MYEZO ENVIRONMENTAL MANAGEMENT SERVICES

Environmental Stewardship

LEBONE ENGINEERING -KLIP MIDDLE SOWETO -ENVIRONMENTAL STUDIES CITY PARKS AND ZOO

DRAFT BASIC ASSESSMENT REPORT FOR THE ENVIRONMENTAL STUDIES THAT WAS UNDERTAKEN IN KLIP MIDDLE SOWETO, IN JOHANNESBURG, WITHIN THE CITY OF JOHANNESBURG MUNICIPALITY

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APPENDIX G.2 GEOHYDROLOGICAL SPECIALIST REPORT

Johannesburg City Parks and Zoo

Geohydrological Impact Assessment for the Rehabilitation of Wetlands in the Klip Middle Water Management Unit in Soweto Within the Johannesburg Municipality, Gauteng Province

Report Ref: 2016/ENV006

June 2016

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EXECUTIVE SUMMARY

INTRODUCTION

The City of Johannesburg intends to rehabilitate several wetlands in Soweto and convert them into recreational parks for the residents. Waters Without Frontiers cc was appointed by Lebone Engineering on behalf of Johannesburg City Parks and Zoo to undertake a geohydrological impact assessment for proposed rehabilitation of wetlands in Klip Middle Water Management Unit in Soweto within the Johannesburg Municipality, Gauteng Province. The wetlands are located within residential, industrial and previously mined areas; all of which have potential to contaminate groundwater.

OBJECTIVE

The main objective of the study was to assess the potential impact of the proposed rehabilitation of the wetland on groundwater in the Klip Middle Water Management Unit in Soweto, and to recommend management options to mitigate or remedy the impact.

METHODOLOGY

The investigation was based entirely on the evaluation of existing data, no new boreholes were drilled and neither were any groundwater samples collected for water quality analysis. The data evaluation was complemented by hydrocensus that sought to identify existing boreholes in the study area

CONCLUSION

The conclusion is based entirely on the evaluation of existing data from 9 boreholes with incomplete data in the study area, coupled with a hydrocensus. No new boreholes were drilled in this investigation.

The main conclusion derived from the study is that the potential impact of the proposed wetland rehabilitation on groundwater will be very little to none. Groundwater resources will actually benefit from the rehabilitation as a result of the elimination or reduction of potential sources of contamination by the rehabilitation exercise.

More specific findings of the study include the following:

- The baseline groundwater conditions (groundwater level and water quality) at the site could not be determined due to inadequate existing data. New boreholes will be required to generate the requisite information.
- Groundwater has potential to act as conduit for contaminants from existing sources to the wetland.
- The hydraulic relationship between groundwater and the wetland could not be determined due the lack of boreholes in the vicinity of the wetland to determine the water-table gradient; hence groundwater flow direction.

RECOMMENDATION

The investigation provided a preliminary understanding of the groundwater situation at the site.

To this end, the following recommendations are made:

- Site and drill at least six monitoring boreholes adjacent to the wetland. Approximate positions of the monitoring boreholes are shown in Figure 11.1, and the coordinates given Table 11.1. These positions were selected to intercept groundwater flow from potential sources of contamination; mainly residential areas, industrial areas, and mining disposal facilities.
- The boreholes should be located outside the 1:100 year flood line or at least 100 metres away from the edge of a natural drainage channel if the location of the flood line is not known.
- The siting of the boreholes should use geophysical survey techniques to increase the chances of intersecting geological structures that influence groundwater flow at the site. Electromagnetic horizontal profiling is recommended in this regard.
- Geophysical surveys lines should be placed parallel to the wetland in order to intersect fracture zones oriented perpendicular to the wetland. These fracture zones channel groundwater from outside to the wetland.
- Boreholes should be drilled to maximum depth of between 30 and 50 metres, or at least 25 metres below the water-table.
- At least three boreholes spread over the entire area of interest should be pump-tested to determine hydraulic parameters of aquifers at the site, to be used later in groundwater modelling. A 12 hour constant rate test is recommended.
- Groundwater from the new monitoring boreholes should be sampled quarterly, and water levels measured monthly.
- Water quality parameters to be monitored should include, but not limited to the following: pH, EC, TDS, Ca, Mg, Na, K, Fe, Mn, Cu, Pb, Zn, Cd, Cr, Cl, SO_4, F, NO_3, PO_4, CO_3, and HCO_3.
- A groundwater flow and transport model should be developed for the site. The model will be used to predict potential long-term impacts of groundwater on the wetland. The potential impacts to be simulated include migration of contaminants from outside sources to the wetland.
- The estimated cost of the proposed activities is given in Table 11.3.

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1.1 BACKGROUND

The City of Johannesburg intends to rehabilitate several wetlands in Soweto and convert them into recreational parks for the residents. Waters Without Frontiers cc was appointed by Lebone Engineering on behalf of Johannesburg City Parks and Zoo to undertake a geohydrological impact assessment for proposed rehabilitation of wetlands in Klip Middle Water Management Unit in Soweto within the Johannesburg Municipality, Gauteng Province. The wetlands are located within residential, industrial and previously mined areas; all of which have potential to contaminate groundwater.

1.2 ASSUMPTIONS AND LIMITATIONS

The main assumption was that groundwater exists at the site based on characteristics of similar geological setup in other parts of the country.

The main limitation was the lack of groundwater data from existing boreholes in and around the site. New boreholes will need to be drilled in order to generate site specific data.

