

SGS MATROLAB (PTY) LTD -CIVIL ENGINEERING SEVICES-

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# Geotechnical Factual Report:

On behalf of:

Nyeleti Consulting (Pty) Ltd

Report 1 of 1

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## **Document Control**

Title:
Site: Woodmead water Upgrade
Client: Nyeleti Consulting (Pty) Ltd
Reference: PL/45743
Version: 1
Prepared by:
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Reviewed by:
Miles deorde Le Grange BSc. (hons) Engineering Geology

### 1. Background

SGS Matrolab was appointed by Nyeleti Consulting (Pty) Ltd to carry out a field investigation to assess the material properties of the materials along the WOODMEAD WATER UPGRADE.

The objective of the investigation as understood from the email correspondence with the client representative of Nyeleti Consulting (Pty) Ltd is to determine the encountered layers and material properties along the pipeline route.



Figure 1: Site Layout (Image source: Google Earth)

The main purpose of the factual report is to assist in the designing and planning process of Nyeleti Consulting (Pty) Ltd in terms of giving relevant information pertaining to possible insitu materials that can be used as construction materials for the pipeline. The investigation therefor concentrated on the engineering properties of the materials encountered.

### 2. Field work

The investigation was done by excavating a number of test pits, (total of 17) to a maximum depth of 2m and profiling the test pits according to the MCCSSO method (Jennings et.al.,

1973). The test pits were reinstated by backfilling the excavated test pit with the excavated material and compacted by driving over the backfilled test pit with the rear wheels of the TLB.

Disturbed soil samples were taken from the test pits according to TMH 5 and were submitted to our soil laboratory for testing. The test consists of:

Road indicator test in accordance with SANS 3001.

### 3. Limitations and Assumptions

In the investigation for the Woodmead Water Upgrade project all care has been taken to provide accurate information based on limited tests and expertise. Any spatial or temporal extrapolation or inference is conjectural, and no liability can be accepted by SGS Matrolab Pty (Ltd) for its accuracy.

A topographical survey or surface hydro census was not part of our scope, therefor no definite results were obtained in terms of catchment areas and storm water preferred natural pathways. Based on experience, desk studies and field observations assumed site topography is given.

Moisture variation will occur.

### 4. Climate

The weather conditions in the Woodmead area can be roughly estimated in accordance with the Weinert's N-Value (Weinert, 1980) with an N-Value range between 2 and 5. The region can be classified as a moderately humid region, and thus the main mode of weathering will be chemical.

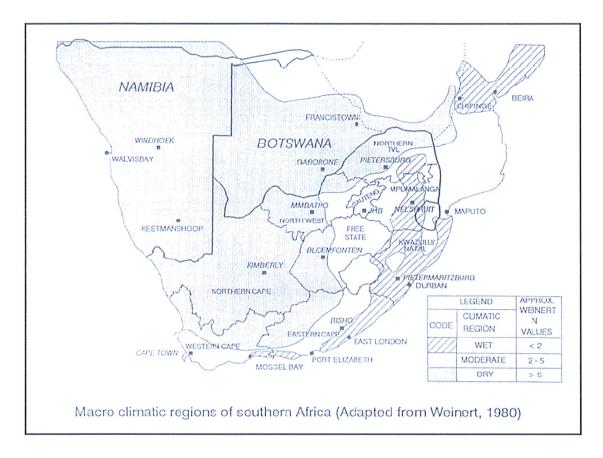


Figure 2: Map of South-Africa climate (SANParks)

### 5. Geology

The water pipeline cuts across a number of different geological structures. The Northern section of the pipe line is underlain by Intrusive rock types namely gneiss, migmatite & porphyritic granodiorite of the Halfway House Granite formation. The southern section of the pipe line is underlain by intrusive rock types namely grey medium grained granodiorite of the Halfway House Granite Formation.

See Figure 3 on next page

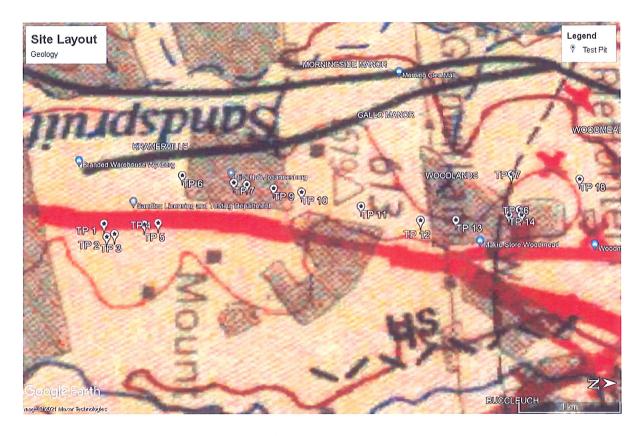


Figure 3: Site Geology (Geological series map 1:250 000 Map 2628 East Rand); cropped not to scale

## 6. Topography

A topographical survey was not part of the scope of works, but a visual aid of the topography along the length of the water pipeline is given by a google Earth image below. See figure 4 on next page.

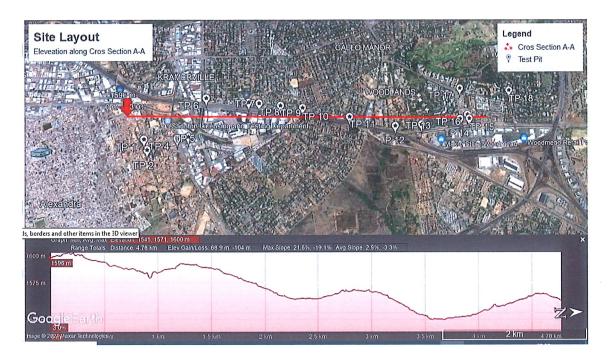


Figure 4: Topography (Image Source: Google Earth)

### 7. Test Pit Profile Summary

The test pit summary is an overlook on the encountered layers, the specific test pit/horizon details, characteristics, descriptions, and properties should be taken from the profile report.

### **Test Pits**

#### Topsoil Layers:

The material encounter in the topsoil layer has varying soil types and varied in thicknesses between 0.1m to 0.8m

#### • Imported Layers:

The test pits where imported layers were encountered had 1-2 layers imported layers. These layers showed signs of reworking. There are imported layers that have building rubble in the soil horizon. The imported material layer thickness varied between 0.15m-1.15m and encountered depths from 0.1m to 0.8m.

#### Residual Layers:

The described residual material encountered in the test pits varied in thickness and depth. The thickness of the layer varied between 0.2m-1.7m and encountered depths of between 0.3m-1.6m.

### 8. Excavatability

During the field work a Tractor Backhoe Loader (TLB) were used for the excavation of the test pits up to a maximum depth of 2 meters with refusal recorded at 4 test pits, namely TP4, TP 8, TP9 & TP10, with varying depth of between 0.4m-1.2m due to difficult excavation of dense soil. The excavatability throughout the site will vary from soft to hard excavation in accordance with SANS D1200 up to 2 meter in depth. Due to the underlying geology and the variation in weathering of the underlying rock formation excavatability will vary significantly.

#### **Bibliography**

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- Weinert, H. (1980). THE NATURAL ROAD CONSTRUCTION MATERIALS OF SOUTHERN AFRICA. Pretoria: National Institute for Transport and Road Research.

### End Report

# APPENDIX A

Photo Profile Reports

# APPENDIX B

Results



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NEYELETI CONSULTING (PTY) TLD PO BOX 35158 MENLOPARK 0102

PROJECT:

WOODMEAD WATER UPGRADE

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#### **PHOTO PROFILE REPORT - TEST PIT 1**

Test Pit TP 1	Water Table		Depth (mm)	SOIL DESCRIPTION  Moisture, Colour, Consistency, Structure, Soil Type, Origin, General	SAMPLING TYPE AND NUMBER
PROFILED BY		000		Topsoil	
GERT KRUGER	<b>∃</b> I	880	400		1
<b>GPS CO-ORDINATES</b> -26,094461		0000		Slightly Moist to Dry, Light Brown, Medium Dense Intact, Sandy Gravel, Imported	A21 3280 R Ind
28,090949	]	0000		Slightly Moist to Dry, Orange, Medium Dense	A21 3281
DATE PROFILED	71	000		Intact, Sandy Gravel, Residual	R Ind
04 October 2021	71	8000			
DATE EXCAVATED	71	000	900 +		
04 October 2021	71	8000		Slightly Moist, Orange, Medium dense, Intact	A21 3282
EXCAVATION MEANS	71	000		Sandy Gravel, Residual	R Ind
TLB	<b>∃</b>	8000			-24

Notes: No refusal - TLB reached maximum depht

no water seepage



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#### **PHOTO PROFILE REPORT - TEST PIT 2**

Test Pit TP 2		(mm)	SOIL DESCRIPTION Moisture, Colour, Consistency, Structure, Soil Type, Origin, General	SAMPLING TYPE AND NUMBER
PROFILED BY GERT KRUGER	6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	500 -	Topsoil	
GPS CO-ORDINATES -26,064317 28,092329		500	Slightly Moist, Light Brown, Dense, Intact Gravelly Sand with Building Rubble, Imported	A21 3283 R Ind
DATE PROFILED  04 October 2021	विश्व	1100		
DATE EXCAVATED  04 October 2021			Slightly Moist, Orange blotched with Black, Dense	A21 3284
EXCAVATION MEANS TLB			Intact, Silty Gravel, Residual	R Ind

Notes:

No refusal - TLB reached maximum depht

No water seepage



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### **PHOTO PROFILE REPORT - TEST PIT 3**

Test Pit	TP 3	Water Table	Soil Depth (mm) 0	SOIL DESCRIPTION Moisture, Colour, Consistency, Structure, Soil Type, Origin, General	SAMPLING TYPE AND NUMBER
PROFIL	ED BY		0000	Topsoil	
GERT K	RUGER		C-C-C <sub>1</sub> 300	SECONDITION AT LIGHTEN HUNGERING SECOND	4/10/2003
GPS CO-OI	RDINATES			Slightly Moist to Dry, Light Brown, Soft Medium Dense, Intact, Sand, Imported	A21 3285 R Ind
-26,09 28,09			800		
20,09	1070		000	Slightly Moist, Orange, Medium Dense	A21 3286
DATE PR	OFILED	11	0000	Intact, Sandy Gravel, Residual	R Ind
04 Octob	per 2021	11	0000		
DATE EXC	CAVATED	]	1100 ﴿ حَجَبُ		
04 Octob	er 2021	11		Slightly Moist, Orange, Medium Dense	A21 3287
EXCAVATION	ON MEANS	11		Intact, Gravelly Clayey Sand, Residual	R Ind
TL	.B	]	A die	which research with the an entire section of the Control of School	0.00000000
		]	2000		- 1

Notes:

No refusal - TLB reached maximum depht

No water seepage



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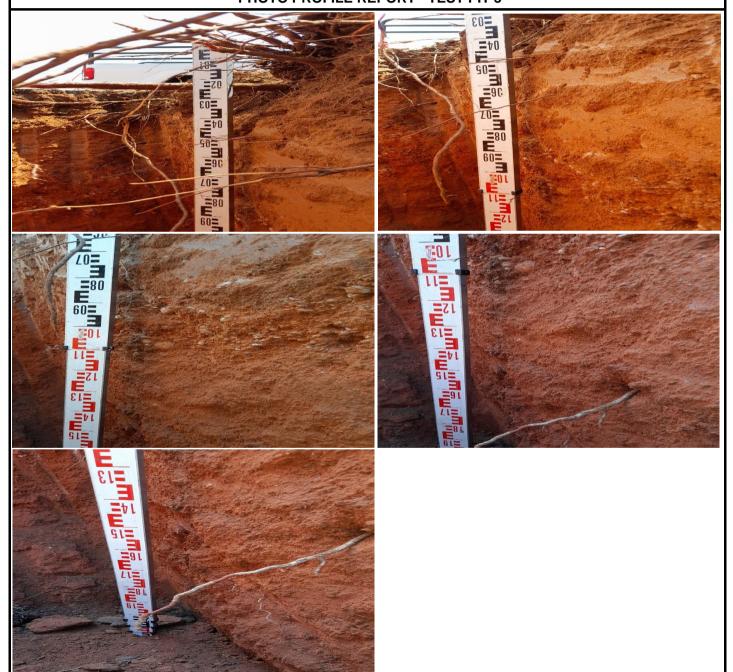
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#### **PHOTO PROFILE REPORT - TEST PIT 4**

Test Pit TP 4	Water Soil Depth Table Legend (mm)	SOIL DESCRIPTION  Moisture, Colour, Consistency, Structure, Soil Type, Origin, General	SAMPLING TYPE AND NUMBER
PROFILED BY	00000	Topsoil	
GERT KRUGER	<u>-C-C-C</u> 200		1
<b>GPS CO-ORDINATES</b> -26,090802		Slightly Moist, Light Brown, Medium Dense Intact, Sand, Imported	A21 3288 R Ind
28,090876	800	Slightly Moist to Dry, Light Grey with	
DATE PROFILED 04 October 2021		Mottled Orange, Dense, Intact, Sandy Gravel Residual	A21 3289 R Ind
DATE EXCAVATED	\$ \$ 1000 ·		-
04 October 2021		Dry, Orange Yellow, Very Dense, Intact	A21 3290
<b>EXCAVATION MEANS</b>		Gravel, Residual	R Ind
TLB	0000		

Notes: Refusal @ 1400 mm - very dense soil

No water seepage



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### **PHOTO PROFILE REPORT - TEST PIT 5**

Test Pit	TP 5	Water Table	Soil Legend	Depth (mm)	SOIL DESCRIPTION Moisture, Colour, Consistency, Structure, Soil Type, Origin, General	SAMPLING TYPE AND NUMBER
PROFIL	ED BY		0000		Topsoil	
GERT K	RUGER	]	0.0.0		\$2000 \$1.100 \$1.00 \$2.00 \$1.00	COVERNO
GPS CO-O	RDINATES	11			Slightly Moist, Light Brown, Soft, Intact Sand, Imported	A21 3291 R Ind
-26,08		]				
28,09	0772	ll .	000			3 &
DATE PR	OFILED	il .	%%		Dry, Orange, Dense, Intact, Gravel Residual	A21 3292 R Ind
04 Octob	per 2021	]	%%			100
DATE EXC	CAVATED		(1)	1700		*
04 Octob	oer 2021		1. 1.		Dry, Light Grey, Medium Dense, Intact	A21 3293
EXCAVATION	ON MEANS	]	20. 40. 10		Sand, Residual	R Ind
TL	В	]				ACCURATION
·		H	to go a	2000 -		-

Notes:

No refusal - TLB reached maximum depht

No water seepage



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#### **PHOTO PROFILE REPORT - TEST PIT 6**

T( D)(	TDA	Water	Soil Dept Legend (mm		SAMPLING TYPE AND NUMBER
Test Pit	TP 6	Tubic	Ĉ Ĉ Ĉ	Topsoil	AND NOMBER
<b>PROFILE</b> GERT KR			150	Slightly Moist, Light Brown, Soft, Intact Gravelly Sand, Imported	A21 32994 R Ind
GPS CO-OR -26,087		- 1	300	Dry, Orange, Dense, Intact, Sandy Gravel Imported	A21 3295 R Ind
28,085			700	Slightly Moist, Light Brown, Medium Dense Intact, Gravelly Sand, Residual	A21 3296 R Ind
04 Octobe	er 2021 AVATED		000 000 000 000	Slightly Moist, Orange, Medium dense, Intact Sandy Gravel, Residual	A21 3297 R Ind
04 Octobe EXCAVATIO	N MEANS	1	<del>9994</del> 1350	slightly Moist, Orange, Medium Dense, Intact Gravelly Clayey Sand, Residual	A21 3298 R Ind

Notes:

No refusal - TLB reached maximum depht

No water seepage



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#### **PHOTO PROFILE REPORT - TEST PIT 13**

Test Pit	TP 13	Water Table			SAMPLING TYPE AND NUMBER
			666	Topsoil	
PROFILE		1	<u>c c</u> 350		424 2240
GERT KR	RUGER	-11	3.0	Slightly Moist, Orange, Intact Medium dense, Gravelly Sand, Imported	A21 3319 R Ind
GPS CO-OR	DINATES	11	450	(5)	
-26,06	091	]	3.0	Slightly Moist, Bark Brown, Medium Dense	A21 3320
28,090	)406			Intact, Gravelly sand, Residual	R Ind
DATE PRO	OFILED	1	<del>プノント</del> 1100	Slightty Moist, Reddish Brown	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
05 Octobe	er 2021	11	in the second	Soft to Medium Dense, Intact	A21 3321 R Ind
DATE EXC	AVATED	]	000	Clayey Gravelly Sand, Residual	11.00
05 Octobe	er 2021	]	1500	slightly Moist, Orange	O SALVANO SE MANOS
EXCAVATIO	N MEANS	]	20 C 20	Soft to Medium dense, Intact	A21 3322
TLE	3	]		Gravelly Silty Sand, Residual	R Ind
		II .	2000		

Notes:

No refusal - TLB reached maximum depht

No water seepage



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### **PHOTO PROFILE REPORT - TEST PIT 14**

Test Pit	TP 14	Water Table		Depth (mm)	SOIL DESCRIPTION Moisture, Colour, Consistency, Structure, Soil Type, Origin, General	SAMPLING TYPE AND NUMBER
PROFIL	ED BY		00000		Topsoil	
GERT KI			C.C.C	500 STATES	5. 5	101 0000
GPS CO-OF	RDINATES	1			Dry, Brown, Medium dense, Intact Sand, Imported	A21 3323 R Ind
-26,05		]	Sec.	050		
28,09	0019	-11		030		
DATE PR	OFILED	1	Sec. 25, 25, 25.		Slightly Moist, Orange, Medium Dense Intact, Gravelly Sand, Imported	A21 3324 R Ind
05 Octob	er 2021	]				
DATE EXC	CAVATED	11		1100		1
05 Octob	er 2021	11		9	Slightly Moist, Orange, Medium dense	A21 3325
EXCAVATION	ON MEANS	11			Intact, Gravelly Silty Sand, Residual	R Ind
TL	В	]				
·		H	is go as	2000		-

Notes:

No refusal - TLB reached maximum depht



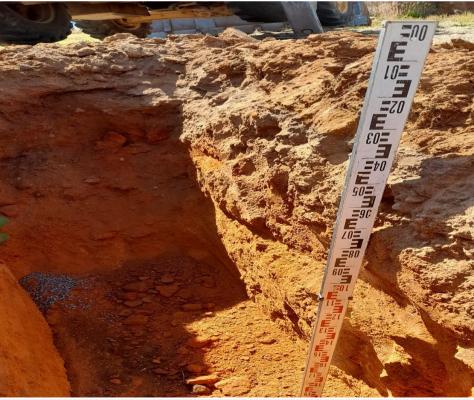
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## **PHOTO PROFILE REPORT - TEST PIT 15 & 16**

<b>Test Pit</b> TP 15 & 16	Water Soil De Table Legend (m	SOIL DESCRIPTION m) Moisture, Colour, Consistency, Structure, Soil Type, Origin, General	SAMPLING TYPE AND NUMBER
PROFILED BY	6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	Topsoil	
GERT KRUGER	-C-C-G 30	0 Slightly Moist, Brownish Red	0.0000000000000000000000000000000000000
<b>GPS CO-ORDINATES</b> -26,056061		Medium Dense, Intact, Gravelly Sand Imported	A21 3328 R Ind
28,088786	80		
DATE PROFILED	8000	Slightly Moist, Brown, Medium dense, Intact Sandy Gravel, Imported	A21 3329 R Ind
05 October 2021	8000		
DATE EXCAVATED	]   Min 12	00	
05 October 2021		slightly Moist, Orange, Medium Dense, Intact	A21 3330
EXCAVATION MEANS		Clayey Silt, Residual	R Ind
TLB	]		
	20	00	

Notes:

No refusal - TLB reached maximum depht

No water seepage

Building rubble @ 800 - 1200 mm



NEYELETI CONSULTING (PTY) TLD PO BOX 35158 MENLOPARK 0102

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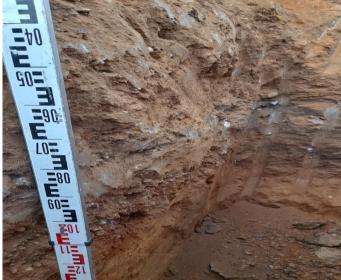
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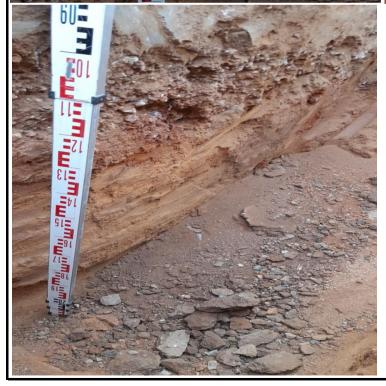
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### **PHOTO PROFILE REPORT - TEST PIT 17**

Test Pit	TP 17	Water Table		Depth (mm)	SOIL DESCRIPTION Moisture, Colour, Consistency, Structure, Soil Type, Origin, General	SAMPLING TYPE AND NUMBER
	ILED BY KRUGER		0,0,0,0,0		Topsoil	
-26,0	ORDINATES 056390 085654	1			Slightly Moist, Reddish - Brown Orange Medium Dense, Intact, Gravelly Sand Imported	A21 3326 R Ind
	PROFILED ober 2021	]		850		
DATE EX 05 Octo	CCAVATED ober 2021	1			Slightly moist, Greyish Brown, Medium Dense Intact, Gravelly Silty Sand, Imported	A21 3327 R Ind
	LB	1			AV 100 MI	

Notes: No refusal - TLB reached maximum depht

No water seepage

Building rubble @ 200 - 850 mm Big boulders @ 850 - 2000 mm



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### **PHOTO PROFILE REPORT - TEST PIT 18**

Test Pit	TP 18	Water Table	Soil Legend	Depth (mm) 0	SOIL DESCRIPTION Moisture, Colour, Consistency, Structure, Soil Type, Origin, General	SAMPLING TYPE AND NUMBER
	LED BY KRUGER		0,0,0,0,0,0		Topsoil	
-26,0	<b>DRDINATES</b> 49795 85837	1	0 0 0	8		
05 Octo  DATE EX  05 Octo	her 2021 CAVATED ber 2021			**************************************	Light Orange Yellow, Medium Dense Intact, Gravelly Sand, Residual	A21 3333 R Ind
	ON MEANS LB			2000 -		

Notes:

No refusal - TLB reached maximum depht



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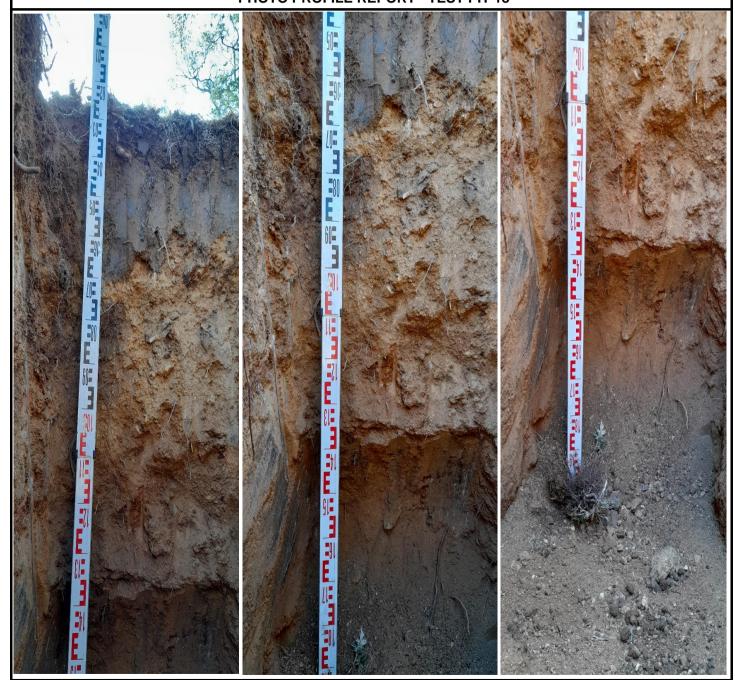
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### **PHOTO PROFILE REPORT - TEST PIT 7**

Test Pit	TP 7	Water Table	Soil Legend	Depth (mm)	SOIL DESCRIPTION  Moisture, Colour, Consistency, Structure, Soil Type, Origin, General	SAMPLING TYPE AND NUMBER
			666		Topsoil	
PROFILE GERT KR		{	2.2.2	150		
OLIVI KIN	COCIN	1	1. 100	- 1	Dry, Light Orange, Very Dense, Intact	A21 3299
GPS CO-OR	DINATES	]	1*		Gravelly Sand, Imported	R Ind
-26,087	7247	]				
28,085	895			800		
DATE PRO	OFILED	1			Slightly Moist, Orange, Dense, Intact Gravelly Clayey Silt, Residual	A21 3300 R Ind
04 Octobe	er 2021	11				
DATE EXC	AVATED	11		1800		*
04 Octobe	er 2021	]			Slightly Moist, Orange Mottled with Pale Red	A21 3301
<b>EXCAVATIO</b>	N MEANS	]			and Black, Medium Dense, intact, Gravelly Clayey Silt, Residual	R Ind
TLE	3	11	114844	1	Jill, Medidudi	

Notes:

No refusal - TLB reached maximum depht



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## **M**ATROLAB

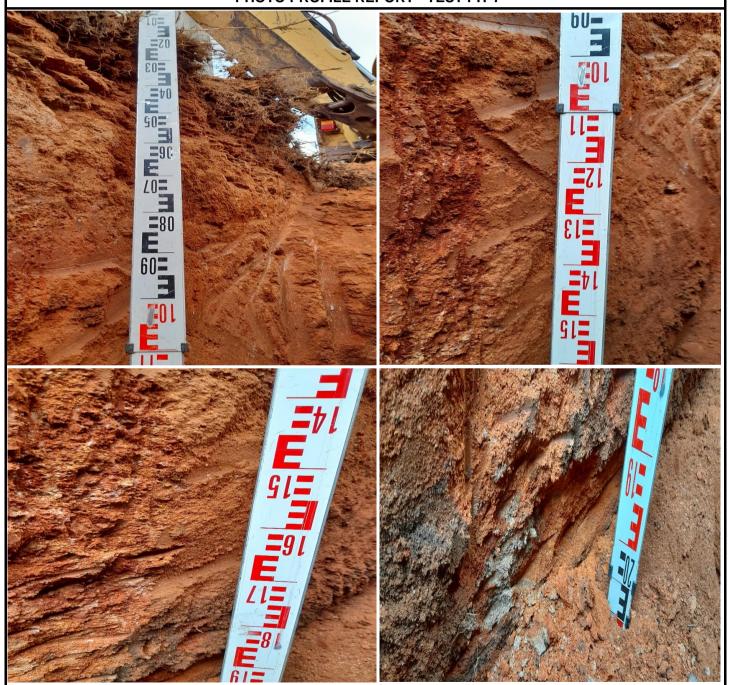
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## **MATROLAB**

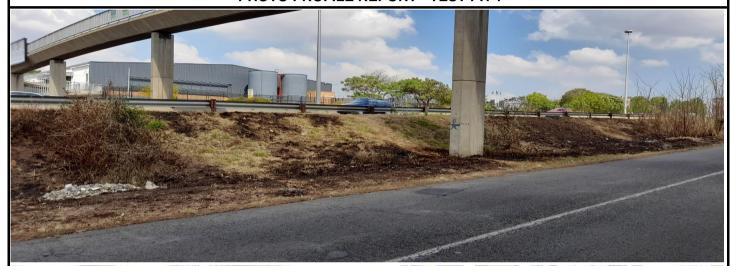
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## **PHOTO PROFILE REPORT - TEST PIT 8**

Test Pit	TP 8	Water Table	Soil Legend	Depth (mm)	SOIL DESCRIPTION Moisture, Colour, Consistency, Structure, Soil Type, Origin, General	SAMPLING TYPE AND NUMBER
	LED BY KRUGER		0,0,0,0,0		Topsoil	
-26,0	<b>DRDINATES</b> 981189 86697			100	Moist, Orange, Soft, Intact, Gravelly Clay Imported	A21 3302 R ind
04 Octo	ROFILED ober 2021 CCAVATED ober 2021				Dry, Light Orange, Very Dense, Intact	A21 3303
_	ION MEANS	1		i l	Gravelly Sand, Imported	R Ind

Notes: Refusal @ 400 mm - very dense soil



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## **PHOTO PROFILE REPORT - TEST PIT 9**

Test Pit	TP 9	Water Table	Soil Legend	Depth (mm)	SOIL DESCRIPTION Moisture, Colour, Consistency, Structure, Soil Type, Origin, General	SAMPLING TYPE AND NUMBER
PROFILE	ED BY	1	0000		Topsoil	
GERT KR		1	99	200	Moist, Orange, Soft, Intact, Gravelly Clay	A21 3304
GPS CO-OR -26,078			99		Imported	R Ind
28,087	'195			8	Slightly Moist, Orange, Dense, Intact	A21 3305
DATE PRO					Gravelly Sand, Imported	R Ind
DATE EXC	AVATED		W. S.	600	Slightly Moist, Pale Brown with Mottled Yellow	
EXCAVATIO	N MEANS			i	Dense to Very Dense, Intact Gravelly Sand, Residual	A21 3306 R Ind
Hand T	OOIS	1	3 - 3 - 1 s	1200		8

Notes: Refusal @ 1200 mm - very dense soil



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### **PHOTO PROFILE REPORT - TEST PIT 10**

Test Pit		Water Table	Soil Legend	Depth (mm)	SOIL DESCRIPTION  Moisture, Colour, Consistency, Structure, Soil Type, Origin, General	SAMPLING TYPE AND NUMBER
PROFILE	D BY		000000000000000000000000000000000000000		Topsoil	
GERT KRU	JGER			300		
GPS CO-ORE	DINATES				Slightly Moist, Orange, Soft, Intact Gravelly Sandy Clay, Imported	A21 3307 R Ind
-26,075 <sup>2</sup> 28,0877				600		
20,0077	40				Dry, Light Orange, Dense, Intact	A21 3308
DATE PRO	FILED		3.		Gravelly Sand, Imported	R Ind
05 October	r 2021					
DATE EXCA	VATED	ł		800		
05 October	r 2021		300		Slightly Moist, Orange, Medium Dense to Dense	A21 3309
EXCAVATION	MEANS			!	Intact, Gravelly Sand, Residual	R Ind
TLB			100			20002000000
		- 1	to great	1200		

Notes:

Refusal @ 1200 mm - dense soil



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### **PHOTO PROFILE REPORT - TEST PIT 11**

Test Pit TP 11	Water Soil Deoth (mm)	SOIL DESCRIPTION  Moisture, Colour, Consistency, Structure, Soil Type, Origin, General	SAMPLING TYPE AND NUMBER
		Topsoil	
PROFILED BY GERT KRUGER	200	Slightly Moist, Orange, Soft, Intact Gravelly Sand, Imported	A21 3310 R Ind
<b>GPS CO-ORDINATES</b> -26,070408	1400	Slightly Moist, Orange, Dense, Intact Gravelly Sand, Imported	A21 3311 R Ind
28,089092  DATE PROFILED		Slightly Moist, Dark Brown, Medium Dense Intact, Sand, Residual	A21 3312 R Ind
05 October 2021  DATE EXCAVATED  05 October 2021	1100	Slightly Moist, Yellowish Brown Soft to Medium Dense, Intact Sand, Residual	A21 3313 R Ind
EXCAVATION MEANS TLB	1600 +	Slightly Moist, Brownish Yellow Soft to Medium dense, Intact Clayey Sand, Residual	A21 3314 R Ind

Notes: No refusal - TLB reached maximum depht



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### **PHOTO PROFILE REPORT - TEST PIT 12**

Test Pit	TP 12	Water Table	Soil Legend	Depth (mm)	SOIL DESCRIPTION Moisture, Colour, Consistency, Structure, Soil Type, Origin, General	SAMPLING TYPE AND NUMBER
			,0,0,	0	Topsoil	
PROFIL	LED BY	<b>]</b>	C C	200		
GERT K	RUGER	4			Slightly Moist, Light Orange, Soft, Intact Gravelly Sand, Imported	A21 3315 R Ind
GPS CO-O	RDINATES	11	10/0	550	F4	
-26,06	64990	71			Moist, Reddish Brown, Soft, Intact	A21 3316
28,09	90453	]			Gravelly Clay, Residual	R Ind
DATE PR	ROFILED	╢		1100	Mark Office and Mark Office and Office	101 0017
05 Octol	per 2021	11			Moist, Olive, Soft, Intact, Sandy Clay Residual	A21 3317 R Ind
DATE EX	CAVATED	11	11/2		TVO TO THE TOTAL T	T III
05 Octol	ber 2021	11	19/9	1700 -	2. Control Michigan March and Control March and	N. 100 (100 (100 (100 (100 (100 (100 (100
EXCAVATION	ON MEANS	7	19/9		Moist, Brownish Yellow, Soft, Intact	A21 3318
TL	В	]	19/19		Gravelly Clay, Residual	R Ind
			1811	2000		3

Notes: No refusal - TLB reached maximum depht



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#### **PHOTO PROFILE REPORT - TEST PIT 12**







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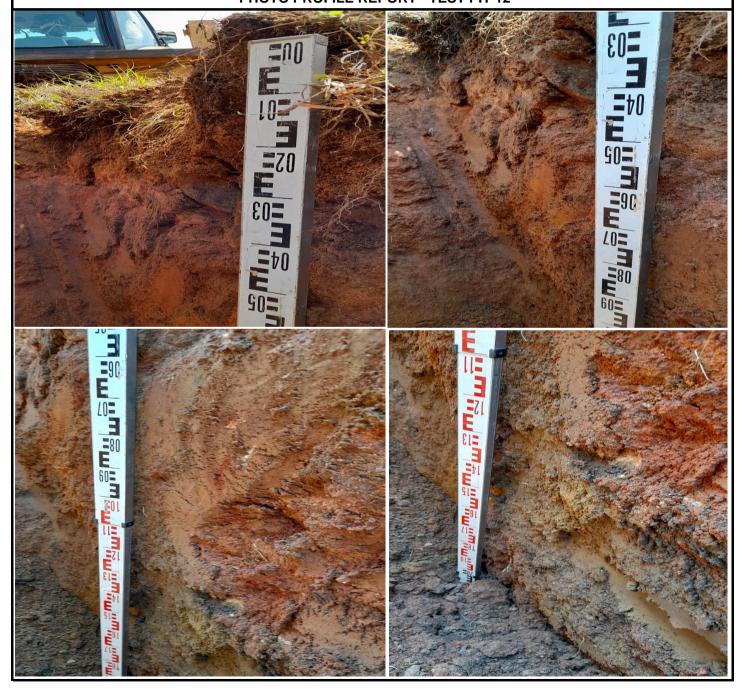
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### **PHOTO PROFILE REPORT - TEST PIT 12**





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#### **PHOTO PROFILE REPORT - TEST PIT 12**



		SUMMARY OF LABORATORY RESULTS (LANE)																																		
		DEPTH (mm)				SIEV	E ANALYSIS (	%PASSING)					SOIL M	ORTAR ANALY (<2mm)	SIS	ATTERBER				MODIFIED	AASHTO			CBR			CBR /	(UCS)			REACTIO	N WITH		CLASSIFIC	ATION	
TEST PIT NO.	COORDINATES	DESCRIPTION  1 HICKNESS (mm)  SAMPLE No.	75.0	63.0	50.0	37.5	20.0	14.0	5.0	0.425	0.075	В	0.425 < CS < 2	0.075 < FS < 0.425	MAT <0.075	± =	SI	ОМС	MDD	Insitu Moisture (%)	In situ Dry Density	Relative Moisture (%)	Relative Density (%)	SWELL	06	88	95	26	86	100	PHENOLPHTALIEN	HOL	4			
TP 01	-26,094461 28,090949	0         400         400         -         Topsoil - no sampling           400         700         300         3280         Slightly moist to dry, light brown, medium dense, intact, sandy gravel, imported           700         900         200         3281         Slightly moist to dry, orange, mrdium dense, intact, sandy gravel, residual           900         2000         1100         3282         Slightly moist, orange, medium dense, intact, sandy gravel, residual					100	98	96	44 30 76 53 76 50		2.06 1.36 1.41	31 30 34		47 4	5 16 15 22 10 20	2 11.0	n/a	n/a n/a n/a	n/a n/a n/a	n/a	n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	_	n/a n/a n/a	n/a n/a n/a		6(0) -6(2) -6(2)	<del></del>		
TP02	-26,064317 28,092329	0   500   500   - Topsoil - no sampling   1100   500   1100   600   3283   Sightly most, torange, intact, gravelly sand with building rubble, imported   1100   2000   900   3284   Sightly moist, crange biotched with black, dense, intact, sandy gravel, residual   1100   110		100		92 9	100	99	94		29	1.32		27		2 8	3.0	n/a	n/a n/a	n/a n/a	n/a		n/a n/a	n/a n/a	n/a n/a	n/a n/a	n/a n/a	n/a				n/a A-2		<del>_</del>	<u> </u>	
TP03	-26,093415 28,091876	0         300         300         - Topsoil - no sampling           300         800         500         3285         Slightly moist to dry, light brown, soft to medium dense, intact, sand, imported           800         1100         300         3286         Slightly moist, orange, medium dense, intact, sandy gravel, residual				100 9	6 93	83		48 34		1.12	28	26	46 3	8 13	1 10.0	n/a	n/a n/a	n/a	n/a	n/a	n/a	n/a n/a	n/a n/a	n/a n/a	n/a n/a	n/a n/a	n/a	n/a	n/a	n/a A-1 n/a A-2 n/a A-2	-6(1)			
TP04	-26,090802 28,090876	1100         2000         900         3287         Slightly moist, orange, medium dense, intact, gravelly clayey sand, residual           0         200         200         -         Topsoil - no sampling           200         800         600         3288         Slightly moist, light brown, medium dense, intact, sand, imported           800         1000         200         3289         Slightly moist to dry, light grey with mottled orange, dense, intact, sandy gravel, residual			100	97 9	3 84		100	97 55 66 36	33	1.37 1.16 1.78		23	33 2	5 11 8 6	6.0	n/a	n/a n/a n/a	n/a n/a n/a	n/a	n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a	n/a	_	n/a A-2 n/a A-2 n/a A-1	6(0)	<del>_</del>	<u> </u>	
TP05	-26,089455 28,090772	1000         1400         400         3290         Dry, orange yellow, very dense, intact, gravel, residual           0         800         800         -         Topsoil - no sampling           800         1400         600         3291         Slightly moist, light brown, soft, intact, sand, imported			100		7 39	99	99		29	1.24	_	22	29 2	9 7		n/a	n/a n/a	_	n/a	n/a		n/a n/a	n/a n/a	n/a n/a	n/a n/a	n/a n/a	n/a	n/a	n/a	n/a A-2	-6(0)			
		1400         1700         300         3292         Dry, orange, dense, intaxt, gravel, residual           1700         2200         500         3293         Dry, light grey, medium dense, intact, sand, residual           0         150         150         -         Topsoil - no sampling           150         300         150         3294         Slightly moist, light brown, soft, intact, gravelly sand, imported				10	100		100	82 47 99 51 85 47	28	1.45	43 49 45	23	28 2	1 7 23 6	3.0	n/a	n/a n/a n/a	n/a n/a n/a	n/a	n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a	n/a n/a n/a	n/a n/a		-4(0) -4(0)	<u>+</u>	<u></u>	
TP06	-26,087247 28,085895	300         700         400         3295         Dry, orange, dense, intact, sandy gravel, imported           700         1100         400         3296         Slightly moist, light brown, medium dense, intact, gravelly sand, residual           1100         1350         250         3297         Slightly moist, orange, medium dense, intact, sandy gravel, residual			100	-	00 97	100 95 70	95 89 50	85 52 85 52 40 25	30 30 16	1.33 1.33 2.2	39 39 36	25 25 24	36 2 36 2 40 3	16 10 16 11 12 15	5.0 5.0 5.0 5.0	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a A-2 n/a A-2 n/a A-2	-4(0) -6(0) -6(0)			
TP07	-26,087247 28,085895	1350         2000         650         3298         Slightly moist, orange, medium dense, intact, gravelly clayey sand, residual           0         150         150         -         Topsoil - no sampling           150         800         650         3299         Dry, light orange, very dense, intact, gravelly sand, imported           800         1800         1000         3300         Slightly moist, orange, dense, intact, gravelly clayey silt, residual					100	94	79	75 49 61 28 61 28	16	1.43 1.94 1.94	35 54 54	20	26 2	8 8 8 8	4.0	n/a	n/a n/a n/a	n/a n/a n/a	n/a	n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a	n/a n/a n/a	_	n/a A-2	-7(2) -4(0) -6(0)	<del>_</del>	<u> </u>	
TP08	-26,081189 28,086697	1800         2000         200         3301         Slightly moist, orange mottled with pale red and black, medium dense, intact, gravelly clayey silt, residual           0         100         100         -         Topsoil - no sampling           100         300         200         3302         Moist, orange, soft, intact, gravelly clay, imported					100	99	97	87 52 85 51	31	1.28	40		37 3	0 13		n/a	n/a n/a	n/a n/a	n/a	n/a	n/a n/a	n/a n/a	n/a n/a	n/a n/a	n/a n/a	n/a n/a	n/a	n/a n/a	n/a	n/a A-2	6(1)			
TP09	-26,078306 28,087195	300         400         100         3303         Dry, light crange, very dense, intact, gravelly sand, imported           0         200         200         -         Topsoil - no sampling           200         350         150         3304         Moist, orange, soft, intact, gravelly clay, imported           350         600         250         3305         Sibnity moist, orange, dense, intact, gravelly sand, imported					100	99	95	69 33 83 49 73 38	30	1.38	52 41 48	23	36 3	1 13	_	_	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a A-2	6(0) 4(0)	<del>_</del>		
TP10	-26,075495 28,087748	1200   600   3306   Slightly most, plea brown with mottled yellow, dense to very dense, intact, gravelly sand, residual   0   300   300   Topsoil - no sampling   300   600   3307   Slightly most, orange, soft, intact, gravelly sandy clay, imported						100		82 46	+	1.47	44		29 1	8 4	2.0	n/a	n/a n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a n/a	n/a n/a	n/a	n/a	n/a n/a	n/a		b(0)	<u>+</u>		
IP10	-25,075495 28,087748	600         800         200         3308         Dry, light orange, dense, intact, gravelly sand, imported           800         1200         400         3309         Slightly moist, orange, medium dense to dense, intact, gravelly sand, residual           0         200         200         -         Topsoil - no sampling					100	100	98		26 31	1.48 1.35	40	23	37 3	6 11	5.0		n/a n/a		n/a	n/a	n/a n/a	n/a n/a	n/a n/a	n/a n/a	n/a n/a	n/a n/a	_	n/a n/a		n/a A-2	6(1)			
TP11	-26,070408 28,089092	200         400         200         3310         Slightly moist, orange, soft, intact, gravelly sand, imported           400         700         300         3311         Slightly moist, orange, dense, intact, gravelly sand, imported           700         1100         400         3312         Slightly moist, dark brown, medium dense, intact, sand, residual           1100         1600         500         3313         Slightly moist, yellowish brown, soft to medium dense, intact, sand, residual					100	99	99	74 38 94 57	29 22 31 34	1.43 1.67 1.18 1.18	49 40	22 27	29 2	9 12 7 9 1 7 7 12	5.0 3.0	n/a n/a	n/a n/a n/a n/a	n/a n/a n/a n/a	n/a n/a	n/a n/a	n/a	n/a n/a n/a n/a	n/a n/a n/a n/a	n/a n/a n/a n/a	n/a n/a n/a n/a	n/a	n/a	n/a n/a	n/a n/a	n/a A-2 n/a A-2 n/a A-2 n/a A-2	4(0)			
TP 12	-26,064990 28,090453	1600         2000         400         3314         Slightly moist, brownish yellow, soft to medium dense, intact, clayey sand, residual           0         200         200         -         Topsoil - no sampling           200         550         350         3315         Slightly moist, light orange, soft, intact, gravelly sand, imported           550         1100         550         3316         Moist, reddish brown, soft, intact, gravelly clay, residual					100	100	99	90 52 81 50	30	1.33	42	24	34 2	3 17 4 9 8 15	5.0	n/a	n/a n/a n/a	n/a n/a n/a	n/a	n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a		n/a	n/a A-2 n/a A-2 n/a A-2	4(0)			
		1100         1700         600         3317         Moist, olive, soft, intact, sandy clay, residual           1700         2000         300         3318         Moist, brownish yellow, soft, intact, gravelly clay, residual           0         350         350         -         Topsoil - no sampling           350         450         100         3319         Slightly moist, orange, medium dense, intact, gravelly sand, imported						100	97	76 48	<u> </u>	1.12	37	24	39 2	2 9 8 10	7.0	n/a	n/a n/a	n/a n/a	n/a	n/a	n/a n/a	n/a n/a	n/a n/a	n/a n/a	n/a n/a	n/a n/a	n/a	n/a	n/a	n/a A-2 n/a A-2	4(0)			
TP 13	-26,060091 28,090406	350         450         100         3319         Slightly moist, orange, medium dense, intact, gravelly sand, imported           450         1100         650         3320         Slightly moist, dark brown, medium dense, intact, gravelly sand, residual           1100         1500         400         3321         Slightly moist, reddish brown, soft to medium dense, intact, clayey gravelly sand, residual           1500         2000         500         3322         Slightly moist, orange, soft to medium dense, intact, gravelly sity sand, residual				100 9	8 97	94 98	94	82 48 82 51	33 27 30 29	1.27 1.43 1.38 1.47	41 37	24 26 26 24	33 2 37 2	2 8	4.0	n/a n/a	n/a n/a n/a n/a	n/a n/a	n/a n/a	n/a n/a n/a n/a	n/a n/a	n/a n/a n/a n/a	n/a n/a n/a n/a	n/a n/a n/a n/a	n/a n/a n/a n/a	n/a	n/a	n/a	n/a n/a	n/a A-2 n/a A-2 n/a A-2 n/a A-2	4(0)	<del>-</del>		
TP 14	-26,057117 28,090019	0         300         300         - Topsoil - no sampling           300         650         350         3323         Dry, brown, medium dense, intact, sand, imported           650         1100         450         3324         Slightly moist, dark brown, medium dense, intact, gravelly sand, residual           1100         2000         900         3325         Slightly moist, reddish brown, soft to medium dense, intacr, clayey gravelly sand, residual				100 9	8 97	96	96 92 98		26 20 25	1.38 1.81 1.63	51	25 19 20	30 3	0 4 1 12 5 16	7.0	n/a	n/a n/a n/a	_	n/a	n/a n/a n/a	n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a		n/a n/a n/a	n/a	n/a	n/a A-2 n/a A-2 n/a A-2	6(0)			
TP 15 & 16	-26,056061 28,088786	0         300         300         3328         Dry, light brown, soft, intact, sandy gravel, imported           300         800         500         3329         Slightly moist, brownish red, medium dense, intact, gravelly sand, imported           800         1200         400         3330         Slightly moist, brown, medium dense, intact, sandy gravel, imported				100 9	8 88 4 90 6 92	83 88 89	70 81 77	59 37 74 46 71 43	21 26 25	1.83 1.54 1.61	38 38 39	26 27 26	36 2 35 2 35 2	3 11 4 9 3 10	5.0 5.0 5.0	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a A-2 n/a A-2 n/a A-2	6(0) 4(0) 4(0)			
TP 17	-26,056390 28,085654	1200         2000         800         3331         Slightly moist, orange, medium dense, intact, clayey silt, residual           0         200         200         -         Topsoil - no sampling           200         850         650         3326         Slightly moist, reddish - brown orange, medium dense, intact, gravelly sand, imported           850         200         -650         3327         Slightly moist, greyish brown, medium dense, intact, gravelly silty sand, imported				100 9		92		74 40	23 22	1.64	46	23 24	31 2		4.0	n/a	n/a n/a n/a		n/a	n/a n/a n/a	'	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a		n/a	n/a A-2 n/a A-2 n/a A-2	4(0)	<del></del>		
TP 18	-26,049795 28,085837	0         300         300         -         Topsoil - no sampling           300         2000         1700         3333         Slightly moist, light orange yellow, medium dense, intact, gravelly sand, residual					100	99	95	82 45	27	1.46	45	22	33 3	1 13	7.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a A-2	6(0)			





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Fax

Email: martinus.schwartz@sgs.com

### **TEST RESULTS**

NYELETI CONSULTING (PTY)LTD

P.O BOX 35158 **MENLO PARK** 

0102

Attention: Yashini

Project

: Woodmead Water Upgrade

Your Ref

: PL/45743

Our Ref Date Reported : 14.10.2021

### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO.	A21/3280	A21/3281	A21/3282	Preparation Method
HOLE NO.	TP1	TP1	TP1	
ROAD NO.	1 ** *		1	
DEPTH	400-700	700-900	900-2000	
CHAINAGE	400-700	700-900	900-2000	
		1		
LAYER TYPE				
STABILISED WITH	Natural	Natural	Natural	
SUPPLIER				
CURING METHOD				
DATE TESTED	04.10.2021	04.10.2021	04.10.2021	
DESCRIPTION	Light brown	Orange	Orange	- Specification
		o ranigo	o range	COTO:2020
CIEVE ANALYGIO (9/ PAGGING)				
SIEVE ANALYSIS (% PASSING)				
100.0 mm				
75.00 mm				
63.00 mm	None management			
50.00 mm	100			
37.50 mm	92		100	
28.00 mm	88	1	97	
20.00 mm	82	100	96	
14.00 mm	76	98	95	
5.000 mm	57	96	93	
2.000 mm	44	76	76	
0.425 mm	30	53	50	
0.075 mm	19	35	33	
SOIL MORTAR				
COARSE SAND <2.0mm >0.425mm	1 31	30	34	
FINE SAND <0.425mm >0.475mm	26	23	23	
MATERIAL <0.075mm	43			
	43	47	43	
CONSTANTS				
GRADING MODULUS	2.06	1.36	1.41	
PRA CLASSIFICATION	A-2-6(0)	A-7-6(2)	A-2-6(2)	
LIQUID LIMIT (%)	35	45	40	1
PLASTICITY INDEX (0.425mm)	16	22	20	
LINEAR SHRINKAGE (%)	9.0	11.0	10.0	
LINEAR SHAINWAGE (70)	9.0	11.0	10.0	

Remarks:

FORM: GR40

4.5.0(SGS)(2021.05.05)





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### **TEST RESULTS**

NYELETI CONSULTING (PTY)LTD

P.O BOX 35158 MENLO PARK

0102

Attention: Yashini

Project

: Woodmead Water Upgrade

Your Ref

Our Ref Date Reported : PL/45743a

: 14.10.2021

#### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

	SAMPLE NO. HOLE NO. ROAD NO.	A21/3283 TP2	A21/3284 TP2		Preparation Method:
	DEPTH CHAINAGE	500-1100	1100-2000		
	LAYER TYPE STABILISED WITH SUPPLIER	Natural	Natural		
	CURING METHOD DATE TESTED DESCRIPTION	04.10.2021 Light brown	04.10.2021 Orange		- Specification
	186,050,000,000 (\$100,000)	Light brown	Grange		COTO:2020
	SIEVE ANALYSIS (% PASSING)				
	100.0 mm				
	75.00 mm 63.00 mm		100		
	50.00 mm		96		
	37.50 mm		92		
	28.00 mm		91		
	20.00 mm	100	90		
	14.00 mm	99	88		
	5.000 mm	94	85		
	2.000 mm	87	71		2
-	0.425 mm 0.075 mm	52 29	33 19		
l		29	19		
,	SOIL MORTAR			<u> </u>	
-	COARSE SAND <2.0mm >0.425mm		54		
-	FINE SAND <0.425mm >0.075mm	27	19		
Į	MATERIAL <0.075mm	33	27		
	CONSTANTS				
1	GRADING MODULUS	1.32	1.77		
1	PRA CLASSIFICATION	A-2-4(0)	A-2-4(0)		
	LIQUID LIMIT (%)	22	29		
	PLASTICITY INDEX (0.425mm) LINEAR SHRINKAGE (%)	8 3.0	10 5.0		
- 1	LITTLY II COLITION TOL (70)	0.0	0.0		

Remarks:

FORM: GR40

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### **TEST RESULTS**

NYELETI CONSULTING (PTY)LTD

P.O BOX 35158 MENLO PARK

0102

Attention: Yashini

Project

: Woodmead Water Upgrade

Your Ref

: PL/45742b

Our Ref Date Reported : 14.10.2021

#### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO. HOLE NO.	A21/3285 TP3	A21/3286 TP3	A21/3287	Preparation Method:
ROAD NO.	1173	1173	TP3	
DEPTH	300-800	800-1100	1100-2000	
CHAINAGE				
LAYER TYPE STABILISED WITH	Natural	Natural	Netural	
SUPPLIER	ivaturai	Naturai	Natural	
CURING METHOD				
DATE TESTED	04.10.2021	04.10.2021	04.10.2021	
DESCRIPTION	Light brown	Orange	Orange	- Specification
				COTO:2020
SIEVE ANALYSIS (% PASSING)				
100.0 mm				
75.00 mm 63.00 mm				
50.00 mm				
37.50 mm		100		
28.00 mm		96		
20.00 mm	52	93		
14.00 mm	100	86	100	
5.000 mm	99	67	99	
2.000 mm	93	48	84	
0.425 mm 0.075 mm	60 36	34 22	48 31	
717.7.11111	30	22	31	
SOIL MORTAR	0.5	T		
COARSE SAND <2.0mm >0.425mm FINE SAND <0.425mm >0.075mm		28	43	
MATERIAL <0.075mm	26 39	26 46	21 36	
	39	40	30	
CONSTANTS				
GRADING MODULUS PRA CLASSIFICATION	1.12 A-6(1)	1.95 A-2-6(1)	1.37	
LIQUID LIMIT (%)	28	39	A-2-6(1) 40	
PLASTICITY INDEX (0.425mm)	13	21	18	
LINEAR SHRINKAGE (%)	6.0	10.0	9.0	

K	er	n	а	ri	(8	6	:
_	_	_	_	_	_	_	_

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### **TEST RESULTS**

NYELETI CONSULTING (PTY)LTD

P.O BOX 35158 MENLO PARK

0102

Attention: Yashini

Project

: Woodmead Water Upgrade

Your Ref

Our Ref

: PL/45743c

Date Reported

: 14.10.2021

#### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO. HOLE NO.	A21/3288 TP4	A21/3289 TP4	A21/3290 TP4	Preparation Method
ROAD NO. DEPTH CHAINAGE	200-800	800-1000	1000-1400	
LAYER TYPE STABILISED WITH SUPPLIER	Natural	Natural	Natural	
CURING METHOD DATE TESTED DESCRIPTION	04.10.2021 Light brown	04.10.2021 Light grey	04.10.2021 Orange yellow	- Specification COTO:2020
SIEVE ANALYSIS (% PASSING)		•		
100.0 mm 75.00 mm 63.00 mm 50.00 mm		100	100	
37.50 mm 28.00 mm 20.00 mm		97 93 84	64 47 39	
14.00 mm 5.000 mm 2.000 mm	100 97	80 72 66	35 23 19	
0.425 mm 0.075 mm	55 33	36 20	11 6	
SOIL MORTAR				
COARSE SAND <2.0mm >0.425mn FINE SAND <0.425mm >0.075mm MATERIAL <0.075mm	1 44   23   33	45 26 29	43 25 32	
CONSTANTS				
GRADING MODULUS PRA CLASSIFICATION LIQUID LIMIT (%) PLASTICITY INDEX (0.425mm) LINEAR SHRINKAGE (%)	1.16 A-2-6(0) 25 11 6.0	1.78 A-1-b(0) 18 6 3.0	2.64 A-2-4(0) 19 7 4.0	

Remarks:

FORM: GR40

4.5.0(SGS)(2021.05.05)

Technical Signatory: Marthus Schwartz/Sunil Dewnath

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### **TEST RESULTS**

NYELETI CONSULTING (PTY)LTD

P.O BOX 35158 MENLO PARK

0102

Attention: Yashini

Project

: Woodmead Water Upgrade

Your Ref Our Ref

: PL/45743d

: 18.10.2021 Date Reported

### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO. HOLE NO.	A21/3291 TP5	A21/3292 TP5	A21/3293 TP5	Pro	eparation Method:
ROAD NO. DEPTH	800-1400	1400-1700	1700-2200		
CHAINAGE	000-1400	1400-1700	1700-2200		
LAYER TYPE		20.2			
STABILISED WITH SUPPLIER	Natural	Natural	Natural		
CURING METHOD					
DATE TESTED	04.10.2021	04.10.2021	04.10.2021		Specification
DESCRIPTION	Light brown	Orange	Light grey	1 -	COTO:2020
SIEVE ANALYSIS (% PASSING)					
100.0 mm					
75.00 mm					
63.00 mm					
50.00 mm					
37.50 mm		100			
28.00 mm 20.00 mm	100	97			
14.00 mm	99	95			
5.000 mm	99	89	100		
2.000 mm	98	82	99		
0.425 mm	50	47	51		
0.075 mm	29	26	28		
SOIL MORTAR			L		
COARSE SAND <2.0mm >0.425mn		43	49		
FINE SAND <0.425mm >0.075mm		25	23		
MATERIAL <0.075mm	29	32	28		
CONSTANTS					
GRADING MODULUS	1.24	1.45	1.22		
PRA CLASSIFICATION	A-2-6(0)	A-2-4(0)	A-2-4(0)		
LIQUID LIMIT (%)	24	21	23		
PLASTICITY INDEX (0.425mm)	11	7	6		
LINEAR SHRINKAGE (%)	5.0	4.0	3.0		

Remarks :									
FORM: GR40									

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### **TEST RESULTS**

NYELETI CONSULTING (PTY)LTD

P.O BOX 35158 MENLO PARK

0102

Attention: Yashini

Project

: Woodmead Water Upgrade

Your Ref

Our Ref

: PL/45743e

Date Reported : 18.10.2021

### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO.	A21/3294	A21/3295	A21/3296	A21/3297	Preparation Method:
HOLE NO.	TP6	TP6	TP6	TP6	
ROAD NO.					
DEPTH	150-300	300-700	700-1100	1100-1350	
CHAINAGE					
LAYER TYPE	Material	Matural	National	National	
STABILISED WITH SUPPLIER	Natural	Natural	Natural	Natural	
CURING METHOD					
DATE TESTED	04.10.2021	04.10.2021	04.10.2021	04.10.2021	
DESCRIPTION	Light brown	Orange	Light brown	Orange	- Specification
BEGGIAII FIGIT	Light brown	Orango	Light brown	Orango	COTO:2020
SIEVE ANALYSIS (% PASSING)					
100.0 mm		T	I	I	
75.00 mm					
63.00 mm					
50.00 mm				100	
37.50 mm				98	1
28.00 mm			100	89	
20.00 mm	100		97	79	
14.00 mm	98	100	95	70	
5.000 mm	95	95	89	50	1
2.000 mm	85	85	85	40	
0.425 mm 0.075 mm	47 27	52 30	52 30	25 16	
	21	30	30	10	
SOIL MORTAR		,			
COARSE SAND <2.0mm >0.425mn		39	39	36	
FINE SAND <0.425mm >0.075mm		25	25	24	
MATERIAL <0.075mm	31	36	36	40	
CONSTANTS					
GRADING MODULUS	1.41	1.33	1.33	2.20	
PRA CLASSIFICATION	A-2-6(0)	A-2-4(0)	A-2-6(0)	A-2-6(0)	
LIQUID LIMIT (%)	25	26	26	32	
PLASTICITY INDEX (0.425mm)	11	10	11	15	
LINEAR SHRINKAGE (%)	5.0	5.0	5.0	8.0	

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FORM: GR40

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### **TEST RESULTS**

NYELETI CONSULTING (PTY)LTD

P.O BOX 35158 MENLO PARK

0102

Attention: Yashini

Project

: Woodmead Water Upgrade

Your Ref

Our Ref

: PL/45743f

Date Reported

: 18.10.2021

### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO. HOLE NO. ROAD NO. DEPTH CHAINAGE LAYER TYPE STABILISED WITH SUPPLIER CURING METHOD DATE TESTED	A21/3298 TP6 1350-2000 Natural			Preparation Method:
DESCRIPTION	Orange			COTO:2020
SIEVE ANALYSIS (% PASSING)				
100.0 mm 75.00 mm 63.00 mm 50.00 mm 37.50 mm 28.00 mm 20.00 mm 14.00 mm 5.000 mm 2.000 mm 0.425 mm 0.075 mm	100 97 75 49 32			
SOIL MORTAR COARSE SAND <2.0mm >0.425mm	1 35	<u> </u>		T
FINE SAND <0.425mm >0.425mm MATERIAL <0.075mm				
CONSTANTS				
GRADING MODULUS PRA CLASSIFICATION LIQUID LIMIT (%) PLASTICITY INDEX (0.425mm) LINEAR SHRINKAGE (%)	1.43 A-2-7(2) 42 20 10.0			

Remarks : FORM: GR40	A	
4.5.0(SGS)(2021.05.05)	Technical Signatory : Martinus Schwartz/Lizette Breiting	





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### **TEST RESULTS**

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: Woodmead Water Upgrade

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Our Ref Date Reported

: PL/45743g : 18.10.2021

SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

		,		
SAMPLE NO.	A21/3299	A21/3300	A21/3301	Preparation Method:
HOLE NO.	TP7	TP7	TP7	
ROAD NO.	1 22 2	2.5	1 24 4	1
DEPTH	150-800	800-1800	1800-2000	1
CHAINAGE	100 000	000 1000	1000-2000	1
LAYER TYPE				
STABILISED WITH	Natural	Natural	Natural	1
SUPPLIER	ivaturai	Naturai	Naturai	1
				1
CURING METHOD				1
DATE TESTED	04.10.2021	04.10.2021	04.10.2021	0 16 11
DESCRIPTION	Light orange	Orange	Orange	- Specification
	***	20047	5407	COTO:2020
SIEVE ANALYSIS (% PASSING)				
100.0 mm				
75.00 mm				
63.00 mm	1			1
50.00 mm	1			
37.50 mm	1			1
28.00 mm				
	100	100		1
20.00 mm	100	100	100	
14.00 mm	94	99	100	1
5.000 mm	79	98	99	
2.000 mm	61	87	87	
0.425 mm	28	57	52	
0.075 mm	16	34	32	
SOIL MORTAR			· · · · · · · · · · · · · · · · · · ·	
COARSE SAND <2.0mm >0.425mm	n 54	34	40	
FINE SAND <0.425mm >0.075mm		26	24	
MATERIAL <0.075mm	26	40	36	
	20	40	30	
CONSTANTS	Υ		<del></del>	·
GRADING MODULUS	1.94	1.22	1.28	
PRA CLASSIFICATION	A-2-4(0)	A-2-6(0)	A-2-6(1)	
LIQUID LIMIT (%)	28	33	33	
PLASTICITY INDEX (0.425mm)	8	12	17	
LINEAR SHRINKAGE (%)	4.0	7.0	7.0	

Remarks:

FORM: GR40

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: PL/45743h

Date Reported

: 18.10.2021

#### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO. HOLE NO.	A21/3302 TP8	A21/3303 TP8		Preparation Method:
ROAD NO. DEPTH	100-300	300-400		
CHAINAGE LAYER TYPE	100 000	000 400		
STABILISED WITH SUPPLIER	Natural	Natural		
CURING METHOD	04.40.0004	04.40.0004		
DATE TESTED DESCRIPTION	04.10.2021 Orange	04.10.2021 Light orange		- Specification
		0.00		COTO:2020
SIEVE ANALYSIS (% PASSING)	,		 	
100.0 mm				
75.00 mm				
63.00 mm 50.00 mm				
37.50 mm				
28.00 mm				
20.00 mm	100			
14.00 mm	99	100		
5.000 mm	97	88		
2.000 mm	85	69		
0.425 mm	51	33		
0.075 mm	31	18		
SOIL MORTAR				
COARSE SAND <2.0mm >0.425mn		52		
FINE SAND <0.425mm >0.075mm		21		
MATERIAL <0.075mm	37	27	5.	
CONSTANTS			 	
GRADING MODULUS	1.33	1.80		
PRA CLASSIFICATION	A-2-6(0)	A-1-b(0)		
LIQUID LIMIT (%)	30	30		
PLASTICITY INDEX (0.425mm) LINEAR SHRINKAGE (%)	13 7.0	6 3.0		
LINEAR SHRINKAGE (70)	7.0	3.0		

Remarks:

FORM: GR40

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### **TEST RESULTS**

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: Woodmead Water Upgrade

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: PL/45743i

Date Reported : 18.10.2021

### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO. HOLE NO.	A21/3304 TP9	A21/3305 TP9	A21/3306 TP9	Preparation Method:
ROAD NO.	507 500		30.000	
DEPTH	200-350	350-600	600-1200	
CHAINAGE				
LAYER TYPE STABILISED WITH	Natural	Natural	Natural	
SUPPLIER	Ivaturai	Ivaturai	Natural	
CURING METHOD				
DATE TESTED	04.10.2021	04.10.2021	04.10.2021	0 15 11
DESCRIPTION	Orange	Orange	Pale red	- Specification COTO:2020
				CO10.2020
SIEVE ANALYSIS (% PASSING)				
100.0 mm				
75.00 mm				
63.00 mm				
50.00 mm 37.50 mm				
28.00 mm				
20.00 mm	100	100		
14.00 mm	99	99	100	
5.000 mm	95	90	98	
2.000 mm	83	73	82	
0.425 mm	49 30	38	46 25	
0.075 mm	30	22	25	
SOIL MORTAR		·		
COARSE SAND <2.0mm >0.425mm		48	44	
FINE SAND <0.425mm >0.075mm		22	27	
MATERIAL <0.075mm	36	30	29	
CONSTANTS			<u> </u>	
GRADING MODULUS	1.38	1.68	1.47	
PRA CLASSIFICATION	A-2-6(0)	A-2-4(0)	A-1-b(0)	
LIQUID LIMIT (%)	31 13	26 9	18	
PLASTICITY INDEX (0.425mm) LINEAR SHRINKAGE (%)	7.0	5.0	2.0	
LINEAR OF MININAGE (70)	7.0	5.0	2.0	

Remarks :				
FORM:	GR40			

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### **TEST RESULTS**

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Project

: Woodmead Water Upgrade

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: PL/45743j

Date Reported : 18.10.2021

### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO. HOLE NO.	A21/3307 TP10	A21/3308 TP10	A21/3309 TP10	Preparation Method:
ROAD NO. DEPTH	300-600	600-800	800-1200	
CHAINAGE	000 000	000 000	000 1200	
LAYER TYPE STABILISED WITH	Natural	Natural	Natural	
SUPPLIER	Naturai	Naturai	Ivaturai	
CURING METHOD DATE TESTED	05.10.2021	05.10.2021	05.10.2021	
DESCRIPTION	Orange	Light orange	Orange	- Specification
20-04-000 (CC 200-02-0)		0 0	3	COTO:2020
SIEVE ANALYSIS (% PASSING)			,	
100.0 mm 75.00 mm				
63.00 mm				
50.00 mm				
37.50 mm				
28.00 mm	400	100		
20.00 mm	100	100	100	
14.00 mm 5.000 mm	99 95	99 94	100 98	
2.000 mm	83	81	84	
0.425 mm	50	45	51	1
0.075 mm	30	26	31	
SOIL MORTAR			·	
COARSE SAND <2.0mm >0.425mn	n 40	44	40	
FINE SAND <0.425mm >0.075mm		24	23	1
MATERIAL <0.075mm	36	32	37	
CONSTANTS				
GRADING MODULUS	1.37	1.48	1.35	
PRA CLASSIFICATION	A-2-4(0)	A-2-6(0)	A-2-6(1)	
LIQUID LIMIT (%)	26	26	33	
PLASTICITY INDEX (0.425mm)	10	11	14	
LINEAR SHRINKAGE (%)	6.0	5.0	7.0	

Remarks:

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### **TEST RESULTS**

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0102 Attention: Yashini Project

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Date Reported

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### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO.	A21/3310	A21/3311	A21/3312	A21/3313	Preparation Method:
HOLE NO.	TP11	TP11	TP11	TP11	
ROAD NO.	1		11 11		1
DEPTH	200-400	400-700	700-1100	1100-1600	1
CHAINAGE	200-400	400-700	700-1100	1100-1000	1
LAYER TYPE			1		1
STABILISED WITH	Natural	Natural	Natural	Natural	1 1
SUPPLIER	Naturai	Maturai	Naturai	INALUIAI	1
			1	1	1
CURING METHOD	05 40 2024	05 10 2021	05 10 2021	05.10.2021	1
DATE TESTED	05.10.2021	05.10.2021	05.10.2021		- Specification
DESCRIPTION	Orange	Orange	Dark brown	Yellow brown	COTO:2020
					0010.2020
SIEVE ANALYSIS (% PASSING)					
100.0 mm					
75.00 mm					1
63.00 mm			1		1
50.00 mm					1
37.50 mm			1	1	1
28.00 mm			1		
20.00 mm		100	1	1	1
14.00 mm	100	99	100	100	1
5.000 mm	95	91	99	99	1
2.000 mm	81	74	94	89	1
0.425 mm	48	38	57	58	
0.075 mm	29	22	31	34	
SOIL MORTAR					
COARSE SAND <2.0mm >0.425mm	n 41	49	40	35	
FINE SAND <0.425mm >0.075mm		22	27	27	
	35	29	33	38	
MATERIAL <0.075mm	35	29	33	30	
CONSTANTS					
GRADING MODULUS	1.43	1.67	1.18	1.18	
PRA CLASSIFICATION	A-2-6(0)	A-2-4(0)	A-2-4(0)	A-2-6(0)	
LIQUID LIMIT (%)	29	27	21	27	
PLASTICITY INDEX (0.425mm)	12	9	7	12	
LINEAR SHRINKAGE (%)	6.0	5.0	3.0	6.0	
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Remarks:

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### **TEST RESULTS**

NYELETI CONSULTING (PTY)LTD

P.O BOX 35158 MENLO PARK

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Attention: Yashini

Project

: Woodmead Water Upgrade

Your Ref Our Ref

: PL/45743I

Date Reported

: 18.10.2021

### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO. HOLE NO.	A21/3314 TP11		Preparation Method:
ROAD NO.			
DEPTH	1600-2000		
CHAINAGE	and the second of the second o		
LAYER TYPE	600m2 7500		
STABILISED WITH	Natural		
SUPPLIER			
CURING METHOD	05 40 0004		
DATE TESTED DESCRIPTION	05.10.2021		- Specification
DESCRIPTION	Brown yellow		COTO:2020
			0010.2020
SIEVE ANALYSIS (% PASSING)	T		
100.0 mm			
75.00 mm			
63.00 mm 50.00 mm			
37.50 mm			
28.00 mm			
20.00 mm			
14.00 mm	100		
5.000 mm	97		
2.000 mm	84		
0.425 mm	51		
0.075 mm	32		
SOIL MORTAR			
COARSE SAND <2.0mm >0.425mn	n 39		
FINE SAND <0.425mm >0.075mm			
MATERIAL <0.075mm	38		
CONSTANTS			
GRADING MODULUS	1.33		
PRA CLASSIFICATION	A-2-6(1)		
LIQUID LIMIT (%)	33		
PLASTICITY INDEX (0.425mm)	17		
LINEAR SHRINKAGE (%)	8.0		

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### **TEST RESULTS**

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P.O BOX 35158 MENLO PARK

0102

Attention: Yashini

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: Woodmead Water Upgrade

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: PL/45743m

Date Reported

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#### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO. HOLE NO.	A21/3315 TP12	A21/3316 TP12	A21/3317 TP12	A21/3318 TP12	Preparation Method:
ROAD NO.					
DEPTH CHAINAGE	200-550	550-1100	1100-1700	1700-2000	
LAYER TYPE					
STABILISED WITH	Natural	Natural	Natural	Natural	
SUPPLIER CURING METHOD					
DATE TESTED	05.10.2021	05.10.2021	05.10.2021	05.10.2021	Charification
DESCRIPTION	Light orange	Red brown	Olive	Brown yellow	- Specification COTO:2020
SIEVE ANALYSIS (% PASSING)					
100.0 mm					
75.00 mm 63.00 mm					
50.00 mm					
37.50 mm					
28.00 mm					
20.00 mm		100			
14.00 mm	100	99	100	100	
5.000 mm	99	95	99	97	
2.000 mm	90	81	93	76	
0.425 mm	52 30	50 30	60 34	48 29	
0.075 mm	30	30	34	29	
SOIL MORTAR			T		T
COARSE SAND <2.0mm >0.425mm		39	35	37	
FINE SAND <0.425mm >0.075mm	24	24	29	24	
MATERIAL <0.075mm	34	37	36	39	
CONSTANTS			•		
GRADING MODULUS	1.28	1.39	1.12	1.47	
PRA CLASSIFICATION	A-2-4(0)	A-2-6(1)	A-2-4(0)	A-2-4(0)	
LIQUID LIMIT (%)	24	28	22	28	
PLASTICITY INDEX (0.425mm)	9 5.0	15 7.0	9	10 7.0	
LINEAR SHRINKAGE (%)	5.0	7.0	4.0	7.0	

Remarks

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### **TEST RESULTS**

NYELETI CONSULTING (PTY)LTD

P.O BOX 35158 MENLO PARK

0102 Attention: Yashini Project

: Woodmead Water Upgrade

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#### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO. HOLE NO. ROAD NO.	A21/3319 TP13	A21/3320 TP13	A21/3321 TP13	A21/3322 TP13	Preparation Method:
DEPTH CHAINAGE	350-450	450-1100	1100-1500	1500-2000	
LAYER TYPE STABILISED WITH SUPPLIER	Natural	Natural	Natural	Natural	
CURING METHOD DATE TESTED DESCRIPTION	05.10.2021 Orange	05.10.2021 Dark brown	05.10.2021 Red brown	05.10.2021 Orange	- Specification COTO:2020
SIEVE ANALYSIS (% PASSING)					
100.0 mm 75.00 mm 63.00 mm 50.00 mm 37.50 mm 28.00 mm 20.00 mm 14.00 mm 5.000 mm 2.000 mm	100 97 87 54 33	100 98 97 94 89 82 48 27	100 98 94 82 51 30	100 99 93 73 41 25	
0.075 mm	33	21	30	25	
SOIL MORTAR COARSE SAND <2.0mm >0.425mm	า 38	41	37	44	1
FINE SAND <0.425mm >0.425mm MATERIAL <0.075mm		26 33	26 37	22 34	
CONSTANTS					
GRADING MODULUS PRA CLASSIFICATION LIQUID LIMIT (%) PLASTICITY INDEX (0.425mm) LINEAR SHRINKAGE (%)	1.27 A-2-6(1) 31 13 7.0	1.43 A-2-4(0) 22 8 4.0	1.38 A-2-4(0) 25 10 5.0	1.61 A-2-6(0) 33 13 7.0	

Remarks: FORM: GR40

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### **TEST RESULTS**

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Attention: Yashini

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### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO. HOLE NO.	A21/3323 TP14	A21/3324 TP14	A21/3325 TP14		Preparation Method
ROAD NO. DEPTH	300-650	650-1100	1100-2000		
CHAINAGE LAYER TYPE					
STABILISED WITH SUPPLIER	Natural	Natural	Natural		
CURING METHOD DATE TESTED	05.10.2021	05.10.2021	05.10.2021		- Specification
DESCRIPTION	Brown yellow	Orange	Orange		COTO:2020
SIEVE ANALYSIS (% PASSING)					
100.0 mm					
75.00 mm					
63.00 mm					
37.50 mm		100			
28.00 mm		98			
20.00 mm	100	97	100		
14.00 mm	99	96	100		
5.000 mm	96	92	98		
2.000 mm	89	67	72		
0.425 mm	48	33	40		
0.075 mm	26	20	25		
SOIL MORTAR					
COARSE SAND <2.0mm >0.425mm		51	45		
FINE SAND <0.425mm >0.075mm	25	19	20		
MATERIAL <0.075mm	29	30	35		
CONSTANTS				*	
GRADING MODULUS	1.38	1.81	1.63		
PRA CLASSIFICATION	A-2-4(0)	A-2-6(0)	A-2-6(1)		
LIQUID LIMIT (%)	20	31	35		
PLASTICITY INDEX (0.425mm) LINEAR SHRINKAGE (%)	4 2.0	12 7.0	16		
LINEAR SHRINKAGE (%)	2.0	7.0	8.0		1

Remarks	; ;

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### **TEST RESULTS**

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Your Ref Our Ref

: PL/45743p

Date Reported

: 18.10.2021

### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO. HOLE NO.	A21/3326 TP17	A21/3327 TP17			Preparation Method:	
ROAD NO. DEPTH	200-850	850-2000				
CHAINAGE LAYER TYPE STABILISED WITH	Natural	Natural				
SUPPLIER CURING METHOD	INatural	Naturai				
DATE TESTED	05.10.2021	05.10.2021			- Specification	
DESCRIPTION	Red brown orange	Grey brown			COTO:2020	
SIEVE ANALYSIS (% PASSING)						
100.0 mm 75.00 mm						
63.00 mm						
50.00 mm						
37.50 mm	100	100				
28.00 mm	98	98				
20.00 mm	93	95				
14.00 mm	92	93				
5.000 mm	85	84				
2.000 mm	74	71				
0.425 mm	40	39				
0.075 mm	23	22				
SOIL MORTAR						
COARSE SAND <2.0mm >0.425mm		45				
FINE SAND <0.425mm >0.075mm		24				
MATERIAL <0.075mm	31	31				
CONSTANTS						
GRADING MODULUS	1.64	1.68				
PRA CLASSIFICATION	A-2-4(0)	A-2-4(0)				
LIQUID LIMIT (%)	26	25				
PLASTICITY INDEX (0.425mm)	8	8				
LINEAR SHRINKAGE (%)	4.0	4.0				

Remarks :			
FORM: GR40			

4.5.0(SGS)(2021.05.05)







SGS MATROLAB (PTY) LTD - CIVIL ENGINEERING SERVICES -Reg.No.: 2003/021980/07 - VAT. Reg.No.: 4040210587

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### **TEST RESULTS**

NYELETI CONSULTING (PTY)LTD

P.O BOX 35158 **MENLO PARK** 

0102

Attention: Yashini

Project

: Woodmead Water Upgrade

Your Ref

Our Ref

: PL/45743q

Date Reported : 18.10.2021

### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO.	A21/3328	A21/3329	A21/3330	A21/3331	Preparation Method	
HOLE NO.	TP15 & 16	TP15 & 16	TP15 & 16	TP15 & 16	1 Toparation Wothou	
ROAD NO.	1	1. 10 0. 10	11 10 4 10	11 10 4 10		
DEPTH	0-300	300-800	800-1200	1200-2000		
CHAINAGE	0-500	300-000	000-1200	1200-2000		
LAYER TYPE						
STABILISED WITH	Natural	Network	N-1	N-7		
	Naturai	Natural	Natural	Natural		
SUPPLIER						
CURING METHOD						
DATE TESTED	05.10.2021	05.10.2021	05.10.2021	05.10.2021		
DESCRIPTION	Light brown	Brown red	Brown	Orange	- Specification	
	32.534				COTO:2020	
SIEVE ANALYSIS (% PASSING)						
100.0 mm						
75.00 mm						
63.00 mm						
50.00 mm	100					
37.50 mm	99	100	100	400		
			100	100		
28.00 mm	98	94	96	99		
20.00 mm	88	90	92	95		
14.00 mm	83	88	89	94		
5.000 mm	70	81	77	89		
2.000 mm	59	74	71	77		
0.425 mm	37	46	43	50		
0.075 mm	21	26	25	32		
SOIL MORTAR						
COARSE SAND <2.0mm >0.425mm	1 38	38	39	35		
FINE SAND <0.425mm >0.075mm	26	27	26	23		
MATERIAL <0.075mm	36	35	35	42		
	30	33	35	42		
CONSTANTS						
GRADING MODULUS	1.83	1.54	1.61	1.41		
PRA CLASSIFICATION	A-2-6(0)	A-2-4(0)	A-2-4(0)	A-2-6(2)		
LIQUID LIMIT (%)	23	24	23	39		
PLASTICITY INDEX (0.425mm)	11	9	10	20		
LINEAR SHRINKAGE (%)	5.0	5.0	5.0	9.0		
	5.0	0.0	0.0	5.0		

Remarks:

FORM: GR40

4.5.0(SGS)(2021.05.05)





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### **TEST RESULTS**

NYELETI CONSULTING (PTY)LTD

P.O BOX 35158 MENLO PARK

0102

Attention: Yashini

Project

: Woodmead Water Upgrade

Your Ref Our Ref

: PL/45743r

Date Reported

: 18.10.2021

### SIEVE ANALYSIS, CONSTANTS(SANS 3001:GR1,GR10,GR12)

SAMPLE NO. HOLE NO.	A21/3332 TP18	A21/3333 TP18			Preparation Method:
ROAD NO. DEPTH	0-300	300-2000			
CHAINAGE LAYER TYPE	0 000	000 2000			
STABILISED WITH	Natural	Natural	201		
SUPPLIER CURING METHOD					
DATE TESTED DESCRIPTION	05.10.2021 Dark brown	05.10.2021 Light orange yellow			- Specification
	Bank Brown	Light ordings yours			COTO:2020
SIEVE ANALYSIS (% PASSING)					
100.0 mm					
75.00 mm 63.00 mm					
50.00 mm					
37.50 mm	100				
28.00 mm	98				
20.00 mm	96	100		1	
14.00 mm	96	99			
5.000 mm	88	95			
2.000 mm	74	82		j j	
0.425 mm 0.075 mm	36 22	45 27			
	22	21			
SOIL MORTAR					
COARSE SAND <2.0mm >0.425mn		45			
FINE SAND <0.425mm >0.075mm		22			
MATERIAL <0.075mm	30	33			
CONSTANTS					
GRADING MODULUS	1.69	1.46			
PRA CLASSIFICATION	A-2-6(0)	A-2-6(0)			
LIQUID LIMIT (%)	34	31			
PLASTICITY INDEX (0.425mm)	15	13			
LINEAR SHRINKAGE (%)	7.0	7.0			

FORM: GR40	
FURIVI. GR40	

4.5.0(SGS)(2021.05.05)



### **WOODMEAD WATER UPGRADING**

## TRAFFIC MANAGEMENT PLAN DRAFT REPORT

REV 01

DATE: 30 November 2022

Prepared by:

Nyeleti Consulting (Pty) Ltd
P O Box 35158
Menlopark

0102

Tel: (012) 361 3629

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#### **DOCUMENT CONTROL SHEET**



CLIENT:

PROJECT: Woodmead Water Upgrading TMP
PROJECT
NO.:

TITLE: Woodmead Water Upgrading Traffic Management Plan

Date	Document No.	Prepared by	Reviewed and Approved by
30 November 2022	16941-TRD- R01	Tintswalo Rikhotso  M Tech Eng (Civil).	Sundran Naicker (PR Eng.) Director
Signatures			

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Certificate Number : 7827 ISO 9001:2008

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### LIST OF ACRONYMS

СОТО	Committee of Transport Officials
GLA	Gross Leasable Area
LOS	Level of Service
SARTSM	South African Road and Traffic Signs Manual
TIA	Traffic Impact Assessment
TMH	Technical Methods for Highways
v/c	Volume capacity ratio
Veh/h	Vehicles per hour
PTF	Public Transport Facility
Km	Kilometre
NMT	Non-Motorized Transport

#### 1 INTRODUCTION

The Johannesburg Roads Agency requested for a traffic management plan along the route which the proposed Woodmead Water Upgrading will be constructed.

