Appendix A

Trenchless Construction Techniques Analysis

Water Corporation

Trenchless Construction Techniques Analysis

Balannup Pressure Main

September 2013

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Executive Summary

In order to continue to service the rapidly growing Balannup (Southern) corridor between Armadale Rd and Ranford Rd the Water Corporation needs to construct 4.5km of sewerage pipeline to connect Collared Rd Pump Station (PS) in Harrisdale to Water Works Rd PS in Haynes.

Of the 4.5km of sewerage pipeline needed, 1.5km traverses a 'Bush Forever' area. Alternative paths for the pipeline which avoid the 'Bush Forever' area are not feasible due to the vicinity of major transport routes and severe congestion of existing underground services.

In order to minimise the environmental impact of constructing the pipeline through the 'Bush Forever' area the Water Corporation is seeking to utilise a 'Trenchless' construction technique. This report represents the outcome of an investigation into the most suitable technique.

A wide range of 'Trenchless' techniques have been evaluated. All but one technique have been eliminated due to either a requirement for some excavation within the 'Bush Forever' area or due to the resultant pipeline being unsuitable for operation by the Water Corporation.

Use of 'Ploughing' technology is recommended as the least invasive and most suitable of existing 'Trenchless' techniques. A 'Plough' can install a DN-450 pipe through the 'Bush Forever' area along an existing cleared track without the requirement for any clearing or dewatering. The pipe can be installed at a constant grade and at a suitable depth with no ongoing operational or environmental risks.

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1. Introduction

1.1 Background

Water Corporation is planning a Mechanical and Electrical upgrade of the Collared Street Wastewater Sewerage Pump Station (WWPS) and to construct a new pressure main along Keane Road to the Waterworks Road WWPS in Haynes. See Water Corporation's sketch of pipeline route at Appendix A.

GHD has been commissioned to carry out the Engineering and Detailed Design for the project.

The chosen alignment of the proposed pressure main along Keane Road passes through a 'Bush Forever' conservation area. The local government authority, City of Armadale, has a road reserve located across the 'Bush Forever' land. A recent proposal by City of Armadale to construct a sealed road within the road reserve has been deferred by the regulatory authorities.

Alternative alignments along Skeet Road and Armadale or Ranford Road have been ruled out by the Water Corporation because of severe congestion of existing underground services and high volume traffic corridors.

There is understandably strong pressure from community groups and environmental regulators for preservation of the 'Bush Forever' area. As such conventional open trenching will not be acceptable and the Water Corporation has subsequently identified trenchless techniques as the way forward.

This report is intended to provide Water Corporation with an overview of available 'Trenchless' construction techniques and discuss the feasibility, risks and opportunities that each offers.

1.2 Scope

This report provides background information as a basis for understanding options, limitations, risks and opportunities associated with trenchless techniques specific to the application of construction of a sewerage pressure main underneath the 'Bush Forever' area at Harrisdale.

The majority of the pressure main is to be DN375 PVC pipe as advised by the Water Corporation, but with HDPE used under the 1.5km 'Bush Forever area'. Trenchless techniques generally require a wall thickness based on the tensile strength required for pulling the pipe into position and this will require an HDPE pipe of 450mm outer diameter.

2. Pipeline design considerations

2.1 General

The design as requested is for a pipeline on a grade with scour valves and air valves at regular intervals. No air valves or scour valves will be permissible within the 'Bush Forever' area. It is therefore a requirement that the final profile of the pipeline has the following characteristics in order to provide a workable pressure main.

- Continuous decent from an air release point (valve) to a low point followed by
- Continuous ascent to another air valve
- No inverted U configurations where air may become trapped (preventing pumping)

2.2 Sedimentation

It is inevitable that some sedimentation in the pipeline will occur. Appropriate flow velocities can minimise sedimentation build up but some means of sediment removal must be considered. Under normal circumstances a scour valve will provide means of sediment removal but a scour valve is not permissible within the 'Bush Forever' area. Therefore two possibilities exist:

- The low point of the section running under the 'Bush Forever' area must occur at one end, just outside the conservation zone
- The section under the 'Bush Forever' area must rely on pigging to remove sediment

Any technique used to construct the pressure main must provide a profile that can be managed for sediment removal.

2.3 Geotechnical and groundwater

In summary the geotechnical and groundwater conditions expected are generally iron or silica cemented silty sand or peaty sand with groundwater at a shallow depth. As such geotechnical issues are not expected to provide any impediments to the use of trenchless techniques. A separate geotechnical report has been prepared to accompany the Engineering Summary Report and this provides a more detailed investigation. Some brief information is provided at Appendix E.

3. Trenchless technology techniques

Trenchless technology has been in development for pipe installation since the 1970s, arising from the oil and gas industry in the United States. Around the world many contractors offer services employing variations of the technology for the purposes of replacing existing services or installation of new services.

Trenchless techniques to be evaluated as alternatives for the purposes of construction of the DN-450 sewerage pipeline are:

1. Pipe Jacking and Guided Boring
2. Horizontal Directional Drilling
3. Ploughing

Tunnel boring as used for the Channel Tunnel between England and France and extensively across Scandinavia is not considered in this family of pipe laying techniques and is beyond the scope of this report.

3.1 Pipe jacking and guided boring

Pipe Jacking uses hydraulic equipment to push lengths of pipe through the ground. Guided Boring uses hydraulics to power a drilling head with spoil taken away by an auger. Alignment is maintained by laser.

Both of these techniques begin with the construction of a shaft that accesses the initial starting elevation (depth) of the pipe to be installed. Equipment to drill or thrust is lowered into the pit and the installation is made in a straight line penetration through the ground. Pit size is dependent on the specific technique and equipment but for this project a minimum pit plan size of 5m x 5m can be expected. Each pit would require clearing, dewatering and ASS management. Excavation would very probably extend below the water table making it more difficult and expensive.

The limit to these construction techniques varies with geotechnical conditions and specific technique involved but in general no installation has been made extending more than approximately 150 meters from a pit. Where greater distances need to be installed then a second pit is required to receive the incoming pipe and the process is repeated to extend again in any direction from this second pit.