2 OBJECTIVE

The main objective of the study was to assess the potential impact of the proposed rehabilitation of the wetland on groundwater in the Klip Middle Water Management Unit in Soweto, and to recommend management options to mitigate or remedy the impact.

3 SCOPE OF WORK

The scope of work will include but not limited to the following:

- Desktop study – collection and review of existing groundwater data to create preliminary understanding of the groundwater regime at the site. This represents a scoping exercise to determine if further activities such siting and drilling of additional boreholes to augment data will be necessary;
- Hydrocensus - field verification of existing boreholes and groundwater related features such as wetlands and springs;
- Establishment of the extent of groundwater use in adjacent areas
- Determination of the current geohydrological environment, hence establish prevailing groundwater conditions against which impacts will be measured;
- Identification of geological structures that influence groundwater flow; such as faults, fracture zones and dykes;
- Assessment of surface water and groundwater interaction;

- Compilation of all the relevant data and recommendations in a report, structured in such a way that it can be incorporated into the integrated water use licence application document.

4. SITE DESCRIPTION

4.1 LOCATION

The wetland under investigation is located in Soweto in the Klip Middle Water Management Unit (WMU). This Water Management Unit is roughly bounded by Koma Road on the south-west, Elias Motsoaledi on the west, Main Reef Road on the north and Klip Valley Road on the south east. The location of the study area is shown Figure 4.1, and the site layout is shown in Figure 4.2.

4.2 TOPOGRAPHY AND DRAINAGE

The study area is situated in the Klip Middle Water Management Unit, which in turn is located in Quaternary Catchment C22A. The topography of the study area is characterised by flat to gently rolling terrain. The prominent morphological features in the area are the artificial mine dumps from previous mining activities, which rise to about 50-60 metres above ground. Ground elevation ranges from 1580 metres above sea level at the southern tip of the wetland to about 1720 metres at the top of the mine dumps. Figure 4.3 shows the topography of the study area, as well as surface water flow directions. Drainage is ultimately to the south into the Klip River.

