Report No: P WMA
19/G10/00/2413/6

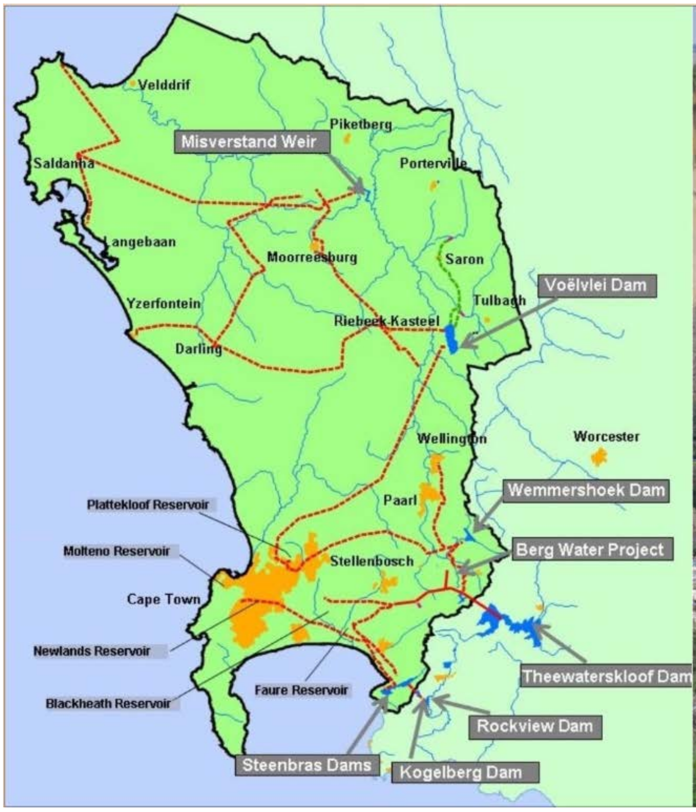
Department of Water Affairs
Directorate: Options Analysis

PRE-FEASIBILITY AND FEASIBILITY STUDIES FOR AUGMENTATION OF THE WESTERN CAPE WATER SUPPLY SYSTEM BY MEANS OF FURTHER SURFACE WATER DEVELOPMENTS

REPORT No.3 – VOLUME 2
Breede-Berg (Michell’s Pass) Water Transfer Scheme

APPENDIX No.8

Geotechnical Investigations for the Berg River-Voëlvlei Augmentation Scheme, and the Breede-Berg (Michell’s Pass) Water Transfer Scheme



December 2012

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Executive Summary

This report presents the results of the geotechnical investigations for two schemes for the possible augmentation of the Western Cape Water Supply System. The potential schemes investigated were:

Scheme A - the winter abstraction of surplus Berg River water into the existing Voëlvlei Dam. The structures would include a weir on the Berg River, an adjacent pump station and a 5km long rising main pipeline delivering water to the dam.

Scheme B - the winter abstraction of surplus Breede River water at Michell's Pass into the Voëlvlei Dam. The structures would include a weir on the Breede River, just upstream of the bridge on the R43, desilting facilities, an inverted siphon under the river and an approximately 8km or 9km pipeline gravitating water to the Blousloot or Boontjies Rivers and thereafter via existing inlet works in Nuwekloof and the existing canal into the dam.

The investigations were conducted at feasibility level and were generally conceptualised by the Western Cape Water Consultants JV and undertaken under contract by Fairbrother Geotechnical Engineering cc with R.A. Bradshaw & Associates cc, Consulting Engineering Geologists, acting as the independent Professional Service Provider.

The investigations comprised mapping of the bedrock and the exploratory drilling of eight boreholes at the Berg River weir site, and the excavation of nine trial pits along the Berg River Pipeline route and thirteen pits along the Michell's Pass route. Basic laboratory testing of soils and groundwater from the trial pits supplemented the field investigations.

The feasibility investigations have provided a general level of information on ground and construction conditions along the pipeline routes and for the weir sites for both Schemes A and B and the information can be used as part of the overall evaluation of the most suitable scheme.

Geotechnical conditions at the Berg River weir site are more favourable than the Michell's Pass site, particularly if an adequate length of spillway can be provided in the general area of the rock exposures on the west side of the river channel.

The least likely impact from groundwater is anticipated along the proposed Berg River pipeline route.

Machine excavation is generally expected to be possible along both pipeline routes. Approximately half of the Berg River route will be excavated in materials in which overbreak can be more easily controlled and narrower excavation profiles could be adopted. In contrast, approximately three-quarters of the Michell's Pass route will be excavated in alluvium which will be less stable and over-excavation is likely.

The potential for use of excavated materials for selected granular material, selected fill and main fill is greater on the Berg River pipeline route.

The routing of the pipeline along the right bank of the Berg River should be investigated because it would avoid a river crossing.

Although only partly geotechnically related, the disruption to farming activities and the traverses through orchards and vineyards along the Berg River pipeline route would be significantly less than that along the Michell's Pass route.

Based on the assessments above, the Berg River pipeline route is considered geotechnically more favourable than the Michell's Pass route.

The investigations undertaken to date have been required by the WCWC JV to support the feasibility studies and the preliminary designs. If either schemes progress to detailed design investigation, then consideration should be given to investigating the following aspects at a greater level of detail (and confidence): (i) the optimum position for a pump station at the Berg River weir, (ii) the nature of the alluvium and particularly the depth to and the condition of the bedrock at the pipeline river crossings, (iii) more detailed trial pitting along the pipeline routes, and (iv) specific laboratory testing to confirm the suitability of the sandy soils for use as selected granular material.

1. INTRODUCTION

The Department of Water Affairs (DWA) appointed the Western Cape Water Consultants Joint Venture (WCWC JV) comprising Aurecon (SA) and Worley Parsons (formerly Kwezi V3 Consulting Engineers) and Southern Waters to undertake a feasibility study for the possible augmentation of the Western Cape Water Supply System.

Two potential schemes are being investigated:

- Scheme A - the winter abstraction of surplus Berg River water into the existing Voëlvlei Dam
- Scheme B - the winter abstraction of surplus Breede River water at Michell's Pass into the Voëlvlei Dam

A geotechnical investigation was required for the proposed pipelines and weirs on the Berg and Breede Rivers, as well as the associated ancillary structures. On the basis of a tender process, Fairbrother Geotechnical Engineering cc (FGE) was appointed to undertake the investigation. FGE subsequently appointed R. A. Bradshaw & Associates cc (RABA) as the specified independent Professional Service Provider to provide professional services related to the drilling of boreholes, excavation of trial pits, laboratory testing, administration of the geotechnical investigations, reporting and liaison with WCWC JV.

This report presents the results of the site investigations, which were undertaken during the period early May to early July 2011, and the associated laboratory testing.

A review of the geotechnical report by Mr. R. McKellar, Specialist Consultant to WCWC JV is annexed as part of this report.

2. DESCRIPTION OF THE PROJECT

The two schemes can be described as follows:

Scheme A (Berg River pipeline and weir)

This scheme would comprise:

- A new weir across the Berg River at Lorelei Farm, which is located approximately 5km due west of the northern part of Voëlvlei Dam.

- A new pump station adjacent to the proposed weir site. The pump station would probably be located on the left bank of the river.

- A large diameter rising main (1.2m to 1.5m diameter) which is approximately 5km long and would discharge into Voëlvlei Dam in the vicinity of the southern abutment of its northern embankment.

Aurecon had reconnoitred the Berg River for suitable or potential weir sites and the site at Lorelei Farm was the only place where outcrop is exposed in the river channel itself.

Scheme B* (Michell's Pass *pipeline and Michell's Pass weir)

This scheme would comprise:

- A new weir across the Breede River at the location of the existing DWA streamflow gauging station (H1H006) at Witbrug (lower end of Michell's Pass).

- Limited desilting facilities

- A large diameter gravity pipeline (1.2m to 1.5m diameter) which is approximately 8km or 9km long and which would deliver water from the abstraction point to an outlet structure and chute on either the Boontjies or Blousloot Rivers. The pipeline would cross below the Breede River as an inverted siphon.

  The water delivered to one of the above rivers will flow down the Boontjies River to the existing diversion weir in the Nuwekloof, and thence to Voëlvlei Dam via the existing canal system.

3. DESCRIPTION OF THE INVESTIGATIONS

The scope of work, particularly with reference to the position and number of boreholes at the Berg River weir site and the method and extent of pitting along the pipelines, was changed during the site investigation period. In addition to describing the field and laboratory investigations, this section therefore also describes the background to the changes.

Field investigations comprised exploratory drilling and geological mapping at the Berg River weir site, and trial pitting along the possible Berg and Michell’s Pass pipeline routes. A trial pit was also excavated on the lower left bank at the existing weir in Michell's Pass. Based on the recommendations from a Geophysicist, and after consultation with DWA, the originally specified seismic survey at the proposed Berg River weir site was substituted by additional exploratory drilling. Laboratory testing of soils and groundwater was also undertaken.

3.1 Exploratory Drilling

The initial scope for the drilling program, which was determined by WCWC JV, included drilling four boreholes, two on the left bank and two on the right bank at the Berg River weir site.

Access to the left bank was initially denied before the exploratory program commenced and the positions of the boreholes were consequently modified. In view of the visible rock outcrop on the left bank and the uncertainty of the geology on the opposite bank, the need to focus the drilling the right bank was further recognized. The modified layout was to include one borehole as close to the right bank as possible and one some 50m to the east along a possible weir centreline. The third hole would be drilled at an appropriate position along the centreline once the initial drilling results were available. The position of the fourth hole had initially been intended to calibrate the results of a seismic survey across the river, the purpose of which (as described above) would no longer be necessary.

Based on the results of the initial three boreholes, the advice obtained from the Consulting Geophysicist was that procurement of meaningful seismic data in the geological and groundwater environment at the weir site was unlikely.

This advice was discussed at a meeting on 20 May 2011 attended by Messrs. R. McKellar, Specialist Consultant to WCWC JV, G. English, Aurecon Consulting Engineers, A. Meerburg (FGE) and R.

Bradshaw (RABA). It was agreed at the meeting that the recommendation to DWA would be to not undertake a seismic survey, but to rather substitute this with additional drilling with special emphasis on the river channel area. RABA were requested to motivate the substitution.

A letter (RABA reference 2-119411, dated 23 May 2011) was submitted to DWA who agreed to the substitution and the following drilling layout was determined in conjunction with Messrs McKellar and English:

- a low angled borehole (BH 4) below the river to determine the depth to bedrock below the river.

- one vertical borehole (BH 5) on the extreme right flank on the possible centreline approximately 30m from BH 1.

- one vertical borehole (BH 6) to be located approximately 30m downstream from BH 2 and as close to the river as possible

A dumpy level survey of the right bank on the centreline revealed that a very low angled borehole would daylight in the river bank and was therefore impractical, with a risk of not obtaining the desired information. A 60° borehole (BH 4A) and a 25° borehole (BH 4B) were therefore proposed and drilled instead of the single very low angle hole.

In mid-June, Mr McKellar requested that an additional vertical borehole should be drilled downstream of the possible centreline on the right bank where the river swings westwards. The borehole (BH 7) completed the current programme of drilling for the feasibility study.

The positions of the boreholes are illustrated on Figure 1.

The eight boreholes were drilled using a combination of washboring, SPT testing and NWD4 double-tube core drilling.

The borehole cores were logged according to standard South African practice and the borehole logs are presented in Appendix A of this report.

The borehole cores are stored at the DWA's premises at Voëlvlei Dam.

3.2 Trial Pitting

Trial pitting was undertaken at the designated positions, which had been predetermined by WCWC JV, along both the Berg and Michell's Pass pipeline routes. A total of twenty-two pits were excavated – nine on the Berg River pipeline route and thirteen on the Michell's Pass pipeline route.

Landowner objections were received by the WCWC JV regarding the intended use of (and likely damage caused by) a track-mounted excavator. As such all the pits were excavated with a wheel-mounted digger/loader. The pits were extended to the practical limit of excavation or refusal. The limit was either at approximately 3m depth or at depths at which massive collapse of the sidewalls of the pits prevented deeper excavation without excessive lateral extension of the pits.

The soils exposed in the sidewalls of the pits were described according to standard South African practice and the descriptions of the soil profiles are presented in Appendix B.

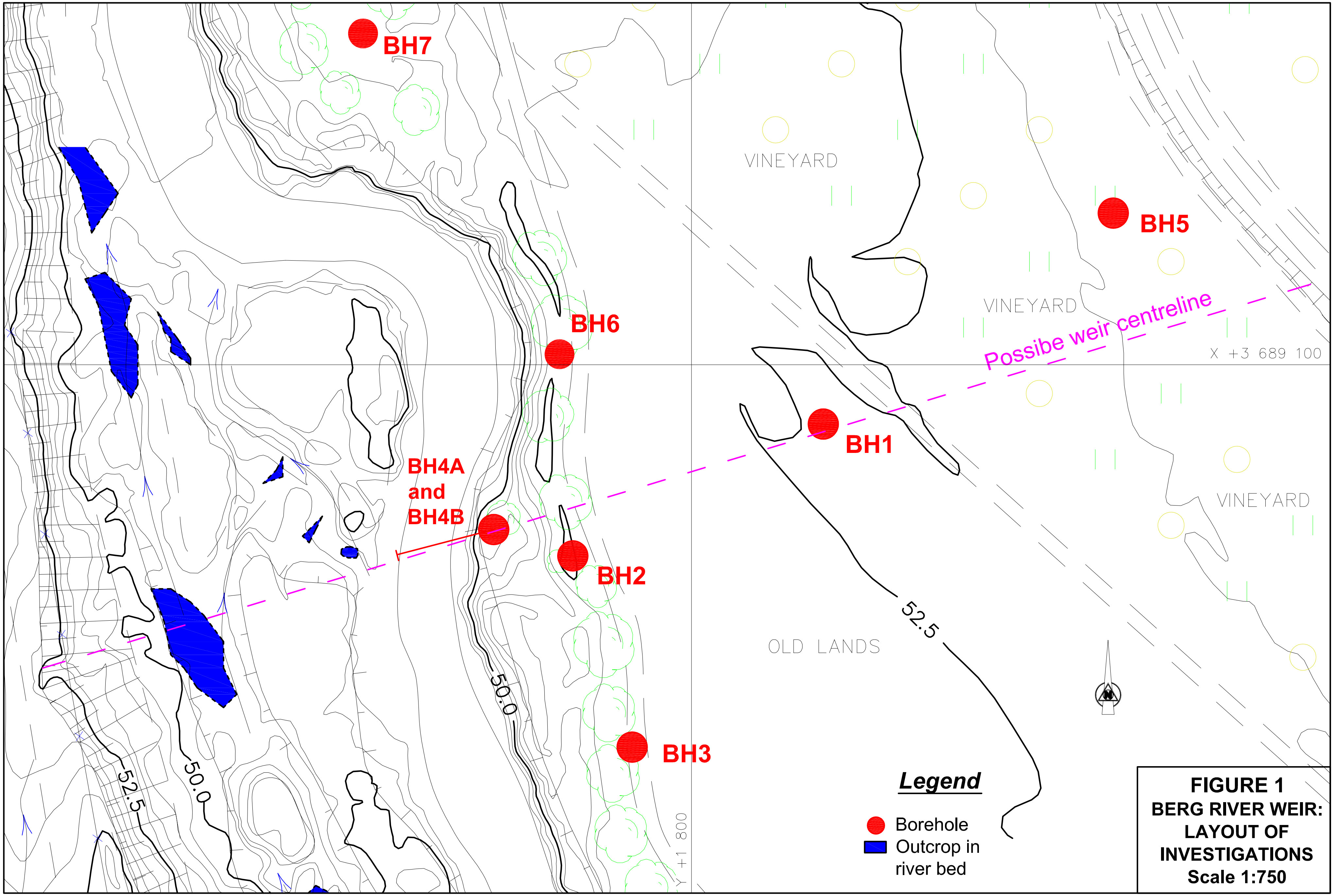


FIGURE 1
BERG RIVER WEIR: LAYOUT OF INVESTIGATIONS
Scale 1:750

The GPS (WGS 84) coordinate of each pit was recorded and the coordinates are shown on the soil profile sheets.

The positions of the pits along the Berg and Michell's Pass pipelines are presented on Figures 3 and 4 respectively.

The use of a wheel-mounted machine further alleviated anticipated problems regarding access to certain trial pit locations.

Formal and informal erosion protection measures and the inlet works for the local Artois irrigation water supply system are present on the left bank of the existing weir at Michell's Pass. Limited access and limited locations for trial pitting close to the weir were encountered. As such MP 1 was excavated some 15m upstream of the weir's centreline and just above river level. Gravel and bouldery alluvium was encountered and, with water inflow, the sidewalls of the pit collapsed before bedrock could be exposed. Deeper excavation with an excavator would be possible at the expense of creating a large hole with consequent disturbance of the ground in an area vulnerable to river erosion.

The sidewalls of trial pits MP 2 and MP 3 collapsed when the pits reached depths of 2.3m and 2.4m respectively. The shape of the initial rectangular excavation changed rapidly to circular and deeper excavation was not possible without creating a very large excavation footprint. An adjacent road and pipeline might also have been damaged at MP 3 if excavation had been continued to that extent.

3.3 Mapping

The exposures of rock in the river channel at the Berg River weir site were mapped using a hand-held GPS instrument to an instrument-indicated accuracy of 3m.

The distribution of the outcrop in this area is illustrated in Figure 1.

3.4 Laboratory Testing

3.4.1 Soil Tests

Twenty-three disturbed samples were taken from representative soil layers in the trial pits along both pipeline routes.

Foundation indicator tests were undertaken on seventeen samples and grading analyses to 0.075mm sieve size were undertaken on six samples. The testing was undertaken by Geoscience Laboratory (Pty) Ltd.

The laboratory test sheets are presented in Appendix C.

3.4.2 Chemical Tests on Water Samples

Samples of groundwater were obtained from three of the four pits where groundwater was encountered. The pits (MP 6 to MP 9) were all located on the Michell's Pass pipeline route. Because of sidewall instability, conditions were deemed too dangerous to enter MP 9 to sample the water.

The following tests were undertaken on these samples: pH, alkalinity, chloride, sulphate and calcium contents and total dissolved salts (TDS).

The testing was undertaken by Bemlab (Pty) Ltd. The laboratory test sheets are presented in Appendix D.

4. DESK STUDY

Part of the scope for the Professional Service Provider was to undertake a desk study to define and finalise the Scope of Works. The information used in this desk study was obtained from the following:

- Two, 1:10 000 rectified, colour aerial photographic images showing the pipeline routes and WCWC JV's proposed trial pit positions. The images were provided by Aurecon.

- A survey of the Berg River weir site with contours and at 0.5m intervals. The survey is based on photogrammetric mapping.

- The 1:250 000 Geological Series Maps 3318 Cape Town and 3319 of Worcester and the explanatory booklets entitled:

    - The Geology of the Cape Town Area, 1992, Geological Survey
    - The Geology of the Worcester Area, 1992, Geological Survey

- Drawings from the Cape Provincial Administration Department of Roads showing details of the design of the bridge immediately downstream from the Michell's Pass weir. The drawings, which were produced in 1986, show a soil profile comprising sandstone gravel and boulders overlying hard to very hard rock quartzite and quartzitic sandstone and an 'interpolated rock line'. Reference is made on the drawings to borehole data, but the borehole data were not provided.

    The drawings indicate that circular caissons were used instead of the originally planned piles and that the caissons were founded significantly deeper than planned presumably either due to thicker alluvium or weathered bedrock.

- Information in the Author's possession from the extensive site investigations undertaken for the proposed Elandsberg Pumped Storage Scheme. The underground power station and the outlet for this scheme were to have been constructed on the eastern side of Voëlvlei Dam.

- Information from the geotechnical site investigations conducted for an emergency transformer yard in Hermon and for low-cost housing in Gouda.

5. BERG RIVER WEIR AND PIPELINE – SCHEME A

This section discusses the geology and geotechnical conditions at the proposed weir site and along the pipeline route.

5.1 Geology and Geomorphology

The 1:250 000 Geological Series Map indicates that the area investigated for Scheme A is underlain by the shales and siltstones of the Porterville Formation of the Malmesbury Group that are masked by alluvial deposits of Quaternary Age.

The Berg River has strongly influenced the geomorphological development of the area.

The river has meandered over a wide swath which extends as far west as the weir site and possibly as far east as Voëlvlei Dam. This process has been accompanied by erosion and, in some areas, peneplanation of the bedrock and deposition of alluvium.

A combination of higher ground to the west of the left bank at the weir site and the occurrence of more extensive outcrop indicates that the river is probably at the westward limit of its meandering at the weir site.

Several possible phases of erosion and their position have probably occurred across the broad alluvial plane between the site and Voëlvlei Dam. The possibility therefore exists that buried river channels also occur locally. However no such channel has been discovered at the weir site, but a step occurs in the bedrock at the eastern edge of outcrop.

5.2 Berg River Weir

5.2.1 The Proposed Weir Structure

The layout of the proposed weir including its full supply or spill level will be determined as part of the feasibility study and was not available at the time. However, based on conceptual planning by the JV the weir is likely to comprise:

- A concrete gravity overspill or spillway section in the western and central parts of the river channel and,

- A possible embankment structure on the right bank

Bedrock elevation is at approximately 48.5m to 49.5m. A spillway elevation of approximately 51.5 m might be utilised with normal storage levels at the weir to be kept below existing ground levels on the right bank.

A view of the Berg River weir site is illustrated on Plate 1.

5.2.2 Geology of the Weir Site

The bedrock geology at the weir site comprises the regionally metamorphosed rocks of the Porterville Formation of the Malmesbury Group which are entirely masked on the right bank and right (eastern) part of the river channel. Scattered areas of outcrop and alluvium occur in the western part of the river channel and weathered outcrop generally occurs on the lower left flank.

Alluvium

The alluvium comprises two generalised layers:

PLATE 1: BERG RIVER WEIR SITE

Possible centreline runs from the area of erosion on the left of the plate through the large green gum tree against the darker green pine trees on the right of the plate. Note the bedrock exposed to the right of the puddle of water in the right, central, lower part of the plate.

a layered deposit of medium brown, fine sand which is slightly silty in places and locally contains fine to medium, sub rounded sandstone gravel. The sands become coarser with depth. The thickness of the sandy alluvium ranged up to 5.5m in the boreholes.

The patches of the alluvium in the western part of the river channel also apparently comprise mainly fine sand.

- The sands are underlain by gravelly alluvium comprising fine to coarse, sub rounded sandstone gravel probably in a fine to coarse sandy matrix. The proportion of matrix to clasts is unknown but probably varies both vertically and laterally within the deposit. The thickness of the gravelly layer varies from approximately 3m (BH 1 to BH 3) to possibly 2m below the river (BH 4A), but 1.5m or less in BH 6 and BH 7 and nil in BH 5.

The distribution of the alluvium along a centreline is shown on Figure 2. The contact between the alluvium and the bedrock lies at elevations of approximately 44m under the right river bank and the 'summer' river channel (i.e. the eastern approximately 15m of the river channel), rising to 47m to nearly 46m eastwards under the vineyard. The outcrop in the western part of the river channel is located at an elevation of approximately 49m and there is therefore a 4m step or very steep contact between the alluvium and the bedrock on the western edge of the 'summer' river channel.

Scattered thin occurrences of sandy alluvium occur between and next to the outcrop in the western half of the river channel. No significant occurrence of alluvium was observed on the lower left flank.

Bedrock

The bedrock comprises weathered shales and greywacke of the Porterville Formation.

The bedrock on the upper left flank is highly weathered, but no investigations were conducted in this area and the precise nature and distribution of this rock mass are unknown.

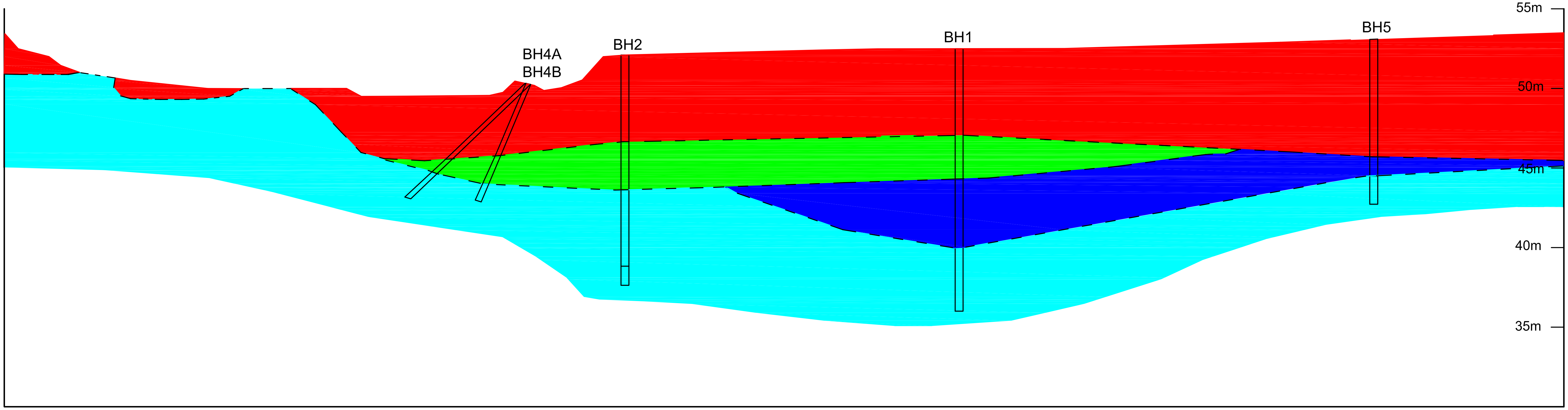
The rock outcrop in the western part of the river channel comprises moderately to slightly weathered, medium hard to hard, highly fractured shale and greywacke. More weathered areas occur locally. A sub vertical schistosity or foliation strikes just west of north.

This relatively unweathered rock mass apparently extends below the river and to an undetermined distance from BH 2 towards BH 1, beyond (east) of which the contact zone of the bedrock is more weathered with highly weathered rock grading, in places, to a soil-like completely weathered condition, particularly in the contact zone. The interpreted distribution of the more weathered rock is illustrated on Figure 2.

5.2.3 Geotechnical Assessment of the Weir Site

5.2.3.1 The Left Flank and the River Section

Assuming the conceptual arrangement discussed in Section 5.2.1 is adopted, it is apparent from Figures 1 and 2 that the western part of the spillway structure could be founded on moderately to slightly weathered bedrock which occurs at approximately 49m elevation. Only nominal thicknesses of mainly sandy alluvium currently occur above this bedrock, but the distribution of the alluvium will change seasonally after each winter flood.



