



**Department of Water Affairs  
Directorate: Options Analysis**

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

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

**APPENDIX No.9**

**LiDAR Aerial Survey, for the Berg River-Voëlville Augmentation Scheme,  
and the Breede-Berg (Michell's Pass) Water Transfer Scheme**



**December 2012**

## STUDY REPORT LIST

REPORT No	REPORT TITLE	VOLUME No.	DWA REPORT No.	VOLUME TITLE
1	ECOLOGICAL WATER REQUIREMENT ASSESSMENTS	Vol 1	PWMA19 G10/00/2413/1	<b>Riverine Environmental Water Requirements</b>
				Appendix 1: EWR data for the Breede River
				Appendix 2: EWR data for the Palmiet River
				Appendix 3: EWR data for the Berg River
				Appendix 4: Task 3.1: Rapid Reserve assessments (quantity) for the Steenbras, Pomers and Kromme Rivers
				Appendix 5: Habitat Integrity Report – Breede River
		Vol 2	PWMA19 G10/00/2413/2	<b>Rapid Determination of the Environmental Water Requirements of the Palmiet River Estuary</b>
				Appendix A: Summary of data available for the RDM investigations undertaken during 2007 and 2008
				Appendix B: Summary of baseline data requirements and the long-term monitoring programme
		Vol 3	PWMA19 G10/00/2413/3	<b>Berg Estuary Environmental Water Requirements</b>
				Appendix A: Available information and data
				Appendix B: Measurement of streamflows in the Lower Berg downstream of Misverstand Dam
				Appendix C: Specialist Report – Physical dynamics and water quality
				Appendix D: Specialist Report – Modelling
				Appendix E: Specialist Report – Microalgae
				Appendix F: Specialist Report – Invertebrates
				Appendix G: Specialist Report – Fish
				Appendix H: Specialist Report – Birds
Appendix I: Specialist Report – The economic value of the Berg River Estuary				
2	PRELIMINARY ASSESSMENT OF OPTIONS		PWMA19 G10/00/2413/4	Appendix 1: Scheme Yield Assessments and Diversion Functions
				Appendix 2: Unit Reference Value Calculation Sheets
				Appendix 3: Yield Analysis and Dam Size Optimization
				Appendix 4: Dam Design Inputs
				Appendix 5: Diversion Weir Layout Drawings
				Appendix 6: Voëlvlei Dam Water Quality Assessment
				Appendix 7: Botanical Considerations
				Appendix 8: Heritage Considerations
				Appendix 9: Agricultural Economic Considerations

**STUDY REPORT LIST (cntd)**

REPORT No	REPORT TITLE	VOLUME No.	DWA REPORT No.	VOLUME TITLE
3	<b>FEASIBILITY STUDIES</b>	Vol 1	PWMA19 G10/00/2413/5	<b>Berg River-Voëlvlei Augmentation Scheme</b>
				Appendix 1: Updating of the Western Cape Water Supply System Analysis for the Berg River-Voëlvlei Augmentation Scheme
				Appendix 2: Configuration, Calibration and Application of the CE-QUAL-W2 model to Voëlvlei Dam for the Berg River-Voëlvlei Augmentation Scheme
				Appendix 3: Monitoring Water Quality During Flood Events in the Middle Berg River (Winter 2011), for the Berg River-Voëlvlei Augmentation Scheme
				Appendix 4: Dispersion Modelling in Voëlvlei Dam from Berg River Water Transfers for the Berg River-Voëlvlei Augmentation Scheme
				Appendix 7 - 12: See list under Volume 2 below
		Vol 2	PWMA19 G10/00/2413/6	<b>Breede-Berg (Michell's Pass) Water Transfer Scheme</b>
				Appendix 5: Scheme Operation and Yield Analyses with Ecological Flow Requirements for the Breede-Berg (Michell's Pass) Water Transfer Scheme
				Appendix 6: Preliminary Design of Papenkuils Pump Station Upgrade and Pre-Feasibility Design of the Boontjies Dam, for the Breede-Berg (Michell's Pass) Water Transfer Scheme
				Appendix 7: Ecological Water Requirements Assessment Summary for the Berg River-Voëlvlei Augmentation Scheme, and the Breede Berg (Michell's Pass) Water Transfer Scheme
				Appendix 8: Geotechnical Investigations for the Berg River-Voëlvlei Augmentation Scheme, and the Breede-Berg (Michell's Pass) Water Transfer Scheme
				Appendix 9: LiDAR Aerial Survey, for the Berg River-Voëlvlei Augmentation Scheme, and the Breede-Berg (Michell's Pass) Water Transfer Scheme
				Appendix 10: Conveyance Infrastructure Design Report, for the Berg River-Voëlvlei Augmentation Scheme, and the Breede-Berg (Michell's Pass) Water Transfer Scheme
				Appendix 11: Diversion Weirs Design for the Berg River-Voëlvlei Augmentation Scheme, and the Breede-Berg (Michell's Pass) Water Transfer Scheme
Appendix 12: Cost Estimates for the Berg River-Voëlvlei Augmentation Scheme, and the Breede-Berg (Michell's Pass) Water Transfer Scheme				
4	<b>RECORD OF IMPLEMENTATION DECISIONS</b>		PWMA19 G10/00/2413/7	

## STUDY REPORT MATRIX DIAGRAM

### PHASE 1: PRE-FEASIBILITY STUDY

#### ECOLOGICAL WATER REQUIREMENT ASSESSMENTS

##### Riverine Environmental Water Requirements

*PWMA19 G10/00/2413/1*

- Data (Electronic format)
- Rapid Reserves (Steenbras, Pomers, Kromme Rivers)
- Habitat Integrity (Breede River)

##### Rapid Determination of the Environmental Water Requirements of the Palmiet River Estuary

*PWMA19 G10/00/2413/2*

- Existing Data Availability
- Baseline Data Requirements and Monitoring Programme
- Abiotic Assessment

##### Berg Estuary Environmental Water Requirements

*PWMA19 G10/00/2413/3*

- Available Information and Data
- Measurement of Streamflows in the Lower Berg
- Physical Dynamics and Water Quality
- Modelling
- Microalgae
- Invertebrates
- Fish
- Birds
- Economic Value of the Estuary

#### PRELIMINARY ASSESSMENT OF OPTIONS

*PWMA19 G10/00/2413/4*

- Scheme Yield Assessments and Diversion Functions
- Unit Reference Value Calculation Sheets
- Yield Analysis and Dam Size Optimization
- Dam Design Inputs
- Diversion Weir Layout Drawings
- Voëlvelei Dam Water Quality Assessment
- Botanical Considerations
- Heritage Considerations
- Agricultural Economic Considerations



### PHASE 2: FEASIBILITY STUDIES

#### BERG RIVER VOËLVLEI AUGMENTATION SCHEME

*PWMA19 G10/00/2413/5*

- Update System Analysis
- Berg River CE-Qual Water Quality Modelling
- Berg River Flood Water Quality Modelling
- Dispersion Modelling in Voëlvelei Dam
- Ecological Water Requirements Summary
- Geotechnical Investigations
- Aerial Survey
- Conveyance Infrastructure Design
- Diversion Weirs Design
- Cost Estimates