Therefore, this method would require a significant level of construction activity within the ‘Bush Forever’ area with approximately ten 5m x 5m pits required.

3.2 Horizontal directional drilling (HDD)

HDD is a trenchless method of installing underground conduits, pipes and cables from the surface. In this group of techniques the drill process begins at ground level from a prepared launch site. The drill is directed into the ground at a relatively steep angle in order to get the drilling head underground and away from the surface as quickly as possible.

The drilling is performed with the assistance of drilling fluids or “mud”. Drilling mud primarily consists of Bentonite and water although in some cases synthetic muds and plasticizers are also used. The mud is pumped under high pressure through the drill string; it powers the drill motor and mixes with the drill cuttings (drill spoil) and the mixture then returns to the drill site. The mud is then processed to remove the cuttings and reused. Another function of the mud is to support the hole from collapse in weak ground.

The installation process begins with construction of entry and exit pits. Estimates of the required area needed for the entry pit construction area for the Balannup project is estimated at approximately 30m x 90m. These pits collect the drilling mud and allow it to be reused. See diagram at Appendix B for full depiction of the drilling pits and construction profile.

Within HDD techniques there are three alternatives, Single Stage HDD, Multi Stage HDD and Intersect Drilling.

3.2.1 Single Stage HDD

The maximum length of a single construction stage varies with ground conditions and with available equipment capacity. Generally however, the maximum length of a single stage is in the range of 600m to 1000m.

Additional risks with this methodology include the drilling fluid (bentonite) bursting through to the surface, particularly in the early stages of the bore. Also, HDD has been known to result in low accuracy in both horizontal and vertical planes of +/- 1 to 2m.

Single Stage HDD can be ruled out as a feasible option due to the reasons stated above.

3.2.2 Multi Stage HDD

A pipeline may be installed in multiple stages in a 'Daisy Chain' profile. In the case of this project, the length of the installation required means that one or two intermediate construction pits are to be located within the 'Bush Forever' area. In addition to the limitations highlighted within Single Stage HDD this would result in significant impact on the 'Bush Forever' area and can be ruled out also.

3.2.3 Intersect Drilling

Intersect drilling almost doubles the potential installation length compared to a single drive. HDD techniques with single stages in the order of 1km are possible depending on geotechnical conditions. The reach may be effectively doubled by drilling from two starting points to meet in the middle. To date the longest pipeline successfully installed in Australia using this method is approximately 2.2 km.

Any option involving intersect drilling would have to begin some distance from the 'Bush Forever' area. This increases the length and therefore the cost of this option. Additionally, there are also implications for the accuracy of the construction meaning risk of impact to the 'Bush Forever' area and costs to the Water Corporation should the method prove unsuccessful during construction.

The depth of installation also presents a significant risk to the Water Corporation and the environment. For any application of HDD there is a requirement to drill steeply through the surface material and maintain that steep profile up or down to a low point in order to avoid trapping air and making pumping impossible. This low point has been estimated conservatively at approximately 25m below natural surface level. A depiction is provided in Appendix B.

In the unlikely event of a requirement to access this pipeline for maintenance or repair it would involve significant excavation in the 'Bush Forever' area and present enormous costs and risk to the Water Corporation.

3.3 Ploughing

Ploughing is a construction technique whereby a machine installs a narrow trench in the ground where neither soil removal nor dewatering is required. Either simultaneously or later a pipe is inserted at a controlled depth. Ploughing is considered in the industry as a trenchless technique.

There are several contractors offering this service in Australia. Most offer some variation of the basic process. To date GHD has been in contact with Underground Services Australia (USA) who conducts operations in several states including WA. Their variant of the process, the Eco-Plough' is described below.

An 'Eco Plough' drags a vertical plough through the ground creating a narrow trench for the pipe to be inserted within (see Appendix C for a diagram). The 'Eco Plough' then returns to the start of the pipe route where the pipe is lifted over the 'Eco Plough' and installed in equipment mounted behind it. The 'Eco Plough' then drives over the previously created trench and as it does so the pipe is ploughed into the 'trench'. The plough vibrates at high frequency as it inserts the pipe to encourage smaller particulate matter to accumulate around the pipe to form bedding material. All the preceding work is completed within the width of the 'Eco Ploughs' tracks which is less than 4m.

The proposal is to utilise the existing track through which the 'Eco Plough' could install the pipeline without any clearing or dewatering. See proposed pipe route in Appendix D. In some places the track is marginally narrower than the 'Eco Plough'. It is proposed to minimise potential impact by pruning back any affected vegetation prior to the plough going through.

The maximum size of pipe that can be inserted is currently 415 mm in outer diameter but, USA have indicated that modification of the equipment to accommodate 450 mm can be performed in order to meet the requirements of the this project without the need for any modification of the 'Eco Plough' machine overall dimensions.

A concern with the use of the Ploughing technique is its ability to install a pipe at a constant grade appropriate for a sewer main. The plough is able to vary the depth of cover over the pipe as it travels. The maximum depth of insertion is approximately 1.5m. This range is not sufficient to provide a grade of 1:500 of the 1.5 km route, however there is a natural ground level difference over the 1.5 km length of the alignment of approximately 2.5m which together with the adjustable cover gives a suitable grade on the pipe of 1:490 (approximate).

Another issue with the ploughing technique is material compaction around the pipe in order to provide the support it needs in service now and in the future. Over specification of the pipe thickness will be sufficient to provide adequate strength in service. This will be specifically addressed at detailed design stage.

The pipe will be installed in the existing cleared track resulting in the alignment not being straight or following any cadastral boundary. This is not standard for the Water Corporation as it places assets at risk of damage by other work amongst other issues.

In order to mitigate this risk it is proposed that a trace wire is installed to facilitate accurate location in future. There are a number of other factors which negate this issue including:

- There are no air or scour valves within the 'Bush Forever' area meaning that the pipeline does not need to be accessed during normal operation.
- The 'Bush Forever' area provides significant protection to the pipeline given the extreme level of difficulty to gain approval to construct in the area.
- In the future should City of Armadale gain approvals and construct Keane Road the Water Corporation could relay the pipeline (with a duplication if needed) on a consistent alignment within the road reserve.