🟥 Sand
🟩 Gravelly sand
🟦 Completely and highly weathered shale and greywacke
🟦 Generally moderately to slightly weathered shale or greywacke bedrock

FIGURE 2
BERG RIVER WEIR
GEOLOGICAL LONG SECTION
Scale 1:500 (H) 1:250 (V)

Weathered, very low and low strength rock occurs on the left flank, but the precise nature and distribution has not been determined.

Current information suggests that there is a step in the bedrock profile or a stepped or a very steep profile along the western edge of the 'summer' river channel and that bedrock only occurs below approximately 44m elevation in this channel, a step or change in level of some 4m.

The degree of weathering of the rock in the upper contact zone of the bedrock is apparently variable with a slightly to a borderline unweathered rock recorded in BH 4B, highly to moderately weathered in BH 4 A, and moderately to slightly weathered in BH 2.

The elevation of the bedrock apparently remains relatively constant between the step and BH 2 and to the east of BH 2, and the spillway structure could be founded at depths from approximately 0.5m below the alluvium/bedrock contact.

No water pressure testing was undertaken but, aside from the contact zone which might be more permeable, outcrop and borehole evidence suggested that the rock mass is relatively impermeable. In any event, seepage losses are not problematic particularly as erosion of the bedrock is unlikely.

5.2.3.2 Right Flank

The right flank is defined as that section of the weir structure or its centreline which extends eastwards from BH 2 to the higher ground (± 54.5m) just to the east of the existing vineyard.

This area is underlain by between approximately 5.5m and 7.5m of sandy alluvium, with gravelly alluvium extending at least an additional 3m apparently only in the western half. The alluvium is underlain, at least in the vicinity of BH 1, by at least 4m (BH 1) of completely to highly weathered rock which is generally soil-like.

With the weathered rock or soil-like completely weathered rock approximately 8m below current ground levels, and only significant floods creating water levels above existing ground level over most of the right flank, it is unlikely that a substantial concrete structure would be constructed in this area. If an extension of the weir structure is required in this area, an embankment type structure would be more appropriate than a concrete structure.

The principal engineering concerns for an embankment will probably be erosion either by overtopping of an embankment structure or piping through or below the embankment.

The sandy soils would probably be classified as SP materials and the gravelly soils as GP equivalents. These soils are pervious and vulnerable to erosion and they would not be suitable for core material or for an effectively impervious homogeneous embankment. They could be marginally suitable for shell material provided that they are protected against rainwater and wave erosion.

Overtopping could be prevented by appropriate design with respect to flood levels. Piping erosion could be prevented by constructing a core with an appropriate depth of cut-off trench and consideration during the preliminary design should be given to the possible use of sheet piling or a diaphragm wall.

Specific attention should be given to the design of the junction between the eastern end of the concrete spillway structure and the adjacent embankment, particularly as gravelly soils occur at depth and seepage-induced erosion could occur around the concrete structure if seepage flow lengths are too short.

5.2.3.3 Pump Station

The layout, size and location of the pump station have also not yet been determined, but based on conceptual designs, the station would be located on the left bank close to the weir.

The sloping ground in this area comprises thin transported soils over weathered bedrock with local outcrops of the relatively unweathered rock, but, based on the information from TP VV 10, thicker clayey soils occur at approximately the same elevation and some 50m upstream from the weir where the ground slopes less steeply.
From the above descriptions, it is apparent that the pump station would be located in cut or on a cut and fill platform.

Excavation conditions will be difficult if areas of relatively massive and unweathered rock occur, but founding conditions would be good in in-situ ground. However, founding the structure partly on in-situ ground and partly on fill could be problematic and the pump station site should preferably be located on flatter ground slightly upstream from the weir.

5.3 *Berg River to Voëlvlei Pipeline*

5.3.1 The Pipeline Structure

The pipeline route shown on Figure 3 is approximately 5km long.

Glass fibre reinforced pipes (GRP) will probably be used and laid at a depth between 3m and 3.5m.

5.3.2 Geotechnical Assessment of the Pipeline Route

The significant geotechnical factors in assessing construction conditions and costs for the pipeline will include excavation conditions, stability of the sidewalls of the pipe trenches, groundwater conditions, use of excavated materials for pipe bedding and backfill and engineering properties of the backfill.

Because the trial pits were so widely spaced, conditions along the pipeline route shown on Figure 3 cannot be discussed in detail. However, for the purposes of supporting the preliminary design during the feasibility study, the objective was to sub-divide the pipeline route into regions or sections in which the soil profile and therefore the geotechnical conditions are broadly similar. Eight such regions have been identified.

The anticipated soil profile along the sections of the route together with the interpreted construction conditions and material usage are summarised in Table 1.

5.3.2.1 Anticipated Soil and Rock Profiles

From Table 1, the anticipated soil and rock profiles along the route can be summarised as follows:

- Section 1 (pump station to 0.05km): Thin transported soils mask relatively unweathered Malmesbury bedrock.

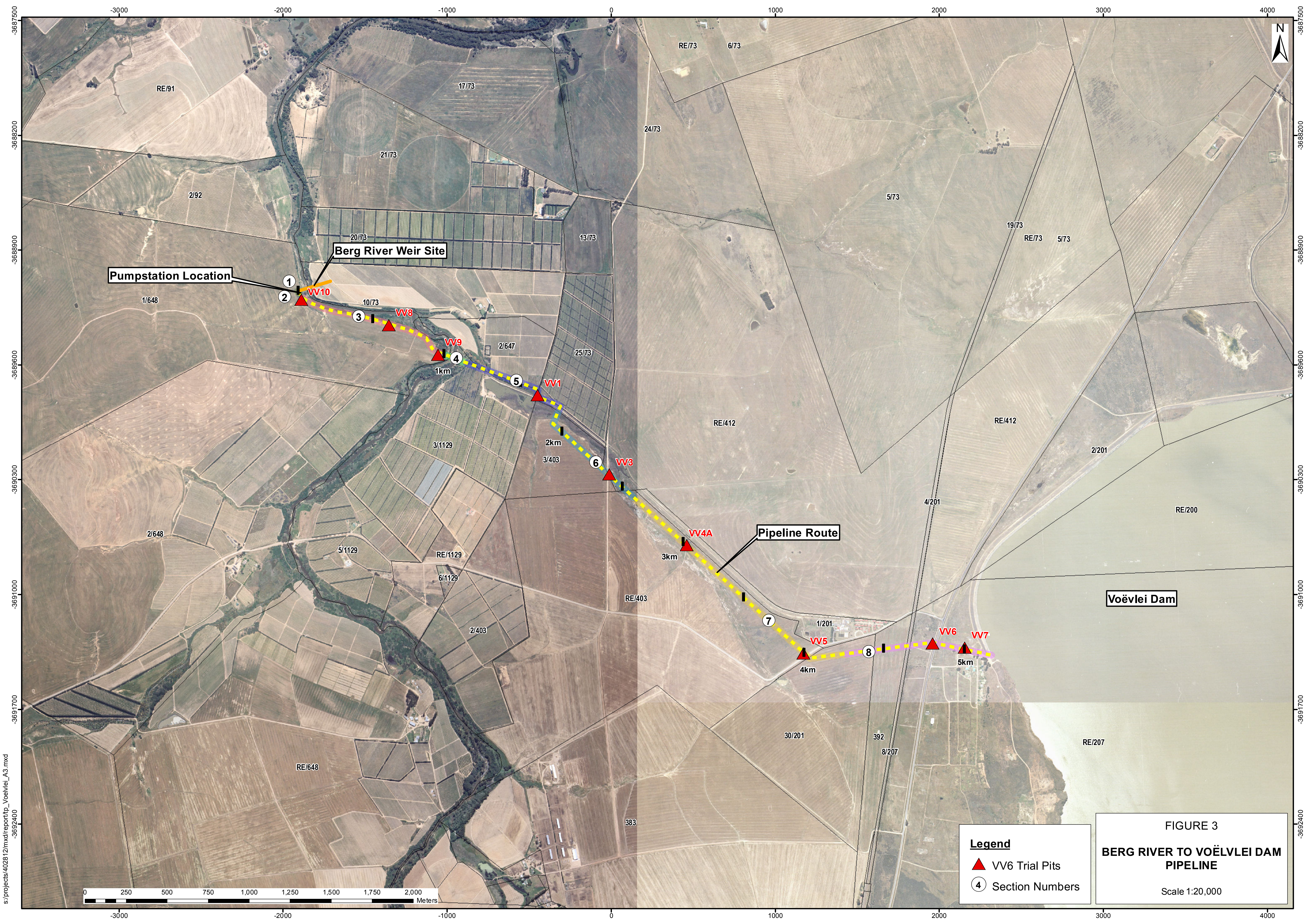


FIGURE 3

BERG RIVER TO VOËLVLEI DAM PIPELINE

Scale 1:20,000

s:/projects/402812/mxd/report/fp_Voelvlei_A3.mxd

TABLE 1: BERG RIVER TO VOËLVLEI PIPELINE - SUMMARY OF GROUND AND CONSTRUCTION CONDITIONS AND MATERIAL USAGE

Section	Anticipated Soil Profile (*)	Groundwater Presence	Excavation Conditions	Stability of trench (**)	Potential Use of Materials (**)			
					Soil type	SGM	SF	MF
1 Pump Station to 0.05km	Very thin clayey silty sand over relatively unweathered Malmesbury rock	No	Some Soft but generally Intermediate with possible local Hard	Soils at 1:1.5, bedrock at 1:0.5	Sandy soils	x	√	√
					Rock	x	x	(√)
2 0.05km to 0.1km	Clayey silty sand over weathered Malmesbury rock (VV10)	No	Soft with some Intermediate at depth	Soils at 1:1.5, bedrock at 1:0.5	Cl sandy Soils	x	x	√
					Rock	x	x	√
3 0.1km to 1km	Silty sandy, clayey silty sandy and possibly gravelly sandy alluvium to >3m depth (VV8 & VV9)	Possible at depth, particularly near the river	Soft	Soils at 1:1.5	Sandy soils	√	√	√
4 1.0km to 1.15km	Berg River Crossing. Sandy and gravelly alluvium. Depth to and nature of bedrock unknown.	Yes. Plus river diversion required.	Soft, possibly with Intermediate or Hard at depth if bedrock encountered	Dewatered soils at 1:1.5, bedrock at 1:0.5	Sandy soils	√	√	√
					Rock	x	x	(√)
5 1.15km to 1.8km	Silty sand, clayey silty sand and possibly minor sandy clayey silt at depth. Route crosses existing canal and drainage course. (VV1)	Yes, in places, particularly near drainage sources and river. Possible seasonally influenced inflow.	Soft possibly with local Intermediate at depth	Soils at 1:1.5	Sandy soils	√	√	√
					Silty soils	x	x	√
6 1.8km to 2.6km	Thin silty sand over completely grading to highly to moderately weathered Malmesbury rock with depth. Pipeline crosses seasonal stream near 1.9km and 2.5km. (VV3)	Generally no, but seasonal, perched occurrences possible.	Assumed approximately 75% soft and 25% Intermediate, but local Hard possible.	Soils at 1:1.5, bedrock at 1:0.5	Sandy soils	√	√	√
					Rock	x	x	√

* Trial pits in each section are noted. ** See qualifications in text. All distances approximate. SGM = selected granular material SF = selected fill MF = main fill

TABLE 1 (CONT): BERG RIVER TO VOËLVLEI PIPELINE - SUMMARY OF GROUND AND CONSTRUCTION CONDITIONS AND MATERIAL USAGE

Section	Anticipated Soil Profile (*)	Groundwater Presence	Excavation Conditions	Stability of trench (**)	Potential Use of Materials (**)			
					Soil type	SGM	SF	MF
7 2.6km to 4.2km	Thin silty sands over sandy clayey silt with and without gravel and gravelly clayey silty sand over highly to generally moderately weathered bedrock at depth. (VV4A and VV5)	Generally no, but seasonal occurrences possible.	Assumed 90% soft and 10% Intermediate but very slight possibility of Hard locally at depth.	Soils at 1:1.5, bedrock at 1:0.5.	Sandy soils	√	√	√
					Silty soils	x	x	(√)
					Rock	x	x	√
8 4.2km to Voëlvlei dam	Thick clayey silty sand over clayey silty gravelly sand and gravelly sandy clayey silt at depth. Possibly Malmesbury bedrock in base of trench, in places. Route crosses the R44 at 4.8km (VV 6 and VV 7)	Possibility of seasonal perched groundwater, generally at depth.	Generally soft but probable Intermediate or Hard near Voëlvlei Dam.	Soils at 1:1.5, bedrock at 1:0.5.	Sandy soils	√	√	√
					Silty soils	x	x	(√)
					Rock	x	x	√

* Trial pits in each section are noted. ** See qualifications in text. All distances approximate. SGM = selected granular material SF = selected fill MF = main fill

- Section 2 (0.05km to 0.1km): Clayey soils overlying weathered Malmesbury rock.

- Section 3 (0.1km to 1km): The alluvial plain of the Berg River extends into a broad strip along the left bank and the soil profile comprises mainly alluvial, slightly silty sands and minor clayey sands and local gravel lenses or layers. Bedrock generally occurs below 3m depth except possible in the extreme western end of this section.

- Section 4 (1km to 1.15km - the Berg River crossing): The soil profile and depth to bedrock where the pipeline passes below the Berg River are unknown. Sandy alluvium is expected, but the depth of bedrock is critical because it would affect excavation conditions and program.

- Section 5 (1.15km to 1.8km): Aluvium associated with the Berg River and alluvial wash associated with the drainage course/seasonal stream, which extends from southwest of TP VV 5 to near the crossing point, extends to the east of the river. The existing canal and the seasonal stream must be crossed. Bedrock might be encountered at depths where the stream has eroded the alluvium and locally lowered ground levels.

- Section 6 (1.8km to 2.6km): The weathered bedrock apparently occurs at shallow depth and the route re-crosses the seasonal stream and an associated seepage area in the vicinity of 1.9km and 2.5km.

- Section 7 (2.6km to 4.2km): Clay and gravelly alluvium occurs with highly to moderately weathered Malmesbury bedrock towards 3m depth. Rapid transition to less weathered, more massive bedrock might occur, in places.

- Section 8 (4.2km to Voëlvlei dam): The final section of the route apparently traverses deeply developed alluvial clayey silty sand with more clayey and locally gravelly soils at depth. Bedrock might occur at shallow depth in close vicinity to the Voëlvlei Dam wall.

5.3.2.2 Groundwater

Table 1 indicates that groundwater might be prevalent at depths in the alluvium to the west and immediately to the east of the Berg River.

Seasonal or local occurrences might occur throughout the sections of pipeline east of the river.

Groundwater will adversely affect excavation conditions, stability of the excavated slopes in the trenches, and pumping and possibly local dewatering will be required.

5.3.2.3 Excavation Conditions

Table 1 also indicates that machine excavation of the pipe trench is generally expected with high proportions of Soft Excavation Class according to SABS 1200 D.

Hard Excavation Class cannot be excluded in some areas, specifically in the area of the pump station and at depths in Sections 5 and 6. Some Hard Excavation Class might also be encountered near Voëlvlei Dam.

Precise quantification of the excavation types is not possible at greater confidence levels (nor considered necessary for supporting preliminary design), because the trial pits for this feasibility study are spaced too far apart to allow detailed extrapolation of excavation conditions.

5.3.2.4 Stability of Excavated Slopes in the Pipe Trench

With few exceptions, cohesionless or near cohesionless soils will occur it in the excavated profile and slope batters must reflect the low shear strength of these soils.

In Table 1, a batter of 1:1.5 has been considered appropriate for temporary cut slopes in soils, and 1:0.5 in bedrock.

Where groundwater occurs, batters at 1:1.5 will not be stable and combinations of dewatering, slope flattening and provision of supplementary measures such as sandbagging will be required to ensure safe working conditions.

The foliation in the bedrock generally strikes just west of north and the dip is generally sub vertical. Those short sections of trench, which are orientated near north-south, will therefore be excavated sub parallel to the strike of the predominant discontinuity in the rock mass. Flatter batters might be required to ensure stability in these areas.

5.3.2.5 Potential Use of Excavated Material

Based on the results of the trial pitting, five generalised soil groups can be identified. The generalised soil groups together with their basic engineering properties (grading and Atterberg Limits) are described below:

- **Silty sand and clayey silty sandy alluvium and gravelly varieties of these soils:** These soils predominate in Sections 3, 4, 5 and 8 and they are thinly, developed to shallow depth in Sections 2, 6 and 7.

  Most of these soils contain 30% or more of fines (material finer than 0.075 mm) and they would be classified as SC or SP soils. The sandy soils with the smallest fines content apparently occur in Section 3 and parts of Section 5 and they are commonly non plastic or slightly plastic, but plastic sandy soils also occur. They are classed as SP, SM, SM-SC and locally as SC soils.

  The sands in Section 8 contain fines contents of approximately 40% or more and they have plasticity indices greater than 15. They are classed as SC soils.

- **Sandy clayey silty alluvium and gravelly varieties of these soils:** These alluvial soils are apparently predominantly developed in Section 7, but they occur as minor components in other sections, commonly at depth, but also at surface in Section 2.

  Based on samples from TP VV 4A and VV 5, the more clayey soils are CH materials with fines contents of 69% and 66% and plasticity indices of 26 and 36.

  The clayey soils in VV 10 in Section 2 had a fines content of 56% and a plasticity index of 12 and it is classed as a SC material.

- **Silty sandy gravelly alluvium and clayey varieties of this soil:** These soils were also encountered in Section 7 and at depth in Section 8. Only the thin clayey sandy gravel in VV 5 was sampled. This soil had a plasticity index of 2, a fines content of 3% and approximately 20% of the soil was coarser than 10mm, but the representativeness of the coarser fraction is uncertain.

- **Gravelly clayey silt:** This residual Malmesbury soil was encountered in TP VV 3 in Section 6 and it probably occurs locally elsewhere, particularly in Section 7. The gravel content comprises highly to moderately weathered, remnant fragments of rock. The sample from VV 3 had a fines content of 39% and a plasticity index of 17%.

- **Shale and greywacke bedrock:** These rocks are commonly light to medium brown but pinkish orange brown in VV 3 and they are highly to moderately weathered. The rock strength commonly varies from very soft to soft, but medium hard to hard rock was also encountered. The upper portion of the bedrock is highly fractured and therefore excavates as a medium to coarse, angular gravel with a clayey silty matrix.

  These rocks will form a predominant part of the excavation in Section 1, where they might be less weathered than indicated above, and they will be present in Sections 6 and 7.

  A sample from VV 3 had a fines content of 53% and a plasticity index of 9. However, the grading of the excavated soils will vary depending on their degree of weathering and fracturing and, to some extent, the excavation method. The material excavated from the trial pits generally presented as a gravelly soil with some fines.

Based on the results of limited pitting and laboratory testing and the assessments above, the potential use of excavated material for selected granular material, selected fill and main fill are summarised in Table 1 for each general soil type in each section of the pipeline route.

The following qualifications and notes are relevant to the tabulation:

- In most sections, several soil types and, in places rock occur. Unless selective excavation is undertaken, all material types will be mixed. The resulting mixture would probably only be suitable for main fill.

- Where the soils occur, for example in Section 6, the specific potential usage indicated in Table 1 therefore assumes selective excavation, stockpiling and use of the thinly developed soils.

- The more cohesive soils, the hard rock and mixtures of cohesive and sandy soils and cohesive soils and rock will only provide a relatively poor quality main fill.

- Similarly, main fill comprising only cohesive soils will be of poor quality or unacceptable and main fill comprising only relatively unweathered rock will be unacceptable.

- With respect to the quality of the main fill, the route generally traverses farmland where backfill requirements can possibly be relaxed slightly given that local small settlement of the fill is unlikely to affect local operations. However, the main fill should be of adequate quality to prevent ingress of water and piping of the sidewalls of the trench or the bedding material.

- The symbols in parenthesis indicate marginal potential for use.

From Table 1, it is apparent that the sandy soils in Sections 3, 4 and 8 are potentially the most suitable source of selected granular material. However, it is noted that these soils contain fines and that their compactibility factors are unlikely to be less than 0.4. These soils are effectively cohesionless and relatively free draining and with additional investigation and testing and relaxation of the requirements of SABS 1200 LB, they could be considered for selected granular material.

Precise quantification of the volumes of soil suitable for selected granular material, selected fill and main fill is not possible because the trial pits for this feasibility study are too far apart to allow detailed extrapolation of soil distributions.

6. MICHELL'S PASS WEIR AND MICHELL'S PASS PIPELINE - SCHEME B

This section of the report presents similar information and assessments to that for the Berg River weir and pipeline (Section 5) and this section can generally be read as a stand-alone assessment of Scheme B with limited cross reference to Section 5.

The qualifications regarding spacing of the trial pits and interpretation of intervening ground conditions that were discussed for Scheme A are also relevant to Scheme B.

6.1 Geology and Geomorphology

The 1:250 000 Geological Series Map, 3319 Worcester, indicates that the area investigated for Scheme B is also underlain by the shales and siltstones of the Porterville Formation of the Malmesbury Group that are masked by alluvial deposits of Quaternary Age.

The Breede River has also strongly influenced the geomorphological development of the eastern and central parts of the study area.

On exiting the gorge-like valley below the R44 in Michell's Pass, the Breede River has meandered and deposited coarse alluvium over an area which extends northwards from the current position of the river to a broad line which runs near the R44 in the east and diverges some 300m south of the road in the west. This fan-like deposit extends below the southern parts of Wolseley.

The ground along the pipeline route runs immediately east of Wolseley then rises above the main Breede River valley. Normal geomorphological and erosional development has resulted in rolling topography, with thinly developed transported and residual soils and weathered rock at shallow depth.

The Blousloot and Boontjies Rivers are the results of a superimposed drainage system and they have localised, associated development of alluvial deposits.

6.2 The Proposed Michell's Pass Weir

6.2.1 The Weir Structure

No details of the dimensions, levels, nature or precise position of this structure have been provided and only general comments can therefore be given. However, the weir, which will be a concrete structure, will be located in close vicinity to the existing DWA weir (H1H006), just upstream from the bridge on the R43 over the Breede River.

A view of the existing Michell's Pass weir (DWA weir H1H006) is illustrated on Plate 2.

6.2.2 Geology of the Weir Site

Based on the results of previous drilling undertaken prior to the bridge design, the indication from assessment of that information is that bedrock might occur approximately 4m below the river level. Based on these results, the interpretation is that bedrock is expected to comprise relatively unweathered and medium fractured sandstone which would provide suitable founding for the weir.

6.2.3 Geotechnical Assessment of the Weir Site

Factors to be considered in the design and construction of the weir include the occurrence of the existing concrete weir structure and the existing inlet structure for the Artois irrigation canal which runs towards Wolseley on the left bank. Both will be impacted by the construction of new works. River diversion would be required during construction and and uninterrupted water supply to the Artois irrigators maintained. Construction in the dry summer months would be necessary.

Weirs are conventionally founded on bedrock, although they could be founded on dense alluvium provided that erosion and seepage losses are not factors. In the case of this weir, seepage is of no concern and the focus will be on ensuring that suitable erosion protection measures are allowed for.

Trial pit MP 1 did not expose bedrock and the actual depth to it and its quality are unknown. To qualify this would require substantially more intensive and costly investigations (core drilling). The JV did not consider that it was necessary to motivate for additional funding from DWA to undertake such drilling. This due to the fact that:

- this is a low weir structure (at an existing weir location),
- it need not be a watertight structure, and
- previous geotechnical investigations at the nearby bridge have been undertaken..

6.3 Michell's Pass Pipeline

6.3.1 The Pipeline Structure

The pipeline route shown on Figure 4 comprises two alternatives with the pipeline either discharging into the Blousloot River (pipeline length of 8.6km) or into the Boontjies River (9.3km pipeline).

Glass fibre reinforced pipes (GRP) will probably be used and laid at a depth between 3m and 3.5m.

6.3.2 Geotechnical Assessment of the Pipeline Route

The significant geotechnical factors in assessing construction conditions and costs for the pipeline will again include excavation conditions, stability of the sidewalls of the pipe trenches, groundwater conditions, use of excavated materials for pipe bedding and backfill, and engineering properties of the backfill.

The anticipated soil profile along the sections of the route together with the interpreted construction conditions and material usage are summarised in Table 2.

