52 kPa	116.0 kPa

Comparing the internal pressures vs the soil bearing pressures at various points along the HDD it is clear that frac out is not probable

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HEAD
TRACKING
TOOL

DigiTrak FALCON F5®

Directional Drilling Guidance System

- Wideband technology evaluates hundreds of frequencies for the best possible performance around active interference
- Ultra-low frequency options for battling passive interference on the jobsite
- Scan for interference, select optimum frequencies, and pair transmitter at the jobsite
- Switch between paired bands mid-bore
- Full Scale Sensitive Pitch provides 0.1% resolution through ±99.9% slope for precision grade work
- Max Mode filters noise to boost weak data signals and stabilize depth readings
- Standard warranty for 19- and 15-inch transmitters is 3 years/500 hours

Falcon F5 Is Now *Passive Aggressive*

The ability to choose the right transmitter frequency is more important than power in overcoming the effect of active interference. In October of 2015, DCI introduced Falcon technology, a significant new approach to overcoming active interference on HDD jobsites. DCI now introduces a new approach to addressing the problem of passive interference: sub-kilohertz frequencies. Falcon F5 with Sub-k Rebar capability allows a locating specialist to scan the jobsite and select the best frequency in the ultra-low frequency range of 0.33–0.75 kHz to combat passive interference.

Falcon Innovation Continues

Falcon is the HDD industry's only walkover guidance system able to specifically address both active and passive interference. Transmitter frequencies below 1 kHz are proven most effective for jobsites where passive interference is a problem. In addition, the new Falcon F5 receiver supports Full Scale Sensitive Pitch (FSSP) for 0.1% resolution through ±99.9% slope for precision grade work.

The Falcon F5 receiver offers the industry's first fully integrated GPS capability using the DigiTrak iGPS module. Snap on the iGPS module and it automatically powers on to receive and record satellite GPS data.

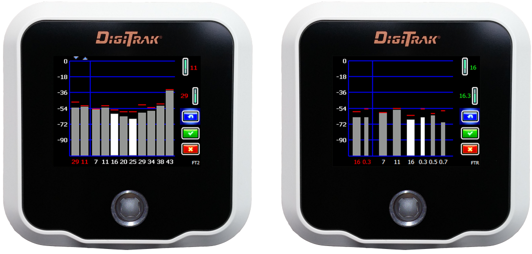
Use the free LWD Mobile app to view the progress of the bore and overlay the iGPS locate points on your smart device.

The Falcon F5 Wideband Transmitter

A Falcon F5 transmitter provides versatility in all types of active interference at frequencies of 4.5–45 kHz. The Falcon F5 wideband design vastly outperforms single-frequency transmitters of past generations. It also comes standard with fluid pressure measurement. No other guidance system allows an operator to scan for active interference and then pair optimized frequencies to a transmitter at every jobsite. This provides substantial cost savings and increases pilot bore productivity.

The Falcon F5 Sub-k Rebar Transmitter

The newest entrant into the Falcon F5 wideband transmitter lineup is the Sub-k Rebar transmitter. It uses frequencies below 1 kHz and provides frequency selection options from 0.33–0.75 kHz. This frequency range is ideal for addressing project scenarios that exhibit passive interference. Whether sidewalk, roadway, or runway, the Sub-k outperforms other options above 1 kHz. These transmitters include fluid pressure measurement as a standard feature.



Wideband **Sub-k Rebar**

Falcon Frequency Optimizer

DIGITAL CONTROL INCORPORATED

dci@digital-control.com ▪ www.DigiTrak.com ▪ 1.425.251.0559, 1.800.288.3610 (US/CAN)

	DigiTrak Sub-kHz			The other guys	DigiTrak Wideband								
Band Number	0.3	0.5	0.7		7	11	16	20	25	29	34	38	43
Range in kHz	.33 – .40	.40 – .58	.58 – .75	1.5 – 4.0	4.5 – 9.0	9.0 – 13.5	13.5 – 18	18 – 22.5	22.5 – 27	27 – 31.5	31.5 – 36	36 – 40.5	40.5 – 45

Ease of Use

Falcon F5 raises the bar on walkover locating system capability and ease of use. Our customers have always relied on the Falcon F5's color, icon-driven screen for easy menu navigation. *Ball-in-the-Box* has never been more powerful and still provides a real-time status of the bore in progress. Minimize downtime caused by alternative products that claim to get the job done but often fall short. Keep your project on DigiTrak and maximize your productivity.