#### BREEDE - BERG (MICHELL'S PASS) WATER TRANSFER SCHEME

*PWMA19 G10/00/2413/6*

- Scheme Operation and Yield Analysis
- Preliminary Design of Papenkuils Pumpstation and Boontjies Dam
- Ecological Water Requirements Summary
- Geotechnical Investigations
- Aerial Survey
- Conveyance Infrastructure Design
- Diversion Weirs Design
- Cost Estimates

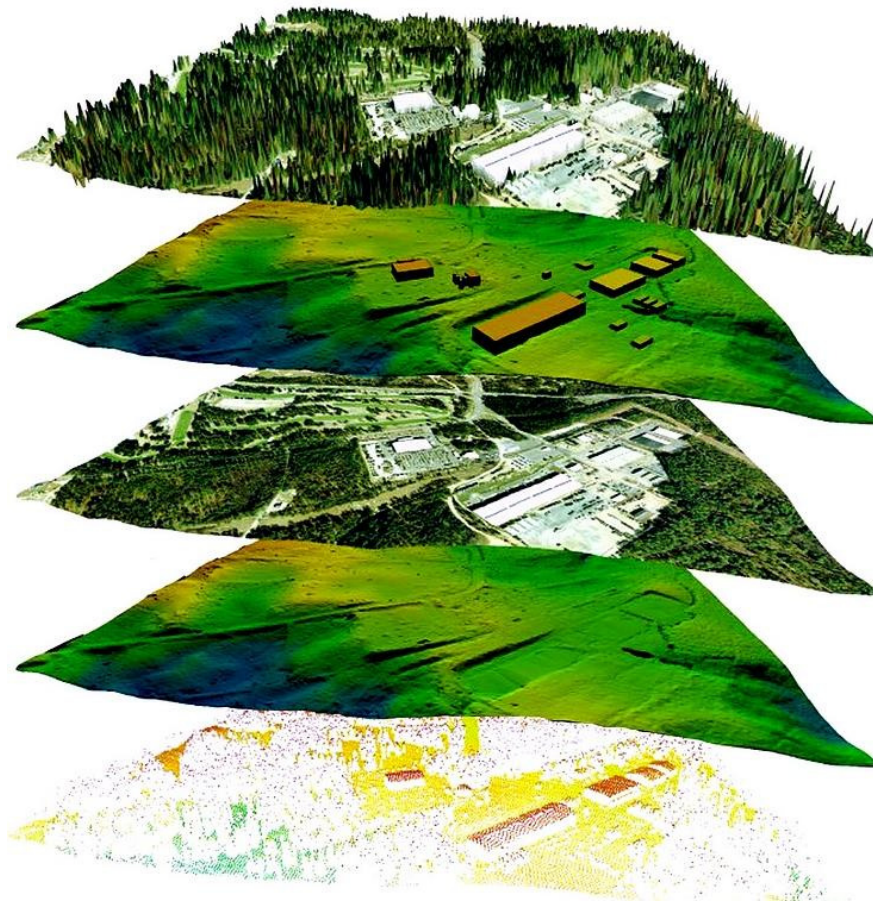


### IMPLEMENTATION DECISION SUPPORT

#### RECORD OF IMPLEMENTATION DECISIONS

*PWMA19 G10/00/2413/7*

**Voëlvlei Dam  
Final Report  
Fli-Map Aerial Survey/DMC Camera**



March 2011



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## 0.0 Background Information

**Aurecon** approached Fugro Maps South Africa in order to do a LiDAR survey (with the Fli-Map LiDAR System) and Aerial Photography utilising a DMC camera for the Voëlvlei Dam area.

Fli-map Lidar acquisition was done on the 9th January 2011 and the DMC acquisition on the 8<sup>th</sup> January 2011.

## 1.0 Flight Parameters

For this project, Fugro MAPS (South Africa) (PTY) Ltd proposed the following flight parameters for data collection in order to provide the product resolution and accuracy that best suits this project's requirements while maintaining the desired project budget.

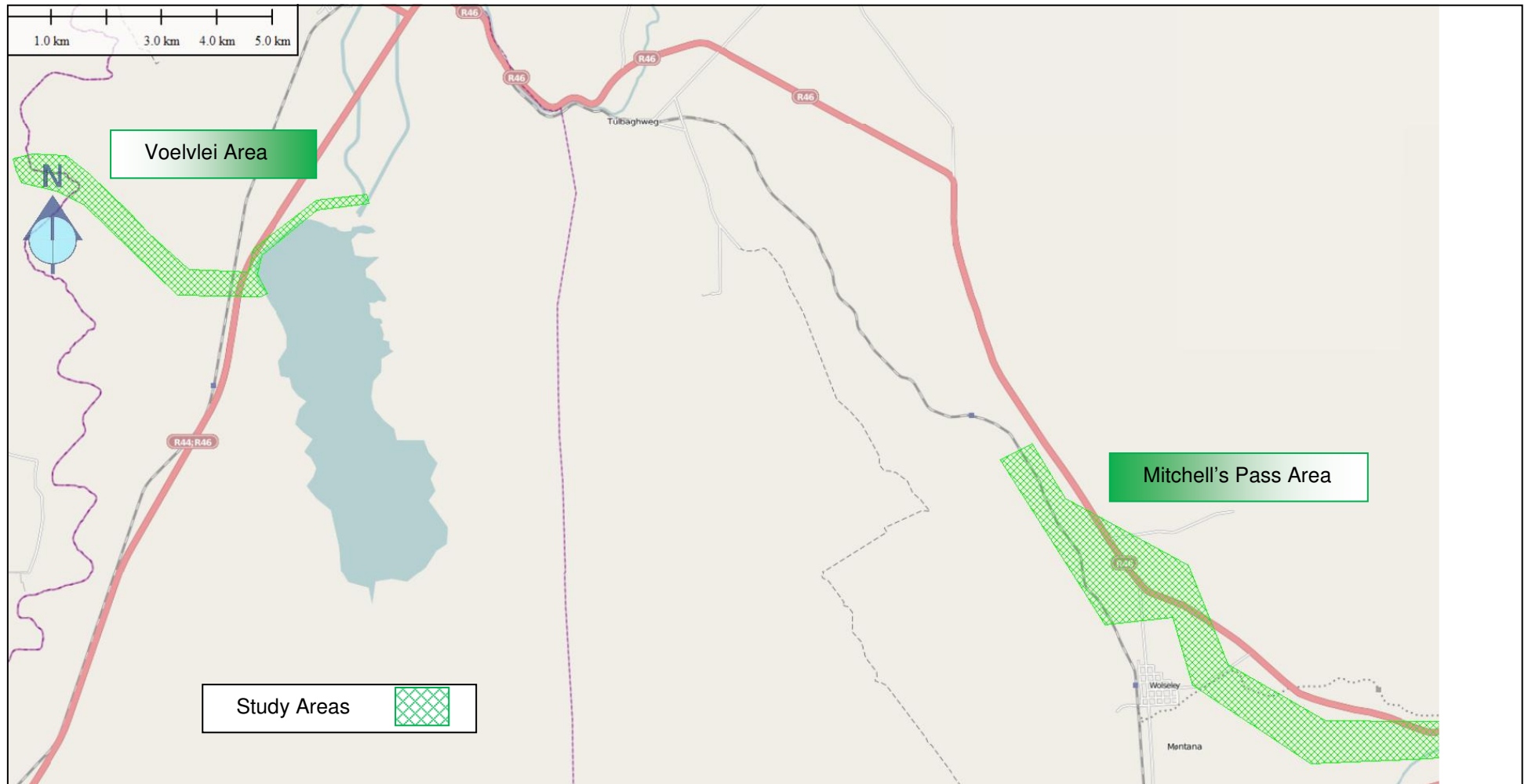
Specific values pertaining to data resolution and accuracy are:

<b>Altitude:</b>	480m AGL
<b>Speed</b>	120 knots (60 m/s)
<b>Nominal Point Density:</b>	7.2 points / m <sup>2</sup>
<b>Image Resolution:</b>	10 cm
<b>Total System Accuracy (absolute)</b>	20 cm horizontal @ 1 sigma 10 cm vertical @ 1 sigma
<b>Total System Accuracy (relative)</b>	<15 cm horizontal and vertical @ 1 sigma



## 2.0 Orientation of Study Area

Map 1 below shows the study area of the aerial survey (1 217 ha)





### 3.0 Quality Control

In order to do quality control on the LiDAR point clouds, a comparison was done between the traditional kinematic survey heights and the DTM LiDAR point cloud. Table 1 below shows the results of the comparison.

Table 1: Comparison

Number	Easting	Northing	Known Z	Laser Z	Dz
1	19241.259	-3697232.899	287.801	287.840	+0.039
2	2032.833	-3691446.203	70.742	70.760	+0.018

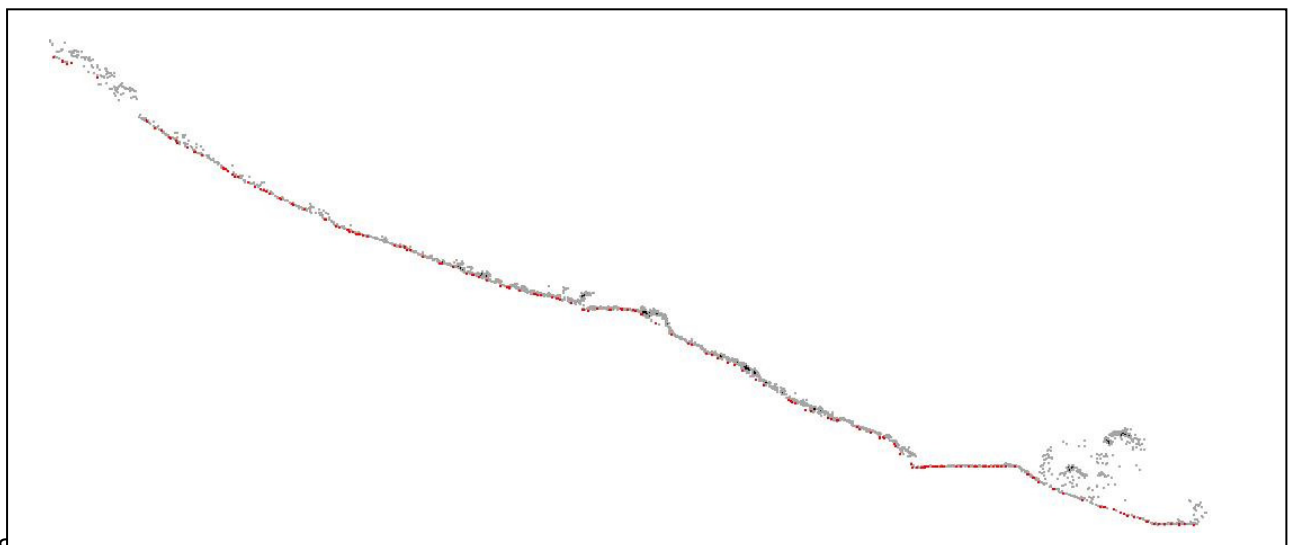
  

Average dz	+0.029
Minimum dz	+0.018
Maximum dz	+0.039
Average magnitude	0.029
Root mean square	0.030
Std deviation	0.015

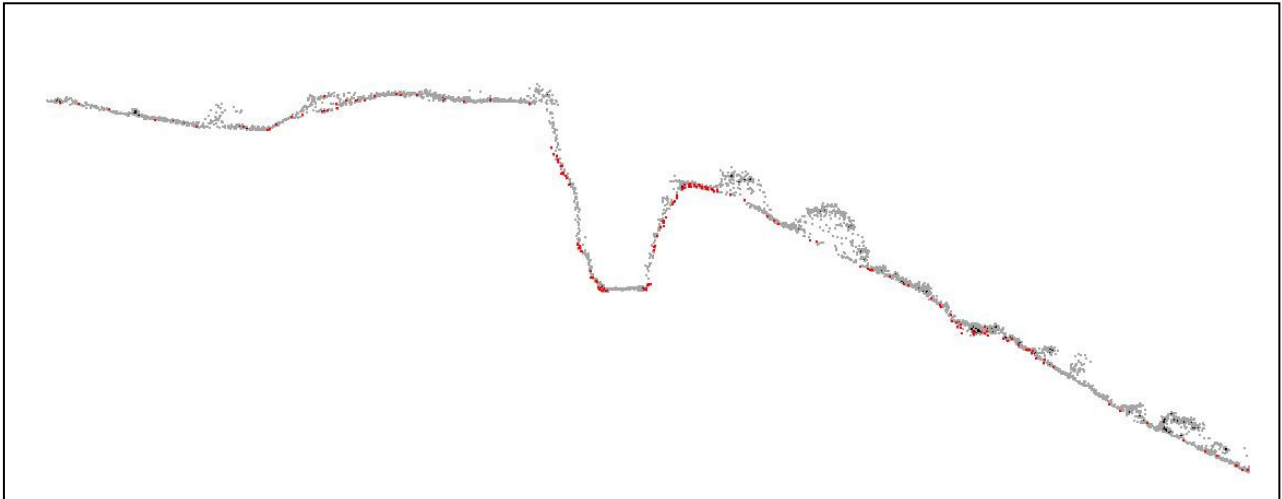
From the table above it is evident that the root mean square of the z value is 3cm.

In order to show the ground filter quality on the LiDAR point cloud two cross-sections are included below to show the ground surface points (red).

Sketch 1: Cross-Section of LiDAR points



Sketch 2: Cross-Section of LiDAR points



### 4.0 Transformations & Projection

The survey was based on Cape Town, Langebaan, Malmesbury and Stellenbosch ITRF Epoch 2010.06 coordinates. In order to transform the LiDAR point clouds and imagery to the published xyz coordinates of TrigNet the following transformations had to be done on the x, y and z respectively (0.303m, 0.423m and 0.06m shift). Table 1 below shows the ITRF and Published/Official coordinates of TrigNet. The projection of this project was **Transverse Mercator, Central Meridian 19 and WGS84**. The height for the whole project was transformed from ellipsoid to orthometric utilising the 2010 SAGEoid model with a further adjustment to the published heights as can be seen in Table 1 below.