PLATE 2: MICHELL'S PASS WEIR SITE

Note the existing inlet structure for the Artois irrigation canal in the foreground of the plate

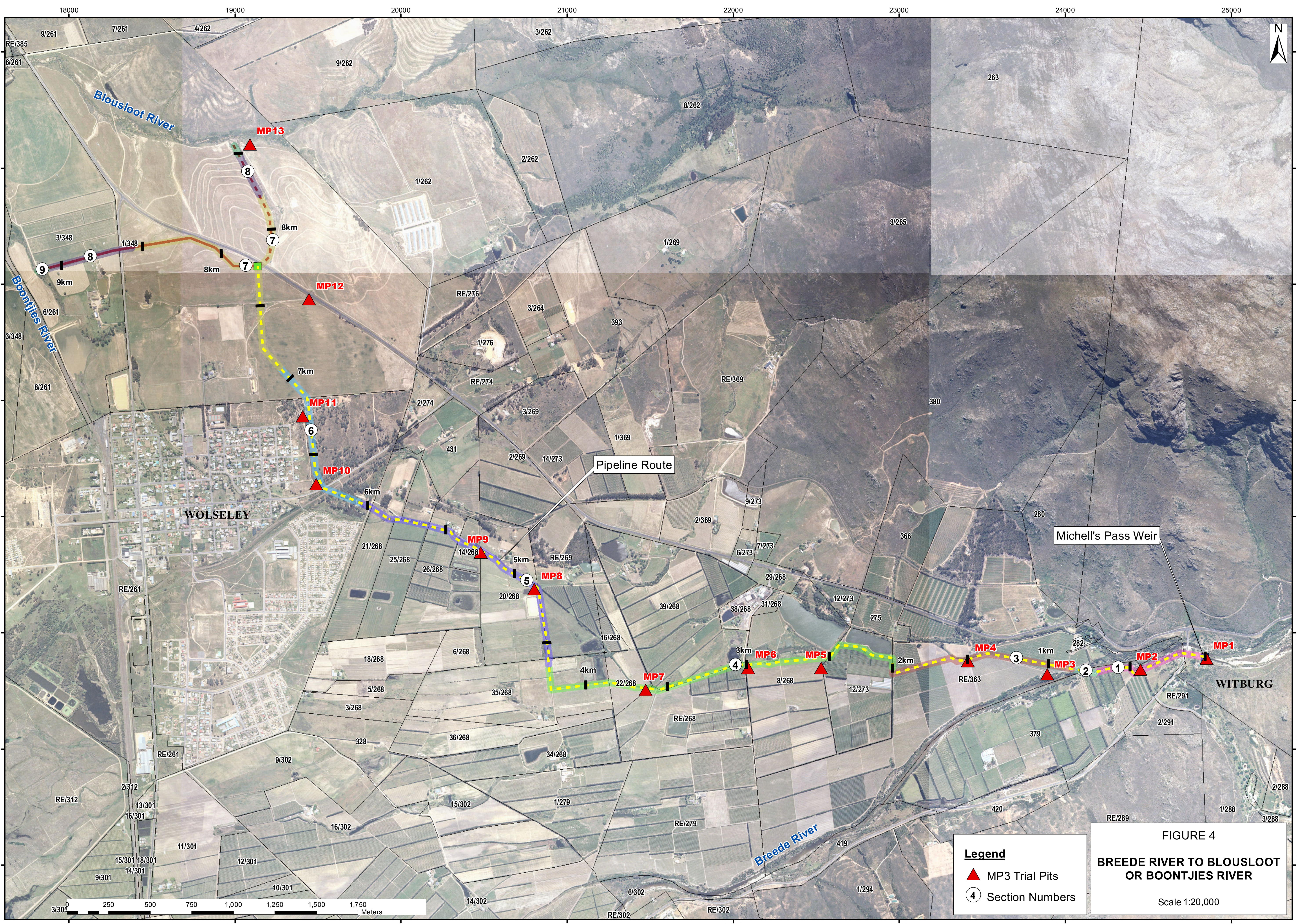


FIGURE 4

BREEDE RIVER TO BLOUSLOOT OR BOONTJIES RIVER

Scale 1:20,000

TABLE 2: MICHELL'S PASS PIPELINE - SUMMARY OF GROUND AND CONSTRUCTION CONDITIONS AND MATERIAL USAGE

Section	Anticipated Soil Profile (*)	Groundwater Presence	Excavation Conditions	Stability of trench (**)	Potential Use of Materials (**)			
					Soil type	SGM	SF	MF
1 Michell's Pass Weir to 0.7km	Combinations of gravelly sand, sandy gravel and apparently minor clayey sandy gravel with various quantities of small boulders. This alluvium is thicker than 3.5m and possibly coarser near the current Breede River course. (MP1 and MP2)	Yes at depth and at shallow depth near the river.	Soft/Intermediate with very local areas of Boulder Class A	Dewatered soils at 1:1.5	Fine alluvium	√	√	√
					Coarse alluvium	x	x	(√)
2 0.7km to 0.8km Siphon below Breede River	Inverted siphon below Breede River. Coarse alluvium over sandstone bedrock. Depth to bedrock unknown.	Yes plus river diversion required.	Soft/Intermediate with very local areas of Boulder Class A. Hard at depth if bedrock encountered	Dewatered soils at 1:1.5. Bedrock at 1:0.5.	Fine alluvium	√	√	√
					Coarse alluvium	x	x	(√)
3 0.8km to 2km	Similar soils to those expected in Section 1 (MP3 and MP 4)	Yes at depth and possibly locally seasonally perched at shallow depth.	Soft/Intermediate with very local areas of Boulder Class A	Dewatered soils at 1:1.5	Fine alluvium	√	√	√
					Coarse alluvium	x	x	(√)
4 2km to 4.35km	Silty sand and sandy alluvium overlying sandy gravel and some gravelly sand with various quantities of small boulders. (MP5 to MP7)	Yes at depth and possibly locally seasonally perched at shallow depth.	Soft/Intermediate with very local areas of Boulder Class A	Dewatered soils at 1:1.5	Fine alluvium	√	√	√
					Coarse alluvium	x	x	(√)
5 4.35km to 6km	Generally finer alluvium comprising sand and also areas with clayey sand and sandy clay and local occurrences of clayey coarse alluvium. (MP8 and MP9)	Yes	Soft	Dewatered soils at 1:1.5	Fine sandy alluvium	√	√	√
					Fine clayey alluvium	x	x	(√)
					Coarse alluvium	x	x	(√)

* Trial pits in each section are noted. ** See qualifications in text. All distances approximate. SGM = selected granular material SF = selected fill MF = main fill

TABLE 2 (CONT): MICHELL'S PASS PIPELINE - SUMMARY OF GROUND AND CONSTRUCTION CONDITIONS AND MATERIAL USAGE

Section	Anticipated Soil Profile (*)	Groundwater Presence	Excavation Conditions	Stability of trench (**)	Potential Use of Materials (**)			
					Soil type	SGM	SF	MF
6 6km to 7.1km	Thin sandy transported soils with basal development of ferricrete and other scattered gravel overlying siltstone and shale bedrock. (MP10 and MP11)	No but local winter seepage at transported soil/residual contact.	Soft possibly with local Intermediate at depth	Transported soils at 1:1.5, bedrock at 1:0.5.	Transp soil	x	x	(√)
					Weath rock	x	x	√
7 7.1km to 8.2km (to Blousloot River) or to 8.65km (to Boontjies River)	Soil profile as per Section 6, but less weathered, more massive bedrock expected at shallower depth. (MP12)	No but local winter seepage at transported soil/residual contact.	Soft in transported soils and generally Soft and Intermediate in bedrock but Hard expected in places at depth	Transported soils at 1:1.5, bedrock at 1:0.5.	Transp soil	x	x	(√)
					Weath rock	x	x	√
					Rock	x	x	(√)
8 8.2km to 8.5km (to Blousloot River) or 8.65km to 9.1km(to Boontjies River)	Soil profile probably as per Section 6.	No but local winter seepage at transported soil/residual contact.	Soft possibly with local Intermediate at depth	Transported soils at 1:1.5, bedrock at 1:0.5.	Transp soil	x	x	(√)
					Weath rock	x	x	√
9 8.5km to 8.6km (to Blousloot River) or 9.1km to 9.3km(to Boontjies River)	Alluvial wash sands, silty sands and basal clayey sandy gravel with weathered bedrock probably occurring at southern or eastern ends of sections. (MP13)	Possible close to the river.	Soft with possible minor Intermediate in bedrock	Soils at 1:1.5.	Fine alluvium	√	√	√
					Coarse alluvium	x	x	(√)
					Weath. rock	x	x	(√)

* Trial pits in each section are noted. ** See qualifications in text. All distances approximate. SGM = selected granular material SF = selected fill MF = main fill

6.3.2.1 Anticipated Soil and Rock Profiles

From Table 2, the anticipated soil and rock profiles along the route can be summarised as follows:

- Section 1 (weir site to 0.7km): Combinations of fine and coarse alluvium with thicker and possibly coarser alluvium near the river. Because the river has meandered, multiple combinations of sandy, gravelly and bouldery alluvial soil types are possible.

- Section 2 (0.7km to 0.8km - the Breede River crossing: The soil profile and depth to bedrock where the pipeline passes below the Breede River are unknown. Coarse alluvium is expected, but the depth to bedrock is critical because it would affect excavation conditions and construction program.

- Section 3 (0.8km to 2km): Similar soils to those expected in Section 1 are also expected in this section.

- Section 4 (2km to 4.35km): Finer alluvium (silty sand and sand) overlie coarser alluvium.

- Section 5 (4.35km to 6km): This section is located towards the northern limits of the alluvial fan and generally finer alluvium with areas of more clayey alluvium is expected.

- Section 6 (6km to 7.1km): Thin transported soils overlie thinly developed ferricrete and gravel overlying weathered Malmesbury bedrock.

- Section 7 (7.1km to various km distances depending on the adopted branch of the pipeline route): The soil profile is expected to be similar to that in Section 6, but less weathered or more massive bedrock is expected at shallower depth.

- Section 8: The soil profile is expected to be similar to that in Section 6.

- Section 9: These sections occur adjacent to the Blousloot and Boontjies Rivers and therefore generally fine alluvial soils are expected with the weathered bedrock occurring at depth particularly in the upslope portions of this section.

6.3.2.2 Groundwater

Table 2 indicates that groundwater will probably be present, generally at depth, but possibly also locally at shallow depth, in the alluvium in Sections 1 to 5. It might also be present in the alluvium in Section 9. Local, seasonal perched water might occur in Sections 6 to 8.

The alluvium in the Breede River alluvium (Sections 1 to 6) is commonly coarse and it will have high permeabilities. The quantity of groundwater inflow could therefore be significant.

Groundwater will adversely affect excavation conditions, stability of the excavated slopes in the trenches, and pumping and possibly local de-watering will be required.

6.3.2.3 Excavation Conditions

Table 2 also indicates that machine excavation of the pipe trench is generally expected.

High proportions of Soft and possibly Intermediate Excavation Class (SABS 1200 D) are expected in Sections 1 to 4 where coarser alluvium occurs. The use of an Intermediate classification would be dependent on the efficiency of excavation because the experience during site investigations was that, although the alluvium could be excavated, continuous instability in the trench meant that slow and additional excavation was required.

Intermediate excavation is expected in Sections 6 to 8 in the Malmesbury bedrock and some Hard Excavation Class cannot be excluded in some areas, particularly in Section 7.

Hard excavation might also be encountered in the pipe trench below the Breede River if bedrock is encountered.

Precise quantification of the excavation types is not possible because the trial pits for this feasibility study are too far apart to allow detailed extrapolation of excavation conditions.

6.3.2.4 Stability of Excavated Slopes in the Pipe Trench

With few exceptions, cohesionless or near cohesionless soils will occur in the excavated profile in Sections 1 to 5 and 8 and slope batters must reflect the low shear strength of these soils. This is particularly relevant because groundwater is expected in the trenches in these sections and this will adversely influence stability.

In Table 2, a batter of 1:1.5 has been considered appropriate for temporary cut slopes in soils, and 1:0.5 in bedrock.

Where groundwater occurs, batters at 1:1.5 will not be stable and combinations of dewatering, slope flattening and provision of supplementary measures such as sandbagging will be required to ensure safe working conditions.

The foliation in the bedrock generally strikes just west of north and the dip is generally sub vertical. The trench in Section 6, 7 and 8 is orientated near north-south and it will therefore be excavated sub parallel to the strike of the predominant discontinuity in the rock mass. Flatter batters might be required to ensure stability in these areas.

6.3.2.5 Potential Use of Excavated Material

Based on the results of the trial pitting, the types of excavated materials can be subdivided or categorised into three generalised soil groups. The generalised soil groups together with their basic engineering properties (grading and Atterberg Limits) are described below:

- **Fine and mainly coarse alluvium:** These soils predominate in Sections 1 to 4 and locally in Section 5. The coarse content (gravel and boulders) is variable and boulders up to 700mm maximum diameter were encountered in some pits, but larger boulders might occur in the intervening areas of the trench.

  Sampling to obtain representative grading of the entire soil mass was not practical and generally only the matrix soils were sampled and tested.

  Samples from MP 2 to MP 7 had fines contents (material finer than 0.075mm) ranging from 1% to 23% and, with the exception of the sample from MP 5 which was slightly plastic, all other soils were non-plastic. The coarse soils would be variously classified as GW, GP and GM soils with local sandy equivalents.

- **Mainly fine alluvium:** These soils occur in Sections 5 and 9, and to some extent in the upper profile at the western end of Section 4.

Samples from MP 8 had a fines content of 29% with a plasticity index of 10, and 61% fines and a plasticity index of 22 at depth. In contrast, the sandy soil from MP 9 had 14% fines and it was non-plastic.

The sample from the upper soil profile in the alluvial soils in MP 13 next to the Blousloot River had 18% fines and it was non-plastic. The more cohesive soil at depth had 30% fines and it was slightly plastic.

The soils in this section would therefore be classified as SP, SC and possibly SM-SC materials, with local gravelly equivalents possible.

- **Thin soils over weathered Malmesbury:** This profile occurs in Sections 6, 7 and 8.

  The samples of weathered Malmesbury from MP 10, MP 11 and MP 12 had fines contents varying from 47% to 85% and plasticity indices from 3 to 11. Although the weathered Malmesbury rock would be classified as ML or ML-CL material based solely on laboratory results, it will excavate, in most places, as a gravelly material which would be coarser or finer depending on the degree of weathering and fracturing of the rock mass.

Based on the results of limited pitting and laboratory testing and the assessments above, the potential use of excavated material for selected granular material, selected fill and main fill are summarised in Table 2 for each general soil type in each section of the pipeline route.

The following qualifications and notes are relevant to the tabulation:

- In most sections, fine and coarse alluvial soil types or cohesive soils or, in places rock occur. Unless selective excavation is undertaken in these sections, all material types will be mixed. The resulting mixture would possibly only be suitable for main fill.

- Where thin soils occur, for example in Section 6, the specific potential usage indicated in Table 2 assumes selective excavation, stockpiling and use of the thinly developed soils.

- The more cohesive soils, the hard rock and mixtures of cohesive and sandy soils and cohesive soils and rock will only provide a relatively poor quality main fill.

- Similarly, main fill comprising only cohesive soils will be of poor quality or unacceptable and main fill comprising only relatively unweathered rock will be unacceptable.

- With respect to the quality of the main fill, the route generally traverses farmland where backfill requirements can possibly be relaxed slightly given that local small settlement of the fill is unlikely to affect local operations. However, the main fill should be of adequate quality to prevent ingress of water and piping of the sidewalls of the trench or the bedding material.

- The symbols in parenthesis indicate marginal potential for use.

From Table 2, it is apparent that only the fine alluvium (sandy soils) in Sections 5 and 9 is potentially the most suitable source of selected granular material. However, it is noted that these soils contain fines and that their compactibility factors are unlikely to be less than 0.4. These soils are effectively cohesionless and relatively free draining and with additional investigation and testing and relaxation of the requirements of SABS 1200 LB, they could be considered for selected granular material.

Table 2 also indicates that there will be a dearth of both selected granular material and selected fill and that the material for main fill is also potentially problematic because of the potentially high proportion of coarse material in the coarse alluvium over approximately half the route. Sieving the coarse alluvium through a grizzly grid would produce material which is suitable for all three fill/bedding types. Quantities of coarse material, which would have to be spoiled, would also be produced.

Precise quantification of the volumes soil suitable for selected granular material, selected fill and main fill is not possible because the trial pits for this feasibility study are too far apart to allow detailed extrapolation of soil distributions.

7. GEOTECHNICAL COMPARISON OF SCHEMES A AND B

Weir sites

The geotechnical conditions at the two weir sites differ significantly.

The weir on the Berg River would be partly located directly on bedrock which would provide good founding, but the founding level steps approximately 4m at the eastern edge of the existing outcrop. A subsidiary embankment structure would probably be required on the right flank.

The Michell's Pass weir should probably also be founded on bedrock which, from current information might lie some 4m below river level. Complications include the existing intake facilities on the left bank which could interfere with the construction and positioning of the weir.

Pipelines

With some exceptions, groundwater is not expected to be problematic on the Berg River pipeline route, but ground and surface water will be encountered near the river crossing.

Groundwater is expected at depth in the pipe trenches over nearly half of the Michell's Pass pipeline route. Extensive dewatering, possibly including formal measures such as standpipes, will be required.

Machine excavation of the trenches along the pipeline routes for both schemes can generally be undertaken. Hard Rock is also expected in some areas, with potentially more extensive occurrences along the Michell's Pass pipeline route.

Approximately half of the Berg River route will be excavated in materials which are cohesive and reduced overbreak is expected and a narrower excavation profile can be implemented. In contrast, approximately three quarters of the Michell's Pass pipeline route will be excavated in coarse or fine alluvium, which will require flat temporary slopes and over-excavation is likely.

With further investigation and probably relaxation of the requirements of SABS 1200 LB, the quantities of excavated material which is potentially suitable for selected granular material and selected fill can be obtained from the Berg River pipeline trenches. In contrast, there is a dearth of material suitable for these bedding/fill types on the Michell's Pass pipeline route. Reworking of coarse alluvium could provide selected granular material and selected fill materials on the Michell's Pass route, but a shortfall of these materials is still expected.

Both Scheme A and B pipeline routes cross the respective rivers, but it might be possible to relocate the Berg River route along the right bank of the river and thus avoid a complicated river crossing. Appropriate design of the weir will then be required to house the pipeline within it.

The Michell's Pass route traverses numerous farms. Numerous subsurface services, drainage ditches, roads and orchards will be affected. In contrast, relatively little disruption would be caused by a pipeline constructed for Scheme A, depending on which option is selected in terms of the Berg River crossing.

8. CONCLUSIONS AND RECOMMENDATIONS

a) The feasibility investigations have provided a general level of information on ground and construction conditions along the pipeline routes and for the weir sites for both Schemes A and B, at a level of detail adequate to support the feasibility studies. However, more detailed investigations are recommended if this option proceeds to implementation (ie. at detailed design stage).

b) The Berg River weir is considered the better weir site, particularly if an adequate length of spillway can be provided in the general area of the rock exposures on the west side of the river channel.

c) The most favourable conditions with respect to groundwater are expected along the Berg River pipeline.

d) Machine excavation is generally expected along both pipeline routes. Approximately half of the Berg River route will be excavated in materials in which overbreak can be more easily controlled and narrower excavation profiles could be adopted. In contrast, approximately three-quarters of the Michell's Pass route will be excavated in alluvium which will be less stable and over-excavation is likely.

e) The potential for use of excavated materials for selected granular material, selected fill and even main fill is greater on the Berg River pipeline route.

f) The routing of the pipeline along the right bank of the Berg River should be investigated because it might be possible to avoid a complicated river crossing, but will need to consider the impact on Lorelei Farm, and the risk of erosion of that embankment during floods

g) Although only partly geotechnically related, the disruption to farming activities and traversing of orchards and vineyards along the Berg River pipeline route would be significantly less than that along the Michell's Pass route.

h) Based on the assessments above, the Berg River pipeline route is considered geotechnically more favorable option than that of the Michell's Pass route.

i) In order to support detailed design, it is recommended that the following areas and conditions should be investigated if this option proceeds to implementation:
- the optimum position for a pump station at the Berg River weir,
- the nature of the alluvium and particularly the depth to and the condition of the bedrock at the pipeline river crossings,

- more detailed trial pitting along the pipeline routes, and
- specific laboratory testing to confirm the suitability of the sandy soils for use as selected granular material.

R.A. Bradshaw Pr.Sci.Nat.
R.A. BRADSHAW & ASSOCIATES cc

ANNEXURE

REVIEW OF THE GEOTECHNICAL REPORT BY MR. R. MCKELLAR, SPECIALIST CONSULTANT TO WCWC JV

Dick Bradshaw

From:	Graham English [Graham.English@aurecongroup.com]
Sent:	27 July 2011 02:50 PM
To:	mackellar
Cc:	Dick Bradshaw
Subject:	RE: WCWS Review of Geotechnical Report by RA Bradshaw

Thank you very much Robin

Hi Dick…I suggest you add Robin's full comment in as an Appendix (Specialist Geotechnical Review) to your report. Then just include any relevant comments where necessary in the body.

Thanks

Graham English
Associate I Professional Engineer (Civil) I Aurecon
T +27 21 481 2458 I **M** +27 82 422 3828
E Graham.English@aurecongroup.com
81 Church Street, Cape Town I
aurecongroup.com

From: mackellar [mailto:mackellar@icon.co.za]
Sent: 27 July 2011 12:06 PM
To: Graham English
Subject: WCWS Review of Geotechnical Report by RA Bradshaw

Dear Graham
As requested I have reviewed the Report and attach a short note on my assessment.
I consider that it is very thorough and provides an excellent basis for proceeding to the design and costing of the preferred scheme.

As noted in the report, there are some areas where additional information will be required to optimise the pipe route, in particular where the line crosses the river.

You may wish to refer to the construction report of the Drakenstein pipeline on the Berg River Project that was constructed in similar conditions.

Please advise if you require any further input.

Regards

Robin MacKellar

APPENDIX A

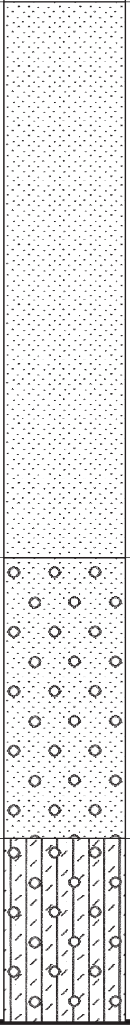
BOREHOLE LOGS

R.A. BRADSHAW & ASSOCIATES cc
CONSULTING ENGINEERING GEOLOGISTS

CONTRACT	BERG RIVER DIVERSION WEIR
SITE	BERG RIVER
CONTRACTOR	FAIRBROTHER GEOTECHNICAL ENGINEERING cc

Date started	3/05/2011	**BH No.**	**1**
Date completed	4/05/2011	***X*-Coord**	3689109X
Water level	See remarks column	***Y*-Coord**	1780Y
Logged by	N.G	**Level**	±52.5m
Date	17/05/2011	**Inclination**	Vertical

DRILL RUN	DRILLING METHOD	CASING DEPTH	% CORE RECOVERY	% RQD	FRACTURE FREQ.	TEST RESULTS	Depth (m)	GENERAL DESCRIPTION	PROFILE	REMARKS
1.00	W/B		W/S	-	-			SAND Medium brown, medium dense, fine sand with scattered, fine to medium, sub rounded gravel between 5m and 5.45m depth. Alluvium.		Water table: 4.55m (12/05/2011) 4.27m (31/05/2011) 4.13m (15/06/2011)
1.45	SPT		67	-		N=11				
2.00	W/B		W/S	-						
2.45	SPT		69	-		N=12				
3.00	W/B		W/S	-						
3.45	SPT		82	-		N=10				
4.00	W/B		W/S	-						
4.45	SPT		60	-		N=20				
5.00	W/B		W/S	-						
5.45	SPT		56	-		N=25	5.45			
6.00	W/B		W/S	-				GRAVELLY SAND Light to medium brown, dense to very dense, fine to coarse sand with fine to medium, sub rounded gravel. Becoming more gravelly between 6.45m and 7m depth. Alluvium.		6.45-7m No matrix recovered.
6.45	SPT		58	-		N=30				
7.00	NWD4		73	-						
7.45	SPT		40	-		N=65				
8.00	NWD4		22	-			8.20			
8.45	SPT		40	-		N=24		GRAVELLY CLAYEY SILT Medium brown and reddish brown, firm to stiff, clayey silt with fine to medium, sub rounded gravel. Completely weathered Malmesbury greywacke grading, in places, to marginal highly weathered, very soft rock.		Grading between 9m and 9.45m to clayey, silty medium to coarse sand with fine to medium, sub rounded gravel. Possible caving (?)
9.00	NWD4		82	-						
9.45	SPT		76	-		N=22				
10.00	NWD4		91	-						



R.A. BRADSHAW & ASSOCIATES cc
CONSULTING ENGINEERING GEOLOGISTS

CONTRACT	BERG/BREEDE RIVER	**Date started**	3/05/2011	**BH No.**	**1**
SITE	-	**Date completed**	4/05/2011	***X*-Coord**	3689109X
CONTRACTOR	FAIRBROTHER GEOTECHNICAL ENGINEERING cc	**Water level**	See page 1 remarks column	***Y*-Coord**	1780Y
		Logged by	N.G	**Level**	±52.5m
		Date	17/05/2011	**Inclination**	Vertical

DRILL RUN	DRILLING METHOD	CASING DEPTH	% CORE RECOVERY	% RQD	FRACTURE FREQ.	TEST RESULTS	Depth (m)	GENERAL DESCRIPTION	PROFILE	REMARKS
10.45	SPT		29	-		N=19		Grading, in places, between 12.15m and 12.5m to highly weathered (?), highly to very highly fractured, soft to very soft rock.	▨	
11.00	NWD4	NX 11.00	49	-						
11.45	SPT		47	-	-	N=29				
12.00	NWD4		100	-						
12.15	SPT		113	-		N=R	12.50			
13.00	NWD4		120	58	6			GREYWACKE Greyish khaki, stained black, moderately weathered, highly to slightly fractured, soft to medium hard rock greywacke. Malmesbury Group. Grading between 13.6m and 14m to medium brown, very stiff, completely weathered rock with scattered fine to medium gravel-size fragments ferruginised rock. Joints sub horizontal and sub vertical. Manganese stained.	▤	
14.00	NWD4		69	43	4					
15.00	NWD4		107	88						
16.50	NWD4		84	60	16 5		16.50			
										END OF BOREHOLE

R.A. BRADSHAW & ASSOCIATES cc **CONSULTING ENGINEERING GEOLOGISTS**		**Date started**	5/05/2011
		Date completed	9/05/2011
CONTRACT	BERG RIVER DIVERSION WEIR	**Water level**	See remarks column
SITE	BERG RIVER	**Logged by**	N.G.
CONTRACTOR	FAIRBROTHER GEOTECHNICAL ENGINEERING cc	**Date**	17/05/2011

BH No.	**2**
***X*-Coord**	3689129X
***Y*-Coord**	1818Y
Level	±52.1m
Inclination	Vertical

DRILL RUN	DRILLING METHOD	CASING DEPTH	% CORE RECOVERY	% RQD	FRACTURE FREQ.	TEST RESULTS	Depth (m)	GENERAL DESCRIPTION	PROFILE	REMARKS
1.00	W/B		W/S	-	-			SAND Medium brown, loose to medium dense, fine sand becoming medium to coarse from 5m. Alluvium.		Water table: 4.40m (12/05/2011) 3.88m (31/05/2011) 3.59m (15/06/2011)
1.45	SPT		51	-		N=16				
2.00	W/B		W/S	-						
2.45	SPT		49	-		N=20				
3.00	W/B		W/S	-						
3.45	SPT		62	-		N=8				
4.00	W/B		W/S	-						
4.45	SPT		51	-		N=15				
5.00	W/B		W/S	-						
5.45	SPT		58			N=23	5.45			
6.00	W/B		W/S	-				GRAVELLY SAND Light to medium brown, medium dense and dense, fine to coarse sand with fine to medium, sub rounded gravel. Alluvium. Becoming more gravelly between 7.45m and 8m depth.		7.45-8m No matrix recovered.
6.45	SPT		49	-		N=38				
7.00	W/B		W/S	-						
7.45	SPT		44	-		N=26				
8.00	NWD4		49	-			8.50			
9.00	NWD4		40	0	>20			SHALE Greyish brown and brown, becoming greenish grey from 10m depth, moderately weathered to slightly weathered, very highly and highly fractured, grading to moderately fractured in places, very soft and soft rock shale. Malmesbury Group.		
9.50	NWD4		74	24						
	NWD4		63	0						