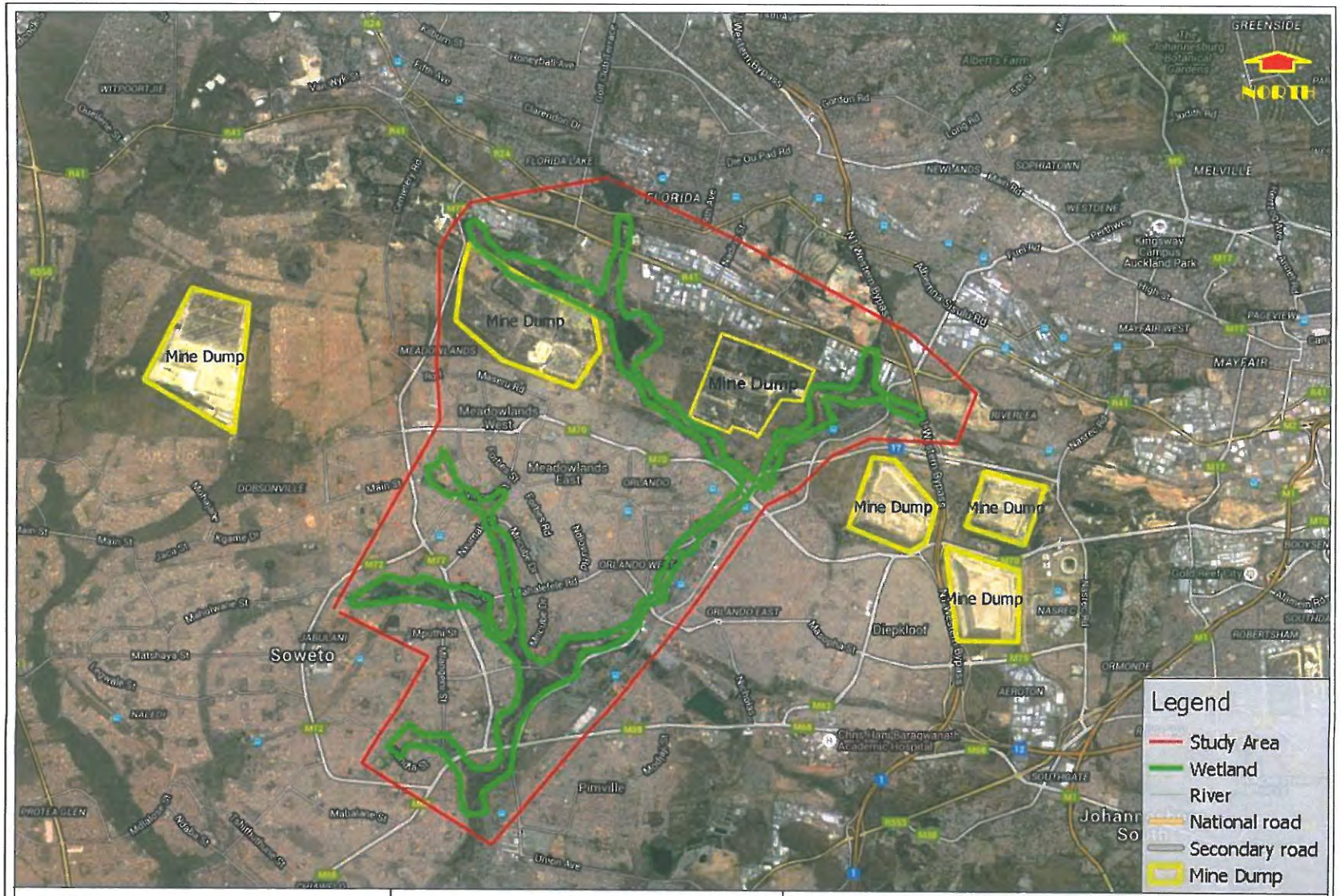
4.3 CLIMATE

Johannesburg receives about 604mm of rain per year, with most rainfall occurring during summer as short thunderstorms. It receives the lowest rainfall (0mm) in July and the highest (113mm) in January. The average midday temperatures for Johannesburg range from 16.6°C in June to 26.2°C in January. The region is the coldest during July when the mercury drops to 0.8°C on average during the night. Weather charts for the study area shown in Figure 4.4.

4.4 LAND USE

The study area is located in a predominantly residential area in Soweto. The northern section of the study area consist of old mine dumps and industry. Soweto is the most populous black urban residential area in South Africa with a population of approximately a million residents. It consists of both formal and informal settlements.

Figure 4.1 Location of the study area


Mine Dump
Mine Dump
Mine Dump
Mine Dump
Mine Dump
Mine Dump
Soweto
Legend
Study Area
Wetland
River
National road
Secondary road
Mine Dump
1 0 1 2 km
Figure 4.2 Site layout
Soweto Wetands Rehabilitation Project