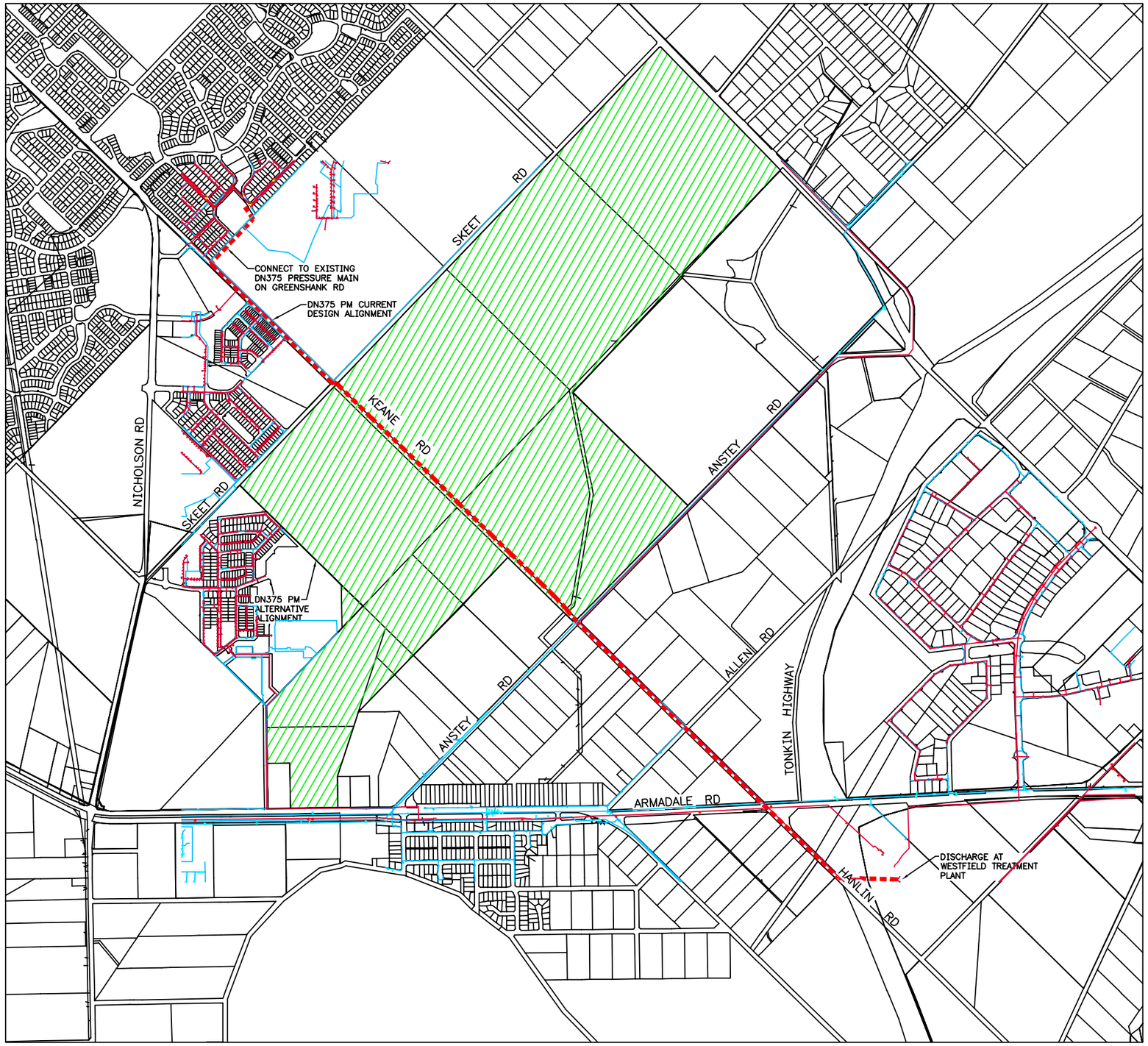
4. Conclusions and recommendations

It is GHD's recommendation that ploughing is taken forward as the preferred option for installation of the pressure main through the Balannup 'Bush Forever' area for the following reason:

- It can be installed without any clearing, open trenching or dewatering.
- It can be installed at a suitable grade over the 1.5km 'Bush Forever' Site with no scour or air valve pits in the 'Bush Forever' site.
- It is cost effective.

Appendices

Appendix A – Route diagram



LEGEND

- DN375 PM ALIGNMENT OPTION 1
- BUSH FOREVER

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PRELIMINARY ONLY
NOT TO BE USED FOR CONSTRUCTION

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NORTH POINT

INFRASTRUCTURE DESIGN BRANCH

RECOMMENDED
CONSULTANT PROJECT MANAGER
APPROVED
CONSULTANT PROJECT DIRECTOR

WATER CORPORATION

METROPOLITAN WASTEWATER
BALLANUP PUMPING STATION NO. 175–01
DN375 PRESSURE MAIN
ROUTE ALIGNMENT

ORIGINAL SHEET SIZE A1

FILE: PROJECT C–S01249 | PLAN: SKETCH 1 | CAD | ISSUE: B | MF

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Appendix B – HDD layouts and profiles