R.A. BRADSHAW & ASSOCIATES cc
CONSULTING ENGINEERING GEOLOGISTS

CONTRACT	BERG RIVER DIVERSION WEIR	**Date started**	5/05/2011	**BH No.**	**2**
SITE	BERG RIVER	**Date completed**	9/05/2011	***X*-Coord**	3689129X
CONTRACTOR	FAIRBROTHER GEOTECHNICAL ENGINEERING cc	**Water level**	See page 1 remarks column	***Y*-Coord**	1818Y
		Logged by	N.G.	**Level**	±52.1m
		Date	17/05/2011	**Inclination**	Vertical

DRILL RUN	DRILLING METHOD	CASING DEPTH	% CORE RECOVERY	% RQD	FRACTURE FREQ.	TEST RESULTS	Depth (m)	GENERAL DESCRIPTION	PROFILE	REMARKS
11.00	NWD4	NX 11.00	63	0	>20			Grading between 12.5 and 13.3m to greenish grey, very stiff, completely weathered shale. Sub vertical and sub horizontal jointing with sub vertical fissility poorly developed.		
11.50	NWD4		110	50						
12.50	NWD4		50	21	3 >20					
13.50	NWD4		60	0	-		13.30	SHALE Greenish grey and grey, slightly weathered, moderately to very highly fractured, soft to medium hard rock shale. Malmesbury Group.		Shale fissile with 'joint' planes sub vertical and smooth to slightly rough.
14.50	NWD4		97	32	10 >20		14.50			
										END OF BOREHOLE

R.A. BRADSHAW & ASSOCIATES cc
CONSULTING ENGINEERING GEOLOGISTS

CONTRACT	BERG RIVER DIVERSION WEIR	**Date started**	11/05/2011	**BH No.**	3
SITE	BERG RIVER	**Date completed**	12/05/2011	***X*-Coord**	3689158X
CONTRACTOR	FAIRBROTHER GEOTECHNICAL ENGINEERING cc	**Water level**	See remarks column	***Y*-Coord**	1809Y
		Logged by	N.G.	**Level**	±52.1m
		Date	17/05/2011	**Inclination**	Vertical

DRILL RUN	DRILLING METHOD	CASING DEPTH	% CORE RECOVERY	% RQD	FRACTURE FREQ.	TEST RESULTS	Depth (m)	GENERAL DESCRIPTION	PROFILE	REMARKS
1.00	W/B		W/S	-	-			SILTY SAND Medium brown, loose to medium dense, slightly silty fine sand becoming fine sand with depth. Aeolian. Grading between 6m and 6.45m to medium sand.		Water table: 3.79m (12/05/2011) 3.78m (31/05/2011) 3.48m (15/06/2011)
1.45	SPT		67	-		N=29				
2.00	W/B		W/S	-						
2.45	SPT		60	-		N=15				
3.00	W/B		W/S	-						
3.45	SPT		47	-		N=8				
4.00	W/B		W/S	-						
4.45	SPT		53	-		N=11				
5.00	W/B		W/S	-						
5.45	SPT		51	-		N=19				
6.00	W/B		W/S	-						
6.45	SPT		53	-		N=22	6.45			
7.00	W/B		W/S	-				GRAVELLY SAND Light brown, medium dense, medium to coarse sand with fine to medium, sub rounded gravel. Alluvium.		7.45-9.0m No matrix recovered. Possibly more gravelly with depth.
7.45	SPT		58	-		N=23				
8.00	NWD4		27	-						
8.50	NWD4		36	-						
9.00	NWD4	NX 9.00	30	-			9.00			
9.50	NWD4		82	-			9.50	CLAYEY SILT Greenish grey, very stiff, completely weathered Malmesbury shale.		Grading in rare places to moderately weathered, very soft rock shale.
	NWD4		97	30	>20 8			SHALE See description on page 2.		

R.A. BRADSHAW & ASSOCIATES cc
CONSULTING ENGINEERING GEOLOGISTS

CONTRACT	BERG RIVER DIVERSION WEIR	**Date started**	11/05/2011	**BH No.**	**3**
SITE	BERG RIVER	**Date completed**	12/05/2011	***X*-Coord**	3689158X
CONTRACTOR	FAIRBROTHER GEOTECHNICAL ENGINEERING cc	**Water level**	See page 1 remarks column	***Y*-Coord**	1809Y
		Logged by	N.G.	**Level**	±52.1m
		Date	17/05/2011	**Inclination**	Vertical

DRILL RUN	DRILLING METHOD	CASING DEPTH	% CORE RECOVERY	% RQD	FRACTURE FREQ.	TEST RESULTS	Depth (m)	GENERAL DESCRIPTION	PROFILE	REMARKS
10.50	NWD4		97	30	-			SHALE Greenish grey, moderately to marginal slightly weathered, highly and moderately fractured becoming very highly fractured with depth, soft rock shale. Malmesbury Group. Sub horizontal joints. Locally fissile.		10-10.5m Greenish grey, highly weathered, very highly fractured, very soft rock shale and completely weathered shale.
					5					
12.00	NWD4		93	42	>20		12.00			
										END OF BOREHOLE

R.A. BRADSHAW & ASSOCIATES cc
CONSULTING ENGINEERING GEOLOGISTS

CONTRACT	BERG RIVER DIVERSION WEIR	**Date started**	2/06/2011	**BH No.**	**4A**
		Date completed	3/06/2011	***X*-Coord**	3689125X
SITE	BERG RIVER	**Water level**	-	***Y*-Coord**	1830Y
		Logged by	N.G.	**Level**	50.5m
CONTRACTOR	FAIRBROTHER GEOTECHNICAL ENGINEERING cc	**Date**	10/06/2011	**Inclination**	60 º

DRILL RUN	DRILLING METHOD	CASING DEPTH	% CORE RECOVERY	% RQD	FRACTURE FREQ.	TEST RESULTS	Depth (m)	GENERAL DESCRIPTION	PROFILE	REMARKS
1.00	W/B		W/S	-	-			SAND Medium brown, loose to medium dense, slightly silty fine sand becoming medium to coarse from 3m depth. Alluvium.		Representativeness of wash samples uncertain. 4.0-4.1m Decomposed organic material. Origin uncertain.
2.00	W/B		W/S	-						
3.00	W/B		W/S	-						
4.00	W/B		W/S	-						
4.45	SPT		64	-		N=9				
5.50	W/B		W/S	-			5.70			
5.95	SPT		-	-		N=11		GRAVELLY SAND Medium and coarse, sub rounded gravel. No matrix recovered.		Core loss occurred between 5.5m and 5.95m depth. Contact between sand and gravelly sand therefore unknown and interpreted.
7.00	NWD4		38	-						
8.00	NWD4		58	-			7.90			
8.20	NWD4		70	0				GREYWACKE Greyish khaki locally stained black, highly to moderately weathered, very highly to highly fractured, soft to medium hard rock greywacke. Locally Manganese stained.		Grading in places, between 7.9m and 8.2m depth, to khaki, probably very stiff, completely weathered Malmesbury greywacke.
8.50	NWD4	NX 8.50	140	0	>20					
9.50	NWD4		78	20	10		9.50			
										END OF BOREHOLE

R.A. BRADSHAW & ASSOCIATES cc
CONSULTING ENGINEERING GEOLOGISTS

CONTRACT	BERG RIVER DIVERSION WEIR	**Date started**	7/06/2011	**BH No.**	**4B**
		Date completed	7/06/2011	***X*-Coord**	3689125X
SITE	BERG RIVER	**Water level**	-	***Y*-Coord**	1830Y
		Logged by	N.G.	**Level**	50.5m
CONTRACTOR	FAIRBROTHER GEOTECHNICAL ENGINEERING cc	**Date**	12/06/2011	**Inclination**	25º

DRILL RUN	DRILLING METHOD	CASING DEPTH	% CORE RECOVERY	% RQD	FRACTURE FREQ.	TEST RESULTS	Depth (m)	GENERAL DESCRIPTION	PROFILE	REMARKS
2.00	W/B		W/S	-	-			SAND Medium brown, probably loose to medium dense, fine to medium sand. Alluvium.	░	Representativeness of samples uncertain.
4.00	W/B		W/S	-						
6.00	W/B		W/S	-			6.00			
	W/B		-	-				No sample recovered due to water loss. Possibly gravelly sand overlying gravelly clayey sand or clayey silt.	○	

R.A. BRADSHAW & ASSOCIATES cc
CONSULTING ENGINEERING GEOLOGISTS

CONTRACT	BERG RIVER DIVERSION WEIR
SITE	BERG RIVER
CONTRACTOR	FAIRBROTHER GEOTECHNICAL ENGINEERING cc

Date started	7/06/2011	**BH No.**	**4B**
Date completed	7/06/2011	***X*-Coord**	3689125X
Water level	-	***Y*-Coord**	1830Y
Logged by	N.G.	**Level**	50.5m
Date	12/06/2011	**Inclination**	25º

DRILL RUN	DRILLING METHOD	CASING DEPTH	% CORE RECOVERY	% RQD	FRACTURE FREQ.	TEST RESULTS	Depth (m)	GENERAL DESCRIPTION	PROFILE	REMARKS
11.30	W/B		-	-	-			As from 6m. No sample recovered.		
11.80	SPT		-	-						
12.50	W/B		-	-			12.50			
12.80	SPT		70	0		N=R	12.80	GREYWACKE Greenish grey, highly weathered, very highly		fractured, soft rock with residual greywacke.
14.00	NWD4	NX 13.50	82	19	>20 8 >20			GREYWACKE Grey, slightly weathered to borderline unweathered, highly to slightly fractured, hard rock greywacke. Joints generally sub vertical.		13.8-14m Brownish grey, moderately to slightly weathered, highly and very highly fractured, medium hard to hard rock greywacke.
15.50	NWD4		93	81	4					
16.70	NWD4		100	100			16.70			
										END OF BOREHOLE

R.A. BRADSHAW & ASSOCIATES cc
CONSULTING ENGINEERING GEOLOGISTS

CONTRACT	BERG RIVER DIVERSION WEIR	**Date started**	10/06/2011	**BH No.**	5
SITE	BERG RIVER	**Date completed**	13/06/2011	***X*-Coord**	1736Y
CONTRACTOR	FAIRBROTHER GEOTECHNICAL ENGINEERING cc	**Water level**	-	***Y*-Coord**	3689077X
		Logged by	N.G.	**Level**	±53.1m
		Date	14/06/2011	**Inclination**	Vertical

DRILL RUN	DRILLING METHOD	CASING DEPTH	% CORE RECOVERY	% RQD	FRACTURE FREQ.	TEST RESULTS	Depth (m)	GENERAL DESCRIPTION	PROFILE	REMARKS
1.00	W/B		52	-	-			SILTY SAND Medium brown, loose and medium dense, becoming dense from 7m, silty fine sand becoming fine to medium sand from 5m. Alluvium. Locally very weakly cemented between 1m and 1.45m.		
1.45	SPT		67	-		N=15				
2.00	W/B		W/S	-						
2.45	SPT		64	-		N=5				
3.00	W/B		W/S	-						
3.45	SPT		60	-		N=11				
4.00	W/B		W/S	-						
4.45	SPT		76	-		N=16				
5.00	W/B		W/S	-						
5.45	SPT		76	-		N=14				
6.00	W/B		W/S							
6.45	SPT		69	-		N=25				
7.00	W/B		W/S	-						
7.45	SPT		82	-		N=35	7.40			
8.00	NWD4	NX 8.00	109	0				CLAYEY SILT Khaki, stained black, very stiff, clayey silt grading in places to highly weathered, very highly fractured, very soft rock shale. Residual Malmesbury shale.		
8.45	SPT		69	0		N=51	8.60			
9.00	NWD4		127	0				SHALE Khaki, stained black, highly weathered, very highly to highly fractured, very soft to soft rock shale. Grading in places to stiff, completely weathered Malmesbury shale.		
9.45	SPT		60	0		N=32				
10.00	NWD4		138	36						

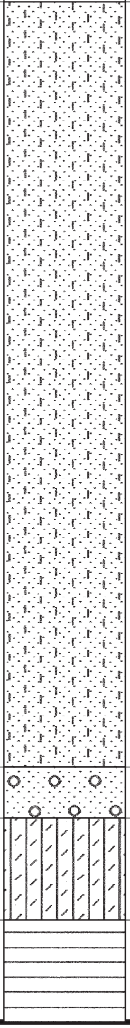
R.A. BRADSHAW & ASSOCIATES cc CONSULTING ENGINEERING GEOLOGISTS		Date started	10/06/2011	BH No.	5
		Date completed	13/06/2011	X-Coord	1736Y
CONTRACT	BERG RIVER DIVERSION WEIR	Water level	-	Y-Coord	3689077X
SITE	BERG RIVER	Logged by	N.G.	Level	±53.1m
CONTRACTOR	FAIRBROTHER GEOTECHNICAL ENGINEERING cc	Date	14/06/2011	Inclination	Vertical

DRILL RUN	DRILLING METHOD	CASING DEPTH	% CORE RECOVERY	% RQD	FRACTURE FREQ.	TEST RESULTS	Depth (m)	GENERAL DESCRIPTION	PROFILE	REMARKS
10.375	SPT		77	0	-	N=R	10.375	SHALE As from 8.60m.		
										END OF BOREHOLE

R.A. BRADSHAW & ASSOCIATES cc
CONSULTING ENGINEERING GEOLOGISTS

CONTRACT	BERG RIVER DIVERSION WEIR	**Date started**	14/06/2011	**BH No.**	6
		Date completed	14/06/2011	***X*-Coord**	3689097X
SITE	BERG RIVER	**Water level**	See remarks column	***Y*-Coord**	1819Y
		Logged by	N.G.	**Level**	±52m
CONTRACTOR	FAIRBROTHER GEOTECHNICAL ENGINEERING cc	**Date**	20/06/2011	**Inclination**	Vertical

DRILL RUN	DRILLING METHOD	CASING DEPTH	% CORE RECOVERY	% RQD	FRACTURE FREQ.	TEST RESULTS	Depth (m)	GENERAL DESCRIPTION	PROFILE	REMARKS
1.50	W/B		W/S	-	-			SILTY SAND Medium brown, loose and medium dense, silty fine sand becoming less silty and coarser with depth. Alluvium.		Watertable: 3.20m (15/06/2011) 3.20m (18/06/2011)
1.95	SPT		73	-		N=14				
3.00	W/B		W/S	-						
3.45	SPT		67	-		N=7				
4.50	W/B		W/S	-						
4.95	SPT		53	-		N=21				
6.00	W/B		W/S	-						
6.45	SPT		84	-		N=25				
7.50	W/B		W/S	-			7.50			
							8.00	GRAVELLY SAND Recovered as fine and medium, sub rounded gravel. Alluvium. No matrix recovered.		SPT attempted at 7.50m. No penetration.
8.50	NWD4		44	-				CLAYEY SILT Medium brown, stained black, stiff and very stiff, clayey silt grading between 8.5m and 8.875m to highly weathered, very highly fractured, very soft and soft rock greywacke.		
8.875	SPT	NX	91	0		N=R	9.00			
9.50	NWD4	9.0	107	49	14			GREYWACKE See description on next page.		
9.95	SPT		89	0	-	N=32				



R.A. BRADSHAW & ASSOCIATES cc
CONSULTING ENGINEERING GEOLOGISTS

CONTRACT	BERG RIVER DIVERSION WEIR
SITE	BERG RIVER
CONTRACTOR	FAIRBROTHER GEOTECHNICAL ENGINEERING cc

Date started	14/06/2011	**BH No.**	**6**
Date completed	14/06/2011	***X*-Coord**	3689097X
Water level	See page 1 remarks column	***Y*-Coord**	1819Y
Logged by	N.G.	**Level**	±52m
Date	20/06/2011	**Inclination**	Vertical

DRILL RUN	DRILLING METHOD	CASING DEPTH	% CORE RECOVERY	% RQD	FRACTURE FREQ.	TEST RESULTS	Depth (m)	GENERAL DESCRIPTION	PROFILE	REMARKS
10.50	NWD4		100	0	-			GREYWACKE Medium brown, stained black, moderately weathered, highly to very highly fractured, soft to medium hard rock greywacke. Manganese stained.		Grading between 9.5m and 9.95m to highly weathered, very highly and highly fractured, largely very soft rock greywacke and between 9.95m and 10.2m to completely weathered greywacke.
12.00	NWD4		114	20	>20		12.00			
										END OF BOREHOLE

R.A. BRADSHAW & ASSOCIATES cc
CONSULTING ENGINEERING GEOLOGISTS

CONTRACT	BERG RIVER DIVERSION WEIR	**Date started**	28/06/2011	**BH No.**	**7**
SITE	BERG RIVER	**Date completed**	28/06/2011	***X*-Coord**	3689050X
CONTRACTOR	FAIRBROTHER GEOTECHNICAL ENGINEERING cc	**Water level**	-	***Y*-Coord**	1850Y
		Logged by	N.G.	**Level**	±51.5m
		Date	1/07/2011	**Inclination**	Vertical

DRILL RUN	DRILLING METHOD	CASING DEPTH	% CORE RECOVERY	% RQD	FRACTURE FREQ.	TEST RESULTS	Depth (m)	GENERAL DESCRIPTION	PROFILE	REMARKS
1.50	W/B		W/S	-	-			SILTY SAND Medium brown and brownish grey at depth, loose, silty fine sand becoming less silty with depth. Alluvium.	▨	
1.95	SPT		60	-		N=4				
3.00	W/B		W/S	-						
3.45	SPT		53	-		N=6				
4.50	W/B		W/S	-						
4.95	SPT		60	-		N=4	5.50			
6.00	W/B		W/S	-				GRAVELLY SAND Light to medium brown, dense, medium and coarse sand with fine to coarse, sub rounded gravel. Alluvium.	○	No matrix recovered between 6.45m and 7.2m depth. Representativeness of recovered core uncertain.
6.45	SPT		40	-		N=41				
7.00	NWD4		33	-			7.20			
7.50	NWD4	NX 7.50	94	0	>20		7.50	GREYWACKE Greenish grey, highly and moderately weathered, very highly fractured, soft	☰	rock greywacke. Grading to completely weathered greywacke in places.
8.80	NWD4		92	42	12		8.80	GREYWACKE Greenish grey to khaki brown, generally moderately weathered, very highly to highly fractured, soft to medium hard rock	☰	
										END OF BOREHOLE

APPENDIX B

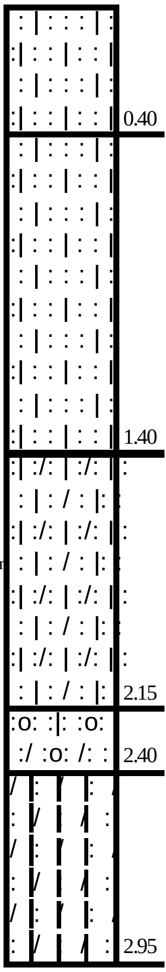
DESCRIPTION OF SOIL PROFILES IN TRIAL PITS

SOIL PROFILE

PROJECT: BERG RIVER - VOELVLEI DAM PIPELINE **PROJECT NO:** 119410

HOLE NO: VV1 **DATE:** 07/06/2011

METHOD OF INVESTIGATION: DIGGER/LOADER **GPS COORDS:** 448Y; 3689784X



	DEPTH (m)	DESCRIPTION
	0.40	SILTY SAND Moist, greyish brown, loose to medium dense, intact, very slightly clayey, silty fine sand. Aeolian. Numerous fine grass roots.
O 0.4-1.4m	1.40	SILTY SAND Slightly moist, light brown, medium dense to dense, intact, very slightly clayey, silty, fine sand. Aeolian. Numerous fine roots.
O 1.4-2.15m	2.15	CLAYEY SILTY SAND Slightly moist to moist, medium brown, dense, intact, clayey, silty, very weakly cemented fine sand. Alluvium. Scattered fine roots.
	2.40	GRAVELLY CLAYEY SILTY SAND Moist to very moist, orange brown, blotched grey, stiff to very stiff, layered, clayey, silty fine sand with fine to medium, very hard quartz gravel Alluv
	2.95	SANDY CLAYEY SILT Very moist, orange brown, blotched grey, very stiff, layered, fine sandy, clayey silt. Alluvium.

Note: Practical depth limit of machine.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

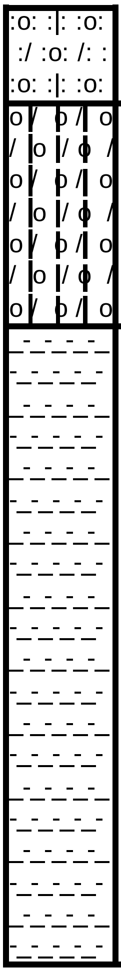
TP VV1

SOIL PROFILE

PROJECT: BERG RIVER - VOELVLEI DAM PIPELINE **PROJECT NO:** 119410

HOLE NO: VV3 **DATE:** 07/06/2011

METHOD OF INVESTIGATION : DIGGER/LOADER **GPS COORDS**: 11Y; 3690266X



	DEPTH (m)	DESCRIPTION
	0.30	GRAVELLY CLAYEY SILTY SAND Very moist, orange brown and greyish brown, firm to stiff, intact, clayey, silty sand with fine to coarse, very hard quartz gravel. Alluvium.
O 0.3-1.1m	1.10	GRAVELLY CLAYEY SILT Moist to very moist, orange brown, stained black, very stiff, slightly slickensided in upper parts, clayey silt with fine to medium, gravel-size fragments of highly weathered to moderately weathered with depth, soft to medium hard rock shale. Residual Malmesbury shale.
O 1.1-3.4m	3.40	SHALE Pinkish orange brown, highly to moderately weathered, sub vertically foliated, very soft to soft rock shale with patches of completely weathered Malmesbury shale. Malmesbury Group.

Note: Practical depth limit of machine.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP VV3

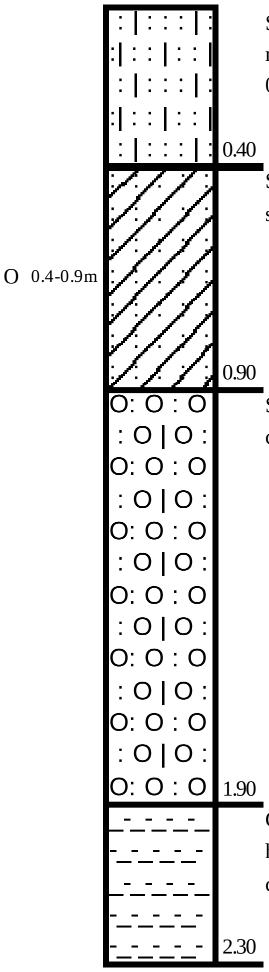
SOIL PROFILE

PROJECT: BERG RIVER - VOELVLEI DAM PIPELINE **PROJECT NO:** 119410

HOLE NO: VV4A **DATE:** 07/06/2011

METHOD OF INVESTIGATION : DIGGER/LOADER **GPS COORDS:** -462Y; 3690698X

DEPTH (m) **DESCRIPTION**



SILTY SAND Very moist, medium brown, soft to firm, intact, slightly clayey, silty fine to medium sand with scattered, fine, sub rounded gravel. Alluvium. Concentrated roots to 0.05m then scattered throughout.

SANDY CLAY Moist and very moist, reddish brown, stiff, intact, silty sandy clay with scattered, fine sub rounded gravel. Alluvium.

SILTY SANDY GRAVEL Very moist, reddish and orange brown, very stiff, intact, slightly clayey, silty, sandy fine to medium gravel. Alluvium.

GREYWACKE Light to medium brown, highly rapidly becoming moderately weathered, highly fractured, medium hard to hard rock greywacke. Calcareous cementations in upper contact.

Note: Machine refusing at 2.3m depth.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

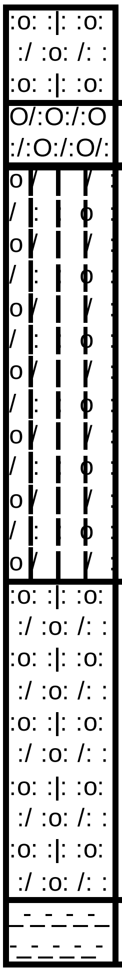
TP VV4A

SOIL PROFILE

PROJECT: BERG RIVER - VOELVLEI DAM PIPELINE **PROJECT NO:** 119410

HOLE NO: VV5 **DATE:** 07/06/2011

METHOD OF INVESTIGATION : DIGGER/LOADER **GPS COORDS**: -1173Y; 3691357X



	DEPTH (m)	DESCRIPTION
	0.30	GRAVELLY CLAYEY SILTY SAND Very moist to wet, medium brown, loose to medium dense, intact, slightly clayey, silty coarse sand with fine to locally medium gravel. Alluvium.
O 0.3-0.5m ¥ 0.5m	0.50	CLAYEY SANDY GRAVEL Wet, medium brown, medium dense, intact, slightly clayey, medium to coarse sandy, fine to locally medium gravel. Alluvium.
O 0.5-1.8m	1.80	SANDY CLAY Wet, orange brown, stiff to very stiff, intact, slightly silty, sandy clay with fine to medium, sub rounded gravel. Alluvium.
	2.80	GRAVELLY CLAYEY SILTY SAND Very moist, orange brown, stiff and very stiff, intact, clayey, silty medium to coarse sand with fine to locally medium, sub rounded gravel. Alluvium. Becoming more gravelly with depth.
	3.00	GREYWACKE Light to medium brown, highly to moderately weathered, highly fractured, medium hard to hard rock greywacke with patches of completely weathered Malmsebury greywacke. Calcareous cementations in upper contact.

Note: Machine refusing at 3m depth.