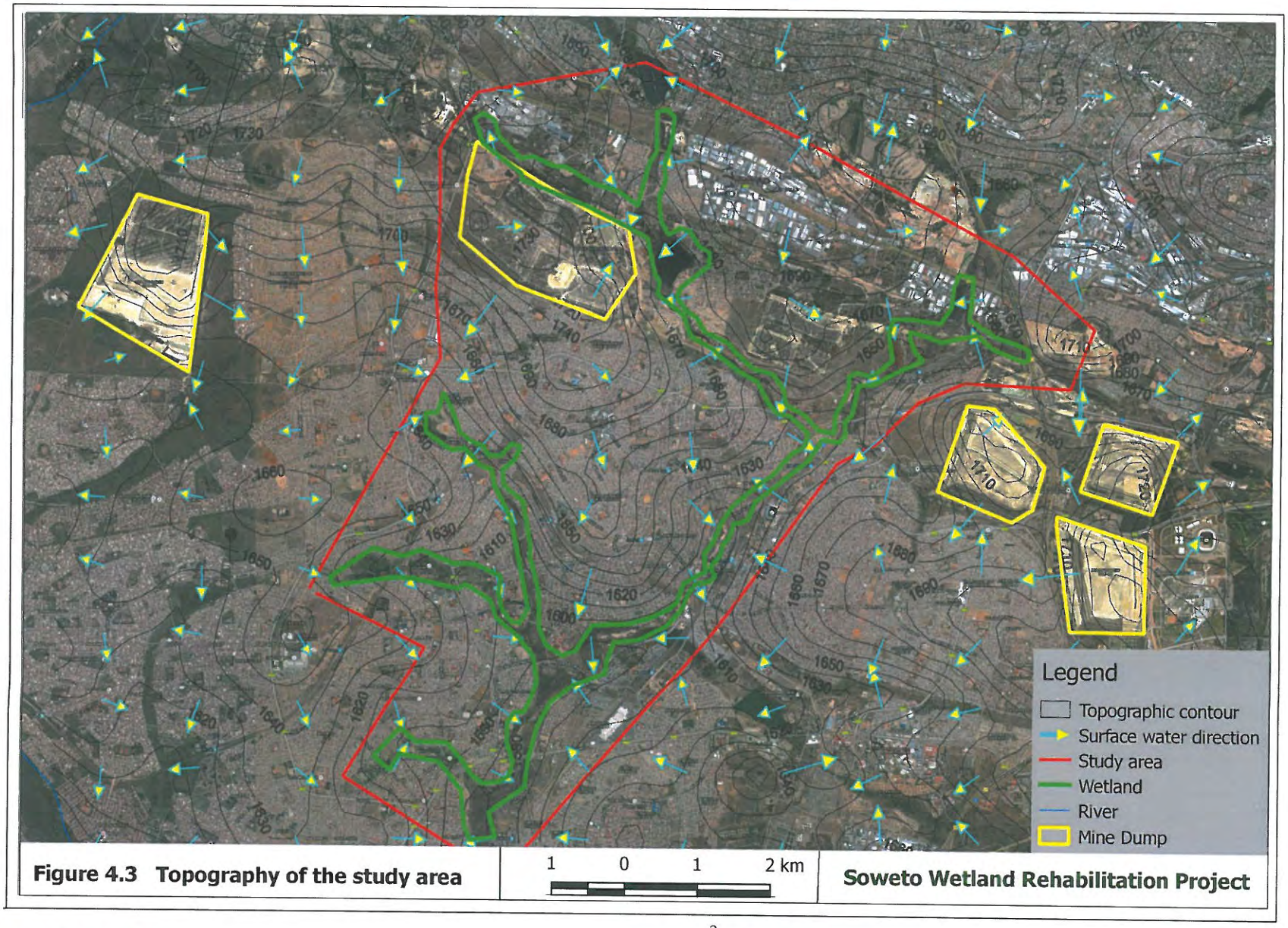


Figure 4.3 Topography of the study area

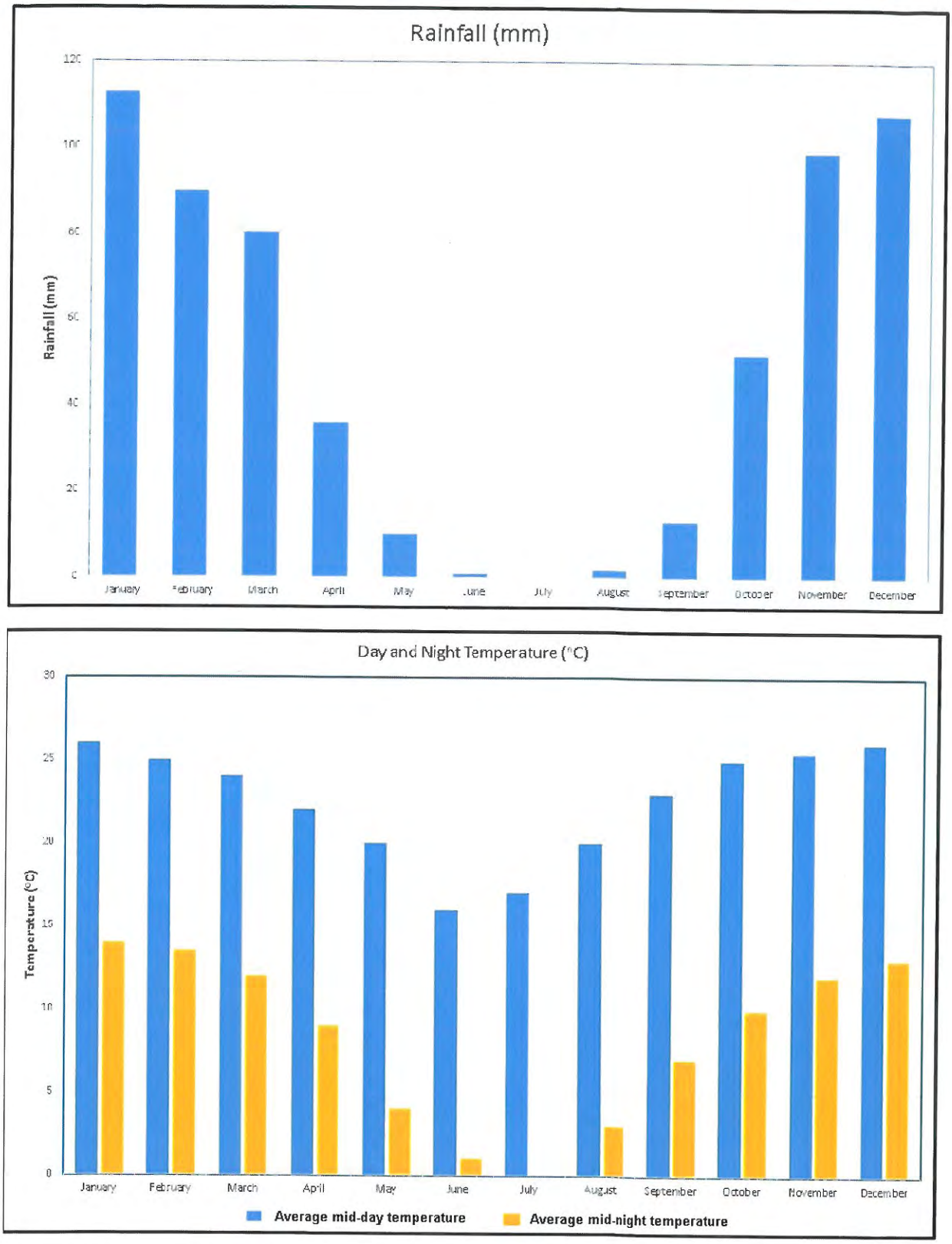


Figure 4.4 Climate graphs

5 GEOLOGICAL SETTING

The regional lithostratigraphical sequence in the project area is given in Table 5.1, a simplified geological map is shown in Figure 5.1. The oldest rocks in the region belong to the Archean Basemen complex represented by the Halfway House granites. These were followed upward by sedimentary rocks of the Witwatersrand, then andesite intrusion of the Ventersdorp. The sequence is completed by the deposition Transvaal followed by the Karoo.

Locally the site is underlain by the andesite of the Ventersdorp Group in the south and, and quartzite, conglomerate and shale of the Transvaal Group in the northern section. These rocks have been intruded by late Karoo dolerite dykes and sills.

Table 5.1 Stratigraphical Sequence in the area

Ma	Erathem (geological period)	Lithology	Stratigraphy		
			Formation	Group	Complex: Super-group
230	Mesazoic	Dolerite	Intrusive		Karoo
	Paleozoic	Sandstone, shale & Coal	Vryheid formation	Ecca Group	
570		Tillite, mudstone, sandstone		Dwyka	
	Valian	Dolomite	Malamani	Chuniespoort	Transvaal
2560		Quartzite, Conglomerate	Black Reef		
	Randian	Andesite	Alanridge	Kliprivier	Ventersdorp
		Sandstone, Conglomerate		Central Rand Group	Witwatersrand Super-group
3090		Quartzite, shale		West Rand Group	
	Swazian	Granite, gneiss	Halfway House	Basement Complex	Basement Complex