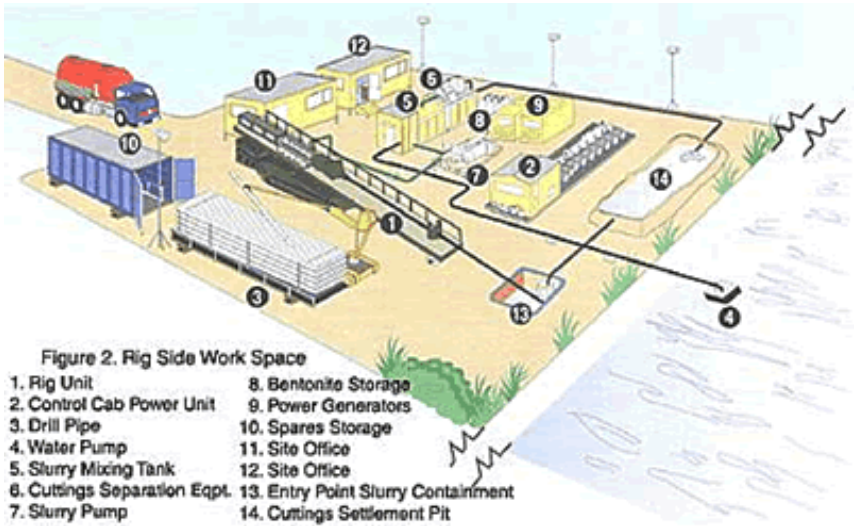
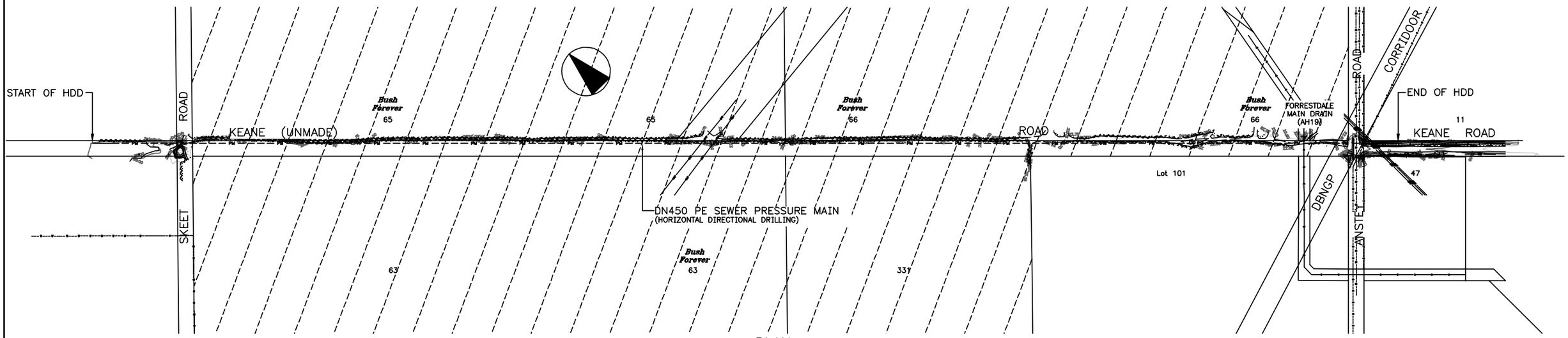


Figure 2. Rig Side Work Space

1. Rig Unit
2. Control Cab Power Unit
3. Drill Pipe
4. Water Pump
5. Slurry Mixing Tank
6. Cuttings Separation Eqpt.
7. Slurry Pump
8. Bentonite Storage
9. Power Generators
10. Spares Storage
11. Site Office
12. Site Office
13. Entry Point Slurry Containment
14. Cuttings Settlement Pit

Drawing reproduced with kind permission of HDD Solutions



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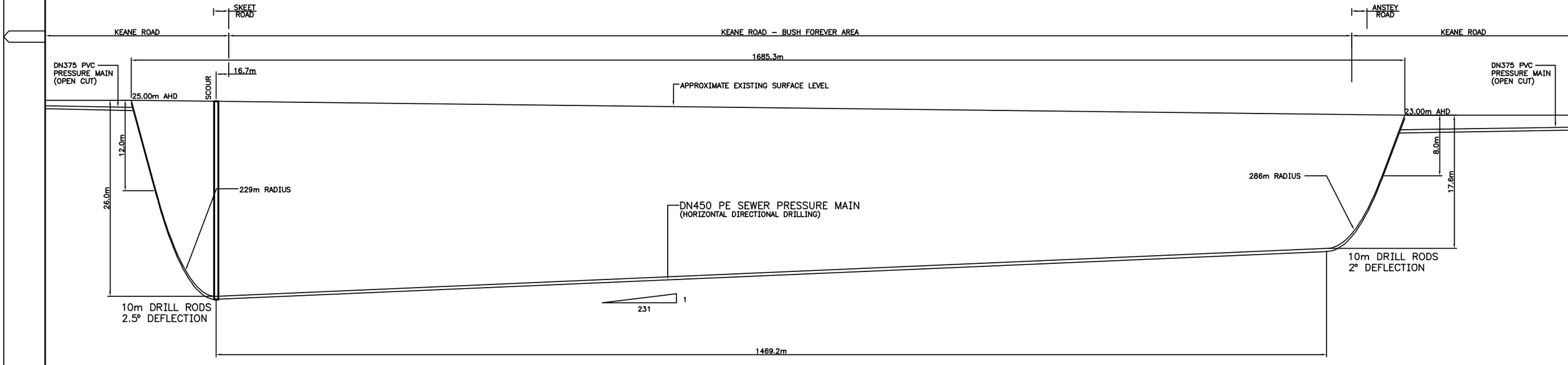

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ASCON SURVEY NONE	DES REF GHD 61-29471	DRN K.BOSMAN / Q.C. CHD

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METROPOLITAN WASTEWATER WAPC 127155
BALANNUP PUMPING STATION NO.175-01 – COLLARED ST & PM
ENGINEERING DESIGN – DN375 PRESSURE MAIN
PLAN AND SECTION – HDD PROFILE OPTION 1