NOT TO SCALE

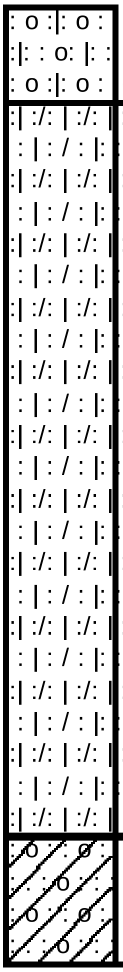
O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP VV5

SOIL PROFILE

PROJECT:	BERG RIVER - VOELVLEI DAM PIPELINE	**PROJECT NO:**	119410
HOLE NO:	VV6	**DATE:**	07/06/2011
METHOD OF INVESTIGATION :	DIGGER/LOADER	**GPS COORDS:**	-1961Y; 3691298X

	DEPTH (m)	DESCRIPTION
	0.30	GRAVELLY SILTY SAND Very moist to wet, greyish brown becoming medium brown, medium dense, intact, slightly clayey, silty fine to medium sand with fine, sub rounded gravel. Alluvium. Numerous fine roots in upper 0.1m.
O 0.7-1.2m	2.60	CLAYEY SILTY SAND Very moist to slightly moist, white and orange brown becoming khaki from 1.8m depth, stiff to very stiff, intact, clayey, silty fine to medium sand with fine, sub rounded gravel. Nodules of calcrete from 0.8m depth. Alluvium (?)
	3.05	SANDY CLAY Moist, orange brown and white, very stiff, intact, slightly silty, sandy clay with fine, sub rounded gravel. Alluvium.



Note: Practical depth limit of machine.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

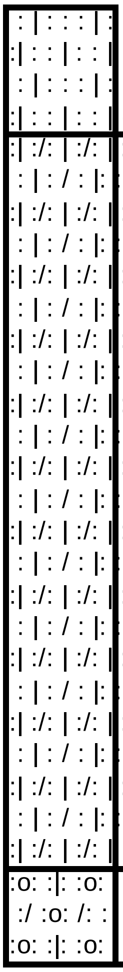
TP VV6

SOIL PROFILE

PROJECT: BERG RIVER - VOELVLEI DAM PIPELINE **PROJECT NO:** 119410

HOLE NO: VV7 **DATE:** 07/06/2011

METHOD OF INVESTIGATION : DIGGER/LOADER **GPS COORDS:** -2155Y; 3691322X



O 1.7-2.5m

DEPTH (m)	DESCRIPTION
0.40	SILTY SAND Very moist to wet, greyish brown, loose to medium dense, intact, slightly clayey silty fine sand. Alluvium. Slightly oragnic in upper 0.1m. Scattered fine roots throughout.
2.80	CLAYEY SILTY SAND Moist, orange brown, stained black, very stiff, intact, clayey, silty fine sandd grading to sandy, clayey silt in places. Alluvium. Very minor scattered grass roots and thick tree roots. Alluvium (?)
3.10	CLAYEY SILTY GRAVELLY SAND Moist, orange brown, very stiff, intact, clayey, silty sand with fine to medium, sub rounded gravel. Alluvium.

Note: Practical depth limit of machine.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP VV7

SOIL PROFILE

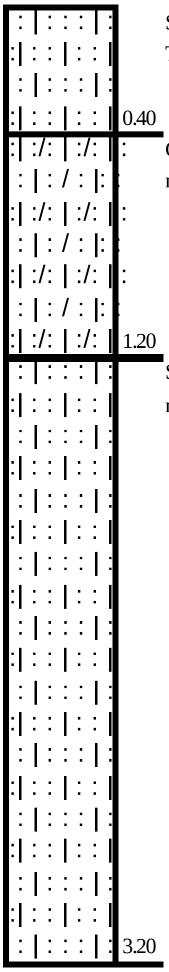
PROJECT: BERG RIVER - VOELVLEI DAM PIPELINE **PROJECT NO:** 119410

HOLE NO: VV8 **DATE:** 05/07/2011

METHOD OF INVESTIGATION: DIGGER/LOADER **GPS COORDS**: 1354Y; 3689356X

DEPTH (m) **DESCRIPTION**

O 1.2-3.2m



SILTY SAND Very moist, grey, very loose, intact, slightly silty, fine to medium sand. Topsoil.

CLAYEY SILTY SAND Moist, orange brown, stiff, intact, slightly clayey, silty fine to medium sand. Alluvium.

SILTY SAND Slightly moist, yellow brown, medium dense, layered, slightly silty, fine to medium sand. Alluvium.

Note: No refusal.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP VV8

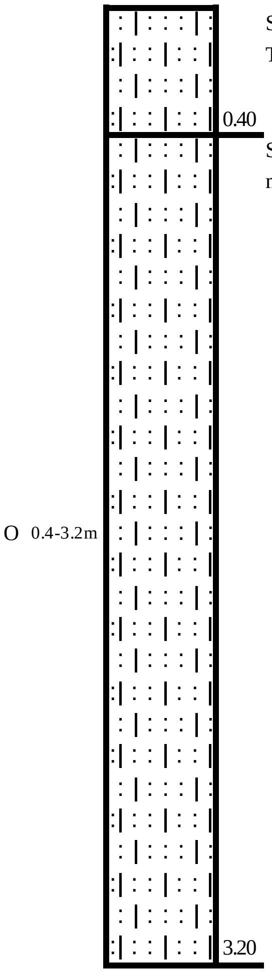
SOIL PROFILE

PROJECT: BERG RIVER - VOELVLEI DAM PIPELINE **PROJECT NO:** 119410

HOLE NO: VV9 **DATE:** 05/07/2011

METHOD OF INVESTIGATION: DIGGER/LOADER **GPS COORDS:** 1054Y; 3689536X

DEPTH (m) **DESCRIPTION**



SILTY SAND Very moist, grey, very loose, intact, slightly silty, fine to medium sand. Topsoil.

SILTY SAND Slightly moist, yellow brown, medium dense, layered, slightly silty, fine to medium sand. Alluvium.

Note: No refusal.

NOT TO SCALE

O	DISTURBED SAMPLE	$\underline{\vee}$	WATER TABLE
[]	UNDISTURBED SAMPLE	¥̲	PERCHED WATER TABLE

TP VV9

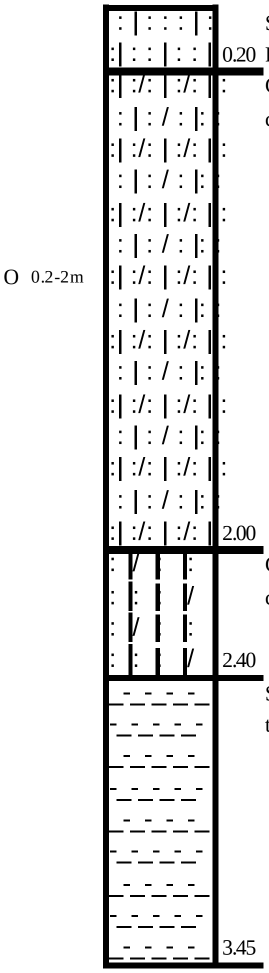
SOIL PROFILE

PROJECT: BERG RIVER - VOELVLEI DAM PIPELINE **PROJECT NO:** 119410

HOLE NO: VV10 **DATE:** 05/07/2011

METHOD OF INVESTIGATION : DIGGER/LOADER **GPS COORDS**: 1888Y; 3689201X

DEPTH (m) **DESCRIPTION**



SILTY SAND Very moist, khaki grey, very loose, intact, silty fine to medium sand. Topsoil. Roots.

CLAYEY SILTY SAND Moist, pinkish brown, blotched light grey, very stiff, fissured, clayey, silty fine to medium sand. Alluvium.

CLAYEY SANDY SILT Moist, pinkish brown, blotched light grey, very stiff, fissured, clayey, sandy silt. Alluvium.

SILTSTONE Light brown and creamy brown, highly weathered, highly fractured, very soft to soft rock siltstone. Malmesbury Group.

Note: No refusal.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP VV10

SOIL PROFILE

PROJECT: BREEDE RIVER PIPELINE

PROJECT NO: 11941

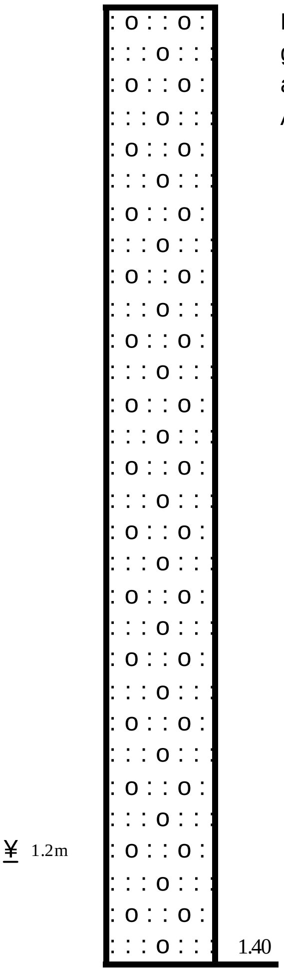
HOLE NO: **TP MP 1**

DATE: 13/6/2011

METHOD OF INVESTIGATION: Digger/loader

COORDINATES: X: 3699555
Y: -24850

DESCRIPTION



BOULDERY GRAVELLY SAND Moist to wet, light greyish brown becoming grey with depth, loose to medium dense, layered, very slightly silty, bouldery and gravelly, fine to medium sand. Boulders up to 700mm maximum diameter. Alluvium.

NOTE: Machine excavating with difficulty.
River water inflow prevented additional deepening.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP MP1

SOIL PROFILE

PROJECT: BREEDE RIVER PIPELINE

PROJECT NO: 11941

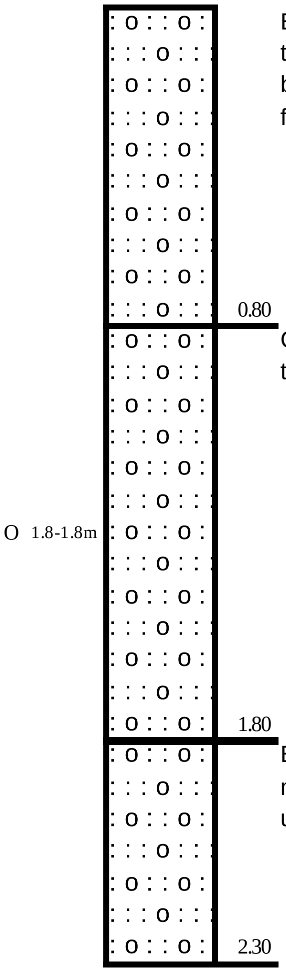
HOLE NO: **TP MP 2**

DATE: 13/6/2011

METHOD OF INVESTIGATION: Digger/loader

COORDINATES: X: 3699622
Y: -24453

DESCRIPTION



BOULDERY GRAVELLY SAND Slightly moist to moist, greyish brown, loose to medium dense, layered, very slightly silty and organic, gravelly and bouldery, fine to medium sand. Numerous grass roots to 0.2m and fine roots throughout. Alluvium.

GRAVELLY SAND Moist, light brown grey, medium dense, layered, medium to coarse sand with fine to coarse sub rounded gravel. Alluvium.

BOULDERY GRAVELLY SAND Moist, light brown grey, medium dense, layered, medium to coarse sand with medium sub rounded gravel. Boulders up to 800mm maximum dimension. Alluvium.

NOTE: Massive collapse of sidewalls of pit. Continuous collapse preventing deeper excavation.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP MP2

SOIL PROFILE

PROJECT: BREEDE RIVER PIPELINE

PROJECT NO: 11941

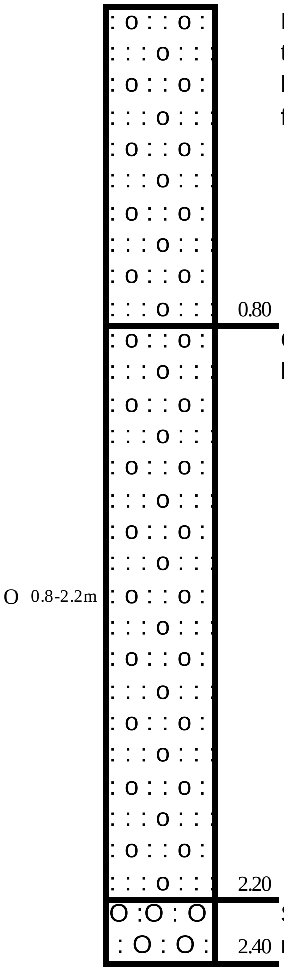
HOLE NO: **TP MP 3**

DATE: 13/6/2011

METHOD OF INVESTIGATION: Digger/loader

COORDINATES: X: 3699649
Y: -23891

DESCRIPTION



BOULDERY GRAVELLY SAND Slightly moist to moist, greyish brown, loose to medium dense, layered, very slightly silty and organic, gravelly and bouldery, fine to medium sand. Numerous grass roots to 0.2m and fine roots throughout. Alluvium.

GRAVELLY SAND Moist, light brown and light greyish brown, medium dense, layered, medium to coarse sand with medium sub rounded gravel. Alluvium.

SANDY GRAVEL Slightly moist, light brown, medium dense, layered, medium to coarse, subrounded gravel in a fine to medium sandy matrix. Alluvium.

NOTE: Massive collapse of sidewalls of pit prevented deeper excavation of pit.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP MP3

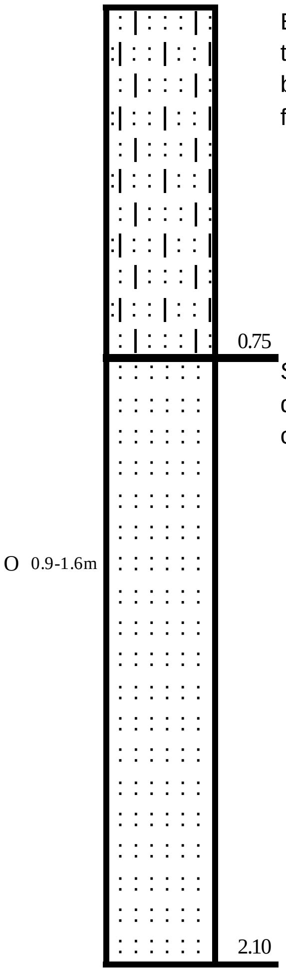
SOIL PROFILE

PROJECT: BREEDE RIVER PIPELINE **PROJECT NO:** 11941

HOLE NO: **TP MP 4** **DATE:** 13/6/2011

METHOD OF INVESTIGATION: Digger/loader **COORDINATES:** X: 3699569
Y: -23413

DESCRIPTION



BOULDERY GRAVELLY SAND Slightly moist to moist, greyish brown, loose to medium dense, layered, very slightly silty and organic, gravelly and bouldery, fine to medium sand. Numerous grass roots to 0.2m and fine roots throughout. Alluvium.

SAND Slightly moist, layered greyish brown and light brown, medium dense, medium to coarse sand with coarse layers and very minor scattered coarse, sub rounded gravel and one boulder (500mm). Alluvium.

NOTE: Massive collapse of sidewalls of pit prevented deeper excavation of pit.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP MP4

SOIL PROFILE

PROJECT: BREEDE RIVER PIPELINE

PROJECT NO: 11941

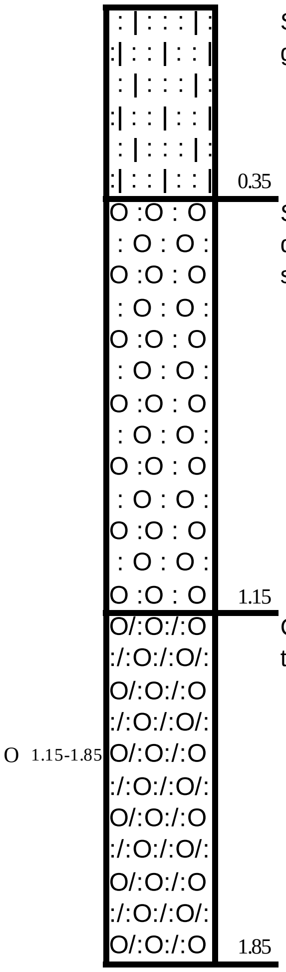
HOLE NO: **TP MP 5**

DATE: 13/6/2011

METHOD OF INVESTIGATION: Digger/loader

COORDINATES: X: 3699611
Y: -22530

DESCRIPTION



SILTY SAND Moist, dark brownish grey, loose, intact, slightly organic and gravelly, silty fine to medium sand. Fine roots. Alluvium/topsoil.

SANDY BOULDERY GRAVEL Slightly moist, light greyish brown, medium dense, layered, bouldery medium to coarse gravel with a minor coarse sandy matrix. Alluvium.

CLAYEY SANDY GRAVEL Wet, yellowish brown, dense, layered, medium to coarse sub rounded gravel in a clayey sandy matrix. Alluvium.

NOTE: Machine refusing on gravels at 1.85m depth.
Minor collapse of sidewalls of pit.
Only soil matrix sampled for testing.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP MP5

SOIL PROFILE

PROJECT: BREEDE RIVER PIPELINE

PROJECT NO: 11941

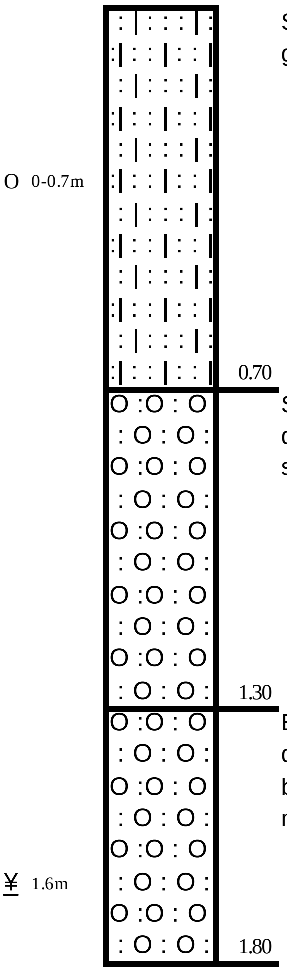
HOLE NO: **TP MP 6**

DATE: 13/6/2011

METHOD OF INVESTIGATION : Digger/loader

COORDINATES: X: 3699610
Y: -22091

DESCRIPTION



SILTY SAND Moist, dark brownish grey, loose, intact, slightly organic and gravelly, silty fine to medium sand. Fine roots. Alluvium/topsoil.

SANDY BOULDERY GRAVEL Very moist, light greyish brown, medium dense, layered, bouldery medium to coarse gravel with a minor coarse sandy matrix. Alluvium.

BOULDERY SANDY GRAVEL Wet, light grey or cream, medium dense to dense, layered, medium to coarse sub rounded gravel and scattered boulders up to 600mm maximum dimension in a slightly clayey and silty, medium to coarse sandy matrix. Alluvium.

NOTE: Sidewalls of pit collapsing and soil 'running' into pit prevented deeper excavation.
Water sample taken for chemical analysis.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP MP6

SOIL PROFILE

PROJECT: BREEDE RIVER PIPELINE

PROJECT NO: 11941

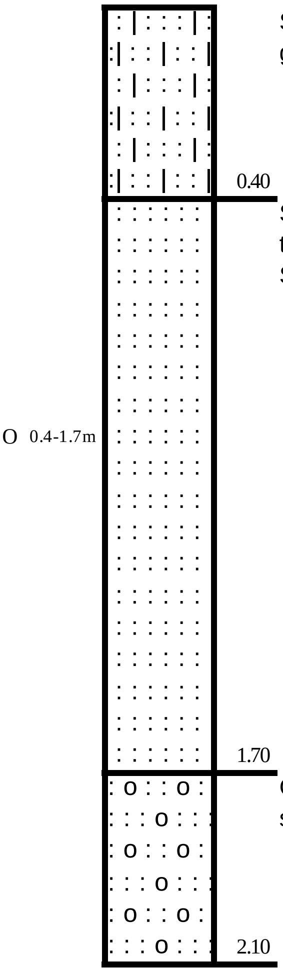
HOLE NO: **TP MP 7**

DATE: 13/6/2011

METHOD OF INVESTIGATION: Digger/loader

COORDINATES: X: 3699744
Y: -21472

DESCRIPTION



SILTY SAND Moist, dark brownish grey, loose, intact, slightly organic and gravelly, silty fine to medium sand. Fine roots. Alluvium/topsoil.

SAND Very moist to wet, light grey sand with black blotching in places, loose to medium dense, layered, very slightly silty, fine to medium sand. Alluvium. Small organic patches.

GRAVELLY SAND Wet, light grey, medium dense, layered, fine to medium sand with minor, medium to coarse sub rounded gravel. Alluvium.

NOTE: Water inflow and massive collapse of sidewalls of pit prevented deeper excavation.
Water sample taken for chemical analysis.

NOT TO SCALE

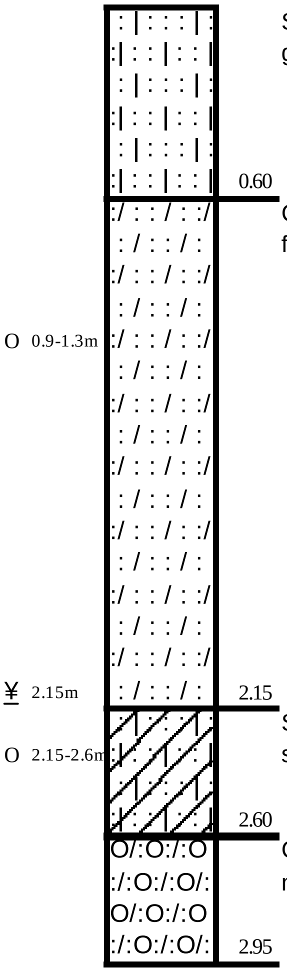
O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP MP7

SOIL PROFILE

PROJECT:	BREEDE RIVER PIPELINE	**PROJECT NO:**	11941
HOLE NO:	**TP MP 8**	**DATE:**	13/6/2011
METHOD OF INVESTIGATION:	Digger/loader	**COORDINATES:**	X: 3699137 Y: -20802

DESCRIPTION



SILTY SAND Moist, dark brownish grey, loose, intact, slightly organic and gravelly, silty fine to medium sand. Fine roots. Alluvium/topsoil.

CLAYEY SAND Slightly moist, light creamy grey, very stiff, fissured, clayey fine to medium sand. Alluvium. Becomes more sandy near basal contact.

SANDY SILTY CLAY Moist to very moist, grey, blotched and stained brown, very stiff, fissured, sandy, silty clay. Alluvium.

CLAYEY SANDY GRAVEL Very moist, light creamy grey, very dense, layered, medium to coarse, sub rounded gravel in a clayey sandy matrix. Alluvium.

NOTE: Practical depth limited by machine.
Water sample taken for chemical analysis.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP MP8

SOIL PROFILE

PROJECT: BREEDE RIVER PIPELINE

PROJECT NO: 11941

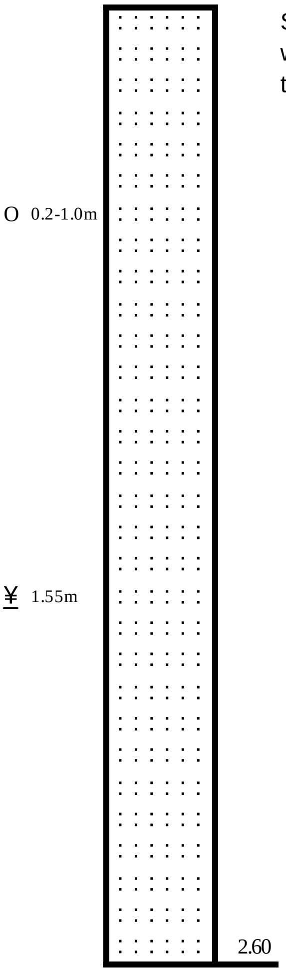
HOLE NO: **TP MP 9**

DATE: 13/6/2011

METHOD OF INVESTIGATION: Digger/loader

COORDINATES: X: 3699915
Y: -20480

DESCRIPTION



SAND Moist becoming moist borderline wet with depth, brown becoming lighter with depth, then light grey, loose to dense, layered, slightly silty, fine to medium to generally fine sand. Alluvium. Grass roots to 0.25m.

NOTE: Massive collapse of sidewalls of trench prevented deeper excavation. Not safe to sample water.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP MP9

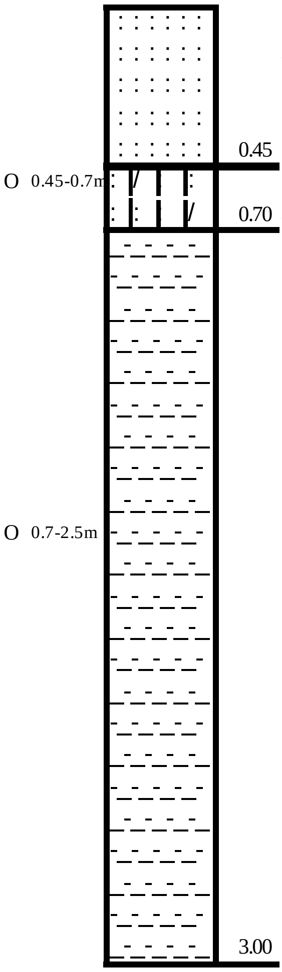
SOIL PROFILE

PROJECT: BREEDE RIVER PIPELINE
PROJECT NO: 11941

HOLE NO: **TP MP 10**
DATE: 13/6/2011

METHOD OF INVESTIGATION: Digger/loader
COORDINATES: X: 3698503
Y: -19189

DESCRIPTION



SAND Very moist, brown, loose, layered, very slightly silty, fine to medium sand. Colluvium. Scattered Port Jackson roots. Ferricrete and sandstone along basal contact.

CLAYEY SANDY SILT Moist, orange brown, very stiff, fissured, clayey, sandy silt with fine, gravel-size fragments of highly weathered shale. Colluvium.

SHALE Light brown and white, highly weathered grading locally to completely weathered, highly fractured, very soft rock shale grading, in places, to very stiff soil. Malmesbury Group.

NOTE: No refusal.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

SOIL PROFILE

PROJECT: BREEDE RIVER PIPELINE

PROJECT NO: 11941

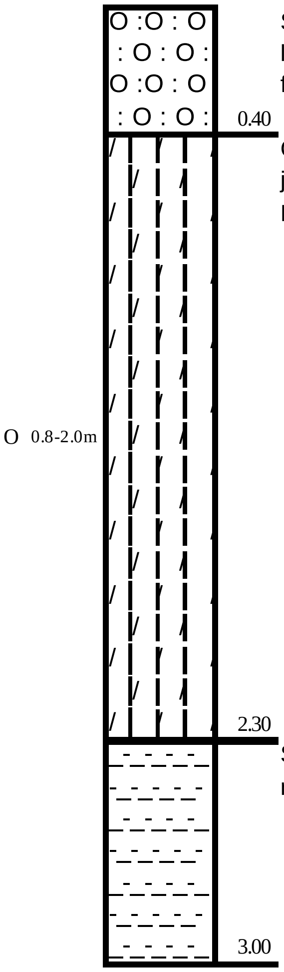
HOLE NO: **TP MP 11**

DATE: 13/6/2011

METHOD OF INVESTIGATION: Digger/loader

COORDINATES: X: 3698094
Y: -19407

DESCRIPTION



SANDY GRAVEL Wet, brownish grey and orange brown, medium dense, layered, medium ferricrete gravel in a slightly sandy matrix. Scatttered fine fynbos roots. Colluvium/pedogenic.