Table 1: Transformations

	WG19 Official						ITRF		
	Y	X	Z	dy	dx	dz	Y	X	Z (SAGEOID 2010)
<b>CTWN</b>	49126.26 0	3758402.15	52.910	0.260	0.442	0.105	49126.000	3758401.708	52.805
<b>LGBN</b>	78735.71 0	3650012.23	33.282	0.344	0.386	0.063	78735.366	3650011.844	33.219
<b>MALM</b>	25020.96 0	3704223.10	129.099	0.309	0.418	0.016	25020.651	3704222.682	129.083
<b>STBS</b>	15117.13 0	3746438.97	235.510	0.298	0.446	0.165	15116.832	3746438.524	235.345
				<b>0.303</b>	<b>0.423</b>	<b>0.060</b>			

## 5.0 Deliverables

The deliverables of the project were as follows:

- 0.5m contours intervals in DXF,DGN & DWG format
- LiDAR (Ground) in a\*.XYZ format
- Imagery in a \*.TIFF & ECW format (0.15 meter resolution)
- 2D Line Mapping (DGN, DWG and DXF format)
- 2D Line Mapping Plans 1:1000 Scale (DGN, DWG, DXF & PDF files)
- 3 X Cross Sections

Survey Report

Final Co-ordinates

**ITRF 2005 (SAGEOID 2010)**

CTWN	49126.000	3758401.708	52.805
LGBN	78735.366	3650011.844	33.219
MALM	25020.651	3704222.682	129.083
STBS	15116.832	3746438.524	235.345
WOLSLEY	-18844.894	3699110.689	261.130
VOELVLEI	-1507.369	3691233.147	66.909
ROV9	-1982.627	3691135.350	71.801
ROV6	-17381.372	3695397.435	232.787
ROV7	-15836.670	3693095.545	217.076
ROV8	-3160.101	3689315.751	71.179
ROV11	-1774.637	3692467.453	72.450
ROV10	-2032.136	3691446.780	70.682
ROV5	-19240.562	3697233.476	287.741
ROV4	-18479.819	3699498.324	261.363
ROV2	-24207.127	3700163.783	291.662
ROV1	-25743.336	3699231.000	315.326

**WG19**

CTWN	49126.303	3758402.131	52.865
LGBN	78735.669	3650012.267	33.279
MALM	25020.954	3704223.105	129.143
STBS	15117.135	3746438.947	235.405
WOLSLEY	-18844.591	3699111.112	261.190
VOELVLEI	-1507.066	3691233.570	66.969
ROV9	-1982.324	3691135.773	71.861
ROV6	-17381.069	3695397.858	232.847
ROV7	-15836.367	3693095.968	217.136
ROV8	-3159.798	3689316.174	71.239
ROV11	-1774.334	3692467.876	72.510
ROV10	-2031.833	3691447.203	70.742
ROV5	-19240.259	3697233.899	287.801
ROV4	-18479.516	3699498.747	261.423
ROV2	-24206.824	3700164.206	291.722
ROV1	-25743.033	3699231.423	315.386

## AS082 VOELVLEI NETWORK ADJUSTMENT

<b>User name</b>	operator	<b>Date &amp; Time</b>	11:18:59 AM 2011/01/12
<b>Coordinate System</b>	South Africa	<b>Zone</b>	WG 19
<b>Project Datum</b>	Hartebeesthoek 94		
<b>Vertical Datum</b>		<b>Geoid Model</b>	South Africa Geoid 2010
<b>Coordinate Units</b>	Meters		
<b>Distance Units</b>	Meters		
<b>Height Units</b>	Meters		

### Adjustment Style Settings - 95% Confidence Limits

**Residual Tolerances**

**To End Iterations** : 0.000010m

**Final Convergence Cutoff** : 0.005000m

**Covariance Display**

**Horizontal**

**Propagated Linear Error [E]** : U.S.

**Constant Term [C]** : 0.00000000m

**Scale on Linear Error [S]** : 1.96

**Three-Dimensional**

**Propagated Linear Error [E]** : U.S.

**Constant Term [C]** : 0.00000000m

**Scale on Linear Error [S]** : 1.96

Elevation Errors were used in the calculations.

**Adjustment Controls**

**Compute Correlations for Geoid** : False

Horizontal and Vertical adjustment performed

**Set-up Errors**

**GPS**

**Error in Height of Antenna** : 0.000m

**Centering Error** : 0.000m

### Statistical Summary

**Successful Adjustment in 1 iteration(s)**

**Network Reference Factor** : 4.60

**Chi Square Test ( $\alpha=95\%$ )** : FAIL

**Degrees of Freedom** : 72.00

**GPS Observation Statistics**

**Reference Factor** : 4.60

**Redundancy Number (r)** : 72.00

#### Individual GPS Observation Statistics

Observation ID	Reference Factor	Redundancy Number
B1	5.21	1.50
B2	4.07	1.96
B14	5.79	1.65
B17	5.17	0.85
B29	3.11	1.11
B82	7.67	2.68
B84	5.11	1.57
B85	4.40	1.44
B90	5.04	1.56
B129	4.05	2.68
B130	3.42	2.51
B134	6.92	2.20
B138	5.62	1.69
B139	2.27	1.25
B140	5.42	1.72
B141	4.04	0.19
B142	2.45	2.13
B143	2.30	1.69
B144	5.57	1.19

B149	6.22	2.71
B151	4.22	2.39
B152	5.05	2.54
B153	2.88	2.44
B154	2.41	2.35
B155	3.88	0.94
B156	2.04	0.79
B159	5.10	2.26
B161	2.54	2.63
B164	2.47	2.69
B165	5.76	1.24
B166	4.47	0.78
B167	8.30	2.48
B168	4.26	2.36
B172	3.64	0.77
B178	3.85	2.17
B182	1.93	2.33
B184	3.89	2.35
B185	2.09	2.08
B186	3.33	2.12

**Weighting Strategies**

GPS  
 Default Scalar Applied to All Observations  
 Scalar : 1.00

Observations

**Adjusted Coordinates**

Adjustment performed in **WGS-84**  
 Number of Points : 16  
 Number of Constrained Points : 1  
 Horizontal and Height Only : 1

**Adjusted Grid Coordinates**

Errors are reported using 1.96σ.

Point Name	Easting	E error	Northing	N error	Elevation	e error	Fix
LGBN	78735.366m	0.002m	3650011.844m	0.002m	N/A	N/A	
CTWN	49126.000m	0.003m	3758401.708m	0.003m	N/A	N/A	
MALM	25020.651m	0.003m	3704222.682m	0.003m	N/A	N/A	
STBS	15116.832m	0.000m	3746438.524m	0.000m	N/A	N/A	N E h
WOLSLEY	-18844.894m	0.003m	3699110.689m	0.003m	N/A	N/A	
VOELVLEI	-1507.369m	0.003m	3691233.147m	0.003m	N/A	N/A	
ROV9	-1982.627m	0.008m	3691135.350m	0.007m	N/A	N/A	
ROV6	-17381.372m	0.007m	3695397.435m	0.007m	N/A	N/A	
ROV7	-15836.670m	0.011m	3693095.545m	0.010m	N/A	N/A	
ROV8	-3160.101m	0.010m	3689315.751m	0.010m	N/A	N/A	
ROV11	-1774.637m	0.006m	3692467.453m	0.006m	N/A	N/A	
ROV10	-2032.136m	0.006m	3691446.780m	0.007m	N/A	N/A	
ROV5	-19240.562m	0.006m	3697233.476m	0.009m	N/A	N/A	
ROV4	-18479.819m	0.009m	3699498.324m	0.008m	N/A	N/A	
ROV2	-24207.127m	0.012m	3700163.783m	0.011m	N/A	N/A	
ROV1	-25743.336m	0.014m	3699231.000m	0.014m	N/A	N/A	

**Adjusted Geodetic Coordinates**

Errors are reported using 1.96σ.