FILE
PROJECT C-S01249
PLAN HDD OPTION 1
CAD
ISSUE 1
ORIGINAL SHEET SIZE A1
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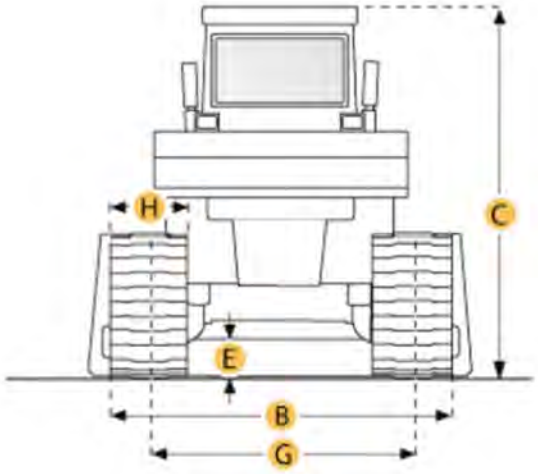
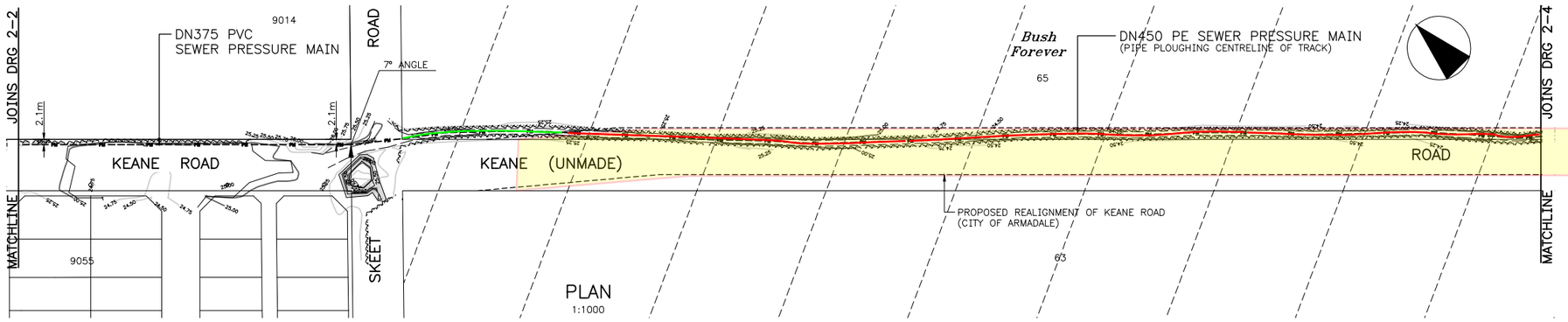
Appendix C – Eco Plough dimensions

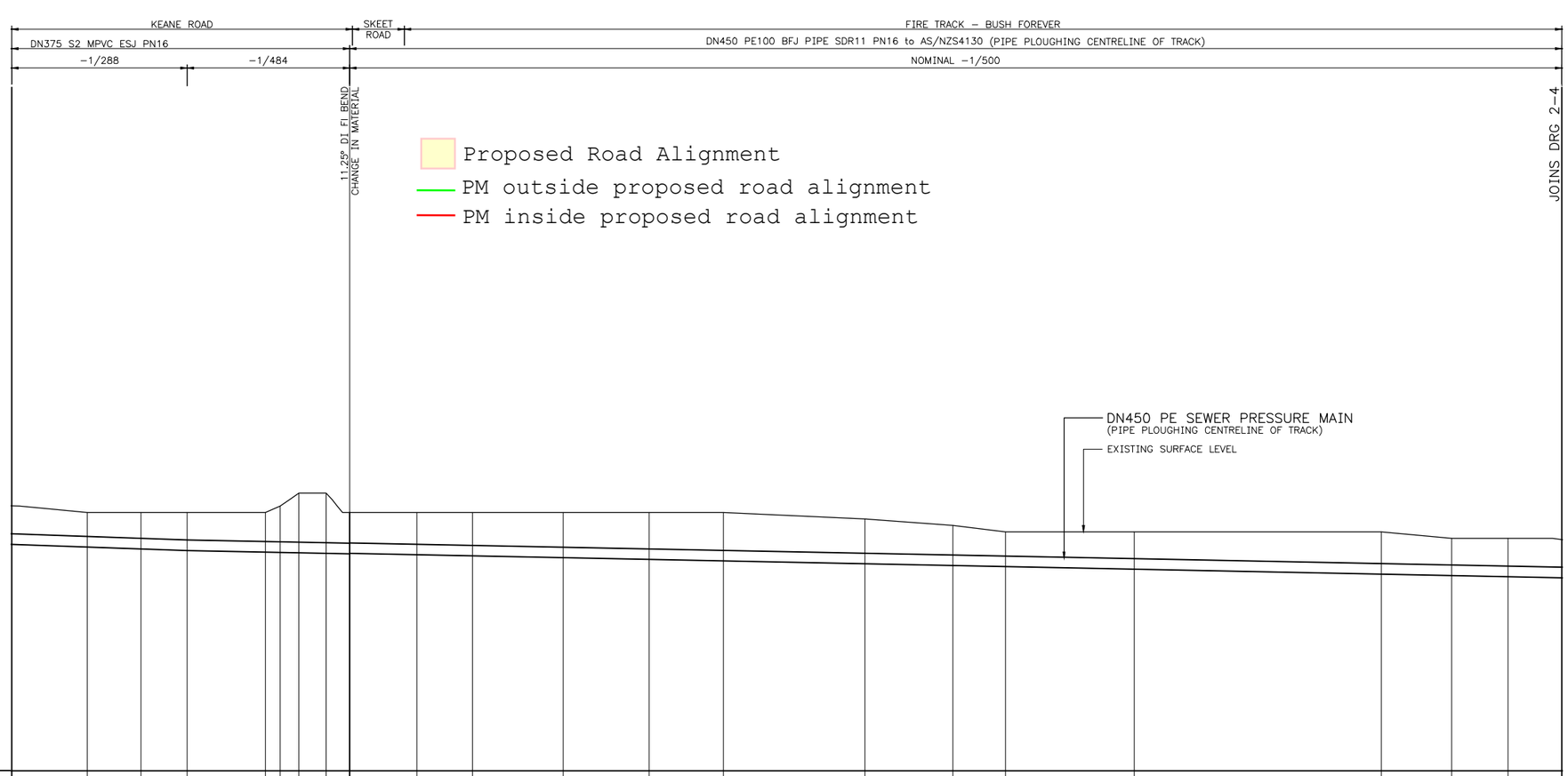


Selected Dimensions		
Dimensions		
A. LENGTH W/ BLADE	34.9 ft in	10637.5 mm
B. WIDTH OVER TRACKS	11.8 ft in	3606 mm
C. HEIGHT TO TOP OF CAB	13.4 ft in	4078 mm
D. LENGTH OF TRACK ON GROUND	12.7 ft in	3855 mm
E. GROUND CLEARANCE	2.2 ft in	674.5 mm
F. LENGTH W/O BLADE	19.8 ft in	6027 mm
Undercarriage		
G. TRACK GAUGE	9.5 ft in	2896 mm
H. STANDARD SHOE SIZE	28 in	710 mm