3 Year/500 Hour Warranty

Register your new Falcon 19- or 15-inch transmitter within 90 days for an enhanced warranty of 3 years or 500 hours, whichever occurs first. Ask your dealer about an extended warranty option that provides 5 year/750 hour coverage.

Transmitter Specifications

See the separate Falcon F5 Transmitter Specification Sheet for details on the six different 19-, 15-, and 8-inch wideband options for active interference and Sub-k Rebar options for combating passive interference. Falcon F5 also supports our popular DucTrak transmitters.

Receiver Specifications

Product ID	FF5
Model number	FAR5
Receiving frequencies	0.33–45.0 kHz
Telemetry channels[1]	4
Telemetry range[2]	defined by remote display
Power source	Lithium-ion battery pack
Battery life	8–12 hrs
Functions	Menu-driven
Controls	Trigger and toggle switches
Graphic display	Full-color LCD
Audio output	Beeper
Accuracy	±5%
Voltage, current	14.4 VDC nominal, 390 mA max
Operating temperature	-20–60° C
Dimensions	27.94 x 13.97 x 38.1 cm
Weight (with battery)	3.9 kg

Aurora Touchscreen Display Specifications

Product ID and model number	AF8, AF10
Power source - cabled	10–28 VDC
Current	1.75, 2.1 A maximum
Controls	21.3, 26.4 cm touchscreen
Graphic display	LCD
Audio output	Speaker
Telemetry channels[1]	4
Telemetry range[2]	500 m
Operating temperature	-20–60° C
Dimensions[3]	24.9 x 16.8 x 8.1, 29.2 x 23.7 x 5.8 cm
Weight	1.9, 2.9 kg

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[1] Local telemetry frequencies and power levels available at www.DigiTrak.com.

[2] Telemetry range can be increased with an optional external receiving antenna.

[3] Dimensions do not include external mounting hardware.

PRE-COM

RISK

ASSESSMENT

CONSTRUCTION ACTIVITY	HAZARD / RISK DESCRIPTION Possible Initiating Events	LIKELIHOOD	CONSEQUENCE	RISK RATING Technical Risk Rating (L x C)		MITIGATION / CONTROLS TO BE IMPLEMENTED Additional Mitigation Measures to reduce risks are listed in red	LIKELIHOOD	CONSEQUENCE	RISK RATING Technical Risk Rating (L x C)		ALARP YES / NO?
		ENTER ASSESSMENT DATA				**Procedural Mitigation, Codes of Practice, Australian Standards, Training and Induction Programmes, Physical Mitigation**	ENTER ASSESSMENT DATA				
Horizontal Directional Drilling	Stakeholder impact - injuries and supply/service disruption	3	4	12	High	• Establish Exclusion zone and signage to isolate drill area • Fencing HDD excavation to ensure restricted access • Warning signage • Hazard lights • SWMS for HDD • Entry and exit pits safe distance from access • Traffic Management, if required • Review Drilling and HDD management plan in conjunction with Shoalhaven Starches	2	3	6	Low	Y
	Handling/Bulk Storage/transporting hazardous or dangerous goods - spills, contamination, skin irritation and burns	3	4	12	High	• Ensuring containers labelled and sealed • Register of Dangerous Goods, MSDS in Site Office • Appropriate lift location • Appropriate equipment for handling/transfer • Correct PPE to be worn in accordance with Shoalhaven Starches and NAP induction as well as MSDS requirements • Spill kits in site yard and on refuelling vehicle • MSDS on file and upto date • Employee trained and competent. • Induction. • Shoalhaven Starches Audits • Licensed operator to carry bulk dangerous goods. • All transport done In accordance with EPA guidelines	2	3	6	Low	Y
	Entanglement occurs during drilling - Unauthorised personnel to work area Automated Actions, Pinch points from rod loading and jaw clamps - Soft tissue injuries	3	4	12	High	• Exclusion zone around drill identified • Authorised Persons Only Signage. • Visitor sign on Log. • Obtain Work permit • SWMS for HDD • Machinery guarding • Trained competent operators verified for employees / subcontractors • No loose clothing allowed • Isolation & tag out protocols for maintenance	2	4	8	Moderate	Y
	Noise emitted from drilling plant - OH&S issues	5	3	15	High	• All plant to be risk assessed and have scheduled maintenance / servicing • Selection of equipment to provide noise attenuation • Appropriate PPE • Job rotation to reduce exposure limit (Where required)	2	2	4	Negligible	Y
	Impact with an existing services - injuries	3	4	12	High	• Approved Boring Procedure and HDD Management Plan in conjunction with NAP and Shoalhaven Starches requirements • Tracking of the bore during drilling • Exposure of services where possible, with spotter when borer is in proximity. • Selection of HDD bore profile during design, with safety margin from underground services and adequate margin from existing pipelines • DBYD and service register to be developed to ascertain risk of impact to services	2	4	8	Moderate	Y
	Drilling Failure - major supply/service issues	3	5	15	High	• Approved Boring Procedures, Fluid Management Plan.	2	4	8	Moderate	Y