Point Name	Latitude	E error	Longitude	N error	Height	h error	Fix
LGBN	32°58'20.95795"S	0.002m	18°09'27.94578"E	0.002m	64.132m	0.014m	
CTWN	33°57'05.16421"S	0.003m	18°28'06.78335"E	0.003m	83.608m	0.018m	
MALM	33°27'49.77180"S	0.003m	18°43'51.05558"E	0.003m	160.387m	0.019m	
STBS	33°50'40.63148"S	0.000m	18°50'12.00426"E	0.000m	266.623m	0.000m	Lat Long h
WOLSLEY	33°25'04.30257"S	0.003m	19°12'09.39912"E	0.003m	293.531m	0.015m	
VOELVLEI	33°20'49.20216"S	0.003m	19°00'58.29605"E	0.003m	98.593m	0.015m	
ROV9	33°20'46.02504"S	0.008m	19°01'16.67544"E	0.007m	103.501m	0.021m	
ROV6	33°23'03.86629"S	0.007m	19°11'12.49521"E	0.007m	265.137m	0.020m	
ROV7	33°21'49.23688"S	0.011m	19°10'12.58456"E	0.010m	249.359m	0.029m	
ROV8	33°19'46.95327"S	0.010m	19°02'02.18974"E	0.010m	102.925m	0.027m	
ROV11	33°21'29.26447"S	0.006m	19°01'08.64114"E	0.006m	104.139m	0.018m	
ROV10	33°20'56.13329"S	0.006m	19°01'18.59263"E	0.007m	102.383m	0.018m	
ROV5	33°24'03.34665"S	0.006m	19°12'24.56908"E	0.009m	320.174m	0.021m	

ROV4	33°25'16.90726"S	0.009m	19°11'55.29746"E	0.008m	293.749m	0.022m
ROV2	33°25'38.09650"S	0.012m	19°15'37.04678"E	0.011m	324.346m	0.037m
ROV1	33°25'07.69168"S	0.014m	19°16'36.41608"E	0.014m	348.054m	0.030m

Coordinate Deltas						
Point Name	ΔEasting	ΔNorthing	ΔElevation	ΔHeight	ΔGeoid Separation	
LGBN	-0.016m	0.008m	N/A	-0.003m	N/A	
CTWN	-0.015m	0.008m	N/A	-0.003m	N/A	
MALM	-0.015m	0.008m	N/A	-0.003m	N/A	
STBS	0.000m	0.000m	N/A	0.000m	N/A	
WOLSLEY	-0.015m	0.008m	N/A	-0.003m	N/A	
VOELVLEI	-0.016m	0.008m	N/A	-0.003m	N/A	
ROV9	-0.016m	0.008m	N/A	-0.003m	N/A	
ROV6	-0.015m	0.008m	N/A	-0.003m	N/A	
ROV7	-0.015m	0.008m	N/A	-0.003m	N/A	
ROV8	-0.016m	0.008m	N/A	-0.003m	N/A	
ROV11	-0.015m	0.008m	N/A	-0.003m	N/A	
ROV10	-0.015m	0.008m	N/A	-0.003m	N/A	
ROV5	-0.015m	0.008m	N/A	-0.003m	N/A	
ROV4	-0.015m	0.008m	N/A	-0.003m	N/A	
ROV2	-0.015m	0.008m	N/A	-0.003m	N/A	
ROV1	-0.015m	0.008m	N/A	-0.003m	N/A	

Control Coordinate Comparisons

Values shown are control coord minus adjusted coord.

Point Name	ΔEasting	ΔNorthing	ΔElevation	ΔHeight
LGBN	-0.001m	0.000m	N/A	0.037m
CTWN	-0.003m	0.007m	N/A	-0.009m
MALM	0.015m	-0.008m	N/A	0.003m
STBS	N/A	N/A	N/A	N/A

Adjusted Observations

Adjustment performed in **WGS-84**

GPS Observations

Number of Observations : 39  
Number of Outliers : 0

Observation Adjustment (Critical Tau = 3.40). Any outliers are in **red**.

Obs. ID	From Pt.	To Pt.		Observation	A-posteriori Error (1.96σ)	Residual	Stand. Residual
B82	WOLSLEY	CTWN	Az.	48°47'25.3775"	0°00'00.0072"	0°00'00.0197"	1.09
			ΔHt.	-209.923m	0.019m	-0.014m	-0.49
			Dist.	90196.143m	0.003m	0.014m	2.42
B14	STBS	CTWN	Az.	70°42'40.2430"	0°00'00.0160"	0°00'00.0022"	0.26
			ΔHt.	-183.015m	0.018m	-0.002m	-0.17
			Dist.	36051.423m	0.003m	-0.004m	-2.15
B167	VOELVLEI	ROV5	Az.	288°41'06.7007"	0°00'00.0979"	-0°00'00.2461"	-2.02
			ΔHt.	221.582m	0.018m	0.002m	0.10
			Dist.	18720.816m	0.005m	0.012m	1.93
B149	MALM	ROV11	Az.	246°27'39.5081"	0°00'00.0452"	0°00'00.0282"	0.36
			ΔHt.	-56.247m	0.020m	0.025m	0.97
			Dist.	29260.362m	0.006m	-0.022m	-1.96
B1	LGBN	CTWN	Az.	345°11'04.8875"	0°00'00.0052"	0°00'00.0047"	1.78
			ΔHt.	19.476m	0.017m	0.005m	0.60
			Dist.	112355.609m	0.002m	0.000m	-0.37
B138	WOLSLEY	ROV6	Az.	158°22'38.4166"	0°00'00.3595"	0°00'00.3907"	1.76
			ΔHt.	-28.393m	0.018m	-0.003m	-0.30
			Dist.	3991.244m	0.007m	0.002m	0.50
B165	WOLSLEY	ROV5	Az.	191°47'26.4367"	0°00'00.5556"	-0°00'00.0249"	-0.10
			ΔHt.	26.644m	0.017m	0.001m	0.13
			Dist.	1918.450m	0.009m	-0.007m	-1.71
B134	STBS	ROV6	Az.	212°34'33.5830"	0°00'00.0241"	-0°00'00.0212"	-0.99
			ΔHt.	-1.486m	0.020m	0.021m	1.38
			Dist.	60508.826m	0.007m	-0.011m	-1.71
B159	LGBN	ROV5	Az.	296°11'33.6665"	0°00'00.0166"	-0°00'00.0015"	-0.09
			ΔHt.	256.042m	0.018m	0.011m	0.66
			Dist.	108759.706m	0.005m	-0.008m	-1.64
B17	MALM	LGBN	Az.	135°24'36.5353"	0°00'00.0070"	0°00'00.0001"	0.08