CLAYEY SILT Slightly moist, white, streaked light brown, very stiff, faintly jointed, clayey silt. Completely weathered, leached siltstone. Malmesbury Group.

SILTSTONE Light brown/tan, highly weathered, highly fractured, very soft rock siltstone. Malmesbury Group.

NOTE: No refusal. Practical depth limit of machine.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP MP11

SOIL PROFILE

PROJECT: BREEDE RIVER PIPELINE

PROJECT NO: 11941

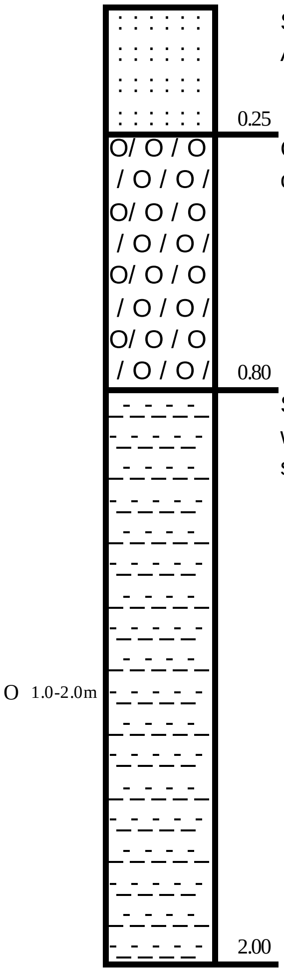
HOLE NO: **TP MP 12**

DATE: 13/6/2011

METHOD OF INVESTIGATION : Digger/loader

COORDINATES: X: 3697389
Y: -19447

DESCRIPTION



SAND Very moist, loose, intact, very slightly sity, fine to medium sand. Aeolian.

CLAYEY GRAVEL Moist, orange and yellowish brown, very stiff, layered, clayey, fine to medium ferricrete gravel. Pedogenic.

SILTSTONE Maroon, highly weathered to 1.2m then, highly to moderately weathered, highly fractured, very soft becoming soft to medium hard rock siltstone with depth. Malmesbury Group.

NOTE: Machine excavating very slowly at 2m depth.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP MP12

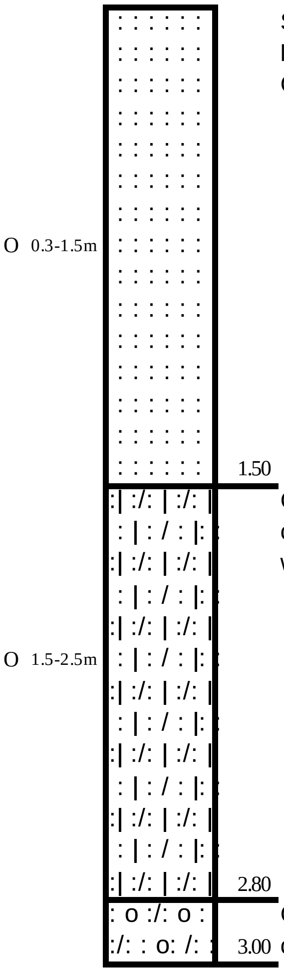
SOIL PROFILE

PROJECT: BREEDE RIVER PIPELINE **PROJECT NO:** 11941

HOLE NO: **TP MP 13** **DATE:** 13/6/2011

METHOD OF INVESTIGATION : Digger/loader **COORDINATES:** X: 3696455
Y: -19089

DESCRIPTION



SAND Moist, brown becoming tan with depth, loose to medium dense, layered, very slightly silty, fine to medium sand. Alluvial wash.
Grass roots to 0.2m.

CLAYEY SILTY SAND Moist, tan, medium dense to dense, layered, very slightly clayey, silty fine to medium sand with rare scattered medium gravel. Alluvial wash.

CLAYEY SANDY GRAVEL Moist, orange brown, very stiff, slightly fissured, clayey fine to medium sand wih medium sub rounded gravel.
Alluvial wash.

NOTE: No refusal. Practical depth limit of machine.

NOT TO SCALE

O	DISTURBED SAMPLE	V	WATER TABLE
[]	UNDISTURBED SAMPLE	¥	PERCHED WATER TABLE

TP MP13

APPENDIX C

RESULTS OF LABORATORY TESTS ON SOIL SAMPLES

CLIENT:	RA Bradshaw & Associates	**PROJECT:**	Berg River- Voelvlei Pipeline
ATT:	Dick Bradshaw	**REF. NO:**	L110675

SAND GRADING / CBR RESULT SUMMARY

SAMPLE NO:	**CLIENT SAMPLE NO.**	**SAMPLE DESCRIPTION**
18823		yellow brown sand

SAMPLE POSITION
VV1 @ 0.4-1.4m

SIEVE ANALYSIS

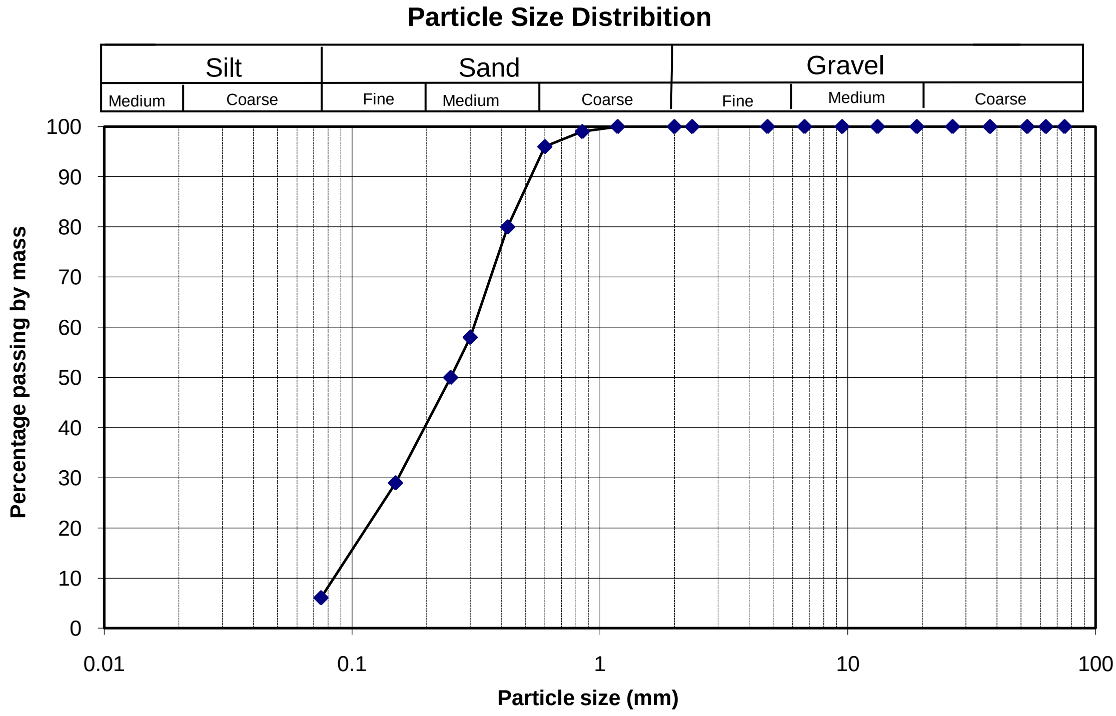
Sieve mm	Percentage Passing	Sieve mm	Percentage Passing
75		2.36	
63		2.00	
53		1.18	100
37.5		0.850	99
26.5		0.600	96
19		0.425	80
13.2		0.300	58
9.50		0.250	50
6.70		0.150	29
4.750		0.075	6.1

ATTERBERG LIMITS

Liquid Limit	
Plastic Index	N-P
Linear Shrinkage %	

MOD / CBR

MOD	
O.M.C.	
100%	
98%	
95%	
93%	
90%	
Max Swell	



GEOSCIENCE
LABORATORIES (PTY) LTD

CLIENT:	RA Bradshaw& Associates 17 Midwood Avenue Newlands 7700	**PROJECT:**	Berg River- Voelvlei Pipeline
		DATE:	23-06-2011
ATT:	Dick Bradshaw	**REF:**	L110675

ASTM D422 SIEVE ANALYSIS

DESCRIPTION :	yellow olive clayey sand	**SAMPLE NO. :**	18824
POSITION :	VV1 @ 1.4-2.15m	**CLIENT SAMPLE NO. :**	

Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	
	13.20	
	9.50	
	6.70	
	4.75	
	2.36	
	2.00	
	1.18	100
	0.600	98
	0.425	92
	0.300	80
	0.150	54
	0.0750	27

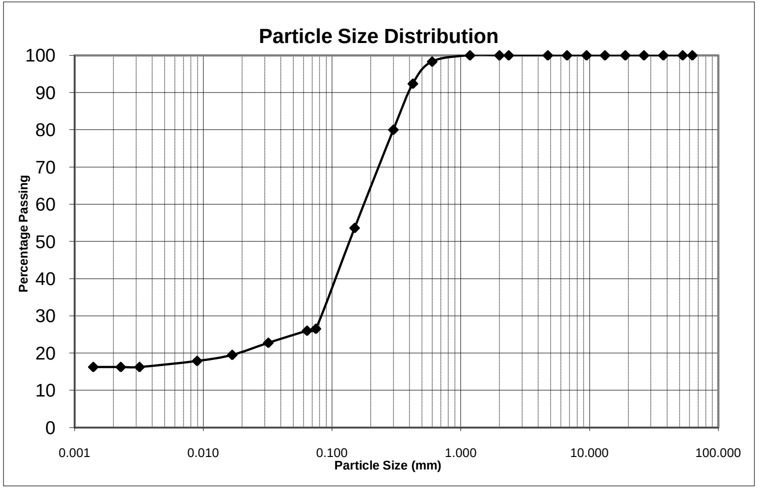
Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0727	26
0.0366	23
0.0185	19
0.0097	18
0.0034	16
0.0024	16
0.0014	16

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	17
Plastic Index	4
Linear Shrinkage	2.0

MOD AASHTO ; C.B.R. : TMH1 A7 & A8	
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	



Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	0
Sand : Percentage - 4.75mm and + 0.075mm	73
Silt : Percentage - 0.075mm and + 0.002mm	11
Clay : Percentage - 0.002mm	16

For Geoscience:

GEOSCIENCE
LABORATORIES (PTY) LTD

CLIENT:	RA Bradshaw& Associates 17 Midwood Avenue Newlands 7700	**PROJECT:**	Berg River- Voelvlei Pipeline
		DATE:	23-06-2011
ATT:	Dick Bradshaw	**REF:**	L110675

ASTM D422 SIEVE ANALYSIS

DESCRIPTION :	yellow olive gvl silty clay	**SAMPLE NO. :**	18825
POSITION :	VV3 @ 0.3-1.1m	**CLIENT SAMPLE NO. :**	

Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	100
	19.00	89
	13.20	88
	9.50	88
	6.70	85
	4.75	82
	2.36	70
	2.00	68
	1.18	64
	0.600	57
	0.425	54
	0.300	50
	0.150	44
	0.0750	39

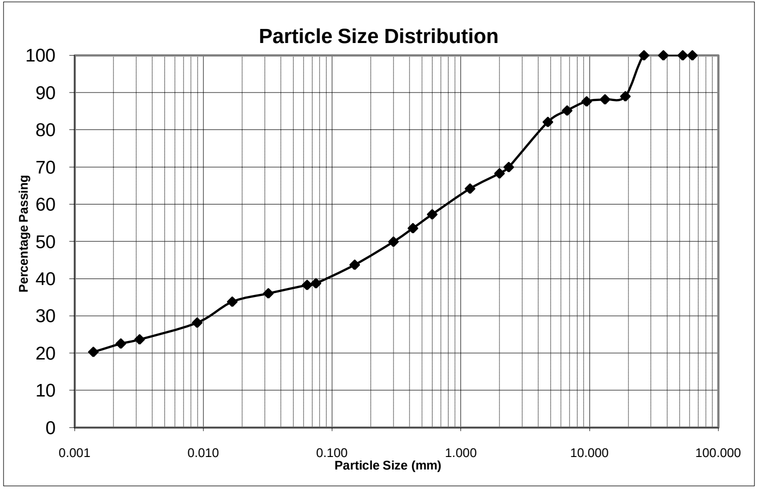
Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0663	38
0.0336	36
0.0169	34
0.0090	28
0.0032	24
0.0023	23
0.0014	20

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	35
Plastic Index	17
Linear Shrinkage	8.0

MOD AASHTO ; C.B.R. : TMH1 A7 & A8	
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	



Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	18
Sand : Percentage - 4.75mm and + 0.075mm	43
Silt : Percentage - 0.075mm and + 0.002mm	17
Clay : Percentage - 0.002mm	22

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Newlands
7700
ATT: Dick Bradshaw

PROJECT: Berg River- Voelvlei Pipeline
DATE: 23-06-2011
REF: L110675

ASTM D422 SIEVE ANALYSIS

DESCRIPTION : lt yellow brown clayey sand
POSITION : VV3 @ 1.1-3.4m
SAMPLE NO. : 18826
CLIENT SAMPLE NO. :

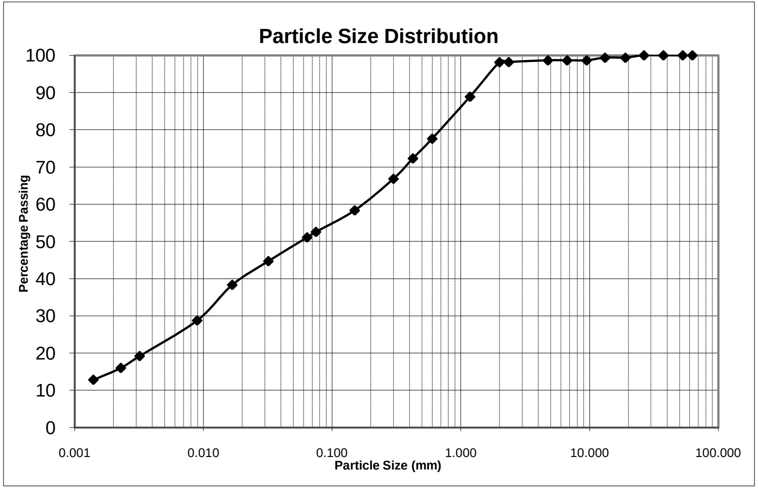
Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	100
	19.00	99
	13.20	99
	9.50	99
	6.70	99
	4.75	99
	2.36	98
	2.00	98
	1.18	89
	0.600	78
	0.425	72
	0.300	67
	0.150	58
	0.0750	53

Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0671	51
0.0343	45
0.0175	38
0.0093	29
0.0034	19
0.0024	16
0.0014	13

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	38
Plastic Index	9
Linear Shrinkage	4.0



MOD AASHTO ; C.B.R. : TMH1 A7 & A8	
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	

Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	1
Sand : Percentage - 4.75mm and + 0.075mm	46
Silt : Percentage - 0.075mm and + 0.002mm	38
Clay : Percentage - 0.002mm	15

For Geoscience:

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CLIENT: RA Bradshaw& Associates
17 Midwood Avenue
Newlands
7700
ATT: Dick Bradshaw

PROJECT: Berg River- Voelvlei Pipeline
DATE: 23-06-2011
REF: L110675

ASTM D422 SIEVE ANALYSIS

DESCRIPTION : red brown sandy clay
POSITION : VV4A @ 0.4-0.9m
SAMPLE NO. : 18827
CLIENT SAMPLE NO. :

Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	
	13.20	
	9.50	
	6.70	100
	4.75	98
	2.36	94
	2.00	93
	1.18	90
	0.600	80
	0.425	77
	0.300	74
	0.150	72
	0.0750	69

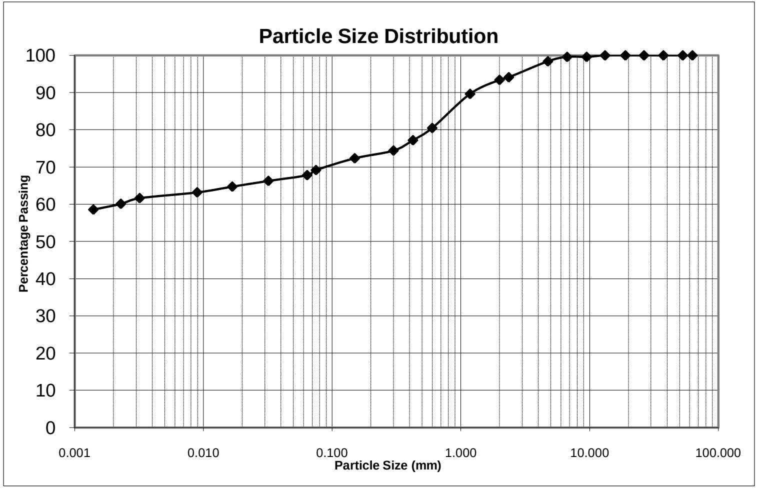
Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0648	68
0.0324	66
0.0162	65
0.0084	63
0.0029	62
0.0021	60
0.0012	59

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	52
Plastic Index	26
Linear Shrinkage	13.0

MOD AASHTO ; C.B.R. : TMH1 A7 & A8	
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	



Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	2
Sand : Percentage - 4.75mm and + 0.075mm	29
Silt : Percentage - 0.075mm and + 0.002mm	9
Clay : Percentage - 0.002mm	60

For Geoscience:

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Newlands
7700
ATT: Dick Bradshaw

PROJECT: Berg River- Voelvlei Pipeline
DATE: 23-06-2011
REF: L110675

ASTM D422 SIEVE ANALYSIS

DESCRIPTION : yellow olive gvl silty sand
POSITION : VV5 @ 0.3-0.5m
SAMPLE NO. : 18828
CLIENT SAMPLE NO. :

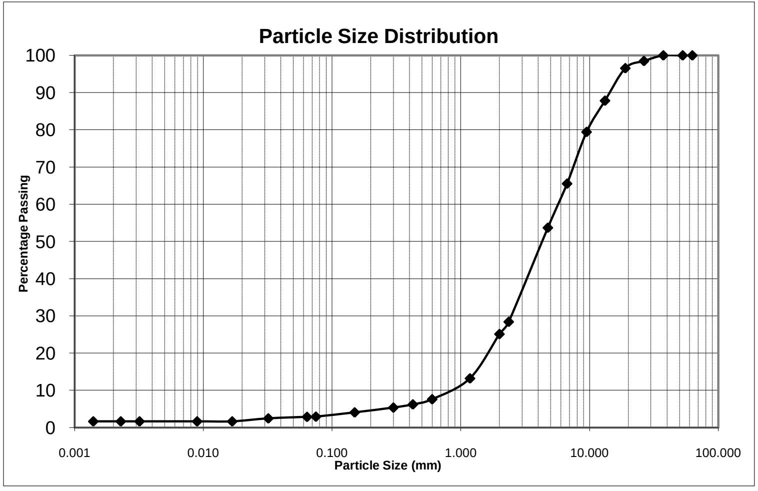
Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	100
	26.50	98
	19.00	97
	13.20	88
	9.50	79
	6.70	66
	4.75	54
	2.36	28
	2.00	25
	1.18	13
	0.600	8
	0.425	6
	0.300	5
	0.150	4
	0.0750	3

Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0760	3
0.0380	2
0.0192	2
0.0099	2
0.0035	2
0.0025	2
0.0014	2

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	12
Plastic Index	2
Linear Shrinkage	1.0



MOD AASHTO ; C.B.R. : A7 & A8	*TMH1*
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	

Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	46
Sand : Percentage - 4.75mm and + 0.075mm	51
Silt : Percentage - 0.075mm and + 0.002mm	1
Clay : Percentage - 0.002mm	2

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Newlands
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ATT: Dick Bradshaw

PROJECT: Berg River- Voelvlei Pipeline
DATE: 23-06-2011
REF: L110675

ASTM D422 SIEVE ANALYSIS

DESCRIPTION : dark olive sandy clay
POSITION : VV5 @ 0.5-1.8m
SAMPLE NO. : 18829
CLIENT SAMPLE NO. :

Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	
	13.20	
	9.50	100
	6.70	99
	4.75	98
	2.36	92
	2.00	91
	1.18	86
	0.600	82
	0.425	79
	0.300	76
	0.150	70
	0.0750	66

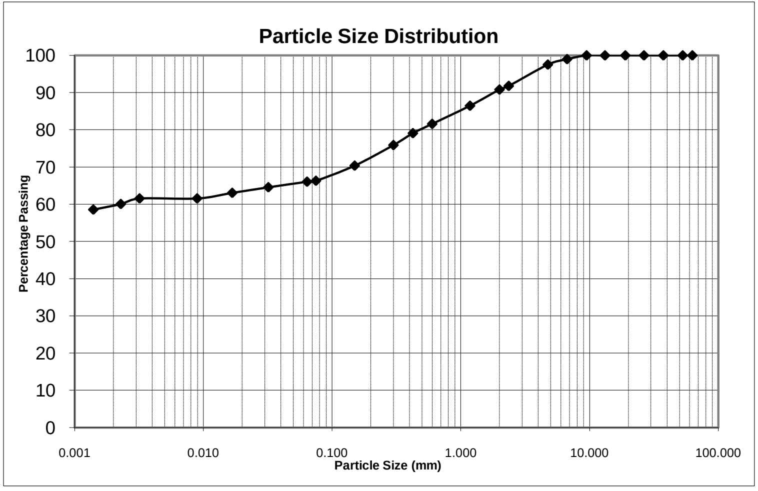
Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0640	66
0.0320	65
0.0160	63
0.0083	62
0.0029	62
0.0020	60
0.0012	59

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	60
Plastic Index	36
Linear Shrinkage	14.0

MOD AASHTO ; C.B.R. : TMH1 A7 & A8	
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	



Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	2
Sand : Percentage - 4.75mm and + 0.075mm	31
Silt : Percentage - 0.075mm and + 0.002mm	6
Clay : Percentage - 0.002mm	60

For Geoscience:

GEOSCIENCE
LABORATORIES (PTY) LTD

CLIENT: RA Bradshaw& Associates
17 Midwood Avenue
Newlands
7700
ATT: Dick Bradshaw

PROJECT: Berg River- Voelvlei Pipeline
DATE: 23-06-2011
REF: L110675

ASTM D422 SIEVE ANALYSIS

DESCRIPTION : dark olive clayey sand
POSITION : VV6 @ 0.7-1.2m
SAMPLE NO. : 18830
CLIENT SAMPLE NO. :

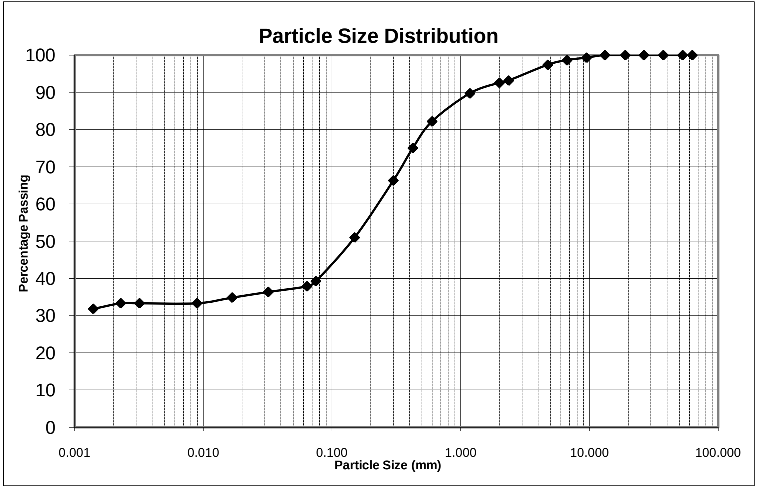
Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	
	13.20	100
	9.50	99
	6.70	99
	4.75	97
	2.36	93
	2.00	93
	1.18	90
	0.600	82
	0.425	75
	0.300	66
	0.150	51
	0.0750	39

Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0699	38
0.0349	36
0.0177	35
0.0091	33
0.0032	33
0.0023	33
0.0013	32

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	33
Plastic Index	18
Linear Shrinkage	6.0



MOD AASHTO ; C.B.R. : A7 & A8	***TMH1***
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	

Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	3
Sand : Percentage - 4.75mm and + 0.075mm	58
Silt : Percentage - 0.075mm and + 0.002mm	6
Clay : Percentage - 0.002mm	33

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For Geoscience:

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LABORATORIES (PTY) LTD

CLIENT:	RA Bradshaw& Associates 17 Midwood Avenue Newlands 7700	**PROJECT:**	Berg River- Voelvlei Pipeline
		DATE:	23-06-2011
ATT:	Dick Bradshaw	**REF:**	L110675

ASTM D422 SIEVE ANALYSIS

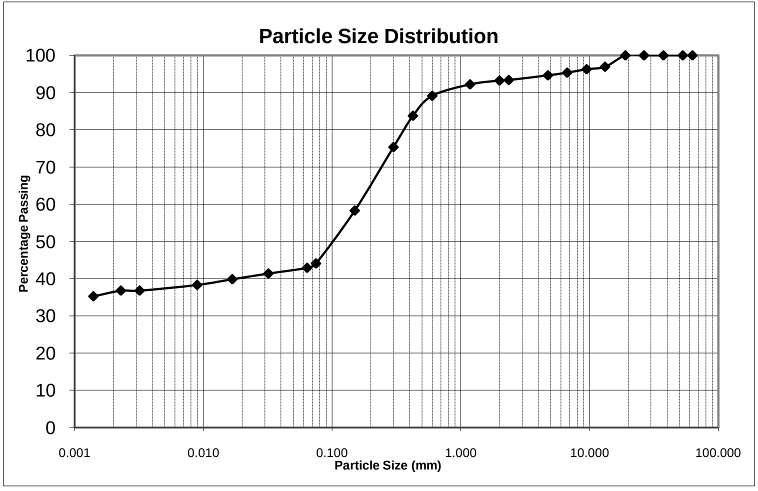
DESCRIPTION :	yellow olive silty sand	**SAMPLE NO. :**	18831
POSITION :	VV7 @ 1.7-2.5m	**CLIENT SAMPLE NO. :**	

Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	100
	13.20	97
	9.50	96
	6.70	95
	4.75	95
	2.36	93
	2.00	93
	1.18	92
	0.600	89
	0.425	84
	0.300	75
	0.150	58
	0.0750	44

Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0685	43
0.0347	41
0.0173	40
0.0090	38
0.0032	37
0.0022	37
0.0013	35

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	



Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	33
Plastic Index	18
Linear Shrinkage	8.0

MOD AASHTO ; C.B.R. : A7 & A8	***TMH1***
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	

Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	5
Sand : Percentage - 4.75mm and + 0.075mm	51
Silt : Percentage - 0.075mm and + 0.002mm	8
Clay : Percentage - 0.002mm	36

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GEOSCIENCE
LABORATORIES (PTY) LTD

CLIENT: RA Bradshaw & Associates **PROJECT:** Breg River Pipeline

ATT: Dick Bradshaw **REF. NO:** L110713

SAND GRADING / CBR RESULT SUMMARY

SAMPLE NO: 18893

CLIENT SAMPLE NO.