Screenshot from USA Website

Appendix D – Proposed 'Eco Plough' alignment





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INVERT LEVEL				23.53					23.40	23.43																	
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PROPOSED SEWER PRESSURE MAIN	PM
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EXISTING UNDERGROUND POWER	UGP
EXISTING OVERHEAD POWER	OHP
EXISTING GAS MAINS	G
EXISTING SEWER MAINS	S
EXISTING SEWER PRESSURE MAINS	PM
EXISTING DRAINAGE	D
EXISTING FENCE	/
EXISTING TREE	

FOR GENERAL NOTES REFER DRG 85-1-2

ENGINEERING DESIGN - NOT FOR CONSTRUCTION

LONGITUDINAL SECTION

HORIZONTAL 1:1000, VERTICAL 1:100

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DATE : 27-Aug-2013

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DES CALC: J.POTTS
DES CHD:
DRN: K.BOSMAN
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METROPOLITAN WASTEWATER WAPC 127155
BALANNUP PUMPING STATION NO.175-01 – COLLARED ST & PM
ENGINEERING DESIGN – DN375 PRESSURE MAIN
PLAN AND LONGITUDINAL SECTION – SHEET 3 OF 8

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ISSUE: 1
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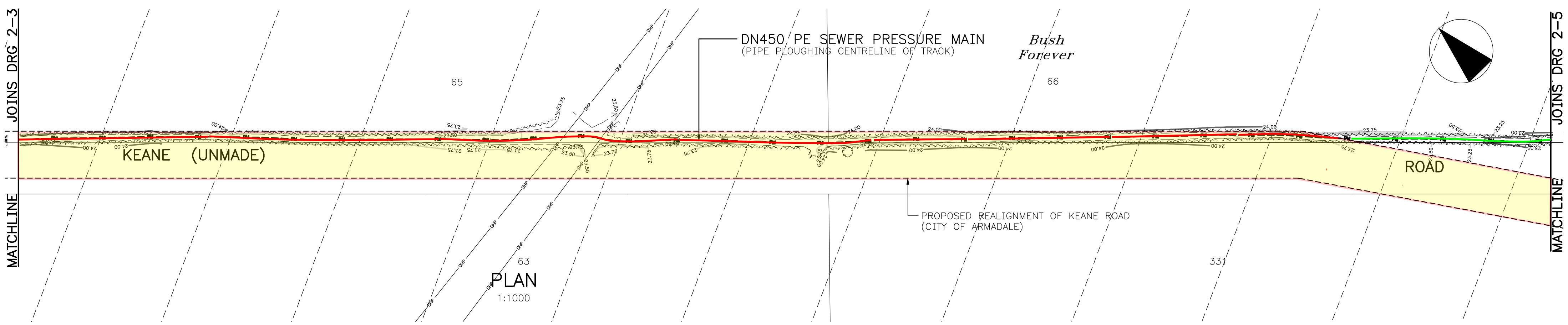

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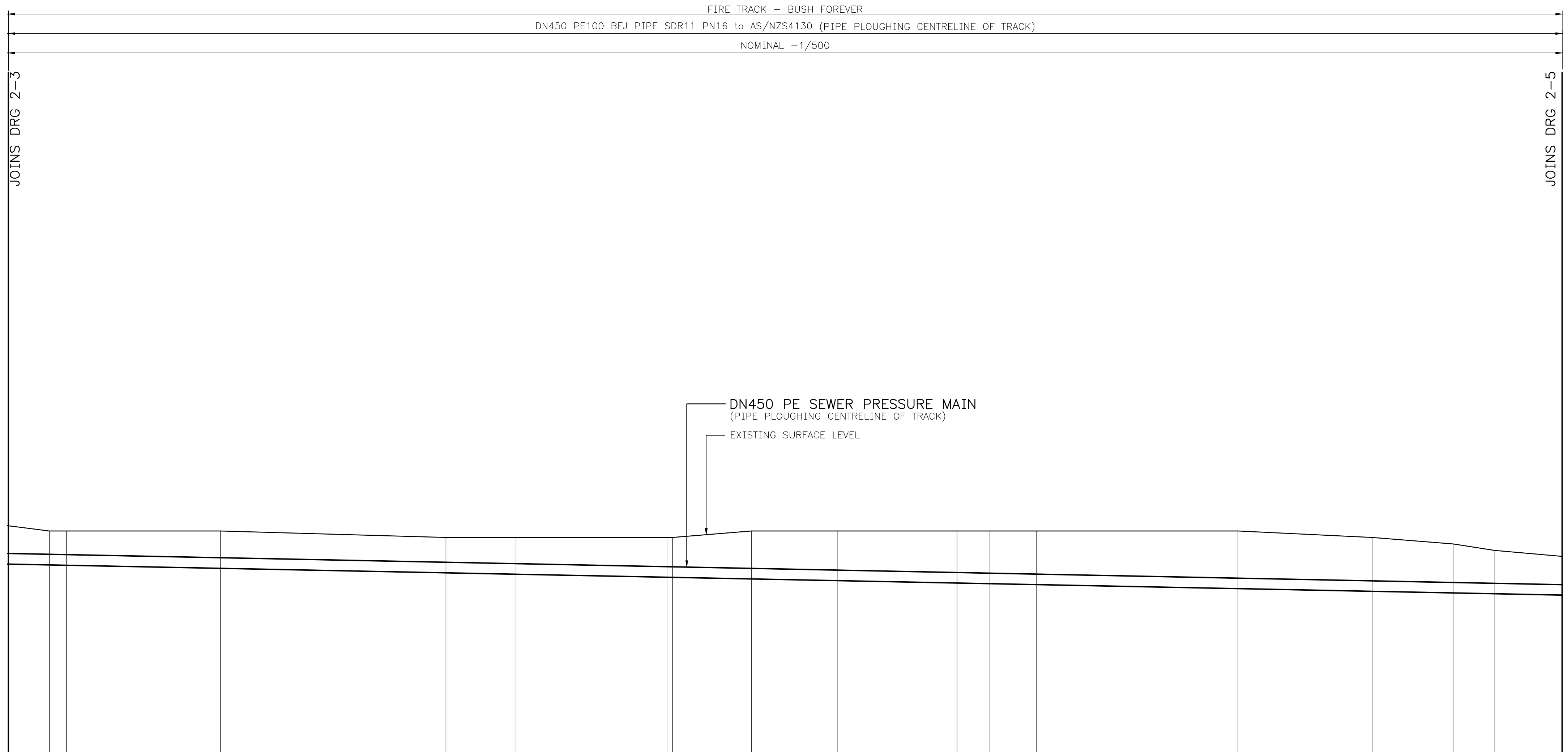