			<b>ΔHt.</b>	-96.255m	0.015m	-0.010m	-1.60
			<b>Dist.</b>	76312.940m	0.002m	0.000m	0.01
B140	WOLSLEY	ROV8	<b>Az.</b>	121°52'21.7942"	0°00'00.1014"	-0°00'00.0938"	-1.60
			<b>ΔHt.</b>	-190.606m	0.024m	0.001m	0.04
			<b>Dist.</b>	18491.954m	0.010m	-0.006m	-0.96
B152	STBS	ROV10	<b>Az.</b>	197°24'37.7826"	0°00'00.0243"	-0°00'00.0228"	-0.69
			<b>ΔHt.</b>	-164.240m	0.018m	-0.026m	-1.50
			<b>Dist.</b>	57603.589m	0.007m	-0.009m	-0.92
B90	VOELVLEI	WOLSLEY	<b>Az.</b>	294°25'34.9768"	0°00'00.0248"	0°00'00.0087"	0.78
			<b>ΔHt.</b>	194.938m	0.011m	-0.013m	-1.49
			<b>Dist.</b>	19043.223m	0.002m	0.000m	0.12
B85	LGBN	VOELVLEI	<b>Az.</b>	297°38'59.3496"	0°00'00.0054"	-0°00'00.0031"	-1.38
			<b>ΔHt.</b>	34.461m	0.012m	-0.006m	-0.78
			<b>Dist.</b>	90209.121m	0.002m	0.001m	0.64
B144	ROV8	VOELVLEI	<b>Az.</b>	40°44'29.7875"	0°00'00.8189"	-0°00'00.3924"	-1.20
			<b>ΔHt.</b>	-4.332m	0.023m	0.003m	0.28
			<b>Dist.</b>	2531.389m	0.009m	0.005m	1.35
B84	WOLSLEY	LGBN	<b>Az.</b>	116°35'52.1347"	0°00'00.0044"	0°00'00.0024"	1.19
			<b>ΔHt.</b>	-229.399m	0.012m	0.012m	1.31
			<b>Dist.</b>	109234.183m	0.002m	0.001m	0.80
B178	WOLSLEY	ROV2	<b>Az.</b>	280°59'57.6946"	0°00'00.4071"	0°00'00.0059"	0.02
			<b>ΔHt.</b>	30.816m	0.036m	0.008m	0.32
			<b>Dist.</b>	5464.632m	0.012m	-0.013m	-1.29
B141	ROV9	VOELVLEI	<b>Az.</b>	78°21'37.7774"	0°00'02.4894"	-0°00'00.0236"	-0.07
			<b>ΔHt.</b>	-4.908m	0.015m	0.002m	1.29
			<b>Dist.</b>	485.216m	0.007m	0.000m	0.45
B129	MALM	ROV9	<b>Az.</b>	244°17'26.8226"	0°00'00.0430"	-0°00'00.0059"	-0.09
			<b>ΔHt.</b>	-56.886m	0.022m	0.037m	1.23
			<b>Dist.</b>	30007.516m	0.008m	-0.004m	-0.28
B151	STBS	ROV11	<b>Az.</b>	197°28'09.4787"	0°00'00.0210"	-0°00'00.0137"	-0.54
			<b>ΔHt.</b>	-162.484m	0.018m	-0.013m	-0.85
			<b>Dist.</b>	56552.567m	0.006m	-0.008m	-1.19
B2	MALM	CTWN	<b>Az.</b>	24°08'05.7554"	0°00'00.0110"	-0°00'00.0090"	-1.17
			<b>ΔHt.</b>	-76.779m	0.019m	-0.002m	-0.13
			<b>Dist.</b>	59298.494m	0.003m	-0.003m	-1.19
B166	WOLSLEY	ROV4	<b>Az.</b>	43°10'18.2236"	0°00'02.9936"	-0°00'00.5054"	-0.52
			<b>ΔHt.</b>	0.218m	0.017m	-0.005m	-0.93
			<b>Dist.</b>	532.483m	0.008m	0.003m	1.15
B168	VOELVLEI	ROV4	<b>Az.</b>	295°57'21.7115"	0°00'00.0891"	-0°00'00.0988"	-1.14
			<b>ΔHt.</b>	195.156m	0.019m	0.013m	0.74
			<b>Dist.</b>	18877.927m	0.008m	0.004m	0.52
B172	ROV2	LGBN	<b>Az.</b>	115°49'51.0669"	0°00'00.0186"	-0°00'00.0029"	-0.55
			<b>ΔHt.</b>	-260.214m	0.035m	0.004m	0.36
			<b>Dist.</b>	114506.978m	0.012m	0.004m	1.13
B155	VOELVLEI	ROV11	<b>Az.</b>	347°46'23.7463"	0°00'00.8362"	-0°00'00.3121"	-1.10
			<b>ΔHt.</b>	5.547m	0.014m	0.002m	0.37
			<b>Dist.</b>	1262.911m	0.006m	-0.002m	-0.78
B186	VOELVLEI	ROV1	<b>Az.</b>	288°15'14.0380"	0°00'00.1283"	0°00'00.0535"	0.68
			<b>ΔHt.</b>	249.461m	0.030m	0.026m	0.99
			<b>Dist.</b>	25521.442m	0.012m	-0.002m	-0.21
B184	STBS	ROV1	<b>Az.</b>	220°58'06.7212"	0°00'00.0330"	-0°00'00.0012"	-0.04
			<b>ΔHt.</b>	81.431m	0.030m	-0.028m	-0.98
			<b>Dist.</b>	62434.667m	0.017m	0.010m	0.33
B29	STBS	LGBN	<b>Az.</b>	146°40'23.6198"	0°00'00.0047"	-0°00'00.0006"	-0.42
			<b>ΔHt.</b>	-202.491m	0.014m	0.007m	0.89
			<b>Dist.</b>	115518.774m	0.002m	0.000m	0.46
B142	VOELVLEI	ROV6	<b>Az.</b>	284°41'25.7137"	0°00'00.0860"	-0°00'00.0050"	-0.07
			<b>ΔHt.</b>	166.545m	0.018m	-0.011m	-0.83
			<b>Dist.</b>	16411.110m	0.007m	0.000m	0.03
B143	VOELVLEI	ROV7	<b>Az.</b>	277°23'46.9999"	0°00'00.1417"	0°00'00.0066"	0.08
			<b>ΔHt.</b>	150.766m	0.026m	0.000m	0.02
			<b>Dist.</b>	14449.807m	0.011m	-0.006m	-0.83
B139	WOLSLEY	ROV7	<b>Az.</b>	153°19'06.4846"	0°00'00.3142"	0°00'00.1051"	0.79
			<b>ΔHt.</b>	-44.172m	0.026m	0.000m	0.01
			<b>Dist.</b>	6725.402m	0.011m	-0.002m	-0.43
B130	MALM	ROV6	<b>Az.</b>	258°23'27.8692"	0°00'00.0336"	0°00'00.0336"	0.78
			<b>ΔHt.</b>	104.751m	0.022m	0.016m	0.74
			<b>Dist.</b>	43310.610m	0.007m	-0.006m	-0.70
B161	MALM	ROV5	<b>Az.</b>	261°10'29.9498"	0°00'00.0390"	0°00'00.0214"	0.37