#### 1.1 Purpose of the report

The purpose of this report is to outline the proposed traffic management plan to be implemented on the road network during the construction of the proposed Woodmead pipeline.

#### 1.2 Study Area

The project area is located on the North-Eastern side of Johannesburg in **Region E**. Refer to the locality plan in Figure 2. The proposed pipeline is located in Woodmead along the following routes:

- Zinnia Drive;
- Lilium Avenue;
- South Road;
- Western Service Road;
- Woodmead Drive;
- Woodlands Drive;
- · Lincoln Street; and
- Jessica Close.

The pipeline will cross the following routes:

- Zinnia Drive (Crossing 1 and 2);
- Gazania Crescent (Crossing 3 and 4);
- Marigold Cresset (Crossing 5);
- Marlboro Drive (Crossing 6);
- South Road (Crossing 7);
- Woodlands (Crossing 8); and
- Lincoln Street (Crossing 9).

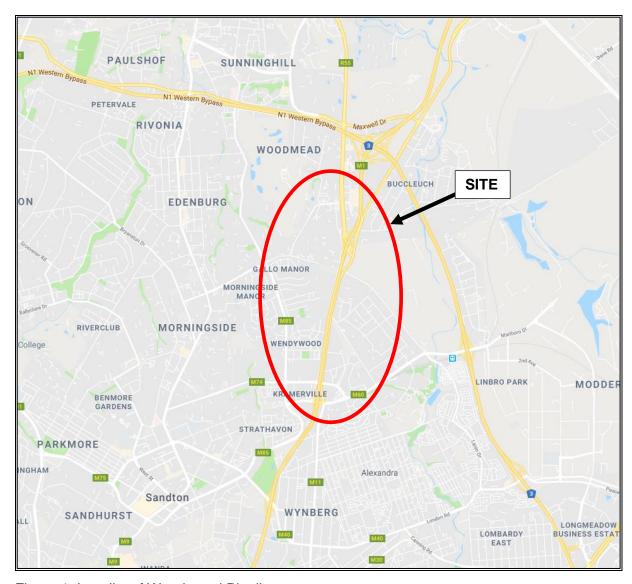


Figure 1: Locality of Woodmead Pipeline

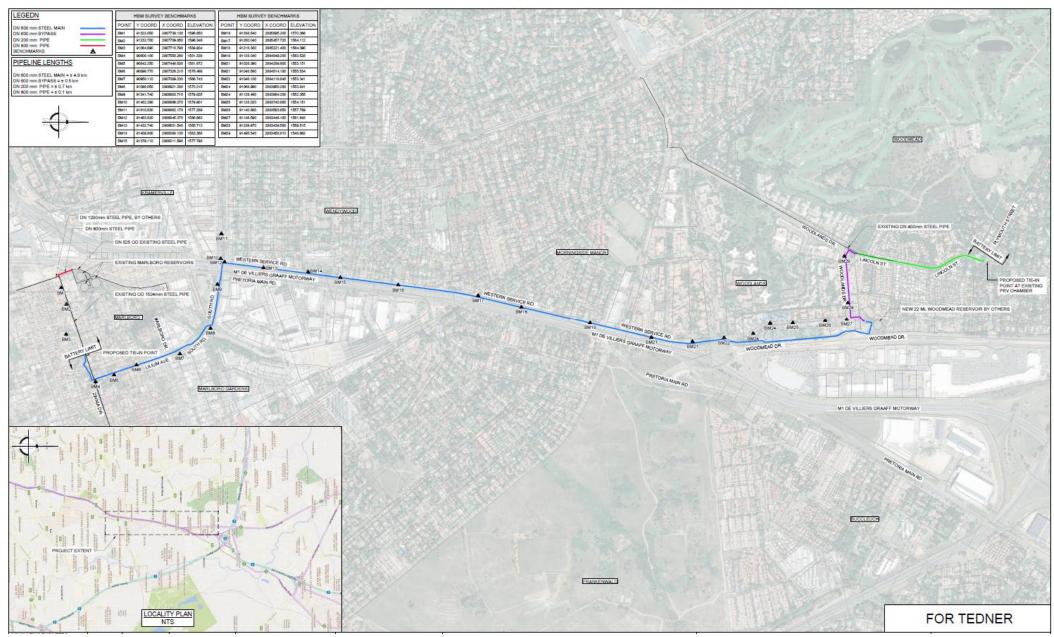


Figure 2: Locality of Woodmead Pipeline.

#### 2 TRAFFIC MANAGEMENT PLAN

Traffic accommodation/management plans are compiled in accordance to the South African Road Traffic Signs Manual (SARTSM). Construction will take place between 09:00 and 15:00, this will be the ideal time for construction to take place as there will be less traffic on the roads. The working area will be barricaded with a new jersey barrier next to the road (areas where there is traffic movement) and a net will be used in areas where there is no traffic movement. Temporary warning signs will be implemented throughout the working area.

#### 2.1 Pipeline road crossings and property access crossings

The proposed Woodmead pipeline will be constructed along (parallel) the following routes as indicated on Figure 2 and Figure 3.:

- Zinnia Drive;
- Lilium Avenue;
- South Road;
- Western Service Road;
- Woodmead Drive;
- Woodlands Drive;
- · Lincoln Street; and
- Jessica Close.

The Woodmead pipeline will cross the following roads and intersections as indicated on Figure 3 by red circles.

- Zinnia Drive (Crossing 1);
- Zinnia Drive and Lilium Avenue (Crossing 2);
- Gazania Crescent and Lilium Avenue (Crossing 3 and 4);
- Marigold Cresset Lilium Avenue (Crossing 5);
- Marlboro Drive (Crossing 6);
- South Road (Crossing 7);
- Woodlands Drive (Crossing 8); and
- Lincoln Street (Crossing 9).

The Woodmead pipeline crosses several roads and the proposed method of construction on each road crossing is indicated on Table 1 below.

Table 1: Proposed Woodmead pipeline method of construction on each road crossing

Road Name	Proposed Method of Construction
Zinnia Drive (Crossing 1 & 2)	Open Trenching
Gazania Crescent (Crossing 3 & 4)	Open Trenching
Marigold Cresset (Crossing 5)	Open Trenching
Marlboro Drive (Crossing 6)	Pipe Jacking
South Road (Crossing 7)	Pipe Jacking
Woodlands Drive (Crossing 8)	Pipe Jacking
Lincoln Street (Crossing 9)	Open Trenching

The following property access points will be affected by the construction of the proposed Wooodmead pipeline as indicated in Figure 3 by blue circles:

- Eastgate Business Park on South Road (Access crossing 1)
- Woodlands Drive Office Park on Jessica Close (Access Crossing 2)
- The Country Club Johannesburg Entrance (Access Crossing 3)
- Golf View Close (Access Crossing 4)
- Lincoln Lane (Access Crossing 5)
- The Pass (Access Crossing 6)
- Playmouth Street (Access Crossing 7)

Table 2: Proposed Woodmead pipeline method of construction on each access crossing

Road Name	Proposed Method of Construction
Eastgate Business Park on South Road (Access crossing 1)	Open Trenching
Woodlands Drive Office Park on Jessica Close (Access Crossing 2)	Open Trenching
The Country Club Johannesburg Entrance (Access Crossing 3)	
Golf View Close (Access Crossing 4)	
Lincoln Lane (Access Crossing 5)	
The Pass (Access Crossing 6)	
Playmouth Street (Access Crossing 7)	



Figure 3: Woodmead Pipeline Road crossings and Property access crossings

### 2.1.1 Zinnia Drive (Crossing 1 and Crossing 2) - Open Trenching

The proposed Woodmead pipeline will cross Zinnia Drive on crossing 1 and crossing 2 as indicated on Figure 4 with red circles, both crossings will be open trenching and the road will be closed for traffic during construction. The traffic will be diverted into Salvia Crescent as indicated on Figure 4 below by the yellow line, warning traffic signs will be implemented to guide traffic in this regard (see Annexure A: drawing no JW14358-16941-T14-S13-00).



Figure 4: Zinnia Drive (Crossing 1 and Crossing 2) - Open Trenching

## 2.1.2 Gazania Crescent and Lilium Avenue (Crossing 3 and Crossing 4) - Open Trenching

Crossing 3 and crossing 4 are located on Gazania Crescent as indicated on Figure 5 and Figure 6 by red circles, both crossings will be open trenching and crossing 3 will be constructed first and the traffic will be diverted to the adjacent Gazania crescent as indicated in Figure 5 by the yellow line. Crossing 4 will be constructed after crossing 3 and the traffic will be diverted to Gazania Crescent as indicated on Figure 6 by the yellow line, warning traffic signs will be implemented to guide traffic in this regard (see Annexure A: drawing no JW14358-16941-T14-S14-00).



Figure 5: Gazania Crescent and Lilium Avenue (Crossing 3) - Open Trenching



Figure 6: Gazania Crescent and Lilium Avenue (Crossing 3) - Open Trenching

#### 2.1.3 Marigold Crescent and Lilium Avenue (Crossing 5) - Open Trenching

Crossing 5 is located on Marigold Crescent and Lilium Avenue as indicated on Figure 7 by a red circle, this crossing will be open trenching and Marigold Crescent will be closed and traffic will be diverted to Gazania Crescent as indicated in Figure 7 by the yellow line. Warning traffic signs will be implemented to guide traffic in this regard (see Annexure A: drawing no JW14358-16941-T14-S15-00).



Figure 7: Gazania Crescent and Lilium Avenue (Crossing 3) - Open Trenching

## 2.1.4 Marlboro Drive (Crossing 6) - Pipe Jacking

The proposed Woodmead pipeline will cross Marlboro Drive on crossing 6 as indicated on Figure 8 with a red circle, this crossing will be pipe jacking and traffic will not be interrupted. Warning traffic signs will be implemented on Marlboro drive, Lillium Avenue and South Road to notify the road users of the construction that will be taking place. (see Annexure A: drawing no JW14358-16941-T14-S16-00).



Figure 8: Marlboro Drive (Crossing 6) - Pipe Jacking

## 2.1.5 South Road (Crossing 7) - Pipe Jacking

South Road crossing 7 as indicated on Figure 9 by a red circle, will be pipe jacking and traffic will not be interrupted. Warning traffic signs will be implemented on South Road and Impala Road to notify the road users of the construction that will be taking place. (see Annexure A: drawing no JW14358-16941-T14-S18-00).



Figure 9: South Road (Crossing 7) - Pipe Jacking

## 2.1.6 Woodlands Drive (Crossing 8) - Pipe Jacking

The proposed Woodmead pipeline will cross Woodlands Drive on crossing 8 as indicated on Figure 10 by a red circle, this crossing will be pipe jacking and traffic will not be interrupted. Warning traffic signs will be implemented on Woodmead Drive, and Woodlands Drive to notify the road users of the construction that will be taking place (see Annexure A: drawing no JW14358-16941-T14-S27-00).



Figure 10: Woodlands Drive (Crossing 8) - Pipe Jacking

## 2.1.7 Lincoln Street (Crossing 9) - Open Trenching

Crossing 9 is located on Lincoln Street and Woodlands Drive as indicated on Figure 11 and Figure 12 by red circles, this crossing will be open trenching and Lincoln Street will be closed and traffic will be diverted on a proposed bypass when construction will be taking place on the Lincoln Street and vice versa. Warning traffic signs will be implemented to guide traffic in this regard (see Annexure A: drawing no JW14358-16941-T14-S29-00).



Figure 11: Lincoln Street (Crossing 9) proposed bypass - Open Trenching



Figure 12: Lincoln Street (Crossing 9) - Open Trenching

## 2.1.8 Eastgate Business Park on South Road (Access crossing 1) - Open Trenching

The proposed Woodmead pipeline will cross the Eastgate Business Park on South Road (Access crossing 1) as indicated on Figure 13 and Figure 14 in blue circles, this crossing will be open trenching and during construction traffic will be diverted on each side of the access point and vice versa. Warning traffic signs will be implemented to guide traffic in this regard (see Annexure A: no JW14358-16941-T14-S17-00).



Figure 13: Eastgate Business Park on South Road (Access crossing 1) - Open Trenching



Figure 14: Eastgate Business Park on South Road (Access crossing 1) - Open Trenching

# 2.1.9 Woodlands Drive Office Park on Jessica Close (Access Crossing 2) - Open Trenching

Woodlands Drive Office Park (Access Crossing 2) are both on Jessica Close as indicated on Figure 15 and Figure 16 (Access crossing 2) and crossing will be open trenching. During construction traffic will be diverted on each side of the access point and vice versa as indicated on Figure 15 and Figure 16. Warning traffic signs will be implemented to guide traffic in this regard (see Annexure A: no JW14358-16941-T14-S28-00).



Figure 15: Woodlands Drive Office Park (Access crossing 2) on Jessica Close - Open Trenching



Figure 16: Woodlands Drive Office Park (Access crossing 2) on Jessica Close - Open Trenching

## 2.1.10 The Country Club Johannesburg Entrance (Access Crossing 3) - Open Trenching

The Country Club Johannesburg Entrance (Access Crossing 3) is on Lincoln Street as indicated on Figure 17 and Figure 18 (Access crossing 3) and crossing will be open trenching. During construction traffic will be diverted on each side of the access point and vice versa as indicated on Figure 17 and Figure 18. Warning traffic signs will be implemented to guide traffic in this regard (see Annexure A: drawing no JW14358-16941-T14-S30-00).



Figure 17: The Country Club Johannesburg Entrance (Access Crossing 3) is on Lincoln Street - Open Trenching



Figure 18: The Country Club Johannesburg Entrance (Access Crossing 3) is on Lincoln Street - Open Trenching

## 2.1.11 Golf View Close (Access Crossing 4) - Open Trenching

Golf View Close (Access Crossing 4) is on Lincoln Street as indicated on Figure 19 and Figure 20 (Access crossing 4) and crossing will be open trenching. During construction traffic will be diverted on each side of the access point and vice versa as indicated on Figure 19 and Figure 20. Warning traffic signs will be implemented to guide traffic in this regard (see Annexure A: drawing no JW14358-16941-T14-S30-00).



Figure 19: Golf View Close (Access Crossing 4) is on Lincoln Street - Open Trenching



Figure 20: Golf View Close (Access Crossing 4) is on Lincoln Street - Open Trenching

## 2.1.12 Lincoln Lane (Access Crossing 5) - Open Trenching

Lincoln Lane (Access Crossing 5) is on Lincoln Street as indicated on Figure 21 and Figure 22 (Access crossing 5) and crossing will be open trenching. During construction traffic will be diverted on each side of the access point and vice versa as indicated on Figure 21 and Figure 22. Warning traffic signs will be implemented to guide traffic in this regard (see Annexure A: drawing no JW14358-16941-T14-S31-00).



Figure 21: Lincoln Lane (Access Crossing 5) is on Lincoln Street - Open Trenching



Figure 22: Lincoln Lane (Access Crossing 5) is on Lincoln Street - Open Trenching

## 2.1.13 The Pass (Access Crossing 6) - Open Trenching

The Pass (Access Crossing 6) is on Lincoln Street as indicated on Figure 23 and Figure 24 (Access crossing 6) and crossing will be open trenching. During construction traffic will be diverted on each side of the access point and vice versa as indicated on Figure 23 and Figure 24. Warning traffic signs will be implemented to guide traffic in this regard (see Annexure A: drawing no JW14358-16941-T14-S32-00).



Figure 23: The Pass (Access Crossing 6) is on Lincoln Street - Open Trenching

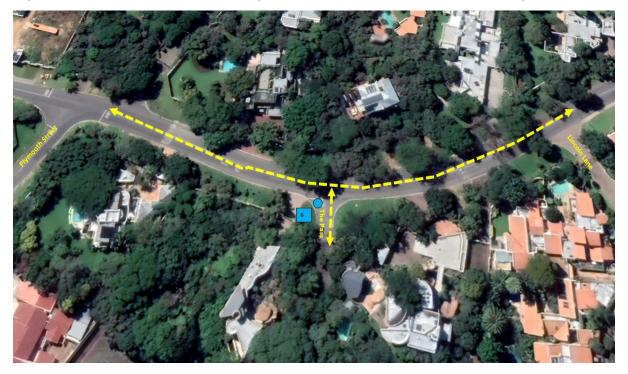


Figure 24: The Pass (Access Crossing 6) is on Lincoln Street - Open Trenching

## 2.1.14 Playmouth Street (Access Crossing 7) - Open Trenching

Playmouth Street (Access Crossing 7) is on Lincoln Street as indicated on Figure 25 and Figure 26 (Access crossing 7) and crossing will be open trenching. During construction traffic will be diverted on each side of the access point and vice versa as indicated on Figure 25 and Figure 26. Warning traffic signs will be implemented to guide traffic in this regard (see Annexure A: drawing no JW14358-16941-T14-S32-00).

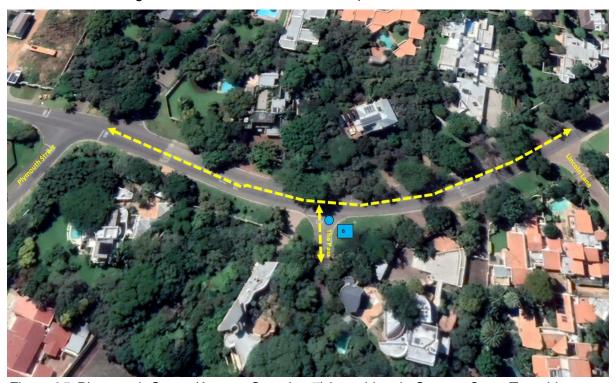


Figure 25: Playmouth Street (Access Crossing 7) is on Lincoln Street - Open Trenching

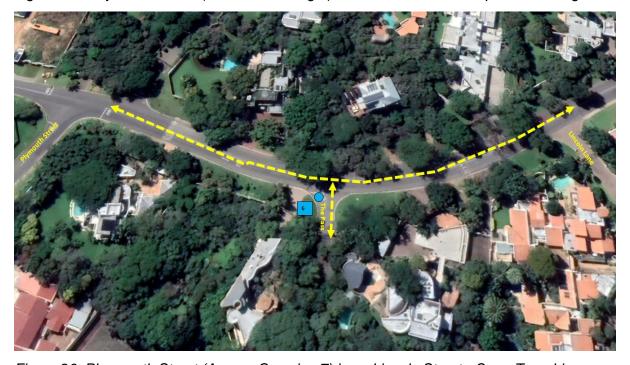


Figure 26: Playmouth Street (Access Crossing 7) is on Lincoln Street - Open Trenching

#### 2.2 Construction of Woodmead pipeline under Woodlands drive

The Woodmead pipeline will be constructed under the road on Woodlands Drive (from Lincoln Street to Jessica Close) these locations are clearly indicated in Figure 3 (the pipeline on Woodland Drive is indicated with a red colour).

The existing eastbound left lane on Woodlands Drive will be used as a working area for the excavation and installation of the pipeline. The median along Woodlands Drive will be removed to accommodate an additional lane since the left lane will be used for construction purposes. Warning traffic signs will be implemented to guide traffic in this regard (see Annexure A: drawing no JW14358-16941-T14-S29-00).

#### 2.3 Construction of Woodmead pipeline next to Western Service Road

The Woodmead pipeline will be constructed next to the road on Western Service Road (between Edison Street and Woodlands Drive and The Woodlands Office Park Entrance Road). The Northbound lane will be used as a working area for the excavation and installation of the pipeline along the Western Service Road. A stop and go traffic accommodation will be implemented during construction, the southbound lane will be used for this purpose during construction phase. The working area along the western service road northbound lane will be in 100m intervals. Warning traffic signs will be implemented to guide traffic in this regard (see Annexure A: drawing no JW14358-16941-T14-S24-00).

#### 3 CONCLUSION

Given the findings in the report, the following conclusions are drawn:

- Woodmead Water Upgrading project area is located on the North-Eastern side of Johannesburg in Region E.
- The proposed pipeline is located in Woodmead along the following routes:
  - Zinnia Drive;
  - Lilium Avenue;
  - South Road;
  - Western Service Road;
  - Woodmead Drive;
  - Woodlands Drive;
  - Lincoln Street; and
  - Jessica Close.
- The pipeline will cross the following routes:
  - Zinnia Drive (Crossing 1 and 2);
  - Gazania Crescent (Crossing 3 and 4);
  - Marigold Cresset (Crossing 5);
  - Marlboro Drive (Crossing 6);
  - South Road (Crossing 7);
  - Woodlands Drive (Crossing 8); and
  - Lincoln Street (Crossing 9).
- Proposed Woodmead pipeline method of construction on each road crossing is as follows:
  - o Zinnia Drive (Crossing 1 & 2) Open Trenching
  - Gazania Crescent (Crossing 3 & 4) Open Trenching
  - Marigold Cresset (Crossing 5) Open Trenching
  - Marlboro Drive (Crossing 6) Pipe Jacking
  - South Road (Crossing 7) Pipe Jacking
  - Woodlands Drive (Crossing 8) Pipe Jacking
  - Lincoln Street (Crossing 9) Open Trenching
- The following property access points will be directly affected by the construction of the proposed Wooodmead pipeline:
  - o Eastgate Business Park on South Road (Access crossing 1)
  - Woodlands Drive Office Park on Jessica Close (Access Crossing 2)
  - The Country Club Johannesburg Entrance (Access Crossing 3)

- Golf View Close (Access Crossing 4)
- Lincoln Lane (Access Crossing 5)
- The Pass (Access Crossing 6)
- Playmouth Street (Access Crossing 7)
- The existing eastbound left lane on Woodlands Drive will be used as a working area for the excavation and installation of the pipeline.
- The median along Woodlands Drive will be removed to accommodate an additional lane since the left lane will be used for construction purposes.
- The Western Service Road northbound lane will be used as a working area for the excavation and installation of the pipeline along the Western Service Road.
- A stop and go traffic accommodation will be implemented during construction on the Western Service Road and the southbound lane will be used for this purpose during the construction phase.

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#### 4 RECOMMENDATIONS

The following recommendations are made:

- It is recommended that construction takes place only between 09:00 am and 15:00 pm during the construction phase.
- It is recommended that all traffic warning signs be manufactured and implemented in accordance to the South African Road Traffic Signs Manual (SARTSM).
- Traffic accommodation on site must be approved by an engineer.
- Access to propertiesduring construction must be communicated to the property owners before construction takes place.

## 5 REFERENCES

- 1. South African Road Traffic Signs Manual (SARTSM), Volume 2.
- 2. South African Road Traffic Signs Manual (SARTSM), Volume 3.

## **ANNEXURE A: TRAFFIC ACCOMODATION DRAWINGS**



## **WOODMEAD WATER UPGRADING**

# TRAFFIC IMPACT STUDY REPORT DRAFT REPORT

REV 02

DATE: 25 November 2022

Prepared by:

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#### **DOCUMENT CONTROL SHEET**



CLIENT:

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## LIST OF ACRONYMS

СОТО	Committee of Transport Officials
GLA	Gross Leasable Area
LOS	Level of Service
SARTSM	South African Road and Traffic Signs Manual
TIA	Traffic Impact Assessment
TMH	Technical Methods for Highways
v/c	Volume capacity ratio
Veh/h	Vehicles per hour
PTF	Public Transport Facility
Km	Kilometre
NMT	Non-Motorized Transport

#### 1 INTRODUCTION

The Johannesburg Roads Agency requested for a traffic impact assessment and a traffic management plan along the route which the proposed Woodmead Water Upgrading will be constructed.

#### 2 CONTEXT AND FRAMEWORK

## 2.1 Purpose of the report

The purpose of this report is to give feedback on the impact the proposed Woodmead Water Upgrading will have during construction on traffic on the adjacent road network. It also aims to provide suggestions regarding traffic accommodation and access that is in line with the requirements and regulations of the authorising authority.

## 2.2 Study Area

The project area is located on the North-Eastern side of Johannesburg in **Region E**. Refer to the locality plan in Figure 2. The proposed pipeline is located in Woodmead along the following routes:

- Zinnia Drive;
- Lilium Avenue;
- South Road;
- Western Service Road;
- Woodmead Drive;
- Woodlands Drive;
- · Lincoln Street; and
- Jessica Close.

The pipeline will cross the following routes:

- Zinnia Drive;
- Road within Alexandra Taxi Rank;
- Gazania Crescent;
- Marigold Cresset;
- Lilium Avenue;
- Marlboro Drive;
- South Road;
- Woodlands Drive; and
- · Lincoln Street.

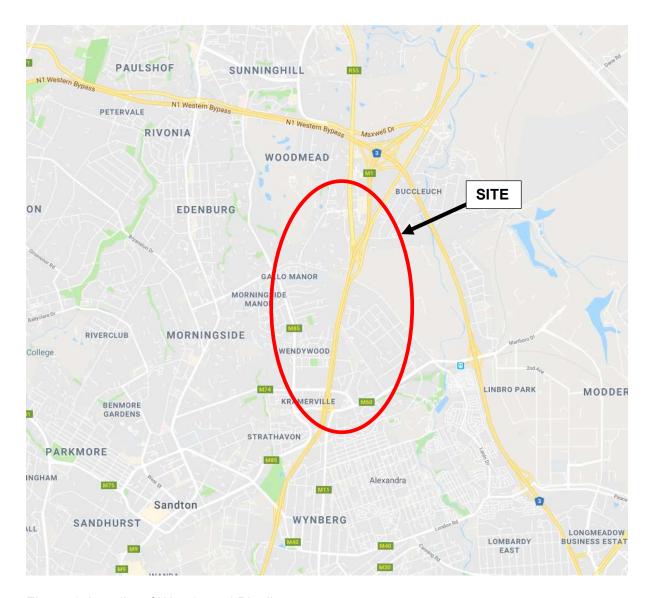


Figure 1: Locality of Woodmead Pipeline

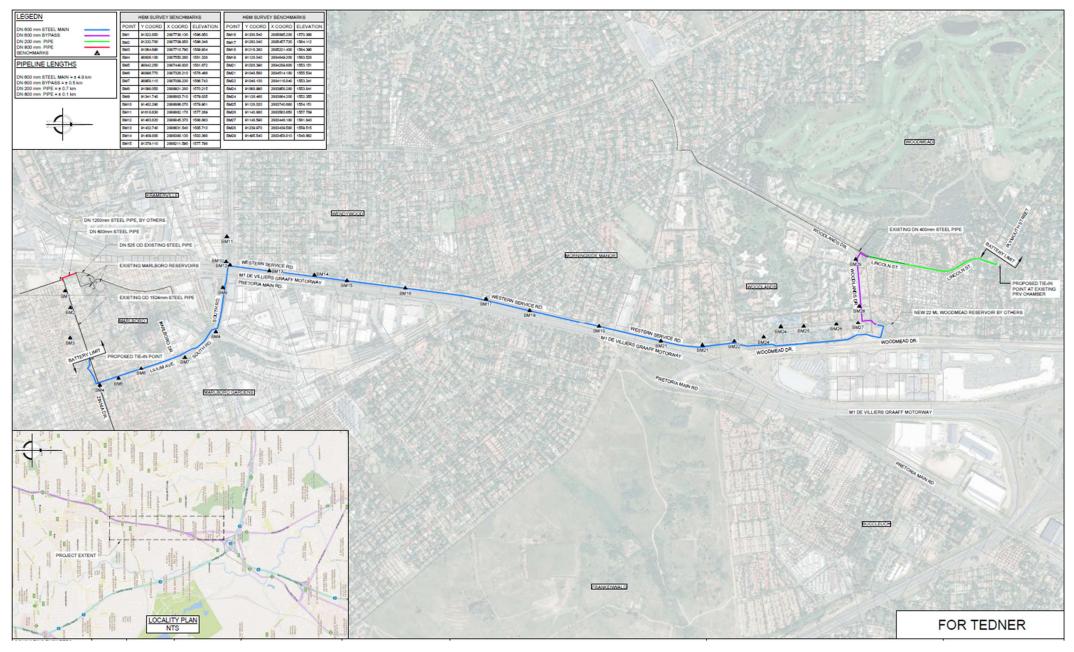


Figure 2: Locality of Woodmead Pipeline.

#### 3 DATA COLLECTION

#### 3.1 Information from external sources

The following information was obtained from various interested and affected parties:

Woodmead pipe locality plan

The information mentioned above is referred to and used in this report.

#### 3.2 Data collected by Nyeleti Consulting

The following data was collected by Nyeleti Consulting:

- Fouteen hour classified traffic counts:
- Fouteen hour turning movement traffic counts;
- Twenty-four hour classified traffic counts;
- Twenty-four hour turning movement traffic counts; and
- Photographs of the area and various affected roads and intersections.

Data was collected through a traffic counting subconsultant on the 3<sup>rd</sup> of November 2022. Traffic counts were collected over a period of 14 hours from 05:00am to 19:00pm and over a period of 24 hours from 00:00 to 00:00.

#### 4 TRAFFIC VOLUMES

#### 4.1 Current traffic volumes

Current traffic volumes were determined by means of 14-hour traffic counts and 24-hour traffic counts. Traffic was counted from 05:00 to 19:00 and 00:00 to 00 00 on Thursday the 3rd of November 2022. Figure 3 indicate the traffic counting stations. Traffic counts consisted of turning movement counts and classified vehicle counts, Table 1 shows the traffic counts data collection times for each intersection. The detailed traffic counting data is attached as **Annexure A**.

#### 4.2 Turning movement traffic volumes

Turning movement traffic counts were conducted at the following intersections as illustrated in *Figure 3*:

- Zania Drive and Lilium Avenue (intersection 1)
- Marlboro Drive (M60) and Lilium Avenue (Intersection 2)
- Impala Road and South Road (Intersection 3)
- Western Service Road and Wendy Road (Intersection 4)
- Western Service Road and Carnation Street (Intersection 5)
- Western Service Road and Harrowdene Office Park Entrance Road (Intersection 6)

- Western Service Road and The Woodlands Office Park Entrance Road (Intersection
   7)
- Woodlands Drive and Western Service Road (Intersection 8)
- Woodlands Drive and Lincoln Street (Intersection 9)
- Woodlands Drive and The Woodlands Office Park Entrance Road/Country Club Estate (Intersection 10)
- Woodlands Drive and The Woodlands Office Park Entrance Road/Pestle Street (Intersection 11)
- Woodmead Drive & Woodlands Drive (Intersection 12)

Turning movement traffic counts were conducted at the following accesses as illustrated in *Figure 3 by blue circles*, the data was collected over a period of 24hrs:

- Marlboro Drive (M60) Westbound Shell Filling Station (Access A1)
- Marlboro Drive (M60) Eastbound Shell Filling Station (Access A2)
- Lilium Avenue Shell Filling Station (Access A3)
- Western Service Road Caltex Filling Station (Access A4)
- Woodlands Drive and Western Service Road Engen Filling Station (Access A5)

Table 1: Current traffic Volumes data Collection Times on intersections

Intersection Name	Intersection Type	Traffic Counts Period	
Zinia Drive and Lilium Avenue - Intersection	Unsignalised,3 Way Stop	14 Hours (05:00 to 19:00)	
Marlboro Drive and Lilium Avenue/South Road - Intersection 2	Signalised,4 Ways	14 Hours (05:00 to 19:00)	
South Road and Impala Road – Intersection 3	Unsignalised, Stop on minor road	14 Hours (05:00 to 19:00)	
Western Service Road and Wendy Road - Intersection 4	Unsignalised, Stop on minor road	14 Hours (05:00 to 19:00)	
Western Service Road and Carnation Street - Intersection 5	Unsignalised, Stop on minor road	14 Hours (05:00 to 19:00)	
Western Service Road and Harrowdene Office Park Entrance Road – Intersection 6	Unsignalised,3 Way Roundabout	14 Hours (05:00 to 19:00)	
Western Service Road and The Woodlands Office Park Entrance Road – Intersection 7	Unsignalised,3 Way Roundabout	14 Hours (05:00 to 19:00)	
Woodlands Drive and Western Service Road – Intersection 8	Signalised,4 Ways	14 Hours (05:00 to 19:00)	
Woodlands Drive and Lincoln Street – Intersection 9	Unsignalised, Stop on minor road	14 Hours (05:00 to 19:00)	
Woodlands Drive and The Woodlands Office Park Entrance Road/Country Club Estate - Intersection 10	Signalised,4 Ways	14 Hours (05:00 to 19:00)	
Woodlands Drive and The Woodlands Office Park Entrance Road/Pestle Street - Intersection 11	Signalised,4 Ways	14 Hours (05:00 to 19:00)	
Woodmead Drive & Woodlands Drive – Intersection 12	Signalised,4 Ways	14 Hours (05:00 to 19:00)	

## 4.2.1 Traffic volumes for the morning peak, midday peak and afternoon peak

The morning peak is between **07:00 to 08:30**, the midday peak is between **12:00 to 15:00** and the afternoon peak is between **15:15 to 17:45** at all respective intersections. Table 2 summarises the peak times for each intersection. The traffic count data can be found in Annexure A show a visual representation of the summarised counts for the morning peak, midday peak and afternoon peak.

Table 3 summarises the peak times for each filling station along the route of the pipeline and also indicates the 24 hr traffic entering and exiting each filling station. It can be seen that 5 Filling stations along the proposed Woodmead pipeline route attract traffic volumes of between 1 408 and 4 241 over a 24hr period.



Figure 3: Traffic counting positions

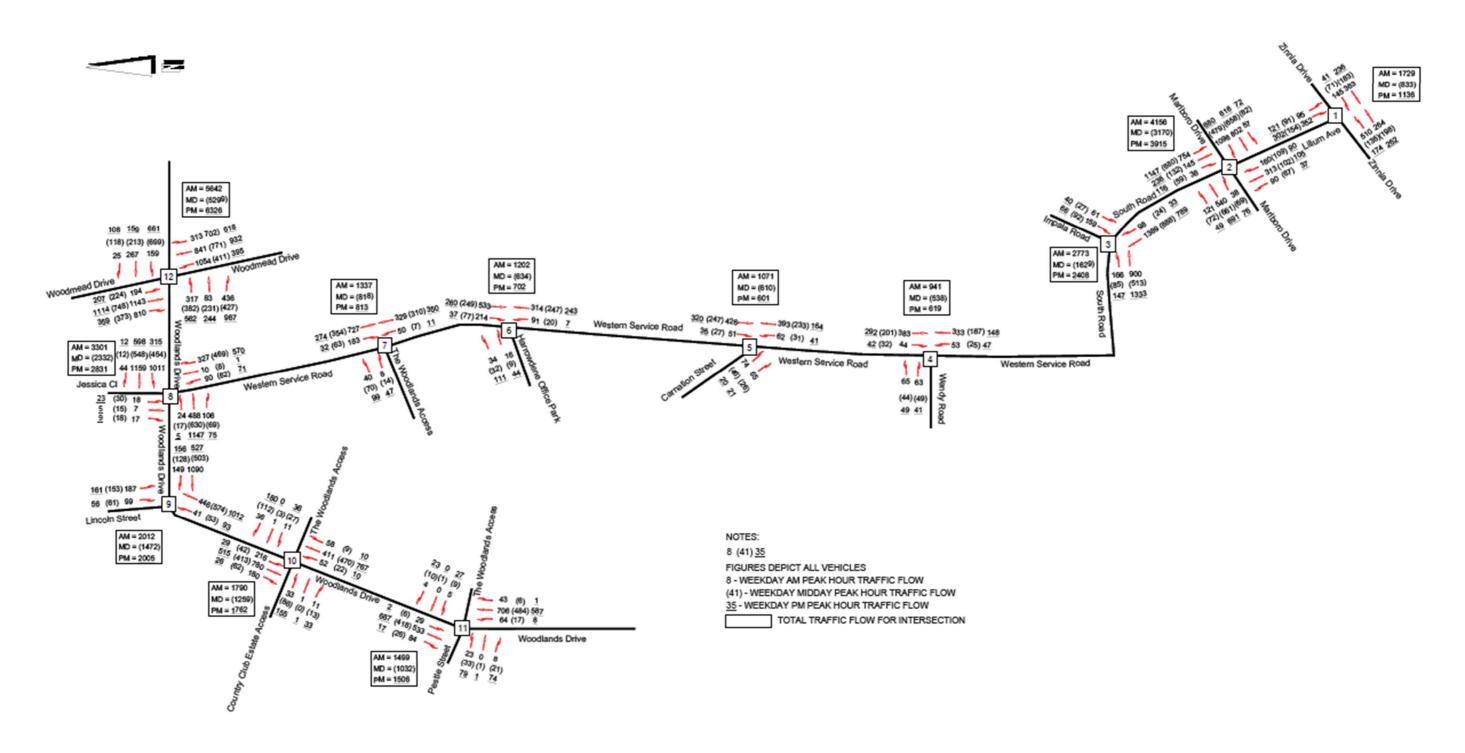


Figure 4:Current Morning Peak, Midday Peak and Afternoon Peak Volumes at intersections

Table 2: Morning, Midday and Afternoon Peak times at intersections

Intersection Name	Intersection Type	Morning Peak Times	Morning Peak Traffic Volume at Intersection	Midday Peak Times	Midday Peak Traffic Volume at Intersection	Afternoon Peak Times	Afternoon Peak Traffic Volume at Intersection
Zinia Drive and Lilium Avenue - Intersection 1	Unsignalised,3 Way Stop	07:15-08:15	1 729	14:00-15:00	833	16:30-17:30	1 136
Marlboro Drive and Lilium Avenue/South Road - Intersection 2	Signalised,4 Ways	07:00-08:00	4 156	14:00-15:00	3 170	16:15-17:15	3 915
South Road and Impala Road – Intersection 3	Unsignalised, Stop on minor road	07:15-08:15	2 773	09:00-10:00	1 629	16:15-17:15	2 408
Western Service Road and Wendy Road - Intersection 4	Unsignalised, Stop on minor road	07:15-08:15	941	13:30-14:30	538	16:15-17:15	619
Western Service Road and Carnation Street - Intersection 5	Unsignalised, Stop on minor road	07:15-08:15	1 071	13:30-14:30	610	16:15-17:15	601
Western Service Road and Harrowdene Office Park Entrance Road – Intersection 6	Unsignalised,3 Way Roundabout	07:30-08:30	1 202	13:30-14:30	634	16:15-17:15	702
Western Service Road and The Woodlands Office Park Entrance Road – Intersection 7	Unsignalised,3 Way Roundabout	07:15-08:15	1 337	13:45-14:45	818	16:15-17:15	813
Western service Road/Jessica Close & Woodlands Drive – Intersection 8	Signalised,4 Way Stop	07:30-08:30	3 301	13:45-14:45	2 332	16:15-17:15	2 831
Woodlands Drive and Lincoln Street - Intersection 9	Unsignalised, Stop on minor road	07:30-08:30	2 012	13:45-14:45	1 472	16:30-17:30	2 005
Woodlands Drive and The Woodlands Office Park Entrance Road/Country Club Estate - Intersection 10	Signalised,4 Ways	07:30-08:30	1 790	14:00-15:00	1 259	16:30-17:30	1 762
Woodlands Drive and The Woodlands Office Park Entrance Road/Pestle Street -Intersection 11	Signalised,4 Ways	07:15-08:15	1 499	12:30-13:30	1 032	16:30-17:30	1 506
Woodmead Drive & Woodlands Drive - Intersection 12	Signalised,4 Ways	07:30-08:30	5 642	12:15-13:15	5 299	16:15-17:15	6 326

Table 3: Peak times at filling station and shopping centre accesses along the route of the proposed Woodmead pipeline

Intersection Name	Total traffic volumes at entrance/exit over 24hrs	Peak Times (between 00:00 and 12:00)	Morning Peak Traffic Volume at Access Point	Peak Times (between 12:00 and 00:00)	Peak Traffic Volume at Access Point
Marlboro Drive (M60) Westbound	1 819	10:30-11:30	136	17:00-18:00	148
Shell Filling Station - Access (A1)	(In/Out) 828/991	10:30-11:30	(In/Out) 56/80	17:00-18:00	(In/Out) 66/81
Marlboro Drive (M60) Eastbound	1 805	10.45.44.45	130	40.00.44.00	139
Shell Filling Station - Access (A2)	(In/Out) 830/975	10:15-11:15	(In/Out) 52/78	13:00-14:00	(In/Out) 74/65
Lilium Avenue Shell Filling Station	1 451	07.00.00.00	113	40.45.47.45	164
- Access (A3)	(In/Out) 625/826	- 07:00-08:00	(In/Out) 44/69	16:45-17:45	(In/Out) 63/101
Western Service Road Caltex Filling Station – Access (A4)	4 241	07.45.00.45	317	40.45.40.45	338
	(In/Out) 2 207/2 034	07:45-08:45	(In/Out) 160/157	12:15-13:15	(In/Out) 165/173
Woodlands Drive and Western	1 408	07.45.00.45	199	40.45.47.45	129
Service Road Engen Filling Station - Access (A5)	(In/Out) 759/649	07:15-08:15	(In/Out) 140/96	16:15-17:15	(In/Out) 68/61

#### 4.3 Classified counts (Modal Split)

Classified counts were done on the following intersections.

- Zania Drive and Lilium Avenue (intersection 1)
- Marlboro Drive (M60) and Lilium Avenue (Intersection 2)
- Impala Road and South Road (Intersection 3)
- Western Service Road and Wendy Road (Intersection 4)
- Western Service Road and Carnation Street (Intersection 5)
- Western Service Road and Harrowdene Office Park Entrance Road (Intersection 6)
- Western Service Road and The Woodlands Office Park Entrance Road (Intersection
   7)
- Woodlands Drive and Western Service Road (Intersection 8)
- Woodlands Drive and Lincoln Street (Intersection 9)
- Woodlands Drive and The Woodlands Office Park Entrance Road/Country Club Estate (Intersection 10)
- Woodlands Drive and The Woodlands Office Park Entrance Road/Pestle Street (Intersection 11)
- Woodmead Drive & Woodlands Drive (Intersection 12)

Table 4 shows a breakdown of the modal split on all intersections respectively.

Table 4: Modal split

Intersection	Car	Taxi	Bus	Truck	Total
Zinia Drive and Lilium Avenue -	8 218	3 316	23	353	11.010
Intersection 1	(69.0%)	(27.8%)	(0.2%)	(3.0%)	11 910
Marlboro Drive and Lilium Avenue/South	38 101	1 256	140	1 554	44.054
Road - Intersection 2	(92.8%)	(3.1%)	(0.3%)	(3.8%)	41 051
Impala Road and South Road –	21 868	725	58	465	00.440
Intersection 3	(94.6%)	(3.1%)	(0.3%)	(2.0%)	23 116
Western Service Road and Wendy Road -	5 831	217	31	52	6 131
Intersection 4	(95.1%)	(3.5%)	(0.5%)	(0.9%)	0 131
Western Service Road and Carnation	6 328	211	31	53	6 622
Street - Intersection 5	(95.5%)	(3.2%)	(0.5%)	(0.8%)	6 623
Western Service Road and Harrowdene	7 403	124	43	56	7 626
Office Park Entrance Road – Intersection 6	(97.1%)	(1.6%)	(0.6%)	(0.7%)	
Western Service Road and The	9 100	145	46	111	9 402
Woodlands Office Park Entrance Road – Intersection 7	(96.8%)	(1.5%)	(0.5%)	(1.2%)	
Western service Road/Jessica Close &	28 568	435	65	297	29 365
Woodlands Drive – Intersection 8	(97.3%)	(1.5%)	(0.2%)	(1.0%)	
Woodlands Drive and Lincoln Street –	18 840	411	32	213	19 946
Intersection 9	(96.6%)	(2.1%)	(0.2%)	(1.1%)	19 940
Woodlands Drive and The Woodlands	16 335	413	37	164	10.040
Office Park Entrance Road/Country Club Estate - Intersection 10	(96.4%)	(2.4%)	(0.2%)	(1.0%)	16 949
Woodlands Drive and The Woodlands	13 403	403	39	139	13 984
Office Park Entrance Road/Pestle Street - Intersection 11	(95.8%)	(2.9%)	(0.3%)	(1.0%)	13 904
Woodmead Drive & Woodlands Drive –	59 732	2 376	243	1 090	63 432
Intersection 12	(94.2%)	(3.7%)	(0.4%)	(1.7%)	
The average modal split on all intersections	93.5%	4.7%	0.3%	1.5%	

The average modal split on all intersections is

#### 5 CAPACITY ANALYSIS

The following design scenarios were adopted for the purpose of this investigation:

• 2022 existing weekday AM, Midday and PM peak hour traffic demand

#### 5.1 Level of Service (LOS)

The criteria for LOS are based on the Highway Capacity Manual 2010 as summarized in *Table 5*. At the very least a LOS D has to be obtained for the traffic flow to be perceived as acceptable. The performance of the intersections is based on the average delay in seconds.

Table 5: Level of Service criteria

	UNS	IGNALIZED INTERSECTION					
Average Control Delay (sec/veh)	Level of Service (LOS)	Expected Delay to Minor Street Traffic					
0 - 10.0	Α	Free Flow					
> 10.0 - 15.0	В	Stable Flow (slight delays)					
> 15.0 - 25.0	С	Stable Flow (acceptable delays)					
> 25.0 - 35.0	D	Approaching unstable flow (tolerate delay, occasionally wait					
> 35.0 - 50.0	E	Very long traffic delays					
> 50.0	F	*					
	SIG	NALIZED INTERSECTION					
Average Control Delay (sec/veh)	Level of Service (LOS)	Expected Delay					
		Expected Delay Free Flow					
Delay (sec/veh)	Service (LOS)						
Delay (sec/veh) ≤ 10	Service (LOS)	Free Flow					
Delay (sec/veh)  ≤ 10 >10 - 20	Service (LOS)  A B	Free Flow Stable Flow (slight delays)					

<sup>\*</sup> When demand volume exceeds the capacity of the lane, extreme delays will be encountered. With the increase in delays, increase in queue lengths will be encountered causing congestion. This condition usually warrants improvement to the intersection.

### 5.2 SIDRA Analysis

>80

The following scenarios were analysed, using the SIDRA computer package:

Zania Drive and Lilium Avenue (intersection 1)

F

- Marlboro Drive (M60) and Lilium Avenue (Intersection 2)
- Impala Road and South Road (Intersection 3)
- Western Service Road and Wendy Road (Intersection 4)

- Western Service Road and Carnation Street (Intersection 5)
- Western Service Road and Harrowdene Office Park Entrance Road (Intersection 6)
- Western Service Road and The Woodlands Office Park Entrance Road (Intersection
   7)
- Woodlands Drive and Western Service Road (Intersection 8)
- Woodlands Drive and Lincoln Street (Intersection 9)
- Woodlands Drive and The Woodlands Office Park Entrance Road/Country Club Estate (Intersection 10)
- Woodlands Drive and The Woodlands Office Park Entrance Road/Pestle Street (Intersection 11)
- Woodmead Drive & Woodlands Drive (Intersection 12)

•

Intersections with level of service A, B and C, depict an average delay in traffic which is acceptable. Intersections with level of service D, depict an average delay in traffic which is acceptable but will soon become unacceptable should traffic volumes increase. Intersections with level of service E and F, depict an average delay in traffic which is unacceptable

Table 6 and Table 9 show the current Levels of Service (LOS) for Intersections 1,2,3,4,5,6,7,8,9,10,11 and 12 with corresponding traffic volumes, peak times and average delays on each intersection for the morning peak, midday peak and afternoon peak periods.

The level of service for intersection 4,5, 6, 7, 8, 10, 11 and 12 is currently within acceptable standards and for intersection 1, 2,3,and 9 is currently not within acceptable standards for the morning peak periods.

The level of service for intersection 1,2,4,5, 6, 7,8,10 and 11 is currently within acceptable standards and intersections 3, 9 and 12 is not within acceptable standards for the midday peak periods.

The level of service for intersection 4,5, 6, 7,8,10 and 11 is currently within acceptable standards and intersections 1,2, 3, 9 and 12 is not within acceptable standards for the affternoon peak periods.

Table 6: 2022 Morning, Midday and Afternoon Peak times with corresponding LOS

Intersection Name	Intersection Type	Morning Peak Times	Morning Peak LOS	Midday Peak Times	Midday Peak LOS	Afternoon Peak Times	Afternoon Peak LOS
Zinia Drive and Lilium Avenue - Intersection 1	Unsignalised,3 Way Stop	07:15-08:15	F	14:00-15:00	С	16:30-17:30	E
Marlboro Drive and Lilium Avenue/South Road - Intersection 2	Signalised,4 Ways	07:00-08:00	F	14:00-15:00	D	16:15-17:15	Е
South Road and Impala Road – Intersection 3	Unsignalised, Stop on minor road	07:15-08:15	N/A* (Northbound: F)	09:00-10:00	N/A* (Northbound: F)	16:15-17:15	N/A* (Northbound: F)
Western Service Road and Wendy Road - Intersection 4	Unsignalised, Stop on minor road	07:15-08:15	N/A* (Westbound: B)	13:30-14:30	N/A* (Westbound: A)	16:15-17:15	N/A* (Westbound: A)
Western Service Road and Carnation Street - Intersection 5	Unsignalised, Stop on minor road	07:15-08:15	N/A* (Northbound: B)	13:30-14:30	N/A* (Northbound: A)	16:15-17:15	N/A* (Northbound: B)
Western Service Road and Harrowdene Office Park Entrance Road – Intersection 6	Unsignalised,3 Way Roundabout	07:30-08:30	А	13:30-14:30	А	16:15-17:15	А
Western Service Road and The Woodlands Office Park Entrance Road – Intersection 7	Unsignalised,3 Way Roundabout	07:15-08:15	А	13:45-14:45	А	16:15-17:15	А
Western service Road/Jessica Close & Woodlands Drive – Intersection 8	Signalised,4 Ways	07:30-08:30	D	13:45-14:45	В	16:15-17:15	В
Woodlands Drive and Lincoln Street – Intersection 9	Unsignalised, Stop on minor road	07:30-08:30	N/A* (Northbound: F)	13:45-14:45	N/A* (Northbound: F)	16:30-17:30	N/A* (Northbound: F)
Woodlands Drive and The Woodlands Office Park Entrance Road/Country Club Estate - Intersection 10	Signalised,4 Ways	07:30-08:30	С	14:00-15:00	С	16:30-17:30	С
Woodlands Drive and The Woodlands Office Park Entrance Road/Pestle Street -Intersection 11	Signalised,4 Ways	07:15-08:15	А	12:30-13:30	А	16:30-17:30	А
Woodmead Drive & Woodlands Drive  — Intersection 12	Signalised,4 Ways	07:30-08:30	D	12:15-13:15	Е	16:15-17:15	F

<sup>\*</sup>Intersection LOS and Major Road Approach LOS values are not applicable for two-way sign control intersection since the average delay is not a good LOS measure due to zero delays associated with major road lanes

Table 7: 2022 Morning, Midday and Afternoon Peak with corresponding LOS and average delays

Intersection Name	Intersection Type	Morning Peak Average Delays(sec)	Morning Peak LOS	Midday Peak Average Delays(sec)	Midday Peak LOS	Afternoon Peak Average Delays(sec)	Afternoon Peak LOS	
Zinia Drive and Lilium Avenue - Intersection 1	Unsignalised,3 Way Stop	162.4	F	19.0	С	36.6	E	
Marlboro Drive and Lilium Avenue/South Road - Intersection 2	Signalised,4 Ways	94.5	F	44.3	D	59.9	Е	
South Road and Impala Road – Intersection 3	Unsignalised, Stop on minor road	976.5	N/A* (Northbound: F)	25.5	N/A* (Northbound: F)	204.8	N/A* (Northbound: F)	
Western Service Road and Wendy Road - Intersection 4	Unsignalised, Stop on minor road	2.4	N/A* (Westbound: B)	2.3	N/A* (Westbound: A)	2.3	N/A* (Westbound: A)	
Western Service Road and Carnation Street - Intersection 5	Unsignalised, Stop on minor road	2.6	N/A* (Northbound: B)	1.8	N/A* (Northbound: A)	1.5	N/A* (Northbound: B)	
Western Service Road and Harrowdene Office Park Entrance Road – Intersection 6	Unsignalised,3 Way Roundabout	5.1	А	4.5	А	4.6	А	
Western Service Road and The Woodlands Office Park Entrance Road – Intersection 7	Unsignalised,3 Way Roundabout	5.2	А	4.8	А	5.0	А	
Western service Road/Jessica Close & Woodlands Drive – Intersection 8	Signalised,4 Ways	38.3	D	12.7	В	13.4	В	
Woodlands Drive and Lincoln Street – Intersection 9	Unsignalised, Stop on minor road	255.3	N/A* (Northbound: F)	10.6	N/A* (Northbound: F)	110.7	N/A* (Northbound: F)	
Woodlands Drive and The Woodlands Office Park Entrance Road/Country Club Estate - Intersection 10	Signalised,4 Ways	28.1	С	23.7	С	26.9	С	
Woodlands Drive and The Woodlands Office Park Entrance Road/Pestle Street -Intersection 11	Signalised,4 Ways	8.5	А	9.2	А	9.0	А	
Woodmead Drive & Woodlands Drive - Intersection 12	Signalised,4 Ways	49.6	D	75.7	E	131.0	F	

<sup>\*</sup>Intersection LOS and Major Road Approach LOS values are not applicable for two-way sign control intersection since the average delay is not a good LOS measure due to zero delays associated with major road lanes

#### 6 OUTCOMES OF TRAFFIC ANALYSIS FOR CONSTRUCTION SCENARIO

The Woodmead pipeline crosses several roads and the proposed method of construction on each road crossing is indicated on Table 11 below,

Table 8: Proposed Woodmead pipeline method of construction on each road crossing

Road Name	Proposed Method of Construction
Zinnia Drive	Open Trenching
Gazania Crescent	Open Trenching
Marigold Cresset	Open Trenching
Lilium Avenue	Open Trenching
Marlboro Drive	Pipe Jacking
South Road	Pipe Jacking
Woodlands Drive	Pipe Jacking
Lincoln Street	Open Trenching
Alexandra Taxi Rank Road	Open Trenching

#### 6.1 Construction of Woodmead pipeline under Woodlands drive

The Woodmead pipeline will be constructed under the road on Woodlands Drive (from Lincoln Street to Jessica Close), these locations are clearly indicated in Figure 2 (the pipeline on Woodland Drive is indicated with a purple colour).

#### 6.1.1 Woodlands Drive Traffic analysis during construction

The existing eastbound left lane on Woodlands Drive will be used as a working area for the excavation and installation of the pipeline. The median along Woodlands Drive will be removed to accommodate an additional lane since the left lane will be used for construction purposes. The following intersections will be affected by the anticipated construction conditions along Woodlands drive as indicated in Figure 2:

- Western service Road/Jessica Close & Woodlands Drive Intersection 8
- Woodlands Drive and Lincoln Street Intersection 9

The morning, midday and afternoon peak were identified for both intersections and analysed for the anticipated construction conditions. Table 9 below indicates the LOS for the intersections where the road lanes will be reduced for construction purposes. Figure 5 and Figure 6 indicate the layout of the intersection 8 and intersection 9 before and during construction of the Woodmead pipeline.

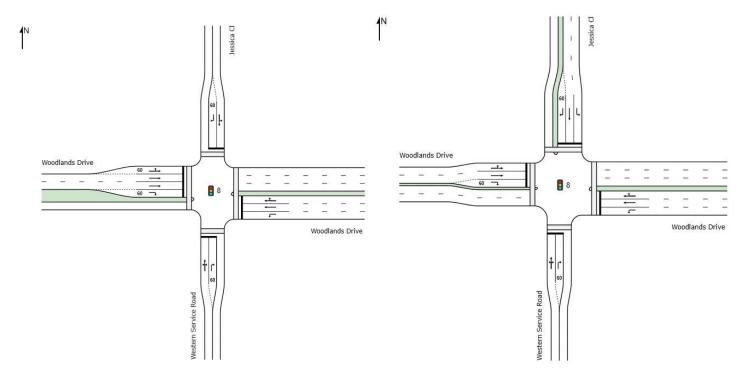


Figure 5: Western service Road/Jessica Close & Woodlands Drive – Intersection 8 layout - Before Construction and During Construction

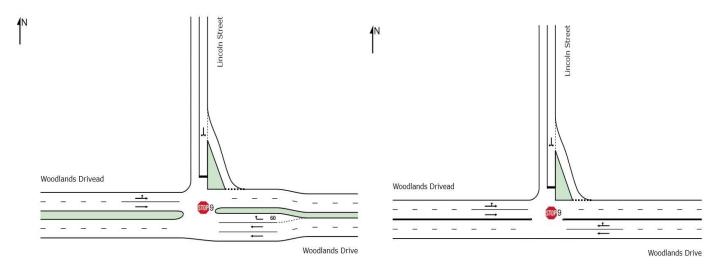


Figure 6: Woodlands Drive and Lincoln Street – Intersection 9 layout - Before Construction and During Construction

Table 9: Morning, Midday and Afternoon Peak with corresponding LOS during construction for intersections along Woodlands Drive

Intersection Name	Intersection Type	Morning Peak Average Delays(sec)	Morning Peak LOS	Midday Peak Average Delays(sec)	Midday Peak LOS	Afternoon Peak Average Delays(sec)	Afternoon Peak LOS
Western service Road/Jessica Close & Woodlands Drive – Intersection 8	Signalised,4 Ways	38.3	D	12.8	В	15.3	В
Woodlands Drive and Lincoln Street – Intersection 9	Unsignalised, Stop on minor road	182,7	N/A* (Northbound: F)	6.4	N/A* (Northbound: F)	49.1	N/A* (Northbound: F)

It can be noted that intersection 8 and intersection 9 will operate at the same LOS as they were operating before construction (see Table 9)

#### 6.1.2 Western Service Road Traffic analysis during construction

The Northbound lane will be used as a working area for the excavation and installation of the pipeline along the Western Service Road. A stop and go traffic accommodation will be implemented during construction, the southbound lane will be used for this purpose during construction phase. The working area along the western service road northbound lane will be in 100m intervals. The table below indicates the calculations for the queue length on Western service road during construction. The highest 15 minutes morning peak traffic volumes were used as the worst case scenario for traffic travelling on Western Service Road. The highest 15 minutes midday peak traffic volumes were used as the worst case scenario for traffic travelling on Western Service Road during construction (between 09:00 am and 15:00 pm). The Table below shows all the inputs taken into consideration when calculating the queue length for traffic accommodation during construction.

Table 10: Inputs used to calculate the queue length on Western Service Road during construction

Input	Units					
Length of construction area	100m (0.1km)					
Driving speed	30km/h					
Space per vehicle	4.5m					
Standard delay per vehicle	3 sec					
Total cycle time	5 min (300 sec)					
All red time (to drive the 0.1km)	0.2min (12 sec)					
Minus all red time	4.6min (276 sec)					
Total Cycles (in 15 min)	3					

Table 11: Western Service Road highest 15 minutes morning peak traffic volumes for calculating queue length during construction

Road Name	Proposed Method of Construction	
	Phase A (Southbound)	Phase B (Northbound)
Total Volume (veh/highest 15min/peak hour)	234	144
% split of vehicles on the road	62%	38%
Green time (min)	2.8min	1.8min
Max vehicles that can enter	57	35
Avg Arrival speed (veh/min)	15.60	9.60

Table 12: Western Service Road highest 15 minutes morning peak queue length during construction

Min	Sec	Cumulative	Phase A (Southbound)	Cars delayed	Cars delayed	Phase B (Northbound)		
2,85	170,86	170,86	GREEN	0	27	RED		
0,20	12,00	182,86	RED	3	29	RED		
1,75	105,14	288,00	RED	30	11	GREEN		
0,20	12,00	300,00	RED	33	13	RED		
2,85	170,86	470,86	GREEN	20	40	RED		
0,20	12,00	482,86	RED	23	42	RED		
1,75	105,14	588,00	RED	50	24	GREEN		
0,20	12,00	600,00	RED	53	26	RED		
2,85	170,86	770,86	GREEN	40	53	RED		
0,20	170,86	941,71	RED	43	55	RED		
1,75	170,86	1112,57	RED	70	37	GREEN		
0,20	170,86	1283,43	RED	73	39	RED		
Lo	ngest qu	eue (veh)	73	3	55			
Qı	ueue Len	gth (km)	0.32	29	0.2	248		

Table 13: Western Service Road highest 15 minutes midday peak traffic volumes for calculating queue length during construction

Road Name	Proposed Method of Construction	
	Phase A (Southbound)	Phase B (Northbound)
Total Volume (veh/highest 15min/peak hour)	131	127
% split of vehicles on the road	51%	49%
Green time (min)	2.3	2.3
Max vehicles that can enter	47	45
Avg Arrival speed (veh/min)	9.37	8.47

Table 14: Western Service Road highest 15 minutes midday peak queue length during construction

Min	Sec	Cumulative	Phase A (Southbound)	Cars delayed	Cars delayed	Phase B (Northbound)	
2,34	140,14	140,14	GREEN	0	20	RED	
0,20	12,00	152,14	RED	2	22	RED	
2,26	135,86	288,00	RED	22	0	GREEN	
0,20	12,00	300,00	RED	24	2	RED	
2,34	140,14	440,14	GREEN	0	22	RED	
0,20	12,00	452,14	RED	2	24	RED	
2,26	135,86	588,00	RED	22	0	GREEN	
0,20	12,00	600,00	RED	24	2	RED	
2,34	140,14	740,14	GREEN	0	22	RED	
0,20	140,14	880,28	RED	2	24	RED	
2,26	140,14	1020,42	RED	22	0	GREEN	
0,20	140,14	1160,56	RED	24	2	RED	
Lo	ngest qu	eue (veh)	24	ļ	24		
Q	ueue Len	gth (km)	0.10	08	0.1	108	

The longest possible queue in vehicles that will be recorded on Western Service Road during the construction of the pipeline is 73 veh and they will stretch over a distance of 329m (this is based on the highest 15 minutes peak).

The longest queue in vehicles that will be recorded between 09:00 and 15:00 on Western Service Road during the construction of the pipeline is 24veh and they will stretch over a distance of 108m (this is based on the highest 15 minutes midday peak).

#### 7 PUBLIC TRANSPORT

Public transport will play an important role due to some public transport vehicles and pedestrians observed in the surrounding area. Public transport will not be allowed to stop within or adjacent to the construction site, therefore public transport facilities are to be accommodated outside the construction site along the roads where construction will take place.

#### 8 NON-MOTORISED TRANSPORT

Non-Motorized Transport (NMT) includes walking (walking is the most familiar form of NMT), bicycling and other forms such as small wheeled transport (skates, skateboards, push scooter and hand carts) and wheelchair travel. These modes of transportation provide both recreation (they are an end in themselves) and transportation (they provide access to goods and activities). Though, users may consider a particular trip to serve both objectives. For example,

some users may choose to walk or cycle rather than drive simply because they enjoy walking or cycling, although it takes longer. The definition of NMT includes any form of transportation that provides personal or goods mobility by methods other than the combustion motor.

Sustainability of a transport system requires integration of all modes of transport inclusive of NMT. NMT plays a leading role in previously disadvantaged communities, and it is an affordable mode of transport. It is important to provide safe NMT infrastructure, such as pedestrian walkways and/or cycling lanes.

There are many benefits to NMT, which include environmental benefits, increased liveability, improved health, economic gains and transport benefits. Some of the benefits can even lead to further advantages such as reduction in accidents and travelling time savings.

Pedestrians are to be accommodated during construction of the proposed pipelines. Temporary walkways with universal access designs(to accommodate wheelchairs, strollers and the elderly) are to be incoporated in the traffic management plan of the construction of the proposed pipeline. The proposed walkways width must be a minimum of 1.5m.

It is therefore recommended that NMT and universal access facilities be incorporated during the construction of the proposed Woodmead pipeline.

#### 9 TRAFFIC MANAGEMENT PLAN

The traffic assessement indicates that traffic is low during the off peak peak period betweeen 09:00 and 15:15, this will be the ideal time for construction to take place as there will be less traffic on the roads. A comprehensive traffic management plan for the construction phase must be designed for each intersection, access and also along the roads where the proposed pipeline will be installed. A traffic management plan such as stop and go with temporary warning traffic signs and barricades on areas where the pipiline will be installed under the road is to be implemented. A detour for traffic passing through the construction area during the night is to be provided and access to the area is to be given to residence only, temporary warning traffic signs and information boards are to be implemented to guide the vehicles well in advance.

Traffic accommodation/management plans must be compiled in accordance to the South African Road Traffic Signs Manual (SARTSM) and be submitted to the affected stakeholders and the relevant road authority for approval.

#### 10 CONCLUSION

Given the findings in the report, the following conclusions are drawn:

- Woodmead Water Upgrading project area is located on the North-Eastern side of Johannesburg in Region E.
- The proposed pipeline is located in Woodmead along the following routes:
  - Zinnia Drive;
  - Lilium Avenue;
  - South Road;
  - Western Service Road;
  - Woodmead Drive;
  - Woodlands Drive;
  - Lincoln Street; and
  - Jessica Close.
- The pipeline will cross the following routes:
  - Zinnia Drive;
  - Road within Alexandra Taxi Rank;
  - Gazania Crescent;
  - Marigold Cresset;
  - Lilium Avenue;
  - Marlboro Drive;
  - South Road;
  - o Woodlands Drive; and
  - Lincoln Street.
- Traffic counts were conducted on the 3<sup>rd</sup> of November 2022 over a period of 14 hrs and 24hrs on intersections where the proposed Woodmead Water pipeline will be located and also on intersections where the proposed Woodmead Water pipeline will cross
- The morning peak is between 06:45 to 09:00, the midday peak is between 12:00 to 15:00 and the afternoon peak is between 15:15 to 17:45 at all respective intersections
- The lowest traffic volumes during the day are between 09:00 and 15:15
- The early morning peak for intersection 7 and intersection 8 is between 04:30 to 05:30 and the late night peak is between 20:00 to 21:00 or both intersections.
- The 3 Filling stations along the proposed Woodmead pipeline route attract traffic volumes of between 1 678 and 3 737 over a 24hr period.
- Dunwoody Shopping Centre along Western Service Road attracts traffic volumes of between 983 and 1 363 over a 24hr period.

- The average modal split on all intersections is made up of Light Vehicles (LV) at about 94% followed by Heavy Vehicles (HV) at about 1% then Taxis at about 4% and Buses at about 1%.
- The level of service for intersection 4,5, 6, 7,10 and 11 is currently within acceptable standards and for intersection 1, 2,3,8,and 9 is currently not within acceptable standards for the morning peak periods.
- The level of service for intersection 1,2,4,5, 6, 7,8,10 and 11 is currently within acceptable standards and intersections 3, and 9 is not within acceptable standards for the midday peak periods.
- The level of service for intersection 2,4,5, 6, 7,8,10 and 11 is currently within acceptable standards and intersections 1,3, and 9 is not within acceptable standards for the affternoon peak periods
- The existing eastbound left lane on Woodlands Drive will be used as a working area for the excavation and installation of the pipeline.
- The median along Woodlands Drive will be removed to accommodate an additional lane since the left lane will be used for construction purposes.
- Intersection 8 and intersection 9 will operate at the same LOS during construction as they were operating before construction.
- The Western Service Road northbound lane will be used as a working area for the excavation and installation of the pipeline along the Western Service Road.
- A stop and go traffic accommodation will be implemented during construction on the Western Service Road and the southbound lane will be used for this purpose during the construction phase.
- The highest 15 minutes morning peak and midday peak traffic volumes were used as the worst case scenario for calculating the queue length for the stop and go on Western Service Road during construction phase
- The highest number of vehicles that will be delayed on Western Service Road during the construction of the pipeline is 117veh and they will stretch over a distance of 526m. (this is based on the highest 15 minutes morning peak).
- The highest number of vehicles that will be delayed between 09:00 and 15:00 on Western Service Road during the construction of the pipeline is 30veh and they will stretch over a distance of 135m. (this is based on the highest 15 minutes midday peak).

#### 11 RECOMMENDATIONS

The following recommendations are made:

- It is recommended that construction takes place only between 09:00 am and 15:00 pm during the construction phase.
- A comprehensive traffic management plan for the construction phase must be designed for each intersection, access and also along the roads where the proposed pipeline will be installed. Traffic management plans must be compiled in accordance to the South African Road Traffic Signs Manual (SARTSM) and be submitted to the affected stakeholders and the relevant road authority for approval.
- A detour for traffic passing through the construction area during the night is to be provided and access to the area is to be given to residence only, temporary warning traffic signs and information boards are to be implemented to guide the vehicles well in advance.
- Access to Properties, Public Transport stops and pedestrians need to be accommodated on the traffic management plans.

#### 12 REFERENCES

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- 6. Urban Transport Guidelines (UTG 1), Guidelines for the Geometric Design of Urban Arterial Roads.
- 7. South African Road Traffic Signs Manual (SARTSM), Volume 2.
- 8. South African Road Traffic Signs Manual (SARTSM), Volume 3.
- 9. Committee of Transport Officials, 2014. TRH 16 South African Traffic Impact and Site traffic Assessment Standards and Requirements Manual, Volume 2 SANRAL.
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- 11. Department of Transport. Pedestrian and Bicycle Facility Guidelines. August 2003.