Rocks highlighted in blue are present in the study area

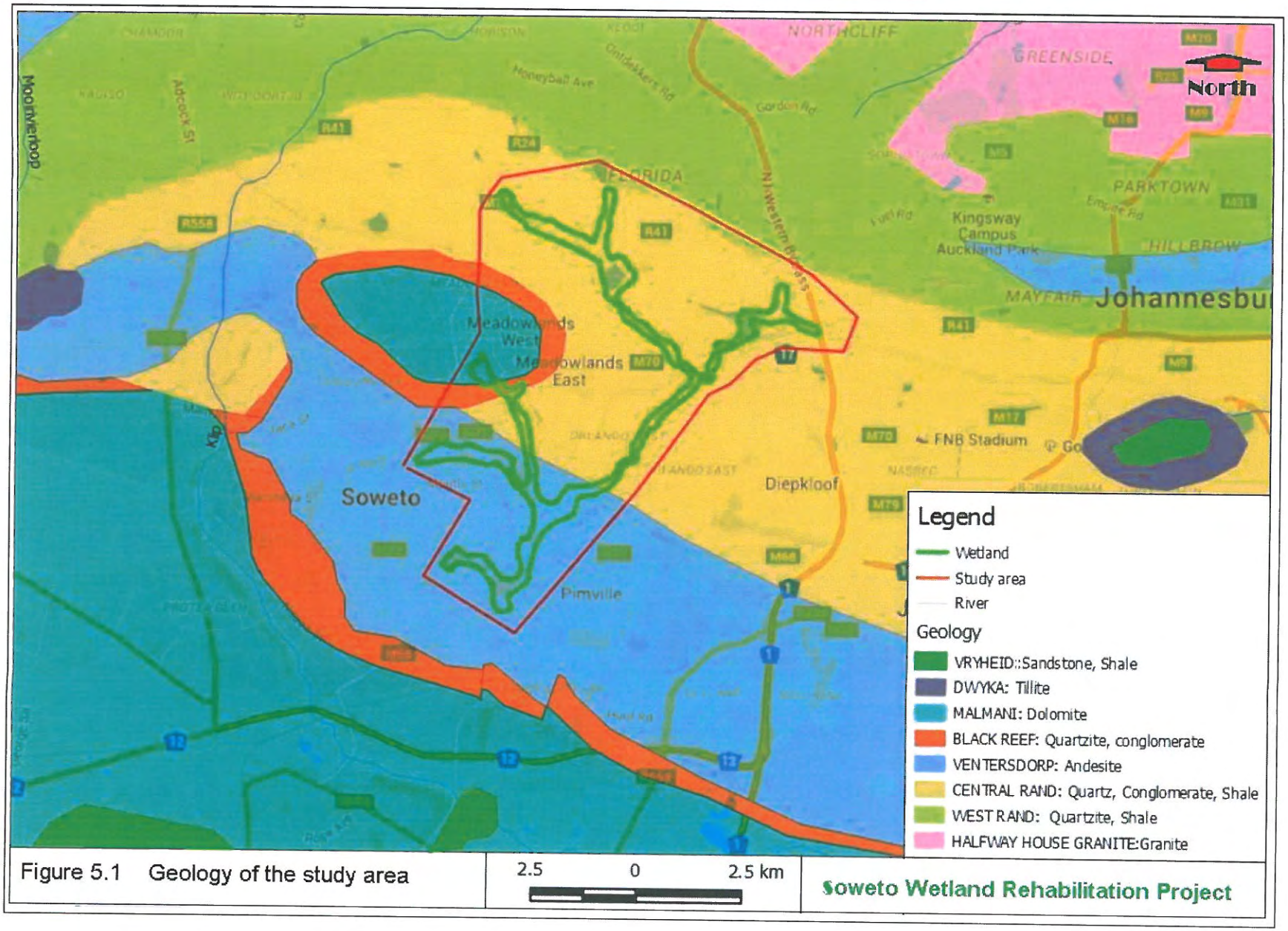


Figure 5.1 Geology of the study area

6 GEOHYDROLOGICAL SETTING

The study area is underlain by predominantly the both sedimentary (shale, sandstone and conglomerate) and igneous rocks (andesite). These rocks possess low primary permeability and porosity. Groundwater occurrence is generally associated with fractures and joints developed along bedding planes in former, weathering and fracturing in the later. Contact zones between dolerite intrusions and the country rocks represent especially good aquifers due to the presence of shrinkage fractures that developed as the dolerite magma rapidly cooled on contact with the cooler country rocks. The groundwater potential in the area is classified as low; with borehole yields generally less than 2 L/s, (Barnard, 2000). However, high yields are occasionally obtained on lithological contact zones described earlier.

Groundwater recharge in the study area is estimated at 95 mm per annum. The harvest potential of the area, which indicates the maximum volume of groundwater that can sustainably be abstracted per square kilometre per annum, is estimated at 11 200m^3/km^2/annum (Vegter, 1995).

7 INVESTIGATION

The investigation was based entirely on the evaluation of existing data, no new boreholes were drilled, and neither were any groundwater samples collected for water quality analysis.

To achieve the objective of the study the following activities were undertaken:

7.1 DESKTOP STUDY

The investigation commenced with a desktop study in which existing data and information pertaining to groundwater characteristics at the site were gathered and analysed. Sources of information and data included the following:

- National Groundwater Archive of the Department of Water and Sanitation,
- Published geological reports and maps,
- Published geohydrological reports and maps,
- Consultant's reports provided by the client,

7.2 HYDROCENSUS

The desktop study was complemented by a hydrocensus in which existing boreholes and other groundwater related features such as springs and wetlands were identified within the study area.