CONSTRUCTION ACTIVITY	HAZARD / RISK DESCRIPTION Possible Initiating Events	LIKELIHOOD	CONSEQUENCE	RISK RATING Technical Risk Rating (L x C)		MITIGATION / CONTROLS TO BE IMPLEMENTED Additional Mitigation Measures to reduce risks are listed in red	LIKELIHOOD	CONSEQUENCE	RISK RATING Technical Risk Rating (L x C)		ALARP YES / NO?
						• Using an experienced drilling contractor • SWMS for HDD • Conduct proving holes prior to commencement for head selection - Geotech Analysis • NAP permit to work procedure for conducting bore • Selection of HDD bore profile during design, with safety margin from underground services and adequate margin from existing pipeline • Emergency response plan (Frac out management plan)					
	Frac out occurring impacting roadways / environment	3	5	15	High	• Approved Boring Procedures, Fluid Management Plan • Using an experienced drilling contractor • SWMS for HDD • Conduct proving holes prior to commencement for head selection - Geotech Analysis • NAP permit to work procedure for conducting bore • Selection of HDD bore profile during design, with safety margin from underground services and adequate margin from existing pipeline / impact to road • Emergency response plan (Frac out management plan)	2	4	8	Moderate	Y

SWMS

Jelmac Industries Pty Ltd

SWMS

Safe Work Method Statement

Jelmac Industries Pty Ltd
2 Jeanette Maree Court
Kilsyth VIC 3137
Phone: 0417 351 908
ABN: 60 165 118 972

THIS FORM IS TO IDENTIFY TASK / SITE HAZARDS AND TO MINIMISE THE RISKS TO PERSONS AND/OR DAMAGE TO PROPERTY.					
Project:	National Australia Pipelines				
Site Address:	Creek Crossing				
Site Muster Point:		**Start Date:**		**Supervisor**	Brad Boote
Specific Task:	Directional Drilling & Vacuum Truck	**Finish Date:**		**Phone:**	0417351908
Plant & Equipment:	Directional Drill, Vacuum Truck, Support Vehicle. Hand tools.				
Hazardous Materials:					
Personal Protective Equipment Required:	Uniform Footwear ☑ Hi Visibility ☑ Hard Hat ☑ Eyewear ☑ Fall Arrest ☐ Gloves ☑ Hearing ☑ Dust Mask ☑ First Aid ☑				
Managers Approval:	Brad Boote	**Signed:**		**Date:**	20-01-2022