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DEPTH TO INVERT																		
INVERT LEVEL																		
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LONGITUDINAL SECTION
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DATE : 27-Aug-2013

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METROPOLITAN WASTEWATER WAPC 127155
BALANNUP PUMPING STATION NO.175–01 – COLLARED ST & PM
ENGINEERING DESIGN – DN375 PRESSURE MAIN
PLAN AND LONGITUDINAL SECTION – SHEET 4 OF 8

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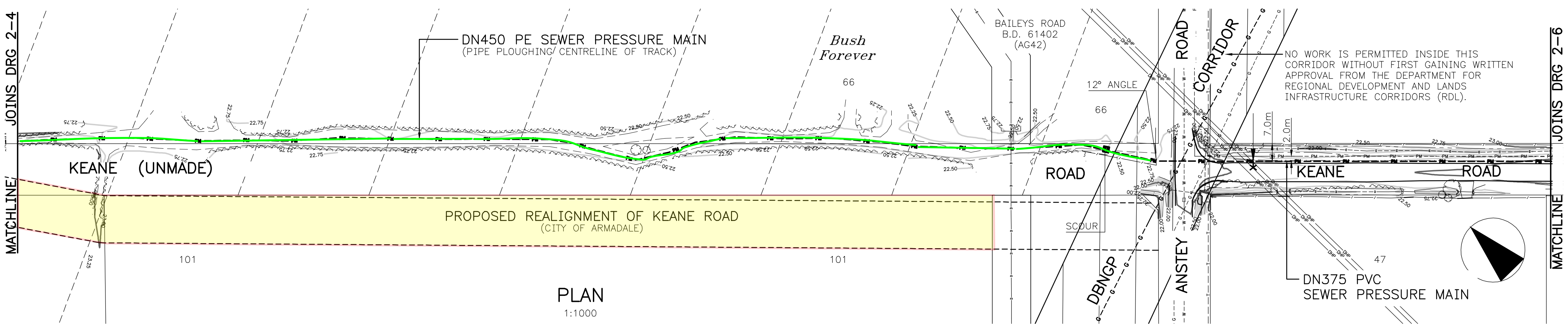

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LEGEND

- PROPOSED SEWER PRESSURE MAIN
- EXISTING WATER MAINS
- EXISTING TELECOMMUNICATION CABLES
- EXISTING OPTIC FIBRE
- EXISTING UNDERGROUND POWER
- EXISTING OVERHEAD POWER
- EXISTING GAS MAINS
- EXISTING SEWER MAINS
- EXISTING SEWER PRESSURE MAINS
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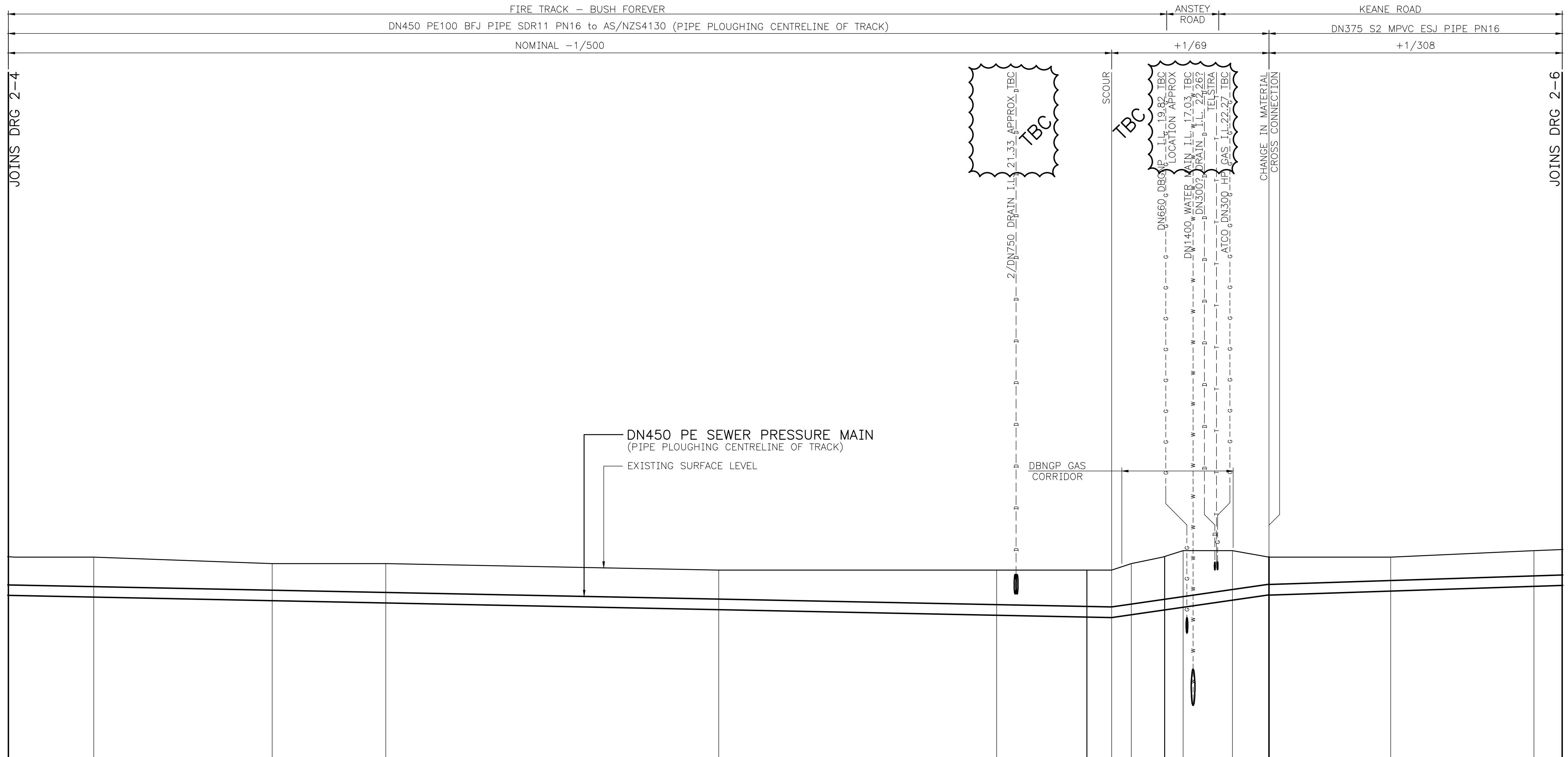
- EXISTING FENCE
- EXISTING TREE