The hydrocensus sought to:

- Provide a feel of the study area.
- Identify existing water points (boreholes, springs, wetlands, etc.) in the area.
- Assess groundwater use in the study area.
- Where accessible, collect groundwater samples and measure water levels in the boreholes

7.3 INTERVIEWS

During the desktop study and the hydrocensus, interviews were conducted with interested and affected people around the site to establish issues relating to their groundwater resources.

8 DISCUSSION OF FINDINGS

8.1 DATA EVALUATION

Groundwater haracterization was based on the evaluation of existing boreholes mainly from the **N**ational **G**roundwater **A**rchive (**NGA**) of the **D**epartment of Water and Sanitation (**DWS**). A total of nine (9) existing boreholes were identified from the NGA in the vicinity of the study area. Information on the boreholes is given in Table 8.1. The positions of the boreholes are shown in Figure 8.1. None of the boreholes could be located in the field; this being attributed to the age of most of the boreholes which were drilled between 1936 and 2001. Residential houses have sprouted where these boreholes existed. Their information, however, still gives a good idea of the groundwater situation in the area.

Table 8.1 Information on the existing borehole

Borehole ID	Latitude	Longitude	BH Depth (m)	Water Level (m)	Water Strike (m)	Blow Yield (L/s)	Date	Geology
2627BD00537	-26.26137	27.88383	84		84		2001/03/13	Dolomite
2627BD00109	-26.2575	27.91078	61	3.35	55	0.2	1938/05/24	Diabase
2627BD00107	-26.25749	27.91078	28		20	0.2	1936/06/13	Lava/Shale
2627BD00544	-26.25498	27.908		55	60	0.4		
2627BD00534	-26.25221	27.90925	79	12	57	5.0	1987/07/07	Quartzite
2627BD00540	-26.25165	27.86633	84		13	0.1	2001/03/15	Dolomite
2627BD00535	-26.25098	27.92239	31		30	1.3	1988/06/02	Quartzite
2627BB00064	-26.23804	27.84911	49		70		1983/12/20	Quartzite
25175	-26.18665	27.89744	86		30	3.0	1973/01/13	Shale/Quartzite /dolomite

8.2 GROUNDWATER QUANTITY

Data from the existing boreholes in the study area indicate borehole yields ranging from 0.1 to 5 L/s, with an average yield of 1.5 L/s, as analysed from 7 boreholes. Water strike depth ranges from 13 to 60 metres blow surface, with an average depth of 42 metres, as analysed from 9 boreholes. High yields are associated with well-developed fractures and fissures in the bedrock; usually associated with lithological contacts. The depth of the majority of the boreholes lies between 28 and 86 metres below surface.