### **ANNEXURE A: TRAFFIC COUNT DATA**

### Zania Drive and Lilium Avenue (intersection 1) Traffic Counts Data

LOCATION: PROJECT NI SURVEY DA	TE:	Thursda	WOODMEAL JT2022-219 ay, 03 Novemb	7 er 2022	PROJECT TI	ON:	WOODMEAD-TRAFFIC COUNT LILIUM AVE & ZINNIA DR							<b>(</b> Uni	traf	
SURVEY TIN	MES:	0	5H00-19H0	0	KMZ FILE N	R:	P11	DATA:	J.A.V	TYPE:	TI .	N-14H-5-19-	С			
					·		ТОТА	L SUMMA	RY							
START	ME END	1	ORTHBOUN 2	ND 3	4	VESTBOUNE 5	6	7 7	OUTHBOUI 8	ND 9	10	ASTBOUNI 11	12	VOLUME	SUMMARY	
05:00	05:15	-	-	-	-	27	4	1	-	6	7	11	- 12	56		
05:15	05:30	-	=:		-	28	3	1	-	9	12	27	-	80		
05:30	05:45		-	-	-	33	6	3 6	-	7	17	29	-	95		
05:45 06:00	06:00 06:15	-	-	-	-	50 48	6	5	-	16 20	22 14	36 39	-	132	3	
06:15	06:30	-	-	-	-	54	6	2	-	30	26	48	-	166	5	
06:30	06:45	+	-	-	-	66	12	10	-	12	44	52	-	196	6	
06:45	07:00	-	-	-	-	70	25	16	-	33	70	60	-	274	7	
07:00	07:15	-	-	-	-	88	24	28	-	40	77	67	~	324	9	
07:15 07:30	07:30 07:45	-	-	-	-	93	46 37	32 23		87 81	153 124	68 65	-	479 424	12	
07:45	08:00	-	-	-	-	103	34	30	-	94	91	61	-	413	15 16	
08:00	08:15	-	-	-	-	73	28	10	-	90	142	70	-	413	17	
08:15	08:30	-	-		-	63	22	20	-	104	101	62	×	372	16	
08:30	08:45	-	ĒA			57	16	18	-	62	69	44		266	14	
08:45	09:00	-	-	-	-	44	14	8	-	53	43	41	-	203	12	
09:00 09:15	09:15 09:30	-	-	-	-	35 34	7 16	11	-	67 63	33	30 27	-	180		
09:30	09:45	-	-	-	-	35	8	9	_	51	29	31	-	163		
09:45	10:00	-	= 1	-	-	36	8	13	-	42	34	47	-	180	7	
10:00	10:15	-		-	-	45	7	10	<u>-</u>	29	41	27		159	6	
10:15	10:30		-	-	-	41	15	12	-	32	24	41	-	165	6	
10:30	10:45	-	-	-	-	32	11	5	-	33	18	29	-	128	6	
10:45 11:00	11:00 11:15	-	-	-	-	33 39	9	12	-	35 33	27	38	-	150 152	5	
11:15	11:30	-	-	-	-	34	18	9	-	40	36	35	-	172	6	
11:30	11:45	-	-	-	-	23	21	9	-	34	16	30	-	133	6	
11:45	12:00	+	-	-	-	25	23	11	-	38	25	34	-	156	6	
12:00	12:15	-	-	-	-	31	11	18	-	35	23	46	-	164	6	
12:15	12:30	-	-	-	-	45	23	34	-	27	26	38	7-1	193	6	
12:30 12:45	12:45 13:00	-	-	-	-	49 36	23 10	20 10	-	41 30	42 24	40 37		215 147	7	
13:00	13:15	-	-	-	-	44	8	22	-	29	33	50	-	186	7	
13:15	13:30	-	-	-	-	42	19	18	-	32	37	37	-	185	7	
13:30	13:45	-	-	-	-	43	11	11	-	34	27	35	-	161	6	
13:45	14:00	-	-	-	-	41	12	18	-	28	24	35		158	6	
14:00	14:15	-	-	-	-	44	10	25	-	38	28	59	-	204	7	
14:15 14:30	14:30 14:45	-	-	-	-	52 37	25 20	27 17	-	41 39	36 28	55 33	-	236 174	7	
14:45	15:00	_	-	-	-	50	16	22	-	36	44	51	-	219	8	
15:00	15:15	-			-	43	15	16	-	51	32	52	-	209		
15:15	15:30	-	-	-	-	50	9	8	-	48	30	56		201		
15:30	15:45	-	-	-	-	43	14	14	-	46	32	51	2	200		
15:45	16:00	-	-	-	-	42	7	14	-	50	31	54	-	198	8	
16:00 16:15	16:15 16:30	-	-	-	-	48 51	12 17	25 17	-	65 71	36 42	61 54	-	247	8	
16:30	16:45	-	-	-	-	54	7	33	-	73	28	85	-	280	9	
16:45	17:00	9		-	-	63	9	24	÷	67	48	69	-	280	10	
17:00	17:15	9	-	-	-	62	16	25	-	74	48	61	-	286	10	
17:15	17:30	-	-	-	-	57	9	39	-	88	50	47	-	290	11	
17:30	17:45	-	-		-	52	19	34	-	85	39	45		274	11	
17:45 18:00	18:00 18:15	-		-	-	50 50	18 12	30	-	70 56	32 29	49 51	-	249	10	
18:15	18:30	-	-	-	-	46	14	20	-	42	16	25	-	163	9	
18:30	18:45	-	-	-	-	47	14	33	-	44	17	49	-	204	8	
18:45	19:00	-	-		-	40	20	21	-	37	27	24	-	169	7	
TO	ΓAL	-	-	-	-	2 715	841	949	-	2 618	2 257	2 530	-	11 910		

## Marlboro Drive (M60) and Lilium Avenue (Intersection 2) Traffic counts Data

LOCATION:		V	VOODMEAD	)	PROJECT TIT	ILE:			WOODM	EAD-TRAFFI	C COUNT				
PROJECT N	R:		T2022-219										hitraf		
URVEY DA			y, 03 Novemb		INTERSECTION	,									IILI di
URVEY TIN	ΛES:	05	5H00-19H0	0	KMZ FILE NF	₹:	P9	DATA:	J.A.V	TYPE:	40	V-14H-5-19-	-C		
							TOTA	L SUMMAI	RY						1
	ME NORTHBOUND					ESTBOUN			UTHBOUN		EASTBOUND				ME SUMMARY
START	05:15	1	2 5	3 8	4	5	6 22	7	8 2	9	10 2	11 24	12	TOTAL 121	
05:00 05:15	05:15	- 2	4	8	5	35 49	37	16 19	2	-	-	19	- 3	145	
05:30	05:45	1	8	10	6	55	43	34	7	-	5	27	3	199	
05:45	06:00	4	9	7	12	89	70	44	5	-	3	60	3	306	
06:00	06:15	9	9	16	14	120	85	52	11	2	9	66	7	400	
06:15	06:30	11	19	17	7	156	167	62	8	1	8	90	4	550	
06:30 06:45	06:45 07:00	17 19	28 46	21 39	7 11	182 187	207 219	95 121	12 11	5	14 21	96 118	9 10	693 807	
07:00	07:15	25	69	34	16	224	287	196	27	9	16	130	5	1 038	
07:15	07:30	24	81	51	12	220	247	211	36	8	32	133	13	1 068	
07:30	07:45	25	79	39	11	178	292	181	39	13	31	132	10	1 030	
07:45	08:00	16	84	36	18	180	272	166	43	8	42	145	10	1 020	
08:00	08:15	17	54	37	7	199	274	164	33	16	21	104	12	938	
08:15 08:30	08:30 08:45	16 20	47 34	41 23	6 12	206 165	256 206	143 127	36 18	15 15	24 25	108 123	12 18	910 786	
08:45	09:00	21	26	29	10	201	175	127	25	9	13	107	7	743	
09:00	09:15	10	17	17	9	172	187	134	18	7	19	134	8	732	
09:15	09:30	10	10	15	9	183	204	115	13	13	17	125	21	735	
09:30	09:45	18	19	19	10	185	177	110	8	8	23	143	7	727	
09:45	10:00	11	14	11	26	163	158	122	21	11	17	136	6	696	
10:00	10:15	11	20	16	15	167	120	109	14	12	20	138	11	653	
10:15 10:30	10:30 10:45	10 13	20	28 16	6	158 172	141 145	127 123	23 18	9 15	9 23	136 138	11 9	678 712	
10:45	11:00	9	15	13	20	165	133	123	13	7	23	153	12	686	
11:00	11:15	15	21	12	12	172	114	106	23	10	18	157	11	671	
11:15	11:30	15	13	20	13	157	133	125	17	21	16	149	16	695	
11:30	11:45	20	18	22	12	142	128	125	17	18	18	136	6	662	
11:45	12:00	11	16	20	26	174	120	112	24	6	13	149	16	687	
12:00	12:15	24	19	20	27	172	98	124	23	12	14	143	16	692	
12:15 12:30	12:30 12:45	19 15	22	20	21 20	169 164	131 140	138 118	30	13 18	13 13	155 140	14	739 718	
12:45	13:00	7	15	17	23	136	156	135	27	14	13	148	18	709	
13:00	13:15	15	24	16	20	152	130	142	32	13	20	144	16	724	
13:15	13:30	13	24	21	20	170	117	163	23	10	20	165	11	757	
13:30	13:45	17	28	18	14	156	141	145	26	10	17	162	13	747	
13:45	14:00	9	31	19	24	160	110	139	23	17	31	175	25	763	
14:00	14:15	16	25	26	28	169	113	177	45	12	15	186	17	829	
14:15 14:30	14:30 14:45	19 14	26 28	35 31	17 16	160 166	116 135	175 166	39 25	24 13	19 14	160 132	16 12	806 752	
14:45	15:00	18	23	17	21	163	115	162	23	10	24	183	24	783	
15:00	15:15	5	30	30	24	145	105	195	29	20	18	182	10	793	
15:15	15:30	11	17	22	20	134	134	184	33	11	12	150	18	746	
15:30	15:45	13	28	29	13	141	120	213	39	21	12	155	19	803	
15:45	16:00	15	25	17	13	148	123	234	28	12	23	188	13	839	
16:00 16:15	16:15 16:30	7	20	13 16	19	139 146	121 166	268 299	50 60	32 38	21	194 166	21 17	905 983	
16:30	16:30	5	19	18	16	150	161	315	53	40	15	177	16	985	
16:45	17:00	7	32	23	11	165	176	259	61	22	14	170	26	966	
17:00	17:15	14	27	33	22	155	177	274	62	16	6	178	17	981	
17:15	17:30	5	23	27	18	136	162	308	76	31	19	139	29	973	
17:30	17:45	6	20	25	30	114	153	244	64	23	6	176	23	884	
17:45	18:00	10	26	23	20	124	137	188	52	6	6	166	22	780	
18:00	18:15	7	18	18	32 19	120 114	95 93	162	31	3	9	145	17	658 593	
18:15 18:30	18:30 18:45	5	13	14 7	21	104	102	129 133	38 27	5	10	134 115	26 18	555	
18:45	19:00	13	25	17	17	75	66	124	19	6	6	116	16	500	
10.000	TAL	708	1 459	1 219	899	8 503	8 212	8 495	1 586	699	888	7 620	763	41 051	

## Impala Road and South Road (Intersection 3) Traffic counts Data

LOCATION:		١	WOODMEA	D	PROJECT TI	TLE:			WOODM	IEAD-TRAFFI	C COUNT				
PROJECT N SURVEY DA			JT2022-219 ay, 03 Novemb	V	INTERSECT	ION:			SOUTH RI	D (M74) & IN	//PALA RD			<b>(</b> unitra	f
SURVEY TIM			5H00-19H0		KMZ FILE N	R:	P8	DATA:	J.A.V	TYPE:	11	N-14H-5-19-	·C		
									- 0						
T.1	45	N/C	DET LIBOUR	up.	,	(ECTROLIN)	20.00.00.00	L SUMMA	20000	up.	_	A CER OLINI		VOLUME CUMANA	274
START	ME END	1	ORTHBOUI 2	3	4	VESTBOUNI 5	6	7	OUTHBOUN 8	9	10	ASTBOUNI 11	12	TOTAL TOTAL	XY
05:00	05:15	-	-	-	-	30	-	-	-	2	5	17	-	54	
05:15	05:30		1.5			37	1	-	1-	3	2	20	(e)	63	
05:30	05:45	-	-	-	-	66	1	1	-	4	-	31		103	
05:45 06:00	06:00 06:15	-	-	-	-	95 106	2	2		10 8	3	49 48		160 170	380 496
06:15	06:30	-	-	-	-	157	5	6	1.5	10	5	74	-	257	690
06:30	06:45	-	-		-	231	3	4	-	15	15	90		358	945
06:45	07:00	-	1-	-		238	4	6	-	17	19	156	-	440	1225
07:00	07:15	-	-	Ξ.	-	242	9	11	-	28	26	216	-	532	1587
07:15	07:30	-	-	-	-	320	25	12	-	38	46	258	-	699	2029
07:30	07:45	-	-	-	-	372	32	14		42	47	236	-	743	2414
07:45	08:00	-	-	-	-	340	14	16	-	41	42	220	-	673	2647
08:00	08:15 08:30	-	-	-	-	357 342	27 37	19	-	38 37	31	186 210	-	658 667	2773
08:15	08:30	-	-	-		255	34	10	-	50	22	189	-	560	2741
08:45	09:00	-	-	-	-	265	10	7	-	26	22	144	-	474	2359
09:00	09:15	-	-	-	-	250	2	7	-	14	25	134	-	432	2333
09:15	09:30	-	-	-	-	228	4	9	-	22	25	158	-	446	
09:30	09:45	-	-	-	-	213	8	7	-	26	19	115	-	388	
09:45	10:00	-		-	<del></del>	197	10	4	-	30	16	106		363	1629
10:00	10:15	-	-	-	-	206	9	6	-	18	17	125	-	381	1578
10:15	10:30	-	-	-	-	177	6	9	-	14	22	182	-	410	1542
10:30	10:45	-	(#	-	-	156	3	2	-	22	19	136	-	338	1492
10:45	11:00 11:15	-	-	-	-	123 165	7	7	-	18 21	20 19	135 146	-	312	1441
11:15	11:30	-	-	-	-	113	5	16	-	19	15	160	-	365 328	1425
11:30	11:45	-	-	-	-	135	11	1	-	7	19	170	-	343	1348
11:45	12:00	-	-	-	-	173	7	10	-	18	18	124	-	350	1386
12:00	12:15	-	12	-	-	114	7	7	-	16	23	150	-	317	1338
12:15	12:30	-	1.0		0-	151	4	7	1.=	14	20	158	o <del>=</del> /	354	1364
12:30	12:45	-	-	-		177	12	26	-	35	14	148	-	412	1433
12:45	13:00	-	-	-	-	118	5	9	1-1	38	20	126	1-1	316	1399
13:00	13:15	-	1.70		- 12	145	3	8		15	24	167		362	1444
13:15	13:30	-	-	-		159	7	6	-	17	21	159	-	369	1459
13:30	13:45 14:00	-	-	-	-	134 161	5	5	-	17 28	20	177 161	-	358 389	1405
14:00	14:00	-	-	-	-	130	5	9	-	16	44	203	-	407	1478
14:15	14:30	-	-	-	-	166	6	12	-	15	20	207	-	426	1580
14:30	14:45	-	-	-	-	151	4	3	-	20	17	168	-	363	1585
14:45	15:00	-		-	-	131	7	5	-	19	29	204	-	395	1591
15:00	15:15	-	-	-	1.	161	5	9	-	21	33	267	-	496	
15:15	15:30	-	-	-	-	150	10	7	-	24	28	235	-	454	
15:30	15:45	-	-		1-	127	4	9	1-	20	31	243		434	
15:45	16:00	-	-	-	-	162	14	11	-	20	21	291	-	519	1903
16:00 16:15	16:15 16:30	-	-	-	-	147	13	16	-	24 15	29 32	326 358	-	555	1962
16:15	16:30	-	-	-	-	208	12	14	-	16	43	312	-	598 605	2106
16:45	17:00	-	-	-	-	209	7	9	-	21	42	318	-	606	2364
17:00	17:15	-	-	-	-	198	6	6	-	14	30	345	-	599	2408
17:15	17:30	-	-	-	-	180	8	7	-	19	40	335	-	589	2399
17:30	17:45	-	-	-	-	171	10	5	-	12	30	341	120	569	2363
17:45	18:00	-	1:-		-	135	8	4	15	23	20	252	-	442	2199
18:00	18:15	٠	-		-	153	4	-	-	8	14	172	-	351	1951
18:15	18:30	-		-	-	108	3	5	-	8	14	160	-	298	1660
18:30	18:45	-	-	-	-	73	- 1	3		2	10	167	-	255	1346
18:45	19:00	-	-	-	-	71 9 752	4	2 426	-	1 101	1 260	119	-	211	1115
TO	IAL	-	-	-	-	9 753	472	426	-	1 101	1 260	10 104	-	23 116	

## Western Service Road and Wendy Road (Intersection 4) Traffic counts Data

OCATION:	-	V	/OODMEAD		PROJECT TI	TLE:			WOODMI	EAD-TRAFFIC	COUNT				
ROJECT N	-		T2022-2197	Autota atta	INTERSECTI	ON:			WESTERN SE	RVICE RD &	WENDY RD			<b>(</b> unitra	f
JRVEY DA			y, 03 Novembe				P.C							ןן טווונו כ	11
JRVEY TIN	VIES:	0:	5H00-19H00	,	KMZ FILE NI	1.	P6	DATA:	J.A.V	TYPE:	4\	V-14H-5-19			
							TOTA	L SUMMA	RY						
CONTRACTOR OF THE	ME		RTHBOUN		700	ESTBOUN			OUTHBOUN		2000	ASTBOUN		VOLUME SUMMA	ARY
START	END	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	
05:00	05:15	1	2	-	-	-	-	-	1	2	-	-	1	7	
05:15	05:30 05:45	-	10	-	-	-	-	-	5	2	1		1	11 19	
05:30 05:45	06:00	-	7		-	-	-	-	7	2	- 1	-	2	18	
06:00	06:15	4	11		-	-	-	-	17	1	2	-	-	35	
06:15	06:30	2	17	-	-	-	-	-	21	5	4	-	3	52	
06:30	06:45	8	34	-	-	-	-	-	39	6	5	-	8	100	
06:45	07:00	2	43	-	-	-	-	-	41	8	4	-	7	105	
07:00	07:15	6	64	-	-		-	-	75	7	4	-	12	168	
07:15	07:30	17	66	-	-	-	-	-	79	6	12	-	17	197	
07:30	07:45	16	91	-	-	-	-	-	108	10	19	-	21	265	
07:45	08:00	7	86	-	-	-	-	-	110	19	13	-	9	244	
08:00	08:15	13	90	-	-	-	-	-	86	9	21	-	16	235	
08:15	08:30	9	72	-	-	-	-	-	60	7	26		11	185	
08:30	08:45	3	61	-	-		-	-	62	7	8		5	146	
08:45	09:00	8	44	-	-	.=0	-	-	50	4	11		10	127	
09:00	09:15	5	34	-	-	-	-	-	44	4	11	-	6	104	
09:15	09:30	4	36	1-1	-	.=1	-	-	41	7	10		7	105	
09:30	09:45	2	21	-	-	-	-	-	28	7	11	-	3	72	
09:45	10:00	2	30	-	-		-	-	37	7	8	-	9	93	
10:00	10:15	3	31	-		-	-	-	25	5	11		7	82	
10:15	10:30	3	29		-	-	-	-	32	3	5		10	82	
10:30	10:45	5	32	-	-	-	-	-	31	2	7	-	10	87	
10:45	11:00	5	21	(-)	-		-	-	27	4	9	-	7	73	
11:00	11:15	5	30			-	-	-	43	7	6	-	5	96	
11:15	11:30	3	29	-	-	-	-	-	22	4	5	-	7	70	
11:30	11:45	3	29		-	-	-	-	37	8	9	-	7	93	
11:45	12:00	12	37	-	-	-	-	-	44	5	8	-	5	111	
12:00 12:15	12:15 12:30	11	33	-	-	-	-	-	45 44	8	13	-	5	108	
12:30	12:45	7	29		-	-	-	-	46	12	15	-	3	112	
12:45	13:00	4	27		-	-	-	-	46	5	7	-	6	95	-
13:00	13:15	4	26		-	-			28	5	11	-	3	77	
13:15	13:30	2	32	-	_	-	_	_	35	6	8	-	7	90	
13:30	13:45	9	43	-	-	-	-	-	47	4	11	-	7	121	
13:45	14:00	8	47	-	-	-	-	-	34	11	5	-	12	117	
14:00	14:15	3	54	-	-	-	-	_	70	11	14	-	22	174	
14:15	14:30	5	43	-	-	-	-	-	50	6	14	-	8	126	
14:30	14:45	3	41	-	-	-	-	-	44	10	7	-	9	114	
14:45	15:00	8	34	-	-	-	-	-	42	15	14	-	9	122	
15:00	15:15	7	21	-	-	-	-	-	70	5	13		7	123	
15:15	15:30	6	25	-	-	-	-	-	105	18	12	-	6	172	
15:30	15:45	5	35	-	-		-	-	91	12	9		6	158	
15:45	16:00	7	29	-	-	-	-	-	10	-	8	-	6	60	
16:00	16:15	4	40		-	-	-	-	18	2	7		6	77	
16:15	16:30	9	38	-	-	-	-	-	73	11	11	-	18	160	
16:30	16:45	14	39	-	-	-	-	-	87	19	13	-	10	182	
16:45	17:00	16	27	-	-	-	-	-	54	6	11	-	4	118	
17:00	17:15	8	44	-	-	-	-	-	78	6	14	•	9	159	
17:15	17:30	15	42	-	-	-	-	-	56	14	10	-	6	143	
17:30	17:45	4	38	-	-	-	-	-	54	7	8		4	115	
17:45	18:00	4	27		-	-	-	-	33	5	11	-	1	81	
18:00	18:15	14	22	-	-	121	-	-	34	8	7	-	2	87	
18:15	18:30	6	20	-	-		-	-	28	7	12		6	79	
18:30	18:45	3	13 11	-	-	-	-	-	14	5	5	-	-	40 37	
18:45	19:00			9-6	-	-	-	-	16	4	3	-	2		

## Western Service Road and Carnation Street (Intersection 5) Traffic counts Data

OCATION:			/OODMEAD		PROJECT TI	TLE:			WOODMI	EAD-TRAFFI	C COUNT			
ROJECT N			T2022-219		INTERSECTI	ON:		W	ESTERN SER	VICE RD & C	ARNATION S	T		Unitraf
JRVEY DA JRVEY TIN			, 03 Novemb		KMZ FILE NI		P7	DATA:						
SAVET III	VIES.	05	1100-1340	0	KIVIZ FILE IV	N.	P/	DATA.	J.A.V	TYPE:	IV	V-14H-5-19-		
							TOTA	AL SUMMA	RY					
TII	ME	NO	RTHBOUN	ND	W	/ESTBOUN		_	UTHBOUN	ID	E/	ASTBOUNE	)	VOLUME SUMMARY
START	END	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
05:00	05:15	2	1	-	-	-	11=1	-	3	-	1=	121	1	7
05:15	05:30	1	4	-		-	1.5	-	3	2	1	-	3	14
05:30	05:45	3	7	-	-	-	-	-	3	1	1-	-	3	17
05:45	06:00	3	4	-	-	-		-	6	=	1	-	4	18
06:00	06:15	1	13	-	-	= 1	-	-	12	-	3	-	4	33
06:15	06:30	6	15	1-1		-	-	-	22 30	2	3	-	8	53 83
06:30 06:45	06:45 07:00	9	31	-	-	-	-	-	39	7	8	-	20	113
07:00	07:00	17	59	-	-	-	-	-	99	11	19	-	21	226
07:15	07:30	21	64	-	-	-	-	-	112	18	15	-	17	247
07:30	07:45	23	116	-	-		_	_	120	14	28	_	22	323
07:45	08:00	8	109	-				_	105	10	18	-	16	266
08:00	08:15	10	104	-	-	-	-		89	9	13		10	235
08:15	08:30	6	92	-	-		-	-	54	2	12	-	11	177
08:30	08:45	5	76	-	-	-	-	-	63	3	12	-	9	168
08:45	09:00	5	58	-	-	-	-	-	43	2	5	-	10	123
09:00	09:15	1	46	-	-	-	-	-	50	8	9	-	2	116
09:15	09:30	3	46	-	-	-	-	-	47	2	8	-	7	113
09:30	09:45	5	23	-	-		7=	-	31	2	7	120	3	71
09:45	10:00	6	33	-	-	-	:-	-	36	4	8	-	7	94
10:00	10:15	7	35		-	-		-	30	5	11	1-1	2	90
10:15	10:30	8	32			-	-	-	31	2	7	-	4	84
10:30	10:45	6	32	-	-	-	-	-	27	9	10	1-	7	91
10:45	11:00	8	25		-	-	1.5	-	27	5	13	15.	9	87
11:00	11:15	8	32	-	-	+	-	-	40	6	8	-	7	101
11:15	11:30	8	26	-	-	-	-	-	27	7	11	1-	4	83
11:30	11:45	4	37	1.5	-	-	-	-	35	8	7	1.00	7	98
11:45	12:00	5	33	-	-		-	-	48	9	6	-	11	112
12:00	12:15	5	46	-		-	1=	-	40	15	6	-	4	116
12:15	12:30	4	38	-	-	-	-	-	45	5	12	-	9	113
12:30	12:45	4	40	-	-		-	-	56	10	8	-	8	126
12:45	13:00	3	33	~	-	-	-	-	50	15	5	-	3	109
13:00	13:15	5	39	-		-	-	-	36	7	9	-	3	99
13:15	13:30	11	30	-	-	-	-	-	42 50	10 7	1	-	5	99
13:30 13:45	13:45 14:00	6	31 44	-	-	*	-	-	79	6	12	-	3	117
14:00	14:00	11	95	-	-	-	-	-	60	7	16	-	7	196
14:00	14:15	8	63	-	-		-	-	58	7	9	-	5	150
14:30	14:45	6	36	-	-	-	-	-	51	7	10	-	6	116
14:45	15:00	8	38	-	-	-	-	-	54	12	5	-	4	121
15:00	15:15	4	51	-	-	-	-	-	63	13	6	-	3	140
15:15	15:30	5	43	-	-		-	-	60	9	5	-	6	128
15:30	15:45	12	35	-	-	-		-	57	3	8	-	5	120
15:45	16:00	6	31	-	-		-		61	13	6	-	5	122
16:00	16:15	10	37	-	-	-	-	-	78	8	1	-	7	141
16:15	16:30	14	39	-		-	-	-	84	6	5	-	4	152
16:30	16:45	9	41	-	-	-	-	-	98	10	6	-	5	169
16:45	17:00	10	33	-	-	-	-	-	61	9	6	-	9	128
17:00	17:15	8	51	-	-	÷	-	-	77	10	3	-	3	152
17:15	17:30	11	46	-	-	-	-	-	69	12	4	-	5	147
17:30	17:45	10	33	.=	-	-	17	-	53	10	2	1-	3	111
17:45	18:00	9	28	-	-	8	-		46	10	6	-	7	106
18:00	18:15	9	19	1-	-	-	-	-	34	6	2	(=)	5	75
18:15	18:30	10	20	-	-		-	-	32	5	5	-	7	79
18:30	18:45	2	16	-		=	-	-	16	10	1	-	1	46
18:45	19:00	2	19	-	-	-	14	-	18	6	6	-	4	55
	TAL	398	2 258	-1		-	-	10-0	2 760	399	421		387	6 623

# Western Service Road and Harrowdene Office Park Entrance Road (Intersection 6) Traffic counts Data

LOCATION:			VOODMEAU		PROJECT TI	TLE:			WOODM	EAD-TRAFFI	C COUNT				
PROJECT NI SURVEY DA			JT2022-219 y, 03 Novemb		INTERSECT	ON:	١	WESTERN SEI	RVICE ROAD	& ACCESS 1	TO HUAWEI	OFFICE PAR	K	<b>//</b> UI	itraf
SURVEY TIN			5H00-19H0		KMZ FILE N	R:	P1	DATA:	J.A.V	TYPE:	4\	V-14H-5-19	-C	<b>U</b>	
							TOTA	AL SUMMA	RY						
TIN	ΜE	NC	ORTHBOU	ND	V	VESTBOUN		Account to the second	OUTHBOUN	ID	Е	ASTBOUN	D	VOLUN	//E SUMMARY
START	END	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	
05:00	05:15	-	1	-	-	-	-	-	2	-	-	-	-	3	
05:15 05:30	05:30 05:45	-	13	-	-	-	-	-	3 8	1	-	-	- 2	5 24	
05:45	06:00	2	12	-	-	-	-	-	14	2	2	-	1	33	
06:00	06:15	2	12	-	-	-	-	-	13	11	2	-	-	40	
06:15	06:30	2	14	-	-	-	1-	-	22	6	5	.=.	-	49	
06:30	06:45	3	24	-	-	-	-	-	43	12	3	-	1	86	
06:45	07:00	4	39	-	-	-	-	-	63	12	5		3	126	
07:00	07:15	1	58	-	-	-	-	-	117	11	3	-	1	191	
07:15 07:30	07:30 07:45	5 7	78 107	-	-	-	-	-	144 173	33	7	-	2	259 327	
07:30	08:00	13	91	-	-	-	-	-	145	48	5		6	308	
08:00	08:15	28	52	-	-	-	-	-	114	51	6	-	2	253	
08:15	08:30	43	64	-	-	-	-	-	101	82	18	-	6	314	
08:30	08:45	8	67	-	-	-	1-	-	126	63	12	1-1	1	277	
08:45	09:00	4	54	-	-	-	-	-	106	27	12	(=)	1	204	
09:00	09:15	1	42	-	-	-	-	-	98	11	7	-	2	161	
09:15	09:30	3	36	-	-	-	-	-	56	6	12	-	2	115	
09:30	09:45	1	47	-		-	-	-	48	11	4	-	2	113	
09:45 10:00	10:00 10:15	2	39 45	-		-	-	-	55 48	20 8	8	-	- 2	126 110	
10:15	10:30	1	43	-	-		-	-	40	6	4		2	96	
10:30	10:45	-	41	-	-	-		-	46	7	10	-	1	105	
10:45	11:00	2	48	-	-	-	-	-	42	6	9	-	-	107	
11:00	11:15	3	50	-	-	_	-	-	44	11	7	-	1	116	
11:15	11:30	5	30	-	-	-	-	-	43	10	8	-	3	99	
11:30	11:45	2	33	-	-	-	1.5	-	49	6	11	-	3	104	
11:45	12:00	1	35	-	-		-	-	44	8	17	-	2	107	
12:00	12:15	2	47		-	-		-	38	7 18	41	-	7	141 149	
12:15 12:30	12:30 12:45	2	49 58	-	-	-	-	-	49	21	35 14	-	3	149	
12:45	13:00	3	44	_	-	_	-	_	48	18	30	-	1	144	
13:00	13:15	1	36	-	-	-	-	-	43	23	15	-	4	122	
13:15	13:30	1	46	-	-	-	-	-	51	19	12	-	3	132	
13:30	13:45	4	44	-	-	-	-	-	58	19	10	-	1	136	
13:45	14:00	4	44	-	-	-	-	-	71	22	5	-	2	148	
14:00	14:15	6	93	-	-	-	-	-	61	22	13	-	4	199	
14:15	14:30	6	66	-	-	-	-	-	59	14	4	-	2	151	
14:30 14:45	14:45 15:00	1	43 50	-		-	-	-	52 57	5 11	5	-	2	110 125	
15:00	15:15	2	81	-	-	-	-	-	60	4	11	-	1	159	
15:15	15:30	1	54		-/	-	-	-	63	2	4	-	1	125	
15:30	15:45	-	48	-	-	-	-	-	53	4	7	-	1	113	
15:45	16:00	1	57	-	-	Ē.	-	-	56	13	8	-	3		
16:00	16:15	1	54	-	-		-	-	62	6	28	-	8	159	
16:15	16:30	2	62	(=)	-	-	-	-	54	7	16	-	7	148	
16:30	16:45	1	57	-	-0	-	-	-	72	10	30	(=)	16		
16:45 17:00	17:00 17:15	3	69 55	-	-	-	-	-	70	9	19 46	-	11	173 195	
17:15	17:30	1	41	-	-	-	-	-	57	8	32	-	7	146	
17:30	17:45	4	54	-	-	-	-	-	59	17	21	-	8	163	
17:45	18:00	1	43	-	-	-	-	-	33	20	38	-	10	145	
18:00	18:15	1	27	-		-	1-	-	38	2	11	1-3	-	79	
18:15	18:30	-	21	-	-	-	-	-	24	1	2	-	1	49	
18:30	18:45	-	18	-	-	-	-	-	20	-	-	-		38	
18:45	19:00	-	21	-	-/	-	-	-	27	-	-	-	-	48	
TO	IAL	194	2 559			-			3 244	806	656		167	7 626	

# Western Service Road and The Woodlands Office Park Entrance Road (Intersection 7) Traffic counts Data

05:00 05:15 05:30 05:45 06:00 06:15 06:30 06:45 07:00 07:15 07:30 07:45 08:00 08:15 09:00 09:15 09:30 09:45 10:00 10:15 11:30 11:45 11:30 11:45 12:00 12:15	E: ES:	Thursday 05	T2022-2197, 03 November 5H00-19H000  PRTHBOUN  2  3  7  10  5  15  22  26  27  63  78  106  80  80  85  71  77  52  54  58  33  52  52  60	ar 2022 D 3 	INTERSECTI KMZ FILE N  V  4		D 6	DATA:	J.A.V	TYPE:	E. 10 1 2 3 6 6 4 5 5 6 6 14 11 9 9 11	ASTBOUNI 11		VOLUM TOTAL 8 13 22 22 55 88 123 147 260 316 354 340 327	itraf  MESUMMARY  1 1 1 1 1 1
SURVEY TIMES  TIME  START  05:00  05:05  05:30  05:45  06:00  06:15  06:30  06:45  07:00  07:15  07:30  07:45  08:00  08:15  08:30  08:45  09:00  09:15  10:00  10:15  10:30  10:45  11:00  11:15  11:30  11:45  12:00  12:15	E END 05:15 05:30 05:45 06:00 06:15 06:30 06:45 07:00 07:15 08:00 08:15 08:30 08:45 09:00 09:15 09:30 09:45 10:00 10:15 10:30 10:45	NO  1	RTHBOUN 2 3 3 7 10 5 15 22 26 27 63 78 106 80 65 71 77 52 54 58 33 33 52	3		VESTBOUN 5	TOTA D 6	SC 7	RY  BUTHBOUN  8  5  6  11  15  29  46  56  87  151  175  185  180  163  116	9 - 1 1 1 7 16 29 23 34 46 63 39 44 54 52	E. 10 1 2 3 6 6 4 5 5 6 6 14 11 9 9 11	ASTBOUNT 11	12 	VOLUM TOTAL 8 13 22 22 55 88 123 147 260 316 354 340 327	1E SUMMARY
TIME  START  05:00  05:15  05:30  05:45  06:00  06:15  06:30  06:45  07:00  07:15  07:30  07:45  08:00  08:15  08:30  08:45  09:00  09:15  10:00  10:15  10:30  10:45  11:30  11:45  12:00  12:15	E END 05:15 05:30 05:45 06:00 06:15 06:30 06:45 07:00 07:15 07:30 08:15 08:30 08:45 09:00 09:15 09:30 09:45 10:00 10:15 10:30 10:45	NO 1	PRTHBOUN  2  3 7 10 5 15 22 26 27 63 78 106 80 65 71 77 52 54 58 33 35 52	3 		VESTBOUN 5	TOTA D 6	SC 7	RY  BUTHBOUN  8  5  6  11  15  29  46  56  87  151  175  185  180  163  116	9 - 1 1 1 7 16 29 23 34 46 63 39 44 54 52	E. 10 1 2 3 6 6 4 5 5 6 6 14 11 9 9 11	ASTBOUNT 11	12 	TOTAL  8 13 22 22 55 88 123 147 260 316 354 340 327	11 11 11
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05:30 05:45 06:00 06:15 06:30 06:45 07:00 07:15 07:30 07:45 08:00 08:15 08:30 08:45 09:00 09:15 10:00 10:15 10:30 10:45 11:00 11:15 11:30 11:45 12:00 12:15	05:45 06:00 06:15 06:30 06:45 07:00 07:15 08:00 08:15 08:30 08:45 09:00 09:15 09:30 09:45 10:00 10:15 10:30	2 2 1 4 4 6 6 5 5 10 0 8 8 15 17 11 11 11 9 9 6 6 4 4 7 7 7 3 3	10 5 15 22 26 27 63 78 106 80 65 71 77 52 54 58 33						11 15 29 46 56 87 151 175 187 185 180 163	1 1 7 16 29 23 34 46 39 44 54	1 2 3 6 4 5 6 14 11		- - - 2 - 2 1 - - 5	22 22 55 88 123 147 260 316 354 340	1 1 1 1
05:45 06:00 06:15 06:30 06:45 07:00 07:15 07:30 07:45 08:00 08:15 08:30 08:45 09:00 09:15 10:00 10:15 10:30 10:45 11:00 11:15 11:30 11:45 12:00 12:15	06:00 06:15 06:30 06:45 07:00 07:15 07:30 08:00 08:15 08:30 08:45 09:00 09:15 09:30 09:45 10:00 10:15 10:30	2 1 4 6 5 10 8 8 15 17 11 11 11 9 9 4 4 7 7	5 15 22 26 27 63 78 106 80 65 71 77 52 54 58 33 35 52						15 29 46 56 87 151 175 187 185 180 163	1 7 16 29 23 34 46 39 44 54	1 2 3 6 4 5 6 14 11 9		- - 2 - 2 1 - 5	22 55 88 123 147 260 316 354 340	1 1 1 1
06:00 06:15 06:30 06:45 07:00 07:15 07:30 07:45 08:00 08:15 08:30 08:45 09:00 09:15 10:00 10:15 10:30 10:45 11:00 11:15 11:30 11:45 12:00 12:15	06:15 06:30 06:45 07:00 07:15 07:30 07:45 08:00 08:15 08:30 08:45 09:00 09:15 09:30 09:45 10:00 10:15 10:30	2 1 1 4 4 6 5 5 10 10 8 8 15 5 17 11 11 11 9 9 9 6 6 4 7 7 7 3 3	15 22 26 27 63 78 106 80 65 71 77 52 54 58 33 35 52						29 46 56 87 151 175 187 185 180 163	7 16 29 23 34 46 39 44 54	2 3 6 4 5 6 14 11 9		- 2 - 2 1 - 5	55 88 123 147 260 316 354 340 327	1 1 1 1
06:15 06:30 06:45 07:00 07:15 07:30 07:45 08:00 08:15 08:30 08:45 09:00 09:15 10:00 10:15 11:30 11:45 11:30 11:45 12:00 12:15	06:30 06:45 07:00 07:15 07:30 07:45 08:00 08:15 08:30 08:45 09:00 09:15 09:45 10:00 10:15 10:30	1 4 6 5 10 8 8 15 17 11 11 11 9 9 6 6 4 4 7 7	22 26 27 63 78 106 80 65 71 77 52 54 58 33			-		-	46 56 87 151 175 187 185 180 163	16 29 23 34 46 39 44 54	3 6 4 5 6 14 11 9	-	2 - 2 1 - 5	88 123 147 260 316 354 340 327	1 1 1 1
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09:45 10:00 10:15 10:30 10:45 11:00 11:15 11:30 11:45 12:00 12:15	10:00 10:15 10:30 10:45	7 7 3	52 52	-	-		-	-	57 57	24	13 12	-	3	161 132	
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10:45 11:00 11:15 11:30 11:45 12:00 12:15		2		- 2	1-	-	-	-	35	16	14	-	3	131	
11:00 11:15 11:30 11:45 12:00 12:15	11:00		46	-	-	-	-	-	54	18	16	-	-	136	
11:15 11:30 11:45 12:00 12:15	1 2 2 2 2 2 2	-	42	-	1-	-	-		41	23	22	-	2		
11:30 11:45 12:00 12:15	11:15	4	44	-	0.5	-	-	-	50	14	13		2	127	
11:45 12:00 12:15	11:30 11:45	6	48 55		-	-	-	-	49 53	14 13	13 17	-	3	131 142	
12:15	12:00	1	67	-	-	-		-	65	9	11	-	2	155	
	12:15	3	95		-	-	-	-	60	14	24	-	5	201	
	12:30	3	90	-	re-	-	-	-	73	21	18	-	-	205	
	12:45	3	71	-	( <b>-</b>	-	-		70	18	29	-	6	197	
	13:00	8	56	-		-	-	-	82	18	17	-	3	184	
	13:15 13:30	7 2	71 57		-	-	-	-	68 63	20	20		- 4	186 171	
	13:45	1	55		-	-	-	-	80	14	12	-	1	163	
	14:00	-	50	-	-	-	-	-	113	18	15	-	2	198	
	14:15	4	110	-	-	-	-	-	78	19	17	-	3	231	
14:15	14:30	1	83	-	-	-	-	-	85	17	21	-	6	213	
	14:45	2	67	-	-	-	-	-	78	9	17	-	3	176	
	15:00	-	51	-	-	-	-	-	66	18	16	-	3	154	
	15:15 15:30	8	59 71	-	1=	-	-	-	66	10 16	26	-	9	177 190	
	15:45	20	40	-	-	-	-	-	56	10	22	-	5		
	16:00	2	69	-	-	-	-	-	69	10	39	-	7	196	
16:00	16:15	4	80	-	1-	1-1			78	5	27	-	13	207	
	16:30	2	66	-	1-	-	-	-	67	11	32	-	15	193	
	16:45	4	90	-	-	-	-	-	70	8	22	-	9	203	
	17:00	3	100	0-	) <del>-</del>	-	1-1	-	58	6 7	15 30	-	11	178	
	17:15 17:30	3	109 71	12	-	-	-	-	79 63	8	30	-	12	239 179	
	17:45	4	63	-	-	-	-	-	60	2	22	-	5		
	18:00	1	72	-	1-	-		-	63	2	13	-	-	151	
18:00	18:15	-	39	Æ	-	-		-	40	5	6	-	2	92	
	ACCUPATION AND ADDRESS.	-	33	-	12	-	-	-	37	1	10	-	1	82	
	18:30	-	23 31	-	S=.	-	-	-	25	-	4	-	- 2	52	
18:45 TOTA	18:30 18:45 19:00	-		-	0.7	-	-	-	3 969	-	3	-	2	61	

## Woodlands Drive and Western Service Road (Intersection 8) Traffic counts Data

LOCATION:			VOODMEA		PROJECT TIT	TLE:			WOODM	EAD-TRAFFI	C COUNT				
PROJECT NI			T2022-219		INTERSECTION	ON:			WOODLA	NDS DR & J	ESSICA CL			Unitraf	f
SURVEY DA			y, 03 Novemb 5H00-19H0		KMZ FILE NF	₹-	P3	DATA:	J.A.V	TYPE:	414	V-14H-5-19-		( ornitial	
JORVET TIK	ALS.	0.5	51100-15110	0	KIVIZ I ILL IVI	\.	F3	DATA.	J.A.V	TIPE.	40	V-14H-3-19-	C		
							TOTA	AL SUMMA	RY						
TIM			RTHBOUN			ESTBOUN			UTHBOUN			ASTBOUND		VOLUME SUMMARY	
START	END 05:15	1 2	2 -	3 4	4 5	5 20	6	7	- 8	9	10	11	12	TOTAL	
05:00 05:15	05:30	4	-	4	6	40	1	-	-	-	-	13	1	47 69	
05:30	05:45	8	- 8	10	25	52	1	-	-	-		22	4	122	
05:45	06:00	10	1	12	40	75	3	2	-	1	1	31	6	182	420
06:00	06:15	10	-	13	43	78	2	1	1		-	35	4	187	560
06:15	06:30	6	1	14	86	117	4	-	-	1		34	2	265	756
06:30	06:45 07:00	16 12	- 2	38 47	103 153	176	11	- 1	1	1	- 6	56 108	7 12	402	1036
06:45 07:00	07:00	16	1	66	201	210 262	11	3	1	3	6	123	14	705	1418
07:15	07:30	26	1	72	241	251	4	4	-	2	5	129	17	752	2423
07:30	07:45	23	2	88	258	292	12	1	-	7	5	134	21	843	2864
07:45	08:00	35	5	84	268	303	10	2	3	4	8	132	19	873	3173
08:00	08:15	18	2	77	254	271	11	9	1	3	5	127	38	816	3284
08:15	08:30	14	1	78	231	293	11	6	3	3	6	95	28	769	3301
08:30	08:45	22	3	89	192	242	8	7	3	8	6	117	21	718	3176
08:45 09:00	09:00 09:15	17 17	3	63 73	143 138	178 143	17 12	17 11	-	4	3 6	105 110	18 17	572 534	2875
09:00	09:15	16	2	94	99	139	12	8	2	11	5	89	7	484	
09:30	09:45	11	-	68	97	115	10	9	4	8	8	122	18	470	
09:45	10:00	17	3	81	88	131	10	9	4	5	5	114	15	482	1970
10:00	10:15	12	3	71	86	140	8	7	3	2	4	123	11	470	1906
10:15	10:30	15	5	77	78	114	5	10	4	3	8	105	12	436	1858
10:30	10:45	11	1	75	84	129	6	5	2	9	3	140	11	476	1864
10:45 11:00	11:00 11:15	18	5 3	77 58	80 85	116 111	7	9	5	6	6 7	122	11	460	1842
11:15	11:15	19	2	89	85	126	5	8	4	3	1	134	13	422 489	1794 1847
11:30	11:45	19	1	83	83	110	9	4	2	5	5	119	12	452	1823
11:45	12:00	16	4	82	86	126	7	8	5	4	1	107	18	464	1827
12:00	12:15	25	1	126	98	134	8	4	-	5	3	144	10	558	1963
12:15	12:30	25	4	126	107	145	16	8	3	6	5	131	22	598	2072
12:30	12:45	25	1	106	102	116	6	9	2	8	4	167	12	558	2178
12:45	13:00	15	3	88	114	132	8	6	5	3	7	120	19	520	2234
13:00 13:15	13:15 13:30	14 19	2	105 92	112 99	124 160	5 7	7 6	3	2	7 4	127 143	14 19	524 556	2200
13:30	13:45	26	5	87	122	136	4	8	2	6	6	123	11	536	2158
13:45	14:00	23	5	79	141	164	2	11	4	10	6	134	15	594	2210
14:00	14:15	17	1	159	106	113	3	9	4	4	4	132	20	572	2258
14:15	14:30	11	1	126	110	127	6	4	4	3	7	159	23	581	2283
14:30	14:45	11	1	105	97	144	1	6	3	1	-	205	11	585	2332
14:45	15:00	14	2	104	99	128	5	6	3	2	8	155	17	543	2281
15:00 15:15	15:15 15:30	22 17	2	136 113	93 88	116 119	6	5	2	6	3	253 207	18 20	662 589	
15:30	15:45	20	1	110	85	123	2	6	2	6	5	260	19	639	
15:45	16:00	17	4	129	83	128	3	5	5	4	6	248	14	646	2536
16:00	16:15	13	3	108	82	142	1	10	2	4	6	278	16	665	2539
16:15	16:30	18	-	130	74	140	5	10	2	2	2	341	18	742	2692
16:30	16:45	11	1	163	78	139	1	8	-	2	-	263	27	693	2746
16:45	17:00	23	-	134	71	139	5	3	1	3	1	253	14	647	2747
17:00	17:15	19	-	143	92	180	1	2	2	2	2	290	16	749	2831
17:15 17:30	17:30 17:45	22 13	-	157 119	73 75	150 140	- 2	7	-	-	- 1	262 182	18 10	696 546	2785
17:45	18:00	12	1	105	63	146	-	-	-	-	1	193	18	539	2638 2530
18:00	18:15	16	-	83	50	122	2	1	-	-	-	149	12	435	2216
18:15	18:30	10	1	62	52	83	-	1	1	-	-	141	9	360	1880
18:30	18:45	13	-	52	39	55	2	2	-	-	-	91	9	263	1597
18:45	19:00	11	-	38	40	60	1	1	1	-	-	88	4	244	1302
TO <sup>*</sup>	TAL	906	102	4 772	5 783	7 965	317	304	112	188	204	7 906	806	29 365	

## Woodlands Drive and Lincoln Street (Intersection 9) Traffic counts data

OCATION:			NOODMEA		PROJECT TI	TLE:			WOODM	EAD-TRAFFI	C COUNT				
ROJECT N			JT2022-219		INTERSECTI	ION:			WOODLA	NDS DR & LII	NCOLN ST			III	hitraf
URVEY DA URVEY TIN			ay, 03 Novemb 15H00-19H0		KMZ FILE N	R.	P4	DATA:	J.A.V	TYPE:	TA	I-14H-5-19-	C		IILIGI
OKVET TIN	VILJ.	0	51100-15110	O	KIVIZ FIEE IV	N.	14	DAIA.	J.A.V	TIPE:	119	1-14П-5-19-			
							TOTA	L SUMMA	RY					la de	
1IT	ME	NO	ORTHBOUN	ND		VESTBOUND	)	SC	UTHBOUN		E	ASTBOUNI	)	VOLUI	ME SUMMARY
START	END	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	
05:00	05:15		-		-	14	7	6	-	3	3	10	-	43	
05:15	05:30	-	-	-	-	25 46	13 13	12	-	1	7 2	9 16	-	63	
05:30 05:45	05:45 06:00	-	-	-	-	75	16	15	-	4	1	21	-	132	
06:00	06:15	-		-	-	69	14	13	-	4	2	23	-	125	
06:15	06:30	-	-	-	-	103	18	10	-	3	10	29	-	173	
06:30	06:45	-	-	-	-	154	25	28	-	5	1	55	-	268	
06:45	07:00	1-	-		-	198	31	40	-	15	12	86	-	382	
07:00	07:15	-	-	-	-	240	39	33	-	11	13	114	-	450	
07:15	07:30	-	-		-	238	34	35	-	21	13	111	-	452	
07:30	07:45	.=	-	-	-	264	41	42	-	19	7	128	-	501	
07:45	08:00		-	-	-	293	51	41	-	26	12	118	-	541	
08:00	08:15	.=	-	-	-	255	34	52	-	19	9	121	-	490	
08:15	08:30	-	-	-	-	278	23	52	-	35	13	79	7-	480	
08:30	08:45		-	-	1-1	220	38	36	-	31	14	107	-	446	
08:45	09:00	-	-	-	-	163	28	30	-	22	5	111	-	359	
09:00	09:15	-	-	-	-	140	23	37		12	7	120	-	339	
09:15	09:30	-	-			150	30	17	-	14	11	97	-	319	
09:30	09:45	-	-	-	-	103 122	28	35	-	12	12	101	-	291	
09:45 10:00	10:00 10:15	-	-		-	108	29 33	19 32	-	18 14	17 8	105		315 300	
10:15	10:30	-	-	-	-	111	24	32	-	13	10	103	-	292	
10:30	10:45	-		_	-	117	30	28	-	11	10	111	-	307	
10:45	11:00	-	-	-	-	115	27	32	-	11	12	107		304	
11:00	11:15	-	_	-	-	105	31	31		8	14	94	-	283	
11:15	11:30	-	_	-	-	103	40	42	_	15	12	113	_	325	
11:30	11:45	-		-	-	103	30	22	-	13	11	112	-	291	
11:45	12:00	-	-	-	-	102	38	27	-	10	21	128	-	326	
12:00	12:15		-	-		132	34	29	-	15	14	127	-	351	
12:15	12:30	-	-	-	-	124	48	36	-	9	15	121	-	353	
12:30	12:45		-	-		134	28	31	-	14	13	154		374	
12:45	13:00	-	-	-	-	119	28	35	-	15	7	143	-	347	
13:00	13:15	) <del>-</del>	-			114	25	38	-	16	6	131		330	
13:15	13:30	-	-	v	-	142	29	26	-	11	8	131	-	347	
13:30	13:45	-	-	-	-	128	34	24	-	8	10	140	-	344	
13:45	14:00	-	×	-	-	156	43	33	-	15	10	117	-	374	
14:00	14:15	-	-	-	-	112	23	36	-	21	5	136	-	333	
14:15	14:30	-	÷	-	-	118	33	42	-	14	21	151	1-	379	
14:30	14:45	-	-	-	-	117	29	42	-	11	17	170	7.5	386	
14:45	15:00	-		-	-	123	34	26	-	9	19	148	je.	359	
15:00	15:15	-	-	-	-	109	34	44	-	4	12	230	-	433	
15:15 15:30	15:30	-	-		-	101 117	26 31	43 27	-	5	9	180 256	-	364 453	
15:45	15:45 16:00	-	-	-	-	117	32	37	-	12	17	233	-	453	
16:00	16:15	-	-	-	-	127	33	49	-	15	17	293	-	534	
16:15	16:30	-	-	-	-	124	35	40	-	8	19	255	-	481	
16:30	16:45	Œ.	9	-	-	105	38	44	-	6	21	257	-	471	
16:45	17:00	2-	-	-	-	125	39	29	-	17	24	227	-	461	
17:00	17:15	1-	-	-	-	157	41	47	-	17	22	297	1-	581	
17:15	17:30	- 4	-	-	-	140	38	41	-	16	26	231	-	492	
17:30	17:45	-	-	-	-	119	35	20	-	12	26	174	-	386	
17:45	18:00	-	¥	-	-	91	51	36	-	15	32	169	-	394	
18:00	18:15	-	-	-	-	98	49	32	-	9	25	134	-	347	
18:15	18:30	18	-	-	-	70	35	15	-	14	15	133		282	
18:30	18:45		-	-	-	51	16	18	-	11	19	89	-	204	
18:45	19:00	-	-	-	-	58	18	14	-	14	9	89	-	202	
TO	TAL	-	-	-	-	7 244	1 727	1 741	-	708	722	7 3 5 4	-	19 496	

# Woodlands Drive and The Woodlands Office Park Entrance Road/Country Club Estate (Intersection 10) Traffic counts data

LOCATION: PROJECT N		^^	/OODMEAD		PROJECT TITL	.E:			WOODM	EAD-TRAFFI	C COUNT				
SURVEY DA			, 03 Novemb		INTERSECTIO	N:		WOODL	ANDS DR &	ACCESS TO	THE WOODL	ANDS		<b>(</b> unitraf	
SURVEY TIM	MES:	05	Н00-19Н0	0	KMZ FILE NR:		P5	DATA:	J.A.V	TYPE:	4W	/-14H-5-19	-C	01	
							TOTAL	SUMMAR	ŧΥ						
TII	ME	NO	RTHBOU	ND	WE	STBOUN	D	so	UTHBOUN	ID	EA	STBOUNI	D	VOLUME SUMMARY	
START	END	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	
05:00 05:15	05:15 05:30	-	12 15	- 1	-	-	2	8 12	9	-	-	-	-	32 40	
05:30	05:45	1	16	2	1	-	1	13	27	3	-	-	-	64	
05:45	06:00	1	20	4	3	-	3	33	40	7	-	-	-	111	24
06:00	06:15	-	23	3	3	-	1	33	33	8	2	-	1	107	32
06:15	06:30	1	32	6	1	-	4	34	57	13	1	-	2	151	43.
06:30	06:45	5	48	2	-	-	6	44	88	24	3	72	-	220	58
06:45	07:00	6	89	6	1	-	6	41	133	26	6	-	2		79
07:00	07:15	4	108	4	6	-	8	58	161	39	5	-	2		108
07:15 07:30	07:30 07:45	7	110	10 19	2	-	5 11	43 37	191 206	24 35	12	-	- 1	404	133
07:45	08:00	14	117	15	6		9	58	210	42	7		- 6		155
08:00	08:15	15	102	15	2	-	14	54	176	44	9	-	3		175
08:15	08:30	16	79	9	1	1	2	67	188	59	11	1	2		179
08:30	08:45	15	94	12	1	3	14	46	151	59	11	1	3		176
08:45	09:00	18	104	7	5	-	9	24	122	40	10	-	2	341	162
09:00	09:15	18	104	4	6	1	12	16	105	25	10	-	2	303	
09:15	09:30	7	69	2	2	-	18	31	100	38	16	-	1		
09:30	09:45	8	101	3	4	-	10	21	71	21	11	3	1	254	3000
09:45	10:00	6	100	4	2	-	14	21	98	18	12	1	4		112
10:00	10:15 10:30	5	101	3	3	1	10	10 11	99 100	13 15	10	- 1	6		107
10:30	10:45	2	101	5	2		10	15	90	13	10		3		103
10:45	11:00	6	97	6	3	2	10	11	98	15	14	1	3		102
11:00	11:15	3	78	1	2	-	11	6	95	7	13	-	2		98
11:15	11:30	2	96	1	5	u u	13	12	97	11	15	-	2	254	98
11:30	11:45	5	102	3	1	-	12	9	92	12	19	-	2	257	99
11:45	12:00	4	93	2	6	Ř	33	15	86	12	17	ja j	4	272	100
12:00	12:15	3	96	4	9	1	26	16	113	14	21	3	6		109
12:15	12:30	5	98	6	5	-	17	18	101	10	20	-	7		112
12:30	12:45	4	111	6	6		27	14	120	9	27	-	7	331	120
12:45 13:00	13:00 13:15	7	114 91	3	7		20 17	18 14	105	14 15	20		8 5		124
13:15	13:15	6	96	1	7		27	16	118	19	16		8		121
13:30	13:45	3	112	2	6	-	13	17	103	14	26		6		123
13:45	14:00	5	105	6	6	2	7	20	127	25	17	12	3		121
14:00	14:15	3	108	-	8	-	12	14	96	16	20	2.5	1	278	121
14:15	14:30	11	120	3	1	2	28	11	105	21	24		3	329	123
14:30	14:45	3	125	3	4	1	34	6	106	9	26	-	3		124
14:45	15:00	5	117	3	14	-	38	11	106	16	16	-	6		125
15:00	15:15	7	147	1	9	1	55	8	93	10	41	-	5		
15:15	15:30	5	132	1	6	-	43	10	90	7	20	1	11	326	
15:30	15:45	1	191 165	- 4	3	1	63 58	8	102 108	9 15	30	1	5 3		
15:45 16:00	16:00 16:15	2	186	- 2	18	- 1	75	12	108	4	54	1	10	393 487	150 161
16:15	16:30	2	191	1	16		46	5	124	3	25	-	10		170
16:30	16:45	1	181	2	8	-	51	7	102	5	51	P.	9		172
16:45	17:00	4	188	1	9	-	40	10	123	6	24	1	4		173
17:00	17:15	2	201	2	12	-	62	4	158	7	50	-	12	510	176
17:15	17:30	3	197	5	7	-	27	8	132	8	30	14	8	425	176
17:30	17:45	4	153	3	6	-	29	5	126	6	16	-	6		169
17:45	18:00	1	169	2	4	9	19	4	94	6	19		6		161
18:00	18:15	1	117	2	5	-	21	6	97	4	14	7-	3		137
18:15	18:30	1	114	2	6	1	13	3	76	3	16	-	5		118
18:30 18:45	18:45	1	94	-	7	-	10	1	58	3	10	-	1		101
	19:00	-	73		-	-	13	1	68	1	4		-	160	85

# Woodlands Drive and The Woodlands Office Park Entrance Road/Pestle Street (Intersection 11) Traffic counts data

			/OODMEAD		PROJECT TIT	LE:			WOODM	EAD-TRAFFIC	CCOUNT				
PROJECT N			T2022-2197		INTERSECTIO	ON:			WOODLA	ANDS DR & P	ESTIE ST			III	nitraf
SURVEY DA SURVEY TIN			y, 03 November 5H00-19H0		KMZ FILE NR		P10	DATA:	J.A.V	TYPE:	4)	N 14H F 10			IILI GI
ORVETTIN	VILJ.	0.5	01100-13110	0	KIVIZ I ILL IVI		110	DAIA.	J.A.V	I TPE:	41	V-14H-5-19	-0		
				0			TOTA	L SUMMAI	RY						
TIN		-	RTHBOUN			ESTBOUN			UTHBOUN			ASTBOUNI			VE SUMMARY
START	END	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	
05:00 05:15	05:15 05:30	3	10	-	-	-	-	1	13 18	- 1	1	- 14	-	23 33	
05:30	05:45	7	17	1	-	-	-	-	15	3	1	-	2	46	
05:45	06:00	4	39	1	-	-		-	20	3	1	-	5	73	
06:00	06:15	4	31	1	-	-	-	1	28	4	2	-	-	71	
06:15	06:30	6	49	3	1	-	-	2	36	4	2	78	1	104	
06:30	06:45	8	69	8	1	-	-	6	51	4	1	1	2	150	
06:45	07:00	10	110	10	-	-	-	2	99	7	2	-	1	241	
07:00	07:15	13	141	12	-	-	1	2	122	16	3	-	-	310	
07:15	07:30	14	168	14	-	-	-	5	127	10	7	19	2	347	
07:30 07:45	07:45 08:00	13 19	191 179	10 15	1 2	-	3	9	144	20	8	72	1	396 395	
07:45	08:00	19	168	4	2	-	1	10	138	26	4	-	4	361	
08:00	08:15	26	156	5	2	-	1	4	102	19	7	-	4	326	
08:30	08:45	12	136	8	1	-	2	6	115	26	4	-	3	313	
08:45	09:00	17	113	6	-	-		1	128	22	5	-	4	296	
09:00	09:15	14	100	:-	1	-	1	6	120	17	6	1-	-	265	
09:15	09:30	12	85	2	-	-	-	2	79	16	4	-	4	204	
09:30	09:45	7	83	1	2	-	-	1	107	11	3	-	4	219	
09:45	10:00	11	93	1	-	-	-	2	101	13	5		3	229	
10:00	10:15	8	99	-	-	-	-	2	103	7	3	-	5	227	
10:15	10:30	7	103	2	1		- 1	- 2	92 98	12 7	7	-	6 5	213 230	
10:30 10:45	10:45 11:00	8	102 94	1	3	-	- 3	1	102	5	5	1	5	230	
11:00	11:15	3	96	1	1	-		-	81	3	8	-	3	196	
11:15	11:30	2	100	1	3	-	1	-	103	7	9		3	229	
11:30	11:45	2	88	1	2	-	1	-	94	4	2	1	4	199	
11:45	12:00	5	97	1	-	-	1	3	98	7	3	-	3	218	
12:00	12:15	7	116	2	3	-	3	1	105	4	12	12	4	257	
12:15	12:30	2	105	3	2	1	1	2	97	3	8		4	228	
12:30	12:45	5	140	3	1	-	2	2	124	8	8	1	5	299	
12:45	13:00	6	104	-	3	-	5	1	104	6	9		7	245	
13:00	13:15	-	108	2	2	-	1	1	95	4	7		4	224 264	
13:15 13:30	13:30 13:45	6	132 115	2	3	. 1	3	2	95 108	8 6	9 7	-	5 7	256	
13:45	14:00	5	125	2	1	-	3	2	109	7	5		9	268	
14:00	14:15	5	101	-	2	_	2	1	93	6	7	-	11	228	
14:15	14:30	2	110	3	5	-	-	1	123	5	12	-	9	270	
14:30	14:45	3	106	2	4	-	5	1	114	9	5	-	10	259	
14:45	15:00	5	122	1	6	-	2	1	112	2	4	-	12	267	
15:00	15:15	3	99	-	-	-	3	1	131	8	11	-	15	271	
15:15	15:30	1	108	1	4	-	2	-	121	5	13		15	270	
15:30	15:45	1	112	1	11	-	6	1	171	6	9	12	17	335	
15:45	16:00	3	111	1			3	1	142	3 7	14		23	307	
16:00 16:15	16:15 16:30	2	153 138	1	11	-	3	- 2	154 156	9	16 11	-	24	370 352	
16:15	16:30	2	138	-	5	-	8	-	171	7	23	1-	15	356	
16:45	17:00	1	139		10	-	5	1	162	4	15	-	23	360	
17:00	17:15	2	179	-	8	-	8	1	174	4	20	1	23	420	
17:15	17:30	3	144	1	4	-	2	-	180	2	21		13	370	
17:30	17:45	3	139	-	4	-	4	1	148	3	14		8	324	
17:45	18:00	2	107	2	2	-	-		161	2	8	100	7	291	
18:00	18:15	1	102	-	2	-	1	-	110	3	2		11	232	
18:15	18:30	-	88	-	3	-	1	-	100	1	5		10	208	
18:30	18:45 19:00	2	59	-	-	-	-	-	96	- 1	4		1	167 146	
18:45			71		1		-		66		4	1 -			

## Woodmead Drive & Woodlands Drive – (Intersection 12) Traffic counts data

OCATION:		V	VOODMEAD						WOODM	EAD-TRAFFI	C COUNT				
ROJECT N		1	T2022-2197		INTERSECTION	ON:		1	WOODLAND	S DR & WOO	DDMEAD DR				itraf
URVEY DA			y, 03 Novemb			_	D4.5					*	_		וונוםו
JRVEY TIN	VIES:	0.	5H00-19H0	J	KMZ FILE NF	C.	P12	DATA:	J.A.V	TYPE:	4V	V-14H-5-19	-C		
							TOTAL	SUMMA	RY						
TIT	ME	NC	RTHBOUN	ID	W	ESTBOUNE	)	SC	UTHBOUN	ID	E.	ASTBOUNI	)	VOLUN	IE SUMMARY
START	END	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	
05:00	05:15	18	30	3	4	-	-	-	14	8	7	-	10		
05:15	05:30	32	48	5	2	2	- 2	- 2	25	12	5	- 2	10	137	
05:30 05:45	05:45 06:00	46 78	61 56	4	8	1	2	5	46 61	31 32	9	3	23 26	231 292	
06:00	06:15	83	81	7	13	-	-	6	99	33	16	-	29	367	
06:15	06:30	135	107	19	6	-	2	5	121	67	16	4	38	520	
06:30	06:45	183	170	27	12	6	3	13	187	72	32	5	68	778	
06:45	07:00	242	170	39	26	8	8	18	230	132	59	12	85	1 029	
07:00	07:15	251	196	63	32	9	3	19	306	191	67	7	112	1 256	
07:15	07:30	230	205	70	26	17	3	25	285	241	76	14	111	1 303	
07:30	07:45	222	198	74	33	65	8	49	324	224	75	16	117	1 401	
07:45 08:00	08:00 08:15	264 289	190 217	69 67	37 40	79 74	7	59 45	287 278	208 187	86 85	20 18	127 108	1 434	
08:15	08:13	279	236	103	49	49	6	41	254	191	71	29	84	1 392	
08:30	08:45	231	203	108	58	26	5	48	235	185	79	31	95	1 304	
08:45	09:00	174	217	112	51	33	7	28	188	121	67	38	90	1 126	
09:00	09:15	160	166	121	50	22	10	35	166	114	54	52	98	1 048	
09:15	09:30	158	165	118	74	28	15	36	189	82	60	49	86	1 060	
09:30	09:45	113	180	133	108	44	18	39	166	76	59	48	86	1 070	
09:45	10:00	122	202	138	100	37	22	32	164	81	65	49	85	1 097	
10:00	10:15	114	176	124	114	35	23	39	159	74	74	46	93	1 071	
10:15	10:30 10:45	100	193 193	135 145	122 118	37 26	27	53 35	212 164	69 86	71 85	48	76 70	1 143	
10:30	11:00	111	180	143	101	40	27	40	196	58	67	47	95	1 092 1 107	
11:00	11:15	92	173	142	114	45	27	41	163	67	71	37	70	1 042	
11:15	11:30	90	192	142	147	38	23	38	164	79	78	55	105	1 151	
11:30	11:45	84	201	136	123	43	27	57	194	69	63	49	89	1 135	
11:45	12:00	97	179	139	143	43	41	47	175	85	77	53	99	1 178	
12:00	12:15	113	188	166	147	46	32	36	181	90	99	57	123	1 278	
12:15	12:30	114	195	183	143	52	26	55	196	91	92	64	107	1 318	
12:30	12:45	87	199	172	184	57	31	58	170	92	108	59	109	1 326	
12:45	13:00	106	199	169	197	57	27	66	192	94	88	53	103	1 351	
13:00	13:15 13:30	104	178 187	178 175	175 159	47 57	34	45 45	190 172	96 93	94	55 58	108 105	1 304	
13:15 13:30	13:30	101	170	139	177	52	39 43	39	212	106	86 85	47	103	1 2 8 6	
13:45	14:00	124	188	171	176	70	38	31	185	116	60	49	109	1 317	
14:00	14:15	90	183	140	172	38	24	48	194	97	124	53	134	1 297	
14:15	14:30	117	203	141	171	44	30	32	189	87	100	50	138	1 302	
14:30	14:45	104	194	136	170	53	25	38	202	74	105	50	144	1 295	
14:45	15:00	109	204	186	148	44	33	43	227	94	77	48	146	1 359	
15:00	15:15	90	178	155	164	38	32	31	203	91	101	59	243	1 385	
15:15	15:30	99	234	165	190	43	20	32	227	58	109	40	155	1 372	
15:30	15:45	87	196	136	160	41	23	31	211	74	109	60	222	1 350	
15:45 16:00	16:00 16:15	92	246 237	156 160	179 160	55 51	24	27 51	258 247	70 85	103 111	51 62	204 244	1 465 1 524	
16:15	16:15	89	226	154	151	42	25	65	280	88	148	56	275	1524	
16:30	16:45	93	241	149	150	34	29	44	299	78	142	60	228	1547	
16:45	17:00	94	241	152	155	35	19	50	289	89	123	68	213	1 528	
17:00	17:15	119	224	163	205	48	35	48	246	104	149	60	251	1 652	
17:15	17:30	106	219	136	187	47	17	33	269	75	152	64	224	1 529	
17:30	17:45	87	250	112	151	33	18	38	230	93	120	46	153	1 331	
17:45	18:00	89	207	61	145	34	20	17	174	78	137	20	144	1 126	
18:00	18:15	95	160	53	141	26	17	22	183	60	93	21	125	996	
18:15	18:30	66	155	27	120	21	18	12	183	53	73	18	106	852	
18:30	18:45	57 56	127 104	19	71	10	12	11	152	34	57	11 5	90 82	651 542	
18:45	19:00 TAL	6 785	10 118	6 169	49 <b>6 111</b>	9 1 992	1 <b>065</b>	1 911	116 10 929	33 <b>5 168</b>	50 4 485	2 121	6 578		

## Marlboro Drive (M60) Westbound Shell Filling Station (Access A1)

LOCATION			WOODMEAD		PROJECT TI	TLE:			WOODM	EAD-TRAFFI	C COUNT				
PROJECT N			JT2022-2197		INTERSECTI	ION:	MA	RLBORO DR	& WESTBO	UNT SHELL	FILLING STA	TION ACCES	SS 1	unit	raf
SURVEY DA SURVEY TIN			ay, 03 Novembe		KMZ FILE N	R:	ACCESS 1	DATA:	D.L	TYPE:	414	V-24H-00-00		al orne	
				-			71002002		D.L	111.5	-4.0	V-2411-00-00	0-0		
1							TOTA	L SUMMA	RY						
TIN	ME		IN						OUT					VOLUME SU	MMARY
START	END	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	
00:00	00:15	-	6	-	-	-	-	-	6	-	-	-	-	12	
00:15	00:30		3	-	-	-	-	-	8	-		-	-	11	
00:30	00:45 01:00	-	1 4	-	-	-	-	-	3	-	-	-	-	8	
01:00	01:15	-	-		-	-	-	-	2	-	-	-	-	2	
01:15	01:30	-	-	-	-	-	-	-	-	-	-	-	-	-	
01:30	01:45	-	-	19	-	-	-	-	-	-		-	-	-	
01:45	02:00	-	1	15	.=:	-	-	-	2	-	-		-	3	
02:00	02:15	-	-			-	-	-	-	-	-	-	-	-	
02:15	02:30	-	-		-	-	-	-	-	-	- 4	-	-	-	
02:30	02:45	-	2	15	-	-	-	1.5	3		-		-	5	
02:45	03:00	-	1	-	-	-	-	-	2	-	-	-	-	3	
03:00	03:15	-	-	-	-	-	-	-	-	-	2	-	-	<u> </u>	
03:15	03:30 03:45	-	1	-	-		-	-	-	-	-		-	1	
03:30	04:00		-		-	-	-	-	7	-	-	-	-	7	
04:00	04:00	-	-	-	-	-	-	-	- '	-	-	-	-	-	
04:15	04:30	-	2	-	-	-	-	-	3	-	-	-	-	5	
04:30	04:45	-	1	-	-	-	-	-	4	-		-	-	5	
04:45	05:00		5		-	-	-	-	6	100		-	-	11	
05:00	05:15	-	5	-	-	7-	.=:	-	12	-	-	-	-	17	
05:15	05:30	-	4	~	-	-	-	-	11	-	-	-	-	15	
05:30	05:45	-	6		-	-	-	-	14	-	-	-	-	20	
05:45	06:00	-	13	(=	-	1+	-	-	11	-	-	-	-	24	
06:00 06:15	06:15 06:30		14	-	-	-	-	-	21 16	-	-	-	-	27 30	
06:30	06:45	-	6		-	-	-	-	4	-	-	-	-	10	
06:45	07:00	-	6		-	-		-	9	-	-	_	-	15	
07:00	07:15		11	-	-	-	-	-	9	-		-		20	
07:15	07:30	-	15		-	-	-	-	14	-	-	-	-	29	
07:30	07:45	-	11	-	-	-	-	-	9	-	-	-	-	20	
07:45	08:00	-	16	- 1	-	-	-	-	11	-	-	-	-	27	
08:00	08:15	-	14	-	-	-	-	-	13	-	-	-	-	27	1
08:15	08:30	-	8	-	-	-	-	-	12	-	-	-	-	20	
08:30	08:45	-	7			-	-		7	-	-		-	14	
08:45 09:00	09:00 09:15	-	10	- :	-	-	-	-	14 11	-	-	-	-	24	
09:15	09:30	-	7		-		-	-	12	-	-	-	-	19	
09:30	09:45	-	15		-	-	-	-	14	-	-	-	-	29	
09:45	10:00	-	14	-	-	-	-	-	15	-		-	-	29	
10:00	10:15	-	12	-	-	-	-	-	15	-	-		-	27	1
10:15	10:30	-	11	7-2	-	-	-	-	11	-	-	-	-	22	1
10:30	10:45	-	10	-	-	1-	-	-	27	-	-	-	-	37	1
10:45	11:00	-	20	-	-	-	-		23	-	-	-	-	43	1
11:00	11:15	-	12	-	-	-	-	-	13	-	-	-	-	25	1
11:15 11:30	11:30 11:45	-	14	-	-	-	-	-	17 15	-	-	-	-	31	1
11:30	11:45	-	13	-	-	-	-	-	11	-	-	-	-	28	1
12:00	12:00	-	14	-	-	-	-	-	13	-	-	-	-	27	1
12:15	12:30	-	17		-	-	-	-	18		-	-	-	35	1
12:30	12:45	-	11	-	-	-	-	-	19	-	-	-	-	30	1
12:45	13:00	-	21	-	-	-	-	-	16	-	-	-	-	37	1
13:00	13:15	Ę.	17	=	-		-	-	17	-		-	-	34	1
13:15	13:30	-	16	-	-	-	-	-	15	-	-	-	-	31	1
13:30	13:45	-	14	-	-	-	-	-	13	-	-	-	-	27	1
13:45	14:00	-	4	-	-	-	-	-	5	-	-		-	9	1
14:00	14:15	-	15		(-)	-	-	-	19	-	-	-	-	34	1
14:15	14:30	-	14	-	-	-		-	14	-	-	-	-	28	
14:30	14:45	-	20	-	-	-	-	-	15		-	1.50	-	35	1
14:45	15:00	-	16	-	-	-	-	-	17	-	-	-	-	33	1

PROJECT NE SURVEY DAT SURVEY TIM TIM START	TE: 1ES:	Thursda	T2022-219 y, 03 Novem 0H00-00H0		INTERSECT	ION:									
SURVEY TIM	IES:			ber 2022			MA	RIBORODE	& WESTBO	INTSHELL	FILLING STA	TION ACCE	55.1	//LIDItest	
TIM		0	OHOO-OOHO						G 1125150	oner onecc	TIEE THE OIL	on Acce		unitraf	
	ΛΕ I		01100-00110	0	KMZ FILE N	IR:	ACCESS 1	DATA:	D.L	TYPE:	4W	-24H-00-0		7'	
	ΛE.						TOTA	AL SUMMA	ny						
			IN				IUIA	AL SUIVINA	OUT					VOLUME SUMMARY	
	END	1	2	3	4	5	6	7	8	9	10	11	12		
15:00	15:15	_	10	-			-		14	-	- 10		- 12	TOTAL	
15:15	15:30	-	15		-	-	_		15		-			30	
15:30	15:45		12		-	_	-		15		-			27	
15:45	16:00		7		-				9				_	16	
16:00	16:00	-	16	•		- 1	-		18	-			-		97
16:00	16:15	-	17	-	-	-	-		23	-	-	-	-	34 40	107
16:15	16:45		16						15						117
_	_	-	14	-	-	-	-		20	•	-	-	•	31	121
16:45 17:00	17:00 17:15	-	14	-	-	-	-		20	-		-	-	34	139
17:15	17:15	-	14	-	-	-	-		16	-		-	•	34	139
2007		-	19	-	-	-	-		18	-	-	-	-	30 37	129
17:30	17:45	•		-	-	-	-			-	-	-	-		135
17:45	18:00		19	-	-	-	-		27	-	-	-	-	46	147
18:00	18:15	•	14	-	-	•	-		13		•	-		27	
18:15	18:30	-	8	-		•	-		19	-	•	-		27	
18:45	19:00	-	10	-			-		11	-				20	
19:00	19:00		9	-	-	-	-		10	-	-	-		19	95
19:15	19:15	-	14	-	-	-	-		15	-			-	29	87
19:30	19:45	-	10	-	-	-	-		12	-	-	-	-	22	89
19:45	20:00		14	-	-	-	-		18	-		-	-	32	91
20:00	20:00	-	6	-	-	-	-		10	-		-	-	16	102
20:00	20:15		3	-	-	-	-		2	-		-	-	5	99
20:30	20:30	-	11	-	-	-	-		11	-			-	22	75
20:30	21:00		7	-	-	-	-		5				-	12	75
21:00	21:00	-	3	-	-	-	-		10	-	-		-	13	55
21:15	21:15	-	3	-	-	-	-	•	2		-	-	-	5	52
21:15	21:45	-	4	-	-	-	-		4	-		-	-	8	52
21:45	22:00	-	1	-	-	-	-		3	-	-	-	-	4	38
22:00	22:15	-	6	-	-	-	-		4		-	-	-	10	30
22:15	22:30	-	4	-	-		-		6		-		-	10	27 32
22:30	22:45	-	3	-	-	-	-		5	-	-	-	-	8	
22:45	23:00	-	2	-	-	-	-		1	-	-		-	3	32
23:00	23:15	-	4	-	-	-	-		1	-	-		-	5	31
23:15	23:30	-	- 4	-	-	-	-		3	-		-	-	3	26
23:30	23:45	-	2	-	-	-	-		2		- 1		-	4	19
23:45	00:00	-	1	-	-	-	-		1				-	2	15
70T		-	828	-	-	-	-		991	-		-		1 819	14

## Marlboro Drive (M60) Eastbound Shell Filling Station (Access A2)

LOCATION		WOODMEAD UT2022-2197			PROJECT TI	TLE:			WOODM	EAD-TRAFFI	C COUNT					
PROJECT NI					INTERSECTI	ON:	AC	CESS 2 EAST	BOUND SHE	LL FILLING	STATION & I	MARLBORO	DR	unit	af	
SURVEY DA			ay, 03 Novembe		KMZ FILE N	D+	ACCESS 2	DATA:	DI	TVDE.	414	V 24H 00 0	0.0	( Orner	aı	
SURVET TIK	VILS.	0	ionoo-oonoc	,	KIVIZ FILE IV	n.	ACCESS 2	DATA.	D.L	TYPE:	40	V-24H-00-0	U-C			
1							TOTA	AL SUMMA	RY							
TIN	ME	IN							OUT					VOLUME SUMMARY		
START	END	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL		
00:00 00:15	00:15		3	-	-	-	-	-	- 2	-			-	2		
00:15	00:30 00:45	-	1		-	-	-	-	3	-	-	-	-	5		
00:45	01:00	-	4		-	-	-	-	2	-		-	-	6		
01:00	01:15	-	-	-	-	-	-	-	-	-		-				
01:15	01:30		1	-	-	-	-	-	-	-	-	-	-	1		
01:30	01:45	-	1	-	-	-	-	-	-	-	-	-	-	1		
01:45	02:00	-	2	-	-	-	-		2	-	-		-	4		
02:00	02:15	-	1	-		-	-	-	1	-	-	-	-	2		
02:15	02:30	-	2	-	-		-	-	2	-	-	-	-	4		
02:30 02:45	02:45 03:00	-	1		-	-	-	-	1	-		-	-	2		
03:00	03:15	-	-		-	-	-	-	1	-	-	-	-	1		
03:15	03:30	-	-	-	-	-	-	-	1	-				1		
03:30	03:45	-	2	7-8	1=0	1-		-	2	(=)	-	-	-	4		
03:45	04:00		-	- 1	-	16	-	-		-	-	-	-	-		
04:00	04:15	-	1	-	-	-	-	-	1	-	-		-	2		
04:15	04:30	-	5	-	-	-	-	-	1	-	-	-	-	6		
04:30 04:45	04:45 05:00		3	- 15	-		-	-	3				-	3		
05:00	05:15	- 1	7	-	-	-	-	-	3	-	-	-	-	10		
05:15	05:30	-	6	-	-	-	-	-	8	-	-	-	-	14		
05:30	05:45	-	7	-	-	-		-	12	-	-		-	19		
05:45	06:00	-	4		-	-	-	-	5	-	-	-	-	9		
06:00	06:15	-	14	-	-	-	-	-	13	-	-	-	-	27		
06:15	06:30	-	8	-	-	-	-	-	8	-		-		16		
06:30	06:45	-	12	-	-	-	-	-	15	-	-	-	-	27		
06:45 07:00	07:00 07:15	-	14		-		-	-	18 14	-	- 1		-	32 24		
07:15	07:30	-	16	-	-	-	-	-	19	-	-	-	-	35		
07:30	07:45	-	7	-	-	-	-	-	17	-	-	-	-	24		
07:45	08:00	-	9	-	-	-	-	-	9					18		
08:00	08:15	-	7	-	-	-	-	-	20	-	-	-	-	27		
08:15	08:30	-	11	-	-	-	-	-	23	-	-	-	-	34		
08:30 08:45	08:45 09:00	-	9		-	-	-	-	10		-		-	19 25		
09:00	09:15	- 1	7	-	-	-	-	-	13	-	- 1	-	-	20		
09:15	09:30	-	15	-	-	-	-	-	12	-	-	-	-	27		
09:30	09:45	-	17	7.0	-	1-	-	-	17		-	-	-	34		
09:45	10:00		14	- 1	-	18	-	-	16	-	-	-	-	30		
10:00	10:15	-	14	•	-	1-	-	-	14	-	-	.=	-	28		
10:15	10:30	-	11	-	-	-	-	-	17		-	-	-	28		
10:30 10:45	10:45 11:00	-	10 21		-	-	-	-	10 27	-		-	-	20 48		
11:00	11:00	-	10		-	-	-	-	24	-	-	-	-	34		
11:15	11:30	-	12	-	-	-	-	-	13	-	-	-	-	25		
11:30	11:45	-	10	-	-	-	-	-	11	150	-	-	-	21		
11:45	12:00	-	13	-	-	-	1-1	-	21	-	-	-	-	34		
12:00	12:15	-	16	-	-		-	-	18	-	-		-	34		
12:15	12:30	-	8		-	-	-	-	14		-	-		22		
12:30	12:45	-	16 14		-	-	-	-	20 11	-	-	-	-	36 25		
12:45 13:00	13:00 13:15	-	14	-	-	-	-	-	22	-	-	-	-	40		
13:15	13:30	-	15	-	-	-	-	-	13	-	-	-	-	28		
13:30	13:45	-	16	-	-	-	-	-	12	-	-	-	-	28		
13:45	14:00	-	25	-	-	1.5	-,	-	18	-	-	-	-	43		
14:00	14:15	-	17	7-	-	7-	-	-	8	-	-	-	-	25		
14:15	14:30	-	18	-	-	-	-	-	9	-	-		-	27		
14:30	14:45	-	11	•	-		-	-	10	-	-		-	21		
14:45	15:00	-	8	-	1=3		-:	~	13	~	-	-	-	21		

LOCATION		١	WOODMEAD	)	PROJECT T	ITLE:			WOODM	EAD-TRAFFI	IC COUNT				T
PROJECT N	IR:	U	T2022-219	7	INTERSECT	ION:		DECC 2 EACT	BOUND SHE	I EILING	STATIONS	MARIBORO	) DP	<b>(</b> unitraf	
SURVEY DA	ATE:	Thursda	y, 03 Novemi	ber 2022	INTERSECT	ION:	ACC	JESS 2 EAST	BOUNDSHE	LLFILLING	STATION &	MAKLBOKO	JUK	Unitrat	
SURVEY TI	MES:	0	0Н00-00Н0	KMZ FILE N	IR:	ACCESS 2	DATA:	D.L	TYPE:	4W	/-24H-00-0		•	4	
							TOTA	L SUMMA	RY						
TI	ME		IN						OUT					VOLUME SUMMARY	1
START	END	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	
15:00	15:15		8	· .		· .		· .	17		-			25	
15:15	15:30	-	9	-		-	-		10	-	-	-	-	19	
15:30	15:45	-	9	-		-	-		10	-	-	-	-	19	
15:45	16:00		13	- 6			-		12	-	-	-	-	25	8
16:00	16:15	-	10	- 2		-	-		19	-	-			29	9
16:15	16:30	-	9	-		-	-		14	-	-	-	-	23	9
16:30	16:45	-	11	- 6		-	-		14	-	-	-	-	25	10
16:45	17:00	-	9	-		-	-		21	-	-	-	-	30	10
17:00	17:15	-	14	-	-	-	-	-	18	-	-	-	-	32	11
17:15	17:30	-	12	-	-	-	-		24	-	-	-	-	36	12
17:30	17:45	-	9	-	-	-	-		20	-	-	-	-	29	12
17:45	18:00	-	14	-	-	-	-		21	-	-	-	-	35	13
18:00	18:15	-	15	-	-	- 2	-		16	-	-	-	-	31	-
18:15	18:30	-	9	-	-	-	-		20	-	-	-	-	29	
18.30	18.45	-	15	-	-	-	-		18	1.	-	-	-	33	
18:45	19:00	-	7	-	-	-	-		15	-	-	-	-	22	11
19:00	19:15	-	17	-		-	-		6	-	-	-	-	23	10
19:15	19:30	-	5			-	-		16	-		-	-	21	9
19:30	19:45	-	17	-		-	-		12	-		-	-	29	9
19:45	20:00		11	-	-	-	-		11	-	-	-	-	22	9
20:00	20:15	-	10			-	-		10	-		-	-	20	9
20:15	20:30	-	10	F.	-	-	-		9	1-	-	-	-	19	9
20:30	20:45	-	8	-	-	-	-		10	-	-	-	-	18	7
20:45	21:00	-	5	-	-	-	-		4	-	-	-	-	9	6
21:00	21:15		7			-	-		4	-	-	-		11	5
21:15	21:30	-	3	-	-	-	-		3	10-	-	-	-	6	4
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22:00	22:15	-	8	-	-	-	1-		7	-	-	-	-	15	3
22:15	22:30		7	-	-	-	-	•	4		-		-	11	4
22:30	22:45	-	5	-	-	-	-		3	10-1	-	-	-	8	4
22:45	23:00	-	4	-		-	-		2	-	-	-	-	6	4
23:00	23:15		4	-	-	-	-		3		-	-	-	7	3
23:15	23:30	-	1	-	-	-	-		-	1-1	-	×	-	1	2
23:30	23:45	-	3	-	-	-	-		3	-	-	-	-	6	2
23:45	00:00	-	2	-		-	-		-	-	-	-	-	2	1
TO	TAL	-	830	-		-	-	-	975	-		-	-	1 805	