CONSEQUENCES	POSSIBLE COURSES OF ACTION	LIKELIHOOD	MINOR (1)	SERIOUS (2)	SEVERE (3)	MAJOR (4)	CATASTROPHIC (5)
MINOR	First Aid, No Medical Treatment required. Spillages, leaks or other escapes, which occur and are contained. Supervisor to report and monitor.	(A)...ALMOST CERTAIN Will likely occur once or more every couple of years. Expected to or occurs regularly.	Medium	High	High	Extreme	Extreme
SERIOUS	Lost time injury/medical treatment required. Spillages or leakages, which have migrated offsite. Supervisor to report and manage by routine procedures. Immediate reparative/first aid action required.	(B)...LIKELY Will likely occur once or more in 10 years.	Low	Medium	High	High	Extreme
SEVERE	Single permanent or partial disability. Discharge of any substance from site, which has the potential to harm the environment. Supervisor to report and manage by specific monitoring plan or procedures. Stop work, immediate reparative/first aid action required.	(C)...POSSIBLE Could occur but not probable. Has not occurred at Jelmac.	Low	Low	Medium	High	High
MAJOR	Total permanent disability. Actual material harm to the environment on or off site with short-term effects and reparable by remedial action. Supervisor to report and allocate responsibility to appropriate senior manager. Stop work, immediate attention needed urgently.	(D)...UNLIKELY Not expected to occur. Has not occurred at Jelmac but has occurred within the industry in Australia.	Negligible	Low	Low	Medium	High
CATASTROPHIC	Multiple fatalities or total permanent disability. Actual material harm to the environment on or offsite with long term or irreparable effects. Supervisor to report and notify appropriate senior manager to manage via detailed control plan. Stop work, quarantine site, supervisor to contact relevant emergency services.	(E)...RARE May occur in exceptional circumstances. Has occurred in known history in the industry.	Negligible	Negligible	Low	Low	Medium

Note: Do not sign this document if you do not understand or agree, or do not intend to comply with the controls prescribed herein.

Standards & Requirements	Occupation Health & Safety (OHS) Act 2004, Occupation Health & Safety (OHS) Regulations 2007,	FSR1: Temporary works, excavations and underground and overhead services FSR 02: Plant Equipment NAP Ground Penetration Permit	NAE PTW Certificates of Competency TM Plan

Ref	DESCRIPTION OF TASK	HAZARDS	PRE-RISK LEVEL			SAFE WORK METHOD RISK TREATMENT OPTIONS & ACTIONS	RESIDUAL RISK			RESPONSIBLE
			L	C	R		L	C	R	
	Safety Management	Lack of safe work practices places workers, public and wildlife at risk.	A	5	E	All Jelmac Directional Drilling staff members are issued upon acceptance of employment a Safety Folder containing all occupational health and safety procedures. Staff members are expected to refer to and follow these procedures to ensure safe work practices. Staff and emergency contact details are provided at the rear of the folder. Site-specific forms SWMS and JSA are available.	E	3	L	Management/ Supervisors/ All Personnel
	First Aid	Lack of sufficient first aid can significantly increase injury.	C	3	M	All vehicles are equipped with a Standard Workplace First Aid Kit. Injury is to be assessed and medical assistance sought if required. Follow Emergency Procedures if required and consult Emergency Contact Details if necessary.	C	2	L	Management/ Supervisors/ All Personnel
	Environmental Management	Wildlife, significant vegetation, noxious weeds, waste, hazardous chemicals and materials.	C	3	M	Identify Environmental Management procedure. Inspect, identify and assess risks. Ensure compliance with local, state or EPA guidelines. Ensure safe removal or avoidance of any wildlife and or vegetation. Ensure wash down of plant and machinery to avoid transfer of any noxious weeds. If asbestos is encountered, stop works immediately and contact engineer or supervisor. Control of Drill slurry , erect silt controls at Bore entry & exit, Remove excess via Vac unit for disposal to EPA accredited site	E	1	N	Management/ Supervisors/ All Personnel