			<b>ΔHt.</b>	159.788m	0.022m	-0.005m	-0.19
			<b>Dist.</b>	44809.547m	0.007m	-0.008m	-0.78
B153	WOLSLEY	ROV11	<b>Az.</b>	111°09'10.7360"	0°00'00.0688"	0°00'00.0472"	0.58
			<b>ΔHt.</b>	-189.391m	0.016m	-0.012m	-0.74
			<b>Dist.</b>	18317.346m	0.005m	-0.002m	-0.36
B154	WOLSLEY	ROV10	<b>Az.</b>	114°23'37.7817"	0°00'00.0728"	0°00'00.0009"	0.01
			<b>ΔHt.</b>	-191.148m	0.015m	0.008m	0.64
			<b>Dist.</b>	18477.101m	0.007m	-0.005m	-0.68
B182	LGBN	ROV1	<b>Az.</b>	295°41'04.9311"	0°00'00.0293"	-0°00'00.0311"	-0.63
			<b>ΔHt.</b>	283.922m	0.030m	0.009m	0.33
			<b>Dist.</b>	115489.370m	0.011m	0.006m	0.56
B185	WOLSLEY	ROV1	<b>Az.</b>	270°53'15.2191"	0°00'00.4215"	-0°00'00.0006"	0.00
			<b>ΔHt.</b>	54.523m	0.030m	0.015m	0.59
			<b>Dist.</b>	6899.448m	0.014m	-0.004m	-0.39
B156	VOELVLEI	ROV10	<b>Az.</b>	292°08'32.7226"	0°00'02.3158"	-0°00'00.3956"	-0.55
			<b>ΔHt.</b>	3.790m	0.013m	0.002m	0.45
			<b>Dist.</b>	566.586m	0.006m	-0.001m	-0.28
B164	STBS	ROV4	<b>Az.</b>	215°41'00.1980"	0°00'00.0293"	0°00'00.0060"	0.03
			<b>ΔHt.</b>	27.126m	0.022m	0.032m	0.25
			<b>Dist.</b>	57724.426m	0.009m	0.055m	0.22

Histograms of Standardized Residuals

Point Error Ellipses		
LGBN	CTWN	MALM
Tick Size: 0.0100m Horizontal Bivariate Scalar: 2.45σ Vertical Univariate Scalar: 1.96σ		
WOLSLEY	VOELVLEI	ROV9
Tick Size: 0.0100m Horizontal Bivariate Scalar: 2.45σ Vertical Univariate Scalar: 1.96σ		
ROV6	ROV7	ROV8
Tick Size: 0.0100m Horizontal Bivariate Scalar: 2.45σ Vertical Univariate Scalar: 1.96σ		
ROV11	ROV10	ROV5
Tick Size: 0.0100m Horizontal Bivariate Scalar: 2.45σ Vertical Univariate Scalar: 1.96σ		
ROV4	ROV2	ROV1
Tick Size: 0.0100m Horizontal Bivariate Scalar: 2.45σ Vertical Univariate Scalar: 1.96σ		

Covariant Terms

Adjustment performed in WGS-84

From Point	To Point	Components	A-posteriori Error (1.96σ)	Horiz. Precision (Ratio)	3D Precision (Ratio)
LGBN	CTWN	<b>Az.</b>	345°11'04.8875"	0°00'00.0052"	1:46846906
		<b>ΔHt.</b>	19.476m	0.017m	
		<b>ΔElev.</b>	?	?	
		<b>Dist.</b>	112355.609m	0.002m	
LGBN	MALM	<b>Az.</b>	315°43'26.7824"	0°00'00.0070"	1:31895180
		<b>ΔHt.</b>	96.255m	0.015m	
		<b>ΔElev.</b>	?	?	
		<b>Dist.</b>	76312.940m	0.002m	
LGBN	STBS	<b>Az.</b>	327°02'49.3814"	0°00'00.0046"	1:48987476
		<b>ΔHt.</b>	202.491m	0.014m	
		<b>ΔElev.</b>	?	?	
		<b>Dist.</b>	115518.774m	0.002m	
LGBN	WOLSLEY	<b>Az.</b>	297°10'11.5586"	0°00'00.0043"	1:49296332
		<b>ΔHt.</b>	229.399m	0.012m	

		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	109234.183m	0.002m		
LGBN	VOELVLEI	<b>Az.</b>	297°38'59.3496"	0°00'00.0054"	1:41152173	1:41152173
		<b>ΔHt.</b>	34.461m	0.012m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	90209.121m	0.002m		
LGBN	ROV5	<b>Az.</b>	296°11'33.6665"	0°00'00.0166"	1:20396292	1:20396292
		<b>ΔHt.</b>	256.042m	0.018m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	108759.706m	0.005m		
LGBN	ROV2	<b>Az.</b>	296°26'04.4571"	0°00'00.0185"	1:9447730	1:9447730
		<b>ΔHt.</b>	260.214m	0.035m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	114506.978m	0.012m		
LGBN	ROV1	<b>Az.</b>	295°41'04.9311"	0°00'00.0293"	1:10694949	1:10694949
		<b>ΔHt.</b>	283.922m	0.030m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	115489.370m	0.011m		
CTWN	MALM	<b>Az.</b>	204°16'49.7895"	0°00'00.0110"	1:18198505	1:18198505
		<b>ΔHt.</b>	76.779m	0.019m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	59298.494m	0.003m		
CTWN	STBS	<b>Az.</b>	250°54'59.3426"	0°00'00.0160"	1:11143291	1:11143291
		<b>ΔHt.</b>	183.015m	0.018m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	36051.423m	0.003m		
CTWN	WOLSLEY	<b>Az.</b>	229°11'51.0588"	0°00'00.0073"	1:25907773	1:25907773
		<b>ΔHt.</b>	209.923m	0.019m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	90196.143m	0.003m		
MALM	ROV9	<b>Az.</b>	244°17'26.8226"	0°00'00.0430"	1:3668722	1:3668722
		<b>ΔHt.</b>	-56.886m	0.022m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	30007.516m	0.008m		
MALM	ROV6	<b>Az.</b>	258°23'27.8692"	0°00'00.0336"	1:5919903	1:5919903
		<b>ΔHt.</b>	104.751m	0.022m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	43310.610m	0.007m		
MALM	ROV11	<b>Az.</b>	246°27'39.5081"	0°00'00.0452"	1:4886393	1:4886393
		<b>ΔHt.</b>	-56.247m	0.020m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	29260.362m	0.006m		
MALM	ROV5	<b>Az.</b>	261°10'29.9498"	0°00'00.0390"	1:6817841	1:6817841
		<b>ΔHt.</b>	159.788m	0.022m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	44809.547m	0.007m		
STBS	ROV6	<b>Az.</b>	212°34'33.5830"	0°00'00.0241"	1:8485504	1:8485504
		<b>ΔHt.</b>	-1.486m	0.020m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	60508.826m	0.007m		
STBS	ROV11	<b>Az.</b>	197°28'09.4787"	0°00'00.0210"	1:8754327	1:8754327
		<b>ΔHt.</b>	-162.484m	0.018m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	56552.567m	0.006m		
STBS	ROV10	<b>Az.</b>	197°24'37.7826"	0°00'00.0243"	1:8113195	1:8113195
		<b>ΔHt.</b>	-164.240m	0.018m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	57603.589m	0.007m		
STBS	ROV4	<b>Az.</b>	215°41'00.1980"	0°00'00.0293"	1:6671941	1:6671941
		<b>ΔHt.</b>	27.126m	0.022m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	57724.426m	0.009m		
STBS	ROV1	<b>Az.</b>	220°58'06.7212"	0°00'00.0330"	1:3641327	1:3641327
		<b>ΔHt.</b>	81.431m	0.030m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	62434.667m	0.017m		
WOLSLEY	VOELVLEI	<b>Az.</b>	114°19'25.7190"	0°00'00.0249"	1:8811827	1:8811827
		<b>ΔHt.</b>	-194.938m	0.011m		
		<b>ΔElev.</b>	?	?		