## Lilium Avenue Shell Filling Station (Access A3)

LOCATION PROJECT NI	p.	WOODMEAD UT2022-2197			PROJECT TI	ITLE:			WOODN	MEAD-TRAFFI	CCOUNT				
SURVEY DA			ay, 03 Novemb		INTERSECT	ION:		LILIUM	AVE & ACC	CESS TO SHEL	L FILLING ST	TATION		<b>(</b> unit	rat
SURVEY TIM			оноо-ооно		KMZ FILE N	R:	ACCESS 3	DATA:	J.A.V	TYPE:	4W	/-24H-00-00	-C	<b>6</b> 1	
							TOTA	LCLINANAA	DV:						
TIN	ME				ľ	OUT	TOTAL SUMMARY			Î		IN		VOLUME SU	MMARY
START	END	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	VIIVIV UCT
00:00	00:15	-	-	-		-	21	-	-	-	-	-	21	-	
00:15	00:30	-		-	-	-	-0	-	-	-		1		1	
00:30	00:45		-	-	-	-	-	-	-	-	-	-	-	-	
00:45	01:00	-	-	-	-	-	-	-	-	-	-	2	141	2	
01:00	01:15	-	-	-	-	1		-	-	-		-		1	
01:15 01:30	01:30 01:45	-	-		-	-	-	-	-	-	-	1	-	1	
01:45	02:00	-	-	-	-	1	-	-	-	-	-	- 1	-	1	
02:00	02:15	-	-	-	_	-	-	-	_	-	-	2		2	
02:15	02:30	-	-	-	-	1	-	-	-	-	-	1	-	2	
02:30	02:45	-	-	-	-	-	-	-		-		-	-	-	
02:45	03:00	-	-	-	-	-	-	-	-	-	-	-	-	-	
03:00	03:15	1-	-	-	-	1	-	-	-	-	1=1	1	27	2	
03:15	03:30	-	-	-	-	-	-	-	-	-	-	-	-	-	
03:30	03:45	-	-	-	-	-	-	-	-	-	-	-	-	-	
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05:00	05:15	-	-	-	-	2	-	-	-	-	-	5	-	7	
05:15	05:30	-	-	-	-:	4	-:	-	-:	-	-	7	-	11	
05:30	05:45	-	-	-	-	9	-	-	-	-		2	-	11	
05:45	06:00	-	-	-	-	5	-	-	-	-	-	5	-	10	
06:00	06:15	-	-	-	-	3		-	-	-	-	5	-	8	
06:15 06:30	06:30 06:45	-	-		-	10 17	-	-	-	-	-	10	-	20	
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	C+.+1	100	-	1 -	-	13	-	-	-	-	-	8	-	21	

LOCATION		١	WOODMEA	D	PROJECT T	ITLE:			WOODM	EAD-TRAFF	IC COUNT					I
PROJECT N	IR:	U	T2022-219	7	INTERSECT	ION:		THUM	AVE 8. ACC	ESS TO SUE	LL FILLING S	TATION			l .	
SURVEY DA	ATE:	Thursda	Thursday, 03 November 2022			IOIV.		LILION	AVE & ACC	E33 10 3HE	LE FILLING 3	IAHON			itraf	l .
SURVEY TIP	MES:	00H00-00H00			KMZ FILE N	IR:	ACCESS 3	DATA:	J.A.V	TYPE:	4W	/-24H-00-00	)-C	•		J
									- 11							1
					,		TOTA	AL SUMMA	.RY							4
	ME					OUT						IN		VOLUN		
START	END	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL		<u> </u>
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15:30	15:45	-	-	-		15	-	-	-	-	-	10	-	25		
15:45	16:00	-		-	•	11	-		-			4	-	15		74
16:00	16:15	-		-	•	14	•	-	-	-		6	-	20		80
16:15	16:30	-	-	-	-	16	-	-	-	-	-	16	-	32		92
16:30	16:45	-	-	-	-	16	-	-	-	-	-	9	-	25		92
16:45	17:00	-	-	-	-	24	-	-	-	-	-	17	-	41		118
17:00	17:15	-	-	-	-	25	-	-	-	-	-	17	-	42		140
17:15	17:30	-	-	-	-	30	-	-	-	-	-	16	-	46		154
17:30	17:45	-	-	-	-	22	-	-	-	-	-	13	-	35		164
17:45	18:00	-	-	-	-	23	-	-	-	-	-	14	-	37		160
18:00	18:15	-	-	-	-1	19	-	-	-	-	-	8	-	27		
18:15	18:30	-	-	-	-	17	-	-	-	-	-	9	-	26		
18:30	18:45	-	-	-	+	11	-	-	-	-	-	4		15		
18:45	19:00	-	-	-	-	14	-	-	-	-	-	10	-	24		92
19:00	19:15	-		-	-	14	-	-	-	-	-	8	-	22		87
19:15	19:30	-	-	-	-	13	-	-	-	-	-	15	-	28		89
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19:45	20:00	-	11-	-	*	7	-	-	-	-		8	-	15		87
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20:30	20:45		-	-	•	13		-	-		-	9	-	22		68
20:45	21:00		-	-	•	4				-	-	3	-	7		60
21:00	21:15	-	-	-	-	6	-	-	-	-	-	8	-	14		54
21:15	21:30	-	-	-	-1	5	-	-	-	-	-	3	-	8		51
21:30	21:45		180	-		2		-		×	-	4	•	6		35
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22:15	22:30		17	-	*1	3	-			-	-	1	-	4		24
22:30	22:45	-	1.4	-	-		-	-	-	-	-	1	-	1		19
22:45	23:00	-	-	-		1	-	-	-	-	-	-	-	1		13
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23:15	23:30	-	1.5	-	- 61	1		-	-	-	-	1	-	2		8
23:30	23:45	-	-	-	-	1	-	-	-	-	-	1	-	2		9
23:45	00:00		-	-	-	1	-	-	-	-	-	2		3		11
TO	TAL	-	-	-	-	826	-	-	-	-	-	625	-	1 451		

## Western Service Road Caltex Filling Station (Access A4)

LOCATION PROJECT NI	R·	WOODMEAD UT2022-2197			PROJECT TI	TLE:			WOODN	/IEAD-TRAFFI	C COUNT					
SURVEY DA			ay, 03 Novemb		INTERSECTI	ON:	V	VESTERN SE	RVICE RD &	V	<b>unit</b>	rat				
SURVEY TIM	ИES:	0	оноо-ооно	10	KMZ FILE N	R:	ACCESS 4	DATA:	J.A.V	TYPE:	4V	V-24H-00-00				
							TOTA	I SUMMA	DV							
TIN	MF					IN	TOTAL SUMMARY					OUT		VOLUME SUMMARY		
START	END	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL		
00:00	00:15	-	-	-	-	4	-	-	-		-	3		7		
00:15	00:30	-	-	-		5	2	v	-		-	4	41	9		
00:30	00:45	-1	-	-	-	4	-	-	-	-	-	4		8		
00:45	01:00	-	-	-	-	1	-	-	-	-	-	2	-	3		27
01:00	01:15	w.	-	-	-	-	-	-	-		141	1		1		21
01:15	01:30		7-	-	-	2	-	-	-		-	1		3		15
01:30 01:45	01:45 02:00	-	-	-	-	- 4	-	-	-	-	-	1	-	1		15
02:00	02:00	-	-	-	-	-	-	-	-	-	-	-	-			13
02:15	02:30	-	-	_	-	2	_	-	-	-	-	1	20	3		12
02:30	02:45	-	-	-	-	1	-	-	-	-	-	1	-	2		6
02:45	03:00	-	-	-	-	2		-	-	ъ.	-	2	-	4		9
03:00	03:15	-		-	-	1	-	121	-		-	2		3		12
03:15	03:30	-	-	-		-	-	-	1	-	-	1		1		10
03:30	03:45	-	-	-	-	1		-	-	-	-	-		1		9
03:45	04:00	-	-	-	-	1	-	-	-		-	1		2		7
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05:30	05:45	-	-	_	-	9	_	-	-	-	-	12	-	21		45
05:45	06:00	-	-	_	-	14	-	-	-		-	18	-	32		68
06:00	06:15	-	-	-	-	12	-	-	-		-	13	51	25		
06:15	06:30	v	-	-	-	6	-	v	-	-	~	23	41	29		
06:30	06:45	-	-	-	-	31	-	-	1-	-	-	15		46		
06:45	07:00		-	-	-	30	-		-		1-1	31		61		161
07:00	07:15	21	-	-	-	46	-	-	-		- 2	34	27	80		216
07:15	07:30	-	-	-	-	27	-	-	-	-	-	32	-	59		246
07:30	07:45	-	-	-	-	29	-	-	-	-	-	25	-	54 75		254
07:45 08:00	08:00 08:15	-	-	-	-	41 30	-	-	-	-	-	34	-	66		268 254
08:15	08:30	-	-	2	-	43	-	-	-	-	-	42	-	85		280
08:30	08:45	-	-	-	-	46	-	-	-	-	-	45	-	91		317
08:45	09:00		-	-	-	33		-	-	-	.=:	41		74		316
09:00	09:15	-	-	-	-	37	-	-	-	-	-	29	-	66		
09:15	09:30	-	0-0	-	-	41	-	-	-	-	1=1	30	-/	71		
09:30	09:45	-	12	-		38		-	-	-	-	39	3-1	77		
09:45	10:00	-	-	-	-	41	-	-	-	-	120	28		69		283
10:00	10:15	->	7-	-		40	-	-	-	-1	-	32		72		289
10:15	10:30	-	-	-	-	28		-	1-		-	38	- 5	66		284
10:30	10:45		-	-	-	35	-	-	-	-1	-	25	-	60		267
10:45 11:00	11:00 11:15	-	-	-	-	38			-		-	30 44	-	77		266
11:00	11:15	-	-	-	-	55	-	-	-	-	-	34	-	89		271 294
11:30	11:45	-	-	-	-	41	-	-	-	-	-	38	-	79		313
11:45	12:00	-	-	-	-	31	-	-	-	-	-	41		72		317
12:00	12:15	-	-	-	-	46	-	-	-		-	41		87		327
12:15	12:30	-	-	-	-	45	-	-	15	-	-	40	-	85		323
12:30	12:45	-	-	-	-	41	-	-	6=	-	-	37	-	78		322
12:45	13:00	-	-	-	-	39	-	-	-	-	-	43	-	82		332
13:00	13:15	-	-	-	-	40	+	-	12	-	-	53	-	93		338
13:15	13:30		-	-	-	41	-	-	-	-	-	37	-7	78		331
13:30	13:45		2.5	-	-	45	-	-	-	-	.=	36		81		334
13:45	14:00	-	-	-		48	2	(2)	-	-	-	27		75		327
14:00	14:15	-	-	-	-	34 39		-	-	-	-	23 37	-	57 76		291
14:15 14:30	14:30 14:45	-	-	-	-	35	-	-	-		-	29	-	64		289
14.50	15:00	-	-	-	-	31	-	-	-	-	-	33	-	64		272 261

LOCATION		١	WOODMEA	D	PROJECT T	ITLE:			WOODM	EAD-TRAFF	C COUNT					
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	ME					IN		_				OUT				
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15:15	15:30	-	-	-	-	36	-	-	-	-	-	43	-	79		
15:30	15:45	-	-	-	-	39	-	-	-	-	-	35	-	74		-
15:45	16:00	-	-	-	-	44	-	-	-	-	-	33	-	77		313
16:00	16:15	-	-	-	-	20	-	-	-	-	-	27	-	47		277
16:15	16:30	-	-	-	-	24	-	-	-	•	•	35	-	59		257
16:30	16:45		-			28	-	-			-	34	-	62		245
16:45	17:00	-	-	-	-	33	-	-	-	-	-	35	-	68		236
17:00	17:15	-	-	-	-	29	-	-	-	-	-	35	-	64		253
17:15	17:30	-	-	-		27		-	•	•	•	30	-	57		251
17:30	17:45	-	-	-		42	-	-	-	-	-	37	-	79		268
17:45	18:00	-	-	-	-	33	-	-	-	-	-	24	-	57		257
18:00	18:15	-	-	-	-	36	-	-	-	-	-	25	-	61		
18:15	18:30	-	-	-	-	37	-	-	-	-	-	29	-	66		
18:30	18:45	-	-	-	-	33	-	-	-	-	-	26	-	59		
18:45	19:00	-	-	-	-	18	-	-	-	-	-	19	-	37		223
19:00	19:15	-	-	-	-	24	-	-	-	-	-	19	-	43		205
19:15	19:30	-	-	-	-	18	-	-	-	-	-	23	-	41		180
19:30	19:45	-	-	-	-	21	-	-	-	-	-	23	-	44		165
19:45	20:00	-	-	-		15	-	-	-	-	-	17	-	32		160
20:00	20:15		-	-	-	20	-	-	•	-		16		36		153
20:15	20:30	-	-	-	-	24	-	-	-	-	•	15	•	39		151
20:30	20:45	•		-	-	12	-	-	•	-	•	15	-	27		134
20:45	21:00		-	-	-	22	-	-	•	-	•	20	-	42 30		144
21:00	21:15	-	-	-		18	-	-	•		•	12	-			138
21:15	21:30			-	-	18 19	-	-	•	-	•	10	-	28		127
21:30		-	•	-	-			-	-	-	-	17	-	36		136
22:00	22:00		-	-	172.1	10 15		-	•	•	•	7		18 22		112
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22:45	23:00	-	-		-	11	-	-	-	-	-	8	-			87
23:00	23:00	-	-	-	-	7	-	-	-	-	-	3	-	19 10		88
23:00	23:15					5						3				76
23:15	23:30	-	-	-	-	3	-	-	•	-	•	3	-	8		62
			-	-	-	4	-	-	-	-	-		-	6		43
23:45	00:00 TAL	-	-	-	-	_		-	-	-	-	3 024	-	7		31
10	TAL	-	-	-	-	2 207	-	-	-	-	-	2 034	-	4 241		l.

# Woodlands Drive and Western Service Road Engen Filling Station (Access A5)

OCATION		٧	WOODMEAL	)	PROJECT TI	TLE:			WOODN	IEAD-TRAFFI	C COUNT					
ROJECT N			JT2022-219		INTERSECT	ION:	W	VESTERN SEI	RVICE RD &	ACCESS TO	ENGEN FILL	ING STATIO	N	(III	itraf	
SURVEY DA SURVEY TIN			oy, 03 Novemb 0H00-00H0		KMZ FILE N	R:	ACCESS 5	DATA:	J.A.V	TYPE:	4W	/-24H-00-00			IILIGI	
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14:30	14:45	-	-	-	-	7	-	-	-	-	-	12	-	19		10
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PROJECT NE SURVEY DAT SURVEY TIM	TE:		T2022-219	7											
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SURVEYTIM	MES:		y, 03 Novem	ber 2022	INTERSECT	ION:	*	ESTERN SER	VICE KD &	ACCESS TO	ENGEN FILL	ING STATIO	N	<b>(</b> unitraf	
		0	оноо-ооно	00	KMZ FILE N	IR:	ACCESS 5	DATA:	J.A.V	TYPE:	4W	/-24H-00-00			
							TOTA	L SUMMA	RY						
TIM						OUT						IN		VOLUME SUMMARY	
START	END	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	
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15:30	15:45	-	-	-	-	7	-	-	-	-	-	8	-	15	
15:45	16:00	-	-	-		14	-	-	-	-		14	-	28	72
16:00	16:15	-	-	-		6	-	-	-	-	-	10	-	16	75
16:15	16:30	-	-	-	-	18	-	-		-	-	19	-	37	96
16:30	16:45	-	-	-	-	12	-	-	-	-	-	18	-	30	111
16:45	17:00	-	-	-	-	9	-	-	-		-	15	-	24	107
17:00	17:15	-	-	-	-	22	-	-	-	-	-	16	•	38	129
17:15	17:30	-	-	-	-	11	-	-	-	-	-	21	-	32	124
17:30	17:45	-	-	-	-	14	-	-	-	-	-	13	-	27	121
17:45	18:00	-	-	-	-	12	-	-	-	-	-	14	-	26	123
18:00	18:15	-	-	-	-	10	-	-	-	-	-	13	-	23	1 1
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20:00	20:00				-	4		-		-	-	6		10	40
20:15	20:30	-	-	-		7	-	-	-	-		9	-	16	45
20:30	20:45	-	-	-	-	1	-	-	-	-	-	4	-	5	46
20:45	21:00	-	-	-		1	-	-	-	-				1	43 32
21:00	21:15	-		-	-	4	-	-	-	-	-	3	-	7	29
21:15	21:30		-	-	-	2	-	-	-			3	-	5	18
21:30	21:45	-	-			1	-	-	-	-		4	-	5	18
21:45	22:00		-	-	-	2		-			-	1	-	3	20
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22:45	23:00	-	-	-	-	1		-	-	-	-	2	-	3	11
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TOT		-	_	-	-	649	-	-	-	-	-	759		1 408	1

# **ANNEXURE B: SIDRA ANALYSIS OUTPUT FILES**



Site: 1 [Lillium Ave and Zinia Drive - Intersection 1 - AM Peak]

Lillium Ave and Zinia Drive - Intersection 1 Site Category: (None) Stop (All-Way)

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back (	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/t
East Z	inia Drive											
5	T1	483	4.1	0.874	33.5	LOS D	9.7	70.4	1.00	2.30	6.64	38.7
6	R2	192	4.1	0.874	33.3	LOS D	9.7	70.4	1.00	2.30	6.64	38.6
Approa	ch	675	4.1	0.874	33.4	LOS D	9.7	70.4	1.00	2.30	6.64	38.7
North: I	Lillium Ave											
7	L2	76	4.1	0.685	31.3	LOS D	4.4	31.9	1.00	1.66	3.84	39.8
9	R2	214	4.1	0.685	30.7	LOS D	4.4	31.9	1.00	1.66	3.84	39.5
Approa	ch	289	4.1	0.685	30.9	LOS D	4.4	31.9	1.00	1.66	3.84	39.6
West: 2	Zinia Drive											
10	L2	571	4.1	1.473	242.7	LOSF	66.1	478.7	1.00	6.93	26.72	12.0
11	T1	301	4.1	1.473	242.4	LOSF	66.1	478.7	1.00	6.93	26.72	12.0
Approa	ch	872	4.1	1.473	242.6	LOS F	66.1	478.7	1.00	6.93	26.72	12.0
All Veh	icles	1836	4.1	1.473	132.4	LOSF	66.1	478.7	1.00	4.40	15.74	18.9

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

#### MOVEMENT SUMMARY



Site: 1 [Lillium Ave and Zinia Drive - Intersection 1 - Midday Peak]

Lillium Ave and Zinia Drive - Intersection 1 Site Category: (None) Stop (All-Way)

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total	HV	Satn	Delay	Service	Vehicles	Distance	Queued	Stop Rate	Cycles	Speed
		veh/h	%	v/c	sec		veh	m				km/t
East: Z	inia Drive											
5	T1	135	4.1	0.304	14.6	LOS B	1.1	8.3	0.82	1.34	2.25	48.2
6	R2	45	4.1	0.304	14.3	LOS B	1.1	8.3	0.82	1.34	2.25	48.0
Approa	ch	180	4.1	0.304	14.5	LOS B	1.1	8.3	0.82	1.34	2.25	48.2
North: I	Lillium Ave											
7	L2	60	4.1	0.403	16.4	LOSC	1.7	12.2	0.85	1.38	2.50	47.4
9	R2	177	4.1	0.403	15.8	LOSC	1.7	12.2	0.85	1.38	2.50	47.0
Approa	ch	237	4.1	0.403	15.9	LOS C	1.7	12.2	0.85	1.38	2.50	47.1
West: 2	Zinia Drive											
10	L2	162	4.1	0.657	27.6	LOS D	4.0	29.2	0.98	1.62	3.66	41.5
11	T1	143	4.1	0.657	27.3	LOS D	4.0	29.2	0.98	1.62	3.66	41.4
Approa	ch	305	4.1	0.657	27.5	LOS D	4.0	29.2	0.98	1.62	3.66	41.5
All Veh	icles	722	4.1	0.657	20.5	LOSC	4.0	29.2	0.90	1.47	2.93	44.8

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akcelik M3D).



Site: 1 [Lillium Ave and Zinia Drive - Intersection 1 - PM Peak ]

Lillium Ave and Zinia Drive - Intersection 1 Site Category: (None) Stop (All-Way)

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back (	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/h
East: Z	inia Drive											
5	T1	217	4.1	0.556	22.2	LOSC	2.9	20.9	0.94	1.50	3.10	44.0
6	R2	54	4.1	0.556	21.9	LOSC	2.9	20.9	0.94	1.50	3.10	43.8
Approa	ch	271	4.1	0.556	22.1	LOSC	2.9	20.9	0.94	1.50	3.10	44.0
North:	Lillium Ave											
7	L2	123	4.1	0.748	25.3	LOS D	5.6	40.7	0.95	1.82	4.49	42.6
9	R2	391	4.1	0.748	24.7	LOSC	5.6	40.7	0.95	1.82	4.49	42.2
Approa	ch	514	4.1	0.748	24.8	LOS C	5.6	40.7	0.95	1.82	4.49	42.3
West: 2	Zinia Drive											
10	L2	173	4.1	1.023	89.3	LOSF	14.2	102.7	1.00	2.66	8.18	24.4
11	T1	197	4.1	1.023	89.0	LOS F	14.2	102.7	1.00	2.66	8.18	24.3
Approa	ch	370	4.1	1.023	89.2	LOSF	14.2	102.7	1.00	2.66	8.18	24.4
All Veh	icles	1154	4.1	1.023	44.8	LOSE	14.2	102.7	0.97	2.01	5.35	34.5

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

#### MOVEMENT SUMMARY



Marlboro Drive and Lillium Ave/South Road - Intersection 2

Site Category: (None)
Signals - Fixed Time Isolated Cycle Time = 150 seconds (Site Practical Cycle Time)
Variable Sequence Analysis applied. The results are given for the selected output sequence.

Mov	Turn	Demand	Flows	Deg	Average	Level of	95% Back	of Queue	Ргор.	Effective	Aver No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/l
South:	Lillium Ave	0.245048.002		0.0000	550,000			25030				23,000,000
1	L2	111	3.4	1.285	201.8	LOS F	84.1	606.1	1.00	1.51	1.84	13.5
2	T1	620	3.4	1.285	196.8	LOSF	84.1	606.1	1.00	1.49	1.85	13.5
3	R2	162	3.4	1.285	206.5	LOS F	31.3	225.3	1.00	1.34	1.91	13.0
Approa	ach	893	3.4	1.285	199.2	LOS F	84.1	606.1	1.00	1.46	1.86	13.4
East: N	Marlboro Drive	3										
4	L2	77	3.4	0.086	26.6	LOSC	2.9	20.9	0.56	0.70	0.56	40.
5	T1	646	3.4	0.343	24.4	LOSC	14.1	101.7	0.65	0.57	0.65	42.5
6	R2	1241	3.4	1.275	198.1	LOS F	82.6	594.9	1.00	1.26	1.84	13.
Approa	ach	1964	3.4	1.275	134.3	LOS F	82.6	594.9	0.87	1.01	1.40	18.
North:	South Road											
7	L2	739	3.4	0.549	12.7	LOS B	19.1	137.7	0.46	0.73	0.49	49.
8	T1	153	3.4	0.523	63.7	LOSE	10.4	75.1	0.97	0.79	0.97	29.
9	R2	36	3.4	0.496	87.1	LOS F	2.8	20.0	1.00	0.73	1.00	24.
Approa	ich	928	3.4	0.549	24.0	LOS C	19.1	137.7	0.57	0.74	0.59	42.
West: I	Marlboro Driv	e										
10	L2	106	3.4	1.047	71.3	LOS E	20.8	149.6	1.00	0.98	1.50	19.
11	T1	353	3.4	1.047	95.9	LOSF	20.8	149.6	1.00	1.06	1.51	19.
12	R2	22	3.4	0.303	85.9	LOSF	1.7	12.0	1.00	0.71	1.00	24.
Approa	ach	481	3.4	1.047	90.0	LOS F	20.8	149.6	1.00	1.03	1.49	19.
All Veh	icles	4266	3.4	1.285	118.9	LOS F	84.1	606.1	0.85	1.05	1.33	19.

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

# Site: 2 [Marlboro Drive and Lillium Ave/South Road - Intersection 2 - PM Peak]

Marlboro Drive and Lillium Ave/South Road - Intersection 2

Site Category: (None)
Signals - Fixed Time Isolated Cycle Time = 80 seconds (Site Practical Cycle Time)
Variable Sequence Analysis applied. The results are given for the selected output sequence.

Mov	Tum	Demand	Flows	Deg	Average	Level of	95% Back (	of Queue	Prop.	Effective	Aver No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/h
South:	Lillium Ave											
1	L2	18	3.4	0.506	40.7	LOS D	5.4	38.9	0.97	0.78	0.97	37.2
2	T1	126	3.4	0.506	35,1	LOS D	5.4	38.9	0.97	0.78	0.97	37.9
3	R2	102	3.4	0.750	50.0	LOS D	4.4	31.6	1.00	0.87	1.26	32.8
Approa	ach	246	3.4	0.750	41.7	LOS D	5.4	38.9	0.98	0.81	1.09	35.6
East: N	Marlboro Drive											
4	L2	121	3.4	0.198	25.9	LOS C	3.4	24.3	0.75	0.75	0.75	41.2
5	T1	512	3.4	0.398	22.0	LOS C	7.7	55.6	0.81	0.68	0.81	44.1
6	R2	853	3.4	0.884	45.5	LOS D	19.0	136.9	0.99	0.99	1.29	33.9
Approa	ach	1486	3.4	0.884	35.8	LOS D	19.0	136.9	0.91	0.86	1.08	37.4
North:	South Road											
7	L2	1117	3.4	0.791	8.8	LOSA	16.1	115.9	0.63	0.79	0.65	51.6
8	T1	346	3.4	0.853	40.3	LOS D	15.1	108.6	1.00	1.00	1.26	36.3
9	R2	119	3.4	0.477	41.6	LOS D	4.5	32.4	0.97	0.78	0.97	35.2
Appro	ach	1582	3.4	0.853	18.2	LOS B	16.1	115.9	0.73	0.83	0.80	45.7
West:	Marlboro Driv	e										
10	L2	21	3.4	0.099	22.7	LOS C	0.9	6.2	0.84	0.67	0.84	44.5
11	T1	38	3.4	0.099	27.8	LOSC	0.9	6.2	0.89	0.66	0.89	40.7
12	R2	2	3.4	0.015	43.8	LOS D	0.1	0.5	0.94	0.61	0.94	34.3
Appro	ach	61	3.4	0.099	26.6	LOS C	0.9	6.2	0.87	0.66	0.87	41.6
All Veh	nicles	3375	3.4	0.884	27.8	LOS C	19.0	136.9	0.83	0.84	0.95	40.8

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements. SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

#### MOVEMENT SUMMARY

#### Site: 2 [Marlboro Drive and Lillium Ave/South Road - Intersection 2 - Midday Peak]

Marlboro Drive and Lillium Ave/South Road - Intersection 2

Site Category: (None)

Signals - Fixed Time Isolated Cycle Time = 80 seconds (Site Practical Cycle Time)

Variable Sequence Analysis applied. The results are given for the selected output sequence.

Mov	Tum	Demand	Flows	Deg	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/h
South:	Lillium Ave											
1	L2	42	3.4	0.449	36.8	LOS D	6.0	43.0	0.93	0.76	0.93	38.4
2	T1	127	3.4	0.449	31.2	LOS C	6.0	43.0	0.93	0.76	0.93	39.2
3	R2	91	3.4	0.669	48.7	LOS D	3.8	27.6	1.00	0.83	1.15	33.2
Approa	ich	260	3.4	0.669	38.2	LOS D	6.0	43.0	0.95	0.79	1.01	36.7
East: N	Marlboro Driv	e										
4	L2	114	3.4	0.180	25.1	LOSC	3.1	22.3	0.73	0.74	0.73	41.6
5	T1	803	3.4	0.601	23.3	LOSC	13.1	94.0	0.88	0.76	0.88	43.4
6	R2	648	3.4	0.841	45.3	LOS D	14.0	100.7	1.00	0.95	1.25	34.0
Approa	ich	1565	3.4	0.841	32.5	LOS C	14.0	100.7	0.92	0.84	1.02	38.8
North:	South Road											
7	L2	598	3.4	0.528	12.4	LOS B	10.9	78.8	0.60	0.76	0.62	49.2
8	T1	98	3.4	0.257	29.7	LOSC	3.3	23.8	0.88	0.69	0.88	40.5
9	R2	58	3.4	0.427	46.7	LOS D	2.3	16.8	0.99	0.75	0.99	33.5
Approa	ich	754	3.4	0.528	17.3	LOS B	10.9	78.8	0.67	0.75	0.68	46.2
West: I	Marlboro Driv	re										
10	L2	92	3.4	0.866	49.4	LOS D	15.9	114.8	1.00	1.07	1.69	34.2
11	T1	631	3.4	0.866	42.4	LOS D	15.9	114.8	1.00	1.04	1.46	35.2
12	R2	63	3.4	0.463	46.9	LOS D	2.5	18.4	1.00	0.75	1.00	33.3
Approa	ich	786	3.4	0.866	43.6	LOS D	15.9	114.8	1.00	1.02	1.45	34.9
All Veh	icles	3365	3.4	0.866	32.2	LOS C	15.9	114.8	0.88	0.86	1.04	39.0

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements. SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).



Site: 3 [South Road and Impala Road - Intersection 3 - AM Peak]

South Road and Impala Road - Intersection 3 Site Category: (None) Stop (Two-Way)

Mov	Tum	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total	HV	Satn	Delay	Service	Vehicles	Distance	Queued	Stop Rate	Cycles	Speed
		veh/h	%	v/c	sec	***************************************	veh	m				km/t
South	East: South	Road										
21a	L1	1799	2.2	0.491	4.7	LOSA	0.0	0.0	0.00	0.55	0.00	54.0
23	R2	47	2.2	0.491	5.6	LOSA	0.0	0.0	0.00	0.56	0.00	53.9
Approa	ach	1846	2.2	0.491	4.7	NA	0.0	0.0	0.00	0.55	0.00	54.0
NorthE	ast: Impala	Road										
24	L2	55	2.2	33.394	14662.5	LOSF	148.7	1060.4	1.00	1.31	2.30	0.2
26a	R1	200	2.2	33.394	14675.5	LOSF	148.7	1060.4	1.00	1.31	2.30	0.2
Approa	ach	255	2.2	33.394	14672.7	LOSF	148.7	1060.4	1.00	1.31	2.30	0.2
West:	South Road											
10a	L1	141	2.2	0.309	5.5	LOSA	1.8	12.7	0.17	0.53	0.17	53.1
12a	R1	902	2.2	0.309	4.8	LOSA	1.8	13.2	0.17	0.52	0.17	53.7
Approa	ach	1043	2.2	0.309	4.9	NA	1.8	13.2	0.17	0.52	0.17	53.6
All Veh	nicles	3144	2.2	33.394	1194.4	NA	148.7	1060.4	0.14	0.60	0.24	2.8

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA: Intersection LOS and Major Road Approach LOS values are Not Applicable for two-way sign control since the average delay is not a good LOS measure due to zero delays associated with major road movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

#### MOVEMENT SUMMARY



## 🥮 Site: 3 [South Road and Impala Road - Intersection 3 - Midday Peak]

South Road and Impala Road - Intersection 3 Site Category: (None) Stop (Two-Way)

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/t
SouthE	East: South	Road										
21a	L1	759	2.2	0.212	4.6	LOS A	0.0	0.0	0.00	0.56	0.00	54.1
23	R2	40	2.2	0.212	5.5	LOSA	0.0	0.0	0.00	0.56	0.00	53.9
Approa	ach	799	2.2	0.212	4.7	NA	0.0	0.0	0.00	0.56	0.00	54.1
NorthE	ast: Impala	Road										
24	L2	35	2.2	1.533	291.9	LOS F	19.7	140.1	1.00	2.08	4.83	9.1
26a	R1	89	2.2	1.533	335.5	LOS F	19.7	140.1	1.00	2.08	4.83	9.0
Approa	ach	124	2.2	1.533	323.2	LOSF	19.7	140.1	1.00	2.08	4.83	9.1
West:	South Road											
10a	L1	115	2.2	0.250	5.5	LOSA	1.4	9.7	0.14	0.53	0.14	53.2
12a	R1	733	2.2	0.250	4.7	LOSA	1.4	10.0	0.14	0.52	0.14	53.8
Approa	ach	848	2.2	0.250	4.8	NA	1.4	10.0	0.14	0.52	0.14	53.7
All Veh	nicles	1771	2.2	1.533	27.1	NA	19.7	140.1	0.14	0.65	0.41	40.0

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA: Intersection LOS and Major Road Approach LOS values are Not Applicable for two-way sign control since the average delay is not a good LOS measure due to zero delays associated with major road movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).



#### Site: 3 [South Road and Impala Road - Intersection 3 - PM Peak ]

South Road and Impala Road - Intersection 3 Site Category: (None) Stop (Two-Way)

Mov	Tum	Demand	Flows	Dea.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/t
SouthE	East: South	Road										
21a	L1	1037	2.2	0.289	4.7	LOS A	0.0	0.0	0.00	0.56	0.00	54.1
23	R2	50	2.2	0.289	5.6	LOSA	0.0	0.0	0.00	0.56	0.00	53.9
Approa	ach	1087	2.2	0.289	4.7	NA	0.0	0.0	0.00	0.56	0.00	54.1
NorthE	ast: Impala	Road										
24	L2	56	2.2	12.759	5393.2	LOS F	65.3	466.0	1.00	1.41	2.69	0.6
26a	R1	76	2.2	12.759	5428.8	LOSF	65.3	466.0	1.00	1.41	2.69	0.6
Approa	ich	132	2.2	12.759	5413.7	LOS F	65.3	466.0	1.00	1.41	2.69	0.6
West:	South Road											
10a	L1	252	2.2	0.560	5.7	LOSA	4.5	32.4	0.24	0.52	0.24	52.9
12a	R1	1631	2.2	0.560	4.9	LOSA	4.7	33.3	0.24	0.51	0.24	53.5
Approa	ach	1883	2.2	0.560	5.0	NA	4.7	33.3	0.24	0.51	0.24	53.4
All Veh	icles	3102	2.2	12.759	235.1	NA	65.3	466.0	0.19	0.57	0.26	11.8

Site Level of Service (LOS) Method: Delay (SIDRA), Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA: Intersection LOS and Major Road Approach LOS values are Not Applicable for two-way sign control since the average delay is not a good LOS measure due to zero delays associated with major road movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

#### MOVEMENT SUMMARY



### Site: 4 [Western Service Road and Wendy Road - Intersection 4 - AM Peak]

Western Service Road and Wendy Road - Intersection 4 Site Category: (None) Stop (Two-Way)

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total	HV	Satn	Delay	Service	Vehicles	Distance	Queued	Stop Rate	Cycles	Speed
		veh/h	%	v/c	sec		veh	m				km/h
South:	Western Se	ervice Road										
1	L2	89	2.3	0.330	5.6	LOSA	0.0	0.0	0.00	0.08	0.00	57.5
2	T1	541	2.3	0.330	0.0	LOSA	0.0	0.0	0.00	0.08	0.00	59.2
Approa	ach	630	2.3	0.330	8.0	NA	0.0	0.0	0.00	0.08	0.00	58.9
North:	Western Se	rvice Road										
8	T1	414	2.3	0.243	0.4	LOS A	0.4	2.7	0.11	0.04	0.11	59.1
9	R2	24	2.3	0.243	9.4	LOSA	0.4	2.7	0.11	0.04	0.11	56.8
Approa	ach	438	2.3	0.243	0.9	NA	0.4	2.7	0.11	0.04	0.11	59.0
West:	Wendy Roa											
10	L2	67	2.3	0.251	11.8	LOS B	0.9	6.6	0.66	1.02	0.73	48.0
12	R2	50	2.3	0.251	18.9	LOS C	0.9	6.6	0.66	1.02	0.73	47.5
Approa	ach	117	2.3	0.251	14.8	LOS B	0.9	6.6	0.66	1.02	0.73	47.8
All Veh	nicles	1185	2.3	0.330	2.2	NA	0.9	6.6	0.10	0.16	0.11	57.6

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA: Intersection LOS and Major Road Approach LOS values are Not Applicable for two-way sign control since the average delay is not a good LOS measure due to zero delays associated with major road movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akcelik M3D).



### Site: 4 [Western Service Road and Wendy Road - Intersection 4 - Midday Peak]

Western Service Road and Wendy Road - Intersection 4 Site Category: (None) Stop (Two-Way)

Mov	Tum	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/t
South:	Western Se	ervice Road	1000					1,700				7,000
1	L2	28	2.3	0.108	5.6	LOS A	0.0	0.0	0.00	0.08	0.00	57.5
2	T1	178	2.3	0.108	0.0	LOS A	0.0	0.0	0.00	0.08	0.00	59.2
Approa	ach	206	2.3	0.108	0.8	NA	0.0	0.0	0.00	0.08	0.00	59.0
North:	Western Se	rvice Road										
8	T1	199	2.3	0.136	0.2	LOSA	0.3	2.4	0.14	0.11	0.14	58.4
9	R2	46	2.3	0.136	6.2	LOSA	0.3	2.4	0.14	0.11	0.14	56.2
Approa	ach	245	2.3	0.136	1.3	NA	0.3	2.4	0.14	0.11	0.14	58.0
West:	Wendy Roa	d										
10	L2	33	2.3	0.075	8.8	LOSA	0.3	1.9	0.34	0.90	0.34	51.2
12	R2	34	2.3	0.075	10.0	LOS A	0.3	1.9	0.34	0.90	0.34	50.7
Approa	ach	67	2.3	0.075	9.4	LOS A	0.3	1.9	0.34	0.90	0.34	50.9
All Veh	nicles	518	2.3	0.136	2.2	NA	0.3	2.4	0.11	0.20	0.11	57.3

Site Level of Service (LOS) Method: Delay (SIDRA), Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA: Intersection LOS and Major Road Approach LOS values are Not Applicable for two-way sign control since the average delay is not a good LOS measure due to zero delays associated with major road movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

#### MOVEMENT SUMMARY



# Site: 4 [Western Service Road and Wendy Road - Intersection 4 - PM Peak]

Western Service Road and Wendy Road - Intersection 4 Site Category: (None) Stop (Two-Way)

Mov	Turn	Demand	Flows	Deq.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/t
South:	Western Se	ervice Road										
1	L2	52	2.3	0.151	5.6	LOS A	0.0	0.0	0.00	0.11	0.00	57.3
2	T1	237	1.3	0.151	0.0	LOSA	0.0	0.0	0.00	0.11	0.00	59.0
Appro	ach	289	1.5	0.151	1.0	NA	0.0	0.0	0.00	0.11	0.00	58.7
North:	Western Se	rvice Road										
8	T1	429	2.3	0.272	0.3	LOSA	0.6	4.3	0.14	0.08	0.14	58.7
9	R2	64	2.3	0.272	6.8	LOSA	0.6	4.3	0.14	0.08	0.14	56.4
Аррго	ach	493	2.3	0.272	1.1	NA	0.6	4.3	0.14	0.08	0.14	58.4
West:	Wendy Roa	d										
10	L2	45	2.3	0.128	9.1	LOSA	0.4	3.2	0.43	0.93	0.43	50.0
12	R2	41	2.3	0.128	13.5	LOS B	0.4	3.2	0.43	0.93	0.43	49.6
Appro	ach	86	2.3	0.128	11.2	LOS B	0.4	3.2	0.43	0.93	0.43	49.8
All Vel	nicles	868	2.0	0.272	2.1	NA	0.6	4.3	0.12	0.17	0.12	57.5

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA: Intersection LOS and Major Road Approach LOS values are Not Applicable for two-way sign control since the average delay is not a good LOS measure due to zero delays associated with major road movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).



# Site: 5 [Western Service Road and Carnation Street - Intersection 5 - AM Peak]

Western Service Road and Carnation Street - Intersection 5 Site Category: (None)

Stop (Two-Way)

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total	HV	Satn	Delay	Service	Vehicles	Distance	Queued	Stop Rate	Cycles	Speed
		veh/h	%	v/c	sec		veh	m				km/h
South:	Western Se	ervice Road										
1a	L1	51	0.9	0.354	5.0	LOS A	0.0	0.0	0.00	0.04	0.00	57.5
2	T1	635	0.9	0.354	0.0	LOSA	0.0	0.0	0.00	0.04	0.00	59.5
Approa	ach	686	0.9	0.354	0.4	NA	0.0	0.0	0.00	0.04	0.00	59.4
North:	Western Se	ervice Road										
8	T1	488	0.9	0.253	0.0	LOS A	0.0	0.1	0.00	0.00	0.00	60.0
9b	R3	- 1	0.9	0.253	10.7	LOS B	0.0	0.1	0.00	0.00	0.00	57.9
Approa	ach	489	0.9	0.253	0.0	NA	0.0	0.1	0.00	0.00	0.00	60.0
NorthV	Vest: Carna	tion Street										
27b	L3	119	0.9	0.179	13.2	LOS B	0.7	4.8	0.59	1.00	0.59	49.4
29a	R1	61	0.9	0.242	21.7	LOS C	0.8	5.5	0.83	1.03	0.91	44.0
Approa	ach	180	0.9	0.242	16.1	LOS C	0.8	5.5	0.67	1.01	0.70	47.5
All Veh	nicles	1355	0.9	0.354	2.4	NA	0.8	5.5	0.09	0.16	0.09	57.6

Site Level of Service (LOS) Method: Delay (SIDRA), Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA: Intersection LOS and Major Road Approach LOS values are Not Applicable for two-way sign control since the average delay is not a good LOS measure due to zero delays associated with major road movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akcelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

#### MOVEMENT SUMMARY



Stop (Two-Way)

# site: 5 [Western Service Road and Carnation Street - Intersection 5 - Midday Peak]

Western Service Road and Carnation Street - Intersection 5 Site Category: (None)

Mov	Turn	Demand	Flows	Deg	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/h
South:	Western Se		/0	- 10	300		, Ton					Killin
1a	L1	32	0.9	0.125	4.6	LOS A	0.0	0.0	0.00	0.07	0.00	57.6
2	T1	209	0.9	0.125	0.0	LOS A	0.0	0.0	0.00	0.07	0.00	59.4
Approa	nch	241	0.9	0.125	0.6	NA	0.0	0.0	0.00	0.07	0.00	59.1
North:	Western Se	rvice Road										
8	T1	168	0.9	0.087	0.0	LOS A	0.0	0.1	0.01	0.00	0.01	59.9
9b	R3	1	0.9	0.087	7.0	LOS A	0.0	0.1	0.01	0.00	0.01	57.9
Approa	ich	169	0.9	0.087	0.0	NA	0.0	0.1	0.01	0.00	0.01	59.9
NorthV	Vest: Carna	tion Street										
27b	L3	24	0.9	0.021	9.8	LOS A	0.1	0.6	0.31	0.85	0.31	51.3
29a	R1	19	0.9	0.025	9.6	LOS A	0.1	0.6	0.40	0.93	0.40	50.9
Approa	ich	43	0.9	0.025	9.7	LOSA	0.1	0.6	0.35	0.89	0.35	51.2
All Veh	icles	453	0.9	0.125	1.3	NA	0.1	0.6	0.03	0.12	0.03	58.6

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA: Intersection LOS and Major Road Approach LOS values are Not Applicable for two-way sign control since the average delay is not a good LOS measure due to zero delays associated with major road movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akcelik M3D).



## Site: 5 [Western Service Road and Carnation Street - Intersection 5 - PM Peak ]

Western Service Road and Carnation Street - Intersection 5

Site Category: (None) Stop (Two-Way)

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total	HV	Satn	Delay	Service	Vehicles	Distance	Queued	Stop Rate	Cycles	Speed
South	Western Se	veh/h ervice Road	%	v/c	sec		veh	m				km/
1a	L1	53	0.9	0.156	5.0	LOSA	0.0	0.0	0.00	0.10	0.00	57.
2	T1	249	0.9	0.156	0.0	LOSA	0.0	0.0	0.00	0.10	0.00	59.
Approa	ich	302	0.9	0.156	0.9	NA	0.0	0.0	0.00	0.10	0.00	58.
North:	Western Se	rvice Road										
8	T1	501	0.9	0.304	0.2	LOS A	0.5	3.8	0.11	0.07	0.11	58.
9b	R3	54	0.9	0.304	7.7	LOS A	0.5	3.8	0.11	0.07	0.11	56.
Approa	ich	555	0.9	0.304	0.9	NA	0.5	3.8	0.11	0.07	0.11	58.
NorthV	Vest: Carna	tion Street										
27b	L3	20	0.9	0.018	10.0	LOS A	0.1	0.5	0.34	0.85	0.34	51.
29a	R1	26	0.9	0.062	14.0	LOS B	0.2	1.3	0.65	1.02	0.65	48.3
Approa	ich	46	0.9	0.062	12.3	LOS B	0.2	1.3	0.51	0.95	0.51	49.
All Veh	icles	903	0.9	0.304	1.5	NA	0.5	3.8	0.10	0.12	0.10	58.

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA: Intersection LOS and Major Road Approach LOS values are Not Applicable for two-way sign control since the average delay is not a good LOS measure due to zero delays associated with major road movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

#### MOVEMENT SUMMARY



# Site: 6 [Western Service Road and Harrowdene Office Park - Intersection 6 - AM Peak ]

Western Service Road and Harrowdene Office Park - Intersection 6 Site Category: (None) Roundabout

Mov	Turn	Demand	Flows	Deg	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total	HV	Satn	Delay	Service	Vehicles	Distance	Queued	Stop Rate	Cycles	Speed
		veh/h	%	v/c	sec		veh	m	That facilities	100000000000000000000000000000000000000		km/h
South:	Western Se	ervice Road										
1	L2	211	2.0	0.240	5.9	LOS A	1.3	8.9	0.51	0.61	0.51	54.5
2	T1	559	2.0	0.457	5.4	LOSA	3.1	21.9	0.56	0.53	0.56	55.4
Approa	ach	769	2.0	0.457	5.6	LOSA	3.1	21.9	0.55	0.55	0.55	55.1
North:	Western Se	rvice Road										
8	T1	542	2.0	0.511	3.6	LOS A	5.1	36.0	0.04	0.48	0.04	56.5
9	R2	317	2.0	0.511	9.2	LOS A	5.1	36.0	0.04	0.48	0.04	56.9
Approa	ach	859	2.0	0.511	5.6	LOS A	5.1	36.0	0.04	0.48	0.04	56.7
West:	Harrowdene	Office Park	Access									
10	L2	5	2.0	0.005	5.8	LOS A	0.0	0.2	0.61	0.51	0.61	54.1
12	R2	2	2.0	0.003	12.4	LOS B	0.0	0.1	0.62	0.60	0.62	51.9
Approa	ach	7	2.0	0.005	7.7	LOSA	0.0	0.2	0.62	0.53	0.62	53.5
All Veh	nicles	1635	2.0	0.511	5.6	LOSA	5.1	36.0	0.28	0.51	0.28	55.9

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Roundabout LOS Method: SIDRA Roundabout LOS.

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

Roundabout Capacity Model: SIDRA Standard.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

Site: 6 [Western Service Road and Harrowdene Office Park - Intersection 6 - Midday Peak ]

Western Service Road and Harrowdene Office Park - Intersection 6 Site Category: (None)

Roundabout

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Saln v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/h
South:	Western Se											
1	L2	23	2.0	0.025	4.2	LOS A	0.1	0.8	0.25	0.43	0.25	55.5
2	T1	201	2.0	0.139	3.9	LOS A	0.7	5.0	0.22	0.37	0.22	57.2
Appro	ach	224	2.0	0.139	3.9	LOSA	0.7	5.0	0.23	0.37	0.23	57.1
North:	Western Se	rvice Road										
8	T1	241	2.0	0.224	3.7	LOSA	1.3	9.6	0.13	0.44	0.13	56.6
9	R2	88	2.0	0.224	9.3	LOSA	1.3	9.6	0.13	0.44	0.13	56.9
Appro	ach	329	2.0	0.224	5.2	LOSA	1.3	9.6	0.13	0.44	0.13	56.7
West:	Harrowdene	Office Park	Access									
10	L2	118	2.0	0.091	4.4	LOSA	0.5	3.3	0.35	0.47	0.35	55.1
12	R2	25	2.0	0.031	10.7	LOS B	0.1	1.0	0.39	0.62	0.39	52.9
Appro	ach	143	2.0	0.091	5.5	LOS A	0.5	3.3	0.35	0.50	0.35	54.7
All Vel	nicles	696	2.0	0.224	4.8	LOSA	1.3	9.6	0.21	0.43	0.21	56.4

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Roundabout LOS Method: SIDRA Roundabout LOS.

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

Roundabout Capacity Model: SIDRA Standard.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akcelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

### MOVEMENT SUMMARY



# Site: 6 [Western Service Road and Harrowdene Office Park - Intersection 6 - PM Peak ]

Western Service Road and Harrowdene Office Park - Intersection 6 Site Category: (None) Roundabout

Mov	Tum	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/h
South:	Western Se	ervice Road										
1	L2	24	2.0	0.025	4.0	LOS A	0.1	0.8	0.21	0.42	0.21	55.7
2	T1	278	2.0	0.183	3.8	LOSA	1.0	7.1	0.19	0.35	0.19	57.4
Аррго	ach	302	2.0	0.183	3.8	LOSA	1.0	7.1	0.19	0.36	0.19	57.3
North:	Western Se	rvice Road										
8	T1	402	2.0	0.332	3.8	LOSA	2.3	16.1	0.23	0.40	0.23	56.7
9	R2	60	2.0	0.332	9.5	LOSA	2.3	16.1	0.23	0.40	0.23	57.0
Appro	ach	462	2.0	0.332	4.6	LOS A	2.3	16.1	0.23	0.40	0.23	56.7
West:	Harrowdene	Office Park	Access									
10	L2	124	2.0	0.101	4.7	LOSA	0.5	3.7	0.41	0.51	0.41	54.9
12	R2	54	2.0	0.057	10.8	LOS B	0.3	1.9	0.43	0.64	0.43	52.7
Appro	ach	178	2.0	0.101	6.5	LOS A	0.5	3.7	0.41	0.55	0.41	54.2
All Vel	nicles	942	2.0	0.332	4.7	LOSA	2.3	16.1	0.26	0.42	0.26	56.4

Site Level of Service (LOS) Method: Delay (SIDRA), Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Roundabout LOS Method: SIDRA Roundabout LOS.

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

Roundabout Capacity Model: SIDRA Standard.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akcelik M3D).

Site: 7 [Western Service Road and The woodlands Access - Intersection 7 - AM Peak]

Western Service Road and The woodlands Access - Intersection 7 Site Category: (None)

Roundabout

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/
South:	Western Se	ervice Road										
1	L2	187	2.0	0.503	5.8	LOS A	3.8	27.0	0.59	0.61	0.59	53.
2	T1	391	2.0	0.503	6.0	LOS A	3.8	27.0	0.59	0.61	0.59	54.
Approa	ich	578	2.0	0.503	5.9	LOS A	3.8	27.0	0.59	0.61	0.59	53.
North:	Western Se	rvice Road										
8	T1	722	2.0	0.618	4.4	LOS A	7.1	50.2	0.27	0.45	0.27	54.
9	R2	259	2.0	0.618	9.0	LOSA	7.1	50.2	0.27	0.45	0.27	54.
Approa	ach	981	2.0	0.618	5.6	LOS A	7.1	50.2	0.27	0.45	0.27	54.
West:	The woodla	nds Access										
10	L2	46	2.0	0.057	5.8	LOSA	0.3	2.4	0.53	0.60	0.53	52.
12	R2	32	2.0	0.057	10.2	LOS B	0.3	2.4	0.52	0.61	0.52	53.3
Approa	ach	78	2.0	0.057	7.6	LOS A	0.3	2.4	0.52	0.60	0.52	52.
All Veh	icles	1637	2.0	0.618	5.8	LOSA	7.1	50.2	0.39	0.52	0.39	54.3

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Roundabout LOS Method: SIDRA Roundabout LOS

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

Roundabout Capacity Model: SIDRA Standard.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

#### MOVEMENT SUMMARY



# Site: 7 [Western Service Road and The woodlands Access - Intersection 7 - Midday Peak ]

Western Service Road and The woodlands Access - Intersection 7 Site Category: (None)

Roundabout

Mov	Tum	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total	HV	Satn	Delay	Service	Vehicles	Distance	Queued	Stop Rate	Cycles	Speed
0	101-1	veh/h	%	v/c	sec		veh	m				km/t
South:	Service and Company	ervice Road										
1	L2	41	2.0	0.251	4.5	LOSA	1.5	10.4	0.30	0.44	0.30	54.1
2	T1	291	2.0	0.251	4.7	LOS A	1.5	10.4	0.30	0.44	0.30	55.4
Approa	ach	332	2.0	0.251	4.7	LOSA	1.5	10.4	0.30	0.44	0.30	55.3
North:	Western Se	rvice Road										
8	T1	359	2.0	0.304	4.3	LOS A	2.1	14.9	0.16	0.46	0.16	55.3
9	R2	110	2.0	0.304	8.9	LOS A	2.1	14.9	0.16	0.46	0.16	55.2
Approa	ach	469	2.0	0.304	5.3	LOSA	2.1	14.9	0.16	0.46	0.16	55.3
West:	The woodla	nds Access										
10	L2	107	2.0	0.092	5.3	LOSA	0.5	3.6	0.43	0.57	0.43	53.1
12	R2	30	2.0	0.092	9.8	LOSA	0.5	3.6	0.43	0.57	0.43	54.4
Approa	ach	137	2.0	0.092	6.3	LOSA	0.5	3.6	0.43	0.57	0.43	53.4
All Veh	icles	938	2.0	0.304	5.2	LOSA	2.1	14.9	0.25	0.47	0.25	55.0

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Roundabout LOS Method: SIDRA Roundabout LOS.

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

Roundabout Capacity Model: SIDRA Standard.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

Site: 7 [Western Service Road and The woodlands Access - Intersection 7 - PM Peak]

Western Service Road and The woodlands Access - Intersection 7 Site Category: (None)

Roundabout

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/l
South:	Western Se	ervice Road										
1	L2	32	2.0	0.216	4.1	LOS A	1.3	9.2	0.20	0.41	0.20	54.6
2	T1	279	2.0	0.216	4.4	LOSA	1.3	9.2	0.20	0.41	0.20	55.9
Appro	ach	311	2.0	0.216	4.3	LOS A	1.3	9.2	0.20	0.41	0.20	55.8
North:	Western Se	rvice Road										
8	T1	295	2.0	0.273	4.9	LOSA	1.7	12.4	0.37	0.50	0.37	54.6
9	R2	51	2.0	0.273	9.5	LOSA	1.7	12.4	0.37	0.50	0.37	54.6
Appro	ach	346	2.0	0.273	5.6	LOSA	1.7	12.4	0.37	0.50	0.37	54.6
West:	The woodla	nds Access										
10	L2	241	2.0	0.252	5.5	LOSA	1.5	10.8	0.45	0.61	0.45	52.6
12	R2	142	2.0	0.252	10.0	LOSA	1.5	10.8	0.46	0.62	0.46	53.7
Appro	ach	383	2.0	0.252	7.1	LOSA	1.5	10.8	0.45	0.61	0.45	53.0
All Veh	nicles	1040	2.0	0.273	5.8	LOSA	1.7	12.4	0.35	0.51	0.35	54.3

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Roundabout LOS Method: SIDRA Roundabout LOS.

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

Roundabout Capacity Model: SIDRA Standard.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

#### MOVEMENT SUMMARY

# Site: 8 [Woodlands Drive and Western Service Road - Intersection 8 - AM Peak]

Woodlands Drive and Western Service Road - Intersection 8

Site Category: (None)
Signals - Fixed Time Isolated Cycle Time = 150 seconds (Site Practical Cycle Time)
Variable Sequence Analysis applied. The results are given for the selected output sequence.

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/l
South:	: Road West	ern Service F	Road									
1	L2	115	1.4	1.126	147.8	LOS F	21.6	153.0	1.00	1.11	1.67	16.7
2	T1	9	1.4	1.126	142.3	LOS F	21.6	153.0	1.00	1.11	1.67	16.9
3	R2	345	1.4	1.126	146.7	LOS F	29.4	208.2	1.00	1.11	1.65	16.8
Appro	ach	469	1.4	1.126	146.9	LOS F	29.4	208.2	1.00	1.11	1.65	16.8
East \	Woodlands I	Orive										
4	L2	962	1.4	1.105	120.3	LOS F	105.0	744.1	1.00	1.12	1.47	19.6
5	T1	1248	1.4	0.736	35.5	LOS D	39.2	277.5	0.89	0.80	0.89	37.9
6	R2	28	1.4	0.736	43.1	LOS D	36.2	256.3	0.90	0.81	0.90	36.5
Appro	ach	2238	1.4	1.105	72.0	LOS E	105.0	744.1	0.93	0.94	1.14	27.0
North:	Jessica CI											
7	L2	13	1.4	0.228	68.7	LOS E	3.8	27.1	0.93	0.72	0.93	28.9
8	T1	45	1.4	0.228	63.1	LOSE	3.8	27.1	0.93	0.72	0.93	29.3
9	R2	14	1.4	0.190	85.0	LOSF	1.1	7.4	1.00	0.69	1.00	24.9
Appro	ach	72	1.4	0.228	68.4	LOS E	3.8	27.1	0.95	0.72	0.95	28.2
West:	Woodlands	Drive										
10	L2	59	1.4	0.741	75.9	LOS E	13.8	97.6	1.00	0.87	1.07	27.1
11	T1	511	1.4	0.741	70.3	LOS E	14.0	99.0	1.00	0.87	1.07	27.8
12	R2	174	1.4	1.092	135.8	LOS F	17.9	126.9	1.00	1.06	1.62	17.8
Appro	ach	744	1.4	1.092	86.0	LOS F	17.9	126.9	1.00	0.91	1.20	24.5
All Vel	hicles	3523	1.4	1.126	84.9	LOS F	105.0	744.1	0.96	0.95	1.21	24.5

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements. SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akcelik M3D).

#### Site: 8 [Woodlands Drive and Western Service Road - Intersection 8 - Midday Peak]

Woodlands Drive and Western Service Road - Intersection 8 Site Category: (None)

Signals - Fixed Time Isolated Cycle Time = 90 seconds (Site Practical Cycle Time)
Variable Sequence Analysis applied. The results are given for the selected output sequence.

Mov	Tum	Demand		Deg	Average	Level of	95% Back		Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/t
South:	Road West	ern Service F	Road									
1	L2	92	1.4	0.884	58.0	LOSE	10.0	71.0	1.00	0.98	1.38	30.3
2	T1	6	1.4	0.884	52.4	LOS D	10.0	71.0	1.00	0.98	1.38	30.8
3	R2	442	1.4	0.884	54.4	LOS D	17.3	122.8	1.00	0.97	1.31	31.3
Appro	ach	540	1.4	0.884	55.0	LOS E	17.3	122.8	1.00	0.97	1.33	31.
East: \	Woodlands [	Orive										
4	L2	476	1.4	0.896	50.8	LOS D	24.3	171.9	1.00	0.98	1.27	32.2
5	T1	687	1.4	0.686	32.2	LOSC	15.2	107.4	0.95	0.82	0.96	39.2
6	R2	20	1.4	0.686	39.2	LOS D	13.2	93.8	0.96	0.83	0.98	37.9
Appro	ach	1183	1.4	0.896	39.8	LOS D	24.3	171.9	0.97	0.89	1.09	36.0
North:	Jessica CI											
7	L2	27	1.4	0.122	40.6	LOS D	1.4	10.3	0.88	0.70	0.88	36.0
8	T1	11	1.4	0.122	35.0	LOS D	1.4	10.3	0.88	0.70	0.88	36.6
9	R2	18	1.4	0.147	50.9	LOS D	0.8	5.6	0.97	0.69	0.97	32.5
Appro	ach	56	1.4	0.147	42.8	LOS D	1.4	10.3	0.91	0.70	0.91	34.9
West:	Woodlands	Drive										
10	L2	21	1.4	0.137	45.8	LOS D	1.2	8.2	0.93	0.70	0.93	34.1
11	T1	66	1.4	0.137	40.2	LOS D	1.2	8.5	0.93	0.68	0.93	36.0
12	R2	55	1.4	0.449	52.5	LOS D	2.5	17.8	1.00	0.75	1.00	31.7
Appro	ach	142	1.4	0.449	45.8	LOS D	2.5	17.8	0.96	0.71	0.96	34.0
All Vel	hicles	1921	1.4	0.896	44.6	LOS D	24.3	171.9	0.98	0.89	1.14	34.3

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

#### MOVEMENT SUMMARY

#### Site: 8 [Woodlands Drive and Western Service Road - Intersection 8 - PM Peak]

Woodlands Drive and Western Service Road - Intersection 8

Site Category: (None)
Signals - Fixed Time Isolated Cycle Time = 90 seconds (Site Practical Cycle Time)
Variable Sequence Analysis applied. The results are given for the selected output sequence.

Mov	Turn	Demand		Deg.	Average	Level of	95% Back		Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/t
South:	Road West	ern Service I	Road									
1	L2	85	1.4	0.726	47.2	LOS D	9.3	66.0	1.00	0.87	1.11	33.3
2	T1	6	1.4	0.726	41.6	LOS D	9.3	66.0	1.00	0.87	1.11	33.9
3	R2	443	1.4	0.726	42.8	LOS D	13.8	98.1	0.98	0.87	1.06	34.7
Appro	ach	534	1.4	0.726	43.5	LOS D	13.8	98.1	0.99	0.87	1.07	34.5
East: \	Woodlands I	Orive										
4	L2	356	1.4	0.792	44.1	LOS D	16.0	113.3	1.00	0.91	1.13	34.2
5	T1	652	1.4	0.724	42.9	LOS D	16.1	114.1	0.98	0.88	1.34	35.2
6	R2	6	1.4	0.724	56.7	LOSE	16.1	114.1	0.98	0.90	1.68	32.2
Appro	ach	1014	1.4	0.792	43.4	LOS D	16.1	114.1	0.98	0.89	1.27	34.8
North:	Jessica CI											
7	L2	16	1.4	0.069	39.1	LOS D	0.9	6.0	0.86	0.68	0.86	36.5
8	T1	7	1.4	0.069	33.6	LOSC	0.9	6.0	0.86	0.68	0.86	37.2
9	R2	11	1.4	0.090	50.4	LOS D	0.5	3.4	0.97	0.67	0.97	32.6
Appro	ach	34	1.4	0.090	41.6	LOS D	0.9	6.0	0.90	0.68	0.90	35.3
West:	Woodlands	Drive										
10	L2	5	1.4	0.853	49.3	LOS D	17.6	124.8	1.00	0.99	1.22	34.3
11	T1	1088	1.4	0.853	43.8	LOS D	17.6	124.9	1.00	0.99	1.22	34.9
12	R2	59	1.4	0.481	52.6	LOS D	2.7	19.1	1.00	0.75	1.00	31.7
Appro	ach	1152	1.4	0.853	44.2	LOS D	17.6	124.9	1.00	0.98	1.21	34.7
All Vel	hicles	2734	1.4	0.853	43.8	LOS D	17.6	124.9	0.99	0.92	1.20	34.7

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab). Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay. Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).



### Site: 9 [Woodlands Drive and Lincoln Street - Intersection 9 - AM Peak ]

Woodlands Drive and Lincoln Street - Intersection 9 Site Category: (None) Stop (Two-Way)

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back (	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/h
East: V	oodlands Di	rive										
5	T1	1188	1.2	0.309	0.0	LOSA	0.0	0.0	0.00	0.00	0.00	59.9
6	R2	119	1.2	0.132	7.8	LOS A	0.5	3.8	0.49	0.71	0.49	51.6
Approa	ch	1307	1.2	0.309	0.7	NA	0.5	3.8	0.04	0.06	0.04	59.1
North:	Lincoln Stree	t										
7	L2	339	1.2	11.851	4912.2	LOSF	212.9	1505.5	1.00	2.95	6.91	0.7
9	R2	277	1.2	11.851	4926.3	LOS F	212.9	1505.5	1.00	2.95	6.91	0.7
Approa	ch	616	1.2	11.851	4918.5	LOS F	212.9	1505.5	1.00	2.95	6.91	0.7
West: \	Voodlands D	rivead										
10	L2	34	1.2	0.117	5.6	LOSA	0.0	0.0	0.00	0.09	0.00	57.5
11	T1	418	1.2	0.117	0.0	LOSA	0.0	0.0	0.00	0.04	0.00	59.6
Approa	ch	452	1.2	0.117	0.4	NA	0.0	0:0	0.00	0.04	0.00	59.4
All Veh	icles	2375	1.2	11.851	1276.2	NA	212.9	1505.5	0.28	0.81	1.82	2.7

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA: Intersection LOS and Major Road Approach LOS values are Not Applicable for two-way sign control since the average delay is not a good LOS measure due to zero delays associated with major road movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

#### MOVEMENT SUMMARY



#### Site: 9 [Woodlands Drive and Lincoln Street - Intersection 9 - Midday Peak ]

Woodlands Drive and Lincoln Street - Intersection 9 Site Category: (None) Stop (Two-Way)

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/h
East: W	/oodlands Di			110	300		2011					KIIIII
5	T1	648	1.2	0.169	0.0	LOSA	0.0	0.0	0.00	0.00	0.00	60.0
6	R2	140	1.2	0.220	10.2	LOS B	0.9	6.1	0.62	0.84	0.63	49.9
Approa	ch	788	1.2	0.220	1.8	NA	0.9	6.1	0.11	0.15	0.11	57.9
North: I	Lincoln Stree	t										
7	L2	157	1.2	1.269	172.9	LOS F	24.3	171.9	1.00	2.67	5.62	14.0
9	R2	61	1.2	1.269	247.8	LOS F	24.3	171.9	1.00	2.67	5.62	14.0
Approa	ch	218	1.2	1.269	193.9	LOS F	24.3	171.9	1.00	2.67	5.62	14.0
West: V	Voodlands D	rivead										
10	L2	46	1.2	0.190	5.6	LOS A	0.0	0.0	0.00	0.08	0.00	57.6
11	T1	686	1.2	0.190	0.0	LOS A	0.0	0.0	0.00	0.03	0.00	59.6
Approa	ch	732	1.2	0.190	0.4	NA	0.0	0.0	0.00	0.04	0.00	59.5
All Vehi	icles	1738	1.2	1.269	25.3	NA	24.3	171.9	0.18	0.42	0.76	41.8

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA: Intersection LOS and Major Road Approach LOS values are Not Applicable for two-way sign control since the average delay is not a good LOS measure due to zero delays associated with major road movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akcelik M3D).



# Site: 9 [Woodlands Drive and Lincoln Street - Intersection 9 - PM Peak]

Woodlands Drive and Lincoln Street - Intersection 9 Site Category: (None) Stop (Two-Way)

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/h
East: V	oodlands Dr	rive	1000	777.00	VECENTAL CONTRACTOR			23541				0.500000
5	T1	568	1.2	0.148	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	60.0
6	R2	130	1.2	0.335	16.3	LOS C	1.4	9.8	0.80	0.97	0.99	46.1
Арргоа	ch	698	1.2	0.335	3.1	NA	1.4	9.8	0.15	0.18	0.18	56.8
North: I	Lincoln Stree	t										
7	L2	185	1.2	2.059	517.2	LOSF	47.0	332.2	1.00	3.42	8.10	6:0
9	R2	51	1.2	2.059	594.1	LOSF	47.0	332.2	1.00	3.42	8.10	6.0
Approa	ch	236	1.2	2.059	533.8	LOSF	47.0	332.2	1.00	3.42	8.10	6.0
West: \	Voodlands D	rive										
10	L2	107	1.2	0.278	5.6	LOSA	0.0	0.0	0.00	0.12	0.00	57.2
11	T1	963	1.2	0.278	0.0	LOSA	0.0	0.0	0.00	0.05	0.00	59.5
Approa	ch	1070	1.2	0.278	0.6	NA	0.0	0.0	0.00	0.06	0.00	59.2
All Veh	icles	2004	1.2	2.059	64.2	NA	47.0	332.2	0.17	0.50	1.02	28.6

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Minor Road Approach LOS values are based on average delay for all vehicle movements.

NA: Intersection LOS and Major Road Approach LOS values are Not Applicable for two-way sign control since the average delay is not a good LOS measure due to zero delays associated with major road movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

#### MOVEMENT SUMMARY

## Site: 10 [Woodlands Drive and Country Club Estate Access - Intersection 10 - AM Peak]

Woodlands Drive and Country Club Estate Access - Intersection 10

Site Category: (None)

Signals - Fixed Time Isolated Cycle Time = 70 seconds (Site Practical Cycle Time)

Variable Sequence Analysis applied. The results are given for the selected output sequence.

Mov	Turn	Demand	Flows	Deg	Average	Level of	95% Back	of Queue	Prop	Effective	Aver No.	Average
ID	100000	Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Slop Rate	Cycles	Speed km/h
South:	RoadNWoo	dlands Drive	ame	0.000	000000000		1500000					30,00,01
1	L2	315	1.2	0.720	22.9	LOS C	13.8	97.6	0.90	0.88	1.11	44.5
2	T1	687	1.2	0.720	21.6	LOSC	14.5	102.2	0.92	0.86	1.03	43.8
3	R2	300	1.2	0.671	32.9	LOS C	9.8	69.0	0.96	0.85	1.00	38.4
Appro	ach	1302	1.2	0.720	24.5	LOS C	14.5	102.2	0.93	0.86	1.04	42.6
East: 1	The Woodlar	nds Access										
4	L2	45	1.2	0.035	7.1	LOS A	0.3	2.0	0.28	0.61	0.28	53.0
5	T1	2	1.2	0.007	26.9	LOSC	0.1	0.4	0.86	0.53	0.86	41.7
6	R2	14	1.2	0.089	39.2	LOS D	0.5	3.3	0.95	0.68	0.95	36.2
Appro	ach	61	1.2	0.089	15.1	LOS B	0.5	3.3	0.45	0.62	0.45	47.5
North:	Woodlands	Drive										
7	L2	80	1.2	0.625	34.7	LOSC	7.3	51.6	0.97	0.82	0.99	39.8
8	T1	349	1.2	0.625	30.0	LOSC	7.3	51.6	0.97	0.82	1.00	40.0
9	R2	118	1.2	0.748	44.0	LOS D	4.4	31.4	1.00	0.88	1.26	34.3
Appro	ach	547	1.2	0.748	33.7	LOS C	7.3	51.6	0.98	0.83	1.06	38.6
West:	Country Clu	b Estate Acc	ess									
10	L2	35	1.2	0.149	18.8	LOS B	1.1	7.9	0.81	0.72	0.81	45.5
11	T1	2	1.2	0.149	13.2	LOS B	1.1	7.9	0.81	0.72	0.81	46.0
12	R2	44	1.2	0.149	29.9	LOSC	1.1	7.9	0.89	0.71	0.89	39.7
Appro	ach	81	1.2	0.149	24.7	LOS C	1.1	7.9	0.85	0.71	0.85	42.2
All Veh	nicles	1991	1.2	0.748	26.7	LOSC	14.5	102.2	0.92	0.84	1.02	41.5

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

#### Site: 10 [Woodlands Drive and Country Club Estate Access - Intersection 10 - Midday Peak]

Woodlands Drive and Country Club Estate Access - Intersection 10 Site Category: (None)

Signals - Fixed Time Isolated Cycle Time = 70 seconds (Site Practical Cycle Time)
Variable Sequence Analysis applied. The results are given for the selected output sequence.

Mov	Turn	Demand		Deg	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/l
South:	RoadNWoo	dlands Drive	eame									
1	L2	107	1.2	0.592	28.4	LOSC	8.3	58.5	0.91	0.83	1.18	42.3
2	T1	477	1.2	0.592	24.6	LOSC	8.7	61.2	0.93	0.80	1.04	42.4
3	R2	100	1.2	0.634	42.4	LOS D	3.6	25.7	1.00	0.82	1.12	34.9
Appro	ach	684	1.2	0.634	27.8	LOS C	8.7	61.2	0.93	0.81	1.07	41.1
East:	The Woodla	nds Access										
4	L2	182	1.2	0.156	8.5	LOS A	1.7	12.2	0.39	0.66	0.39	51.9
5	T1	3	1.2	0.010	27.0	LOSC	0.1	0.6	0.86	0.55	0.86	41.6
6	R2	31	12.0	0.211	40.2	LOS D	1.1	8.2	0.96	0.72	0.96	35.6
Appro	ach	216	2.8	0.211	13.3	LOS B	1.7	12.2	0.48	0.66	0.48	48.6
North:	Woodlands	Drive										
7	L2	30	1.2	0.480	30.0	LOSC	6.8	47.9	0.90	0.75	0.90	42.5
8	T1	423	1.2	0.480	24.8	LOSC	6.8	48.0	0.90	0.75	0.90	42.6
9	R2	42	1.2	0.266	40.2	LOS D	1.4	10.2	0.97	0.73	0.97	35.5
Appro	ach	495	1.2	0.480	26.4	LOS C	6.8	48.0	0.91	0.75	0.91	41.9
West:	Country Clu	b Estate Acc	ess									
10	L2	73	1.2	0.352	32.5	LOSC	3.8	26.9	0.90	0.77	0.90	38.9
11	T1	2	1.2	0.352	26.9	LOSC	3.8	26.9	0.90	0.77	0.90	39.2
12	R2	161	1.2	0.352	33.7	LOSC	3.8	26.9	0.92	0.77	0.92	38.1
Appro	ach	236	1.2	0.352	33.3	LOS C	3.8	26.9	0.91	0.77	0.91	38.3
ΔII Vel	hicles	1631	1.4	0.634	26.3	LOSC	8.7	61.2	0.86	0.77	0.92	41.8

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements. SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

#### MOVEMENT SUMMARY

#### Site: 10 [Woodlands Drive and Country Club Estate Access - Intersection 10 - PM Peak]

Woodlands Drive and Country Club Estate Access - Intersection 10

Site Category: (None)
Signals - Fixed Time Isolated Cycle Time = 70 seconds (Site Practical Cycle Time)
Variable Sequence Analysis applied. The results are given for the selected output sequence.

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/l
South:	RoadNWoo	dlands Drive	ame									
1	L2	48	1.2	0.557	31.3	LOS C	8.2	58.1	0.91	0.81	1.21	41.4
2	T1	515	1.2	0.557	25.3	LOS C	8.4	59.6	0.91	0.79	1.05	42.3
3	R2	42	1.2	0.266	40.2	LOS D	1.4	10.2	0.97	0.73	0.97	35.7
Appro	ach	605	1.2	0.557	26.8	LOS C	8.4	59.6	0.92	0.78	1.06	41.7
East 1	The Woodlan	nds Access										
4	L2	184	1.2	0.150	6.8	LOS A	1.0	7.4	0.27	0.63	0.27	53.2
5	T1	11	1.2	0.036	27.5	LOSC	0.3	2.3	0.87	0.60	0.87	41.4
6	R2	70	1.2	0.444	41.0	LOS D	2.5	17.4	0.99	0.75	0.99	35.5
Appro	ach	265	1.2	0.444	16.7	LOS B	2.5	17.4	0.49	0.66	0.49	46.5
North:	Woodlands	Drive										
7	L2	21	1.2	0.502	29.4	LOS C	7.4	52.5	0.89	0.75	0.89	43.0
8	T1	480	1.2	0.502	24.2	LOS C	7.5	52.8	0.90	0.75	0.90	42.9
9	R2	38	1.2	0.241	40.1	LOS D	1.3	9.2	0.97	0.72	0.97	35.6
Appro	ach	539	1.2	0.502	25.5	LOS C	7.5	52.8	0.90	0.75	0.90	42.3
West:	Country Clu	b Estate Acc	ess									
10	L2	109	1.2	0.533	32.1	LOS C	6.5	45.8	0.93	0.81	0.93	39.0
11	T1	2	1.2	0.533	26.5	LOS C	6.5	45.8	0.93	0.81	0.93	39.4
12	R2	251	1.2	0.533	34.7	LOSC	6.5	45.8	0.95	0.80	0.95	37.7
Appro	ach	362	1.2	0.533	33.9	LOS C	6.5	45.8	0.94	0.80	0.94	38.1
All Veh	nicles	1771	1.2	0.557	26.3	LOS C	8.4	59.6	0.85	0.76	0.90	41.7

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements. SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

#### Site: 11 [Woodlands Drive and Woodlands Office Park Entrance/Pestle Street - Intersection 11 - AM Peak ]

Woodlands Drive and Woodlands Office Park Entrance Road/Pestle Street - Intersection 10 Site Category: (None)
Signals - Fixed Time Isolated Cycle Time = 40 seconds (Site Practical Cycle Time)

Mov	Turn	Demand	Flows	Deg	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/h
South:	Woodlands		70	VIC	300		VCII	-111				KILUTI
1	L2	58	1.2	0.045	6.6	LOS A	0.2	1.3	0.32	0.63	0.32	52.6
2	T1	533	1.2	0.501	6.2	LOS A	6.6	46.8	0.66	0.58	0.66	54.5
3	R2	229	1.2	0.693	21.4	LOSC	4.6	32.8	0.92	0.91	1.13	43.5
Approa	ach	820	1.2	0.693	10.5	LOS B	6.6	46.8	0.71	0.68	0.77	50.8
East: V	Voodlands (	Office Park E	ntrance R	oad								
4	L2	56	1.2	0.078	9.5	LOS A	0.5	3.2	0.57	0.67	0.57	51.2
5	T1	1	1.2	0.003	16.0	LOS B	0.0	0.1	0.87	0.51	0.87	47.6
6	R2	19	1.2	0.065	22.2	LOSC	0.3	2.4	0.89	0.68	0.89	43.4
Approa	ach	76	1.2	0.078	12.8	LOS B	0.5	3.2	0.65	0.67	0.65	48.9
North:	Woodlands	Drive										
7	L2	66	1.2	0.036	5.6	LOSA	0.0	0.0	0.00	0.53	0.00	54.9
8	T1	688	1.2	0.646	6.9	LOS A	9.6	68.1	0.75	0.67	0.75	53.9
9	R2	153	1.2	0.371	15.3	LOS B	2.3	16.0	0.74	0.77	0.74	46.7
Approa	ach	907	1.2	0.646	8.3	LOS A	9.6	68.1	0.69	0.67	0.69	52.6
West:	Pestle Stree	et										
10	L2	8	1.2	0.032	22.0	LOSC	0.2	1.1	0.88	0.65	0.88	43.5
11	T1	1	1.2	0.032	16.5	LOS B	0.2	1.1	0.88	0.65	0.88	44.4
12	R2	9	1.2	0.030	22.0	LOSC	0.2	1.1	0.88	0.65	0.88	43.4
Approa	ach	18	1.2	0.032	21.7	LOS C	0.2	1.1	0.88	0.65	0.88	43.5
All Veh	nicles	1821	1.2	0.693	9.6	LOSA	9.6	68.1	0.70	0.67	0.73	51.5

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

#### MOVEMENT SUMMARY

#### B Site: 11 [Woodlands Drive and Woodlands Office Park Entrance/Pestle Street - Intersection 11 - Midday Peak ]

Woodlands Drive and Woodlands Office Park Entrance Road/Pestle Street - Intersection 10

Site Category: (None)
Signals - Fixed Time Isolated | Cycle Time = 30 seconds (Site Practical Cycle Time)

Mov	Turn	Demand		Deg.	Average	Level of	95% Back		Prop.	Effective	Aver. No.	Average
ID		Total	HV	Satn	Delay	Service	Vehicles	Distance	Queued	Stop Rate	Cycles	Speed
South	Woodlands	veh/h Drive	%	v/c	sec		veh	л				km/l
1	L2	20	1.2	0.018	6.9	LOSA	0.1	0.4	0.42	0.63	0.42	52.3
2	T1	502	1.2	0.649	8.8	LOSA	6.5	46.2	0.86	0.78	0.93	52.
3	R2	72	1.2	0.213	17.3	LOSB	1.0	6.8	0.87	0.74	0.87	45.
Appro	110	594	1.2	0.649	9.8	LOSA	6.5	46.2	0.85	0.77	0.90	51.
Fast \	Mondlands (	Office Park E	ntrance R	nad								
4	L2	61	1.2	0.073	9.2	LOSA	0.4	2.8	0.64	0.68	0.64	51.
5	T1	2	1.2	0.005	10.7	LOSB	0.0	0.2	0.82	0.50	0.82	51.
6	R2	67	1.2	0.176	17.2	LOS B	0.9	6.2	0.86	0.73	0.86	46.
Appro	ach	130	1.2	0.176	13.3	LOS B	0.9	6.2	0.76	0.70	0.76	48.
North:	Woodlands	Drive										
7	L2	56	1.2	0.030	5.6	LOSA	0.0	0.0	0.00	0.53	0.00	54.
8	T1	492	1.2	0.636	8.6	LOSA	6.3	44.6	0.86	0.76	0.91	52.
9	R2	20	1.2	0.060	16.7	LOS B	0.3	1.8	0.84	0.69	0.84	45.
Appro	ach	568	1.2	0.636	8.6	LOSA	6.3	44.6	0.77	0.74	0.82	52.
West:	Pestle Stree	t										
10	L2	25	1.2	0.076	16.8	LOS B	0.4	2.5	0.84	0.68	0.84	46.
11	T1	3	1.2	0.076	11.2	LOS B	0.4	2.5	0.84	0.68	0.84	47.
12	R2	14	1.2	0.035	16.5	LOS B	0.2	1.2	0.83	0.66	0.83	46.
Appro	ach	42	1.2	0.076	16.3	LOS B	0.4	2.5	0.84	0.68	0.84	46.
All Vel	nicles	1334	1.2	0.649	9.8	LOSA	6.5	46.2	0.81	0.74	0.85	51.