FOR GENERAL NOTES REFER DRG 85-1-2



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DEPTH TO INVERT									1.82					1.45 1.46			
INVERT LEVEL									20.42					21.30 21.29			
HORIZONTAL DISTANCE	2150	2183.0	2251.9	2295.7	2424.3	2531.6	2542.1	2566.5	2576.0	2583.6	2596.5	2603.6	2622.7	2636.8	2683.8	2739.1	2750

ENGINEERING DESIGN - NOT FOR CONSTRUCTION

LONGITUDINAL SECTION
HORIZONTAL 1:1000, VERTICAL 1:100

DATE : 27-Aug-2013

(1:1000) (1:100)

ISSUE	DATE	GRID	REVISION	DRN	REC	APPD
1	05/13		ISSUED FOR INFORMATION	KB	GD	PGS

DESIGN SURVEY: GHD 2661551 V01
VERTICAL DATUM: AHD
DES CALC: K.BOSMAN
COORDINATE SYS: MGA94-50
DES CHD
ASCON SURVEY: NONE
DES REF: GHD 61-29471
DRN: K.BOSMAN
Q.C. CHD
NORTH POINT

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RECOMMENDED
CONSULTANT JOB MANAGER
APPROVED
CONSULTANT PROJECT DIRECTOR

WATER CORPORATION

METROPOLITAN WASTEWATER WAPC 127155
BALANNUP PUMPING STATION NO.175-01 - COLLARED ST & PM
ENGINEERING DESIGN - DN375 PRESSURE MAIN
PLAN AND LONGITUDINAL SECTION - SHEET 5 OF 8

ORIGINAL SHEET SIZE A1

FILE | PLAN | CAD | ISSUE
PROJECT C-S01249 | HW91-85-2-5 | | 1 | MF

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Appendix E – Geotechnical investigation

Published data on ground conditions

Ground conditions are shown on published 1:50,000 scale maps as predominantly “thin Bassendean Sand overlying Guildford Formation”. Bassendean Sand is aeolian quartz sand, with a typical relative density of medium dense. A thin covering of Bassendean Sand, in the local context, implies a thickness between approximately 5 m and less than 1 m.

The Guildford Formation is an alluvial deposit, comprising a mixture of a wide variety of soil types. Local experience suggests that it is likely to principally comprise Clayey Sand or Silty Sand. Iron- or silica- cemented soils are known in the area, particularly where the Guildford Formation is overlain by Bassendean Sands with shallow groundwater. Often an iron-cemented Silty Sand (colloquially called “Coffee Rock”) forms at the interface between the two units, where seasonal fluctuation of the groundwater table results in precipitation of dissolved iron in the groundwater.

Discrete zones of “peaty sand” are mapped for the ‘Bush Forever’ locality. Along the proposed pressure main route, two such locations are shown. One is approximately central to the ‘Bush Forever’ component of the alignment, the other near the southern boundary. Local experience suggests peaty sand is likely to comprise Silty Sand with significant diatomite content. These can be acid sulphate soil risks.

A number of exploratory boreholes have been drilled in the area by various government agencies. A graphic lithology log of these boreholes, shown with the published ground conditions map, indicates these comprise sand only to between 25 and 30 m depth overlying the Osborne Formation. The borehole locations appear to be confined to localities where Peaty Sand is mapped and may not be representative of the broader ground conditions.

The Osborne Formation in this area comprises the Kardinya Shale member. Published information suggests the interface between the Osborne Formation and superficial units to be approximately -10 m AHD. The Kardinya Shale consists of moderately to tightly consolidated interbedded siltstones and shales. These are often puggy, glauconitic and contain thin interbeds of fine grained sandstone. It is also a confining bed for the underlying Leederville aquifer. Kardinya Shale is likely to persist to approximately -40 m AHD.

Groundwater Conditions

Published data (Davidson, 1995) shows that groundwater is shallow, with actual depth fluctuating seasonally. Groundwater is likely to be brackish and high in dissolved iron.

To the west of ‘Bush Forever’ land is the Jandakot mound, which is one of the more important groundwater supply and recharge areas for the Perth metro area. The ‘Bush Forever’ site occupies a col between the Jandakot mound (~25 m AHD) and the Armadale area recharge (water table also ~25 m AHD). Therefore superficial groundwater should be expected at slightly less than 25 m AHD.

The Leederville aquifer is a confined aquifer that, in the vicinity of the site, is contained by the Kardinya Shale member of the Osborne Formation. Interaction with the Leederville aquifer should be avoided or minimised, as the risk of undesirable environmental impacts is relatively high.

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