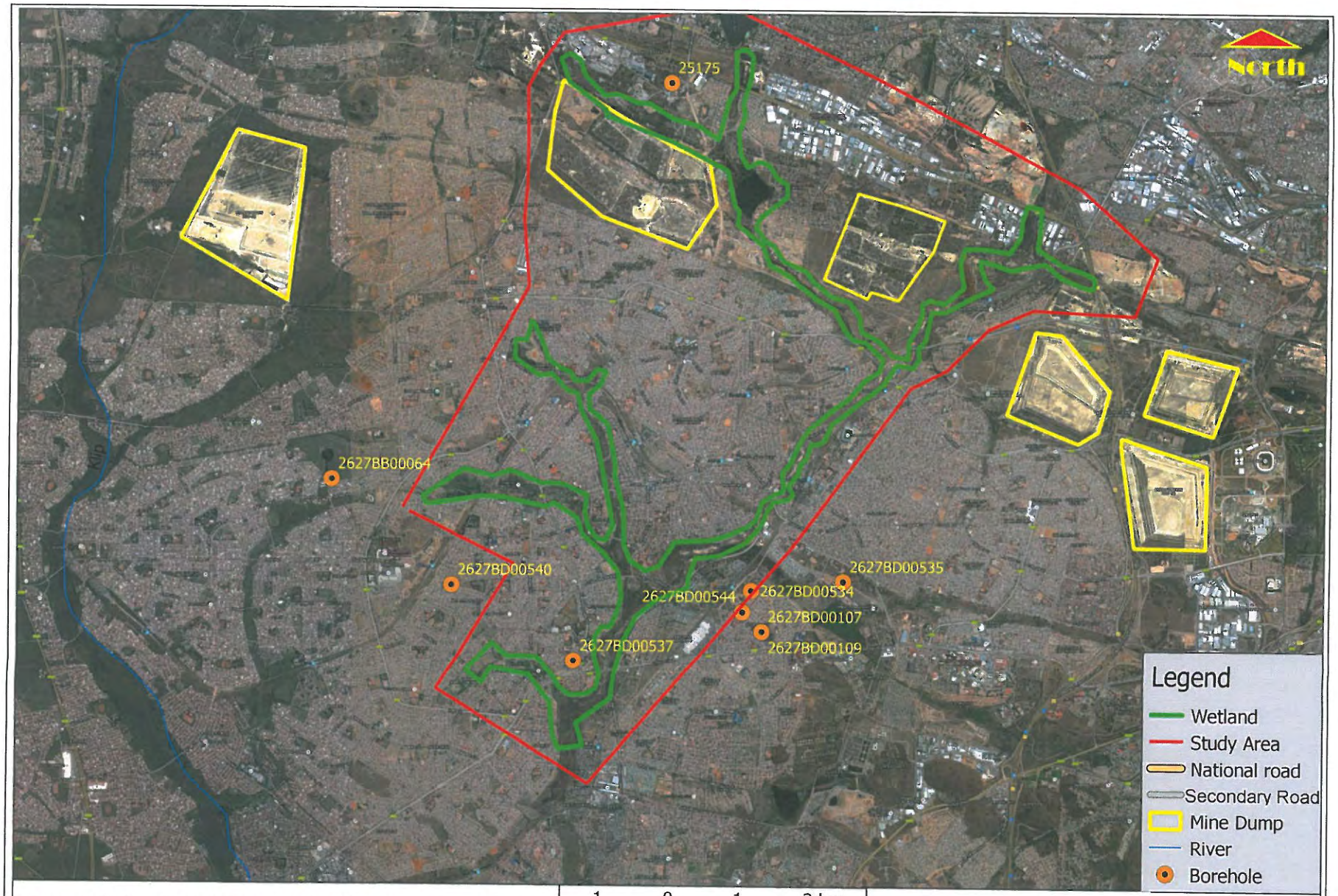


Figure 8.1 Positions of existing boreholes

Soweto Wetland Rehabilitation Project

8.3 GROUNDWATER LEVEL

Groundwater level data were evaluated from 3 boreholes, which incidentally occur close to each other. These boreholes show water level ranging from 3.5 to 55 metres below surface. Such variation of water level in boreholes located in such close proximity to each other would suggest that the boreholes are tapping different and hydraulically unconnected aquifers. The shallow water level of between 3.5 and 10 metres in two of the boreholes indicate a water-table lying higher than the water level in the wetland; resulting in groundwater following and contributing to the wetland. This remains to be confirmed by drilling boreholes adjacent to the wetland.

Lack of adequate water level elevation data precluded the construction of a piezometric surface map that would show the groundwater flow patterns at the site. Under these circumstances, it is assumed that the water-table mimics surface topography; hence groundwater flows from topographic highs towards topographic lows. Estimated groundwater flow patterns at the site are shown in Figure 8.2.

8.4 GROUNDWATER QUALITY

Groundwater quality could not be evaluated due to lack of data. New boreholes will have to be drilled to generate such information.