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay

Gap-Acceptance Capacity: SIDRA Standard (Akcelik M3D).

#### Site: 11 [Woodlands Drive and Woodlands Office Park Entrance/Pestle Street - Intersection 11 - PM Peak]

Woodlands Drive and Woodlands Office Park Entrance Road/Pestle Street - Intersection 10

Signals - Fixed Time Isolated Cycle Time = 30 seconds (Site Practical Cycle Time)

Mov	Turn	Demand		Deg	Average	Level of	95% Back		Ргор.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/
South:	Woodlands		70	1/0	300		VCII	- 11				KILL
1	L2	11	1.2	0.010	6.9	LOS A	0.0	0.2	0.41	0.62	0.41	52.
2	T1	552	1.2	0.713	10.0	LOSA	7.8	55.2	0.89	0.85	1.03	51.
3	R2	32	1.2	0.114	19.0	LOS B	0.4	3.2	0.91	0.70	0.91	44.
Approa	ach	595	1.2	0.713	10.4	LOS B	7.8	55.2	0.89	0.83	1.02	51.
East: V	Voodlands (	Office Park E	ntrance R	oad								
4	L2	69	1.2	0.090	10.3	LOS B	0.5	3.7	0.71	0.69	0.71	50.
5	T1	1	1.2	0.003	10.6	LOS B	0.0	0.1	0.81	0.48	0.81	51.
6	R2	216	1.2	0.592	18.8	LOS B	3.2	22.8	0.95	0.83	1.05	45.
Approa	ach	286	1.2	0.592	16.7	LOS B	3.2	22.8	0.90	0.80	0.97	46.
North:	Woodlands	Drive										
7	L2	16	1.2	0.009	5.6	LOS A	0.0	0.0	0.00	0.53	0.00	54.
8	T1	606	1.2	0.783	11.9	LOS B	9.6	67.6	0.93	0.94	1.19	50.
9	R2	2	1.2	0.007	17.3	LOS B	0.0	0.2	0.85	0.61	0.85	45.
Approa	ach	624	1.2	0.783	11.8	LOS B	9.6	67.6	0.91	0.93	1.15	50.
West: I	Pestle Stree	t .										
10	L2	48	1.2	0.136	17.0	LOS B	0.6	4.6	0.85	0.71	0.85	46.
11	T1	2	1.2	0.136	11.4	LOS B	0.6	4.6	0.85	0.71	0.85	47.
12	R2	28	1.2	0.070	16.7	LOS B	0.4	2.5	0.84	0.69	0.84	46.
Approa	ach	78	1.2	0.136	16.8	LOS B	0.6	4.6	0.85	0.71	0.85	46.

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akcelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

# MOVEMENT SUMMARY

# Site: 7 [Western Service Road and The woodlands Access - Intersection 7 - AM Peak - After Hours Traffic]

Western Service Road and The woodlands Access - Intersection 7 Site Category: (None) Roundabout

Mov	Turn	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total	HV	Satn	Delay	Service	Vehicles	Distance	Queued	Stop Rate	Cycles	Speed
		veh/h	%	v/c	sec		veh	m				km/r
South:	Western Se	ervice Road										
1	L2	6	2.0	0.022	5.4	LOSA	0.1	0.7	0.12	0.50	0.12	53.2
2	T1	18	2.0	0.022	5.0	LOSA	0.1	0.7	0.12	0.50	0.12	54.0
Approa	ich	24	2.0	0.022	5.1	LOSA	0.1	0.7	0.12	0.50	0.12	53.8
North:	Western Se	rvice Road										
8	T1	34	2.0	0.040	4.8	LOSA	0.2	1.3	0.02	0.60	0.02	53.5
9	R2	25	2.0	0.040	7.6	LOSA	0.2	1.3	0.02	0.60	0.02	53.1
Approa	ich	59	2.0	0.040	6.0	LOS A	0.2	1.3	0.02	0.60	0.02	53.4
West:	The woodla	nds Access										
10	L2	1	2.0	0.001	5.8	LOSA	0.0	0.0	0.09	0.61	0.09	51.8
12	R2	1	2.0	0.001	7.7	LOSA	0.0	0.0	0.09	0.62	0.09	52.3
Approa	ach	2	2.0	0.001	6.8	LOSA	0.0	0.0	0.09	0.61	0.09	52.1
All Veh	icles	85	2.0	0.040	5.7	LOSA	0.2	1.3	0.05	0.57	0.05	53.4

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Roundabout LOS Method: SIDRA Roundabout LOS.

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

Roundabout Capacity Model: SIDRA Standard.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

# Site: 7 [Western Service Road and The woodlands Access - Intersection 7 - PM Peak - After Hours Traffic ]

Western Service Road and The woodlands Access - Intersection 7 Site Category: (None) Roundabout

Mov	Tum	Demand	Flows	Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance	Queued	Stop Rate	Cycles	Speed km/h
South:	Western Se	ervice Road	70	V/C	306		Vell	m				550000
1	L2	1	2.0	0.034	5.3	LOSA	0.2	1.1	0.01	0.51	0.01	53.6
2	T1	49	2.0	0.034	4.8	LOSA	0.2	1.1	0.01	0.51	0.01	54.4
Appro	ach	50	2.0	0.034	4.8	LOS A	0.2	1.1	0.01	0.51	0.01	54.4
North:	Western Se	ervice Road										
8	T1	39	2.0	0.027	4.8	LOS A	0.1	0.9	0.02	0.52	0.02	54.4
9	R2	1	2.0	0.027	7.6	LOSA	0.1	0.9	0.02	0.52	0.02	54.0
Appro	ach	40	2.0	0.027	4.9	LOSA	0.1	0.9	0.02	0.52	0.02	54.4
West:	The woodla	nds Access										
10	L2	1	2.0	0.001	6.0	LOS A	0.0	0.0	0.16	0.59	0.16	51.7
12	R2	1	2.0	0.001	7.8	LOSA	0.0	0.0	0.16	0.60	0.16	52.1
Appro	ach	2	2.0	0.001	6.9	LOS A	0.0	0.0	0.16	0.59	0.16	51.9
All Veh	nicles	92	2.0	0.034	4.9	LOSA	0.2	1.1	0.02	0.51	0.02	54.4

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab). Roundabout LOS Method: SIDRA Roundabout LOS.

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

Roundabout Capacity Model: SIDRA Standard.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akcelik M3D).

HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

### MOVEMENT SUMMARY

## Site: 8 [Woodlands Drive and Western Service Road - Intersection 8 - AM Peak - After Hours]

Woodlands Drive and Western Service Road - Intersection 8

Site Category: (None)

Signals - Fixed Time Isolated Cycle Time = 60 seconds (Site Practical Cycle Time)

Variable Sequence Analysis applied. The results are given for the selected output sequence.

Mov	Turn	Demand	Flows	Deg	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h	HV %	Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/t
South:	Road West	ern Service F	Road		2000000		10.51.51.5					
1	L2	19	1.4	0.134	31.1	LOS C	0.8	5.4	0.93	0.71	1.02	39.1
2	T1	1	1.4	0.134	25.6	LOS C	0.8	5.4	0.93	0.71	1.02	39.8
3	R2	30	1.4	0.134	33.4	LOS C	0.8	5.4	0.94	0.70	0.96	38.1
Appro	ach	50	1.4	0.134	32.4	LOSC	8.0	5.4	0.94	0.71	0.98	38.5
East: \	Noodlands [	Orive										
4	L2	114	1.4	0.286	27.5	LOS C	2.9	20.5	0.88	0.76	0.88	40.5
5	T1	159	1.4	0.202	21.4	LOSC	2.1	14.8	0.86	0.66	0.86	44.4
6	R2	2	1.4	0.202	27.1	LOSC	1.9	13.5	0.86	0.66	0.86	43.5
Appro	ach	275	1.4	0.286	24.0	LOSC	2.9	20.5	0.86	0.71	0.86	42.7
North:	Jessica CI											
7	L2	1	1.4	0.006	27.3	LOSC	0.0	0.3	0.83	0.56	0.83	42.0
8	T1	41	1.4	0.006	21.7	LOSC	0.0	0.3	0.83	0.56	0.83	42.8
9	R2	4	1.4	0.005	32.5	LOSC	0.0	0.2	0.92	0.58	0.92	38.7
Appro	ach	3	1.4	0.006	27.2	LOS C	0.0	0.3	0.86	0.57	0.86	41.1
West:	Woodlands	Drive										
10	L2	1	1.4	0.080	32.2	LOSC	0.5	3.5	0.92	0.64	0.92	40.8
11	T1	53	1.4	0.080	26.7	LOSC	0.5	3.5	0.92	0.64	0.92	41.7
12	R2	7	1.4	0.038	33.1	LOS C	0.2	1.4	0.93	0.65	0.93	38.1
Appro	ach	61	1.4	0.080	27.5	LOS C	0.5	3.5	0.92	0.64	0.92	41.2
All Vel	nicles	389	1.4	0.286	25.6	LOSC	2.9	20.5	0.88	0.70	0.89	41.9

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

SIDRA Standard Delay Model is used: Control Delay includes Geometric Delay.

Gap-Acceptance Capacity: SIDRA Standard (Akcelik M3D).

### Site: 8 [Woodlands Drive and Western Service Road - Intersection 8 - PM Peak - After Hours]

Mov	Turn	Demand		Deg.	Average	Level of	95% Back	of Queue	Prop.	Effective	Aver. No.	Average
ID		Total veh/h		Satn v/c	Delay sec	Service	Vehicles veh	Distance m	Queued	Stop Rate	Cycles	Speed km/h
South:	Road West	ern Service F	Road				100000	7,500				-
1	L2	42	1.4	0.587	46.6	LOS D	2.6	18.3	1.00	0.85	1.52	33.5
2	T1	1	1.4	0.587	41.1	LOS D	2.6	18.3	1.00	0.85	1.52	34.0
3	R2	124	1.4	0.587	44.2	LOS D	3.8	27.2	1.00	0.81	1.14	34.2
Approa	ach	167	1.4	0.587	44.8	LOS D	3.8	27.2	1.00	0.82	1.24	34.0
East: \	Voodlands [	)rive										
4	L2	98	1.4	0.210	29.8	LOS C	2.9	20.4	0.83	0.75	0.83	39.5
5	T1	143	1.4	0.151	23.3	LOSC	2.1	15.0	0.81	0.63	0.81	43.4
6	R2	1	1.4	0.151	28.6	LOS C	2.0	14.1	0.80	0.62	0.80	42.0
Approa	ach	242	1.4	0.210	26.0	LOSC	2.9	20.4	0.81	0.68	0.81	41.
North:	Jessica CI											
7	L2	1	1.4	0.005	29.5	LOS C	0.1	0.4	0.79	0.55	0.79	40.9
8	T1	1	1.4	0.005	24.0	LOSC	0.1	0.4	0.79	0.55	0.79	41.
9	R2	1	1.4	0.006	39.5	LOS D	0.0	0.2	0.92	0.59	0.92	36.
Approa	ach	3	1.4	0.006	31.0	LOSC	0.1	0.4	0.84	0.57	0.84	39.
West:	Woodlands	Drive										
10	L2	1	1.4	0.319	39.7	LOS D	2.6	18.4	0.95	0.73	0.95	37.
11	T1	221	1.4	0.319	34.2	LOSC	2.6	18.5	0.95	0.73	0.95	38.
12	R2	38	1.4	0.194	40.2	LOS D	1.3	9.5	0.95	0.72	0.95	35.
Approa	ich	260	1.4	0.319	35.1	LOS D	2.6	18.5	0.95	0.73	0.95	38.
All Veh	nicles	672	1.4	0.587	34.2	LOSC	3.8	27.2	0.91	0.73	0.97	38.

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Vehicle movement LOS values are based on average delay per movement.

Intersection and Approach LOS values are based on average delay for all vehicle movements.

SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay. Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).



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# Woodmead bulk upgrade pipeline GPR scan

GPR Scan of the underground services along the pipe route
Prepared for

r repared for

Nyeleti – Municipal Services

Prepared by

C Moodley

Reviewed by

C.P Willemse

2020/01/22

Llikuse

# **DOCUMENT CONTROL SHEET**

Nyeleti – Municipal Services **CLIENT:** 

GPR Scan of the underground services along the pipe route PROJECT:

**PROJECT NO.:** 21074

TITLE: GPR Scan of the underground services along the pipe route

Date	Document No.	Prepared by	Reviewed and Approved by
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## INTRODUCTION

Johannesburg Water appointed Nyeleti Consulting – Municipal services to design a 5.2 km pipeline in extents of Marlboro and Woodmead, Johannesburg. Following the initial appointment, Johannesburg water added 1 km of pipeline north of the initial 5.2 km pipeline and a 100 m pipeline close to the Marlboro reservoir area, project no. UR1305B. The project area is located on the North-Eastern side of Johannesburg in Region E. The pipeline route will be from Marlboro to Woodmead and will be constructed predominantly along Western Services Road.

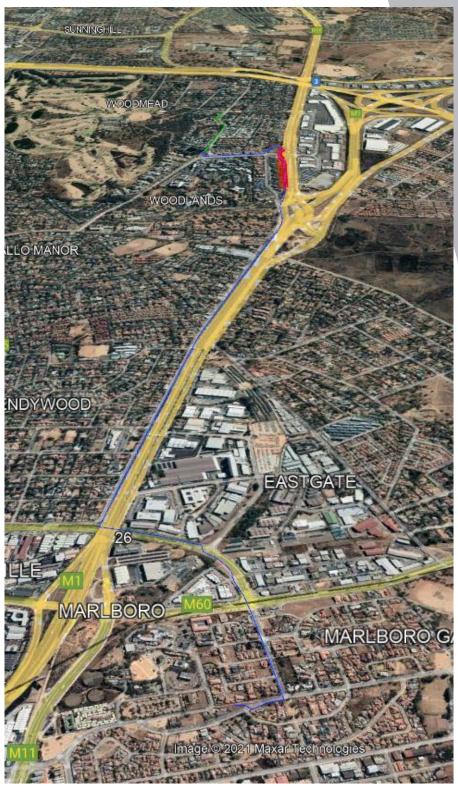


Image 1: This is an indication of the layout of the proposed pipeline and route that was scanned.



## **SCOPE OF WORK**

Nyeleti Consulting - Municipal services as appointed Nyeleti Consulting - Forensic services to conduct a GPR Survey of the pipeline route.

The GPR survey will comprise of'

- · GPR scan of relevant areas.
- Layout plan drawings of findings
- Report with finds

## **EQUIPEMENT**

### **GSSI Duel antenna GPR scanner**



**GSSI utility Scan** 

UtilityScan® DF is GSSI's premium GPR unit for utility locating. It incorporates our innovative digital dual-frequency antenna (300 and 800 MHz) and an easy-to-use touchscreen interface to view shallow and deep targets simultaneously in a single scan. With an operation life of up to eight



hours and a survey speed up to 10 km/h (6.25 mph), data collection is fast and efficient.

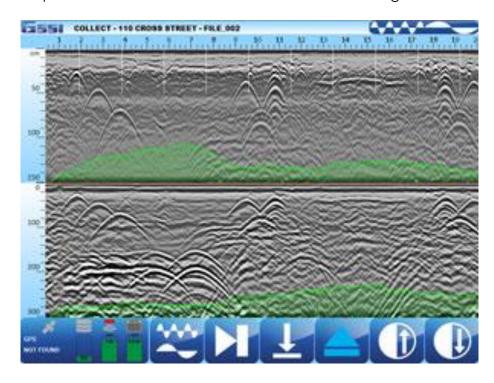
Locate the position and depth of metallic and non-metallic objects, including service utilities such as gas, communications, sewer lines as well as underground storage tanks and PVC pipes.

Typical Uses for UtilityScan DF Include:

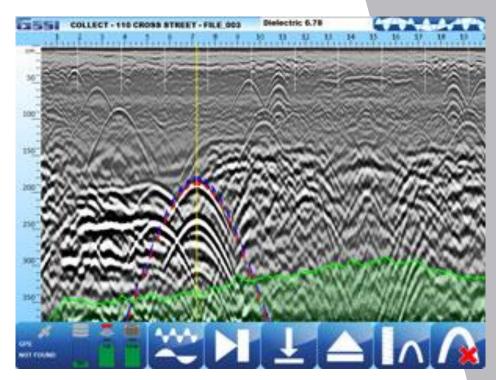
- Utility detection metallic and non-metallic
- Environmental assessment
- Damage prevention
- Geological investigation
- Archaeology
- Forensics
- Road inspection

#### Other Benefits

- Dual-frequency antenna (300 and 800 MHz)
- Specifically designed for Utility industry
- Operates exclusively with the GSSI digital dual-frequency antenna
- Locate metallic and non-metallic utilities real-time
- Simple user interface
- Easy to transport and deploy
- Fast data collection, up to 10 km/h (6.25 mph)
- High definition, full-color touchscreen screen that provides clear images
- 32-bit data quality delivers clear, precise images
- Advanced display modes and signal floor tracking
- Durable components that have been tested in the world's toughest field conditions







**GSSI utility Scan Examples** 



# **FINDINGS**

## 4.1 Sheet 1







The images above shows that there are verious services crossing the path of the pipeline, a AutoCad co-ordinated drawing has been provided.



# 4.2 Sheet 2 & 3







Legend				
● <sub>R.P</sub>	Reference point			
O <sup>0.0</sup>	Position of reading and depth			
U.S	Unknown service detected			
L.E.S	Live electrical service detected			
	service detected			
⊕мн	Manhole			

Nyeleti Engineered to Excel

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lyeleti Consulting -Municipal Services Voodmead GPR Scan Sheet 2 16941-002



Nyeleti Engineered to Excel

INO.	Description	Date

Nyeleti Consulting -Municipal Services Woodmead GPR Scan

Sheet 3	3		
Project number	16941		
Date	14 September, 2021	1694	1-003
Drawn by	C.Moodley		
Checked by	C.P Willemse	Scale	1:100

The images above shows that there are verious services crossing the path of the pipeline, a AutoCad co-ordinated drawing has been provided.



# 4.3 Sheet 4 & 5









The images above shows that there are verious services crossing the path of the pipeline, a AutoCad co-ordinated drawing has been provided.



#### **Sheet 5 & 6** 4.4





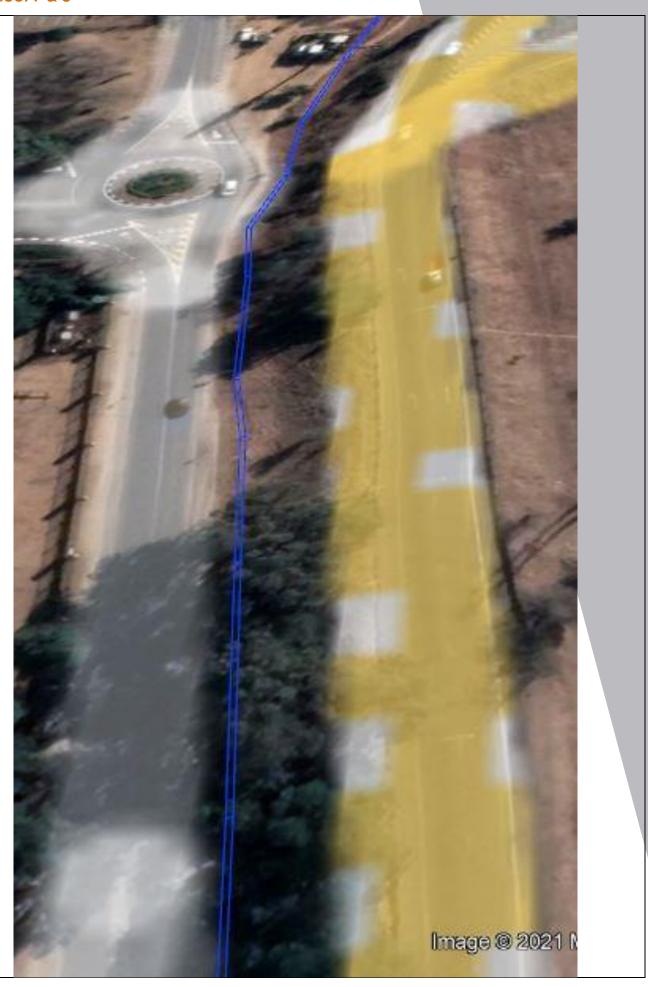




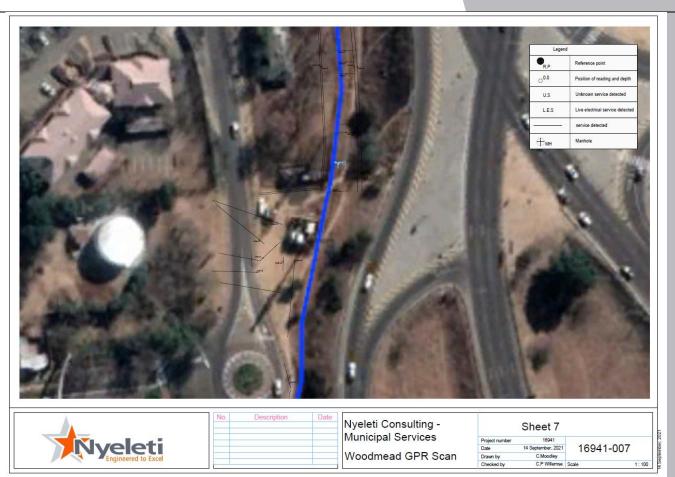
The images above shows that there are verious services crossing the path of the pipeline, a AutoCad co-ordinated drawing has been provided.



# 4.5 Sheet 7 & 8









The images above shows that there are verious services crossing the path of the pipeline, a AutoCad co-ordinated drawing has been provided.



## 4.6 Sheet 9





The images above shows that there are verious services crossing the path of the pipeline, a AutoCad co-ordinated drawing has been provided.



## 4.7 Sheet 10





The images above shows that there are verious services crossing the path of the pipeline, a AutoCad co-ordinated drawing has been provided.



### **CONCLUSION**

As per our scope of work Nyeleti Consulting - forensic department scanned various parts of the 5.3 km pipeline situated on the North-Eastern side of Johannesburg in Region E. The proposed pipeline route will be from Marlboro to Woodmead and will be constructed predominantly along Western Services Road. Nyeleti consulting found various underground services at various depths crossing the proposed route and have indicated so on the layout plans with-in this report and have issues an AutoCad co-ordinated drawing showing this.



Prince Moyo Power Delivery Engineering Senior Manager Eskom Megawatt Park, Sunning hill Date:

**Enquiries:** Brenda Morrison Tel +27 11 629 5266

# AUTHORISATION OF - 240-66418968 - GUIDELINE ON THE ELECTRICAL CO-ORDINATION OF PIPELINES AND POWER LINES

This letter will serve as proof that this document has been authorized without going for review comments. The following subject matter experts did see the document:

- Arthur Burger
- Bharat Haridas
- Bart Druif

### **Motivation:**

To ensure the documents included in the following schedule are in date and are in the current format. Any prospective future content changes will complete by the custodian and routed through the standard process.

Yours sincerely

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Compiler:

AABurger 15 January 2021

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Authorized:

25 January 2021

Prince Moyo

General Manager: PDE



### Guideline

**Technology** 

Title: **GUIDELINE ON THE** 

ELECTRICAL CO-ORDINATION OF PIPELINES AND POWER

**LINES** 

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Supported by SCOT/SC

Riaz Vajeth

SCOT/SC Chairperson

Date:

24/4/2015

PCM Reference: 010-120

SCOT Study Committee Number/Name: Overhead Lines

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#### 1. Introduction

As is the case in a number of other countries, increased urbanization in South Africa has been accompanied by an increasing number of applications by pipeline operators (water, gas, petroleum) to use the existing power line servitudes. These servitudes are particularly important to pipeline planners in urban areas where there may be few viable alternatives, but also in rural areas where the long tracts of land provided by power line servitudes are increasingly valued by pipeline operators. At the same time, the number of situations is on the increase where new power lines have to be installed next to existing pipelines.

When pipelines are located in (or cross) power line servitudes, there are a number of important issues to consider by both the electrical utility and the pipeline operators. During a power line fault, very high voltages can be induced in the pipeline, which can damage the cathodic protection systems and rupture the coating, and present a significant safety hazard for maintenance personnel. During normal operation the induced pipeline voltages are lower, but could still present a safety hazard due to the extended duration, and can result in accelerated corrosion of the pipeline.

From Eskom's perspective, an additional concern is that the d.c. potentials of the pipeline's cathodic protection system can produce leakage currents on power line structures resulting in electrolytic corrosion. This can generally be circumvented by insulating the earth wires of the pylons near pipelines. Though effective, this measure has cost implications for the utility and can, in the case of long parallelisms, present a safety hazard for live line workers and OPGW maintenance personnel if not carefully managed.

Internationally, safety and mitigation measures have been developed to cater for the co-use of power line servitudes by virtually all types of pipelines, as reflected in a number of IEEE, IEC, CEN, NACE and national standards. In South Africa however, there has been no local standard or guideline available to comprehensively deal with these issues, neither are there specific voltage (or current) limits recommended or regulated. This has led to either over- or under-design of mitigation measures, resulting in cases of damaged pipelines, corroded power line towers and earth wires, and electrical shocks experienced by maintenance personnel on both power line and pipeline infrastructure.

To address this issue, a SABS working group was established during 2010 representing the local electricity supply, pipeline and cathodic protection industries, with the objective of developing a standard or guideline. Due to the time scale involved in drafting SANS documents however, Eskom's Line Engineering Services proposed to develop an in-house guideline to address the immediate needs. This guideline can then be submitted to the SABS for possible use in the new SANS document.

### 2. Supporting clauses

### 2.1 Scope

This Guideline addresses safety and interference issues arising from electrical coupling between a.c. or d.c. power lines and pipelines. It is applicable when pipelines cross power line servitudes, when pipelines and power lines share the same servitudes or when pipelines and power lines are installed in adjacent servitudes.

Capacitive, inductive and conductive coupling modes are considered during normal load and fault conditions, for overhead lines or underground cables coupling with pipelines above or below ground, when the phase-to-phase voltage exceeds 40 kV r.m.s. on overhead lines, or 10 kV r.m.s. on cables.

This Guideline provides interference limits, guidance on the calculation and measurement of coupling levels, protection and mitigation methods, safe installation practices in power line servitudes as well as the coordination and management procedures required between the respective authorities.

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### 2.1.1 Purpose

Eskom's power lines and bulk pipelines often compete for the same land space (servitudes). In some cases, where the power lines already exist, a new pipeline can impact the existing power lines plus any additional power lines that are planned. In the opposite situation, where a pipeline(s) exist, new power lines may have an impact on the pipeline(s).

This document is aimed at setting up the framework that describes how the impacts are calculated and dealt with in either of these situations.

### 2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited Divisions whenever a pipeline and power line interaction is identified (covering existing and all planned future infrastructure).

#### 2.2 Normative/informative references

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

#### 2.2.1 Normative

- [1] ISO 9001 Quality Management Systems.
- [2] IEC 60050-161, International electrotechnical vocabulary. Chapter 161: Electromagnetic compatibility
- [3] Electricity Regulation Act
- [4] Occupational Health and Safety Act
- [5] SANS 10280, Overhead Power Lines for conditions prevailing in South Africa, Part 1: Safety
- [6] SANS 10142-1, The wiring of Premises, Part 1 : Low voltage Installations

#### 2.2.2 Informative

- [7] TST 41 321, Transmission Standard, Earthing Transmission Towers
- [8] TPC 41-1078, Procedure for the approval of work there Eskom Tx Rights may be encroached or its assets placed at risk
- [9] DGL 34-363, Guide for co-use of Eskom Servitudes, Restriction Areas and Assets
- [10] DGL 34-600, Building line restrictions, Servitude Widths, Line Separations and Clearances from power lines
- [11] SANS 50162:2010, Protection against corrosion by stray current from direct current systems
- [12] SANS 61643-1:2006, Low-voltage surge protective devices, Part 1: Surge protective devices connected to low-voltage power distribution systems Requirements and tests
- [13] DST 32-319, Determination of conductor ratings in Eskom
- [14] CIGRE 95 36.02 : 1995, Guide on the influence of High Voltage AC Power Systems on Metallic Pipelines
- [15] CIGRE 290 C4-2-02 : 2006, AC Corrosion on Metallic Pipelines due to Interference from AC Power Lines phenomenon, Modelling and Countermeasures
- [16] ANSI/IEEE Std 80, IEEE Guide for Safety in AC Substation Grounding
- [17] ANSI/IEEE Std 81, IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System Part 1: Normal Measurements

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- [19] SANS 10199:2004, The design and installation of earth electrodes
- [20] NRS084-2:2003: Electricity Supply Quality of Supply Part 2: Voltage characteristics, compatibility levels, limits and assessment methods
- [21] CAN/CSA-C22.3 No. 6-M91: R2003, Principles and practices of electrical coordination between pipelines and electric supply lines
- [22] AS/NZS 4853 : 2011, Electrical hazards on metallic pipelines
- [23] prEN 15280, Evaluation of a.c. corrosion likelihood of buried pipelines applicable to cathodically protected pipelines"
- [24] prEN 50443: 2009, Effects of electromagnetic interference on pipelines caused by high voltage a.c. railway systems and/or high voltage a.c. power supply systems
- [25] NACE Standard RP0177: 2000, Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Cathodic Protection Systems
- [26] NACE Internal Publication 35110: 2010: AC Corrosion State-of-the-Art: Corrosion Rate, Mechanism, and Mitigation Requirements
- [27] VON BAECKMANN W., SCHWENK W. et al, 1997, Handbook of Cathodic Corrosion Protection, 3rd Edition, Gulf Professional Publishing
- [28] FRAZIER, M.J., 2001, Predicting Pipeline Damage from Powerline Faults, NACE Corrosion 2001, Paper No. 1595
- [29] CEA Report 239 T817, 1994, Powerline Ground Fault Effects on Pipelines, Prepared by Powertech Labs Inc.
- [30] ITU-T Directives, R2005, Directives concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines, Volume II Calculating induced voltages and currents in practical cases
- [31] ITU-T Rec K68: 2006, Management of electromagnetic interference on telecommunication systems due to power systems
- [32] SEALY-FISHER, V., WEBB N., 1999, Cahora Basa Power Line Interference Study, Technical Bulletin No. 12, SAECC/4/1

### 2.3 Definitions

### 2.3.1 General

For the purposes of this guideline, the terms, definitions and abbreviations given in IEC 60050-161 and the following apply:

Definition	Description	
anode ground bed an installation of conductors below the surface by which directly discharged into the earth in an impressed current cathodic protects		
appurtenance that which is connected to a pipeline, e.g. a valve in a pipeline		
auto-reclosure	action of the power line protection whereby the line is automatically re- energised one or more times after tripping	
balanced current exist when the phasor sum of the phase currents in a three phase equals zero		
bond a low impedance connection designed to maintain a common electric		

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Definition	Description		
coating stress	the difference in voltage potential between the pipeline wall and the surrounding soil at a given location		
counterpoise a conductor or system of conductors below ground, connected to the for of power line towers			
d.c. decoupling device	a device used in electrical circuits that allows the flow of a.c. in both directions and prevents or substantially inhibits the flow of d.c.		
d.c. potential shift	a potential developed between a metallic structure and the surrounding earth as a result of stray d.c. currents in the earth, which can result in electrolytic corrosion of the metallic structure		
dielectric breakdown potential	a voltage potential in excess of the rated voltage that causes the destruction of the coating or other insulating material		
discharge current	current that will flow if the conductor with induced voltage is connected to the earth via a zero impedance bond		
dead front	a type of construction in which the energized components are recessed or covered to preclude the possibility of accidental contact		
earth potential rise	the product of a earth electrode impedance, referenced to remote earth, and the current that flows through that electrode impedance		
earth resistivity measure of the electrical resistance of a unit volume of soil  NOTE The commonly used unit is the ohm-meter, [Ω□m] whice impedance measured between opposite faces of a cubic meter of the electrical resistance of a unit volume of soil.			
galvanic corrosion cell corrosion caused by dissimilar metals in an electrolyte			
gradient control wire	one or two ribbons installed adjacent to and connected to a pipeline in order to reduce the pipeline coating stress		
gradient control mat	a system of bare conductors or ribbon on or below the earth's surface, so designed as to provide an area of equal potential within the range of step distances		
impressed current cathodic protection	a system whereby the cathodic protection current is applied using a d.c. rectifier, connected between the protected item and an anode ground bed		
remote earth	a location on earth that is far enough from the affecting structure that the soil potential gradients associated with the currents entering the earth from the affecting structure are insignificant		
residual current (or zero sequence current)  Electrical current, that is equal to the phasor sum of the phase currents, returns through the earthing system of the power network  NOTE When balanced current conditions exist, the residual current exists are conditions exists.			
ribbon	a bare zinc or magnesium profiled conductor, specifically designed for gradient control		
right (or right-of-way) means the right to traverse or occupy land and includes inter alia ser surface right permits, way leaves, exercised options, licences and permit to occupy			
sacrificial anode an anode that is attached to a metal object subject to electrolysis decomposed instead of the object			

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Definition	Description	
screening factor	a factor smaller than unity, by which an inducing quantity (current or voltage) may be multiplied to represent the reducing effect of a screening conductor	
servitude	a right registered at the Registry of Deeds against the property title deed, binding against all the successors in title.	
step voltage	the voltage difference between two points on the earth's surface separated by a distance of one pace, which is assumed to be 1 m, in the direction of the maximum voltage gradient	
switching surge	the transient wave in an electrical system that results from the sudden change of current flow caused by the opening or closing of a circuit breaker	
touch voltage	the voltage difference between a metal structure and a person in contact with the earth's surface or another metal structure	
test post	a location at ground elevation above the pipeline where leads connected to the pipeline and/or pipeline coupons are accessible for the measurement of the voltage of the pipeline and/or the corrosion current	
voltage limiting device	a protective device that normally presents a high impedance in an electrical circuit but presents a low impedance when its rated clamping or spark-over voltage is exceeded	
zone of influence	area adjacent to a power line or installation in which inductive, capacitive or conductive coupling or a combination of them can produce harmful effects on a pipeline installation	

### 2.3.2 Disclosure classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

### 2.4 Abbreviations

Abbreviation	Description	
ACSR	Aluminium Composite, Steel Reinforced	
ARC	Auto reclose	
СР	Cathodic Protection	
CVES	Continuous Vertical Electrical Sounding	
DCVG	Direct Current Voltage Gradient	
DSR	Deep Soil Resistivity	
Dx	Distribution (MV and HV)	
EHV	Extra High Voltage (>132kV)	
emf	electromotive force	
EPR	Earth Potential Rise	
ESI	Electricity Supply Industry	
ESA	Electricity Supply Authority	

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Abbreviation	Description		
ESO	Electrical Safety Officer		
GIS	Geographical Information System		
GMR	General Machinery Regulation		
HV	High Voltage (44kV to 132kV)		
ICCP	Impressed Current Cathodic Protection		
LV	Low Voltage (<1kV)		
MV	Medium Voltage (1kV to 33kV)		
NEC/R	neutral earthing compensator/resistor		
OHS	Occupational Health and Safety		
OPGW	optical ground wire		
ORHVS	Eskom operating regulations for high-voltage systems		
PILC	paper insulated, lead covered		
РО	Pipeline Operator		
PSS/E	power systems software simulator for engineering		
SA	sacrificial anode		
SCOT	Steering Committee of Technology		
SPD	surge protection device		
Tx	Transmission (EHV)		
TxSIS	Eskom Tx division's spatial information system		
VLD	Voltage limiting device		
XLPE	cross-linked polyethylene		
ZOI	Zone of influence		

### 2.5 Roles and responsibilities

Eskom's Power Delivery group, which resorts under the Group Technology Commercial Division, participates in power line design and development work through guidelines and standards that are handled under SCOT.

Within Power delivery, Line Engineering department is the main supplier of Tx line designs. However, throughout Dx offices countrywide, there are also designers at work doing Dx line designs and development work.

Regardless of whether power lines are designed and developed by Tx or Dx offices, whenever there is a possibility for pipelines to run adjacent or cross one or more of the power lines, the designer must take cognisance of this guideline document.

Land development departments in Tx and Dx should also take note of this document and involve the required engineering skills to advise them on the process (as set out in Annex A – required technical data and Annex D – flow diagram of the process to be followed towards approval of servitude rights and co-use)

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### 2.6 Process for monitoring

The electrical working group in the Overhead Lines study committee of SCOT will monitor this document and others that are related to power line design and operation. It will take place either under a working group or a care group depending in the needs identified. The SCOT focus is both on technical issues as well as operational issues that may require modifications or updates. Advances in pipe coatings and CP systems need to be monitored continuously to ensure that the technical impacts remain acceptable.

The pipeline industry of South Africa as well as Eskom is keen to support the continued development of this document into a national standard through the NRS mechanisms.

Through the formulation of this document, with inputs and interaction by the pipeline owners, Eskom has set the benchmark for what would be required from a power lines point of view when power lines and pipelines interact.

The onus is still on the pipeline owners to agree on their requirements should a power line have an impact on already installed and operational pipelines.

### 2.7 Related/supporting documents

Not applicable.

### 3. The Electrical Coordination of Pipelines and Power Lines

### 3.1 Statutory and Utility Requirements

### 3.1.1 Applicable legislation

When a new electrical transmission or distribution scheme or extension to a scheme is considered in the vicinity of an existing pipeline, or when a new pipeline or extension of an existing pipeline is considered in the vicinity of an electricity transmission or distribution scheme, the following legislation is applicable in South Africa:

- the OHS Act, 1993 (Act No. 85 of 1993) and its accompanying regulations, notably the Electrical Machinery Regulations, 2011 (GNR.250 published in Government Gazette 34154 of 25 March 2011),
- b) the Electricity Regulation Act 4 of 2006.

The OHS Act also has specific regulations for gas and petroleum pipelines related to the dangers posed by the transported medium (the Major Hazard Installation Regulations, section 43 of Act No 85), which are outside the scope of this document.

#### 3.1.2 Relevant statutory requirements

Relevant requirements, in the context of this guideline, from the legislation listed in 3.1.1 stipulate the following:

- a) In terms of section 8(1) of the OHS Act, POs and ESAs are obliged to provide and maintain safe working environments which include working environments where pipelines or works are under or in the vicinity of power lines.
- b) In terms of the Electricity Regulation Act (Section 25), in the event of civil proceedings arising from damage or injury caused by induction, leakage or any other means of unwanted transmission of electricity, the ESA will be presumed to have been negligent unless it can prove otherwise.

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c) The Electrical Machinery Regulations obliges POs and ESAs to conform to the safety clearances as set out in Regulation 15 in respect of overhead power lines, and it is necessary to define all electrical works and pipeline facilities to which safety clearances may be applicable and to agree on the safety clearances that must apply in each case.

### 3.1.3 Utility requirements for pipeline installations in Eskom's servitudes

The minimum requirements for Eskom's servitudes are given in DGL 34-363 [9] for Dx lines, in TPC 41-1078 [8] for Tx lines and in DGL 34-600 [10] for both types of line, in addition to further requirements listed here. The specific requirements in the context of this document are:

### 3.1.3.1 Common requirements (Dx and Tx servitudes)

- No work may commence unless Eskom has received the applicant's written acceptance of the conditions specified in the letter of consent.
- b) The applicant or his / her contractor on site must at all times be in possession of the letter of consent. Should the site agent or contractor on site not be able to produce the required approval on inspection, all site activities will be stopped.
- c) Eskom's rights and duties in the servitude shall be accepted as having prior right at all times and shall not be obstructed or interfered with.
- d) Eskom's consent does not relieve the applicant from obtaining the necessary statutory, land owner or municipal approvals. The applicants are reminded that a power line servitude does not imply land ownership by Eskom.
- e) Eskom shall at all times retain unobstructed access to and egress from its servitudes.
- f) Pipelines shall not conflict with Eskom's future expansion plans in the servitude.
- g) In general, parallel encroachments into the servitudes are limited to 2 (two) metres from the boundary of the servitude, to allow reasonable maintenance access to Eskom in the servitude.
- h) Pipeline transitions from one side of the power line servitude to the other are not permitted without written approval.
- i) The angle of all crossings should preferably be from 45 degrees to 90 degrees.
- j) Venting and blow off valves on gas or petroleum pipelines shall be outside the power line servitude and be vented away from potential ignition sources.
- k) Pipeline markers shall be installed at 10 m intervals (or as otherwise specified by Eskom) to indicate the location of underground pipelines. Markers shall indicate the owner of the pipeline and be concrete cast and resistant to vandalism.
- Sufficient cover or pipe jacking shall be provided at servitude roads to prevent breakage by Eskom's vehicles and heavy equipment.
- m) In case of a proposed above-ground pipeline, a bridge shall be provided to allow permanent Eskom access to the servitude. This bridge, if of conductive material, shall be earthed, but the earthing shall not be onto Eskom structures or within five metres of Eskom's own earthing.
- At a pipeline crossing, corrosion-free sleeves must be installed at least 600 mm below undisturbed ground level to provide for future installation of Eskom cables. [The number and diameter shall be determined by the internal assessor]
- The construction of new temporary or permanent metallic fences in power line servitudes can be extremely hazardous and is prohibited without written approval.
- p) The use of explosives of any type within 500 metres of Eskom's services is prohibited without written approval. The application should be in accordance with DGL 34-364 for Dx lines and in TPC 41-1078 for Tx lines respectively.

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q) The pipeline voltages as a result of electrical coupling during normal and fault conditions on the power line(s) shall not exceed the respective values indicated in 3.3.3 and 3.3.4.

- r) The stray d.c. voltages near power line structures as a result of ICCP systems shall not exceed the values indicated in 3.3.8.
- s) Test posts shall use dead front construction in accordance with NACE RP0177.
- t) It is required of applicants to familiarize themselves with all safety hazards related to Electrical plant. Safe working procedures shall be applied during construction (see 3.8).
- u) The clearances between Eskom's live electrical equipment and the proposed construction work shall be observed as stipulated by Regulation 15 of the Electrical Machinery Regulations of the Occupational Health and Safety Act, 1993 (Act 85 of 1993) (see 3.8.2, table 15).
- v) No mechanical equipment, including mechanical excavators or high lifting machinery, shall be used in the vicinity of Eskom's apparatus and/or services, without prior written permission having been granted by Eskom. If such permission is granted the applicant must give at least seven working days prior notice of the commencement of work. This allows time for arrangements to be made for supervision and/or precautionary instructions to be issued. The internal assessor must provide the applicant with the details of an Eskom person to be contacted in this regard.
- w) Changes in ground level may not infringe statutory ground to conductor clearances or statutory visibility clearances. After any changes in ground level, the surface shall be rehabilitated and stabilised so as to prevent erosion. The measures taken shall be to Eskom's requirements.
- x) Electrical installations on the pipeline for example the cathodic protection system, protection devices and electrical wiring shall comply with the applicable provisions in SANS 10142, and inspected and certified by a qualified installation electrician (or master installation electrician in case of hazardous locations).
- y) Eskom shall not be liable for the death of or injury to any person or for the loss of or damage to any property whether as a result of the encroachment or of the use of the servitude area by the applicant, his/her agent, contractors, employees, successors in title, and assignees.
- z) The PO shall indemnify Eskom in writing against loss, claims or damages including claims pertaining to consequential damages by third parties and whether as a result of damage to or interruption of service or interference with Eskom's services or apparatus or otherwise. Eskom shall not be held responsible for damage to the applicant's equipment.
- aa) The PO's construction manager shall report any damage to Eskom's property, private property or public facilities, and the PO agrees to pay all expenses incurred in connection with the repair of such damages.

### 3.1.3.2 Further requirements for Tx servitudes

- a) No excavations are permitted within 20 m of above-ground power line structures including towers, guy wires, anchors and other attachments. Exceptions may be permitted, subject to a case by case evaluation of the foundation and the soil conditions.
- b) No above-ground buildings are permitted within the following distances of a Tx power line, measured from the centreline of the power line, as a function of the voltage level:

i. 220 kV - 275 kV (delta): 18 m
 ii. 220 kV - 275 kV (horizontal): 23.5 m
 iii. 400 kV (self-supporting): 23.5 m
 iv. 400 kV (stayed) 27.5 m
 v. 765 kV 40 m

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#### 3.1.3.3 Further requirements for Dx servitudes

a) No excavations are permitted within 6 m of above-ground power line structures including towers, guy wires, anchors and other attachments. Where this cannot be achieved, or where there is a risk of a ruptured pipe eroding a tower foundation, the pipe section is to be placed in concrete.

b) No above-ground buildings are permitted within the following distances of a Dx power line, measured from the centreline of the power line, as a function of the voltage level:

i. all voltages below 22 kV: 9 m
 ii. 22 kV: 9 m
 iii. 33 kV - 88 kV: 11 m
 iv. 132 kV: 18 m

### 3.2 Co-ordination and Management Procedure

#### 3.2.1 Co-ordination

Good co-operation between Eskom and the POs is essential to ensure that all the co-ordination requirements are met. Both parties must ensure that adequate specialist skills are available to them, to enable professional assessment of the methods and measures used to prevent conditions which may be dangerous to employees concerned or to the public, or which may damage or degrade the pipeline or power line works.

Co-ordination and service meetings between the specialists of the POs and Eskom should complement the formal meeting mentioned in 3.2.2 o), particularly in the case of long or complex exposures.

When the servitude under consideration contains both Dx and Tx power lines, the co-operation must extend to both Eskom's Dx and Tx departments. It is emphasised that since the respective Land & Rights issues are under the management of separate offices, any approval granted by Eskom Dx does not automatically imply Eskom Tx approval, or vice versa.

Further liaison between the specialists of the respective parties is recommended through the forum of the SAECC. The preferred arrangement is that an SAECC working group is established with the responsibility of sharing information and developing skills in respect of electrical coupling between power lines and pipelines, including the training of safety officers.

### 3.2.2 Procedure for obtaining approval for new installations

When a new pipeline is planned that involves any construction in Eskom's servitudes, the following steps are required towards approval of the right of way (flow chart provided in Annex D):

- a) the PO's right of way application (annex A of TPC41-1078 for Tx servitudes, or annex A of DLG 34-363 for Dx servitudes, or both in case of combined Tx/Dx servitudes) along with the pipeline design details according to checklist A.1 of Annex A, is completed and submitted to Eskom's regional office for attention of Land and Rights, at least six months prior to planned commencement of the project,
- b) the application is checked for completeness, registered on the system (Investigations\_ logbook.xls) and assigned a Senior Advisor: Investigations and Audit (Tx) or to an Internal Assessor (Dx), according to the procedures described respectively in TP C41-1078 and DLG 34-363,
- c) the Senior Advisor or Internal Assessor examines the application and identifies the affected Tx and Dx power lines or cables on TxSIS GIS, and captures this information using the template A.2 in Annex A,

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d) the Senior Advisor or Internal Assessor query the Manager: Land Management and Grid Planning if any future power lines or cables will be affected by the application in a 20 year window, and also captures this information,

- e) the Senior Advisor or Internal Assessor prepares maps or .kmz or .dxf files clearly indicating the routes of all the affected power lines or cables as well as other infrastructure in the area of interest,
- f) the Senior Advisor or Internal Assessor updates TxSIS GIS with the pipeline ID and route and also forwards this information to the SCOT committee (for attention: SCOT chairperson),
- g) the Senior Advisor or Internal Assessor next forwards the application with the power line route maps to Eskom's Engineering Services, who performs an assessment of the ZOI (Zone of Influence) for the various coupling modes, using the information obtained in steps a) e) and following the method discussed under 3.4,
- h) if the exposure or crossing is benign, the application is returned to the Senior Advisor or Internal Assessor for further processing and subsequent approval or otherwise according to the procedure described respectively in TP C41-1078 (Tx) or DLG 34-363 (Dx), but noting that if any construction work is to be done in a power line servitude, the safe working procedures of 3.8 are applicable,
- i) if the pipeline falls within the ZOI of inductive and/or conductive coupling, or if the power line or any substations fall inside the ZOI of the pipeline's CP system, the exposure is regarded as possibly hazardous and a detailed coupling study is required for the respective coupling mode(s),
- j) the design details of the relevant power lines or cables are then obtained from Lines Engineering and Grid Planning, taking network expansion for a 20 year period into account, using the checklist A.3 in Annex A.
- k) next Eskom's Engineering Services performs a PSS/E or similar analysis to calculate the network impedances and fault current levels for the power lines or cables in question, using the checklist A.4 in Annex A, using case files 20 years ahead,
- the list of possibly hazardous coupling modes and all the relevant power system data (from checklists A.2, A.3 and A.4) is forwarded to the PO.
- m) the PO designs the a.c. mitigation based on this data, according to the methods indicated in 3.7 and elsewhere in this guideline, and submits a proposal to the Senior Advisor who submits same to Eskom's Engineering Services,
- n) if necessary, Eskom's Engineering Services initiates and proceeds with a project to asses the suitability of the a.c. mitigation measures proposed by the PO.
- a co-ordination meeting is held between Eskom's Engineering Services and the PO to reach
  agreement on designs that will ensure that the coupling limits will not be exceeded and to discuss
  the necessary clearances and safety procedures to be observed,
- p) Eskom's Engineering Services initiates a project (in Eskom Construction Department) to isolate the power line's earth wires as may be required in terms of TST 41 321 or as indicated by the conductive coupling analysis,
- q) the application is returned to the Senior Advisor for further processing and approval subject to the agreed design, according to the procedure described in the right of way application, TP C41-1078,
- r) before construction starts, the PO appoints an Electrical Safety Officer (ESO), who is to be responsible for maintaining safe working conditions in the servitude and adjacent to the servitude for the duration of the works (see 3.8),
- s) during construction, the ESO maintains contact with Eskom and permits inspections by Eskom representatives to ensure that all conditions are met and the required clearances are adhered to,
- t) the ESO keeps a written record of all voltage measurements, safety-related incidents and accidents during construction, exposed underground infrastructure such as counterpoises or cables and any damage to Eskom's power line structures, and submits this information to Eskom,

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u) upon completion of the pipeline works and surface restoration, an Eskom representative performs an inspection of all a.c. mitigation measures, the pipeline markers, any damage to power line structures and the quality of the surface restoration (see 3.9 and checklist in Annex E),

- if so agreed upon by the parties, measurements are performed at this stage to determine if the d.c.
  potential shift at selected pylons or earth mats, resulting from switching the CP system on and off,
  is within the required limits,
- w) providing the outcome of steps u) and v) is positive, the final approval for the commissioning of the installation is granted (see 3.9).

When a new power line or installation is planned in an existing pipeline servitude, essentially the same procedure is followed; in this case initiated by Eskom, and subsequently inspected and approved by the PO.

### 3.2.3 Cost of mitigation, protection and maintenance measures

In the case of new works, the cost of the agreed upon measures shall be borne by the party initiating the new installation. This includes the cost of any modification required to the existing works belonging to the owner of the servitude. In the case of a pipeline application in existing power line servitude this would include, for example, the cost of isolating the power line's earth wires. In the case of a new power line influencing an existing pipeline, this would include the cost of all the a.c. mitigation measures required.

The owner of the servitude shall further be entitled to recuperate from the applicant the cost of the assessment described in 3.4, the cost of the modelling exercise described in 3.6, the cost of inspections and if damage occurred, the cost of any repairs to the existing works.

In the case of induction problems arising on existing installations, the cost shall be borne by the party on whose installation the protection or mitigation measures are implemented.

In the case of a benign co-location becoming hazardous as a result of a power line upgrade or an increase in the level of cathodic protection used on the pipeline, the cost shall be borne by the party who was granted permission for co-use of the servitude by the owner.

In the case of there being no registered servitude owner yet at the time that the co-location is planned, each party shall be responsible for the cost of the measures on their own equipment, whilst the cost of the assessment and modelling exercise shall be equally shared.

In all cases, each party is responsible for the cost of maintaining the integrity of their own equipment including attachments, insulation and earthing.

### 3.3 Coupling Limits

#### 3.3.1 Origin of safety limits

Safe limits of step and touch voltages are based on the maximum body current that can be endured by a person without affecting muscular control or causing ventricular fibrillation. The standards IEEE 80 and IEC 60479-1 provide safety criteria based on the fibrillation current derived from empirical studies.

The safety limits used here for fault conditions are adopted from the IEC standard, which is based on more recent research. The fibrillation current curve C1 is used, representing 95% of the population (see Fig 20 in IEC 60479-1).

For pipeline sections exposed to the general public, the worst-case condition considered is where both hands are in contact with the pipeline and both feet in contact with the earth. No reduction factor for footwear is applied, as some pipelines may be accessible to bare-footed children, for example.

For pipeline sections accessible only by authorised personnel, the worst condition considered is likewise where both hands are in contact with the pipeline and both feet with the earth, but footwear is accounted for with a conservative resistance of 1000 ohm.

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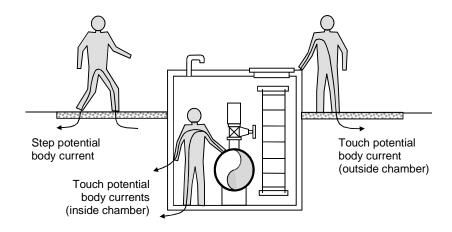
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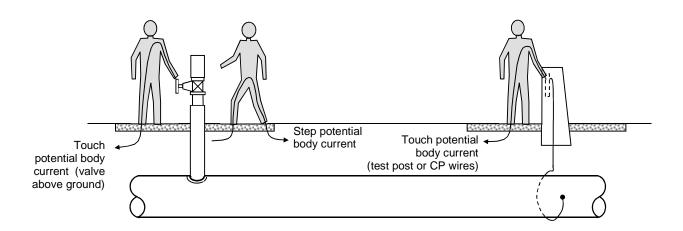
The safety limits for steady state conditions are based on a 10 mA r.m.s. body current, which is the maximum safe let-go current for adult men. For pipelines or sections of the pipeline exposed to the public including children, the maximum let-go current is reduced to 5 mA r.m.s. The hand-to-hand or hand-to-foot resistance is considered to be equal to or higher than 1 500 ohm, a reasonably safe assumption when touch voltages remain within the limits required (see Table 1, IEC 60479-1).

#### 3.3.2 Contact scenarios

Some typical contact scenarios with an energised pipeline and the resultant body current paths are depicted in Fig1 (a)-(c).



#### (a) at partially buried valve chambers



#### (b) at above-ground appurtenances

Figure 1 – Typical contact scenarios with an energised pipeline and resulting body currents due to step and touch potentials (contd../)

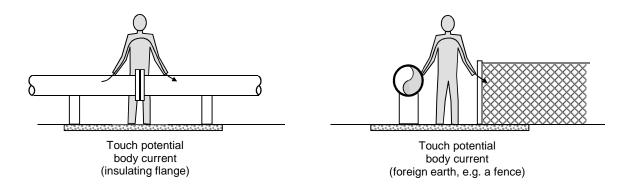
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### (c) across insulating flanges and to separate earths

Figure 1 (contd.) – Typical contact scenarios with an energised pipeline and resulting body currents due to step and touch potentials

Inside valve chambers, direct contact with the pipeline is possible, and the current path can be through the wall or the floor (see Fig 1 (a)). Outside the valve chambers, indirect touch potentials can occur through the chamber roof and walls.

Step potentials can result from the voltage gradient around the chamber or the above-ground appurtenance (see Fig 1 (b)).

In the case of pipelines installed on plinths above ground, direct touch potentials are possible to local earths, to foreign earths or across insulating flanges (see Fig 1 (c)).

### 3.3.3 Limits relating to danger during fault conditions

In the event of an earth fault on the power line(s), the touch and step voltages with respect to local earth at any accessible section of the pipeline shall not exceed the values given in Table 1, for public and occupational exposure respectively.

For most pipelines the occupational exposure limits will be applicable. The public exposure limits are only applicable for above - ground pipelines or appurtenances that are not protected from public access.

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Table 1: Limiting values for induced pipeline touch and step voltage during faults

Exposure	Fault duration <sup>1)</sup> , t	Maximum touch (T) and step (S) voltages for different surface layers: [V r.m.s.]		
		Natural soil or concrete slab <sup>2)</sup>	15-20 cm crushed stone layer <sup>2)</sup>	15-20 cm asphalt layer <sup>2)</sup>
	t ≤ 0,1	170 (T) 220 (S)	570 (T) 1 800 (S)	4 300 (T) > 5 000 (S)
	0,1 < t ≤ 0,2	160 (T) 200 (S)	510 (T) 1 600 (S)	3 800 (T) > 5 000 (S)
General public	0,2 < t ≤ 0,5	60 (T) 70 (S)	170 (T) 510 (S)	1 200 (T) 4 600 (S)
	0,5 < t ≤ 1,0	34 (T) 40 (S)	90 (T) 260 (S)	600 (T) 2 300 (S)
	1,0 < t ≤ 20	26 (T) 32 (S)	70 (T) 200 (S)	450 (T) 1 700 (S)
	t ≤ 0,1	340 (T) 900 (S)	820 (T) 2 600 (S)	4 500 (T) > 5 000 (S)
	0,1 < t ≤ 0,2	300 (T) 800 (S)	730 (T) 2 300 (S)	4 000 (T) > 5 000 (S)
Authorised personnel	0,2 < t ≤ 0,5	105 (T) 260 (S)	240 (T) 720 (S)	1 250 (T) 4 800 (S)
	0,5 < t ≤ 1,0	60 (T) 135 (S)	130 (T) 370 (S)	640 (T) 2 400 (S)
	1,0 < t ≤ 20	45 (T) 110 (S)	95 (T) 270 (S)	460 (T) 1 800 (S)

#### Notes:

The benefit of a protective surface layer is evident from Table 1. Asphalt in particular exhibits a very high soil resistivity. Concrete slab (and also soilcrete, i.e. backfill mixed with cement) on the other hand, is a very poor insulator, due do the hygroscopic nature of cement.

The fault duration on Eskom lines of usual construction is given in Table 2. In accordance with IEEE 80, the cumulative fault duration should be applied taking account of the auto-reclosures.

<sup>1)</sup> Use the cumulative fault duration of the maximum number of reclosures.

Assumed resistivity of natural soil or concrete slab: 30 ohm.m, crushed stone: 1000 ohm.m, asphalt: 10 000 ohm.m; all under wet conditions, ref. IEEE 80.

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Table 2: Typical fault duration on Eskom power lines

Voltage level	Maximum fault duration [s]	Total number of successive trips 1)	Cumulative fault duration [s]	Backup protection duration <sup>2)</sup> [s]
11 kV – 33 kV <sup>3)</sup>	4.0	5	20	20
44 kV – 132 kV	with teleprotection:  0.1  with stepped-distance protection 4):  0.5	2	with teleprotection:  0.2  with stepped-distance protection <sup>4)</sup> :  0.5	0.8 <sup>5)</sup>
220 kV – 765 kV	0.1	2	0.2	0.8 <sup>5)</sup>

#### Notes:

- 1) Trips in quick succession with auto-reclose, excluding controlled closure after ARC lock-out
- Apply backup protection times only for pipelines continuously and frequently exposed to the general public, e.g. above-ground pipelines in public walkways
- 3) Eskom's MV circuits are earthed with NEC/Rs which limit the earth fault current to 360 A
- 4) This value applies only to the last 20% of the line, which uses Zone 2 protection and does not auto-reclose. Between 20% and 80% of the line, the fault will be cleared within 0.1 sec by Zone 1 from both ends
- 5) This applies to Zone 3 protection. High impedance faults (Zfault > 20 ohm) may take 1 sec or longer to clear, but have a reduced fault current

### 3.3.4 Limits relating to danger during steady state conditions

During worst case conditions on the power line(s), the touch voltage of the pipeline and its appurtenances shall not exceed:

- a) 15 V r.m.s. at pipeline sections exposed only to authorised personnel,
- b) 7.5 V r.m.s at pipeline sections exposed to the general public.

Worst case conditions shall take into consideration the emergency load current, the phase current unbalance, effects of multiple circuits and planned expansion or upgrade of the power network.

For most pipelines the 15 V r.m.s. limit will be applicable. The 7.5 V r.m.s. limit is only applicable for above - ground pipelines or appurtenances that are not protected from public access.

The locations on the pipeline where the voltage peaks will most likely occur are discussed in 3.6.9.

### 3.3.5 Limits relating to damage of pipeline coatings

The maximum permissible pipeline coating voltage stress is dependant on the dielectric strength of the coating material and the method used to cover field joints.

Bitumen can experience glow and arc discharges for coating stress above 1 000 V r.m.s., limiting the maximum permissible value for bitumen-based coatings to about 900 V r.m.s., irrespective of coating thickness.

Polyurethane -, epoxy - and polyethylene - based coatings of normal thickness can tolerate voltages in excess of 10 000 V r.m.s., although the coating stress is generally limited to around 5 000 V r.m.s., to take future deterioration and the effect of field joints into account. For these coatings, the dielectric breakdown strength increases with coating thickness.

The respective value, to be established in consultation with the PO, shall be applied during worst case fault conditions (see 3.6.3.3).

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### 3.3.6 Limits relating to damage of cathodic protection equipment

The full induced a.c. voltage (i.e. without any localised mitigation) will appear across the CP rectifier during an earth fault. With proper design, this voltage will not exceed the maximum permissible coating stress.

The CP rectifier must hence be capable of withstanding the maximum coating stress voltage (see 3.3.5) for the duration of a fault cleared by the backup protection system (see Table 2).

The full induced steady state a.c. voltage will also appear across the CP rectifier and can be converted to a d.c. voltage, which can increase the ground bed d.c. current. The resultant increase in anode ground bed consumption needs to be taken into account during the ground bed design.

The CP equipment will further be vulnerable to lightning and switching surges through its power supply, in addition to possible transients from nearby d.c. traction systems. For this reason, the transformer and rectifier are equipped with SPDs, typically rated as follows:

Lightning current rating 8/20 µsec 40 kA
 Lightning impulse clamping voltage (min) 500 V
 Response time 25 ns

Where surge levels are expected to exceed this rating, special precautions are required.

### 3.3.7 Limits relating to a.c. induced pipeline corrosion

The induced voltage limit to prevent possible a.c. induced corrosion damage at pipeline coating defects has to be decided on by the PO, and is not enforceable by the ESA.

Whilst the study of this phenomenon is ongoing, there is some evidence that for modern coatings in certain soils, a.c. induced corrosion is possible at voltage levels well below the safety limits of 3.3.4. Recommendations in this regard are given in CIGRE TB 290, CEN TS 15280 and NACE 35110. These documents suggest the following voltage and current density limits to significantly reduce a.c. corrosion likelihood, based on the practical experience of European operators:

- a) 10 V r.m.s. and 100 A r.m.s./m² where the local soil resistivity exceeds 25 ohm.m
- b) 4 V r.m.s. and 40 A r.m.s./m² where the local soil resistivity is less than 25 ohm.m

The current density limits apply to the discharge current at a coating holiday. For a 1 cm<sup>2</sup> holiday, the current limit is 10 mA and 4 mA for a) and b) respectively. The voltage limits indicated will ensure that the current density limits are not exceeded.

Unlike the safety limit, these limits are intended to be applied at accessible as well as inaccessible sections of the pipeline. Because a.c. corrosion is a long term process however, it is only necessary that these limits are met during normal load conditions and not during short term, emergency load conditions on the inducing power line(s).

### 3.3.8 Limits relating to d.c. leakage from pipelines and anode ground beds

In terms of earthing standard TST-41-321, all transmission line towers within 800 m of pipelines employing impressed current CP systems must have their earth wires isolated from the towers with suitable insulators, to prevent circulating d.c. currents.

Where it can be shown however by proper measurement and/or modelling that the d.c. potential shift limits indicated in a) or b) below are not exceeded, or if the towers are cathodically protected, this requirement may be waived, in consultation with Eskom.

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### a) Leakage from pipelines

With the pipeline at a negative potential, the adjacent soil will assume a negative potential through coating imperfections. Current can then be extracted from any earthed structure such as a power line tower, resulting in anodic interference (corrosion). To limit this effect, the maximum permissible positive d.c. potential shift with respect to the surrounding soil resulting from the CP system is (from Table 1, SANS 50162):

maximum positive d.c. potential shift (resulting from pipeline leakage): 200 mV

This is the limit applicable for a steel structure in a concrete foundation, and includes the IR - drop in the concrete surrounding the structure. It can be evaluated by toggling the CP system on and off whilst measuring the corresponding change in the structure's d.c. voltage, using a simple voltmeter and a reference electrode inserted into the soil next to the foundation. The maximum rated CP current should be applied to the pipeline during this test.

A 200 mV d.c. potential shift can manifest itself at the tower footing of a power line when the d.c. voltage gradient exceeds 200 mV over the length of a single power line span.

### b) Leakage from anode ground beds to towers connected by earth wires

Anode ground beds produce a localised positive d.c. voltage in the adjacent soil, which injects current into nearby earthed structures, resulting in cathodic interference (protection).

Where this current exits the structure and re-enters the soil however, anodic interference (corrosion) occurs. When the power line's earth wires are directly connected to the towers, this return current is typically shared by a number of towers further away, before returning through the soil to the pipeline and back to the source.

The requirement in this case is that the return currents at these remote towers will not produce a positive d.c. potential shift in excess of 200 mV.

In view of this, post-installation measurements should be performed at all the towers where the current is expected to return to earth, to confirm that the 200 mV limit is met.

Such measurements are required whenever the negative d.c. potential shift at the current entry point exceeds 200 mV, and should be made with the maximum rated current applied to the anode ground bed.

### Leakage from anode ground beds to isolated towers

When anode ground beds are installed near power line towers (<500 m separation), the surface d.c. gradient across the individual legs or guy wire anchors can be large enough to cause corrosion even on isolated towers. The applicable limit in this case is:

maximum positive d.c. potential shift (resulting from anode ground beds): 200 mV

This d.c. potential shift can manifest when the surface d.c. voltage gradient exceeds 400 mV over the distance between the legs or guy anchors. When this limit is exceeded, the tower has to be protected with sacrificial anodes.

### 3.4 Assessment of the possible hazardous nature of an exposure

#### 3.4.1 Data gathering

A significant amount of information concerning the pipeline and the power line(s) is required to enable a detailed study of the safety and corrosion aspects that results from the various electrical coupling mechanisms. The required information is covered in the checklists A.1 – A.4 of Annex A.

The step-by-step procedure for obtaining this information is provided in 3.2.2. Various sign-off areas are included in the checklists for each of the contributors to sign off before passing it on to the next step.

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Only the information covered in checklists A.1 and A.2 of Annex A is required to determine the Zones of Influence (ZOIs) for the different coupling mechanisms, as outlined in 3.4.2. If no soil data is provided, a conservative value for deep soil resistivity of 1 000 ohm.m should be used for determining the ZOI for inductive coupling (see 3.4.2.1), or a surface resistivity of 5 000 ohm.m for determining the ZOIs for conductive coupling and d.c. coupling from the CP system (see 3.4.2.2, 3.4.2.4).

When the pipeline is found to be within one of the ZOIs of the power line, the corresponding information of checklists A.3 and A.4 is also required. Measurement of soil resistivity then becomes essential, as outlined in 3.5.

### 3.4.2 Establishing Zones of Influence

### 3.4.2.1 ZOI from overhead power lines and cables due to inductive coupling

This ZOI is determined by the distance between the centre of the power line and a parallel pipeline beyond which, the voltage developed on the pipeline cannot exceed a given limit. It is a function of the soil resistivity, the length of the exposure, the earth fault current level, the power system screening factors, the fault duration and the corresponding voltage limit.

For this calculation, the pipeline is assumed to be completely isolated, with no leakage through its coating, and with no earthing or mitigation measures applied.

The zone width  $a_i$  (applicable on both sides of the power line, see Fig 2) may be established for a specific situation from the equation:

$$a_i = 110 \cdot \sqrt{\frac{\rho}{e^{v/L_p} - 1}}$$
 [m]

where:

ρ is the soil resistivity (see 3.4.1), [ohm.m],

L<sub>n</sub> is the length of the exposure, projected onto the power line (see Fig 3), [km],

and  $V = \frac{64 \cdot V_{max}}{k_{II} \cdot k_{D} \cdot l_{f}}$  is a parameter calculated from the following values:

V<sub>max</sub>, the induced voltage limit for an earth fault, from Table 1, [V r.m.s.],

k<sub>u</sub>, the screening factor due to urban infrastructure, from ITU-T K.68 (see Table 3),

k<sub>p</sub>, the screening factor due the earth wires or the power cable sheath (see Table 3),

If, the maximum phase-to-earth fault current level, [A r.m.s.].

Conversely, the maximum length  $L_p$  of an exposure with an average separation  $a_i$  is given by the equation:

$$L_{p} = \frac{v}{\ln\left(\frac{12100 \cdot p}{a_{i}^{2}} + 1\right)}$$
 [km]

For pipelines crossing power lines at right angles,  $L_p = 0$  and no inductive coupling occurs. For crossings at angles greater than  $60^{\circ}$ , inductive coupling remains very small and can be disregarded, provided the pipeline does not change direction towards the power line.

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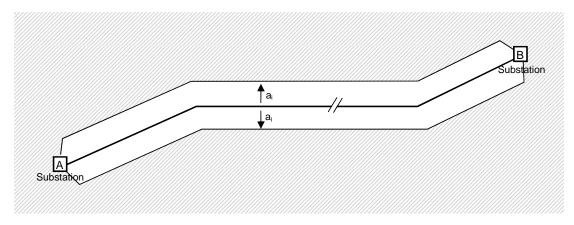


Figure 2: Zone of influence for inductive coupling

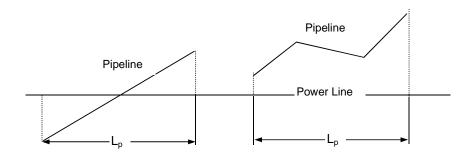


Figure 3: Exposure length Lp for crossings and non-parallel exposures

Eqns (1) and (2) are applicable only for relatively short exposures,  $L_p \le 20$  km for perfectly insulated pipelines. On practical lines with standard coatings, when  $L_p$  exceeds 20 km the coating leakage will prevent any further increase in the pipeline voltage, irrespective of the additional exposure length (see 3.6.9). Hence when  $L_p > 20$  km, the value of  $a_i$  determined for  $L_p = 20$  km may be applied.

The zone width  $a_i$  calculated from Eqn (1) for some typical scenarios is shown in Figs 4 – 5.

Table 3: Approximate values of screening factors for inductive coupling

Screening factor of			Screening factor
earth	wires o	f power lines	
a)	singl	le earth wire	
	•	ACSR, dc resistance < 0,5 Ω/km	0,70
	•	19/2.7 mm steel, dc resistance < 2,0 Ω/km	0,90
	•	7/3.51 mm steel, dc resistance < 3,0 $\Omega$ /km	0,95
b)	doub	ble earth wire	
	•	ACSR, dc resistance < 0,5 Ω/km	0,55
	•	19/2.7 mm steel, dc resistance < 2,0 Ω/km	0,80
	•	7/3.51 mm steel, dc resistance $< 3.0 \Omega/km$	0,85

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		Screening factor of	Screening factor
MV/H	IV cable	s (sheath cross section in mm <sup>2</sup> )	
a)	lead	sheath cable (PILC)	
	•	11 kV - 44 kV, 200 mm <sup>2</sup>	0,8
	•	66 kV - 132 kV, 240 mm <sup>2</sup>	0,7
b)	alum	ninium sheath cable (XLPE)	
	•	11 kV - 44 kV, 200 mm <sup>2</sup>	0,3
	•	66 kV - 132 kV, 240 mm <sup>2</sup>	0,2
infras	structur	e	
a)	urban	environment (urban factor, k <sub>u</sub> )	
	•	soil resistivity 10 $\Omega$ .m – 150 $\Omega$ .m	0,45
	•	soil resistivity 150 $\Omega$ .m – 1500 $\Omega$ .m	0,35
	•	soil resistivity 1500 $\Omega$ .m – 10000 $\Omega$ .m	0,25
b)	rural e	environment	1,0

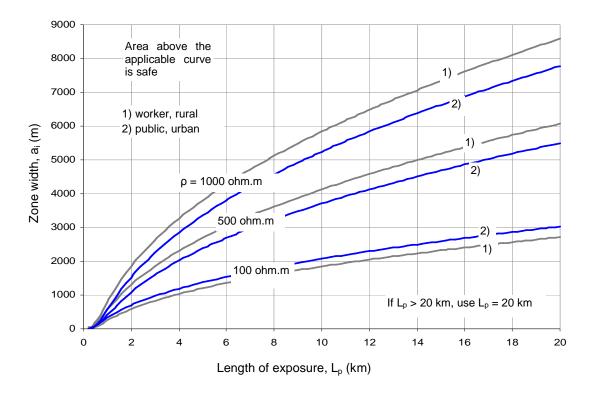


Figure 4: Separation distance vs. exposure length for urban and rural overhead lines (10 kA earth fault, 0.2 sec duration)

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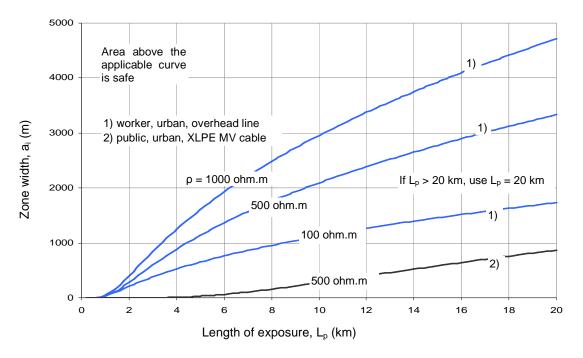


Figure 5: Separation distance vs. exposure length for urban power lines (10 kA earth fault on overhead line, 0.2 sec duration) (360 A earth fault on MV cable, 20 sec duration)

### 3.4.2.2 ZOI from substation earthing grids and power lines due to conductive coupling

#### a) Power arc

A fault initiated by a lightning strike to a tower or overhead earth wires can produce a sustained arc between the tower footing or earthing grid and any coating defect on the pipeline, which can melt the pipeline steel and rupture the pipeline wall. From research performed by the Canadian Electricity Association and Powertech Labs (Inc), this can occur when the separation distance is smaller than  $S_{arc}$  given by the equation:

$$S_{arc} = 0.1058 \cdot V - 0.0137$$
 [m]

Here V is the voltage of the tower or earthing grid during a fault, in kV r.m.s. Earthing grids are usually designed not to exceed 5 kV, and on towers with earth wires the voltage will rarely exceed 30 kV r.m.s. Adopting a maximum value of 40 kV r.m.s. to include any inductive coupling effect, yields the minimum allowable separation distance between pipelines and earthing grids or towers equipped with earth wires, to prevent a power arc:

$$S_{arc} = 0.1058 \cdot 40 - 0.0137 = 4.22$$
 [m]

The voltage on towers without earth wires can exceed 40 kV r.m.s. during a fault and in this case, the full phase to earth voltage should be applied in Eqn. (3).

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### b) Earth potential rise

It is also necessary to consider the safety aspect of the earth potential distribution around the faulted tower or grid during an earth fault. With the normal pipeline potential being close to the reference potential of remote earth (i.e. zero potential), the full EPR at the location of the pipeline is applied across its coating, or to a person in simultaneous contact with the pipeline and earth. The unsafe zone extends to a distance where the EPR has reduced to safe levels (see Fig 6).

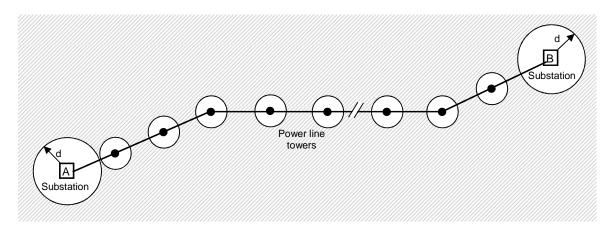


Figure 6: Zone of influence for conductive coupling

The zone size is dependant on the magnitude of the fault current, the resistance of the earthing grid or tower footing, the resistivity of the soil, the fault duration and the corresponding voltage limit. Earth wires on power lines decrease the fault resistance which increases the fault current magnitude, but by distributing this current to multiple towers decrease the zone size for individual towers.