SAMPLE DESCRIPTION yellow orange silty sand

SAMPLE POSITION VV8 @ 1.2-3.2m

SIEVE ANALYSIS

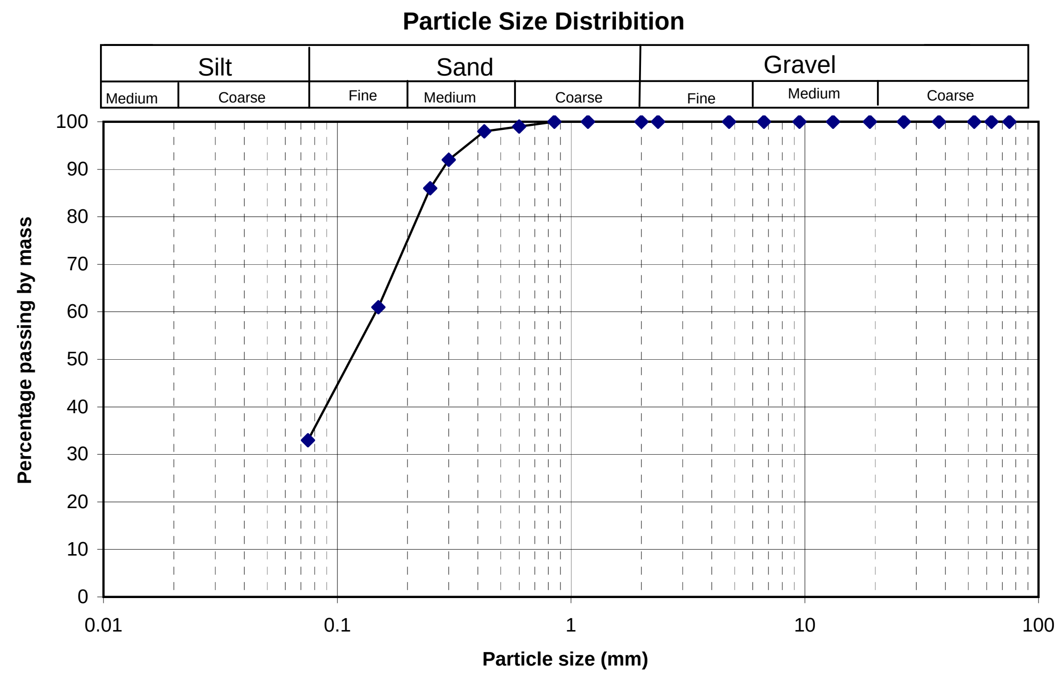
Sieve mm	Percentage Passing	Sieve mm	Percentage Passing
75		2.36	
63		2.00	
53		1.18	
37.5		0.850	100
26.5		0.600	99
19		0.425	98
13.2		0.300	92
9.50		0.250	86
6.70		0.150	61
4.750		0.075	33.0

ATTERBERG LIMITS

Liquid Limit	
Plastic Index	
Linear Shrinkage %	

MOD / CBR

MOD	
O.M.C.	
100%	
98%	
95%	
93%	
90%	
Max Swell	



GEOSCIENCE
LABORATORIES (PTY) LTD

CLIENT: RA Bradshaw & Associates **PROJECT:** Breg River Pipeline

ATT: Dick Bradshaw **REF. NO:** L110713

SAND GRADING / CBR RESULT SUMMARY

SAMPLE NO: 18894

CLIENT SAMPLE NO.

SAMPLE DESCRIPTION yellow orange silty sand

SAMPLE POSITION VV9 @ 0.4-3.2m

SIEVE ANALYSIS

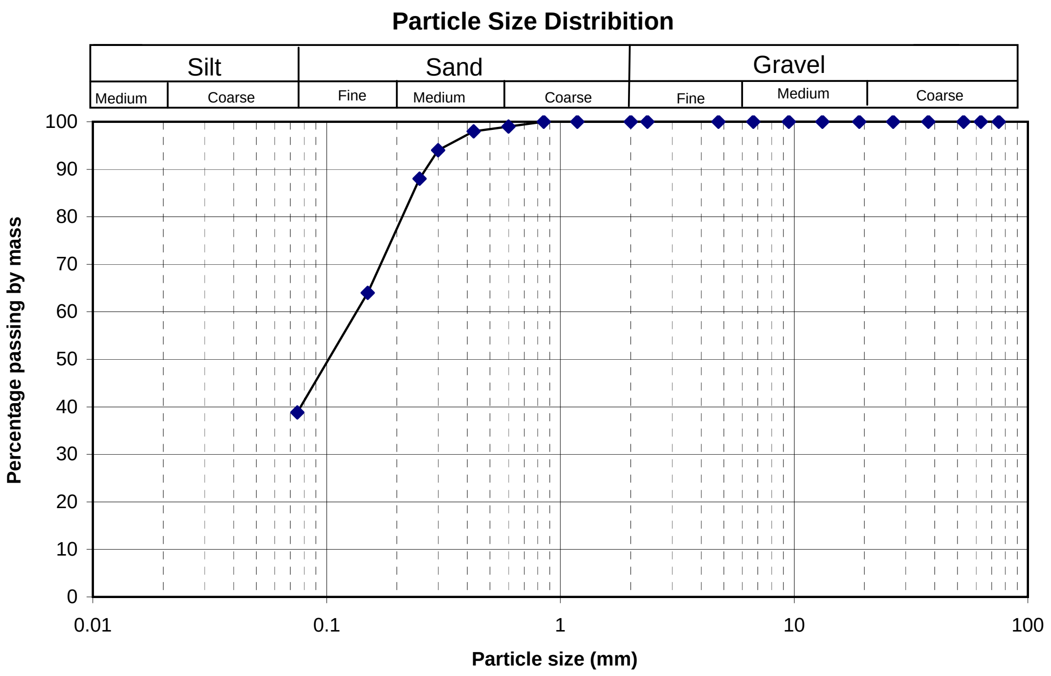
Sieve mm	Percentage Passing	Sieve mm	Percentage Passing
75		2.36	
63		2.00	
53		1.18	
37.5		0.850	100
26.5		0.600	99
19		0.425	98
13.2		0.300	94
9.50		0.250	88
6.70		0.150	64
4.750		0.075	38.8

ATTERBERG LIMITS

Liquid Limit	
Plastic Index	
Linear Shrinkage %	

MOD / CBR

MOD	
O.M.C.	
100%	
98%	
95%	
93%	
90%	
Max Swell	



GEOSCIENCE
LABORATORIES (PTY) LTD

CLIENT: RA Bradshaw & Associates
17 Midwood Avenue
Newlands
7702
ATT: Dick Bradshaw

PROJECT: Bewrg River Pipeline
DATE: 11-07-2011
REF: L110713

ASTM D422 SIEVE ANALYSIS

DESCRIPTION : lt red sandy silty clay
POSITION : VV10 @ 0.2-2.0m
SAMPLE NO. : 18895
CLIENT SAMPLE NO. :

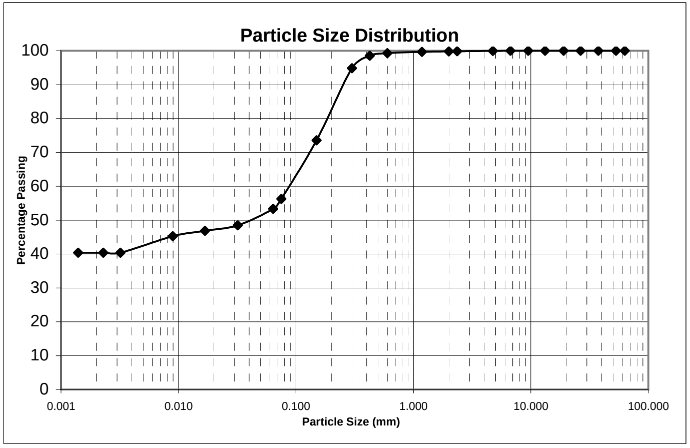
Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	
	13.20	
	9.50	
	6.70	
	4.75	
	2.36	
	2.00	
	1.18	100
	0.600	99
	0.425	99
	0.300	95
	0.150	74
	0.0750	56

Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0680	53
0.0343	48
0.0173	47
0.0090	45
0.0032	40
0.0023	40
0.0013	40

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	31
Plastic Index	12
Linear Shrinkage	6.0



MOD AASHTO ; C.B.R. : A7 & A8	***TMH1***
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	

Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	0
Sand : Percentage - 4.75mm and + 0.075mm	44
Silt : Percentage - 0.075mm and + 0.002mm	16
Clay : Percentage - 0.002mm	40

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For Geoscience:

CLIENT: RA Bradshaw & Associates **PROJECT:** Breede River Pipeline

ATT: Dick Bradshaw **REF. NO:** L110676

SAND GRADING / CBR RESULT SUMMARY

SAMPLE NO: 18832

CLIENT SAMPLE NO.

SAMPLE DESCRIPTION dark brown gravelly sand

SAMPLE POSITION MP 2 @ 0.8-1.8m

SIEVE ANALYSIS

Sieve mm	Percentage Passing
75	
63	
53	100
37.5	97
26.5	92
19	89
13.2	87
9.50	86
6.70	85
4.750	84

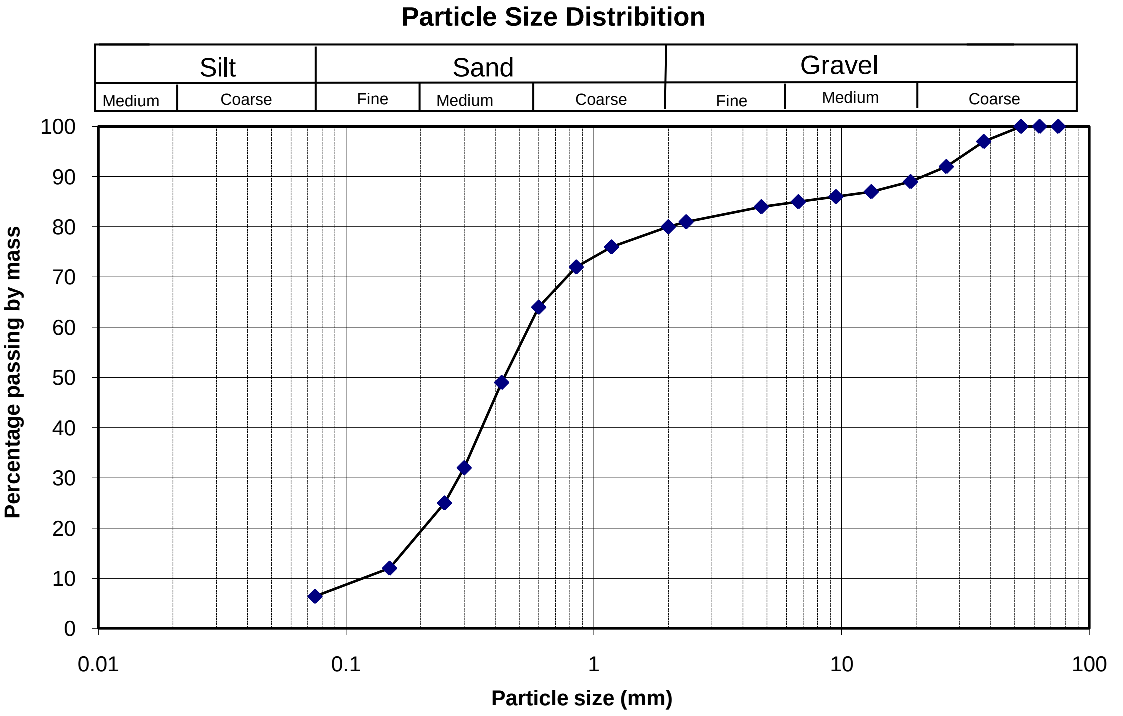
Sieve mm	Percentage Passing
2.36	81
2.00	80
1.18	76
0.850	72
0.600	64
0.425	49
0.300	32
0.250	25
0.150	12
0.075	6.4

ATTERBERG LIMITS

Liquid Limit	
Plastic Index	N-P
Linear Shrinkage %	

MOD / CBR

MOD	
O.M.C.	
100%	
98%	
95%	
93%	
90%	
Max Swell	



CLIENT:	RA Bradshaw & Associates	**PROJECT:**	Breede River Pipeline
ATT:	Dick Bradshaw	**REF. NO:**	L110676

SAND GRADING / CBR RESULT SUMMARY

SAMPLE NO:	**CLIENT SAMPLE NO.**	**SAMPLE DESCRIPTION**
18833		dark brown sand

SAMPLE POSITION

MP 3 @ 0.8-2.2m

SIEVE ANALYSIS

Sieve mm	Percentage Passing
75	
63	
53	
37.5	
26.5	
19	
13.2	
9.50	
6.70	100
4.750	99

Sieve mm	Percentage Passing
2.36	98
2.00	96
1.18	95
0.850	91
0.600	80
0.425	65
0.300	43
0.250	32
0.150	11
0.075	3.9

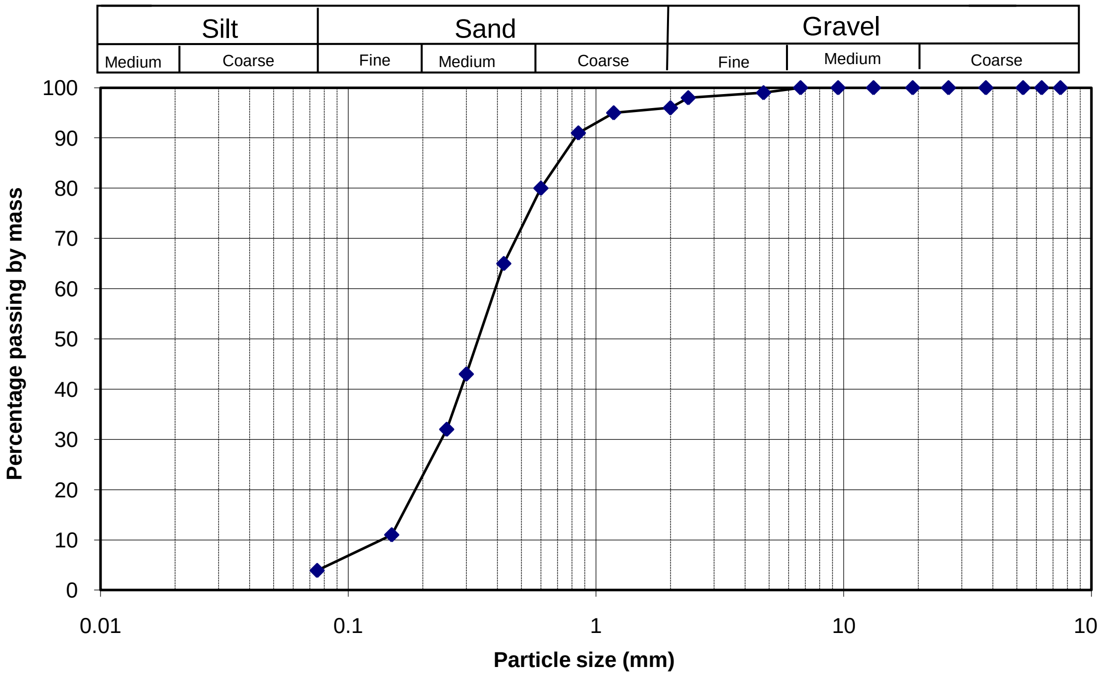
ATTERBERG LIMITS

Liquid Limit	
Plastic Index	N-P
Linear Shrinkage %	

MOD / CBR

MOD	
O.M.C.	
100%	
98%	
95%	
93%	
90%	
Max Swell	

Particle Size Distribition



CLIENT: RA Bradshaw & Associates **PROJECT:** Breede River Pipeline

ATT: Dick Bradshaw **REF. NO:** L110676

SAND GRADING / CBR RESULT SUMMARY

SAMPLE NO:	CLIENT SAMPLE NO.	SAMPLE DESCRIPTION
18834		yellow brown sand

SAMPLE POSITION
MP 4 @ 0.9-1.6m

SIEVE ANALYSIS

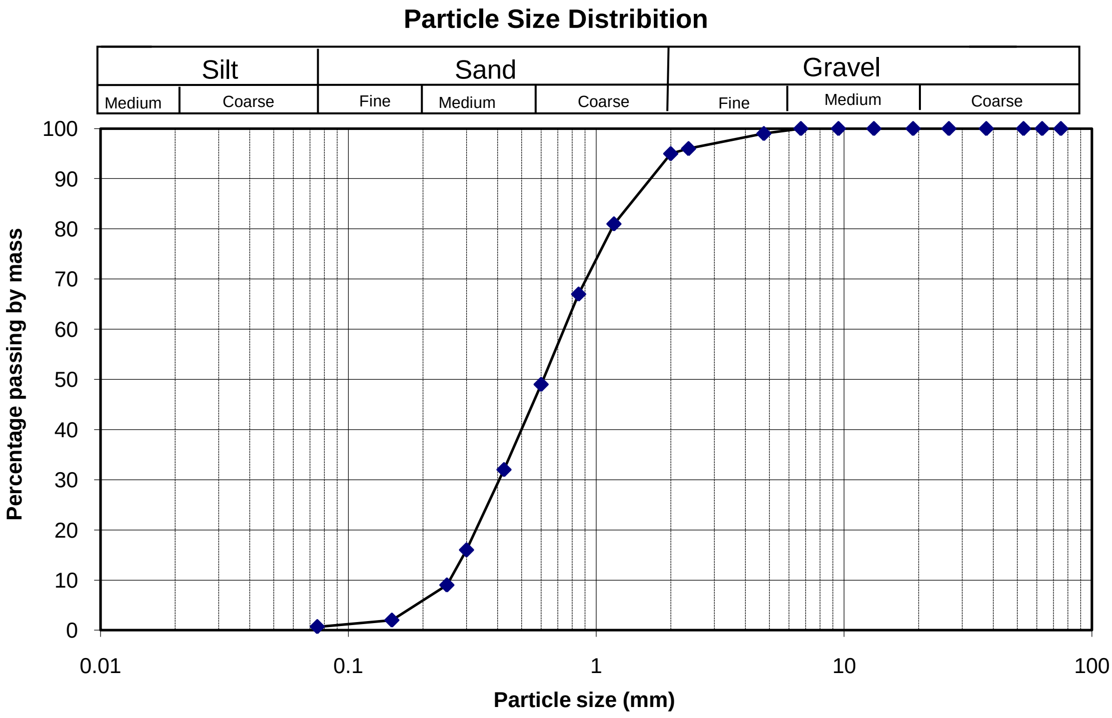
Sieve mm	Percentage Passing	Sieve mm	Percentage Passing
75		2.36	96
63		2.00	95
53		1.18	81
37.5		0.850	67
26.5		0.600	49
19		0.425	32
13.2		0.300	16
9.50		0.250	9
6.70	100	0.150	2
4.750	99	0.075	0.7

ATTERBERG LIMITS

Liquid Limit	
Plastic Index	N-P
Linear Shrinkage %	

MOD / CBR

MOD	
O.M.C.	
100%	
98%	
95%	
93%	
90%	
Max Swell	



GEOSCIENCE
LABORATORIES (PTY) LTD

CLIENT:	RA Bradshaw& Associates 17 Midwood Avenue Newlands 7700	**PROJECT:**	Breede River Pipeline
		DATE:	28-06-2011
ATT:	Dick Bradshaw	**REF:**	L110676

ASTM D422 SIEVE ANALYSIS

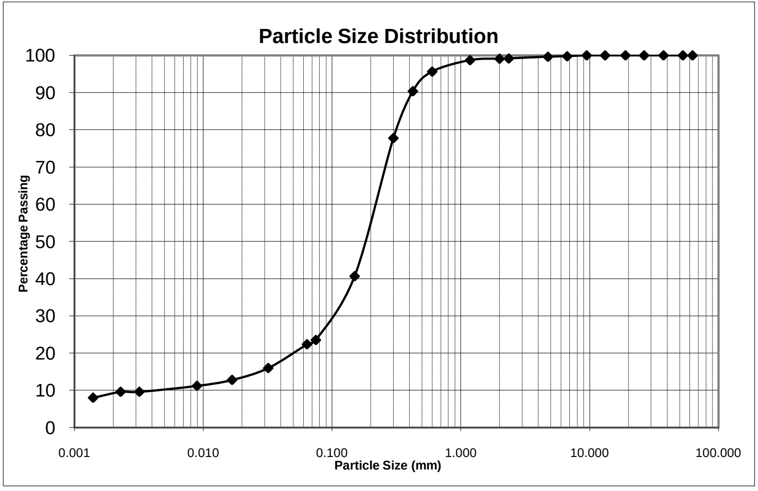
DESCRIPTION :	yellow olive clayey sand	**SAMPLE NO. :**	18835
POSITION :	MP 5 @ 1.15-1.85m	**CLIENT SAMPLE NO. :**	

Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	
	13.20	
	9.50	
	6.70	
	4.75	100
	2.36	99
	2.00	99
	1.18	99
	0.600	96
	0.425	90
	0.300	78
	0.150	41
	0.0750	23

Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0742	22
0.0378	16
0.0190	13
0.0099	11
0.0034	10
0.0025	10
0.0014	8

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	



Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	
Plastic Index	S-P
Linear Shrinkage	

MOD AASHTO ; C.B.R. : A7 & A8	*TMH1*
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	

Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	0
Sand : Percentage - 4.75mm and + 0.075mm	76
Silt : Percentage - 0.075mm and + 0.002mm	14
Clay : Percentage - 0.002mm	9

The above test results are pertinent to the samples received and tested only. For Geoscience:

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		DATE:	28-06-2011
ATT:	Dick Bradshaw	**REF:**	L110676

ASTM D422 SIEVE ANALYSIS

DESCRIPTION : dark brown sand
POSITION : MP 6 @ 0-1.7m
SAMPLE NO. : 18836
CLIENT SAMPLE NO. :

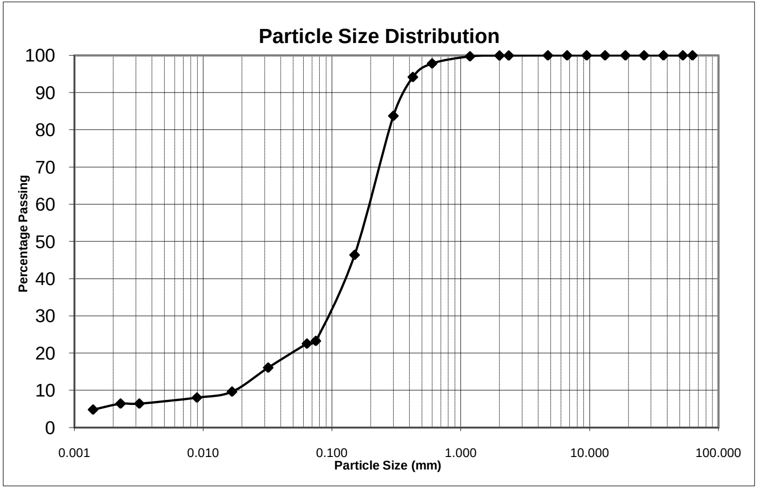
Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	
	13.20	
	9.50	
	6.70	
	4.75	
	2.36	
	2.00	
	1.18	100
	0.600	98
	0.425	94
	0.300	84
	0.150	46
	0.0750	23

Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0742	23
0.0378	16
0.0192	10
0.0100	8
0.0035	6
0.0025	6
0.0015	5

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	
Plastic Index	N-P
Linear Shrinkage	



MOD AASHTO ; C.B.R. : A7 & A8	*TMH1*
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	

Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	0
Sand : Percentage - 4.75mm and + 0.075mm	77
Silt : Percentage - 0.075mm and + 0.002mm	17
Clay : Percentage - 0.002mm	6

The above test results are pertinent to the samples received and tested only.
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CLIENT:	RA Bradshaw& Associates 17 Midwood Avenue Newlands 7700	**PROJECT:**	Breede River Pipeline
		DATE:	28-06-2011
ATT:	Dick Bradshaw	**REF:**	L110676

ASTM D422 SIEVE ANALYSIS

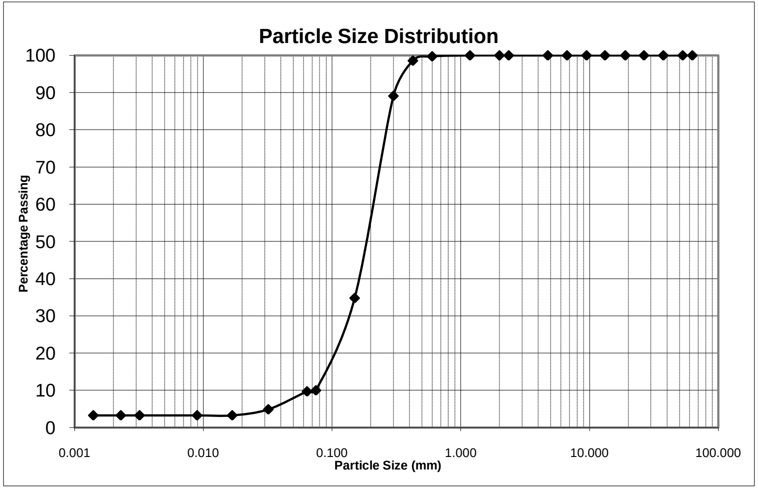
DESCRIPTION :	lt olive & grey sand	**SAMPLE NO. :**	18837
POSITION :	MP 7 @ 0.4-1.7m	**CLIENT SAMPLE NO. :**	

Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	
	13.20	
	9.50	
	6.70	
	4.75	
	2.36	
	2.00	
	1.18	
	0.600	100
	0.425	99
	0.300	89
	0.150	35
	0.0750	10

Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0769	10
0.0391	5
0.0195	3
0.0101	3
0.0035	3
0.0025	3
0.0015	3

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	



Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	
Plastic Index	N-P
Linear Shrinkage	

MOD AASHTO ; C.B.R. : A7 & A8	***TMH1***
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	

Tabulated Summary	**Percentage**
Gravel : Percentage - 4.75 mm	0
Sand : Percentage - 4.75mm and + 0.075mm	90
Silt : Percentage - 0.075mm and + 0.002mm	7
Clay : Percentage - 0.002mm	3

The above test results are pertinent to the samples received and tested only. While the tests are carried out according to recognized standards Geoscience shall not be liable for erroneous testing or reporting thereof. This report may not be reproduced except in full without prior consent of Geoscience.