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Ref	DESCRIPTION OF TASK	HAZARDS	PRE-RISK LEVEL			SAFE WORK METHOD RISK TREATMENT OPTIONS & ACTIONS	RESIDUAL RISK			RESPONSIBLE
			L	C	R		L	C	R	
	Emergency Preparedness	Fire, explosion, flood, bush fire, bomb threats.	E	5	M	Plant and LV Inductions need to be completed. Identify Emergency Procedures procedure. Assess location and impending weather conditions and forecast. All trucks and plant are equipped with fire extinguishers, which are all current with tags as per legislative requirements. Ensure any hoses are clearly labelled and accessible, ensure work areas suitable, secure and clear, avoid creating fire hazards and consider evacuation plans. Identify Emergency Contact Details form. Ensure all staff are identified and accounted for in the event of an emergency.	E	3	L	Management/ Supervisors/ All Personnel
	Weather	Exposure to UV radiation, extreme weather conditions (Extreme heat, Rain, Storms), Visibility.	C	2	L	Identify and assess impending weather conditions and forecast. Use sunscreen, hats/protective brims, long sleeve shirts, and neck flaps. Reassess site and work conditions in extreme weather conditions or poor visibility. Source extra equipment; modify safe work practices or hours of work as necessary.	E	2	N	Management/ Supervisors/ All Personnel
	PPE (Personal Protective Equipment)	Inappropriate or inadequate personal protective equipment can result in injury, overexposure to elements and lack of identification to the public or co-workers.	C	2	L	Issue of appropriate personal protective equipment prior to works or as required per task – long sleeves and trousers to be worn at all times. All staff must wear high visibility clothing and/or vests and approved safety boots wherever applicable. Hard hats and safety glasses are issued at employment and are to be worn at all times. Sunscreen is available to all staff at all times. Staff members are expected to return worn/damaged items to management for replacement.	E	2	N	Site Supervisor / All Personnel

Ref	DESCRIPTION OF TASK	HAZARDS	PRE-RISK LEVEL			SAFE WORK METHOD RISK TREATMENT OPTIONS & ACTIONS	RESIDUAL RISK			RESPONSIBLE
			L	C	R		L	C	R	
	Drive to or from site and site access	Vehicular and Pedestrian Traffic. Collisions with other vehicles. Collisions with static structures. Collisions with pedestrians.	**A**	**5**	**E**	Driver must be appropriately licenced for the class of vehicle being driven/operated. Driver must abide all road rules. Driver must ensure vehicle is fit for task, road worthy, registered and must complete a Daily Plant Checklist prior to use. All personnel are to be made aware of the “Safe Entry and Exit of Worksite” procedure and be pre-started prior to entering site.	**B**	**5**	**E**	Driver
	Establish correct location	Time Wastage / economic loss.	**B**	**1**	**L**	Correct documentation and plans, effective communication. Refer to engineers construction pack,	**E**	**1**	**N**	Site Supervisor
	Traffic Management	Struck By Traffic Pedestrian Interface Non Compliance	**B**	**3**	**H**	No works within 7 metres of road without Traffic Management in place. Must have a spotter/observer to monitor pedestrian traffic and any site movement. Pedestrians to be escorted around works where required. Ensure a No Go Zone around Directional Drill and points of drill head entry and exit by placement of Temporary fencing for full perimeter of work zones to ensure public and personnel safety. Works in shared user path, access to be maintained at all times. Beware of pedestrians and implement exclusion zone. Refer to vehicle access plan	**E**	**2**	**N**	Site Supervisor / All Personnel
	Manual Handling	Physical Injury	**C**	**2**	**L**	Determine position, size and weight of object. Consider use of mechanical aids or extra personnel for task. Ensure appropriate personal protective equipment is worn. Adopt good posture and movement technique. Two persons required to reposition temporary timber stairs for batter access. Report any injuries or near miss and always consider any relevant improvements.	**D**	**1**	**N**	Site Supervisor / All Personnel

Ref	DESCRIPTION OF TASK	HAZARDS	PRE-RISK LEVEL			SAFE WORK METHOD RISK TREATMENT OPTIONS & ACTIONS	RESIDUAL RISK			RESPONSIBLE
			L	C	R		L	C	R	
	Using hand tools	Manual Handling, condition and maintenance, incorrect usage, risk of injury, use as a weapon.	C	2	L	Ensure manual handling advice and techniques are employed. Consider and ensure you are using the appropriate tool for the task. Ensure tools are inspected and maintained, replace if damaged. Ensure all tools are accounted for and secure.	E	2	N	Site Supervisor / All Personnel
	Working with chemicals	Spillage, Explosion, Inhalation, Absorption & Ingestion	D	3	L	All chemicals to be used in conjunction with appropriate SDS, which are attached to the back of the SWMS. Ensure compliance with EPA guidelines. Ensure suitable storage and transport. SDS available at hand. Ensure user competency, adequate signage, and chemical spill / clean-up kits available, personal protective equipment available. Identify Emergency Contact Details.	E	3	L	Site Supervisor / All Personnel
	Presence of existing services	Striking of services	B	4	H	Identify and assess location. NAP Ground Penetration Permit Action Dial Before You Dig information. Identify asset owners. Pothole, hand expose and sight all high-risk services outside of rail corridor on each side of the proposed alignment in order to ascertain inverts and alignments of assets in the design vicinity so the bore design can be considered in relation to existing assets. Modify route and or employ safe work practices to avoid disturbance or damages to at risk services.	E	3	L	Management/ Site Supervisor