Table 4: Zone of influence for conductive coupling from substation earthing grid (0.2 s fault duration)

Earthing grid dimensions m and EPR assumed during a fault	Zone distance d from edge of earthing grid [m]  Exposure / environment					
	urban	rural	urban	rural		
10 m x 10 m 10 kV	120	260	57	140		
30 m x 30 m 10 kV	340	780	172	400		
50 m x 50 m 10 kV	570	1 300	290	670		
200 m x 200 m 5 kV	1 100	2 600	500	1 300		
500 m x 500 m 5 kV	2 700	6 400	1 300	3 300		

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Table 5: Zone of influence for conductive coupling from power line towers (0.2 s fault duration)

Type of earth wire(s) on power line	Soil resistivity [ohm.m]	Fault current assumed [kA]	Zone distance d from tower footing [m]				
			Exposure / environment				
			General public 160 V r.m.s. limit		Authorized personnel 300 V r.m.s. limit		
			urban	rural	urban	rural	
none (see note)	50	0,36	10	20	6	13	
	500	0,36	60	180	32	95	
	5 000	0,03	80	300	38	152	
steel	50	10	110	240	57	125	
	500	10	160	460	82	230	
	5 000	10	160	650	97	330	
ACSR	50	10	40	80	20	44	
	500	10	55	150	25	76	
	5 000	10	55	220	32	114	
NOTE: Applicable to	MV power lines of	nly.		<u>'</u>		1	

The pre-calculated values of Table 4 should be applied for earthing grids of a.c. substations, and the pre-calculated values of Table 5 for power line poles, masts or towers. These values were calculated using ITU-T REC K.68 methodology. A touch voltage limit of 160 V r.m.s. and 300 V r.m.s. is used for public and authorized exposure respectively, as applicable for a 0.2 sec fault duration.

For other voltage limits, the zone distances in Table 4 and Table 5 can be changed in direct proportion. For example, from Table 5, the zone distance d for a power line tower with steel earth wires in a rural area with 500 ohm.m soil is 460 m, for public exposure. Supposing that a fault duration of 0.5 seconds is applicable, the exposure limit is reduced from 160 V r.m.s. to 60 V r.m.s (see Table 1). The zone distance d then becomes:

d = 460.160/60 = 1.227 m

In the case of fault current levels other than those indicated in Table 5, the zone sizes are changed in a similar manner. Thus, for the example above, if the actual fault current level is not 10 kA but 5 kA, the zone distance d becomes:

d = 1 227.5/10 = 614 m

### 3.4.2.3 ZOI from overhead power lines due to capacitive coupling

Capacitive coupling is only of consequence for pipelines or sections of pipeline above ground and insulated from earth. Normally this is limited to construction activity, for example during lifting and lowering in operations of coated pipeline sections, or sections stored on skids. Underneath power lines, large electrostatic voltages can develop on such sections, which can discharge to earth through a person coming in contact with the section.

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The power – to – pipeline capacitance (and hence the energy transferred by this mechanism) is however very small, and when the safety distances (see 3.8) are observed, the discharge current limit for authorised personnel of 10 mA r.m.s. will not be exceeded for sections of normal length. Still, it could be discernable as a shock similar to that from electrostatic electricity, and could cause a secondary safety hazard if someone working on the pipeline overreacted to this sensation. Moreover, metal contact would produce a spark that could ignite a fuel vapour.

For long, insulated pipelines installed above ground on plinths alongside or underneath power lines, the discharge current could reach 10 mA r.m.s. for lengths in excess of 200 m. This can however be readily mitigated by earthing; even a relatively high resistance earth (100 ohm - 200 ohm) will totally neutralize any capacitive coupling hazard.

The zone of influence is in this case limited to the power line servitude.

### 3.4.2.4 ZOI from anode ground beds and pipelines due to d.c. leakage

### a) Anode ground beds

For homogenous soil, the distance d, from an anode comprising a single horizontal or vertical conductor installed a coke backfill, beyond which the d.c. potential of the soil will be below the 200 mV limit may be calculated using the equation:

$$d = 2.5 \cdot V_a \cdot (L_a)^{0.65}$$
 [m]

where:

V<sub>a</sub> is the maximum d.c. voltage applied to the anode [V],

L<sub>a</sub> is the length of the anode [m].

With the anode length adjusted according to soil resistivity, the distance d can vary from a few hundred metres in low resistivity soils to several kilometres in high resistivity soils, for typical CP current requirements.

### b) Pipelines

Considering a semi-infinite, straight, ICCP - protected pipeline with evenly distributed coating defects, buried at 1 m depth in homogenous soil, the difference  $\Delta U$  in the surface potential between two points, one separated by x [m] and one separated by x + s [m] from the pipeline for x  $\geq$  1m, is given by Eqn (5):

$$\Delta U = J \cdot \rho \cdot d \cdot \left[ ln(x+s) - ln(x) \right]$$
 [V]

$$= J \cdot \rho \cdot d \cdot ln \left( \frac{x+s}{x} \right)$$
 [V]

where:

- J is the protection current density, [A/m²],
- ρ is the soil resistivity, [ohm.m],
- d is the pipeline diameter, [m],
- s is the span distance between subsequent towers, [m].

For a d.c. potential shift limit of 200 mV at the tower footing, the minimum potential difference  $\Delta U$  over a full span is 200 mV. The resulting minimum lateral distance x to be applied for a power line with 400 m spans approaching the pipeline diagonally, is as indicated in Table 6, for a large-bore (1 m diameter) pipeline, as a function of protection current density and soil resistivity:

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Table 6: Zone of influence for d.c. leakage (1 m ø pipe, diagonal crossing, 400 m span)

Zone distance from pipeline [m] for soil resistivity of					
50 Ω.m	500 Ω.m	1000 Ω.m	5000 Ω.m		
no influence	no influence	no influence	10		
no influence	no influence	10	330		
no influence	10	65	820		
no influence	330	820	see Note		
10	820	see Note	see Note		
330	see Note	see Note	see Note		
	no influence no influence no influence no influence	$\begin{array}{c c} & & & & & \\ \hline 50 \ \Omega.m & & 500 \ \Omega.m \\ \hline \text{no influence} & & \text{no influence} \\ \hline \text{no influence} & & \text{no influence} \\ \hline \text{no influence} & & 10 \\ \hline \text{no influence} & & 330 \\ \hline 10 & & 820 \\ \hline \end{array}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		

Note: with normal CP voltages, this current density cannot be achieved in this soil

When the power line does not approach the pipeline diagonally, the full span distance s [m] is replaced by the lateral separation increase or decrease of subsequent towers; the zone distance is then decreased.

The protection current density is determined not as much by the resistivity of the coating material, as by the imperfections and defects in the coating and joints (see 3.6.5). Bitumous coatings are prone to such imperfections and also to water absorption, which can increase current demand with the age of the pipeline. The protection current density for existing bitumen and tape wrap, 40-year old Transnet pipelines can reach up to 5 000  $\mu$ A/m2 in low soil resistivity regions.

With modern pipeline coatings of high mechanical strength (e.g. polyurethane or polyethylene) usually only a few widely spaced defects occur. A current density in the range 10 - 50  $\mu$ A/m2 is regarded as normal, although 500  $\mu$ A/m2 is usually allowed for in the CP system design.

### 3.5 Soil Resistivity Measurements

### 3.5.1 General background

The value of the soil resistivity has a significant influence on the level of conductive and inductive coupling. Calculations for voltages resulting from inductive coupling at 50 Hz can be in error by up to 100% if the soil resistivity value is incorrect. Conductive coupling is even more sensitive to the soil resistivity and the possible error is much larger.

Soil resistivity can vary from about 10 ohm.m to 10 000 ohm.m depending on the type and age of the formation. With electrical conduction in soils being largely electrolytic, it is also considerably affected by the amount of soluble salts and other minerals present. It increases abruptly when the moisture content drops below 15 % the soil's weight, or when the soil temperature drops below freezing point.

With Southern Africa's temperate climate, ground frost to any significant depth is not common, and the worst inductive or conductive coupling usually occurs in the dry season, i.e. when soil resistivity is at its highest. This is therefore the preferred time for measurements. When measurements are done outside this season, allowance should be made for seasonal variation of the soil resistivity.

Soil is very rarely homogenous in a given area, it is more likely to exhibit variation with depth owing to layers of different type and structure, referred to as stratification. Stratification can increase the size of the ZOI resulting from conducted coupling, particularly when thin layer(s) of low resistivity overlay high resistivity bedrock. Lateral changes also occur, but in comparison to the vertical ones, these changes usually are more gradual.

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Numerous tables can be found in the literature that provide soil resistivity ranges based on the type of soil formation. The use of such tables is generally not recommended for coupling studies, partly due to the possibility of stratification which is not visible from the surface, and partly due to the possible incorrect assessment of the soil type due to lack of experience.

#### 3.5.2 Measurement methods

For inductive and conductive coupling calculations, the soil resistivity measurement method used has to penetrate into the deep soil layers to establish if there are any important variations of resistivity with depth. The Wenner four - probe method as described in SANS 10199 (2004), par 3.2.2 or in IEEE 80 (2000), par 13.3 is the simplest and most commonly used method. The probe spacing should be according to tables 7 - 9, depending on the situation under study.

With the Wenner method, soil resistivity soundings at a given probe spacing provide a measure of the apparent resistivity,  $\rho_a$ , taking into account soil layers to a depth of about 80 % of the probe spacing. Unless the soil is homogenous, this apparent resistivity will not be constant with increasing depth.

From the apparent resistivity soundings it is then possible to deduce how many soil layers are present, and what the thickness and resistivity of each of these layers is. A typical example is shown in Fig 7. This relatively complex calculation generally requires the use of computer software (see 3.6.2.c). Graphical curve-matching methods as outlined in SANS 10199 and IEEE 80 may also be used, but are limited to simple soil compositions comprising no more than 2 layers.

Table 7: Wenner soil resistivity soundings for inductive coupling studies

Probe spacing a [m]	Specific depth D = 0.8·a [m]	Tester reading R [ohm]	Geometric factor K= 2π·a [m]	Apparent resistivity ρ <sub>a</sub> = K·R [ohm.m]
0.5	0.4		3.14	
1	0.8		6.28	
3	2.4		18.85	
10	8		62.83	
20	16		125.7	
30	24		188.5	
50	40		314.2	
70	56		439.8	
100	80		628.3	
120	96		754.0	

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Table 8: Wenner soil resistivity soundings for conductive coupling studies

Probe spacing a	Specific depth D = 0.8·a	Tester reading R	Geometric factor K= 2π·a	Apparent resistivity
[m]	[m]	[ohm]	[m]	$\rho_a = K \cdot R \text{ [ohm.m]}$
0.5	0.4		3.14	
1	0.8		6.28	
2	1.6		12.57	
4	3.2		25.13	
10	8		62.83	
20	16		125.7	
30	24		188.5	

Table 9: Wenner soil resistivity sounding for soil corrosivity studies

Probe spacing a	Specific depth D = 0.8·a	Tester reading R	Geometric factor K= 2π·a	Apparent resistivity
[m]	[m]	[ohm]	[m]	$\rho_a = K \cdot R \text{ [ohm.m]}$
2	1.6		12.57	

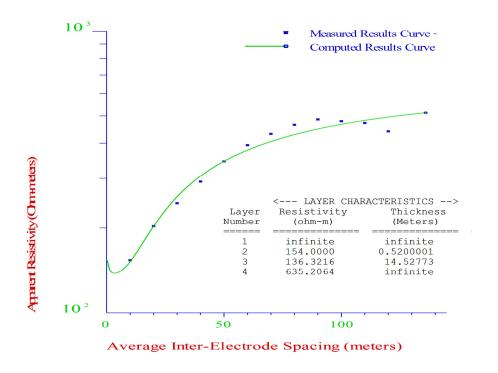


Figure 7: Example of apparent resistivity graph and calculated soil layers

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A further development of the Wenner method is CVES (Continuous Vertical Electrical Sounding), which uses a much larger linear array of probes and enables the calculation of two-dimensional soil resistivity map, used for example to identify underground water, mineral pockets etc. This level of detail cannot be used in current power line / pipeline coupling software, however the raw data from the array can be averaged for each specific sounding depth and these averages analysed similar to Wenner soundings, resulting in improved accuracy.

When used for inductive or conductive coupling studies, a typical CVES array would consist of 36 probes at 10 m intervals, providing penetration ranging from about 8 m to 100 m. To determine the surface resistivity, a measurement with the probes at 0.5 m intervals is also required, or alternately three conventional Wenner measurements at 0.5 m, 1 m and at 3 m probe spacings.

Another alternative, non – invasive method for measuring subsurface resistivity employs inductive electromagnetic (EM) probes. Without the requirement of contact with the soil, these devices can be mounted on a vehicle trailer facilitating fast readings with high spatial resolution. Penetration depth typically varies from 1.5 m to 4.5 m, depending on coil spacing and polarization. EM probes are generally not suitable for deep soil resistivity measurements.

#### 3.5.3 Selection of measurement sites

The selection of sounding sites depends on the study under consideration.

- a) For inductive coupling studies, the distance between DSR sounding sites along a parallelism should not exceed 5 km. For short parallelisms (< 10 km) this should be reduced to 2 km, to ensure a better average. These soundings should be done with the probe array perpendicular to the power line axis and centred near this axis, well away from the power line towers and guy wires (preferably at midspan).
- b) For conductive coupling studies where no parallelism is present, only a single DSR sounding site is required. The probe array should start near the centre of the side of the substation grid or tower footing facing the pipeline, at a point separated some 10 m from the substation fence or footing and move perpendicularly outwards.
- c) For soil corrosivity studies, surface resistivity measurements are recommended at intervals not exceeding 100 m, along the intended pipeline route. In wet, water logged or clay areas, the interval should be reduced to 50 m. Whilst these measurements are not essential for safety calculations, they are essential for an assessment of the corrosion risk and the design of the cathodic protection and monitoring systems. They can also be very useful in the design of a.c. mitigation measures, possibly leading to significant savings in the total length of gradient wire required.

## 3.5.4 Measurement precautions

- a) Avoid sounding sites with the probe array parallel or quasi-parallel to metallic structures such as fences, existing pipelines, underground cables, railways, earthing grids or other man-made structures if possible. If the site has to cross a pipeline or fence, the sounding should be done with the probe array perpendicular to the pipeline or fence.
- b) Where possible, the direction of the array should be parallel to the geological strike of the site. The direction of the strike will usually be shown by lines of outcropping rock (ref. SANS 10199).
- c) Wenner soundings should be analysed on site to enable identification of measurement errors, due for example to leakage, anomalous effects at the probes, a.c. induction, damaged leads etc. If the apparent resistivity is above 10 000 ohm.m or below 10 ohm.m, or differs greatly from a given trend in geologically similar conditions, the sounding should be regarded as suspect.
- d) To ensure adequate measurement resolution with pin spacings of 30 m and larger, the instrument used for Wenner soundings should have a rating of at least 600 V / 2.5 A.
- e) Inductive EM probes may be subject to interference near power lines due to corona noise or power line carriers in the frequency band of the instrument's receiver.

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#### 3.6 Calculation of pipeline voltages

#### 3.6.1 General

A metallic pipeline subject to inductive influence can be modelled by multiple discrete sections, each consisting of a series impedance representing the resistance and inductive reactance of the metal casing, a shunt impedance representing the leakage resistance and capacitive reactance, and a voltage source representing the emf developed in the section by the power line currents, which may be calculated with the formulas developed by Carson and Pollaczek.

In this form the pipeline closely resembles a leaky transmission line, and the theory for calculating the currents and voltages on transmission lines can be effectively applied. In this sense, the transmission line concepts of propagation constant, electric length and characteristic impedance also become valid for a pipeline.

This model further enables the study of mitigation measures. For instance, an earthed electrode connected to the pipeline at a given point will reduce the corresponding section's shunt resistance to earth, whereas an insulating flange in the pipeline will increase the section's series resistance. By altering these resistances accordingly in the model, the effect of the measure(s) on the pipeline currents and voltages can be readily observed.

The effect of capacitive coupling can be predicted using the Maxwell potential coefficient method. This is necessary only for above-ground pipelines or pipeline sections inside the servitude without regular earthing points.

The effect of conductive coupling can be modelled using the concept of an equivalent hemispheric electrode for the tower footing or earth grid under study, although this method provides only limited accuracy near the electrode, or when the soil is stratified. More detailed, finite element computer models take account of the exact shape of the electrode and the soil layers, and can accurately predict the potential transfer to a pipeline, and its dissipation with distance from the region of injection.

The theory of capacitive, inductive and conductive coupling is comprehensively covered in CIGRE Guide 95, "Guide on the Influence of High Voltage AC Power Systems on Metallic Pipelines".

In general, for realistic exposures, analysis of the respective coupling components requires the use of suitable computer software.

#### 3.6.2 Software packages

A number of software packages for the calculation of the voltages on pipelines subject to power line coupling are commercially available. Software selected for this purpose should meet the following minimum requirements:

- a) Inductive coupling calculations:
  - calculation of pipeline voltage and currents during steady state nominal and emergency load conditions with a single or with multiple adjacent power line(s),
  - calculation of pipeline voltage and currents during fault conditions at any point on the power line.
  - account for tower configuration, conductor sag, earth wires and phase transpositions,
  - capable of modelling and optimising the performance of earthing points, insulating flanges, gradient control wires, drainage units, sacrificial anodes and resistive bonds on the pipeline.
- b) Capacitive coupling calculations:
  - calculation of the voltage of pipelines above ground subject to capacitive coupling from an overhead power line.

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c) Conductive coupling calculations:

- · calculation of multi-layer soil model from resistivity measurements,
- earth potential rise (EPR) around a faulted tower or substation grid,
- step potential, touch potential and coating stress on a pipeline traversing the EPR zone.
- d) d.c. leakage calculations:
  - calculation of the d.c. potential distribution around ICCP-equipped pipelines and ground beds.
- e) Fully benchmarked against known calculation or measurement results.

For proper utilisation of these software packages, training of personnel through courses approved by the software developer are essential. Personnel using the software should also have fundamental training in electrical power networks, fault current calculations and electromagnetic coupling phenomena.

#### 3.6.3 Inducing currents on a.c. power lines

#### 3.6.3.1 Currents during normal operation

#### a) Phase conductor ratings

For inductive coupling calculations under normal operating conditions, the maximum rated current of the power line should be applied as inducing current. This rating is a function of the type and number of subconductors in the bundle. Table 10 indicates the rating for standard Eskom overhead conductor types, from DST 32-319 [13].

Rate A is the maximum operating current for normal load conditions, and is used for calculating the pipeline voltage when checking against the limit for a.c. corrosion (3.3.7). Rate B is the maximum operating current for emergency load conditions, and is used for calculating the pipeline voltage when checking against the safety limit (3.3.4).

For XLPE and PILC cables, the conductor ratings depend on the copper cross section as well as the configuration (trefoil, single core or three core) and applicable de-rating factors, depending on the method of installation. These ratings should be obtained from the relevant department in Eskom on a case-by-case basis.

#### b) Applying phase unbalance

The magnitude of the individual phase currents on 3-phase power lines normally lines differ slightly due to different loading per phase. This introduces a zero-sequence current that has to return through the earthing system of the power line. Zero-sequence or earth return currents can cause inductive coupling over much greater distances than the balanced component.

Local quality of supply standards recommend a maximum of 3% phase current unbalance in supply networks (ref. NRS048-2). For pipeline coupling calculations, an unbalance of 3% may hence be assumed. This can be applied directly to the magnitude of one of the phase currents.

For example, from Table 5, the emergency load current per Dinosaur sub-conductor is 1 380 A r.m.s, i.e. 4 140 A r.m.s. for a 3- conductor bundle. The resulting emergency phase currents on a RWB – sequence circuit with Triple Dinosaur phase conductors will be:

Red phase: IR =  $4 \cdot 140 + 3\% = 4 \cdot 264 \text{ A r.m.s}$ , angle  $0^{\circ}$ 

White phase: IW = 4 140 A r.m.s, angle -120° Blue phase: IB = 4 140 A r.m.s, angle 120°

This method is sufficiently accurate even though the precise definition of phase unbalance is slightly more complex (see 3.1 in NRS048-2).

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#### c) Effect of transpositions

Transpositions place a different phase closest to the pipeline, normally with the result that, during steady-state induction, the induced pipeline emf is around 120° out of phase on either side of the transposition. This produces a pipeline voltage maximum at the transposition.

Because of this important effect on the pipeline voltage profile, it is essential that transpositions are accounted for and that the correct sequence change is applied (a RWB – BRW transposition will have a different effect than a RWB – WRB transposition, for example).

Table 10: Standard Eskom overhead conductor ratings (50°C), from DST 32-319 [13]

Conductor type	Overall diameter [mm]	d.c. resistance at 20°C [ohms]	Rate A [A r.m.s.] (see Note)	Rate B [A r.m.s.] (see Note)
Tiger	16.52	0.2202	322	466
Wolf	18.13	0.1828	363	528
Lynx			401	584
Chickadee	18.87	0.1427	608	823
Panther	21.00	0.1363	441	642
Pelican	20.70	0.1189	475	698
Bear	23.45	0.1093	521	767
Kingbird	23.90	0.0891	586	831
Goat	25.97	0.0891	618	866
Tern	27.0	0.0718	665	963
Zebra	28.62	0.0674	710	1022
Bunting			881	1324
Dinosaur	35.94	0.0437	938	1380
Beresford	35.56	0.0421	965	1420
Antelope	26.73	0.0773	628	921
Rail	29.59	0.0598	765*	1063*
Squirrel	6.33	1.3677	104	143
Fox	8.37	0.7822	148	203
Mink	10.98	0.4546	206	285
Hare	14.16	0.2733	280	392
Magpie	6.35	2.707	33	40
Acacia	6.24	1.39	108	153
"35"	8.31	0.785	158	216
Pine	10.83	0.462	219	302
Oak	13.95	0.279	297	417
Ash	17.4	0.184	381	548
Yew	28.42	0.0696	761	1073
Sycamore	22.61	0.11	549	775
Elm			424	625

**NOTE:** Multiply the rated current by the number of sub-conductors in the bundle

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### d) Phase sequence of double circuit power lines and multiple power lines

On double circuit power lines, there are six possible phase configurations of the second circuit with respect to the first circuit. Assuming the latter to be RWB, the combinations are RWB-RWB, RWB-BRW, RWB-WBR, RWB-BWR and RWB-RBW. The emf induced on the pipeline will be increased or decreased depending on the relative position of the corresponding phases.

Theoretically the highest emf will occur when the phase configurations in both circuits are the same (RWB-RWB), whist for the one or more of the other combinations, a cancellation or reducing effect can occur. This must however be investigated for each specific case, as it is dependant on the tower geometry and the relative position of the pipeline.

Changing the phase configuration of double-circuit lines to minimise induction is normally not a viable mitigation option except possibly on new lines, in which case it must be ensured that no changes (e.g. transpositions) will occur on the line over the operational life of the line.

A more conservative approach is to allow for changes in phase configuration, by selecting the worst-case phase combination and designing the pipeline mitigation accordingly. Assuming identical conductor characteristics on the two circuits, the worst-case double circuit induction level may be obtained by doubling the emf induced in the pipeline by the nearest circuit.

For pipelines in servitudes with multiple power lines, the worst-case phase combination must similarly be accounted for. With three or more power lines however, the number of possible combinations to simulate increases greatly. A compounding factor for power lines operating from different busbars is the phase angle of the zero sequence currents, which is a function of the phase unbalance and can be different on each individual line. The worst case would be when all the zero sequence currents are in phase, whilst out-of-phase zero sequence currents would result in reduced induction levels.

For multiple power lines it is therefore simpler to establish the worst case combination by starting with the line nearest to the pipeline (or the line with the greatest overall influence) and assigning a RWB phase sequence. The next nearest line then added and the phase sequence of this line adjusted until maximum pipeline voltage is obtained, and then remains fixed. This process is repeated for all lines, each time without any further adjustment of the previous lines.

For all lines, the unbalance is applied to the same phase (e.g. Red).

This procedure effectively ensures the worst-case combination of phases and in-phase addition of all emfs produced by the zero-sequence currents.

### 3.6.3.2 Currents during faults

#### a) Sliding fault current profile

On a typical ring-fed power line, the inducing current magnitude is at a maximum for a fault near the substations feeding the line, and at a minimum near the middle of the line, due to the increased line impedance with distance to the fault. This impedance gives rise to the sliding fault current profile of the power line (see Fig 8).

At the substations, the fault level is determined by the equivalent source impedance, which represents the sum of all impedances of the network between that point and the power generating station(s). In a 3-phase system, this impedance may be represented by its positive, negative and zero sequence components. The sequence components can be calculated for any substation in the network with power systems analysis software such as PSS/E or PowerFactory.

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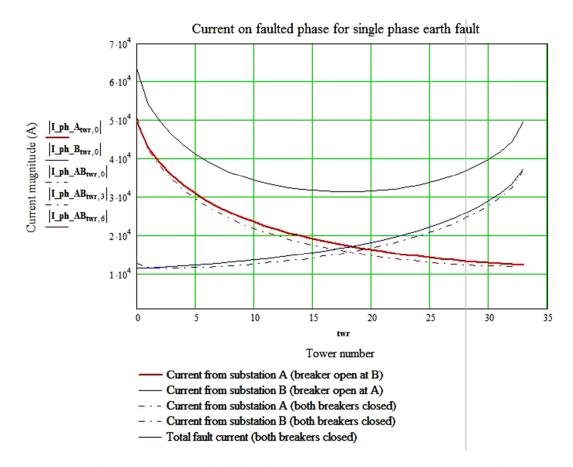


Figure 8: Example of sliding fault current vs. tower number, 220 kV line

To compute the sliding fault current for a given line, the substation's equivalent source impedances are required without this line in place. The line's circuit breakers must therefore be temporarily opened in the analysis software when the equivalent source impedances are computed.

With the substation's equivalent source impedances and the line data (tower configuration and conductor data, checklist A.3) available, the sliding fault current profile can be computed using suitable software. The sub-conductor's radius and d.c. resistance is provided in Table 10. Only a 1- phase to earth fault needs to be considered, since the residual currents during 2- and 3- phase to earth faults will be of a smaller magnitude.

#### b) Currents producing tower footing EPR

In power lines equipped with earth wires, the returning fault current is distributed between the faulted tower and the footings of adjacent towers by the earth wires. Some of the current never enters the earth, being carried back to the substation along the earth wires. When calculating the earth potential rise around a tower therefore, this division of the current has to be carefully established. The nominal tower footing resistance in terms of Transmission standard TST41-321 [7] as indicated in Table 11 and the diameter and d.c. resistance of commonly used earth wires, is given in Table 12.

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Table 11: Nominal tower footing resistance (maximum)

Voltage rating [kV]	Nominal footing resistance [ohm]
132	20
220	30
275	30
400	40
765	50

Table 12: d.c. resistance of standard Eskom earth wires

Conductor type	Overall diameter [mm]	d.c. resistance at 20°C [ohms]
7/3.51 mm steel	10.53	2.86
19/2.7 mm steel	13.48	1.80
OPGW(48 core)	17.50	0.220
Horse ACSR	13.95	0.394
Tiger ACSR	16.52	0.220

The nominal footing resistances increase with voltage rating due to the back-flashover rate required for power lines, and may be regarded as an upper limit. Actual footing resistance can be much lower, particularly for large towers with extensive foundations.

An example for of the calculated current distribution of a 15 kA fault on a horizontal 132 kV line with 2  $\times$  7/3.51 mm steel earth wires is shown in Fig 9.

For this example, which has typical values for the tower footing resistances and substation earth mat resistance, the current  $I_F$  entering the earth through the faulted tower's footing is less than 13% of the total fault current. This is the fraction of the fault current that has to be considered in the calculation of EPR around the faulted tower.

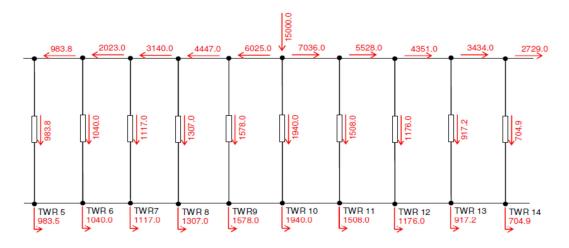


Figure 9: Example of current distribution for a 15 kA fault on the 10th tower of a 132 kV line

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#### c) Currents producing substation EPR

If there is 1- phase to earth fault in or near a substation, the current  $I_E$  flowing through the earthing system of the substation causes the EPR. This current is always smaller than the substation's rated fault level,  $I_d$ , because a significant portion returns through the earth wires (see Fig 10).

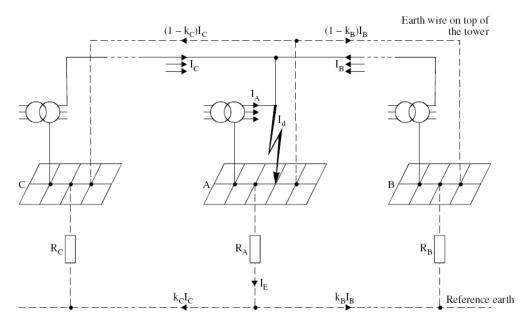


Figure 10: Calculation of electrode current, I<sub>E</sub>, with a fault inside a substation (from ITU-T Directives, Vol II [30])

There are also two components of  $I_E$ , namely the transformer's contribution and the system's contribution. One of them is decisive from the point of view of EPR.

If the earth fault occurs within the substation, the transformer's contribution circulates in the station and never enters the earth, hence only the zero-sequence currents coming from the system outside the station in question can cause EPR.

In this case, the current through the earth (i.e. the current from the network flowing through the earthing resistance  $R_A$  of the station) is given by Eqn (6):

$$I_{E} = \sum_{i=1}^{N} \mathbf{k}_{i} \cdot \mathbf{I}_{i} \tag{6}$$

where

N is number of the lines entering the station,

k<sub>i</sub> the screening factor of the respective lines (see below), and

Ii the fault current of the line i

If the earth fault occurs outside the substation, the EPR is caused by the zero-sequence current which the station itself feeds into the fault as well as the zero-sequence currents from the system, taking into account the different screening factors (see Fig 11).

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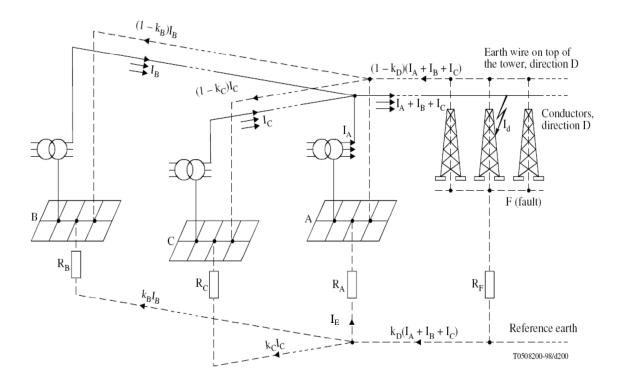


Figure 11: Calculation of electrode current,  $I_E$ , with a fault outside a substation (from ITU-T Directives, Vol II [30])

If N-1 is number of the lines entering the station excluding the faulted line, the current flowing through the earthing impedance of the station is given by Eqn (7):

$$I_{E} = k_{D} \cdot I_{A} + \sum_{i=1}^{N-1} (k_{D} - k_{i}) \cdot I_{i}$$
 [A]

where

k<sub>D</sub> is the screening factor of the faulted line,

k<sub>i</sub> is the screening factor of the remaining lines feeding the station,

I<sub>A</sub> is the fault current supplied by the substation transformer [A],

Ii is the fault current of the line i [A].

Depending on the amount of current provided by remote stations relative to the current provided by the local transformer, the decisive location of the fault may be either inside the substation or outside. Both situations should be evaluated to determine the worst case EPR at the substation of interest.

In step-down substations, this evaluation should be done on the side of the station transformer which results in the highest fault current. Depending on the transformer rating, this can occur on the lower voltage level.

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#### 3.6.3.3 Determination of the most hazardous location(s) of a power system earth fault

#### a) Conductive coupling only

For conductive coupling, an earth fault at the mast or tower closest to the pipeline will normally produce the highest coating stress, however all masts or towers with a ZOI overlapping the pipeline route need to be considered individually, taking due account of the power line's sliding fault current and the local soil conditions.

#### b) Inductive coupling only

For inductive coupling, the worst location for an earth fault is usually at one end of the exposure. In Fig 12, a fault at position Y will expose the entire pipeline X-Y to a fault level  $I_Y$ , resulting in the highest induced voltage from substation A. The current from substation B will give the highest induced voltage at the fault position X, exposing the entire pipeline to a fault level  $I_X$ . Since  $I_Y$  is larger than  $I_X$ , a fault at position Y will give the worst case.

Should the fault occur between X and Y, the fault level from each side would be higher than  $I_X$  and  $I_Y$ , however the pipeline is only partially exposed. With both breakers closed, the currents flow in opposite directions and the emfs developed in the pipeline will be 180 $^{\circ}$  out of phase, resulting in an overall reduction of the induced voltage.

When the pipeline extends beyond substations A or B, point X or Y will move directly opposite substation A or B and the worst case will result from a fault at substation A or B, respectively.

Breakers at substation A and B will usually not open and auto-reclose at precisely the same instant, and at a given instant following the insulation breakdown, the fault may be fed from substation A only, from substation B only, or from both substations. From the viewpoint of inductive coupling, the highest coupling will occur with the fault fed from one (highest) end only. From the viewpoint conductive coupling, the highest EPR around a tower structure will occur with a fault fed from both ends.

For more complex situations, it may be necessary to calculate the pipeline voltage for a number of possible fault locations, to confirm the worst position.

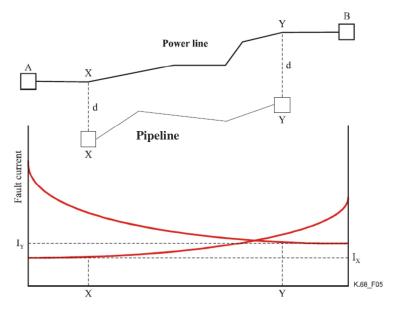


Figure 12: Finding the worst fault position location on arbitrary exposures (adapted from ITU-T Rec K68 [31])

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#### c) Conductive and inductive coupling

For conductive coupling from a power line encroachment that also contains a parallelism, the coating stress is the vector sum of the inductive and conductive coupling effects. The voltage profile produced by inductive coupling must then be established first (see 3.6.6) and considered in combination with the faulted tower's EPR, to determine where the highest pipeline coating stress will occur.

#### 3.6.4 Inducing currents on HVDC power lines

HVDC fault or load currents do not produce any inductive coupling, however, during the transient when the current changes from normal to fault level, or during operational switching transients, inductive coupling will occur. This coupling is proportional to the rate of change of the current and can produce considerable pipeline voltages.

The rate of change (dl/dt) is dependant on the impedances inherent to the power line. For HVDC lines of normal construction, the induced transient voltages can be closely approximated by applying a 50 Hz steady state current with a magnitude corresponding to the transient. The d.c. current is replaced by an a.c. waveform with a peak value equal to the d.c. voltage (or Va.c. r.m.s. = 0.707 Vd.c.). The d.c. circuit can be either monopolar (earth return) or bipolar, and the a.c. current should be applied accordingly.

Tests conducted on a pipeline parallel to the Apollo-Pafuri HVDC lines showed that switching transients actually produce higher voltages than earth faults. It was also observed that the duration of switching transient's peak can exceed 0.2 sec, with some ringing occurring even after 1 sec [32].

The permissible touch voltage should therefore be based on an event duration of 1 sec, and the worst condition considered is a switching transient from 0 A to the line's maximum current capacity.

HVDC converters also produce steady state harmonic currents, that can couple inductively with the pipeline. A 6 – pulse converter such as Apollo for example, produces a 6<sup>th</sup>, 12<sup>th</sup> and 18<sup>th</sup> current harmonics (300 Hz, 600 Hz and 900 Hz) on the d.c. side. Their magnitude is however limited by means of harmonic filters, typically to less than 0.2% of the load current, and the resulting pipeline voltages do not pose any significant safety hazards.

#### 3.6.5 Pipeline coating resistivity

The variation in coating resistivity, thickness and specific resistance of commonly used pipeline coatings is indicated in Table 13:

Table 13: Typical variation of coating resistivity and thickness

Coating material	Laboratory resistivity [ohm.m]	Field resistivity, minimum [ohm.m]	Field resistivity, maximum [ohm.m]	Coating thickness [mm]	Specific resistance [ohm.m²]
Bitumen	> 10 <sup>12</sup>	0.2 x 10 <sup>6</sup>	2 x 10 <sup>6</sup>	4 – 10	$0.8 \times 10^3 - 20 \times 10^3$
Polyethylene (e.g. 3LPE, MDPE)	10 <sup>16</sup>	20 x 10 <sup>6</sup>	200 x 10 <sup>6</sup>	0.8 – 4.0	$16 \times 10^3 - 0.8 \times 10^6$
Fusion-bonded epoxy (FBE)	10 <sup>13</sup>	2 x 10 <sup>6</sup>	20 x 10 <sup>6</sup>	0.3 – 0.5	$0.6 \times 10^3 - 10 \times 10^3$
Polyurethane (rigid PU, 2-component PU)	10 <sup>14</sup>	20 x 10 <sup>6</sup>	200 x 10 <sup>6</sup>	0.4 – 3.0	$8 \times 10^3 - 0.6 \times 10^6$

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Resistivities of coatings in field conditions are considerably lower than the same material under laboratory conditions, due to defects or holidays in the coatings, poorly coated fittings, defects in the coating of the field joints and moisture absorption. For bitumous coatings in particular, the resistivity has a tendency to decrease over time.

Pipelines with low resistivity coatings will exhibit lower induced voltages than pipelines with high resistivity coatings (see 3.6.9). For calculations related to safety and a.c. induced corrosion, the highest expected resistivity value should be applied. For d.c. leakage calculations however the lowest expected value should be used, since the cathodic protection current increases with decreasing resistivity.

#### 3.6.6 Calculation of inductive coupling during a power system earth fault

With the worst fault location(s) established according to 4.6.3.3 and the corresponding fault current according to 4.6.3.2, the fault current can be applied to the phase conductor positioned closest to the pipeline. The condition resulting in the highest induction level is when the circuit breaker at the opposite end of the line has already opened, hence the current beyond the fault point as well as the current in the non-faulted conductors are set to zero. Normal load currents in any adjacent power lines may be ignored, in view of the much larger zero-sequence current produced by the faulted line.

The next step is to calculate the current induced in the earth wires during the fault. Following this, and subsequent to data entry of the respective pipeline and power line routes, pipeline coating and soil characteristics, the emf induced in the pipeline sections may be calculated. To ensure that the effect of the power line catenary is accounted for, section lengths should not exceed 50 m.

The pipeline voltage profile and shunt and series current is calculated next from these discrete section emfs and any specified earthing points or any discontinuities on the pipeline (e.g. insulating flanges). At this stage it is also possible to experiment with different earthing points as a means of mitigation, if the coating stress limit or the safety limit is exceeded (see 3.6.9, 3.6.11).

#### 3.6.7 Calculation of conductive coupling from towers and substation earthing grids

#### 3.6.7.1 Calculation of the EPR or surface potential

In homogenous soil, the EPR of the soil around a faulted tower or substation decreases as the inverse of the distance from the centre of the equivalent hemispherical electrode. This simple relationship does however not apply for stratified soil, which can cause order of magnitude EPR increases or decreases at a distance from the point of current injection. In particular, when the soil is comprised of a low resistivity upper layer over high resistivity bedrock, the current is confined to the upper layer and the EPR may spread over a much greater distance.

To model the faulted tower footing or earthing grid in multilayer soil, a wire or grid model is required. For substation grids, a suitable model is a rectangular meshed grid of roughly the same size as the actual substation, consisting of 10 mm diameter copper conductors, buried at a depth of 1 m.

In low or medium resistivity soil, the grid model needs to have no more than about 10 conductors in total, i.e. a 200 m x 200 m grid can be modelled with sufficient accuracy by a mesh size of 50 m x 50 m, even though the actual conductor density would be higher. Additional conductors will not reduce the grid's effective resistance to earth or affect the EPR profile outside the station, but will increase computation time.

In high resistivity soil (> 1000 ohm.m) the conductor density should be increased until there is no further decrease in the grid's effective resistance to earth.

Modelling tower footings can be more complex due to the variance of foundation designs, which are adapted to suit the mechanical properties of the local soil. Acceptable accuracy will however result from approximate models. For lattice-type self-supporting EHV towers with concrete-encased footings, a suitable model would consist of four interconnected rod electrodes, each of 1.5 m diameter and 5 m depth, spaced according to the tower's base dimensions.

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For guyed towers, the anchors and mast support foundations may be similarly modelled, and the model may be scaled down for smaller HV towers. Metallic or reinforced concrete pole-type tower footings may be modelled as a single rod electrode, with dimensions in accordance with the actual footing and concrete foundation diameter.

When there are counterpoises installed, these will have a significant effect and they should be modelled according to their actual dimensions.

Some software packages will permit the modelling of the concrete around the footings, however, being relatively conductive, the concrete may as a first approximation be regarded as being part of the metallic structure. More accurate modelling of the foundations (pads, piles etc.) will also have only a limited influence on the calculated EPR around the tower.

As discussed in 3.6.3.2, only a fraction of the fault current will enter the earth at the tower footing. With this fraction determined, the grid or tower model entered and soil layers specified, it will be possible to compute the potential rise of the footing and the EPR as a function of distance from the tower or grid to the pipeline.

A useful check is that the potential rise should not exceed 5 kV for substation grids or 30 kV for tower footings. Substation grids will only rarely exceed 5 kV, and only in the case of smaller HV substations in poor soils; for Eskom's EHV substation grids 5 kV is the design limit. In the case of towers equipped with earth wires, a potential of the faulted tower greater than 30 kV is highly unlikely.

#### 3.6.7.2 Calculation of pipeline touch voltage

For a pipeline traversing an EPR zone, some of the potential will be transferred to the pipeline through its coating. Some of this transferred potential can appear on the pipeline well beyond the shared servitude. The pipeline touch voltage (which, for practical purposes, is equal to the coating stress) is then the difference between the local EPR and the voltage transferred to the pipeline (see Fig 13).

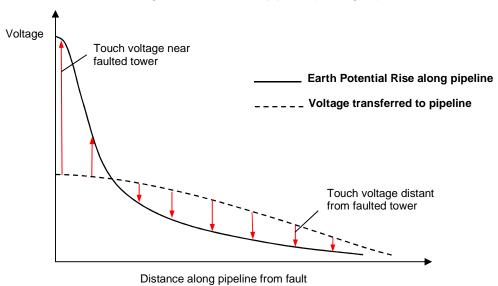


Figure 13: Touch voltage resulting from conductive coupling from a faulted tower

To calculate the voltage transferred to the pipeline requires the model to extend to a point where the EPR has effectively diminished, which can be several kilometre. At the ends of this length, an earth point is required to represent the remainder of the pipeline's coating admittance to earth. A further uncoated 500 m section of pipeline may be specified to provide such an earth.

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If the exposure involves a parallel or quasi-parallel section, the total pipeline touch voltage must take both inductive and conductive coupling into account. This may be achieved by summation of magnitudes of the pipeline voltage profile due to induction and the pipeline touch voltage due to conductive coupling.

This worst-case summation closely represents the actual situation, since the induced pipeline voltage is usually close to 180° out of phase with the EPR. The effects must therefore be added and will produce more severe touch voltages and coating stresses in combination.

#### 3.6.8 Calculation of pipeline voltages during normal and emergency load conditions

Compared to fault conditions, the emf produced by a power line carrying a balanced load current is much more sensitive to the precise juxtaposition of the phase conductors with respect to the pipeline - under a tower with a horizontal layout for example, the emf is near zero underneath the central conductor but reaches a maximum underneath the outer conductors.

It is therefore important that the relative positions of the phases is accurately represented for the normal and emergency load calculations. These are dependant on the tower configuration, the conductor catenary and on the layout of any transpositions.

If there are multiple circuits or multiple power lines in the servitude, the respective phasing of the conductors has to be considered, as discussed in 3.6.3.1 d).

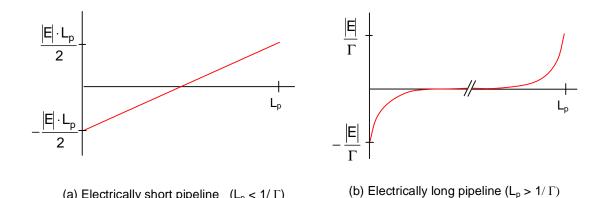
There is no conducted component present as in the case of fault conditions.

The calculation of the pipeline voltage profile is otherwise very similar to 3.6.7, and earthing points can be applied to the pipeline to ensure that the safety limit is met during emergency load conditions and the a.c. corrosion limit is met during normal load conditions.

At peaks in the voltage profile, the safety limit may be exceeded - provided further measures are taken to raise the potential of the local soil to ensure that the touch and step limits are not exceeded (e.g. by means of valve station gradient mats, or gradient wire).

#### 3.6.9 Determination of the most likely locations of pipeline voltage peaks

For a short, parallel exposure with uniform soil conditions and no earths, the voltage developed on the pipeline due to inductive coupling will have a linear profile with maxima at the pipeline ends and a zero crossing in the centre, as shown in Fig 14 (a). For a similarly uniform, but long exposure, the pipeline will become more lossy and the linear profile will be replaced by an exponential decay, Fig 14 (b).



(a) Electrically short pipeline  $(L_p < 1/\Gamma)$ 

Figure 14: Voltage developed on uniformly exposed pipelines with no earthing

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The distinction between long and short exposures is made on the basis of the electrical length of the pipeline,  $1/\Gamma$ , where the parameter  $\Gamma$  is the pipeline's propagation constant (m<sup>-1</sup>). For a given inducing field strength E (V/m), the pipeline voltage magnitude will not increase beyond the value  $|E|/\Gamma$ , irrespective of any further increase in exposure length.

The electrical length  $1/\Gamma$  is a function of the pipeline's depth, wall and coating properties, diameter, the soil resistivity and the frequency. Typical values for 50 Hz range from 1 km to 5 km for pipelines with bitumous coatings, and from 10 km to 30 km for pipelines with epoxy, polyethylene or polyurethane coatings.

As a result, the voltages developed on long pipelines with modern, high resistivity coatings can be around ten times higher than on pipelines with bitumous coatings, and the width of the voltage peak is increased by the same order.

For both short and long lines with uniform exposures, the most effective mitigation earthing will be at the pipeline ends, i.e. at the peaks of the voltage profile.

For long, non-uniform exposures, voltage peaks are likely to develop in addition at any discontinuities in the exposure, for example at power line or pipeline route deviations, at crossings or power line transpositions (under steady-state conditions only) and at insulating flanges (see Fig 15).

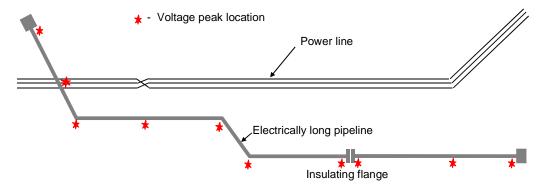


Figure 15: Location of voltage peaks on non-uniform exposure pipeline with no earthing

These voltage peaks will exhibit the same exponential decay on either side of the discontinuity as indicated in Fig 14(b), and will again not exceed the value  $|E|/\Gamma$  in magnitude (E in this case being the maximum inducing field strength applicable to the section in question).

The most effective mitigation earthing is usually at the location of these voltage peaks. When earthing is applied at a given point on a pipeline however, the voltage can increase or "balloon" at another point, and for this reason additional earthing points may also be required in the uniform sections of the exposure, as will be evident from the calculated voltage profile.

#### 3.6.10 Calculation of d.c. leakage from pipelines and anode ground beds

The surface potential distribution adjacent to a pipeline may be calculated for homogenous soil from Eqn.(5) for a given protection current density.

In case of stratified soil, a computer simulation is required. A substantial section of the pipeline should be modelled (e.g. 5 km) to ensure that the field distribution remains cylindrical up to the distance considered, and the surface profile should be computed at its centre. The pipeline should be energised to -1.5 V d.c. If using an a.c. model, the frequency should be adjusted to 1 Hz or less, to simulate d.c. conditions.

The resulting lateral surface potential profile is then examined to establish if the potential difference between the towers of any span exceeds 200 mV. This could result in the 200 mV positive d.c. potential shift limit being exceeded at the tower footing.

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The anode ground bed should be modelled according to its actual dimensions (typically a linear conductor) energised to the maximum capacity of the CP rectifier (typically 50 V). If the resulting lateral surface potential profile indicates that the potential difference between two towers of a span exceeds 200 mV, the 200 mV limit could be exceeded at the towers where the current returns to earth.

If the ground bed is very close to a tower with an insulated earth wire, the profile has to be examined to ensure that the potential difference across the tower legs or guy anchors does not exceed 400 mV.

Should any of these limits be exceeded, this would serve as an indication that post-installation measurements are required at the tower footings where the current returns to earth, to determine the actual level of interference occurring under operational conditions. (see 3.3.8 (b)).

## 3.6.11 Calculation of pipeline voltages with mitigation measures applied

The calculation of pipeline voltages due to inductive coupling with mitigation earthing applied is similar to the calculation without earths, as discussed in 3.6.6 and 3.6.8, but with all the earthing points and isolating flanges included in the circuit. The applied earths should include zinc ribbons, earth rods, pump station earthing mats and other earths connected to the pipeline through d.c. decouplers, but should exclude the valve station gradient mats which are connected to the pipeline through SPDs, unless the calculated voltage profile indicates that the SPD's breakdown voltage is exceeded at any specific valve station, as is likely to occur during fault conditions.

In most software packages, this calculation will only provide the resultant pipeline voltage with respect to remote earth. The touch voltages will be further reduced by gradient mats at valve chambers, and both the touch voltage and the coating stress will be further reduced along pipeline sections with gradient wire(s).

Properly designed and installed gradient mats around valve chambers will invariably bring the step and touch voltages at the chamber to within the required limits, and further simulation of this situation is generally not required. If no external mat is used and only the chamber's re-bar is earthed, it may be necessary to model this situation specifically.

The effect of the gradient wire also needs to be investigated with a suitable simulation. For example, Fig 16 shows the result of CDEGS simulation of short (150 m) sections of Type II zinc ribbon, installed next to a 1100 mm diameter pipeline with a polymer-modified bitumen coating, in soil consisting of a 15 m thick layer of 500 ohm.m over 1500 ohm.m bedrock. The pipeline is energized to 100 V.

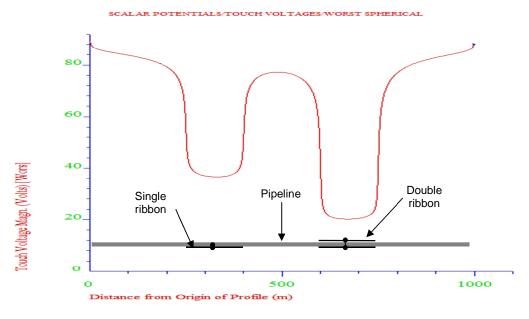


Figure 16: Example of the reduction of touch voltages by zinc ribbon installed in pipeline trench

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In this example, a single and double ribbon is seen to reduce the touch voltage by more than 60% and 80% respectively. Generally, this effectiveness decreases with increasing soil resistivity, but it is also sensitive to soil stratification. Each specific situation must therefore be confirmed with a similar calculation.

In the case of conducted coupling, a zinc ribbon section opposite tower footings will also be effective in reducing the touch voltages where there are sharp EPR gradients present – however, the ribbon can have the undesirable effect that the potential transferred to the pipeline as discussed in 3.6.7.2 increases substantially, creating hazardous touch voltages remote from the fault location, as shown in Fig 17:

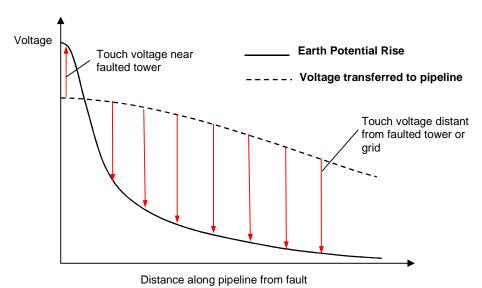


Figure 17: Touch voltage resulting from conductive coupling from a faulted tower, with zinc ribbon installed near the faulted tower or grid

Because of this effect, it is not always advisable to install zinc ribbon near close approaches with towers or substation grids - though this may be unavoidable if the coating stress limit is also exceeded. If only the safety limit is exceeded, gradient mats may be used for mitigation in these areas. When zinc ribbon is used, the resultant touch voltage away from the tower or grid must in any event always be evaluated by means of an appropriate simulation model.

#### 3.6.12 Determination of current rating of d.c. decoupling devices, SPDs and cables

Included in the coupling simulation results for both emergency load and fault conditions will be the individual currents flowing to earth at each earthing point, as well as the series current along the length of the pipeline. These current levels have to be compared against the d.c. decoupler device ratings, e.g. the maximum continuous a.c. rating and the fault rating specified in B.2 and B.4 of Annex B. This also applies to d.c. decouplers installed across insulating flanges, which will carry the full series current at the respective point on the pipeline.

If the predicted current levels are higher than the rated values, the device ratings have to be increased, or the earthing resistance of the individual mitigation earthing point has to be reduced (e.g. by splitting the length of the zinc ribbon section in two). If increased device ratings are used, the copper cable cross-section specification B.5 of Annex B has to be increased accordingly.

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### 3.7 Mitigation measures

#### 3.7.1 Mitigation measures applicable to pipelines

#### 3.7.1.1 Routing of the pipeline

If the permitted coupling levels are exceeded, increasing the separation between the power line and pipeline may in some cases be a viable option to reduce coupling to acceptable levels.

Increasing separation is especially suitable for conductive coupling from power line towers, substations and transformers, where a reasonable increase in separation can overcome most problems.

Substantial re-routing is usually required to reduce inductive coupling because of the slow decrease of inductive coupling with distance, and is often not a practical solution.

#### 3.7.1.2 Gradient control wires / ribbons

Gradient control wires provide a.c. mitigation by two mechanisms - firstly, by providing an earthing point which reduces the overall pipeline voltage, and secondly, by changing the potential of the soil around the pipeline, thereby reducing the coating stress and touch voltages.

They are most effective in conditions of low resistivity soil overlaying high resistivity bedrock, and least effective in high resistivity soil overlaying low resistivity soil.

Gradient control wires typically consist of a specified length of one or two uninsulated profiled zinc conductors (also referred to as zinc "ribbons") installed in the corner(s) of a pipeline trench, prior to bedding and backfill material. A suitable specification for zinc ribbon is provided in B.1, Annex B.

If the pipeline is protected with an ICCP system, they have to be connected to the pipeline through appropriately rated d.c. decouplers. The d.c. decouplers are normally installed above ground, housed in suitably designed a.c. mitigation stations.

For pipelines without ICCP systems, the zinc ribbon may be connected directly to the pipeline, at regular intervals (nominally 300 m). In this case they will behave as sacrificial anodes and provide cathodic protection to the pipeline, in addition to providing a.c. mitigation.

The connections between the ribbon, the d.c. decoupler and the pipeline have to be made with copper wire as specified in B.5, Annex B.

The earthing resistance is determined primarily by the resistivity of the layer in which the ribbon is installed, and is calculated from Eqn (9):

$$R = \frac{\rho}{2\pi\ell} \cdot \ln\left(\frac{\ell^2}{sd}\right)$$
 [ohm]

where:

ρ is the soil resistivity [ohm.m],

 $\ell$  is the length of the ribbon [m],

s is the burial depth [m],

d is the average thickness or the diameter [m].

Eqn (6) ignores the self-resistance of the wires; this limits its application to lengths to approximately 500 m for type II zinc ribbon (see Annex B). The resulting earthing resistance for some typical conditions is shown in Table 14.

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Table 14: Earthing resistance provided by gradient control wire, buried 2 m deep

Electrode type (Type II Zinc)	R <sub>electrode</sub> for soil resistivity [ohm]				
	100 ohm.m	250 ohm.m	500 ohm.m		
100 m zinc ribbon	2.1	5.4	10.8		
200 m zinc ribbon	1.1	2.7	5.4		
300 m zinc ribbon	0.8	1.9	3.8		
400 m zinc ribbon	0.6	1.5	3.0		

To limit both the current rating requirement of the d.c. decouplers and the voltage gradient along the ribbon's length resulting from its self-impedance, ribbon sections should generally not exceed 400 m in length. For optimum current distribution the d.c. decouplers should be connected near the centre and successive sections should not be in direct contact.

The earthing resistance of the zinc ribbon improves only very marginally by using two ribbons as opposed to one. Using two ribbons is only necessary when the coating stress is very high, in which case a second ribbon can provide some improvement (see Fig 19).

#### 3.7.1.3 Vertical earth rods

Like gradient control wires, vertical earth rods can be used to provide an earthing point and thereby reduce the pipeline voltage, but they are not as effective in changing the potential of the earth around the pipeline.

They find application mainly when the resistivity of the upper soil levels is very high compared to the lower levels, when gradient control wires are least effective. They can also be used in combination with gradient control wires, i.e. by connecting one or more vertical rods to the horizontal ribbon, thereby providing access to the low resistivity layers.

Vertical earth rods for this purpose require a borehole to be drilled into the conductive layers and can exceed 100 m in depth. To prevent wall collapse, a steel pipe sleeve is normally inserted, typically of 200 mm – 300 mm diameter. The earth rod may be implemented with Type II zinc ribbon, fitted centrally in the sleeve which is then filled with carbonaceous backfill. This arrangement improves durability and increases the effective contact surface.

For homogenous soil, the earthing resistance of a vertical earth rod is given by Eqn (10):

$$R = \frac{\rho}{2\pi\ell} \cdot \ln\left(\frac{4\ell}{d}\right)$$
 [ohm]

where:

ρ is the soil resistivity [ohm.m],

 $\ell$  is the length of the ribbon [m],

d is the diameter of the steel sleeving [m].

For stratified soil, the earthing resistance can be calculated using suitable software. The actual resistance can also be measured during the drilling process, to determine if the low value required has been achieved and if further drilling is warranted.

Connection to the pipeline is done in the same manner as gradient control wires, i.e. through a d.c. decoupler in the case of pipelines equipped with ICCP systems or with a direct connection otherwise, using stranded copper wire as specified in B.5, Annex B.

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### 3.7.1.4 Gradient control grids

Gradient control grids can be used at exposed appurtenances of buried pipelines (i.e. valve chambers, pigging stations, CP stations etc. but excluding test posts, see 3.7.1.6) to equalise the soil potential around (or inside) the appurtenance to the pipe potential, thereby reducing the touch and step potentials.

Gradient control grids typically consist of a wire mesh or spiral at a depth of about 0.3 m installed around the appurtenance to a distance of at least 1.2 m, so that a person in contact with the appurtenance or enclosure will always be standing over the mat.

Spiral type mats are usually constructed of zinc ribbon as used for gradient control wires. To ensure that the step potential limits are not exceeded, the pitch between successive rings should not exceed 300 mm.

Wire mesh type grids are usually constructed of welded, 6 mm diameter, 200 mm x 200 mm steel meshes as used in the building trade. To prevent corrosion, these grids have to be encased in a concrete layer.

Both spiral and wire mesh type gradient control grids provide very effective touch and step potential mitigation at 50 Hz. Mesh type grids have however become the preferred type, because they allow more effective dissipation of current during surges (e.g. from switching and from lightning).

In the case of valve chambers constructed with steel reinforcing in the floor and/or walls, the reinforcing can be used for gradient control inside the chamber, by forming a Faraday cage at pipeline potential. This reduces the internal touch and step potentials to zero for 50 Hz and to very low values for surges.

The efficiency of a gradient control grid as an earthing point is usually quite low, although the cumulative effect of a number of mats can be of some benefit during fault conditions. In homogenous soil, the earthing resistance of a gradient control grid is given by Eqn (11):

$$R = \frac{\rho}{4} \sqrt{\frac{\pi}{A}}$$
 [ohm]

where:

ρ is the soil resistivity [ohm.m],

A is the area of the grid [m<sup>2</sup>].

The connection to the pipeline is normally made through a voltage limiting device (see 3.7.1.5), and the grid remains out of circuit under normal operating conditions. An example specification of a wire mesh type gradient control grid is given in B.3, Annex B.

#### 3.7.1.5 Solid state d.c. decouplers and voltage limiting devices

Any direct earthing applied to the pipeline burdens the CP system, and d.c. decouplers are required which provide d.c. isolation whilst exhibiting a very low a.c. impedance.

For all mitigation earthing such as vertical rods or gradient control wire, which have to be functional during steady state and fault conditions on the power line, d.c. decouplers are designed with multiple parallel paths to accommodate the normal current, fault current and lightning surges respectively.

The d.c. blocking voltage of these devices has to be asymmetric (-3V /+1V) to ensure that with high a.c. interference levels, the pipeline remains approximately 1 V more negative than the earthing points. If the pipeline is also influenced by d.c. traction or other stray d.c. sources, the asymmetry has to be increased (-12V/+1V). A suitable specification is provided in B.2, Annex B.

Similar d.c. decouplers are required to provide a low impedance a.c. path across insulating flanges, however if both sides are cathodically protected, the voltage should be symmetric (-2V/+2V). This permits 2 V blocking when the CP on either side is switched off. In case one side is earthed, for example at a pump station, an asymmetrical unit is used.

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For gradient control mats at valve chambers, an a.c. path is not required during steady state conditions. In this case a voltage limiting device is used that is functional only during transients due to a.c faults or lightning. An SPD (e.g. a GDT or a MOV) with an a.c. clamping voltage around 75 V r.m.s. is suitable for this purpose. A specification for this type of device is provided in B.4, Annex B.

#### 3.7.1.6 Test posts with a.c. coupons

Test posts with carbon steel coupons are usually installed in a.c. induction zones at intervals of approximately 1 km, or at specific locations of high corrosivity, for the purpose of monitoring the performance of the CP and a.c. mitigation systems. The coupons simulate a coating defect of 1 cm², and the a.c. and d.c. coupon currents are directly proportional to the current densities at actual pipeline defects.

Test post terminals are typically housed in pre-cast concrete bunkers or in above- ground galvanized steel cabinets installed on a pre-cast concrete base.

Gradient control mats should not be used at test posts, as these can modify the electric field around the pipeline and thus affect the coupon readings. Test post terminals must however be installed with a "dead-front" arrangement according to NACE RP0177, to prevent accidental contact with the terminal of the cable connected to the pipeline. Test posts may be equipped with a stone or asphalt ground cover around the base for additional protection.

#### 3.7.1.7 Bonding with existing structures

When a new pipeline subject to a.c. coupling is installed next to an existing pipeline, and if there is any possibility of a person being in simultaneous contact, the two pipelines must be cross-bonded with bonding links at intervals not exceeding 1 000 m, to prevent any hazardous potential differences. These can be direct bonds, resistive bonds or d.c. decouplers, as dictated by the CP requirements.

At crossings or close approaches with d.c. railways, pipelines should be bonded to the rails with a directional drainage bond in accordance with SANS 50162.

Pipelines should under no circumstances be bonded to power line towers, tower counterpoises, substation earth grids, power cable screens or any other earthed component of MV, HV or EHV a.c. power networks, as any surges in the power network would then be transferred directly to the pipeline.

Bonding to the earthing of any other infrastructure that is not well defined should generally be avoided.

#### 3.7.1.8 Isolating flanges

Isolating flanges can be used to sectionalise the pipeline and thereby reduce the accumulated voltage in a parallelism. They can also be used to prevent transferred potentials, for example on pipeline spurs or tees.

As each section created requires a separate CP station, this mitigation method can be uneconomical.

Isolating flanges are typically rated less than 15 kV, and a surge diverter with a 1.2 kV breakdown voltage is usually supplied with the unit to prevent damage to the flange in case of voltage surges. Breakdown may not occur during earth faults, as this would defeat the purpose of the isolating flange.

Isolating flanges are not effective with pipelines transporting water or other conductive media, unless an inner lining with the appropriate dielectric properties is used.

When installed in areas where stray d.c. currents are expected, isolating flanges must be housed in an underground chamber to prevent potentially large d.c. currents bypassing the flange through the surrounding soil, causing localised corrosion.

#### 3.7.1.9 Pipeline coatings and coating integrity surveys

The most beneficial pipeline coating type from an a.c. mitigation viewpoint depends on the type of coupling that is most pronounced or problematic. Inductive coupling levels and transferred potentials can be significantly reduced by low resistivity coatings such as bitumen or modified bitumen, especially on long pipelines.

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Conductive coupling and d.c. leakage in particular is, on the other hand, greatly reduced or even effectively eliminated by the use of high resistivity PE, rigid PU or epoxy coatings. These coatings are also more tolerant of high voltage gradients during earth faults and would hence be preferred if the pipeline is very close to a number of power line towers.

Increasing the coating thickness near power line towers can also be a very effective method of mitigation, as this reduces the risk of coating damage. This can be done during the coating process at the supplier, or by a procedure referred to as armour wrapping, where membrane layers and bitumen are applied over the existing coating on site.

The risk of having any significant coating defects near tower footings may be further mitigated by a post-installation coating integrity (e.g. DCVG) survey to locate and repair any coating defects.

#### 3.7.1.10 Location selection of anode ground beds

Anode ground beds should preferably be located at least 1 km away from any earthed power installation, and with the pipeline positioned in between them. In practice their location is confined to a areas of low earth resistivity with an available LV or MV supply point, and maintaining this separation with power lines is not always possible.

Locating the anode bed close to substations is never advisable as in this can cause a much larger current to enter the power system through the earthing grid, given the grid's lower impedance and greater footprint. All the towers of the power lines connected to the substation then become the drain points and therefore potential corrosion sites.

#### 3.7.2 Mitigation measures applicable to power lines

#### 3.7.2.1 Routing of the power line

Re-routing the power line away from the pipeline may be an option for new power lines. See 3.7.1.1.

#### 3.7.2.2 Use of ACSR as power line earth wires

Using ACSR instead of steel earth wires on power lines improves the screening factor for inductive coupling during earth faults. By suitable selection of conductor type, a 40 % to 60 % reduction of the induced voltage is usually achievable.

Using ACSR earth wires also results in an important reduction of a faulted tower's EPR, and therefore the level of conducted coupling from power line towers.

#### 3.7.2.3 Use of power cables with improved screening factor

Inductive coupling from MV/HV power cables can be reduced by selecting a cable with an improved screening factor, for example cables with thick aluminium sheaths.

#### 3.7.2.4 Employ a power system with isolated or high impedance neutral

Power lines with isolated or high impedance transformer neutrals have significantly lower earth fault current levels than power lines with earthed transformer neutrals. This method concerns voltages induced during earth faults, and may be an option for certain MV and HV power systems.

#### 3.7.2.5 Use of phase arrangements to reduce steady-state coupling

When the power line carries two or more circuits, an appropriate choice of phase arrangement can result in a significant reduction of the steady-state induced voltages, if this option is available. For example, for vertical 2 circuit configuration, the phase sequence of circuit 1 (e.g. RWB) should be the opposite of the phase sequence of circuit 2 (e.g. BWR).

Changing phase arrangements is not effective for reducing induced voltages during earth faults.

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#### 3.7.2.6 Earth wire isolation to prevent tower footing corrosion

Isolating the towers in the EPR zone of a d.c. energised pipeline or anode ground beds prevents the circulation of d.c. currents on the earth wires and the associated corrosion.

#### 3.7.2.7 Sacrificial anodes to prevent tower footing corrosion

Magnesium or zinc anodes connected to the tower footing or guy anchors when the positive d.c. potential shift exceeds the required 200 mV limit, will prevent damage to the footing. Anodes for this purpose have to be designed according to the actual soil characteristics and the measured d.c. potential shift with the maximum CP current applied.

#### 3.8 Safe working procedures in power line servitudes

#### 3.8.1 Appointment of Electrical Safety Officer (ESO)

- **3.8.1.1** Prior to any work commencing an Electrical Safety Officer (ESO) shall be appointed by the PO or the PO's agent. This person shall:
- a) be the designated safety officer for the project,
- b) have completed Eskom's ORHVS responsible person training course,
- be authorised by a ORHVS authorised person (GMR2.1) to work without constant supervision in a power line servitude,
- d) have completed the SAECC Electrical Safety Officer training course,
- have experience in the supervision and management of temporary mitigation measures during pipeline construction, and
- be furnished with the authority and equipment required to implement and maintain safe working conditions.
- keep a record of any non-compliance and advise the construction manager and the project safety officer.

#### 3.8.2 General Safe Working procedures

- No person, equipment or machinery shall enter the HV/EHV servitude without the approval of the ESO. All affected areas shall be suitably demarcated and access restricted to those personnel who have been advised of the hazards and requirements when working underneath or adjacent to HV/EHV power lines.
- All personnel shall be made aware of and be able to recognize the potential shock hazards and be trained in the approved safety procedures.
- Pipeline construction personnel shall avoid contact with HV/EHV structures and supports. No mechanical equipment shall come closer than 5 m from any power line tower.
- 4) Direct connections to the power line tower structures or buried counterpoise earthing system are not permitted under any circumstances. The earthing systems of the power line and the pipeline must be kept separate.
- 5) Temporary construction sheds, trailers, living quarters, pipe sections, storage areas or vehicle fuelling facilities are not permitted in the HV/EHV servitude.

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No mechanical equipment, including mechanical excavators or high lifting machinery, shall be used in the vicinity of Eskom's apparatus and/or services, without prior written permission having been granted by Eskom. If such permission is granted the applicant must give at least seven working days prior notice of the commencement of work. This allows time for arrangements to be made for supervision and/or precautionary instructions to be issued. The internal assessor must provide the applicant with the details of an Eskom person to be contacted in this regard.

- 7) All rubber tyre construction vehicles used in the HV/EHV servitude shall be equipped with a steel chain secured to the chassis at one end and freely dragging on the earth at the other, to discharge any electrostatic build-up.
- 8) The minimum vertical clearance between construction equipment and overhead conductors shall be in accordance with Table 15. The actual height of the conductors at their lowest point shall be measured by means of optical measuring equipment to ensure that this minimum clearance is achieved.

Table 15: Minimum vertical clearance underneath power line conductors

Nominal r.m.s. voltage (kV)	66	88	132	220	275	400	533 d.c.	765
Minimum vertical clearance (m)	3.2	3.4	3.8	4.5	4.9	5.6	6.1	8.5

(from Regulation 15 of the Electrical Machinery Regulations of the OHS Act (Act 85 of 1993))

- 9) Vehicles such as mobile cranes with extendable members that can potentially exceed this minimum vertical clearance height shall be identified and the operators issued with specific instructions with regard to the maximum permissible extension, prior to doing any work in the HV/EHV servitude.
- If for any unforeseen reason, the life-threatening situation occurs where a construction vehicle comes into contact with a live HV/EHV conductor or a flash-over occurs, the operator(s) shall remain inside the vehicle and attempt to get it out of the contact situation using ONLY the vehicle's own power. On NO account shall the operator(s) leave the vehicle and on NO account shall any person approach the vehicle, until the contact situation has been reversed, or until the ESO has received confirmation from the electricity utility that the power line has been de-energized. Arcing may temporarily stop due to the action of the protection, however this in itself shall NOT be taken as an indication that the line is safe, since the line may automatically attempt to re-energize. Effective assistance in this situation entails ensuring that all persons present maintain a safe distance from the vehicle (>10 m) and alarming the electricity utility's operational centre.
- Any foreign metal structures exposed during trenching inside or alongside HV/EHV servitudes shall be treated as a live electrical conductor, until measurement proves otherwise. The pipeline shall not be bonded any foreign structures without an assessment by a qualified engineer and written permission from the owner.
- 12) The use, storage, disposal, treatment or generation of any hazardous substances shall not be permitted in the power line servitude.

#### 3.8.3 Daily measurements

- Qualified personnel shall measure and record the pipeline voltage to earth to verify that conditions
  are safe to work (a.c. < 15V r.m.s.), on all sections and on each day prior to the commencement of
  any construction or other activity involving contact with the pipeline.</li>
- 2) For pipeline voltage measurements, a voltmeter of suitable range and impedance shall be used. Low resistance earth connections shall be used to avoid induction or capacitive pickup on test leads and related items that could result in erroneous readings on a high impedance instrument. A suitable reference is a metal rod driven into the earth.

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Test leads shall be attached to the instrument first and then to the pipeline. After measurement, the leads shall be removed from the pipeline first and from the instrument last.

- 4) Each time a voltage measurement is made, the following data shall be recorded:
  - i. location,
  - ii. time,
  - iii. date, and
  - iv. pipe-to-earth voltage.

#### 3.8.4 Temporary earthing

- 1) Pipelines exhibiting voltages greater than 15 V r.m.s. shall be earthed with temporary driven earth rods. Pipelines parallel to a.c. power systems shall be earthed opposite the midpoint of each span, maximising the distance to the nearest HV/EHV structure.
- 2) The temporary connections to the pipeline shall be made with earthing clamps that apply firm pressure at the contact point with a mechanically sound connection, and with the coating at the contact point removed down to the bare metal.
- 3) The connection between the earthing clamp and the earth rod shall be made with 25 mm² stranded copper cable, green PVC insulated.
- 4) To prevent the risk of personal injury or arc burns, the connection and disconnection of temporary earths shall be carried out in the following order:
  - a) connection:
    - i. the earthing clamp is connected to the pipeline,
    - ii. the earthing cable is connected to the earth rod,
    - iii. the earthing cable is connected to the earthing clamp.
  - b) disconnection:
    - i. the earthing cable is disconnected from the earthing clamp,
    - ii. the earthing cable is disconnected from the earth rod,
    - iii. the earthing clamp is removed from the pipeline.
- 5) Temporary earths shall be left in place until immediately prior to backfilling. Sufficient temporary earths shall be maintained on each section until adequate permanent grounding connections have been made.
- 6) When the pipeline voltage remains above 15 V r.m.s. in spite of the temporary earth rods, temporary earth mats that extend a minimum of 1 m outside the work area shall be used. The connection between the pipeline earthing clamp and the temporary earth mat shall be made with 16 mm2 or larger stranded copper cable. There shall be no contact between persons over the earth mat and those not over the mat, including the handing over of tools or materials.

#### 3.8.5 Bonding of isolating flanges, joints and couplings

- 1) Work on isolating flanges, joints, or couplings shall only proceed after the AC status has been verified. A temporary bond across the flange or the use of a properly sized temporary earth mat shall be used to protect personnel while they work on the pipe.
- 2) When cutting a pipeline, adequate bonding across the point to be cut shall be used, irrespective of the AC voltage measured between the pipeline and earth. When this voltage exceeds 15 V r.m.s, additional earthing shall be installed BEFORE cutting commences.

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#### 3.8.6 Precautions during coating and lowering-in operations

1) Where coating is to be applied at field joints, precautions shall be taken to ensure that equipment contacting the bare pipe is adequately bonded and earthed.

2) For the lowering-in operation, the coated pipeline shall be handled with nonconductive slings. Because the coated pipeline may not be effectively earthed during part of this operation, contact with the bare portion of the pipeline shall be avoided when the support slings are removed from the end of the pipeline.

#### 3.8.7 Work stoppage

- 1) The ESO shall have liaison with the electrical utility to determine planned switching, outages, and load changes that may affect pipeline voltage. Work involving contact with the pipeline shall be stopped during scheduled switching of the electric power system.
- 2) WORK SHALL BE STOPPED WHEN ANY LIGHTNING ACTIVITY IS PRESENT.

# 3.9 Inspection and testing and of pipeline a.c. mitigation components prior to commissioning

- a) When the a.c. mitigation measures agreed upon by the Eskom and the Pipeline Operator have been installed, an Eskom representative shall be permitted to inspect all the components of this installation and to perform necessary measurements according to the inspection sheet provided in annex E.
- b) Final approval of the a.c. mitigation installation is subject to the outcome of this inspection.

# 3.10 Long term maintenance requirements of pipeline and power line a.c. mitigation components

- a) The a.c. mitigation measures shall be maintained by regular inspection and measurement of the effectiveness of the measures. The interval between inspections shall not exceed 6 months.
- b) Maintenance personnel shall be provided with special training to acquaint them with the a.c. mitigation components, measurements and safety requirements.
- c) Clear and detailed maintenance records shall be kept available for inspection by an Eskom representative for the full operational lifetime of the pipeline.

#### 4. Authorization

This document has been seen and accepted by:

Name and surname	Designation	
V Singh	Power Plant Technologies Manager	
AA Burger	Chief Engineer – Eskom Lines Engineering Services	
B Haridass	Chief Engineer – Eskom Lines Engineering Services	
L Motsisi	Eskom Land Development	
E Grunewald	TX Land Development Manager	
C Meintjies	Land Development Manager: Central	
S Mabaso	Land Development Manager: Central	
N Purdon	Land Development Manager: Eastern	

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Name and surname	Designation	
B Maudu	Land Development Manager: Northern	
L Human	Land Development Manager: Northern	
X Songcaka	Land Development Manager: North West	
T Smith	Land Development Manager: Southern	
B van Geems	Land Development Manager: Western	

#### 5. Revisions

Date	Rev.	Compiler	Remarks
May 2015	1	B Druif/A Burger	First issue.

## 6. Development team

This guideline was prepared for Line Engineering Services by a Working Group that comprised the following members:

B Haridass Eskom Line Engineering Services
 A Burger Eskom Line Engineering Services

L Motsisi
 Eskom Land & Rights

B Druif EM Consulting

P H Pretorius Trans-Africa Projects

### 7. Acknowledgements

This work was made possible through funding and opportunity provided by Eskom Holding SOC Ltd, in particular the Transmission Line Engineering Services (LES).

Members of the SABS's Power line and Pipeline Working Group that were consulted during the drafting of this guideline were:

E Livesly Johannesburg Water (Pty) Ltd

T Madonsela Rand Water

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N Webb Isinyithi Cathodic Protection

V Sealy-Fisher Isinyithi Cathodic Protection

C Ringas Pipeline Performance Technologies (Pty) Ltd
A Schwab Pipeline Performance Technologies (Pty) Ltd

G Haynes Corrosion & Technology Consultants

A Asraf Sasol Gas
C Downs Transnet
T du Plessis Eskom

K R Hubbard Eskom Corporate Services Division

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V Sewchand Eskom Technology Standardization

F Thuynsma Eskom Industry Association Resource Centre
T Mundie Eskom Industry Association Resource Centre

D Carter LMC Corrosion

R Pillay Paradigm Projects (Pty) Ltd M Lebenya Paradigm Projects (Pty) Ltd

S Moodley Integrityafrica

G Turner Pipe and Tank Africa Consultants

A Copley IMESA

E Peralta Disa Anodes (Pty) Ltd

B Nkambule Ekuhurleni Metro

D Raath Cathtect Engineering (Pty) Ltd

J Mtombeni SABS

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## Annex A - Checklists of particulars required

#### A.1 - Pipeline Details

1.1	Pipeline name:			
1.2	Pipeline construction start date:			
1.2	Pipeline construction completion date:			
1.3	Pipeline pumped product(s):			
	Pipeline outer diameter (mm):			
1.4	Wall thickness (mm):			
1.4	Wall material:			
	Section lengths if sectionalised (m):			
1.5	Pipeline height / burial depth @ centreline (+/- m):			
	Pipeline or appurtenances exposed to the public? Y/N			
	Coating type and material:			
	Thickness (mm):			
1.6	Final insulation strength (kV):			
	Resistivity ( $\Omega$ .m) <i>OR</i> Specific Resistance ( $\Omega$ .m <sup>2</sup> ):			
	Relative permittivity:			
1.7	Pipeline route map or .kmz attached (see Note 1):			
1.8	All available soil resistivity data attached:			
1.9	Details of cathodic protection attached (see Note 2):			
1.10	Details of lightning protection attached (e.g. spark gaps, surge protectors across isolating joints):			
1.11	Drawings of valve chambers, pump stations, reservoirs, test post, etc. attached, showing structural steel and other earthing, and final height/level:			
1.12	Details of any existing adjacent pipelines, cables, railways and other earthed structures attached:			
1.13	Details of all construction vehicles to be used in power line servitude (incl. maximum extended height of booms, vehicles causing excessive vibration etc.) attached:			
1.14	Details of activities which will occur (e.g. excavation, blasting, lifting by crane, maintenance inspections by helicopter etc.) provided (see Note 3):			
NOTE 1: Clearly indicate the location of all bend points, pump stations, reservoirs, tanks, valve chambers, off takes, test posts and isolating joints  NOTE 2: For ICCP systems, indicate the location and DC current of all anode ground beds and the maximum CP current density expected on the pipeline				
NOTE 3: For blasting within 500 m of Eskom's structures, use separate application in TPC41-1078				
<b>Approv</b>	<u>/ed by</u> : <u>Date:</u>			

Pipeline Applicant / Technical Representative:

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		Line Name Voltage Level	Tx, Dx or other?
2.1	Existing and planned power lines or cables crossing or running parallel to the pipeline, within 6 km separation distance for overhead lines or 1 km for cables (ignore overhead lines below 44 kV and cables below 11 kV)		
	1	<del> </del>	
	Existing and planned	Substation Name Voltage Level	Tx, Dx or other?
	substations within 3 km separation		
2.2	distance from the pipeline		
2.2	(ignore substations with overhead lines		
	below 44 kV only or with cables below		
	11 kV only)		
<u> </u>			
2.3	Maps showing route of (alternatively the .kmz, .	elevant lines/cables and location of substations attached gdb or .dxf route files):	

2.3	Maps showing route of relevant lines/cables and location of substations attached (alternatively the .kmz, .gdb or .dxf route files):	

Approved by:	Date:		
GIS Specialist / Land & Rights representative:			
GIS Specialist / Land & Rights representative.			