For Geoscience:

GEOSCIENCE
LABORATORIES (PTY) LTD

CLIENT: RA Bradshaw& Associates
17 Midwood Avenue
Newlands
7700
ATT: Dick Bradshaw

PROJECT: Breede River Pipeline
DATE: 28-06-2011
REF: L110676

ASTM D422 SIEVE ANALYSIS

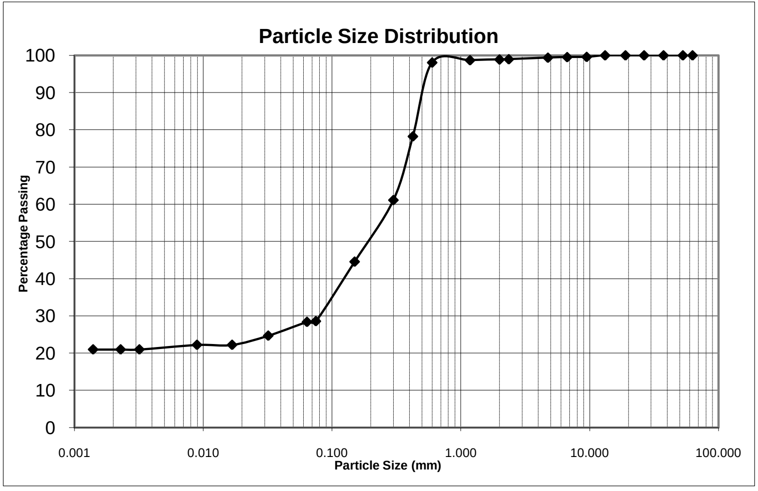
DESCRIPTION : lt green clayey sand
POSITION : MP 8 @ 0.9-1.3m
SAMPLE NO. : 18838
CLIENT SAMPLE NO. :

Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	
	13.20	
	9.50	
	6.70	100
	4.75	99
	2.36	99
	2.00	99
	1.18	99
	0.600	98
	0.425	78
	0.300	61
	0.150	45
	0.0750	29

Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0715	28
0.0362	25
0.0182	22
0.0094	22
0.0033	21
0.0024	21
0.0014	21

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	



Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	29
Plastic Index	10
Linear Shrinkage	5.0

MOD AASHTO ; C.B.R. : TMH1 A7 & A8	
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	

Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	1
Sand : Percentage - 4.75mm and + 0.075mm	71
Silt : Percentage - 0.075mm and + 0.002mm	8
Clay : Percentage - 0.002mm	21

For Geoscience:

GEOSCIENCE LABORATORIES (PTY) LTD

CLIENT:	RA Bradshaw& Associates 17 Midwood Avenue Newlands 7700	**PROJECT:**	Breede River Pipeline
		DATE:	28-06-2011
ATT:	Dick Bradshaw	**REF:**	L110676

ASTM D422 SIEVE ANALYSIS

DESCRIPTION :	yellow olive & grey sandy clay	**SAMPLE NO. :**	18839
POSITION :	MP 8 @ 2.15-2.6m	**CLIENT SAMPLE NO. :**	

Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	100
	13.20	99
	9.50	98
	6.70	96
	4.75	95
	2.36	94
	2.00	94
	1.18	93
	0.600	92
	0.425	88
	0.300	79
	0.150	70
	0.0750	61

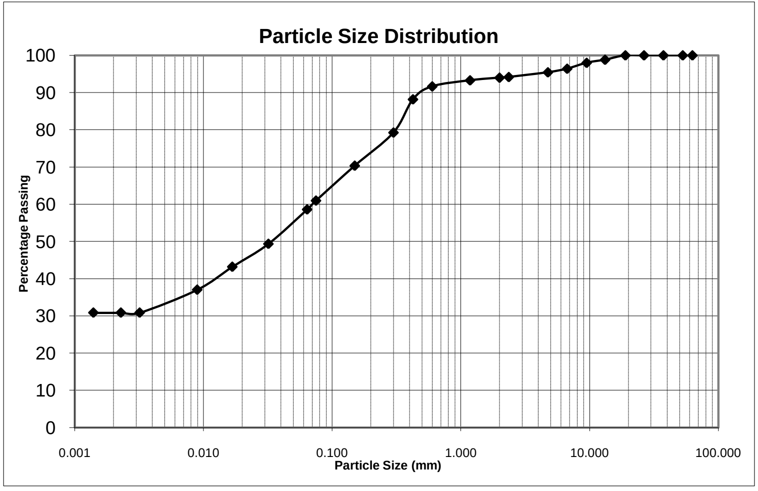
Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0657	59
0.0340	49
0.0173	43
0.0091	37
0.0032	31
0.0023	31
0.0013	31

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	37
Plastic Index	22
Linear Shrinkage	10.0

MOD AASHTO ; C.B.R. : A7 & A8	*TMH1*
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	



Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	5
Sand : Percentage - 4.75mm and + 0.075mm	34
Silt : Percentage - 0.075mm and + 0.002mm	30
Clay : Percentage - 0.002mm	31

For Geoscience:

CLIENT:	RA Bradshaw& Associates 17 Midwood Avenue Newlands 7700	**PROJECT:**	Breede River Pipeline
		DATE:	28-06-2011
ATT:	Dick Bradshaw	**REF:**	L110676

ASTM D422 SIEVE ANALYSIS

DESCRIPTION :	yellow brown sand	**SAMPLE NO. :**	18840
POSITION :	MP 9 @ 0.2-1.0m	**CLIENT SAMPLE NO. :**	

Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	
	13.20	
	9.50	
	6.70	
	4.75	
	2.36	
	2.00	
	1.18	100
	0.600	99
	0.425	93
	0.300	71
	0.150	41
	0.0750	14

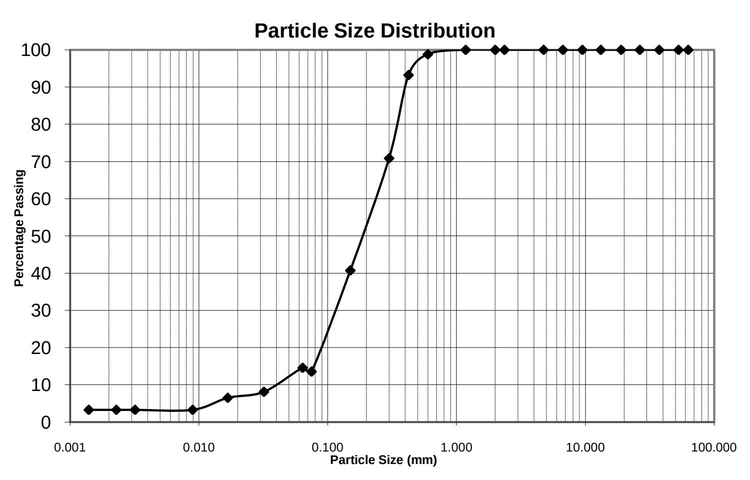
Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0762	15
0.0388	8
0.0194	6
0.0101	3
0.0035	3
0.0025	3
0.0015	3

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	
Plastic Index	N-P
Linear Shrinkage	

MOD AASHTO ; C.B.R. : TMH1 A7 & A8	
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	



Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	0
Sand : Percentage - 4.75mm and + 0.075mm	86
Silt : Percentage - 0.075mm and + 0.002mm	11
Clay : Percentage - 0.002mm	3

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CLIENT: RA Bradshaw& Associates
17 Midwood Avenue
Newlands
7700
ATT: Dick Bradshaw

PROJECT: Breede River Pipeline

DATE: 28-06-2011
REF: L110676

ASTM D422 SIEVE ANALYSIS

DESCRIPTION : yellow olive silty sand
POSITION : MP 10 @ 0.45-0.7m

SAMPLE NO. : 18841
CLIENT SAMPLE NO. :

Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	100
	26.50	99
	19.00	97
	13.20	96
	9.50	95
	6.70	94
	4.75	92
	2.36	84
	2.00	82
	1.18	78
	0.600	71
	0.425	67
	0.300	61
	0.150	55
	0.0750	51

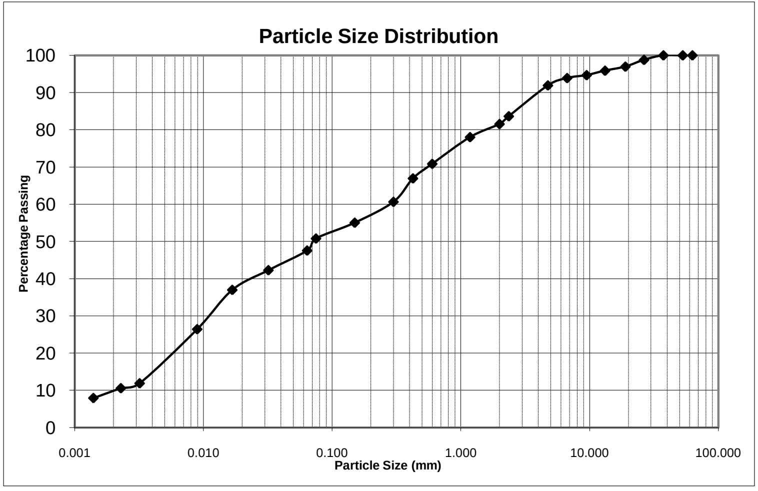
Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0663	48
0.0340	42
0.0173	37
0.0093	26
0.0034	12
0.0024	11
0.0014	8

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	40
Plastic Index	8
Linear Shrinkage	4.0

MOD AASHTO ; C.B.R. : TMH1 A7 & A8	
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	



Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	8
Sand : Percentage - 4.75mm and + 0.075mm	41
Silt : Percentage - 0.075mm and + 0.002mm	42
Clay : Percentage - 0.002mm	9

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		DATE:	28-06-2011
ATT:	Dick Bradshaw	**REF:**	L110676

ASTM D422 SIEVE ANALYSIS

DESCRIPTION :	yellow olive clayey sand	**SAMPLE NO. :**	18842
POSITION :	MP 10 @ 0.7-2.5m	**CLIENT SAMPLE NO. :**	

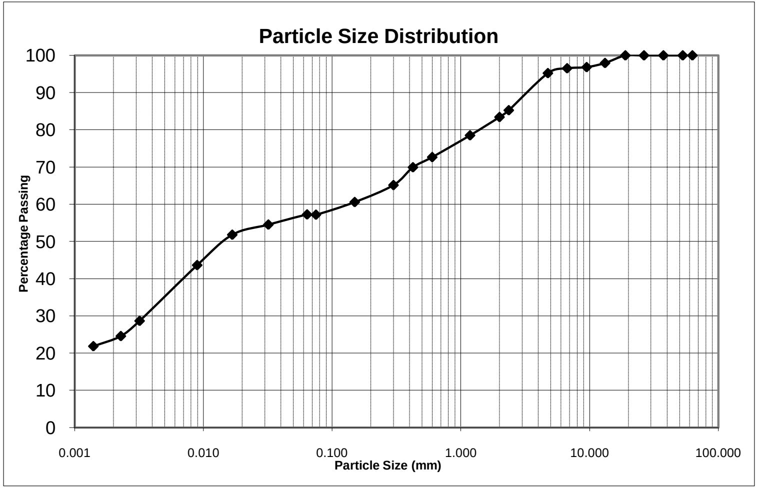
Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	100
	13.20	98
	9.50	97
	6.70	97
	4.75	95
	2.36	85
	2.00	83
	1.18	79
	0.600	73
	0.425	70
	0.300	65
	0.150	61
	0.0750	57

Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0648	57
0.0324	55
0.0164	52
0.0088	44
0.0032	29
0.0023	25
0.0014	22

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : *TMH1 A2, A3 & A4*	
Liquid Limit	39
Plastic Index	11
Linear Shrinkage	5.0



MOD AASHTO ; C.B.R. : ***A7 & A8***	***TMH1***
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	

Tabulated Summary	**Percentage**
Gravel : Percentage - 4.75 mm	5
Sand : Percentage - 4.75mm and + 0.075mm	38
Silt : Percentage - 0.075mm and + 0.002mm	33
Clay : Percentage - 0.002mm	24

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For Geoscience:

CLIENT:	RA Bradshaw& Associates 17 Midwood Avenue Newlands 7700	**PROJECT:**	Breede River Pipeline
		DATE:	28-06-2011
ATT:	Dick Bradshaw	**REF:**	L110676

ASTM D422 SIEVE ANALYSIS

DESCRIPTION : off-white clayey sandy silt
POSITION : MP 11 @ 0.8-2.0m
SAMPLE NO. : 18843
CLIENT SAMPLE NO. :

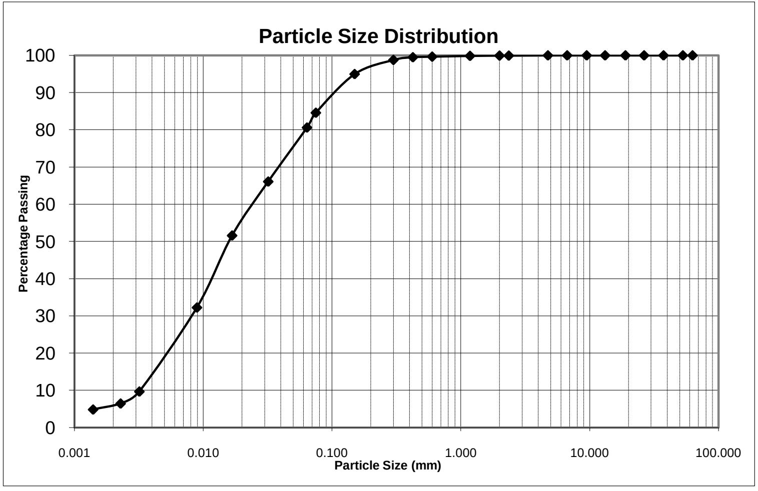
Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	
	13.20	
	9.50	
	6.70	
	4.75	
	2.36	
	2.00	
	1.18	
	0.600	
	0.425	100
	0.300	99
	0.150	95
	0.0750	85

Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0609	81
0.0324	66
0.0170	52
0.0093	32
0.0034	10
0.0025	6
0.0015	5

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	33
Plastic Index	5
Linear Shrinkage	2.0



MOD AASHTO ; C.B.R. : A7 & A8	***TMH1***
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	

Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	0
Sand : Percentage - 4.75mm and + 0.075mm	15
Silt : Percentage - 0.075mm and + 0.002mm	79
Clay : Percentage - 0.002mm	6

The above test results are pertinent to the samples received and tested only. While the tests are carried out according to recognized standards Geoscience shall not be liable for erroneous testing or reporting thereof. This report may not be reproduced except in full without prior consent of Geoscience.

For Geoscience:

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CLIENT:	RA Bradshaw& Associates 17 Midwood Avenue Newlands 7700	**PROJECT:**	Breede River Pipeline
		DATE:	28-06-2011
ATT:	Dick Bradshaw	**REF:**	L110676

ASTM D422 SIEVE ANALYSIS

DESCRIPTION :	dark red brown silty sand	**SAMPLE NO. :**	18844
POSITION :	MP 12 @ 1.0-2.0m	**CLIENT SAMPLE NO. :**	

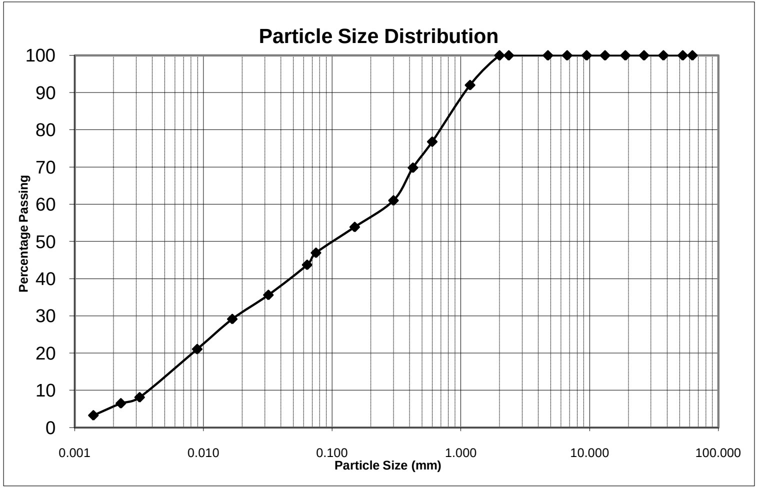
Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	
	13.20	
	9.50	
	6.70	
	4.75	
	2.36	
	2.00	100
	1.18	92
	0.600	77
	0.425	70
	0.300	61
	0.150	54
	0.0750	47

Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0702	44
0.0358	36
0.0182	29
0.0097	21
0.0035	8
0.0025	6
0.0015	3

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : *TMH1 A2, A3 & A4*	
Liquid Limit	36
Plastic Index	3
Linear Shrinkage	1.0



MOD AASHTO ; C.B.R. : ***A7 & A8***	***TMH1***
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	

Tabulated Summary	**Percentage**
Gravel : Percentage - 4.75 mm	0
Sand : Percentage - 4.75mm and + 0.075mm	53
Silt : Percentage - 0.075mm and + 0.002mm	42
Clay : Percentage - 0.002mm	5

For Geoscience:

GEOSCIENCE
LABORATORIES (PTY) LTD

CLIENT: RA Bradshaw & Associates **PROJECT:** Breede River Pipeline

ATT: Dick Bradshaw **REF. NO:** L110676

SAND GRADING / CBR RESULT SUMMARY

SAMPLE NO:	CLIENT SAMPLE NO.	SAMPLE DESCRIPTION
18845		yellow brown silty sand

SAMPLE POSITION
MP 13 @ 0.3-1.5m

SIEVE ANALYSIS

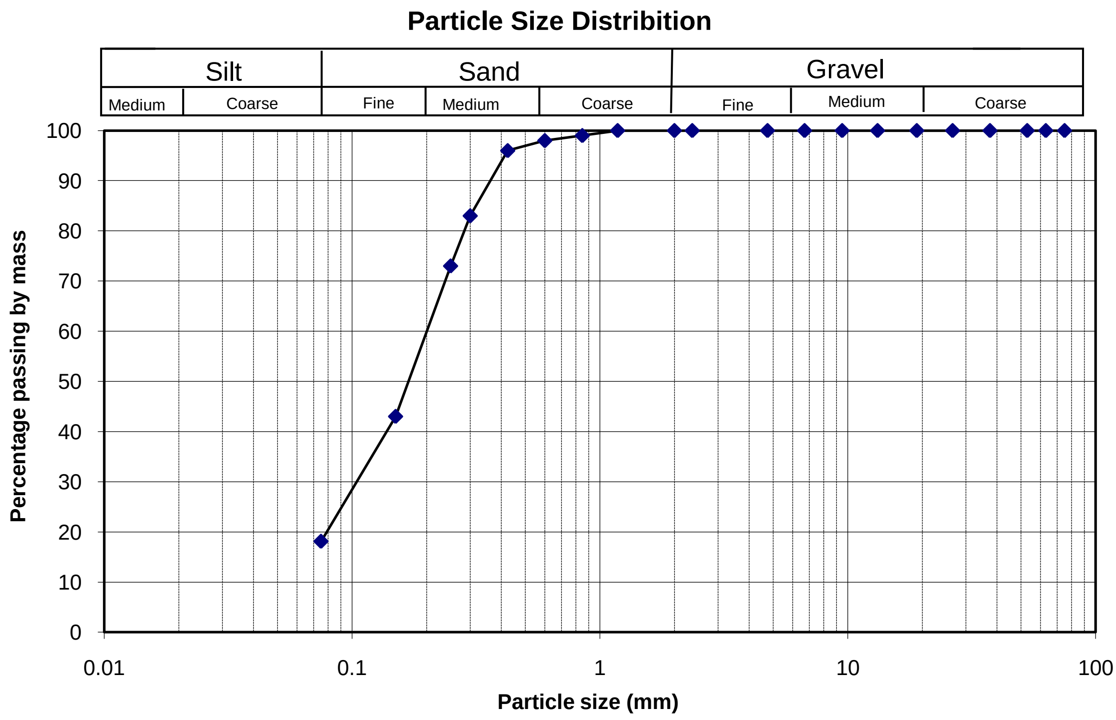
Sieve mm	Percentage Passing	Sieve mm	Percentage Passing
75		2.36	
63		2.00	
53		1.18	100
37.5		0.850	99
26.5		0.600	98
19		0.425	96
13.2		0.300	83
9.50		0.250	73
6.70		0.150	43
4.750		0.075	18.1

ATTERBERG LIMITS

Liquid Limit	
Plastic Index	N-P
Linear Shrinkage %	

MOD / CBR

MOD	
O.M.C.	
100%	
98%	
95%	
93%	
90%	
Max Swell	



GEOSCIENCE
LABORATORIES (PTY) LTD

CLIENT:	RA Bradshaw& Associates 17 Midwood Avenue Newlands 7700	**PROJECT:**	Breede River Pipeline
		DATE:	28-06-2011
ATT:	Dick Bradshaw	**REF:**	L110676

ASTM D422 SIEVE ANALYSIS

DESCRIPTION :	yellow brown clayey sand	**SAMPLE NO. :**	18846
POSITION :	MP 13 @ 1.5-2.5m	**CLIENT SAMPLE NO. :**	

Sieve Analysis		Percent Passing
SIEVE SIZE (mm)	75.00	
	63.00	
	53.00	
	37.50	
	26.50	
	19.00	
	13.20	
	9.50	
	6.70	
	4.75	
	2.36	
	2.00	100
	1.18	99
	0.600	98
	0.425	97
	0.300	83
	0.150	57
	0.0750	30

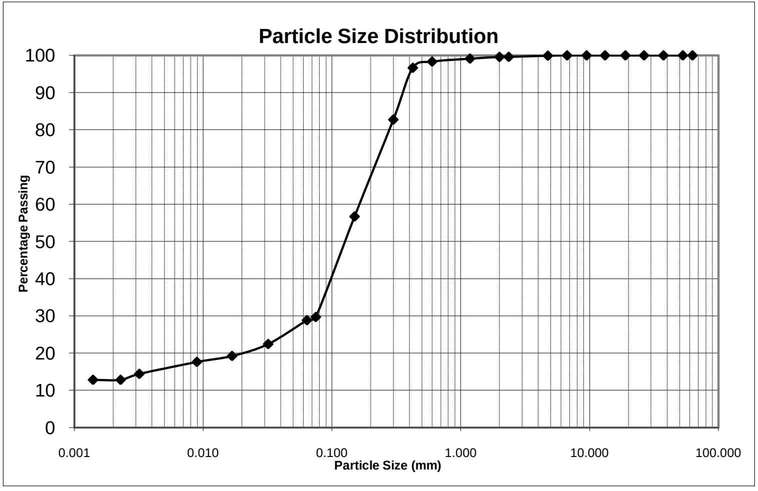
Hydrometer Analysis	
Diameter of particle (mm)	Percentage of soil suspension (%)
0.0729	29
0.0371	22
0.0187	19
0.0098	18
0.0034	14
0.0024	13
0.0014	13

SCS Dispersion Test	
Diameter of particle (mm)	Percentage of soil suspension (%)

Specific Gravity:	
Initial Moisture Content (%) :	
pH :	
Conductivity mS/m :	

Atterberg Limits : TMH1 A2, A3 & A4	
Liquid Limit	
Plastic Index	S-P
Linear Shrinkage	

MOD AASHTO ; C.B.R. : TMH1 A7 & A8	
MOD AASHTO (Kg/m³)	
O.M.C. (%)	
C.B.R. @ 100% Comp.	
C.B.R. @ 98 % Comp.	
C.B.R. @ 95 % Comp.	
C.B.R. @ 93 % Comp.	
C.B.R. @ 90 % Comp.	
Swell (max) %	



Tabulated Summary	Percentage
Gravel : Percentage - 4.75 mm	0
Sand : Percentage - 4.75mm and + 0.075mm	70
Silt : Percentage - 0.075mm and + 0.002mm	17
Clay : Percentage - 0.002mm	13

The above test results are pertinent to the samples received and tested only. For Geoscience:
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APPENDIX D

RESULTS OF LABORATORY TESTS ON WATER SAMPLES

BemLab

SANAS Accredited Testing Laboratory
No T0475

16 Van der Berg Crescent
Gant’s Centre
Strand

PO Box 684
Somerset Mall,
7137

Tel. (021) 853-1490
Fax. (021) 853-1423
Cell. 082-804-7499
E-Mail akotze@bemlab.co.za

Vat Reg. No. 4200161414

Report No.: **WT4591/2011**

Nanine Gildenhuys
R.A. Bradshaw & Associates
17 Midwood Avenue
Newlands
7708

Water Analyses Report

Date received: 14/06/2011
Date tested: 15/06/2011

Reference No.	Lab. No.	pH	Alkalinity mg/l	Cl mg/l	SO4 mg/l	Ca mg/l	TDS mg/l
MP6	4591	6.9	144.074	154.517	15.427	17.975	237.0
MP7	4592	6.7	60.240	220.738	5.107	6.459	77.3
MP8	4593	7.0	32.630	246.344	107.980	10.039	588.0

Breede River Pipeline Project

Sample conditions

Samples in good condition.

Statement

The reported results may be applied only to samples recieved. Any recommendations included with this report are based on the assumption that the samples were representative of the bulk from which they were taken. Opinions and recommendations are not accredited.

Dr. W.A.G. Kotzé
....
for BemLab

17-06-2011
....
Date

Technical Signatory: Dr. W.A.G. Kotzé
Arrie van Deventer (Chemical Analyses)
Annerina Esterhuyse (Microbiology)