Ref	DESCRIPTION OF TASK	HAZARDS	PRE-RISK LEVEL			SAFE WORK METHOD RISK TREATMENT OPTIONS & ACTIONS	RESIDUAL RISK			RESPONSIBLE
			L	C	R		L	C	R	
	Plant, machinery and equipment	Compliance/ Failure	D	2	L	All plant and equipment to be site inspected. Ensure all plant and equipment is inspected and cleared for use. Pre-start equipment checks, Regular service and maintenance checks and records.	E	1	N	All Personnel
		Movement of vehicles and machinery	B	4	H	Ensure machinery is equipped with suitable warning and hazard identifying devices (e.g. signs, lights, and alarms) and appropriately maintained. All operators hold appropriate license/s, to be VOC'd and comply with plant manufacturers operating guidelines. Ensure site awareness and security is maintained prior to operation. Exclusion zone of 5m to be maintained from drill head when operational.	D	4	M	All Personnel
		Spillage of diesel fuel and/or oil and lubricants	D	2	L	Refuelling to occur at properly designated area e.g. service station or depot refuelling area. Vehicle to carry Spills Kit to absorb any accidental leakage.	D	1	N	All Personnel
		Presence of existing overhead services	C	3	M	Identify any overhead services and ensure safe working distance from service is maintained.	E	3	L	All Personnel
	Unloading and Set Up Of Machinery.	Unloading plant from truck	C	3	M	Assess area for potential hazards i.e. uneven ground, overhead obstacles, safe deployment of ramps. No standing or climbing on the back of trucks without handrails.	E	1	N	All Personnel
		Overhead obstacles	C	3	M	Move to safer location.	E	1	N	All Personnel
		Ramps	C	2	L	Ensure appropriate ramps are installed and maintained.	E	2	N	All Personnel

Ref	DESCRIPTION OF TASK	HAZARDS	PRE-RISK LEVEL			SAFE WORK METHOD RISK TREATMENT OPTIONS & ACTIONS	RESIDUAL RISK			RESPONSIBLE
			L	C	R		L	C	R	
	Boring.	Machine Failure	C	1	L	Pre-start equipment checks, regular service and maintenance checks and records.	E	1	N	All Personnel
		Slipping from batter	C	5	H	No walking on batter. Access only using the stairs provided.	E	2	N	All Personnel
		Excess Drill Mud	C	1	L	Use vacuum truck to remove sludge during the drilling process. Dispose of excess Drilling slurry to an EPA accredited facility	D	1	N	All Personnel
		Frac out	C	1	L	Stop and assess immediate risk and secure if necessary. Use Vac Truck to remove sludge. Erect Silt Controls Prevent any flows to Drainage system, inclusive of Ground water. All clean up via vac unit	D	1	N	All Personnel
		Pipe pull back	C	3	M	Ensure effective communication with drill rig operator. Monitor Mud flows as annular space is filled, Removing excess via vac unit for disposal to an EPA facility.	E	3	L	All Personnel
	Site Reinstatement	Open excavations / Open pits	C	3	M	Backfill or secure. Ensure all lids are replaced or open pits secured.	E	2	N	All Personnel
		Trip Hazards	C	2	L	Remove.	E	1	N	All Personnel
		Heavy equipment, tools, products	C	2	L	Correct manual handling techniques.	D	1	N	All Personnel

EMPLOYEE SIGN OFF

I have read and understood all tasks, hazards and control measures described within this document and agree to comply with the controls prescribed herein.

No.	Name of Employee	Date	Signature
1.			
2.			
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Note: Do not sign this document if you do not understand or agree, or do not intend to comply with the controls prescribed herein.