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## A.3 - Overhead power line details (complete for each overhead line listed in A.2.1)

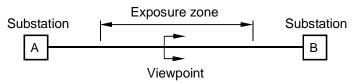


Figure A.1 - Plan view of power line

3.1	System Voltage ( V r.m.s., phase-phase):	
3.2	Station A: Station B:	
3.3	Number of circuits:	
3.4	Power line total length (km): Start of exposure at (km): End of exposure at (km):	
3.5	Transposition(s) at (km) (or None):	
3.6	Dominant tower type no. in exposure zone:  Tower sketch attached showing phase and earth conductor attachment height and separation (Y/N):  Avg. span length (m):  Avg. conductor sag at midspan (m):  Avg. tower footing resistance (ohm):	(see Note)
3.7	Phase conductor type and trade name: Number of sub-conductors: Spacing between sub-conductors (m): Earth wire conductor type and trade name: Earth wires insulated from towers at tower number(s) (or None):	
3.8	Peak load current (A r.m.s.): Emergency load current (A r.m.s.): Maximum load unbalance between phases (%)	

**NOTE:** Indicate conductor phases (R/W/B) on sketch (at start of exposure, looking towards station B, and if applicable, after each transposition in the exposure)

Approved by:	Date: _	
Power Line Design / Engineering representative:		

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A.4	l - 1	Fai	ılt	CIII	ren	t I	eve	els

		Line Name	Sub Start fault level (kA)	Sub End fault level (kA)
	Maximum 1 phase-earth fault level at each			
4.1	substation of each power line listed in 2.1 over next			
	20 years, on the busbar connected to the line			
			I	
		Out of offers News	Maximum fault	On busbar of
		Substation Name	current	voltage
		Substation Name	(kA)	(kV)
		Substation Name		_
	Maximum 1 phase – earth fault current at each	Substation Name		_
4.4	earth fault current at each substation listed in 2.2	Substation Name		_
4.4	earth fault current at each	Substation Name		_
4.4	earth fault current at each substation listed in 2.2	Substation Name		_
4.4	earth fault current at each substation listed in 2.2	Substation Name		_
4.4	earth fault current at each substation listed in 2.2	Substation Name		_
4.4	earth fault current at each substation listed in 2.2			_

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Power Line Design / Engineering representative: \_\_\_\_\_\_\_

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## **Annex B – Specification of Mitigation Components**

#### B.1 Gradient control wire

Gradient control wires shall be zinc ribbon. The composition of the zinc shall be as per ASTM B418 – 95 – Type II, with a steel wire inner core. The ribbon shall be of the following specification:

a) Cross section (D1 x D2): 12.7 mm x 14.3 mm

b) Radii (R1 x R2): 2 mm x 5 mmc) Zinc weight: 0.89 kg/md) Core wire diameter: 3.3 mm

e) Potential: -1.1 V vs. Cu/CuSO<sub>4</sub> electrode

f) Capacity: 780 Ah/kg

The gradient control wire, where required, shall be installed in the corners of the trench. Fig B.1 shows a section with two gradient control wires. A minimum lateral separation distance to the pipeline of 200 mm shall be maintained. In the case of a single gradient control wire, the wire shall be installed in either corner of the trench.

The gradient wire shall be covered with either native soil (sifted if necessary) or with a gypsum / bentonite mixture, prior to the bedding material.

The gradient control wire shall comprise discrete sections of up to (but not exceeding) 400 m in length. The ends of successive sections shall not be in direct contact.

The connection to the pipeline shall be made near the centre of each section, using a d.c. decoupling device for ICCP equipped pipelines, or a direct bonding link when no ICCP is used and the gradient control wires are used as sacrificial anodes.

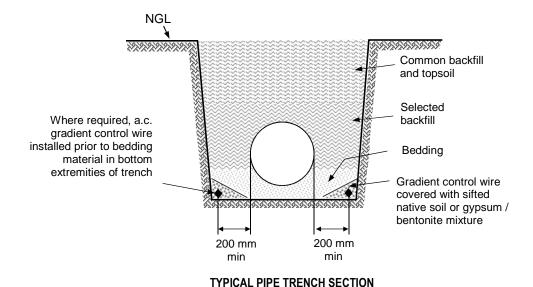


Figure B.1 - Installation of gradient control wire in trench

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#### B.2 Decoupling devices for gradient control wire

For pipelines equipped with ICCP systems, the zinc ribbon shall not be connected to the pipeline directly but only through a solid state d.c. decoupling device, housed in a valve chamber or a dedicated a.c. mitigation station. The device shall be certified by a suitably accredited test laboratory to meet the specifications given in Table B.1:

Table B.1 - Performance specification for d.c. decoupling device for gradient control wire

Specification / Test	Level / Requirement	Comment
1) Class I impulse current rating	10 kA, 10/350 μsec	to SANS 61643-1 requirement
2) Front of wave spark-over voltage	≤ 500 V, 1.2/50 µsec	to SANS 61643-1 requirement
3) Rated a.c. short circuit	3.7 kA r.m.s., 1 sec, 50 Hz	to SANS 61643-1 requirement
4) Rated a.c. load current	45 A r.m.s., 50 Hz, max temp incr. 40° C	at maximum d.c. blocking voltage, to SANS 61643-1 requirement
5) a.c. impedance	≤ 0.04 Ohm	at rated load current
6) d.c. blocking voltage	-12 V/+1V (+/- 10%)	If not influenced by spurious d.c. (railway, anode ground bed), reduce to -3V/+1V
7) d.c. leakage (blocked)	≤ 1 mA	at a.c. load thermal limit
8) d.c. current withstand	60 A for 15 mins	without overheating, test in both directions
9) Housing dielectric withstand voltage	5.8 kV	to SANS 61643-1 requirement
10) Environmental, enclosure	IP55	adjust upwards for more extreme environments
11) Ambient temperature range	-15° C to 60° C	
12) Air clearance and creepage distances	10 mm, 15 mm min resp.	to SANS 61643-1 requirement
13) Protection against direct contact	no direct contact	using IEC60529 test finger

Additional requirements for the d.c. decoupling device are:

- a) The decoupling device shall comprise a suitably rated diode stack capable of blocking direct current in both directions at the specified voltages.
- b) The device shall exhibit a progressive, smooth transition from blocking to conduction and vice versa without commutating.
- c) A bypass capacitor (network) shall be connected in parallel with the diode stack to conduct 50Hz a.c. up to the blocking voltage of the diode stack.
- d) The capacitor and diode network shall be protected by a suitably rated SPD for high voltage and lightning-induced transients. The SPD shall be decoupled from the capacitor and diode network with the appropriate inductance, in accordance with SANS 61312-3. This inductance shall remain effective (i.e. not saturated) during simultaneous transient and maximum d.c. current conditions.
- e) The decoupling device shall preferably be of open frame construction to permit maintenance and replacement of component parts. The frame shall be sized to fit on a standard 800 mm x 600 mm chassis plate.
- f) The decoupling device shall be provided with two M10 terminals at each installation point for the connection of 25 mm² single core cables.

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g) If housed in a location classified as hazardous in SANS 10108 and ARP0108, for example in case of gas or fuel pipelines, the decoupling device shall be explosion proof (Ex-rated). The nature of the Ex-rating required and the applicable test standard shall be determined by a specialist following a classification study in accordance with SANS 10108.

#### B.3 Valve chamber gradient control

Gradient control mats may be implemented with zinc spirals or with steel weld mesh mats. An example of a steel weld mesh mat around a valve chamber is shown in Fig B.2. The following is required:

- a) A 200 mm x 200 mm weld mesh, of 6 mm diameter steel wire, not galvanized, extending 1.2 m beyond the external wall of the chamber.
- b) All overlaps shall be 100 mm minimum, joined at two (2) places with crimped ferrules.
- c) For 2 m circular chambers the weld mesh shall be two overlapping panels with a circular cut-out to achieve a 4.4 m x 4.4 m square surround.
- d) The weld mesh is centrally located in a 85 cm, 15/19 MPa concrete encasement.
- e) The minimum depth of the weld mesh is 300 mm below normal ground level.
- f) The panels are connected to the pipeline with at least two (2) cables through a voltage limiting device, cables kept as short as possible (1 m or less).
- g) Continuity of the floor reinforcing is established with 2 bars at right angles welded to each bar, or by including a weld mesh layer cut to the floor size, above the structural re-bar.
- h) Continuity of the wall reinforcing is established with a continuity ring is installed just below roof height and welded to each vertical bar, and equipped with a connector plate protruding through the wall.
- i) The connector plate is connected to the pipeline with two (2) cables through a voltage limiting device, cables kept as short as possible (≤ 1.5 m).
- j) If there is any likelihood of a galvanic cell forming between the steel reinforcing bar and the external weld mesh (i.e. dissimilar metals or dissimilar concrete encasement), two separate voltage limiting devices shall be used, as shown in Fig B.2.
- k) For air valves with the chamber situated above the pipeline, the mat may be installed at the same depth as the chamber floor.
- For air valves using pre-cast concrete rings as walls, the steel reinforcing is generally inaccessible and only the reinforcing in the concrete floor is connected to the pipeline.

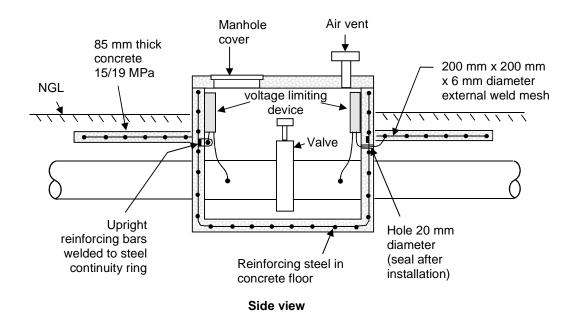
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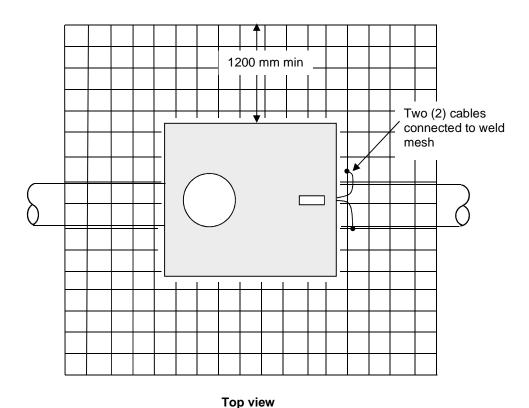


Figure B.2 - Valve chamber with external weld mesh gradient control mat

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When the step and touch voltages around the chamber do not exceed the values indicated for asphalt cover in table 1, the external gradient control mat may be replaced by external asphalt cover, as shown in Fig B.3:

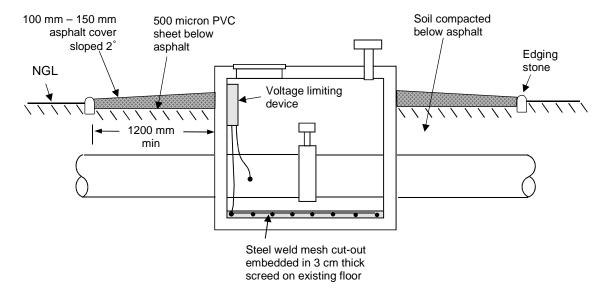


Figure B.3 - Valve chamber with external asphalt cover and internal gradient control mat

Fig B.3 also shows an alternative internal arrangement, suitable when access the steel reinforcing it is not possible. This method would be applied to existing valve chambers, to new valve chambers without reinforcing steel or when for engineering reasons, the reinforcing bars cannot be welded.

The installation requirements in this case are:

- m) compact soil and install asphalt cover of 100 mm or thicker, extending to 1.2 m around the chamber, suitably sloped for surface water dispersion away from chamber (2° min).
- n) use 500 µm thick PVC sheet below asphalt to prevent weed growth through cracks etc.
- o) install weld mesh cut-out on chamber floor, comprising 200 mm x 200 m x 6 mm diameter steel weld mesh, not galvanized,
- where required, weld mesh sections overlap by at least 100 mm, connect with at least two (2) crimped ferrule connections,
- q) at least two (2) cable connections to the weld mesh,
- r) weld mesh embedded in a thin (3 cm) layer of screed, sloped as required for water dispersion,
- s) use VLD to connect the weld mesh to the pipeline using at least two (2) connections,
- t) all cables kept as short as possible (≤ 1.5 m).

#### B.4 Voltage limiting devices for gradient control mats

For pipelines equipped with ICCP systems, the gradient control mats or valve chamber reinforcing steel shall not be connected to the pipeline directly but only through a voltage limiting device.

A low-voltage, solid-state SPD (e.g. a MOV or GDT) shall be used for this purpose. The device shall be certified by a suitably accredited test laboratory to meet the specifications given in Table B.2:

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Table B.2 - Performance specification for VLD for gradient control mats

Specification / Test	Level / Requirement	Comment
1) Class I impulse current rating	10 kA, 10/350 µsec	to SANS 61643-1 requirement
2) Front of wave spark over voltage	≤ 500 V, 1.2/50 µsec	to SANS 61643-1 requirement
3) Response time	≤ 25 nsec	
5) Short circuit withstand	3.7 kA r.m.s., 1 sec, 50 Hz	to SANS 61643-1 requirement
6) Housing dielectric withstand voltage	5.8 kV	to SANS 61643-1 requirement
7) a.c. clamping voltage	75 V r.m.s. (+/- 10%)	
8) d.c. breakdown voltage	100 V (+/- 10%)	
9) d.c. leakage (blocked)	≤ 1 mA	
10) Environmental, enclosure	IP55	Adjust upwards for more extreme environments
11) Ambient temperature	-15° C to 60° C	
12) Air clearance and creepage distances	10 mm , 40 mm resp.	to SANS 61643-1 requirement
13) Protection against direct contact	no direct contact	using IEC 60529 test finger

If housed in a location classified as hazardous in SANS 10108 and ARP 0108, for example in case of gas or fuel pipelines, the SPD shall be explosion proof (Ex-rated). The nature of the Ex-rating required and the applicable test standard shall be determined by a specialist following a classification study in accordance with SANS 10108.

#### B.5 Cabling

For connecting of d.c. decoupling devices to the pipeline, insulated 25 mm<sup>2</sup> copper earth cables (Cu/PVC) shall be used.

For connection of VLDs to the pipeline, insulated 16 mm<sup>2</sup> copper earth cables shall be used.

Copper earth cables shall have a green and yellow colour combination, shall be doubled for redundancy and shall be kept as short as possible, not exceeding 1.5 m in length.

The cable to zinc and cable to weld mesh connections shall comprise of a suitably sized ferrule crimping the cable connection to the weld mesh or to the exposed anode core wire of the zinc ribbon, silver soldering and use of an approved, self-vulcanizing butyl rubber tape to cover over the joint area.

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### Annex C – Worked Example

#### C.1 Introduction

This worked example concerns a bulk water pipeline in the Steelpoort valley which forms one component of the Olifants River Water Resources Development Project (ORWRDP), which was initiated in 2003 to cater for the increasing water requirements of the Limpopo and Mpumalanga Provinces.

#### C.2 Pipeline description

This 40.8 km long steel pipeline between the new De Hoop dam and a pump station in Steelpoort is exposed to a number of planned and existing power lines, ranging from 400 kV to 132 kV (see Fig C.1). It also traverses very close to a main transmission 275 kV substation, Senakgangwedi (see Fig C.2). It is interconnected to an existing pipeline at Spitskop pump station and balancing dam, and share its route from there onwards towards Steelpoort pump station.

The new pipeline varies in diameter, starting at 1.8 m at De Hoop and reduced successively down to 1.3 m at Steelpoort pump station. It will be cathodically protected using an ICCP system with the planned location of the anode ground beds indicated as GB1-3 in Fig C.1.

A number of take-offs serve the mines and communities along the pipeline's length. These take-offs are electrically isolated from the main pipeline with insulating flanges. The pipeline is buried at 1.5 m depth and coated with a 5 mm bitumen – based Bituguard layer. It is not exposed to the public.

#### C.3 Power line description

The characteristics of the power lines influencing the pipeline are listed in Table C.1.

Senak Tubatse -Merensky -Merensky -Arnot -Merensky -Senak Power line: Merensky gangwedi Tubatse 2 Uchoba Merensky (future) gangwedi - Simplon Voltage rating (kV) 400 kV 400 kV 275 kV 275 kV 132 kV 132 kV Phase conductors 2 x Dinosaur 1 x Wolf 1 x Wolf 4 x Tern 2 x Dinosaur 2 x Zebra 2 x 19/2.64 2 x 19/2.64 2 x 19/2.64 2 x 19/2.64 2 x 7/2.64  $2 \times 7/2.64$ Earth wires mm steel mm steel mm steel mm steel mm steel mm steel t.b.a. 510A 419A 419A 248 Tower type 259 vertical horizontal horizontal horizontal horizontal horizontal **Transpositions** none none none none none none

Table C.1 – Power lines influencing the pipeline

The planned Tubatse – Merensky 400 kV line will run closely parallel to the pipeline for 14 km from De Hoop dam and again for 2 km near Merensky substation. A 510A type tower was assumed for this line for the purpose of simulations.

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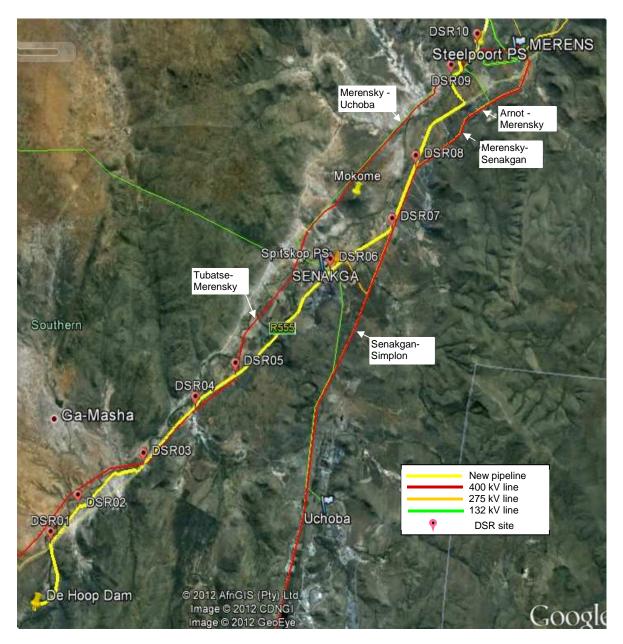


Figure C.1 – Pipeline and power line route overview

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Figure C.2 - Pipeline route detail near Senakgangwedi substation

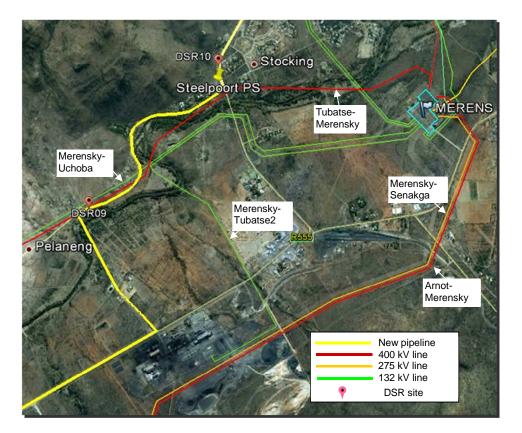


Figure C.3 – Pipeline route detail near Steelpoort pump station

#### C.4 Determination of applicable limits

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The existing 400 kV and 275 kV lines are equipped with teleprotection, with a resultant cumulative fault duration of 0.2 sec or less (see Table 2). The new 400 kV line will be similarly equipped. The two 132 kV lines use stepped distance protection, with a worst-case cumulative fault duration of 0.5 sec. To ensure a conservative design however, a total cumulative fault clearance time of 1 sec is assumed for all the power lines.

From Table 1, the resulting safety voltage limits for occupational exposure during earth faults are 60 V r.m.s. (touch) and 135 V r.m.s. (step), with no surface layer modification. With an asphalt layer, these values increase to 640 V r.m.s (touch) and 2 400 V r.m.s. (step).

For the bitumous coating, the maximum permissible coating stress is 900 V r.m.s.

For steady state conditions, the touch voltage is limited to 15 V r.m.s. during emergency load.

The a.c. corrosion voltage limits adopted by the pipeline operator are 10 V r.m.s. and 4 V r.m.s, for areas with soil resistivities larger or smaller than 25 ohm.m respectively, applicable during normal load.

#### C.5 Determination of zones of influence

The ZOI for *inductive coupling* is 31.7 km, from Eqn (1) (see 3.4.2.1). with  $V_{max} = 60 \text{ V r.m.s.}$ ,  $k_u = 1$ ,  $k_p = 0.8$ ,  $l_f = 20 \text{ kA r.m.s.}$ ,  $L_p = 20 \text{ km}$  and  $\rho = 1 000 \text{ ohm.m.}$ 

The ZOI for conductive coupling from the substations is 6.5 km, from Table 4, for a 200 m x 200 m rural substation and with the voltage limit adjusted from 300 V r.m.s. to 60 V r.m.s.

The ZOI for *conductive coupling from power line towers* is 1.15 km, from Table 5, for a power line with steel earth wires and 500 ohm.m surface resistivity, again adjusted to a 60 V r.m.s. voltage limit.

The ZOI of the anode ground bed is 1 775 m, from Eqn (4), for a 60 m anode energised to 50 V, for a maximum EPR of 200 mV.

The ZOI of the *pipeline* in terms of d.c. leakage is 330 m, from Table 6, for an assumed maximum protection current density of 500 A/m² and a soil surface resistivity of 500 ohm.m.

With all these zone limits exceeded, soil resistivity measurements were required for the detailed calculations of each case.

#### C.6 Soil resistivity analysis

Surface resistivity measurements were made at 100 m intervals along the pipeline route with a Wenner array and 2 m probe spacing. The surface resistivity was found to be relatively low, averaging at 50 ohm.m and with a number of sections having a resistivity less than 25 ohm.m (see Fig C.4).

Deep soil resistivity measurements were made at the sites labelled DSR01 – DSR10 in figs C.1 - C.3., using a CVES linear array of 12 electrodes spaced at 10 m intervals. The subsequent analysis of the resulting data showed that the soil in this area can be accurately represented by just three layers, with the upper two layers in the range 6 ohm.m – 150 ohm.m and the lower (infinite) layer in the range 90 ohm.m – 1000 ohm.m.

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#### Olifants River Water Resource Development Project Phase 2

Soil Resistivity Survey (Phase 2C) (07 December 2010 - 14 December 2010)

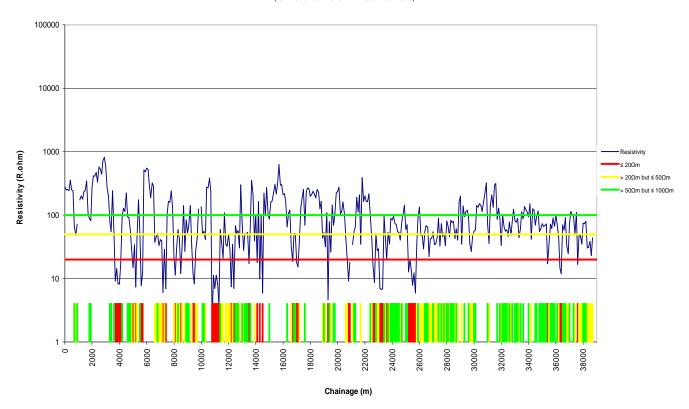


Figure C.4 – Surface resistivity along pipeline route (starting at De Hoop dam)

#### C.7 Software used

The inductive coupling simulations were performed using a Mathcad software module developed for Eskom/TAP by EM Consulting.

The conductive coupling simulations were performed with CDEGS software modules RESAP, MALT and MALZ, developed by Safe Engineering Services (SES), Canada.

#### C.8 Sliding fault current calculation

The sliding fault current profile of all the respective power lines was calculated using the power line details of Table C.1 and the power system parameters provided by Line Engineering Services, representative of the network in 2022. The resulting sliding fault current profile for the planned Tubatse – Merensky 400 kV line, which will have the strongest influence on the pipeline, is as shown in Fig C.5

With more accurate information not yet available, identical span lengths of 400 m are assumed for this line, and a nominal tower footing resistance of 40 ohm is used on all towers.

#### C.9 Determination of worst fault location

Considering the route layout in combination with the fault current levels of Fig C.5, worst induction is most likely to occur for a fault at either DSR01 or DSR03, supplied from Merensky; calculation at both confirmed that a fault at DSR01 produces the highest induction levels. This corresponds to tower number 72.

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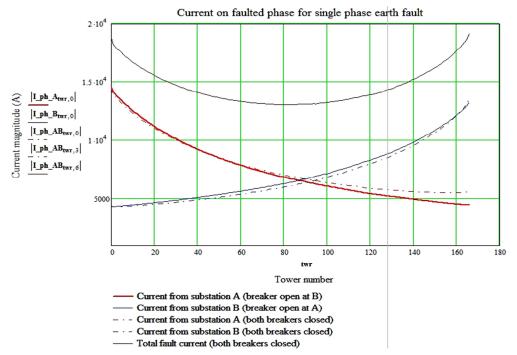


Figure C.5 - Sliding fault current profile on Tubatse-Merensky 400 kV line

#### C.10 Determination of tower voltages and currents

In terms of TST 41-321, the earth wires of the Tubatse – Merensky 400 kV line will be isolated from towers within 800 m of the pipeline route, and each tower isolator equipped with a 12 kV spark gap. Accordingly, these towers are initially removed from the simulation model. For a fault at tower at 72, the calculated tower voltages and footing currents are as indicated in Fig C.6. The voltage at this tower reaches 26 kV and the current 650 A.

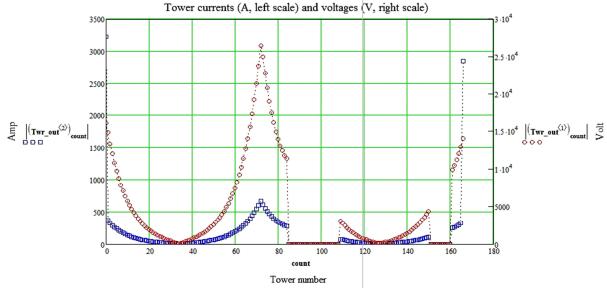


Figure C.6 - Tower voltages and currents, fault at tower 72, Tubatse – Merensky 400 kV line (towers within 800 m insulated, with 12 kV spark gaps)

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At a number of towers equipped with isolators the spark gaps will spark over, i.e. where the voltage exceeds 12 kV. These towers have to be re-inserted into the circuit, in an iterative procedure. At towers 84 – 109 and 150 -161, the voltage remains below 12 kV and these towers remain out of circuit, with a tower voltage of zero, as shown in Fig C.6.

#### C.11 Determination of earth wire currents

The calculated earth wire currents for the same conditions are shown in Fig C.7. At the faulted tower the current in each earth wire reaches 3.5 kA. This reduces to less than 900 A at a distance of 10 km from the fault.

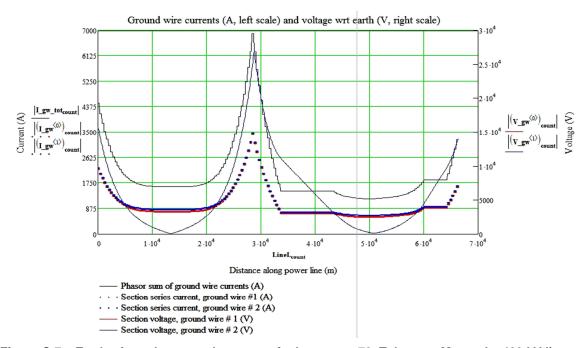


Figure C.7 - Earth wire voltages and currents, fault at tower 72, Tubatse - Merensky 400 kV line

#### C.12 Determination of inductive coupling during an earth fault on Tubatse – Merensky 400 kV

At this stage the route data is entered, along with the soil resistivity of each section and the pipeline parameters – diameter, wall thickness, wall resistivity, coating thickness, coating resistivity and permittivity. With the fault current and earth wire currents established, it is possible to compute the pipeline voltage and current profile, as shown in Fig C.8.

The calculated voltage reaches 1 700 V r.m.s., well in excess of the 900 V r.m.s. coating stress limit for a large section of the pipeline. The touch voltage limits are also exceeded for its entire length. The pipeline current reaches a maximum of 1 450 A r.m.s.

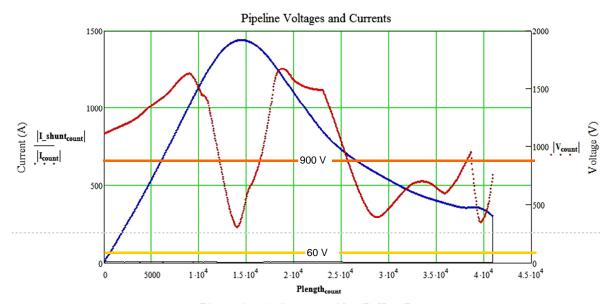
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Distance along pipeline, measured from De Hoop Dam

- Section shunt current to earth (A) (spikes indicate electrode)
- · · · Section series current (A)
- · · · Section voltage to earth (V)

Figure C.8 – Pipeline induction, fault at tower 72 (near DSR01), no mitigation

#### C.13 Determination of inductive coupling during an earth fault, other power lines

Repeating the same procedure for earth faults on the other lines of Table C.1, it was established that the coating stress and safety limits are similarly exceeded. For the Arnot-Merensky line, a fault near DSR07 produces a maximum of 2 300 V r.m.s.

#### C.14 Determination of inductive coupling during steady state conditions

Under normal load conditions, the pipeline will be influenced by the currents of all the power lines listed in Table C.1 simultaneously. This calculation is dependent on the phase sequence of the respective phases of the lines. With the actual phase sequence of the future line unknown, and the sequences of the existing lines not made available, the worst-case combination had to be accounted for.

Following the procedure described in 3.6.3.1 d) of the main text, starting with the Tubatse-Merensky line and adding further lines one at a time, the resulting worst-case voltage is established as shown in Fig C.9 (red curve), for a 3% current unbalance applied to all the Red phases.

The induced voltage on the pipeline for these conditions is well in excess of the 15 V r.m.s. safety limit and the a.c. corrosion limits of 4 V r.m.s. and 10 V r.m.s. respectively.

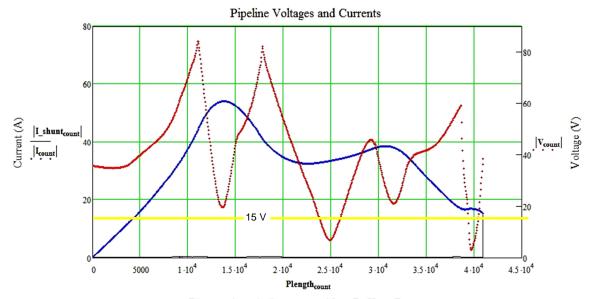
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Distance along pipeline, measured from De Hoop Dam

- Section shunt current to earth (A) (spikes indicate electrode)
- · · · Section series current (A)
- · · · Section voltage to earth (V)

Figure C.9 – Pipeline induction, influence from all 6 power lines, normal load, 3% unbalance, no mitigation

#### C.15 Application of gradient wire and other earthing

The nature of the soil, i.e. a low resistivity layer over a higher resistivity layer, is ideally suited for horizontal gradient wire (zinc ribbon). The earthing resistance offered by each section of given length varies in direct proportion to the surface resistivity indicated in Fig C.4, and was calculated accordingly, using Eqn 9 (see 3.7.1.2).

The application of the resulting earthing points at the voltage maxima is next undertaken, starting with the normal load simulation which, in this case, is the most challenging to mitigate, mainly due to the very low voltage limits for a.c. corrosion. In areas where the soil resistivity is lower than 25 ohm.m, the 4 V r.m.s. limit is applicable – some of the ribbon sections are hence not at voltage maxima but in low resistivity areas where this limit was exceeded. Depending on the requirement, the ribbon length was varied from 200 m to 400 m.

The resistances of the earth grids at De Hoop dam and Steelpoort pump station are also brought into the a.c. circuit by connecting a d.c. decoupler across the insulating flanges. The off-takes have to remain isolated to prevent unwanted transferred potentials.

With all these earthing points connected, the resulting normal load voltage profile is as shown in Fig C.10 (red curve).

The resulting voltage profile is generally below 10 V r.m.s. with the exception of some peaks, however all these peaks coincide with a zinc section which raises the local soil potential and thereby reduces the voltage across the coating, to less than 10 V r.m.s. (this was confirmed by a MALZ conductive coupling analysis similar to that discussed in 3.6.11 in the main text).

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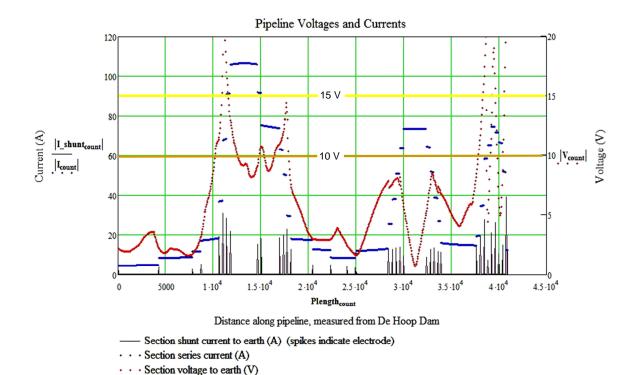


Figure C.10 – Pipeline induction, influence from all 6 power lines, normal load, 3% unbalance, with mitigation

Under emergency load conditions, the current increases by a factor of 1.45 for the Tern conductors of Tubatse-Merensky (from Table 10). Assuming, conservatively, that all the power lines operate 1.45 times normal load, the resulting voltage profile will increase by the same factor. The 15 V r.m.s. safety limit is still met under these conditions.

Each spike on the horizontal axis of Fig C.10 represents the current drawn from the pipeline by a zinc ribbon section, or by a terminal earth grid, through a d.c. decoupler. The considerable number of earthing points required near Steelpoort pump station is the result of the voltage "ballooning" in this area when the other earths are applied.

The maximum current spike level is 40 A r.m.s., which is within the standard d.c. decoupler steady state rating of 45 A r.m.s. (see Table B.2, annex B). The pipeline series current (blue curve) peaks at 106 A r.m.s., however at the insulating flanges at the terminals, the current levels are lower; 4 A r.m.s at De Hoop and 14 A r.m.s at Steelpoort pump station, both well below the d.c. decoupler rating.

#### C.16 Determination of inductive coupling during an earth fault, with mitigation

Fig C.11 shows the pipeline voltage profile for the same earth fault as in Fig C.8, but with the earthing points connected. The maximum voltage is now reduced to 300 V r.m.s., thus the coating stress limit of 900 V r.m.s. is not exceeded. The 60 V r.m.s. safety limit is however still exceeded.

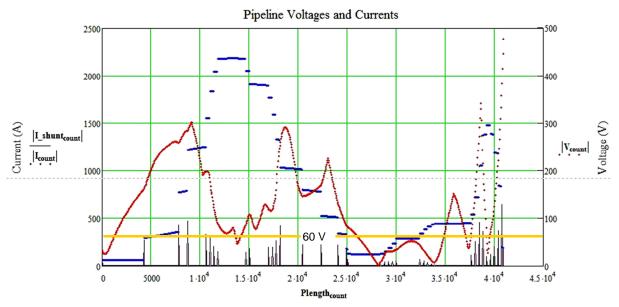
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Distance along pipeline, measured from De Hoop Dam

- Section shunt current to earth (A) (spikes indicate electrode)
- · · · Section series current (A)
- · · · Section voltage to earth (V)

Figure C.11 - Pipeline induction, fault at tower 72 (near DSR01), with mitigation

The induction level was next calculated for a number of other possible fault locations on Tubatse – Merensky and the other power lines. The maximum pipeline voltage was found to occur for a fault on Arnot – Merensky tower 389, reaching 400 V r.m.s. The shape of the voltage profile is then very different to Fig C.11 with the maximum occurring near chainage 3 200 m, i.e. at a minimum in Fig C.11.

Shunt current spikes in Fig C.11 are limited to 670 A r.m.s. and no other fault conditions produced a higher current. The 3.7 kA r.m.s fault current rating of a standard d.c. decoupler (see Table B.2, annex B) is therefore sufficient, with a considerable safety margin.

From this analysis it was evident that, taking account of the inductive coupling component, the coating stress limit will be met, but further mitigation is required at the pipeline appurtenances to ensure that the safety limit is met.

#### C.17 Determination of conductive coupling from power line towers

The smallest separation between the power line and any tower footing occurs at tower 4 of the Senakgangwedi – Simplon power line, at a distance of 25 m. The fault current level at this tower is 14 kA, of which 5 kA will return through the footing and the remainder through the earth wires.

With the tower footing modelled as described in 3.6.7.1 of the main text, the resulting pipeline coating stress is 1 550 V r.m.s. (see Fig C.12). With the 900 V r.m.s. coating limit thus exceeded, a gradient control wire is required. A single 200 m zinc ribbon section reduces the coating stress opposite this tower to 320 V r.m.s. (see Fig C.13).

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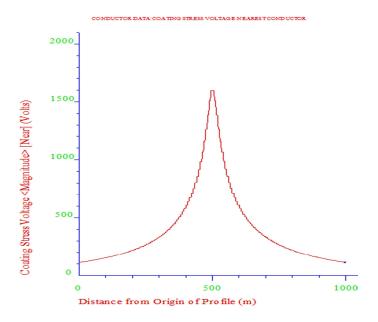


Figure C.12 – Pipeline coating stress during a twr 4 earth fault (5 kA tower energization) – Senakgangwedi – Simplon 275 kV, no mitigation

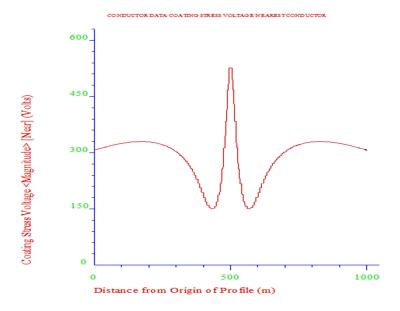


Figure C.13 – Pipeline coating stress during a twr 4 earth fault (5 kA tower energization) – Senakgangwedi – Simplon 275 kV, single 200 m ribbon

Comparing figs C.12 and C.13, the potential transfer effect of the zinc ribbon as discussed in 3.6.7.2 and 3.6.11 is clearly evident, with the pipeline coating stress increasing beyond the ends of the ribbon section. This effect is muted however by the bitumen coating's low resistivity, and the maximum voltage remains below 500 V r.m.s.

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With the coating stress due to inductive coupling less than 100 V r.m.s. for a fault at this tower, the total (inductive plus conductive) stress is less than 600 V r.m.s., i.e. well below the 900 V r.m.s. limit.

A similar analysis was performed for other towers close to the pipeline, and similar mitigation measures where required. The results were consistent with the above, but with lower voltage levels.

#### C.18 Determination of conductive coupling from substation grids

#### C.18.1 Senakgangwedi substation

A phase to earth fault in the 275 kV network at Senakgangwedi substation would result in a total fault current of 16 kA r.m.s., taking account of upgrades until 2022 (no planning or case files were available beyond this date). Of this, a maximum of 10 kA r.m.s. will enter the earth mat and the remainder distribute into the earth wires of the connected power lines, determined in accordance with 3.6.3.2 c) of the main text.

The earthing grid size is  $250 \text{ m} \times 150 \text{ m}$  and the soil represented by DSR06 (comprising of a 22 m thick layer of 6 ohm.m over an infinite lower layer of 125 ohm.m). The resulting earth potential rise (EPR) at the station is 900 V r.m.s. (see fig. C.14). This value is lower than usual for a station of this size, due to the low soil resistivity in this area.

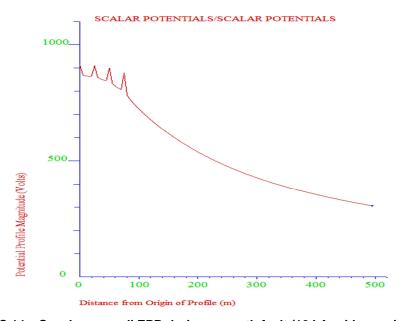


Figure C.14 – Senakgangwedi EPR during an earth fault (10 kA grid energization), from centre of earthing grid

The lateral distance from the pipeline to the edge of the earthing grid is 22 m. Without mitigation, the resulting maximum pipeline coating stress is 570 V r.m.s. (see fig. C.15). In combination with the inductive component, the coating stress limit is approached, and a single 400 m ribbon section was specified. This reduces the maximum touch voltage to 190 V r.m.s. (see Fig C.16).

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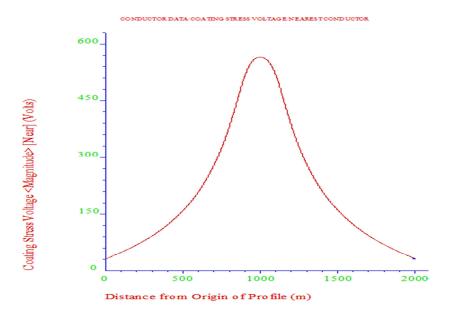


Figure C.15 – Pipeline coating stress during an earth fault (10 kA grid energization) - along pipeline opposite Senakgangwedi, no mitigation

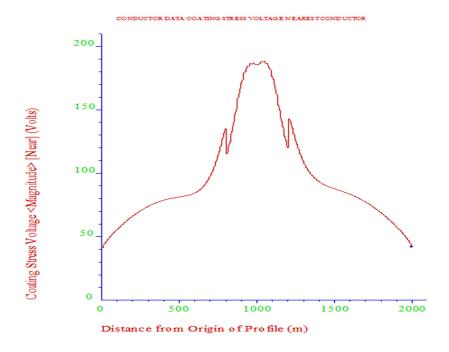


Figure C.16 – Pipeline coating stress during an earth fault (10 kA grid energization) - along pipeline opposite Senakgangwedi, single 400 m ribbon

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In Fig C.16, small voltage discontinuities are observed near the ends of the gradient wire, and some potential is transferred to the pipeline sections beyond the ends. This is however mitigated by the low coating and soil resistivities, making these increases acceptable.

#### C.18.2 Merensky substation

At Merensky substation, the maximum earth fault level occurs on the 132 kV side, at 31 kA r.m.s. Without mitigation, the maximum pipeline coating stress due to this substation's EPR is 400 V r.m.s., in spite of the 2 030 m separating the pipeline and substation. In combination with the inductive component the total coating stress will, however, remain below the 900 V r.m.s. limit.

The already extensive use of zinc ribbon on this section of the pipeline for inductive coupling mitigation will further reduce the conducted component and no additional zinc ribbon is required.

#### C.19 Determination of d.c. coupling from the cathodic protection system

#### C.19.1 Coupling from pipeline

The d.c. potential gradient adjacent to the pipeline was calculated for an average pipeline voltage of -1.5 V d.c. and a surface soil resistivity of 250 ohm.m, representing the higher of the measured values. It is assumed that the coating defects are evenly distributed.

The results indicate that a minimum lateral distance of 150 m from the pipeline must be maintained to prevent a soil potential gradient greater than 1 mV/m, which over a 400 m span can result in a d.c. gradient exceeding 400 mV (see Fig C.17). Since this distance is smaller than the 800 m required by the earthing standard TST-41-321, the standard should be maintained, and the earth wires of towers within 800 m of the pipeline should be isolated.

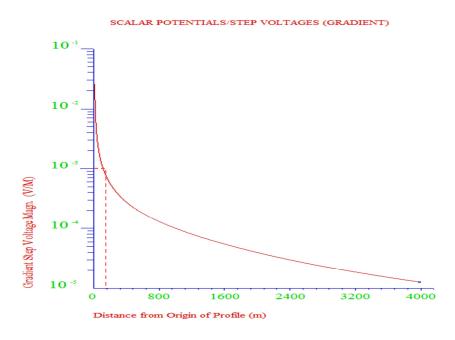


Figure C.17 – Earth d.c. potential gradient vs. lateral distance from pipeline, 5 mm Bituguard coating, 250 ohm.m surface soil

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#### C.19.2 Coupling from anode ground beds

The planned location of the anode ground beds is indicated as GB1 – GB3 in Fig C.1 – C.3. Each ground bed consists of a single 60 m horizontal conductor installed in a carbonaceous backfill.

The d.c. ground shift was calculated around these using the soil layers of the respective DSR region. At 10 A nominal CP current, an earth potential rise in excess of +200 mV extends to the following distances around the ground beds:

GB1:700 mGB2:900 mGB3:800 m

For the power line towers falling inside these distances, isolating the earth wires would prevent hazardous current levels from entering the power lines.

None of the planned ground beds can cause a voltage gradient in excess of 400 mV across the legs or anchors of the nearest towers.

#### C.20 Pipeline a.c. mitigation requirements

From the analysis, it was evident that the applicable steady state limits can be met with selected gradient wire sections and with the earthing systems at the pipeline's extremities connected to the pipeline.

It was further evident that the 900 V r.m.s. coating stress limit for fault conditions will be met, but the 60 V r.m.s. touch limit can be exceeded at most of the valve stations and other pipeline appurtenances, depending on the location of the fault, indicating that further localised mitigation is required.

Externally, gradient control mats installed around the pipeline appurtenances and connected to the pipeline through appropriately rated VLDs will constitute an effective mitigation method.

Alternately, a 10 cm – 15 cm thick asphalt layer can be used around the appurtenances, increasing the touch voltage limit to 640 V r.m.s., a level not exceeded for any of the fault conditions.

In addition to the external protection method (i.e. gradient control mat or asphalt layer), further protection is required inside the valve chambers. This may be done by connecting the chamber's reinforcing steel to the pipeline, also through a VLD. For this purpose, the steel reinforcing has to be made galvanically continuous, and equipped with a suitable connection point, prior to concrete casting.

The specific requirements are summarised in tables C.4 and C.5.

#### C.21 Protection of existing pipeline

To prevent hazardous potentials between the new pipeline and the existing pipeline running from Spitskop pump station to Steelpoort pump station, cross-bonds are required at points where simultaneous contact is possible for a maintenance person standing between the pipelines or pipeline attachments. Cross-bonds are also recommended at regular intervals not exceeding 1 000 m, using either resistive or direct bonds or d.c. decoupling devices, as dictated by the cathodic protection system's requirements.

The existing valve chambers not equipped with a.c. mitigation require retrofitting with internal earth mats comprising a suitably shaped steel weld mesh cut-out, laid on the floor and encased in a 3 cm thick screed layer. The earth mat is connected to the pipeline through a VLD.

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Table C.4: Location and lengths of zinc ribbon

Start chainage [m]	End chainage [m]	Site description	Electrode description
4 230	4 690	near DSR01	1 x 400 m ribbon
7 850	8 250	between DSR02 & DSR03	1 x 400 m ribbon
8 820	9 220	between DSR02 &DSR03	1 x 400 m ribbon
9 970	11 570	near DSR03	4 x 400 m ribbon
13 920	14 720	near DSR04	2 x 400 m ribbon
16 840	18 440	near DSR05	4 x 400 m ribbon
19 940	20 340	at Dwars river bridge	1 x 400 m ribbon
21 400	21 800	at old farm ruins	1 x 400 m ribbon
23 120	23 520	at Xtrada mine entrance	1 x 400 m ribbon
24 380	24 780	at Senakgangwedi substation	1 x 400 m ribbon
25 480	25 680	at 275 kV crossing near Spitskop	1 x 200 m ribbon
27 640	29 640	near DSR07	5 x 400 m ribbon
30 990	32 990	near DSR08	5 x 400 m ribbon
36 500	40 100	end of pipeline	9 x 400 m ribbon
		Ribbon total length:	14 600 m

Table C.5: Location and type of valve station gradient control measures

Start chainage (m)	End chainage (m)	Section description	Measures required
0	40 300	entire pipeline	earth chamber re-bar plus external mat OR
		·	earth chamber re-bar plus external asphalt layer

#### C.22 Measures at pump stations and dam outlet works

To prevent hazardous voltage differences, a meshed earthing topology has to be applied inside the pump station buildings at Steelpoort and Spitskop and at the De Hoop dam outlet works, in accordance with SANS 61000-5-2.

The buildings require a ring earth or bonding bar, 25 mm x 3 mm copper (or equivalent), to which all metal structures (pipes, steel floor reinforcement, structural steel, stairs, walkways, handrails etc.) are bonded. The pump casing itself is also bonded to this bonding bar.

The incoming and outgoing pipelines having a CP potential must remain d.c. insulated from the earth mesh. To permit a.c. current and surges to flow, d.c. decoupling devices are connected between the insulated pipeline and the earthing system (e.g. across the insulating flanges).

#### C.23 Mitigation of d.c. leakage effects at power line towers

The earth wires of all metallic power line towers within 800 m of the pipelines or in the vicinity of anode ground beds GB1, GB2 and GB3, have to be isolated (see Table C.6).

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The gap size of the spark gaps across the insulators should be set to 8 mm, and in accordance with the issued line hardware specifications. Warning plaques have to be installed on the insulated towers, clearly

indicating that the earth wire must be treated as "live" and temporary earthing is required during maintenance.

Table C.6: Towers requiring insulators on the earth wires

Power line	km	Tower no. (approx)
Tubatse - Merensky 400 kV	29.0 - 43.5 59.63 - 64.55	73 – 109 149 - 161
Arnot -Merensky 400 kV	136.5 – 144.0	390 - 412
Merensky-Senakgangwedi 275 kV	8.0 – 15.0	23 - 43
Senakgangwedi – Simplon 275 kV	0 – 1.8	1 - 6
Merensky-Uchoba 132 kV	1.8 – 6.0	7 - 24
Merensky – Tubatse 132 kV	1.8 – 4.0	7 - 16
Jane Furse – Uchoba 132 kV	25.0 – 27.0	100 - 108

**Note:** The tower numbers shown are based on equal span lengths - the actual tower numbers to be confirmed, using the kms indicated.

Eskom's existing lines can often not be de-energised for a sufficient period to permit fitting of earth wire insulators. In this case, the affected towers may be protected with zinc or magnesium sacrificial anodes.

The design of sacrificial anodes is dependant on the local soil properties and the actual d.c. potential shift at each tower, and should be undertaken by a cathodic protection specialist, once the CP system is activated and the resulting d.c. potential shift has been measured.

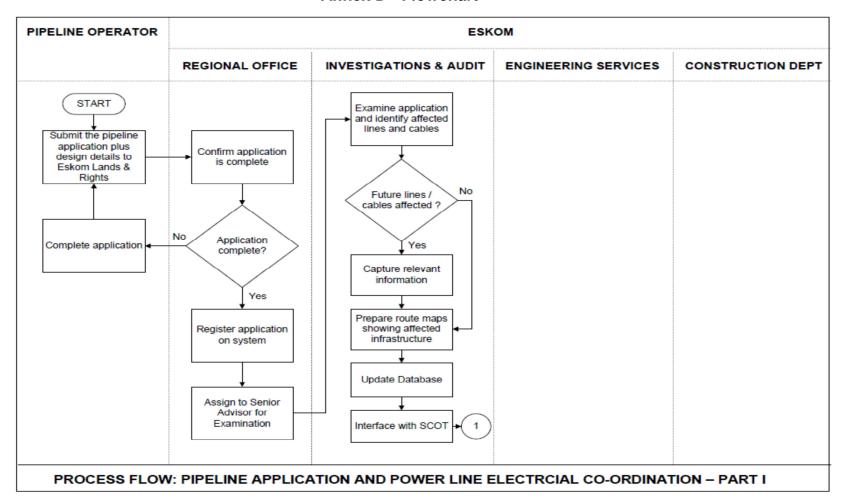
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#### **Annex D - Flowchart**



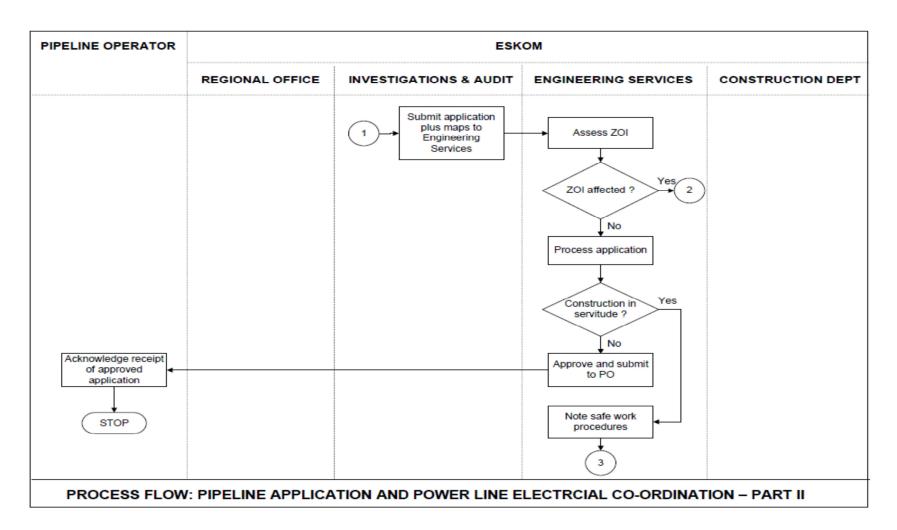
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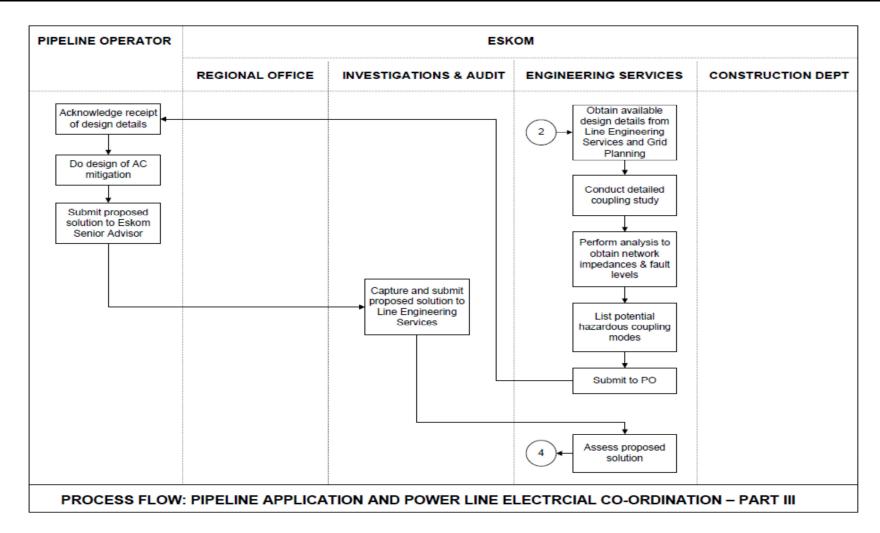
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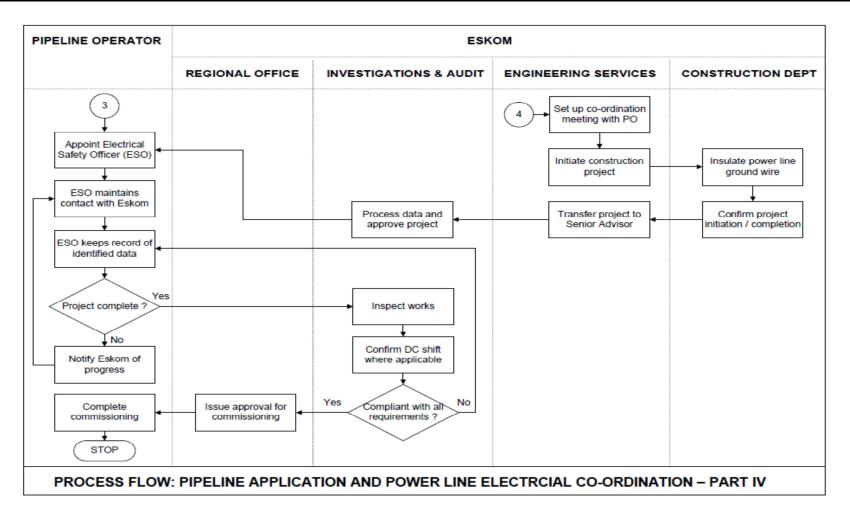
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## Annex E – Inspection sheet for a.c. mitigation components and servitude works

Inspection sheet No:		Date of issue:			
Pipeline name and location:					
Pipeline owner and address:					
Contractor responsible for a.c. mitigation design:					
Contractor responsible for a.c. mitigation i	installa	tion:			
INSTALLATION					
New installation on new pipeline		New installation on existing pipelin	ne 🗌	Alteration / extension	
Type of exposure:		General Public		Authorised personnel	
Type of cathodic protection:		Impressed current		Sacrificial anodes	
Type of pipeline product:	of pipeline product:  Hazardous substance  Non-hazardous substance				
Name and voltage rating of power line(s) or cable(s) influencing this pipeline:					
Owner and address of the power line(s): .					
Section of pipeline inspected: KP KP KP					
Description of installation covered by this inspection (add additional pages or drawings as applicable):					

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## Inspection sheet (continued)

NUMBER OF ITEMS COVERED BY THIS INSPECTION				
Item	Existing installation	New / altered installation		
CP rectifier				
Vertical earth rod electrode				
Zinc ribbon electrode				
Gradient control mat				
d.c. decoupler				
Magnesium or zinc anode				
Surge protection or voltage limiting device				
Bonding link				
Drainage unit				
Earth cover around installations				
Rehabilitation of servitude				
Pipeline markers				
Power line tower earth wire isolation				
Power line tower sacrificial anode				
d.c. shift at tower footing				
Impressed current ground bed (location check)				
Maintenance schedule				

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## Inspection sheet (continued)

INSPECTION AND TESTS				
Inspection	Existing installation	New / altered installation		
1 Accessible components correctly selected				
2 All protective devices of the correct rating				
3 Components have been correctly installed				
4 The enclosures used are of the correct IP rating				
5 Bonding links and cables of the correct thickness and leng	gth			
6 Components that may become "live" protected from direct	t contact (dead front	construction)		
7 Components correctly labelled				
8 SANS 1014-1 Certificate of Compliance issued for the CF	rectifier installations	S		
Tests	Units	Instrument	Reading /result	
			Existing installation	New / altered installation
1 Continuity of cables and bonding	Ohm			
2 Resistance of earth electrode (a.c. measurement)	Ohm			
3 Impedance of d.c. decoupler (below 15 V r.m.s. applied)	Ohm			
4 Pipeline voltage to remote earth	V r.m.s.			
5 d.c. potential shift at tower footing due to CP system	mV			

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Inspection sneet (continued)	
INSPECTION AND TESTS	
Comments:	
RESPONSIBILITY	
I/We, being the person(s) responsible for the INSPECTION AND TESTING of the a.c. n the installation conforms to the design requirements approved by the relevant Electrical signatory is limited to the installation described in this form.	nitigation measures, particulars of which are given in this form, confirm that Supply Authority and the Pipeline Operator. The extent of the liability of the
Name (in block letters):	
Capacity:	Signature:
Address:	Date:

Proposed Emergency
Ecological Assessment at
Woodmead Water Pipe
Upgrade, City of
Johannesburg, Gauteng
Province.



Prepared For: NTC Environmental (Pty) Ltd Attention: Ms. Ethel Chifunda

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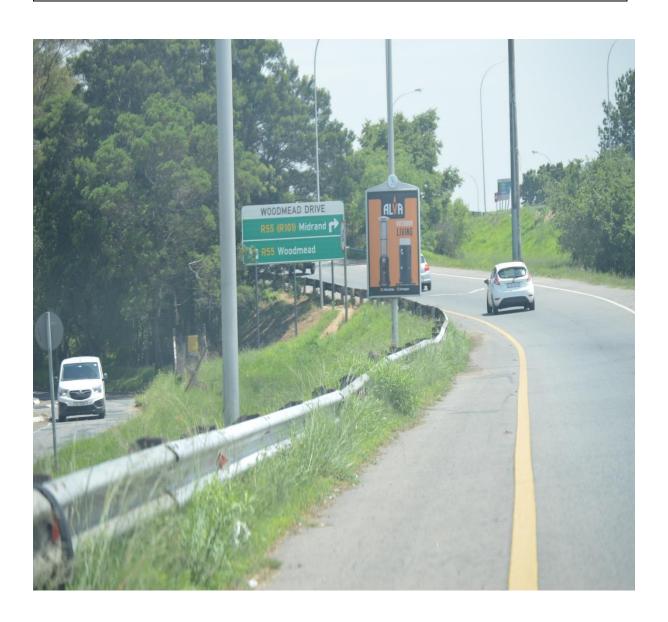
Prepared By:
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# November 2022



## **Executive Summary**

#### Introduction and Background

Johannesburg Water (JW) proposes to upgrade the water pipeline in Woodmead Park, Johannesburg. The proposed pipeline is approximately 6,3Km.

Mboneni Ecological Services (Pty) Ltd was appointed by NTC Environmental (Pty) Ltd to undertake a Terrestrial Biodiversity Assessment as part of the Environmental Impact Assessment (EIA) process in order to assess the impacts that the proposed development will have on the receiving environment. The objective of this study was to identify sensitive species and their habitats on the study area. The current ecological status and conservation priority of vegetation on the site were assessed. Potential faunal habitats were investigated in the study area and all mammals, birds and reptiles known to occur or seen along the pipeline route.

## **Study Area**

The proposed water pipeline upgrade route is situated on the Farms Haakdoornkraal 2 JR, Waterval 5 IR, Elkin 3 IR, Woodlands 7 IR, Bergvalei 37 IR and Zandfontein 42 IR, City of Johannesburg, City of Johannesburg, Gauteng Province.

#### **Regional Vegetation**

The proposed pipeline route falls within the <u>Grassland Biome</u> and this Biome has a high biodiversity, ranked only below the Fynbos biome in terms of biodiversity in South Africa. This Biome is found mainly on the high central plateau of South Africa, and the inland areas of KwaZulu-Natal Province and the Eastern Cape Province. Grasslands are dominated by a single layer of grasses. Trees are absent, except in a few localised habitats and geophytes are often abundant.

The proposed pipeline route is classified as falling within the Egoli Granite Grassland vegetation type and no remnants of this vegetation type exists on site.

#### **Terrestrial Threatened Ecosystems**

"Ecosystem protection level" is an indicator of how adequately an ecosystem is protected or not. Ecosystems can be classified as *not protected*, *poorly protected*, *moderately protected* or *well protected* depending on the proportion of each ecosystem that is under conservation management within a protected area, as recognized in the National Environmental Management: Protected Areas Act (Act 57 of 2003) –these protected areas include state or privately-owned protected areas as well a land under biodiversity stewardship agreements.

According to Government Gazette SANBI Threatened Ecosystems, the project site falls within the Egoli Granite Grassland terrestrial threatened ecosystem. This ecosystem/vegetation type is listed as **Poorly Protected (PP)** on a national scale. An ecosystem is considered "not protected" if under 5% of its biodiversity target is met within protected areas, "poorly protected"

if 5% to 49% of its target is met in protected areas, and "moderately protected" if 50% to 99% of its target is met. If more than 100% of the target is met in protected areas, it is considered "well protected".

#### **Gauteng Conservation Plan**

Gauteng Conservation Plan 3.3 includes the following units that will be used as input into the National Bioregional Plan for the country:

- <u>Critical Biodiversity Areas (CBA):</u> containing *Irreplaceable, Important* and *Protected Areas* all merged together into one layer.
- <u>Ecological Support Areas (ESA):</u> containing all layers that are part of the entire hierarchy of biodiversity, but it is not possible to include all biodiversity features.

The proposed pipeline route does not fall within any of the Gauteng CBAs and ESA regions.

#### **Gauteng Ridges**

Ridges are specialized by high spatial heterogeneity due to the range of differing aspects (north, south, east, west and variations thereof), slopes and altitudes resulting in differing soil characteristics (e.g., depth, moisture, temperature, drainage, nutrient content), light and hydrological conditions. Moist cool aspects are more conducive to the leaching of nutrients than warmer drier slopes. Variations in aspect, soil drainage and elevation/altitude have been found to be especially important predictors of biodiversity. The project route does not fall within any of the Gauteng ridge classes, with Classes 3 and 4 ridges situated North and West.

#### Methodology

Survey methodology included a comprehensive desktop review, utilising available provincial and national ecological data, relevant literature, GIS databases, topographical maps and aerial photography. This was then supplemented through a ground-truthing phase, where pertinent areas associated with the project area were visited during field survey undertaken on 25 November 2022. The survey focused on flora (vegetation) and fauna (mammals, avifauna, reptiles and amphibians). Several Red Listed Data floral and faunal species pertaining to the project area were identified during the desktop review and their habitat suitability was assessed through the ground-truthing phase of the survey.

#### Results and Discussion – Flora and Fauna

The proposed pipe upgrade route is situated along the servitudes/ road reserve, and traverses main roads such as Marlboro and M1. It is situated in an urban environment and most of the plants were cultivated as part of street trees project, landscaping and gardening. During the field survey, no threatened plant species or protected trees were observed along the proposed route. However, the following plant species are listed as "Protected Plants" in terms of Schedule 11 (Section 86 (1) (a)) of Transvaal Nature Conservation Ordinance No. 12 of 1983, namely all species of agapanthus *Agapanthus africanus*.

A plant species such as *Hypoxis hemerocallidea*, is listed as Orange Listed Plant species. Orange lists are those within the Red list that are categorised as rare, Data deficient, declining

or near threatened. *Hypoxis hemerocallidea* occurs in an open grassland and woodland and is widespread in South Africa in the eastern summer rainfall provinces (Eastern Cape, Free State, KwaZulu-Natal, Mpumalanga, Gauteng and Limpopo). It also occurs in Botswana, Lesotho and Swaziland and it's a highly sought-after medicinal plant. This species used to be classified as *Declining*, but now de-classified as *Least concern*. Species classified as Least concern are considered at low risk of extinction and are widespread and abundant, however, Gauteng Department of Agriculture and Rural Development (GDARD) has indicated that this species must remain classified as Orange list plant species due to its provincial level pressures.

Therefore, in order to mitigate the impacts to these plant species, all provincially protected plant species and Orange listed plants found along the route, should be protected and avoided. These plants should be planted just outside of the development route after the completion of construction activities. Where this proves not to be possible, a permit will be required from GDARD to transplant these plant species outside of the proposed pipeline route or donated to Conservation areas. The permit application should be preceded by a Search, Rescue and Relocation Plan. This Plan must be compiled by a competent Ecologist/Botanist. This Plan should also take into account medicinal plant species such as *Albuca virens* recorded along the route site.

Fauna species recorded along the proposed route were common and are typical of grassland vegetation. No fauna Species of Conservation Concern were recorded along the study route. The fragmented and transformed area has lost the ecological ability to sustain any faunal assemblage or community. The human presence and associated disturbances taking place usually have a detrimental impact on fauna species (especially mammals and snakes) in the area.

### **Terrestrial Sensitivity**

The entire proposed water pipeline upgrade route is assigned a **Low** sensitivity because they have low ecological value and provide limited to none of the ecosystem services. The species diversity along the route are low and all species present have a much wider distribution beyond this habitat or locality.

#### **Conclusion and Recommendations**

Generally, the development activities proposed within the route will not have a significant impact on biodiversity conservation within the region. It is the opinion of the ecologist, that the proposed water pipeline upgrade project be considered favourably, provided that the mitigation measures are implemented and adhered to. The methodologies used and results found during the field survey, together with the impacts and mitigation measures provide confidence that the project can go ahead.

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# List of Abbreviations

ADU Animal Demography Unit

AIPs Alien Invasive Plant species

BODATSA Botanical Database of Southern Africa

CBAs Critical Biodiversity Areas

CARA Conservation of Agricultural Resources Act

CoJ City of Johannesburg

DFFE Department of Forestry, Fisheries and the Environment

EIA Environmental Impact Assessment

EMPr Environmental Management Programme

ESAs Ecological Support Areas
GPS Global Positioning System

GIS Geographic information system

QDS Quarter degree Squares

GDARD Gauteng Department of Agriculture and Rural Development

JW Johannesburg Water

IBA Important Bird and Biodiversity Area

IUCN International Union for Conservation of Nature

NBA National Biodiversity Assessment

NEMA National Environmental Management Act
PRECIS Pretoria Computer Information Systems
SAAB South African Association of Botanists

SAIEES South African Institute of Ecologists and Environmental Scientists

SABAP South African Bird Atlas Project

SACNASP South African Council for Natural Scientific Professions

SANBI South African National Biodiversity Institute

SARCA Southern African Reptile Conservation Assessment

SCC Species of Conservation Concern
TOPS Threatened or Protected Species

#### Declaration of Independence

#### I, Avhafarei Phamphe, declare that I -

- act as the independent specialist;
- do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the Environmental Impact Assessment Regulations 2014;
- will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- there are no circumstances that may compromise my objectivity in performing such work;
- have expertise in conducting the specialist report relevant to this application, including knowledge of the National Environmental Management Act, 1998 (Act No. 107 of 1998), regulations and any guidelines that have relevance to the proposed activity;
- will comply with the Act, regulations and all other applicable legislation;
- · have no, and will not engage in, conflicting interests in the undertaking of the activity;
- undertake that the report adheres to Appendix 6 of GN No. R 982 of 4 December 2014 (as amended), and
- will provide the Competent Authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not.

#### Avhafarei Phamphe:

- Holds a M. Sc in Botany from the University of the Pretoria;
- Is registered with South African Council for Natural Scientific Professions (SACNASP) as a Professional Natural Scientist (Pr.Sci.Nat) Ecological Science, (Registration No.: 400349/12), with expertise in floral and faunal ecology;
- Has been actively involved in the environmental consultancy field for over 18 years;
- Is a Professional Member of South African Institute of Ecologists and Environmental Scientists (SAEES) and
- Is a member of the South African Association of Botanists (SAAB).

vhafarei Phamphe
lame of Specialist
Iboneni Ecological Services (Pty) Ltd
lame of Company
9 November 2022
Pate
ignature

#### 1 Introduction And Background

Johannesburg Water (JW) proposes to upgrade the water pipeline in Woodmead Park, Johannesburg. The proposed pipeline is approximately 6,3Km.

Mboneni Ecological Services (Pty) Ltd was appointed by NTC Environmental (Pty) Ltd to undertake a Terrestrial Biodiversity Assessment as part of the Environmental Impact Assessment (EIA) process in order to assess the impacts that the proposed development will have on the receiving environment. The objective of this study was to identify sensitive species and their habitats on the study area. The current ecological status and conservation priority of vegetation on the site were assessed. Potential faunal habitats were investigated in the study area and all mammals, birds and reptiles known to occur or seen along the pipeline route.

# 2 STUDY AREA

The proposed water pipeline upgrade route is situated on the Farms Haakdoornkraal 2 JR, Waterval 5 IR, Elkin 3 IR, Woodlands 7 IR, Bergvalei 37 IR and Zandfontein 42 IR, City of Johannesburg, Gauteng Province (**Figures 1** and **2**).

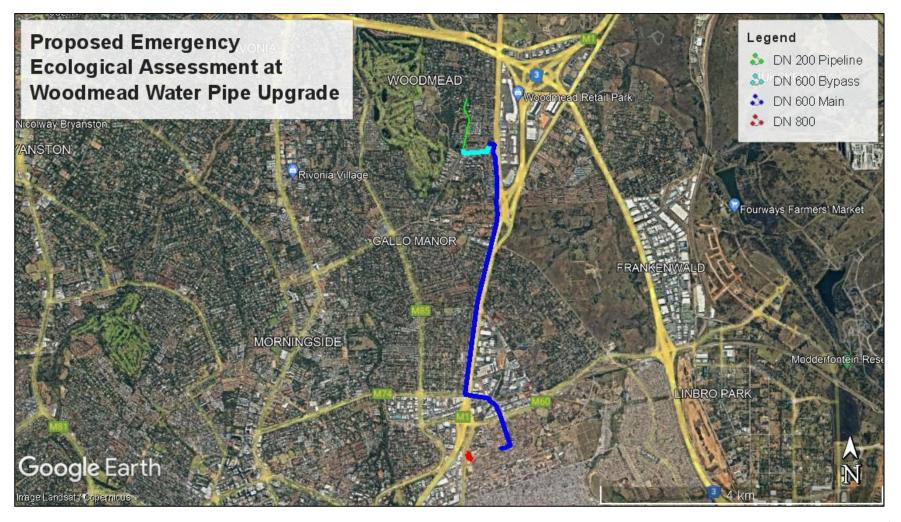


Figure 1. Google Earth image of the proposed pipeline route

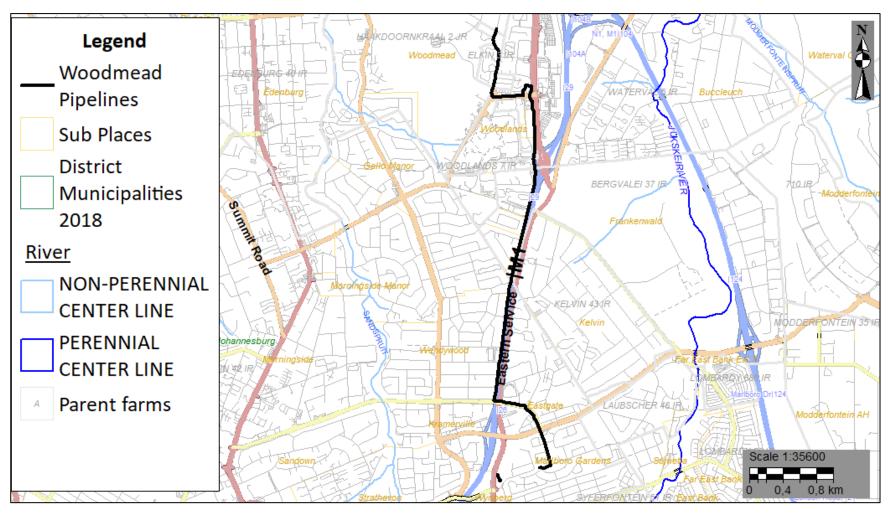


Figure 2. Locality Map of the project site

## 3 RELEVANT LEGISLATION AND GUIDELINES

The following legislations are relevant to this project:

- Transvaal Nature Conservation Ordinance, 1983 (Act No. 12 of 1983);
- The Constitution, 1996 (Act No. 108 of 1996) Section 24;
- Conservation of Agricultural Resources Act, 1983 (Act No. 43 of 1983);
- The white paper on the Conservation and Sustainable Use of South Africa's Biological Diversity (1997);
- National Forests Act, 1998 (Act No. 84 of 1998);
- National Environmental Management Act, 1998 (Act No. 107 of 1998);
- National Environmental Management Biodiversity Act, 2004 (Act No. 10 of 2004);
- National Environmental Management: Biodiversity Act, 2004 (Act No. 10 of 2004)
   Threatened or Protected Species regulations;
- Guidelines for Involving Specialists in the EIA Processes Series (2005);
- Gauteng Ridge Guidelines (2006);
- The National Environmental Management Act (NEMA) No. 107 of 1998): Environmental Impact Assessment Regulations, 2014 as amended. Specifically, the requirements of the specialist report as per the requirements of Appendix 6;
- Gauteng Conservation Plan Version 3.3 (2011);
- Draft Bioregional Plan for the City of Johannesburg (2011);
- National Environmental Management: Biodiversity Act, 2004 (Act No. 10 of 2004) -Alien and Invasive Species (AIS) Regulations which became law on 1 October 2014;
- Gauteng Department of Agriculture and Rural Development (GDARD) Requirements for Biodiversity Assessments Version 3 (2014) and
- National Biodiversity Assessment (2018).

# 4 LIMITATIONS, GAPS AND ASSUMPTIONS

The following constraints/limitations were applicable to this assessment:

• The field survey was conducted in November 2022, which covers optimal time of the year to find animals and plant species of high conservation priority. It is unlikely that any more visits would reveal information that would change the outcome of this assessment both in terms of ecosystems of special conservation concern or suitable habitats of species of particular conservation concern. A site visit which was conducted therefore appear to be sufficient to address the objectives of this study.

- The survey areas were concentrated along the proposed development route.
- Weather condition during the survey was favourable for recording both fauna and flora.
- The focus of the survey remains a habitat survey that concentrates on the possibility that species of particular conservation priority occur on the site or not.
- While assessment of the potential occurrence of SCC has been undertaken, and
  is informed by readily available information, this provides only a surrogate indicator
  of the likelihood of such species occurring. This is however regarded as appropriate
  given the level of habitat degradation/transformation across much of the project
  area.
- Data collection in this study relied heavily on data from representative, homogenous sections of vegetation units, as well as general observations, analysis of satellite imagery from the past until the present, generic data and a desktop analysis.
- The potential of future similar developments in the same geographical area, which could lead to cumulative impacts cannot be meaningfully anticipated.
- The impact descriptions and assessment are based on the author's understanding
  of the proposed development based on the site visit and information provided.
  Since ecological impact studies deal with dynamic natural systems additional
  information may come to light at a later stage and this Specialist can thus not
  accept responsibility for conclusions and mitigation measures made in good faithbased information gathered or databases consulted at the time of the investigation.

# 5 METHODOLOGY

#### 5.1 Flora

The flora assessment consisted of two complementary approaches:

- A desktop analysis, which included literature review, previous biodiversity reports, local knowledge, topographical maps, and Google Earth imagery; and
- Site visit was conducted on 25 November 2022.

Satellite imagery of the area was obtained from Google Earth and was studied in order to acquire a three-dimensional impression of the topography and land-use and also to identify potential "hot-spots" or specialized habitats such as ridges, rivers and natural vegetation on or near the project area.

The computerized data storage and retrieval system, called the Botanical Database of Southern Africa (BODATSA) was consulted to retrieve a list of Red Data plants recorded from the 2628AA Quarter Degree Square (QDS) http://posa.sanbi.org/searchspp.php). This list was used to determine which Red Data plant species could potentially occur on the project route. Version 2022 of the Red List of South African plants (<a href="http://redlist.sanbi.org/index.php">http://redlist.sanbi.org/index.php</a>), which is managed as part of SANBI's Threatened Species Programme, was consulted for the current conservation status of each species in the above list. The term "Species of Conservation Concern" (SCC) as defined by Raimondo et al. (2009) was followed in this report, namely all species classified as threatened (Critically Endangered, Endangered and Vulnerable), as well as species classified as Near Threatened, Critically Rare and Rare.

The vegetation map published by Mucina and Rutherford (2018) was consulted to identify vegetation types that are found along the project route. The description of the vegetation types follows Mucina and Rutherford (2006).