		<b>Dist.</b>	19043.223m	0.002m		
WOLSLEY	ROV6	<b>Az.</b>	158°22'38.4166"	0°00'00.3595"	1:592210	1:592210
		<b>ΔHt.</b>	-28.393m	0.018m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	3991.244m	0.007m		
WOLSLEY	ROV7	<b>Az.</b>	153°19'06.4846"	0°00'00.3142"	1:617349	1:617349
		<b>ΔHt.</b>	-44.172m	0.026m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	6725.402m	0.011m		
WOLSLEY	ROV8	<b>Az.</b>	121°52'21.7942"	0°00'00.1014"	1:1825831	1:1825831
		<b>ΔHt.</b>	-190.606m	0.024m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	18491.954m	0.010m		
WOLSLEY	ROV11	<b>Az.</b>	111°09'10.7360"	0°00'00.0688"	1:3374337	1:3374337
		<b>ΔHt.</b>	-189.391m	0.016m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	18317.346m	0.005m		
WOLSLEY	ROV10	<b>Az.</b>	114°23'37.7817"	0°00'00.0728"	1:2793828	1:2793828
		<b>ΔHt.</b>	-191.148m	0.015m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	18477.101m	0.007m		
WOLSLEY	ROV5	<b>Az.</b>	191°47'26.4367"	0°00'00.5556"	1:219630	1:219630
		<b>ΔHt.</b>	26.644m	0.017m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	1918.450m	0.009m		
WOLSLEY	ROV4	<b>Az.</b>	43°10'18.2236"	0°00'02.9936"	1:65692	1:65692
		<b>ΔHt.</b>	0.218m	0.017m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	532.483m	0.008m		
WOLSLEY	ROV2	<b>Az.</b>	280°59'57.6946"	0°00'00.4071"	1:459379	1:459379
		<b>ΔHt.</b>	30.816m	0.036m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	5464.632m	0.012m		
WOLSLEY	ROV1	<b>Az.</b>	270°53'15.2191"	0°00'00.4215"	1:504379	1:504379
		<b>ΔHt.</b>	54.523m	0.030m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	6899.448m	0.014m		
VOELVLEI	ROV9	<b>Az.</b>	258°21'47.8806"	0°00'02.4894"	1:66578	1:66578
		<b>ΔHt.</b>	4.908m	0.015m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	485.216m	0.007m		
VOELVLEI	ROV6	<b>Az.</b>	284°41'25.7137"	0°00'00.0860"	1:2357075	1:2357075
		<b>ΔHt.</b>	166.545m	0.018m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	16411.110m	0.007m		
VOELVLEI	ROV7	<b>Az.</b>	277°23'46.9999"	0°00'00.1417"	1:1283847	1:1283847
		<b>ΔHt.</b>	150.766m	0.026m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	14449.807m	0.011m		
VOELVLEI	ROV8	<b>Az.</b>	220°45'04.9023"	0°00'00.8191"	1:278718	1:278718
		<b>ΔHt.</b>	4.332m	0.023m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	2531.389m	0.009m		
VOELVLEI	ROV11	<b>Az.</b>	347°46'23.7463"	0°00'00.8362"	1:211788	1:211788
		<b>ΔHt.</b>	5.547m	0.014m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	1262.911m	0.006m		
VOELVLEI	ROV10	<b>Az.</b>	292°08'32.7226"	0°00'02.3158"	1:89096	1:89096
		<b>ΔHt.</b>	3.790m	0.013m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	566.586m	0.006m		
VOELVLEI	ROV5	<b>Az.</b>	288°41'06.7007"	0°00'00.0979"	1:3526821	1:3526821
		<b>ΔHt.</b>	221.582m	0.018m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	18720.816m	0.005m		
VOELVLEI	ROV4	<b>Az.</b>	295°57'21.7115"	0°00'00.0891"	1:2352794	1:2352794
		<b>ΔHt.</b>	195.156m	0.019m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	18877.927m	0.008m		

VOELVLEI	ROV1	<b>Az.</b>	288°15'14.0380"	0°00'00.1283"	1:2203387	1:2203387
		<b>ΔHt.</b>	249.461m	0.030m		
		<b>ΔElev.</b>	?	?		
		<b>Dist.</b>	25521.442m	0.012m		

## 6.0 Fugro Maps South Africa

### **Physical Address**

Unit 2C and 2D, Bondev Business Park, Cnr. Willem Botha and Wierda Road, Eldoraigne, 0147

### **Postal Address**

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### **Point of Contact:**

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GIS Manager

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### **Office Location**

Fugro Maps South Africa has two offices in South Africa, one in Cape Town and one in Pretoria. For this project the Pretoria office will be the prime point of contact where the Project Director (Brummer Grobbelaar) and the Project Manager (Janco van der Merwe) will be based.

Fugro Maps South Africa, one of the most progressive spatial data processing companies in Africa, has the necessary resources to provide the quality products and services as detailed in this submission. Fugro Maps South Africa employs 20 personnel providing professional services based on LiDAR and Photogrammetry.

We have fully committed ourselves to policies of safety and continuous improvement and, have implemented a Business Management System complying with the requirements of Standard ISO 9001:2000. As such, we are well placed to successfully complete this project on time, within budget and to the high standards that one can expect.

Fugro Maps South Africa brings together a wealth of experience in the airborne spatial industry, with the financial backing of the global Fugro Group, a financially sound International organisation consisting of more than 13,000 personnel worldwide.

To this end, and through the global resources available within Fugro, we are able to offer to the global market a unique technological solution to provide high precision LiDAR survey data, accompanied with high resolution still imagery. This FLI-MAP technology has been specifically designed for DEM generation, topographic mapping and asset capture of linear assets and corridors.

FLI-MAP has been widely proven throughout the world, with over 150,000 km of survey undertaken in the last five years or so.