The project route was traversed on foot and species listed as they were encountered. Attention was paid to the occurrence of medicinal, Red data plant species, protected trees, provincially protected plants, alien invasive and declared weed species. Field guides such as van Wyk *et al.* (1997), Pooley (1998), van Oudshoorn (1999) and Manning (2009) were consulted during the field visit to aid in the identification of plant species.

Regulations published for the National Forests Act (Act 84 of 1998) as amended, provide a list of protected tree species for South Africa. The species on this list were assessed in order to determine which protected tree species have a geographical distribution that coincides with the study area and habitat requirements that may be met by available habitat in the study area. The distributions of species on this list were obtained from published sources (e.g., van Wyk & van Wyk 1997) and from the South African National Biodiversity Institute (SANBI) Biodiversity Information System website (http://sibis.sanbi.org/) for the quarter degree grid in which species have been previously recorded.

Alien Invasive plant species are controlled by the National Environmental Management: Biodiversity Act, 2004 (Act No. 10 of 2004) - Alien and Invasive Species (AIS) List, 2016 (and the latest revised edition of 2019-02-13) was consulted. The AIS Regulations list different categories of invasive species that must be managed, controlled or eradicated from areas where they may cause harm to the environment, or that are prohibited to be brought into South Africa.

Alien Invasive plant species are divided into four categories, namely:

 Category 1a: Invasive species which must be combatted and eradicated. Any form of trade or planting is strictly prohibited.

- Category 1b: Invasive species which must be controlled and wherever possible, removed and destroyed. Any form or trade or planting is strictly prohibited.
- Category 2: Invasive species, or species deemed to be potentially invasive, in which a
  permit is required to carry out a restricted activity. Category 2 species include
  commercially important species such as pine, wattle and gum trees.
- Category 3: Invasive species which may remain in prescribed areas or provinces.
   Further planting, propagation or trade, is however prohibited.

#### 5.2 <u>Mammals</u>

The Animal Demographic Unit (ADU) website, previous biodiversity reports, South African National Biodiversity Institute (SANBI) and Skinner & Chaminda (2005) were consulted in order to draw up a list of mammal species potentially occurring along the proposed pipeline route.

During the site visit, mammals were identified by spoor, burrows and visual sightings through random transect walks and documented. The habitat quality and quantity for Red Listed species potentially present were evaluated. The adjoining properties (approximately 50m) were also scanned for the presence of Red Listed mammal species/habitat. The confirmed list of presences was augmented with anecdotal information provided by the local community residing in the vicinity of the proposed pipeline route.

#### 5.3 Avifauna

The online databases of the Southern African Bird Atlas Project (SABAP 2), previous biodiversity reports and *Mybirdpatch* were consulted as a means to determine which Red Listed bird species were previously recorded from the area.

During the site visit, this list was audited based on confirmed sightings of Red Listed bird species and the evaluation of suitable habitat for Red Listed bird species potentially present.

The study route, including the adjoining properties within 50 m, were surveyed on foot during random transect walks and all sightings were documented.

Birds were identified through visual identification by using a 10 x 50 Voyager binocular, by call, and from feathers. Where necessary, identifications were verified using field guides such as Sasol birds of Southern Africa (Sinclair *et al.* 2002) and the Chamberlain Guide to Birding Gauteng (Marais & Peacock, 2008).

## 5.4 Reptiles

The ADU website, previous biodiversity reports, SANBI and historic distributions (Alexander & Marais, 2007) of reptile species were consulted in order to draw up list of potential occurrences. During site visit, reptiles were identified by visual sightings during random transect walks. Possible reptile retreats such as burrows were inspected for any inhabitants. The habitat quality and quantity for Red Listed species potentially present were evaluated. The adjoining properties (approximately 50 m) were also scanned for sensitive reptile species and habitats. The list of confirmed presences was augmented with anecdotal information provided by the local community residing in the vicinity of the proposed pipeline route.

## 6 GAUTENG CONSERVATION PLAN

Gauteng Nature Conservation, a unit within GDARD, produced the Gauteng C-Plan Version 3 (C-Plan 3) in December 2010. C-Plan is critical in ensuring adequate protection of biodiversity and the environment in Gauteng Province (Gauteng Conservation Plan Version 3.3, 2011). Gauteng C-Plan 3.3 includes the following that will be used as input into the National Bioregional Plan for the country:

- <u>Critical Biodiversity Areas (CBA):</u> containing *Irreplaceable, Important* and *Protected Areas* all merged together into one layer.
- <u>Ecological Support Areas (ESA):</u> containing all layers that are part of the entire hierarchy of biodiversity, but it is not possible to include all biodiversity features.

CBAs include natural or near-natural terrestrial and aquatic features that were selected based on an areas biodiversity characteristics, spatial configuration and requirement for meeting both biodiversity pattern and ecological process targets.

ESAs are areas that are not essential for meeting biodiversity representation targets/thresholds, but nonetheless play an important role in supporting the ecological functioning of critical biodiversity areas and/or in delivering ecosystem services that support socio-economic development, such as water provision, flood mitigation or carbon sequestration. The proposed pipeline route does not fall within of the Gauteng CBAs and ESA regions (**Figure 3**).

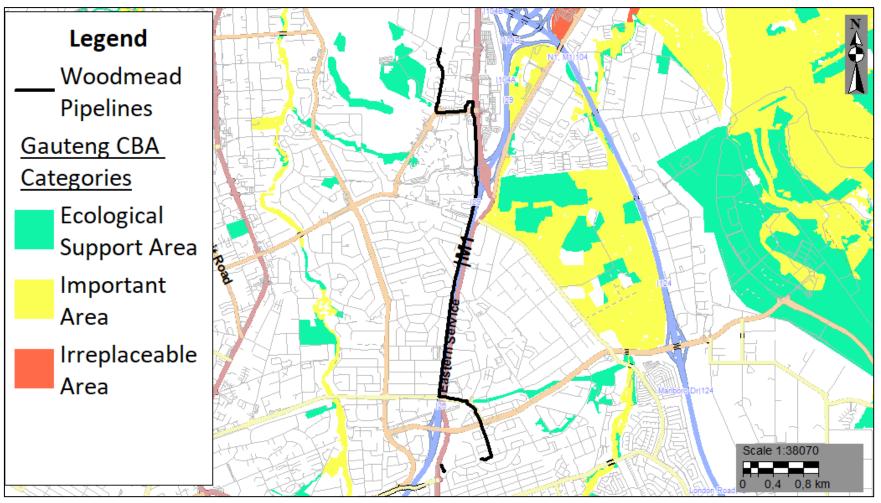


Figure 3. Gauteng C-Plan in relation to the project route

# 7 GAUTENG RIDGES

Ridges are specialized by high spatial heterogeneity due to the range of differing aspects (north, south, east, west and variations thereof), slopes and altitudes resulting in differing soil characteristics (e.g., depth, moisture, temperature, drainage, nutrient content), light and hydrological conditions (Samways and Hatton, 2000). Moist cool aspects are more conducive to the leaching of nutrients than warmer drier slopes (Lowrey and Wright, 1987). Variations in aspect, soil drainage (Burnett *et al.* 1998) and elevation/altitude (Primack, 1995) have been found to be especially important predictors of biodiversity. According to Tshwane Open Space Framework (2005), Seventy-four (74%) percent of the twenty-two (22) globally threatened plant species occur on the ridges and hills of Gauteng, while at least three (3) threatened mammal species, several bird species of conservation concern, three (3) rare reptile species and a Red Data Butterfly inhabit ridges.

All ridges in Gauteng have been classified into four classes (**Table 1**) based on the percentage of the ridge that has been transformed (mainly through urbanization or other human activities) using the 1994 CSIR/ARC Landcover data.

The project route does not fall within any of the Gauteng ridge classes, with Classes 3 and 4 ridges (Gauteng C-Plan 3.3) situated North and West, as indicated in **Figure 4**.

Table 1. Four classes of ridges in Gauteng Province, percentage of transformation and land use guidelines

Ridge type	% of	Gauteng	Policy
Class 1 (0-5% transformed) includes Suikerbosrand & parts of Magaliesberg	58%		Only low impact activities with an ecological footprint of 5% or less in the 200-metre buffer zone of the ridge will be supported, no development will be permitted on the ridge itself.
Class 2 (5-35% transformed) includes parts of Magaliesberg, Cradle of Humankind World Heritage site, Klipriviersberg, Bronberg, Skurweberg	23%		Development activities and uses that have a high environmental impact on a Class 2 ridge will not be permitted. Low impact development activities, such as tourism facilities, which comprise of an ecological footprint of 5% or less of the property may be supported. (The ecological footprint includes all areas directly impacted on by a development activity, including all paved surfaces, landscaping, property access and service provision).  Low impact development activities on a ridge will be supported where is it feasible to undertake the development on a portion of the property abutting the ridge.

Ridge type	% of	Gauteng	Policy
	ridges		
Class 3 (35-65% transformed) Includes Northcliff, Roodepoort and Krugersdorp ridge	8%		The guidelines for Class 2 ridges will be applied to areas of the ridge that have not been significantly impacted on by human activity.  The guidelines for Class 3 will be applied to areas of the ridge that have been significantly impacted on by human activity
Class 4 (65-100% transformed) includes Melville Koppies & Linksfield ridge	11%		Further development activities will not be supported in areas of the ridge where the remaining contiguous extent habitat is 4ha or more.

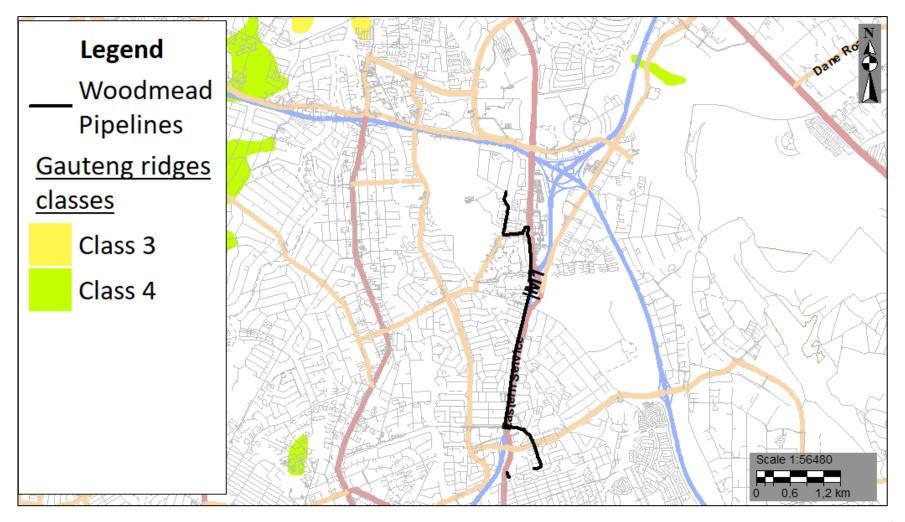


Figure 4: The proposed pipeline upgrade route does not fall within any of the Gauteng ridges

## 8 REGIONAL VEGETATION

The proposed pipeline route falls within the <u>Grassland biome</u> (**Figure 5**) and this Biome has a high biodiversity, ranked only below the Fynbos biome in terms of biodiversity in South Africa (Driver *et al.* 2004). This Biome is found mainly on the high central plateau of South Africa, and the inland areas of KwaZulu-Natal Province and the Eastern Cape Province. Grasslands are dominated by a single layer of grasses. Trees are absent, except in a few localised habitats and geophytes are often abundant (Low and Rebelo, 1996

Mucina and Rutherford (2018) classified the proposed pipeline route as falling within the Egoli Granite Grassland vegetation type, as indicated in **Figure 6**. No remnants of this vegetation type exists on site.



Figure 5. Biome on the project route

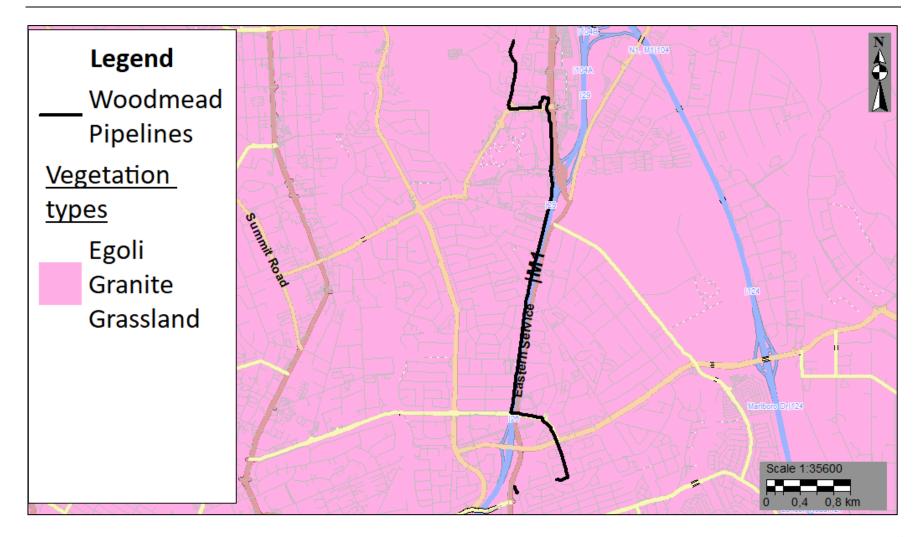


Figure 6. Vegetation type within the proposed pipeline route

The description of the vegetation type follows below:

#### 8.1 Egoli Granite Grassland

Egoli Granite Grassland vegetation type is found in Gauteng Province. It occurs in Johannesburg Dome extending in the region between northern Johannesburg in the south, and from near Lanseria Airport and Centurion (south of Pretoria) to the north, westwards to about Muldersdrif and eastwards to Tembisa (Mucina and Rutherford, 2006).

The following species are important in the Egoli Granite Grassland vegetation type: Graminoids: Aristida canescens, A. congesta, Cynodon dactylon, Digitaria monodactyla, Eragrostis capensis, E. chloromelas, E. curvula, E. racemosa, Heteropogon contortus, Hyparrhenia hirta, Melinis repens subsp. repens, Monocymbium ceresiiforme, Setaria sphacelata, Themeda triandra, Tristachya leucothrix, Andropogon eucomus, Aristida aequiglumis, A. diffusa, A. scabrivalvis subsp. borumensis, Bewsia biflora, Brachiaria serrata, Bulbostylis burchellii, Cymbopogon caesius, Digitaria tricholaenoides, Diheteropogon amplectens, Eragrostis gummiflua, E. sclerantha, Panicum natalense, Schizachyrium sanguineum. Setaria nigrirostris. Tristachya rehmannii, Urelytrum agropyroides. Herbs: Acalypha angustata, A. peduncularis, Becium obovatum, Berkheya insignis, Crabbea hirsuta, Cyanotis speciosa, Dicoma anomala, Helichrysum rugulosum, Justicia anagalloides, Kohautia amatymbica, Nidorella hottentotica, Pentanisia prunelloides subsp. Pseudognaphalium luteo-album and Senecio venosus. Geophytic Herbs: Cheilanthes deltoidea, C. hirta. Low Shrubs: Anthospermum hispidulum, A. rigidum subsp. pumilum, Gnidia capitata, Helichrysum kraussii, Ziziphus zeyheriana. Tall Shrub: Searsia pyroides. Succulent Shrub: Lopholaena coriifolia (Mucina & Rutherford, 2006).

The conservation status of this vegetation type is classified as **Endangered**, with a national conservation target of 24%. Only about 3% of this unit is conserved in statutory reserves (Diepsloot and Melville Koppies Nature Reserves) and a number of private conservation areas including Motsetse and Isaac Stegmann Nature Reserves, Kingskloof Natural Heritage Site, Melrose and Beaulieu Bird Sanctuaries as well as the Walter Sisulu National Botanical Garden. More than two thirds of the unit has already undergone transformation mostly by urbanisation, cultivation or by building of roads. Current rates of transformation threaten most of the remaining unconserved areas. There is no serious alien infestation in this unit, although species such as *Eucalyptus grandis*, *E. camaldulensis* and *E. sideroxylon* are commonly found (Mucina and Rutherford, 2006).

## 9 THREATENED TERRESTRIAL ECOSYSTEMS

In terms of section 52(1) (a), of the National Environmental Management: Biodiversity Act, 2004 (Act No. 10 of 2004), a national list of ecosystems that are threatened and in need of protection was gazetted on 9 December 2011 (Government Notice 1002 (Driver *et al.* 2004). The list classified all threatened or protected ecosystems in South Africa in terms of four categories; Critically Endangered (CR), Endangered (EN), Vulnerable (VU), or Protected. The purpose of categorising these ecosystems is to prioritise conservation areas in order to reduce the rates of ecosystem and species extinction, as well as preventing further degradation and loss of structure, function, and composition of these ecosystems.

It is estimated that threatened ecosystems make up 9.5% of South Africa, with critically endangered and endangered ecosystems accounting for 2.7%, and vulnerable ecosystems 6.8% of the land area. It is therefore vital that Threatened Terrestrial Ecosystems inform proactive and reactive conservation and planning tools, such as Biodiversity Sector Plans, municipal Strategic Environmental Assessments (SEAs) and Environmental Management Frameworks (EMFs), Environmental Impact Assessments (EIAs) and other environmental applications (Mucina *et al.* 2006).

'Ecosystem protection level' is an indicator of how adequately an ecosystem is protected or not. Ecosystems can be classified as not protected, poorly protected, moderately protected or well protected depending on the proportion of each ecosystem that is under conservation management within a protected area, as recognized in the National Environmental Management: Protected Areas Act (Act 57 of 2003) –these protected areas include state or privately-owned protected areas as well a land under biodiversity stewardship agreements.

According to Government Gazette SANBI Threatened Ecosystems (2011), the project route falls within the Egoli Granite Grassland terrestrial threatened ecosystem (**Figure 7**). However, according to the Skowno *et al.* (2019), this ecosystem/vegetation type is listed as **Poorly Protected (PP)** on a national scale (**Figure 8**). According to the Driver *et al.*, (2012), an ecosystem is considered "not protected" if under 5% of its biodiversity target is met within protected areas, "poorly protected" if 5% to 49% of its target is met in protected areas, and "moderately protected" if 50% to 99% of its target is met. If more than 100% of the target is met in protected areas, it is considered "well protected".

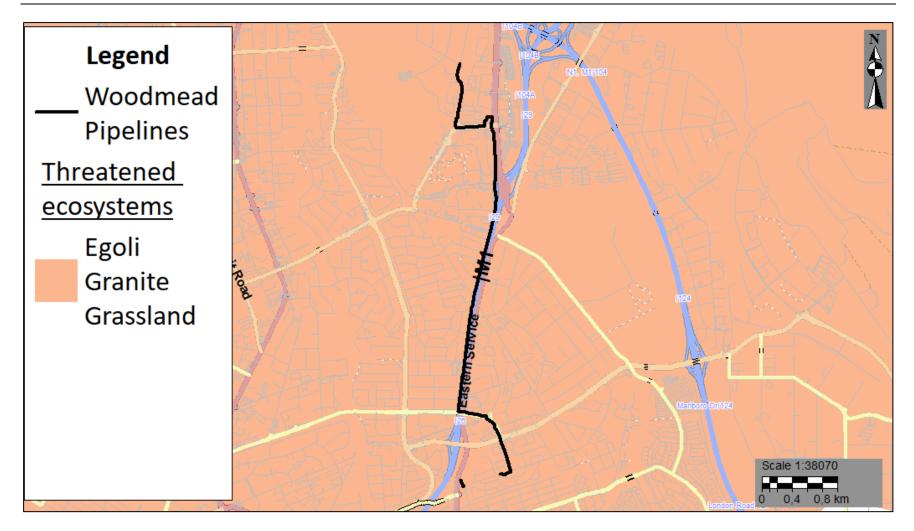


Figure 7. Threatened ecosystem within the project area (SANBI, 2011)

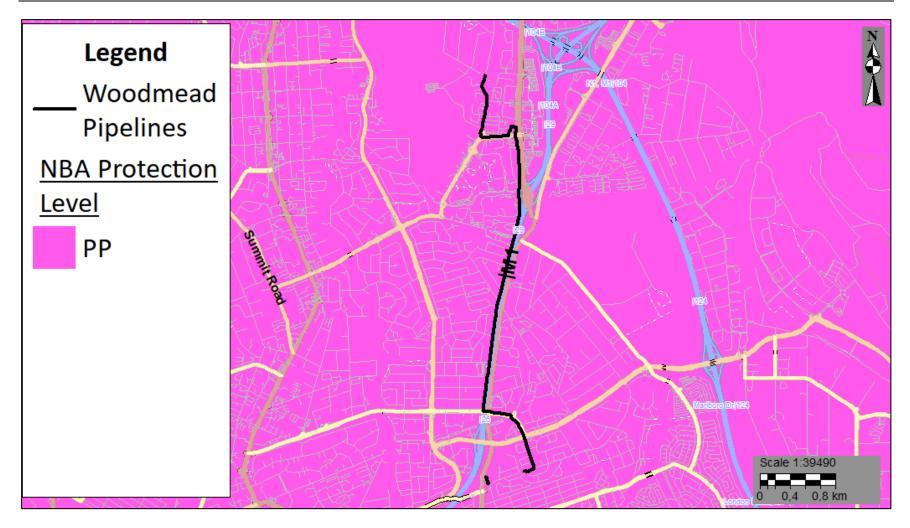


Figure 8. Threatened ecosystem Protection Level on the study area (NBA, 2018)

## 10 RESULTS AND DISCUSSION

## 10.1 Flora

#### 10.1.1 Desktop study results

According to the data sourced from BODATSA (SANBI) (2628AA QDS) and previous biodiversity studies, Red Data plant species which are known to occur on or near the project site are indicated in **Table 2** below. The definitions of the conservation status are provided in **Table 3**.

Table 2. Red Data Plant species recorded in grid 2628AA which could potentially occur in the project site (SANBI data).

Family	Taxon	Conservation status	Endemism
Aizoaceae	Khadia beswickii (L.Bolus) N.E.Br.	Vulnerable	South African endemic
Crassulaceae	Adromischus umbraticola C.A.Sm. subsp. umbraticola	Near Threatened	South African endemic
Asteraceae	Cineraria austrotransvaalensis Cron	Near Threatened	South African endemic
Apocynaceae	Stenostelma umbelluliferum (Schltr.) Bester & Nicholas	Near Threatened	South African endemic
Proteaceae	Leucospermum saxosum S.Moore	Endangered	Not endemic to South Africa
Fabaceae	Indigofera hybrida N.E.Br.	Vulnerable	South African endemic
Fabaceae	Pearsonia bracteata (Benth.) Polhill	Near Threatened	South African endemic
Lamiaceae	Salvia schlechteri Briq.	Data Deficient - Insufficient Information	South African endemic
Proteaceae	Protea compacta R.Br.	Near Threatened	South African endemic
Fabaceae	Argyrolobium longifolium (Meisn.) Walp.	Vulnerable	South African endemic

Table 3. Definitions of Red Data status (Raimondo et al. 1999)

Symbol	Status	Description
EN	Endangered	A species is <b>Endangered</b> when the best available evidence indicates that it meets at least one of the five International Union
		for Conservation of Nature (IUCN) criteria for Endangered, indicating that the species is facing a very high risk of extinction
VU	Vulnerable	A species is <b>Vulnerable</b> when the best available evidence indicates that it meets at least one of the five IUCN criteria for

Symbol	Status	Description
		Vulnerable, indicating that the species is facing a high risk of extinction.
NT	Near Threatened	A species is <b>Near Threatened</b> when available evidence indicates that it is close to meeting any of the five IUCN criteria for Vulnerable, and is therefore likely to qualify for a threatened category in the near future.
DDD	Data Deficient - Insufficient Information	A species is <b>DDD</b> when there is inadequate information to make an assessment of its risk of extinction, but the species is well defined. Listing of species in this category indicates that more information is required and that future research could show that a threatened classification is appropriate.

#### 10.1.2 Plant species recorded on the project route

The proposed pipe upgrade route is situated along the servitudes/ road reserve, and traverses main roads such as Marlboro and M1. It is situated in an urban environment and most of the plants were cultivated as part of street trees project, landscaping and gardening. A list of plant species recorded along the project route are listed in **Table 3** below.

Table 4. Plant species recorded along the proposed pipeline route

Scientific name	Common name	Ecological status	<b>Growth Form</b>
Acacia mearnsii	Black wattle	Category 2 AIS	Tree
Aloe arborescens	Candelabra aloe	Indigenous/Medicinal	Succulent Herb
Agapanthus africanus	African lily	Least	Herb
		concern/Medicinal	
Agave sisalana	Sisal	Exotic	Succulent
Bauhinia galpinni	Pride of De Kapp	Least	Shrub
		concern/Medicinal	
Celtis africana	White stinkwood	Least concern	Tree
Combretum erythrophyllum	River bushwillow	Indigenous	Tree
Conyza bonariensis	Flax-leaf fleabane	Weed	Herb
Cynodon dactylon	Couch Grass	Indigenous/ Least	Grass
		concern	
Cycas revoluta	Sago palm	Least concern	Shrub
Eupatorium macrocephalum	Pompom weed	Category 1b AIS	Herb
(=Campuloclinium			
macrocephalum)			
Eriobotrya japonica	Loquat	Exotic	Tree
Erythrina lysistemon	Common Coral Tree	Indigenous/ Least	Grass
		concern	
Hypochaeris radicata	Hairy Wild Lettuce	Weed	Herb
Hypoestes aristata	Ribbon Bush	Least	Herb
		concern/Medicinal	
Iris germanica	German iris	Exotic	Herb
Jacaranda mimosifolia	Jacaranda	Not listed for urban	Tree
		areas in Gauteng	
Lantana camara	Common Lantana	Category1b AIS	Shrub

Scientific name	Common name	Ecological status	<b>Growth Form</b>	
Ligustrum lucidum	Chinese wax –	Category3 AIS	Tree	
	leaved privet			
Melia azedarach	Persian Lilac/Syringa	Category 3 AIS in	Tree	
		urban areas		
Morus alba	White mulberry	Category 3 AIS	Tree	
Olea europaea subsp. africana	Wild olive	Indigenous	Shrub	
Pelargonium inquinans	Scarlet Geranium	Least	Herb	
		concerm/Medicinal		
Pinus patula	Patula pine	Category 2 AIS	Tree	
Plantago major	Broadleaved Ribwort	Weed	Herb	
Plectranthus fruticosus	Forest spurflower	Least	Shrub	
	•	concerm/Indigenous		
Populus deltoides				
Prunus persica	Peach tree	Exotic	Tree	
Quercus alba	White oak	Exotic	Tree	
Senna didymobotrya	African Senna	Category 1b AIS	Shrub	
Schinus molle	Peruvian peppertree	Exotic	Tree	
Searsia lancea	Karee	Indigenous	Tree	
Searsia chirindensis	Red currant	Least concern	Tree	
Solanum mauritianum	Bugweed	Category 1b AIS	Shrub	
Sonchus asper	Spiny sowthistle	Weed	Shrub	
Strelitzia reginae	Orange strelitzia	Least concern	Herb	
Tagetes minuta	Tall Khaki Weed	Weed	Herb	
Tecomaria capensis	Cape honeysuckle	Least	Tree	
·		concern/indigenous		
Tipuana tipu	Tipa tree	Category 3 AIS	Tree	
Vachellia karroo	Sweet thorn	Least	Tree	
		concern/indigenous		
Vachellia sieberiana	Paperbark thorn	Least	Tree	
	-	concern/indigenous		
Vachellia xanthophloea	Fever tree	Least	Tree	
		concerm/Medicinal		

Note: AIS=Alien Invasive Species

# 10.1.3 Threatened Species, Species of Conservation Concern and provincially protected plants

According to the South African Red data list categories done by SANBI (**Figure 9**), **threatened species** are species that are facing a high risk of extinction. Any species classified in the IUCN categories Critically Endangered, Endangered or Vulnerable is a threatened species whereas **Species of conservation concern** are species that have a high conservation importance in terms of preserving South Africa's high floristic diversity and include not only threatened species, but also those classified in the categories Extinct in the Wild (EW), Regionally Extinct (RE), Near Threatened (NT), Critically Rare, Rare, Declining and Data Deficient - Insufficient Information (DDD).

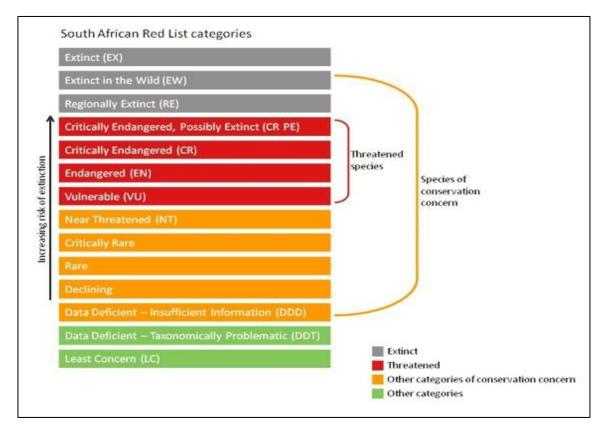


Figure 9. South African Red Data list categories

During the field survey, no threatened plant species or protected trees were observed along the proposed route. However, the following plant species are listed as "Protected Plants" in terms of Schedule 11 (Section 86 (1) (a)) of Transvaal Nature Conservation Ordinance No. 12 of 1983, namely all species of agapanthus *africanus* (**Figure 10**). However, these plant species were planted as part of landscaping to create an ecological aesthetic. According to the information obtained from GDARD,



Figure 10. Agapanthus africanus on site

A plant species such as *Hypoxis hemerocallidea* (**Figure 11**), is listed as Orange Listed Plant species. Orange lists are those within the Red list that are categorised as rare, Data deficient, declining or near threatened. *Hypoxis hemerocallidea* occurs in an open grassland and woodland and is widespread in South Africa in the eastern summer rainfall provinces (Eastern Cape, Free State, KwaZulu-Natal, Mpumalanga, Gauteng and Limpopo). It also occurs in Botswana, Lesotho and Swaziland (Wyk. *et al.* 1997) and it's a highly sought-after medicinal plant. This species used to be classified as *Declining* (Raimondo *et al* 2009), but now declassified as *Least concern*. Species classified as Least concern are considered at low risk of extinction and are widespread and abundant, however, GDARD has indicated that this species must remain classified as Orange list plant species due to its provincial level pressures.

Therefore, in order to mitigate the impacts to these plant species, all provincially protected plant species and Orange listed plants found along the route, should be protected and avoided. These plants should be planted just outside of the development route after the completion of construction activities. Where this proves not to be possible, a permit will be required from GDARD to transplant these plant species outside of the proposed pipeline route or donated to Conservation areas. The permit application should be preceded by a Search, Rescue and Relocation Plan. This Plan must be compiled by a competent Ecologist/Botanist. This Plan should also take into account medicinal plant species such as *Albuca virens* (**Figure 12**) recorded along the route site. The distribution of all these medicinal and provincially protected plant species on site are shown in **Figure 13** below.



Figure 11. Hypoxis hemerocallidea on site



Figure 12. Albuca virens on site

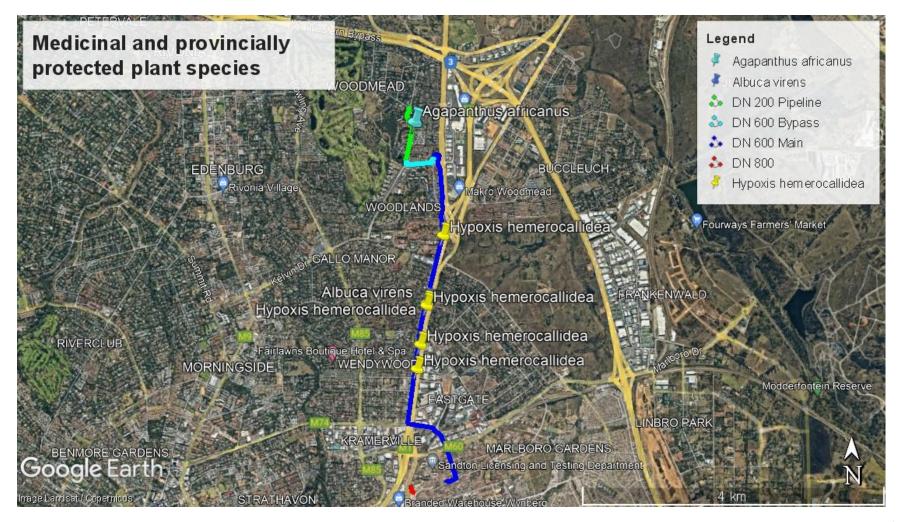


Figure 13. Medicinal and provincially protected plant species on site

#### 10.1.4 Alien invasive plant species recorded on the study area

Alien invader plant species (AIS) are species of exotic origin that typically invade undeveloped or disturbed areas (Bromilow, 2018). AIS pose a threat to ecosystems because by nature they grow fast, reproduce quickly and have high dispersal abilities allowing them to replace indigenous species (Henderson, 2001).

Alien invasive plant species on the study area (**Table 4**) were observed to occur in clumps, scattered distributions or as single individuals. Invader and weed species on site must be controlled to prevent further infestation and it is recommended that all individuals of invader and weeds species (especially Category 1b) must be removed and eradicated.

Alien plant species such as Senna didymobotrya (Figure 14), Solanum mauritianum (Figure 15), Eupatorium macrocephalum (=Campuloclinium macrocephalum) (Figure 16) and Lantana camara (Figure 17) (Category 1b) were recorded along the proposed pipeline route.



Figure 14. Senna didymobotrya recorded along the project route



Figure 15. Eupatorium macrocephalum (=Campuloclinium macrocephalum) recorded along the project route



Figure 16. Solanum mauritianum recorded along the project route



Figure 17. Lantana camara recorded along the project route

#### 10.1.5 Trees which will be directly affected by the construction activities

**Table 5** below indicates indigenous tree species, which are mostly above 2m, which will be directly affected by the construction activities. These trees are too big to be transplanted and therefore, tree species of same species should be transplanted along the route after the completion of the project. The pictures are shown in **Figures 18-26.** 

Table 5. Indigenous tree species which will be directly affected by the construction activities

Plant Species	Common Name	Number of Trees
Bauhinia galpinni	Pride of De Kapp	1
Celtis africana	White stinkwood	8
Combretum erythrophyllum	River bushwillow	11
Erythrina lysistemon	Common Coral Tree	6
Olea europaea subsp. africana	Wild olive	12
Searsia lancea	Karee tree	26
Searsia chirindensis	Red currant	2
Vachellia karroo	Sweet thorn	12
Vachellia xanthophloea	Fever tree	6



Figure 18. Bauhinia galpinni recorded along the project route



Figure 19. Celtis africana recorded along the project route



Figure 20. Combretum erythrophyllum recorded along the project route



Figure 21. Erythrina lysistemon recorded along the project route



Figure 22. Olea europaea subsp. africana recorded along the project route



Figure 23. Searsia lancea recorded along the project route



Figure 24. Searsia chirindensis recorded along the project route



Figure 25. Vachellia karroo recorded along the project route



Figure 26. Vachellia xanthophloea recorded along the project route

#### 10.1.6 Potential occurrence of Red Data plant species

Data sourced from SANBI website (BODATSA) indicates that there are plant species on the Red Data List that are known to occur in or on areas surrounding the project area. The Probability of Occurrence is based on suitable habitat and known distribution ranges. The plant species and their probability of occurrence are indicated in **Table 6** below. Only plant species which have higher probability to occur on the project site are shown in the table below.

Table 6. Probability of occurrence of Red Data Plant species which could potentially occur on the project area.

Taxon	Conservation status	Suitable habitat	Probability of Occurrence
Khadia beswickii (L.Bolus) N.E.Br.	Vulnerable	Open shallow soil over rocks in grassland.	Low
Adromischus umbraticola C.A.Sm. subsp. umbraticola	Near Threatened	South-facing rock crevices on ridges, restricted to Gold Reef Mountain Bushveld in the northern parts of its range, and Andesite Mountain Bushveld in the south	Low
Cineraria austrotransvaalensis Cron	Near Threatened	Amongst rocks on steep hills and ridges, at the edge of thick bush or under trees on a	Low

Taxon	Conservation status	Suitable habitat	Probability of Occurrence
		range of rock types: quartzite, dolomite and shale, 1400-1700 m.	
Stenostelma umbelluliferum (Schltr.) Bester & Nicholas	Near Threatened	Deep black turf in open woodland mainly in the vicinity of drainage lines.	Low
Leucospermum saxosum S.Moore	Endangered	This species is common on quartzite outcrops. It is a long-lived species, and survives fires by resprouting from underground boles or rootstocks. Seeds are released after ripening, and dispersed by ants to their underground nests, where they are protected from predation and fire. It is pollinated by birds.	Low
Indigofera hybrida N.E.Br.	Vulnerable	Dry highveld grassland.	Low
Pearsonia bracteata (Benth.) Polhill	Near Threatened	Plateau grassland.	Low
Salvia schlechteri Briq.	Data Deficient - Insufficient Information	Coastal grasslands.	Low
Protea compacta R.Br.	Near Threatened	Lowland sandstone fynbos and sandy coastal flats, 0-200 m. Mature individuals are killed by fires, and only seeds survive. Wind-dispersed seeds are stored in fire-resistant inflorescences, and released after fires. It is pollinated by birds.	Low
Argyrolobium longifolium (Meisn.) Walp.	Vulnerable	Ngongoni and sandstone grassland.	Low

# 10.2 <u>Fauna</u>

#### **10.2.1 Mammals**

#### 10.2.1.1 Desktop survey results

The potential mammal species that could be found on the study area are those which have been recorded in grid cell 2628AA (FitzPatrick Institute of African Ornithology, 2022), previous biodiversity reports & SANBI data and also from distributions based on records documented in Skinner and Chimimba (2005), Monadjem *et al.*, (2010) and Stuart & Stuart (2013) (**Table 7**). Conservation status assessments for each species were obtained from Child *et al.* (2016).

Family	Genus	Species	Common Name	Red list category
Erinaceidae	Atelerix	frontalis	Southern African	Near Threatened
			Hedgehog	
Felidae	Acinonyx	jubatus	Cheetah	Vulnerable
Hyaenidae	Hyaena	brunnea	Brown Hyena	Near Threatened
Hyaenidae	Crocuta	crocuta	Spotted Hyaena	Near Threatened
Muridae	Otomys	auratus	Southern African Vlei	Near Threatened
			Rat	
Mustelidae	Aonyx	capensis	African Clawless	Near Threatened
		-	Otter	
Nesomyidae	Mystromys	albicaudatus	African White-tailed	Vulnerable
-			Rat	
Soricidae	Crocidura	mariquensis	Swamp Musk Shrew	Near Threatened
Vespertilionidae	Pipistrellus	rusticus	Rusty Pipistrelle	Near Threatened
•	(Pipistrellus)			

Table 7. Red Data Mammal species potentially occurring on the project area

#### 10.2.1.2 Mammals recorded on the study area

As previously mentioned, the proposed route falls within habitats which are highly fragmented and disturbed. The project route in its present state is not considered optimal habitat for mammal species due to anthropogenic activities such as human habitation. However, the riparian vegetation provides suitable habitats for water-dependant mammal species. Mammal species such as House rat *Rattus rattus* and Four-striped Grass Mouse (*Rhabdomys pumilio*) were recorded on site.

#### 10.2.1.3 Potential occurrence of Red Data mammal species

The potential Red data mammal species that could be found along the proposed pipeline route are those which have been recorded in grid cell 2628AA (FitzPatrick Institute of African Ornithology, 2022), SANBI data and also from distributions based on records documented in Skinner and Chimimba (2005), Monadjem *et al.*, (2010) and Stuart & Stuart (2013). The probability of occurrence (**Table 8**) was based on the consideration of the following factors:

- Known distribution;
- Overall abundance of a species;
- Availability of suitable habitat on the study area;
- Availability of prey items on the study area and surrounding areas;
- · Level of anthropogenic disturbance; and
- Species tolerance to anthropogenic disturbance.

The Likelihood of occurrence was generally assessed as follows:

- **Confirmed**: either through current survey or through sightings, and local knowledge where provided.
- High: Distribution of the species occurs over the sites and the sites and immediate surrounds provide habitat, roosting and food requirements of the specific species. There is nothing to prevent the species from residing on site for a length of time (season or year).
- Medium: Distribution of the species occurs over the sites but the specific habitat, roosting and/or food requirements are absent or sparse on site, but are present in the greater area. Species are not likely to reside on site, but may forage over or traverse the site. Species population is at low density or erratic over site, but habitat and / or foraging areas are present on site and in the immediate surrounds.
- **Low**: Distribution is on the edge of site and habitat, roosting and/or food requirements are absent or sparse in the sites and surrounds. Species population is at low density or erratic over site and habitat and foraging areas are sparse or absent.

Table 8. Probability of occurrence of Red Data mammal species which could potentially occur on the project site.

Common Name	Red list category	Suitable Habitat	Probability Of Occurrence
Southern African Hedgehog	Near Threatened	The distribution mainly falls within savannah and grassland vegetation types, within which it is found in a wide variety of semi-arid and sub-temperate habitats, including scrub brush, western Karoo, grassland and suburban gardens.	Low
Cheetah	Vulnerable	Cheetahs are habitat generalists and as such can survive where sufficient food is available and threats are tolerable.	Very Low
Brown Hyena	Near Threatened	It inhabits desert areas, semi-desert, and open woodland savannahs. It can survive close to urban areas by scavenging.	Very Low
Spotted Hyaena	Near Threatened	Although the Spotted Hyaena is predominantly a savannah species, it has been found to occur in most habitat types including semi-desert, open woodland and dense dry woodlands. In many parts of its range, it occurs in close association with human habitation	Very Low
Southern African Vlei Rat	Near Threatened	This species is associated with mesic grasslands and wetlands within alpine, montane and sub-montane regions, typically occurring in dense vegetation in close proximity to water	
African Clawless Otter	Per Near Threatened Cape Clawless Otters are predominantly aquatic and seldom found far from permanent water. Fresh water is an essential habitat requirement, not only for drinking but also for rinsing their fur		Medium
African White-tailed Rat	Vulnerable	They are often associated with calcrete soils within grasslands. They are never found on soft, sandy substrate, rocks, wetlands or river banks.	Low
Swamp Musk Shrew	Near Threatened	This species has highly specific habitat requirements, occurring only close to open water with intact riverine and semi-aquatic vegetation such as reedbeds, wetlands and the thick grass along river banks. They are found both in the wet substrates and drier grassland away from the water's edge. They are often sampled in waterlogged areas, such as inundated grasslands and vleis.	Low
Rusty Pipistrelle	Near Threatened	It occurs in savannah woodland and is associated with open water bodies, but is absent from moist miombo woodland and arid savannah	Low

#### 10.2.2 Avifauna

#### 10.2.2.1 Desktop survey results

The Important Bird and Biodiversity Areas (IBA) Programme identifies and works to conserve a network of sites critical for the long-term survival of bird species that are globally threatened, have a restricted range and are restricted to specific biomes/vegetation types (Barnes, 2000). As shown in **Figure 27** below, the project area does not fall within any of the IBAs. The nearest IBA is Magaliesberg IBA, situated North-West of the project area.

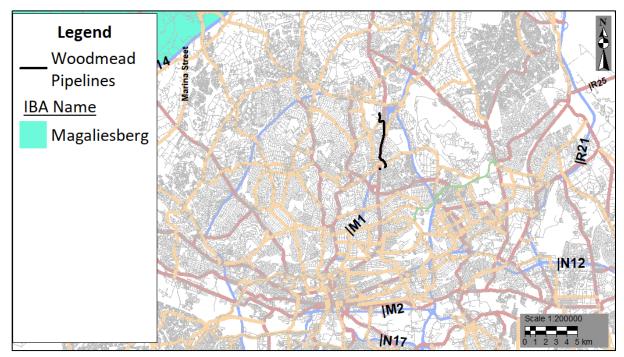


Figure 27. Magaliesberg IBA in relation to the project area

The online database of the Southern African Bird Atlas Project (SABAP2), and SANBI were queried for a list of bird species confirmed to occur in the relevant pentad (mapping unit) that the project area is located in, namely 2628AA. Taylor *et al.* (2015) was consulted for the most current conservation status of each species of conservation concern on the list (**Table 9**).

Table 9. Red listed bird species which could potentially occur on the project area

Common Name	Species	Red List Category
African Grass-Owl	Tyto capensis	Vulnerable
African Marsh-Harrier	Circus ranivorus	Endangered
Blue Crane	Anthropoides paradiseus	Near Threatened

Common Name	Species	Red List Category
Cape Vulture	Gyps coprotheres	Endangered
Half-collared Kingfisher	Alcedo semitorquata	Near Threatened
Martial Eagle	Polemaetus bellicosus	Endangered
Secretarybird	Sagittarius serpentarius	Vulnerable
Greater Flamingo	Phoenicopterus roseus	Near Threatened
Lesser Flamingo	Phoenicopterus minor	Near Threatened
Maccoa Duck	Oxyura maccoa	Near Threatened
Lanner Falcon	Falco biarmicus	Vulnerable
Black Stork	Ciconia nigra	Vulnerable
Yellow-billed Stork	Mycteria ibis	Endangered
Saddle-billed Stork	Ephippiorhynchus senegalensis	Endangered
Verreaux's Eagle	Aquila verreauxii	Vulnerable
Greater Painted-snipe	Rostratula benghalensis	Near Threatened
Red-footed Falcon	Falco vespertinus	Near Threatened
European Roller	Coracias garrulus	Near Threatened
White-bellied Korhaan	Eupodotis senegalensis	Vulnerable
Black-winged Pratincole	Glareola nordmanni	Near Threatened
Abdim's Stork	Ciconia abdimii	Near Threatened
Marabou Stork	Leptoptilos crumeniferus	Near Threatened

#### 10.2.2.2 Field work results and discussion

Within the vegetation types found in the study area and immediate surrounding areas, two major bird micro-habitat systems were identified, namely exotic trees and Disturbed & transformed area.

**Exotic trees** often provide roosting and nesting habitat for various bird species, and as such their importance for avifauna should not be underestimated. Exotic trees provide perching, roosting and nesting habitat for various raptor species, as well as larger birds such as francolins, Guineafowl, Herons and Hadeda ibises. Although stands of *Eucalyptus* are invader species, these stands have become important refuges for certain species of raptors including Eagles and Buzzards. Birds such as Lesser Kestrel and Falcons make use of large *Eucalyptus* trees, where they roost in large numbers. No nests were identified on the study area.

**Disturbed and transformed area:** Suburban gardens and parks have created an evergreen habitat for many avifaunal species, where birds can hide, breed and forage for food. Many avifaunal species have adapted to human-altered areas and these species are mainly the more common avifaunal species found within southern Africa. Large gardens, parks, sport fields and golf courses with open lawns also create ideal habitat for ground-feeding birds. These lawns are usually well watered and the ground soft, making it easy for birds that probe in the ground with their beaks in search of worms and other ground-living insects. There is

Darkcap Bulbul

Cape Wagtail

Least concern

Least concern

usually water present, in the form of irrigation systems, ponds, man-made dams such as at golf courses, water features and/or swimming pools. Only the more common avifaunal species that are able to adapt to areas changed by man are likely to make use of this habitat system.

Fourteen (14) bird species (**Table 10**) were recorded during the field survey. Species recorded were common and widespread and typical of grassland biome. No Red Data bird species associated with the study route were recorded. Bird species recorded along the route are shown in **Figures 28-29**.

Common name	Scientific name	Conservation status
Black-headed Heron	Ardea cinerea	Least concern
Hadeda Ibis	Bostrychia hagedash	Least concern
African Sacred ibis	Threskiornis aethiopicus	Least concern
Blacksmith Lapwing (Plover)	Vanellus armatus	Least concern
Rock Dove (Feral Pigeon)	Columba livia	Least concern
Laughing Dove	Streptopelia senegalensis	Least concern
Cape turtle (Ring-necked) dove	Streptopelia capicola	Least concern
Pied Crow	Corvus albus	Least concern
Common Fiscal (Fiscal Shrike)	Lanius collaris	Least concern
Common (Indian) Myna	Acridotheres zeylonus	Introduced species
House Sparrow	Passer domesticus	Least concern
Southern-masked Weaver	Ploceus velannus	Least concern

Pycnonotus barbatus

Motacilla capensis

Table 10. Bird species recorded along the proposed pipeline route



Figure 28. Common (Indian) Myna on site



Figure 29. Pied crow on site

# 10.2.2.3 Potential occurrence of Red Data bird species

**Table 11** below indicates the preferred habitat, together with the probability of occurrence. The probability of occurrence is based on the availability of suitable habitat, known distribution, overall abundance, food availability, disturbance factors, anthropogenic change and the preferred habitats of the species. Only bird species which have higher probability of occurrence on the study area are discussed in the table below.

Table 11. Probability of Occurrence of Red listed bird species which could potentially occur along the proposed pipeline route

Common Name	Species	Red List Category	Suitable Habitat	Probability of occurrence
African Grass- Owl	Tyto capensis	Vulnerable	This species occurs predominately in rank grass, typically but not always at fairly high altitudes. It breeds mainly in permanent and seasonal vleis, which it vacates while hunting or during post-breeding. Prefers permanent or seasonal vleis and vacates the latter when these dried up or are burnt	Very Low
African Marsh- Harrier	Circus ranivorus	Endangered	It generally favours inland and coastal wetlands.	Very Low
Blue Crane	Anthropoides paradiseus	Near Threatened	This crane breeds in dry grasslands at high elevations where there is less disturbance. They may roost and breed in wetlands if available and some individuals prefer to nest in arable and pastureland.	Very Low
Cape Vulture	Gyps coprotheres	Endangered	It can occupy a variety of habitat types, although it especially favours subsistence farming communal grazing areas, where there is plenty of livestock to feed on.	Very Low
Half-collared Kingfisher	Alcedo semitorquata	Near Threatened	It generally prefers narrow rivers, streams and estuaries with dense vegetation onshore, but it may also move into coastal lagoons and lakes	Very Low
Martial Eagle	Polemaetus bellicosus	Endangered	Occurs in a variety of habitats but seem to prefer arid and mesic savannah but is also commonly found at forest edges and in open shrubland	Very Low
Secretarybird	Sagittarius serpentarius	Vulnerable	Prefers open grassland with scattered trees, shrubland, open Acacia and Combretum savannah. Restricted to large conservation areas in the region. Avoids densely wooded areas, rocky hills and mountainous areas	Very Low
Greater Flamingo	Phoenicopterus roseus	Near Threatened	This species inhabits relatively shallow water bodies, including saline lagoons, salt pans, estuaries, and large saline or alkaline lakes.	Very Low
Lesser Flamingo	Phoenicopterus minor	Near Threatened	It generally favours open, eutrophic and shallow wetlands, coastal mudflats, salt works and sewage treatment plants; it exclusively breeds on salt pans and saline lakes	Very Low
Maccoa Duck	Oxyura maccoa	Near Threatened	Prefers permanent wetlands that have rich concentrations of bottom-dwelling (benthic) invertebrates.	Very Low

Common Name	Species	Red List Category	Suitable Habitat	Probability of occurrence
Lanner Falcon	Falco biarmicus	Vulnerable	Inhabits a wide variety of habitats, from lowland deserts to forested mountains.	Very Low
Black Stork	Ciconia nigra	Vulnerable	It can occupy almost any type of wetland, such as pans, rivers, flood plains, ponds, lagoons, dams, swamp forests, mangrove swamps, estuaries, tidal mudflats and patches of short grass close to water.	Very Low
Yellow-billed Stork	Mycteria ibis	Endangered	It generally prefers wetlands, such as pans, flood plains, marshes, streams, flooded grassland and small pools, occasionally moving into mudflats and estuaries.	Very Low
Saddle-billed Stork	Ephippiorhynchus senegalensis	Endangered	It generally prefers freshwater marshes, rivers through open savanna, lake shores, pans and flood plains.	Low
Verreaux's Eagle	Aquila verreauxii	Vulnerable	It generally prefers mountains and other rocky habitats with cliffs.	Very Low
Greater Painted- snipe	Rostratula benghalensis	Near Threatened	It generally prefers dams, pans and marshy river flood plains, or any waterside habitat with mud and vegetation.	Low
Red-footed Falcon	Falco vespertinus	Near Threatened	It generally prefers open habitats with scattered trees, such as open grassy woodland, wetlands, forest fringes and croplands, although it often roosts in stands of alien trees (especially <i>Eucylaptus</i> ) in the suburbs of small towns.	Low
European Roller	Coracias garrulus	Near Threatened	It is locally common in northern and central Namibia, Botswana, Zimbabwe, Mozambique and north-eastern and central South Africa. It generally prefers savanna, such as broad-leaved and <i>Acacia</i> woodland.	Low
White-bellied Korhaan	Eupodotis senegalensis	Vulnerable	It generally prefers fairly tall, dense sour or mixed grassland, either open or lightly wooded, occasionally moving into cultivated or burnt land.	Low
Black-winged Pratincole	Glareola nordmanni	Near Threatened	It generally prefers open seasonally wet grassland, edges of pans and cultivated land.	Low
Abdim's Stork	Ciconia abdimii	Near Threatened	It generally prefers savanna woodland, grassland, pastures, pan edges, cultivated land and suburban areas.	Low
Marabou Stork	Leptoptilos crumeniferus	Near Threatened	It generally prefers open semi-arid habitats and wetlands, such as pans, dams and rivers.	Low

#### 10.2.3 Reptiles

### 10.2.3.1 Desktop survey results

As previously stated, the proposed pipeline route falls within the grassland biome and this biome houses 22% of South Africa's endemic reptiles (O' Connor and Bredenkamp, 1997). According to the data sourced from the SANBI, South African Reptile Conservation Assessment (FitzPatrick Institute of African Ornithology, 2022) for the grid cell 2628AA and historic distribution (Alexander & Marais, 2007), two Red data reptile species are known to occur in the region (**Table 12**).

Table 12. Red data reptile species which could potentially occur on the study area

Family	Genus	Species	Common name	Red list category
Cordylidae	Chamaesaura	aenea	Coppery Grass Lizard	Near Threatened
Lamprophiidae	Homoroselaps	dorsalis	Striped Harlequin Snake	Near Threatened

#### 10.2.3.2 Reptiles recorded on and around the study area

The trees and buildings provide suitable habitats for reptile species to occur along the project area. Only one reptile species was recorded during the survey, namely Speckled Rock Skink (*Trachylepis punctatissima*). No reptile Species of Conservation Concern were recorded on the project development site. According to the anecdotal information, Brown House Snake (*Boaedon capensis*) has been seen on site. This reptile species is known to frequent human dwellings where it feeds on rodents or lizards. It is widespread in South Africa and very common in suburban gardens (Branch, 2001).

## 10.2.3.3 Potential occurrence of Red Data reptile species

Two reptile species of conservation concern are expected to be present on the project area, namely Striped harlequin snake (*Homoroselaps dorsalis*) and Coppery Grass Lizard (*Chamaesaura aenea*) (Branch, 1998 & Bates *et al.* 2014). **Table 13** below indicates the reptiles' preferred habitat together with their probability of occurrence on the project area. The probability of occurrence was based on the consideration of the following factors:

- Known distribution;
- Availability of suitable habitat on the study area;
- Availability of prey items on the study area and surrounding areas;
- · Level of anthropogenic disturbance; and
- Species tolerance to anthropogenic disturbance.

Table 13. Probability of occurrence of Red Data reptile species which could potentially occur on the project area.

Common name	Red list	Suitable habitat and ecology	Probability of
	category		Occurrence
Coppery Grass	Near	Restricted to the Grassland Biome. Found	Low
Lizard	Threatened	on the grassy slopes and plateau of the	
		eastern escarpment and Highveld.	
Striped Harlequin	Near	It is found in the Free State, Gauteng,	Low
Snake	Threatened	Mpumalanga and Limpopo provinces and	
		is known to occasionally inhabit termite	
		mounds in grasslands	

# 11 TERRESTRIAL ECOLOGICAL SENSITIVITY ANALYSIS OF THE STUDY AREA

The determination of specific ecosystem services and sensitivity of ecosystem components and processes, both abiotic and biotic, is rather complex and no single overarching criterion will apply to all habitats investigated. Sensitivity analysis does not only consider aspects that are found on the study area, but also consider the possibility of reinstatement or reestablishment of the original environment and its biota, or at least the rehabilitation of ecosystem services resembling the original state after an area was significantly degraded. The main aspects of an ecosystem that need to be incorporated in the ecological sensitivity analysis included the following:

- Describing the nature and number of species present, taking into consideration their conservation value as well as the probability of such species to survive or re-establish itself following disturbances, and alterations to their specific habitats, of various magnitudes;
- Identifying the species or habitat features that are 'key ecosystem providers' and characterising their functional relationships (Kremen, 2005);
- Determining the aspects of community structure that influence function, especially aspects which influence the stability or rapid decline of communities (Kremen, 2005);
- Assessing key environmental factors that influenced the provision of services (Kremen, 2005)
- Gaining knowledge about the spatio-temporal scales over which these aspects operate (Kremen, 2005).

Based on the information above, sensitivity classes have been summarised as follows (**Table 14**):

Table 14. Sensitivity classes (Kremen, 2005)

CATEGORY	DESCRIPTION
High sensitivity	<ul> <li>Areas that are relatively undisturbed or pristine, and;</li> <li>Very species-rich relative to immediate surroundings;</li> <li>Or have a very unique and restricted indigenous species composition;</li> <li>Otherwise, constitute specific habitats for fauna and flora of conservation concern, and where the total extent of such habitats and associated species of conservation concern remaining in southern Africa is limited; and</li> </ul>
	<ul> <li>Excessive disturbance of such habitats may lead to species or ecosystem loss.</li> </ul>
Medium	Areas where disturbances are at most limited and;
sensitivity	<ul> <li>Areas with a species diversity representative of its natural state, but not exceptionally high or unique compared to its surroundings;</li> <li>Areas of which the biotic or abiotic configuration does not constitute a very specific or restricted habitat or very high niche diversity;</li> </ul>

CATEGORY	DESCRIPTION
	<ul> <li>Areas which provide ecosystem services needed for the continued functioning of the ecosystem and the continued use thereof (e.g., grazing);</li> <li>While species of conservation concern may occur on the area, these are not restricted to these habitats only;</li> <li>Areas which need to remain intact to ensure the functioning of adjacent ecosystems, or wildlife corridors or portions of land that prevent the excessive fragmentation of natural flora and fauna populations, or areas that will be difficult to rehabilitate to a functional state after physical alteration; and</li> <li>With a high species diversity and potentially higher number of species of conservation concern.</li> </ul>
Low sensitivity	<ul> <li>Areas which have been previously disturbed or;</li> <li>Areas that have a low ecological value.</li> <li>Areas which provide limited ecosystem services.</li> <li>Species diversity may be low or all species present have a much wider distribution beyond this habitat or locality;</li> <li>Plant SCC may be present on such areas, but these are not restricted to these habitats only and can be relocated with ease;</li> <li>Further inputs may include landscapes where the abiotic nature is such that it can be rehabilitated relatively easy to allow the reestablishment of the original species composition, and where the development will not lead to any unjustified degradation of landscapes or ecosystem services if adequately mitigated.</li> </ul>

The entire proposed water pipeline upgrade route is assigned a **Low** sensitivity because they have low ecological value and provide limited to none of the ecosystem services. The species diversity along the route are low and all species present have a much wider distribution beyond this habitat or locality.

# 12 ENVIRONMENTAL IMPACT ASSESSMENT

# 12.1.1 Methodology

The impacts and the proposed management thereof are first discussed on a qualitative level and thereafter quantitatively assessed by evaluating the duration, extent, magnitude, probability and ultimately the significance of the impacts (refer to methodology provided below). The assessment considers impacts before and after mitigation measures.

The duration of the impact

The duration of the impac	·L	
Score	Duration	Description
1	Short term	0 – 1 years
2	Short to medium term	2 – 5 years
3	Medium term	5 – 15 years
4	Medium to long term	15+ years

Score	Duration	Description
5	Permanent	Permanent

The extent (spatial scale) of the impact

Score	Extent	Description
1	Site specific	Within the site boundary
2	Local	Affects immediate surrounding areas
3	Regional	Extends substantially beyond the site boundary
4	Provincial	Extends to almost entire province or larger region
5	National	Affects country or possibly world

The magnitude (severe or beneficial) of the impact

Score	Severe/beneficial effect	Description
0	None	No effect – No disturbance/benefit
2	Slight	2 Little effect – negligible disturbance/benefit
4	Slight to moderate	Effects observable – environmental impacts reversible with time
6	Moderate	Effects observable – impacts reversible with rehabilitation
8	Moderate to high	Extensive effects – irreversible alteration to the environment
10	High	Extensive permanent effects with irreversible alteration

The probability of the impact

Score	Rating	Description
1	Very Improbable	Probably won't occur
2	Improbable	Low likelihood of occurring
3	Probable	Distinct possibility of occurring
4	Highly Probable	Very likely to occur
5	Definite	Will occur, regardless of any intervention

Significance of the impact, Degree of Irreversibility, Degree of loss of Resource are rated as follows:

Significance Rating	Description
Low (score of 1-29)	Impact will not significantly change fauna biodiversity and requires no
	significant mitigation measures.
Moderate (score of 30-60)	Impact will change fauna biodiversity and requires some mitigation
	measures.
High (Score of 61-100)	Impact will significantly change fauna biodiversity and significant
	mitigation measures and management is required. Potential fatal flaw.

The Significance = (Magnitude + Spatial Scale + Duration) x Probability

#### 12.1.2 Assessment of Environmental Impacts and Suggested Mitigation Measures

Only the ecological issues identified during the appraisal of the receiving environment and potential impacts are assessed below (**Table 15**). Mitigation measures are provided to prevent (first priority), reduce or remediate adverse environmental impacts.

The pre/construction phases of the proposed development is anticipated to have direct impacts on floral habitat. Site clearing will potentially result in permanent removal of floral habitat and therefore the disturbance of vegetation must be limited to areas of construction only. According to the information obtained from GDARD, all provincially protected plant

species (especially *Agapanthus* sp),highly sought-after medicinal plant species (*Albuca virens*) and an Orange listed plant species (*Hypoxis hemerocallidea*) such as found along the route, should be preserved and avoided. Therefore, in order to mitigate the impacts to these plant species, all provincially protected plant species and Orange listed plants found along the route, should be protected and avoided. These plants should be planted just outside of the development route after the completion of construction activities. Where this proves not to be possible, a permit will be required from GDARD to transplant these plant species outside of the proposed pipeline route or donated to Conservation areas. The permit application should be preceded by a Search, Rescue and Relocation Plan. This Plan must be compiled by a competent Ecologist/Botanist.

Based on the results of the field survey, it is evident that the project site provides low habitat to a number of fauna species. Although it is assumed that the majority of fauna species will move to different areas as a result of disturbance, many SCC fauna species have a specific habitat requirement and the destruction of their habitats will result in displacement to less optimal habitats, or ultimately may result in their demise. However, due to the study site providing low suitable habitats for SCC fauna to occur, this impact can be mitigated.

The project will lead to the disturbance of flora habitat, which then creates opportunities for invasion by invasive and alien species. The potential disturbance of soil and vegetation during construction activities encourages the establishment of pioneer vegetation, in many cases creating an ideal opportunity and optimal conditions for weeds and alien invasive plants to invade both disturbed and undisturbed areas after construction has been completed. Alien Invasive plants can have far reaching detrimental effects on indigenous vegetation and has been widely accepted as being a leading cause of biodiversity loss. The large amount of disturbance created during construction will leave the study area and adjacent undeveloped areas vulnerable to alien plant invasion. Failure to manage rehabilitation and landscaping well can lead to serious alien invasive plant infestation.

Increased levels of noise, disturbance and human activity during construction may be detrimental to fauna. The risk of illegal hunting/poaching/trapping of wildlife for various uses is likely. Many species would however become habituated to the existing activities and would return to normal activity after some time. The operational phase of the development will be permanent. Potential impacts on local faunal species as a result of disturbance/displacement has been assessed as not significant at a local scale.

If disturbed areas are not rehabilitated/re-vegetated/landscaped post construction, soil erosion may continue throughout the operational phase of the development. This is likely to be exacerbated by stormwater runoff from any hardened/impermeable surfaces such as compacted soil, etc. Due to the extensive disturbance likely to be created by construction within the project area, this impact is most likely to occur within the project area, but could

potentially occur outside the project area as well if suitable avoidance and mitigation measures were not implemented during construction.

The potential impacts associated with the pre-construction, construction and operational activities are discussed in **Table 15** below.

#### 12.1.2.1 Pre-construction / Construction Phases

Activities associated with the pre-construction and construction phases, include the following:

- Site establishment, such as construction camps, laydown and storage areas on site;
- Earthmoving activities e.g. excavation and soil stockpiling;
- · Vegetation clearance of the site;
- · Storage of hazardous and non-hazardous material and wastes; and
- Landscaping and rehabilitation of the site.

Potential impacts to flora and fauna during the pre-/and construction phases, include the following:

- · Destruction of indigenous flora during site establishment;
- Potential loss of provincially protected plants species and medicinal plants;
- Inadvertent killing and injury of fauna species during vegetation clearance and excavation;
- · Potential loss of soil due to fuel and chemical spills (soil contamination);
- Encroachment, proliferation and spread of weeds and alien invasive plant species;
- Loss/displacement of fauna species potentially present on site;
- Increased soil erosion due to compaction by vehicles and construction activities, and incorrect storm water management measures;
- Soil contamination from hazardous substance spillages (Fuel) outside their primary and secondary containment during maintenance work and re-fuelling.
- · Loss of topsoil and increased erosion;
- Disturbance of local fauna populations due to construction activities; and
- Loss of flora and fauna habitat due to vegetation clearance.

#### 12.1.2.2 Operational Phase

Activities associated with the operational phase, include the following:

- Vegetation management activities; and
- Fauna management activities.

Potential impacts associated with the operational phase, include the following:

- AIPs and weeds
- Disturbance to ecological processes due to altered habitat and disturbance to natural movements/processes;

- Disturbance of local faunal communities; and
- · Loss of habitat due to operational activities.

Table 14: Potential impacts and recommended mitigation measures with significance rating before and after mitigation for the proposed Emergency Ecological Assessment at Woodmead Water Pipe Upgrade

Potential impac	t BEFORE mi	itigation				Mitigation	Potential impact AFTER mitigation				
Nature of the impact	Duration	Extent	Probability	Magnitude	Significance	- Measures	Duration	Extent	Probability	Magnitude	Significanc e
Destruction of ndigenous lora medicinal and Drange listed blants) during site establishment and potential oss of regetation	Short to medium term (2)	Site specific (1)	Highly Probable (4)	Slight to moderate (4)	28 Low) Status (-ve)	The provincially protected plant species and medicinal plants found along the route, should be protected and avoided and where this proves not to be possible, a permit will be required from GDARD to transplant these species outside of the proposed development route.  Development planning must ensure that loss of vegetation and disturbance are restricted within the recommende	Short to medium term (2)	Site specific (1)	Improbable (2)	Slight (2)	10 (Low) Status (-ve)

Potential impac	t BEFORE mi	tigation				Mitigation	Potential impact AFTER mitigation					
Nature of the impact	Duration	Extent	Probability	Magnitude	Significance	Measures	Duration	Extent	Probability	Magnitude	Significanc e	
						d site layout						
						footprint.						
						Clearly						
						demarcate						
						the						
						construction						
						footprint prior						
						to clearing of						
						vegetation.						
						Areas cleared						
						of vegetation						
						must be re-						
						vegetated/lan						
						dscaped prior						
						to contractor						
						leaving the						
						site.						
						• Pre-						
						construction						
						environmenta						
						I induction						
						must be						
						conducted to						
						all:						
						construction						
						staff on site to						
						ensure that						
						basic						
						environmenta I principles						
						are adhered						
		1		1		to. This				1		
						includes						
						awareness as						
						to						
						conservation						
						and						

Potential impact	BEFORE mi	itigation				Mitigation	Potential impact AFTER mitigation					
Nature of the impact	Duration	Extent	Probability	Magnitude	Significance	Measures	Duration	Extent	Probability	Magnitude	Significanc e	
impast.						importance of provincially protected plants, protected trees and medicinal plants.  • Environment al Control Officer (ECO) should provide supervision and oversight of vegetation clearing activities.  • All laydown, storage areas, site camps etc. should be restricted to within the project area and should preferably be situated within areas of low sensitivity (already disturbed						

Potential impac	otential impact BEFORE mitigation					Mitigation	Potential impact AFTER mitigation				
Nature of the impact	Duration	Extent	Probability	Magnitude	Significance	- Measures	Duration	Extent	Probability	Magnitude	Significanc e
Loss and displacement of animals on site due to habitat loss and mortality	Short to medium term (2)	Site specific (1)	Highly Probable (4)	Slight to moderate (4)	28 Low) Status (-ve)	Building material or ablution facilities should not be stored or kept in areas containing natural vegetation.     Surrounding areas with indigenous vegetation should under no circumstance s be fragmented or disturbed further or used as an area for dumping of waste.      Training of construction personnel to recognise threatened animal species will reduce the probability of	Permanen t (5)	Site specific (1)	Improbable (2)	Slight (2)	16 (Low) Status (-ve)

Potential impac	t BEFORE mi	itigation				Mitigation	Potential impact AFTER mitigation					
Nature of the impact	Duration	Extent	Probability	Magnitude	Significance	- Measures	Duration	Extent	Probability	Magnitude	Significanc e	
						unnecessarily						
						• The						
						contractor						
						must ensure						
						that no faunal						
						species are						
						disturbed,						
						trapped,						
						hunted or						
						killed during						
						the pre-and construction						
						phases.						
						Vehicles						
						must adhere to the set						
						speed limit.						
						• All						
						construction						
						vehicles must use						
						designated						
						access roads.						
						Off-road						
						driving should						
						be strictly						
						prohibited.						
						• Fauna						
						(mammals						
						and reptiles)						
						that become						
						trapped in						
						any						
						excavation or				1		
						in any						

Potential impac	t BEFORE mit	igation				Mitigation	Potential impact AFTER mitigation					
Nature of the impact	Duration	Extent	Probability	Magnitude	Significance	- Measures	Duration	Extent	Probability	Magnitude	Significanc e	
						construction related activity, may not be harmed and must be rescued and relocated by suitably qualified personnel. • Any fauna threatened by the construction activities should be removed to safety by the ECO or any suitable qualified personnel.						
Encroachment , proliferation and spread of weeds and alien invasive plant species	Permanent (5)	Regional (3)	Highly Probable (4)	High (10)	72 (High) Status (-ve)	Alien invasive plants (listed in this study) can be removed manually or with the help of simple tools. This entails damaging or removing the plant by physical	Medium to long term (4)	Local (2)	Probable (3)	Moderate to slight (4)	30 (Medium) Status (-ve)	

Potential impac	t BEFORE m	itigation				Mitigation	Potential in	npact AFTE	R mitigation		
Nature of the impact	Duration	Extent	Probability	Magnitude	Significance	Measures	Duration	Extent	Probability	Magnitude	Significanc e
•						action.					
						Different					
						techniques					
						could be					
						used, e.g.,					
						uprooting,					
						ring-barking					
						or bark					
						stripping.					
						These control					
						options are					
						only really					
						feasible in					
						sparse					
						infestations					
						or on small					
						scale, and for					
						controlling					
						species that					
						do not					
						coppice after					
						cutting. It					
						would be					
						preferable to					
						uproot alien					
						vegetation to					
						limit regrowth					
						after cutting.					
				1		It should be					
						noted that all					
						infestations					
						cannot be					
						cleared at					
						once, as					
						these plant					
						species do					
						currently play					

Potential impac	t BEFORE r	nitigatio	on				Mitigation	Potential impact AFTER mitigation					
Nature of the impact	Duration	Ext	tent	Probability	Magnitude	Significance	- Measures	Duration	Extent	Probability	Magnitude	Significanc e	
							a role in stabilising soils and therefore, the sequence of alien plant removal should be planned, along with revegetation of the cleared areas.  Regular monitoring for alien invasive plants within the study area as well as adjacent areas which receive runoff as there are also likely to be prone to invasion problems.						
Inadvertent killing and injury of fauna species during vegetation clearance.	Short medium term (2)	to Site spe (1)	ecific	Highly Probable (4)	Slight to moderate (4)	28 Low) Status (-ve)	If possible, the clearance of vegetation should commence during non- breeding season of fauna species (i.e., winter).	Short to medium term (2)	Site specific (1)	Improbable (2)	Slight (2)	10 (Low) Status (-ve)	

Potential impac	t BEFORE m	itigation				Mitigation	Potential in	npact AFTE	R mitigation		
Nature of the impact	Duration	Extent	Probability	Magnitude	Significance	- Measures	Duration	Extent	Probability	Magnitude	Significanc e
						Any fauna					
						threatened by					
						the					
						construction					
						activities					
						should be					
						moved to					
						safety by a suitable					
						qualified ECO					
						or an					
						Ecologist.					
						All personnel					
						should					
						undergo an					
						environmenta					
						I induction					
						with regards					
						to fauna, in					
						particular					
						awareness					
						about					
						harming or					
						collecting					
						species such					
						as snakes,					
						tortoises.					
						If trenches					
						are to be dug,					
						these should					
						not be left					
						open for					
						extended					
						periods of					
1						time as fauna					
						may fall in					

Potential impac	t BEFORE m	itigation				Mitigation	Potential impact AFTER mitigation					
Nature of the impact	Duration	Extent	Probability	Magnitude	Significance	Measures	Duration	Extent	Probability	Magnitude	Significanc e	
						and become						
						trapped in						
						them.						
						Trenches						
						which are left						
						open should						
						have places						
						where there						
						are soil						
						ramps, which						
						will allow						
						fauna to						
						escape the						
						trench.						
						No animals						
						should be						
						intentionally						
						destroyed or						
						killed, and no						
						hunting or						
						poaching of						
						animals is						
						allowed in the						
						project site or						
						adjacent						
						areas.						
						No food or						
						similar waste						
						that may						
						attract wild						
						animals						
						should be						
						disposed of at						
						the site. All						
						food and litter						
						waste should						
						be placed in						

Potential impac	t BEFORE mit	igation				Mitigation	Potential impact AFTER mitigation					
Nature of the impact	Duration	Extent	Probability	Magnitude	Significance	- Measures	Duration	Extent	Probability	Magnitude	Significanc e	
						sealed bins and removed from the site each day.						
						In order to reduce collisions of vehicles with fauna, animals						
						should have right of way.						
Operational pha	ases											
Erosion caused by inadequate/fail ing stormwater management measures/desi gns.	Medium (3)	Local (2)	Highly Probable (4)	Moderate (6)	44 (Medium) Status (-ve)	Regular monitoring for erosion after construction to ensure that no erosion problems have developed as result of the disturbance.      All erosion problems observed should be rectified as soon as possible, using the appropriate soil erosion control structures	Short to medium term (2)	Site specific (1)	Improbable (2)	Slight (2)	10 (Low) Status (-ve)	

Potential impac	t BEFORE mi	tigation				Mitigation	Potential impact AFTER mitigation					
Nature of the impact	Duration	Extent	Probability	Magnitude	Significance	- Measures	Duration	Extent	Probability	Magnitude	Significanc e	
						and revegetation techniques.  • All cleared areas should be landscaped and/or re- vegetated.						
Disturbance of local fauna populations.	Short to medium term (2)	Site specific (1)	Highly Probable (4)	Slight to moderate (4)	28 Low) Status (-ve)	<ul> <li>Animals residing within the designated area shall not be unnecessarily disturbed.</li> <li>No hunting, trapping, killing of any animal should be permitted.</li> <li>Snake and or animal handling should be strictly limited to qualified staff or a dedicated external snake handler.</li> <li>When accessing the site, vehicles are to utilise</li> </ul>	Short to medium term (2)	Site specific (1)	Improbable (2)	Slight (2)	10 (low) Status (-ve)	

Potential impa	ntial impact BEFORE mitigation					Mitigation	Potential impact AFTER mitigation					
Nature of the impact	Duration	Extent	Probability	Magnitude	Significance	- Measures	Duration	Extent	Probability	Magnitude	Significanc e	
						the existing roads.  Ensure that no unnecessary clearing of faunal habitat occurs during maintenance activities.  No fires by maintenance personnel are allowed.  No wild animal may be fed on site.  Ensure that the site is kept clean, tidy and free of rubbish that would attract animal pests.  All vehicles accessing the site should avoid collisions with susceptible species such as snakes and small rodents.  All waste generated at						

Potential impac	t BEFORE miti	gation				Mitigation	Potential impact AFTER mitigation					
Nature of the impact	Duration	Extent	Probability	Magnitude	Significance	- Measures	Duration	Extent	Probability	Magnitude	Significanc e	
						should be kept in scavenger proof bins and removed from site at regular intervals.						
Rehabilitation/l andscaping of the site after construction activities	Medium to long term (4)	Site specific (1)	Probable (3)	Slight to moderate (4)	27 (Low) Status (-ve)	Bare surfaces should be grassed as soon as possible after construction to minimise time of exposure.  Take appropriate remedial action where vegetation establishmen t is unsuccessful or erosion is evident.  As much vegetation growth as possible should be promoted within the study area in order to protect soils and to reduce the	Permanen t (5)	Local (2)	Highly Probable (4)	Moderate to high (8)	60 (Medium) Status (-ve)	

Potential impac	Potential impact BEFORE mitigation						Potential impact AFTER mitigation					
Nature of the impact	Duration	Extent	Probability	Magnitude	Significance	- Measures	Duration	Extent	Probability	Magnitude	Significanc e	
						percentage of the surface area which is left as bare ground.						

# 13 CONCLUSION AND RECOMMENDATIONS

The proposed pipe upgrade route is situated along the servitudes/ road reserve, and traverses main roads such as Marlboro and M1. It is situated in an urban environment and most of the plants were cultivated as part of street trees project, landscaping and gardening. During the field survey, no threatened plant species or protected trees were observed along the proposed route. However, the following plant species are listed as "Protected Plants" in terms of Schedule 11 (Section 86 (1) (a)) of Transvaal Nature Conservation Ordinance No. 12 of 1983, namely all species of agapanthus *Agapanthus africanus*.

A plant species such as *Hypoxis hemerocallidea*, is listed as Orange Listed Plant species. Orange lists are those within the Red list that are categorised as rare, Data deficient, declining or near threatened. *Hypoxis hemerocallidea* occurs in an open grassland and woodland and is widespread in South Africa in the eastern summer rainfall provinces (Eastern Cape, Free State, KwaZulu-Natal, Mpumalanga, Gauteng and Limpopo). It also occurs in Botswana, Lesotho and Swaziland and it's a highly sought-after medicinal plant. This species used to be classified as *Declining*, but now de-classified as *Least concern*. Species classified as Least concern are considered at low risk of extinction and are widespread and abundant, however, GDARD has indicated that this species must remain classified as Orange list plant species due to its provincial level pressures.

Therefore, in order to mitigate the impacts to these plant species, all provincially protected plant species and Orange listed plants found along the route, should be protected and avoided. These plants should be planted just outside of the development route after the completion of construction activities. Where this proves not to be possible, a permit will be required from GDARD to transplant these plant species outside of the proposed pipeline route or donated to Conservation areas. The permit application should be preceded by a Search, Rescue and Relocation Plan. This Plan must be compiled by a competent Ecologist/Botanist. This Plan should also take into account medicinal plant species such as *Albuca virens* recorded along the route site

Fauna species recorded along the proposed route were common and are typical of grassland vegetation. No fauna Species of Conservation Concern were recorded along the study route. The fragmented and transformed area has lost the ecological ability to sustain any faunal assemblage or community. The human presence and associated disturbances taking place usually have a detrimental impact on fauna species (especially mammals and snakes) in the area.

Generally, the development activities proposed within the route will not have a significant impact on biodiversity conservation within the region. It is the opinion of the ecologist, that the proposed water pipeline upgrade project be considered favourably, provided that the mitigation measures

are implemented and adhered to. The methodologies used and results found during the field survey, together with the impacts and mitigation measures provide confidence that the project can go ahead.

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