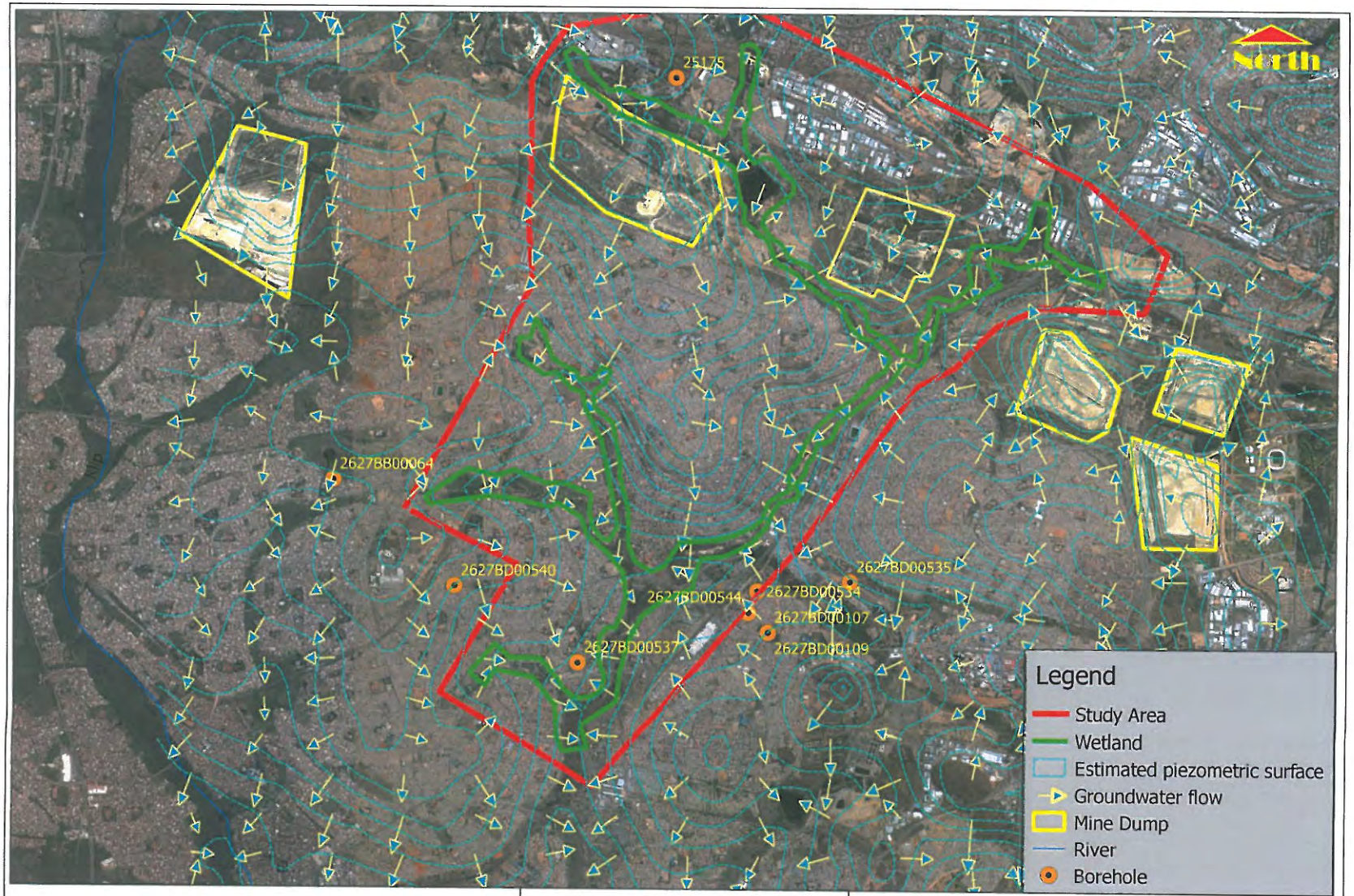


Figure 8.2 Groundwater flow patterns

Soweto Wetland Rehabilitation Project

9 ASSESSMENT OF IMPACT PROPOSED ACTIVITY ON GROUNDWATER RESOURCES

9.1 PRESENT STATUS OF WETLAND SYSTEM

The wetland system under investigation has been highly modified from its natural state by human activities around it. The site is located in a predominantly residential area, but also close to old mine dumps and industrial area. The major impacts on the wetland system include, amongst others illegal dumping, sewage leakages, overgrazing and tramping by livestock, unsustainable reed harvesting, erosion due to increased storm-water from paved areas and sedimentation. The ecological status of the wetland has significantly deteriorated (Personal communication with wetland specialist). The wetland is therefore no longer pristine. The current study seeks to rehabilitate the wetland to a functional ecological system; but not necessarily to its original state.

9.2 ASSESSMENT OF IMPACT ON GROUNDWATER RESOURCES

The current study seeks to identify potential impacts of the proposed wetland rehabilitation on groundwater resources. The rehabilitation exercise aims at cleaning up the wetland by eliminating or minimising all potential sources of deleterious effect on the wetland. The proposed activities will have very little or no negative impacts on groundwater resources. As a matter of fact, groundwater resources will benefit from the rehabilitation of the wetland as a result of the elimination of potential sources of contamination around the site.

The main threat to groundwater resources are the existing sources of contamination at the site, and these have nothing to do with the proposed rehabilitation activities. These include:

- Residential areas: Leakage from the sewage system and storm water drainage.
- Industrial activities: Leakage from sewage system and illegal discharge of toxic effluent.
- Old mine dumps: Seepage of leachate into underlying aquifers.
- Illegal dumping. Seepage of leachate into underlying aquifers.

The main concern relates to the discharge of contaminated groundwater into the wetland. This impact is governed by the wetland's hydraulic relationship with groundwater. If groundwater level elevation in the vicinity of the wetland is higher than the water level in the wetland, then groundwater will flow towards and discharge into the wetland; and if groundwater level elevation is lower, water will flow from the wetland to the aquifer. These scenarios are illustrated in Figures 9.1 and 9.2 respectively. Available groundwater data suggest that both scenarios may exist in the study area. This will have to be confirmed by drilling monitoring boreholes adjacent to the wetland.

Groundwater abstraction in the vicinity of the wetland has potential to lower water level and flow in the wetland. However, no groundwater abstraction was observed during the hydrocensus.

In summary, the current status of groundwater in terms of both water levels and water quality at the site is unknown due to lack of data.

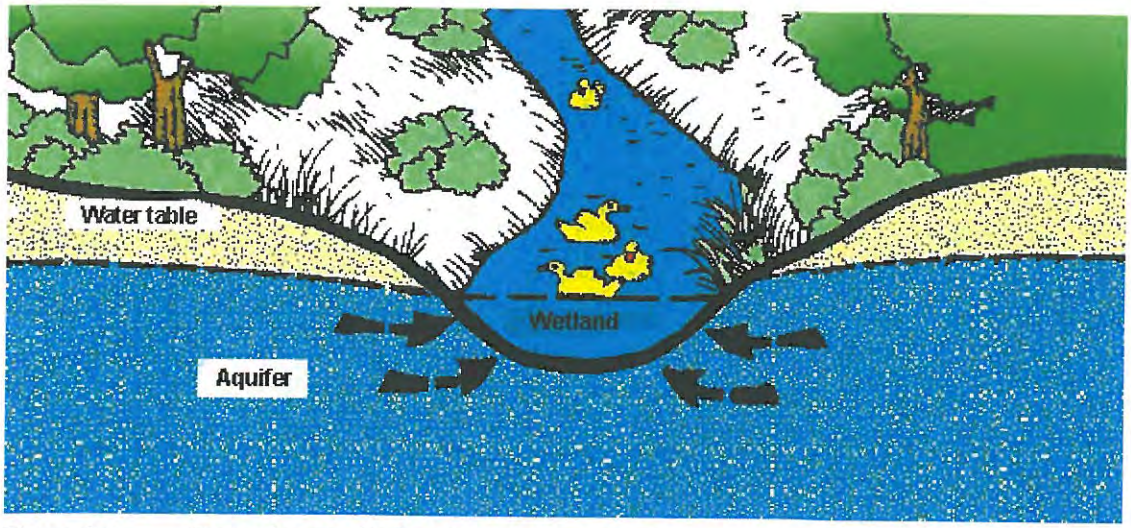


Figure 9.1 Groundwater discharging into a wetland

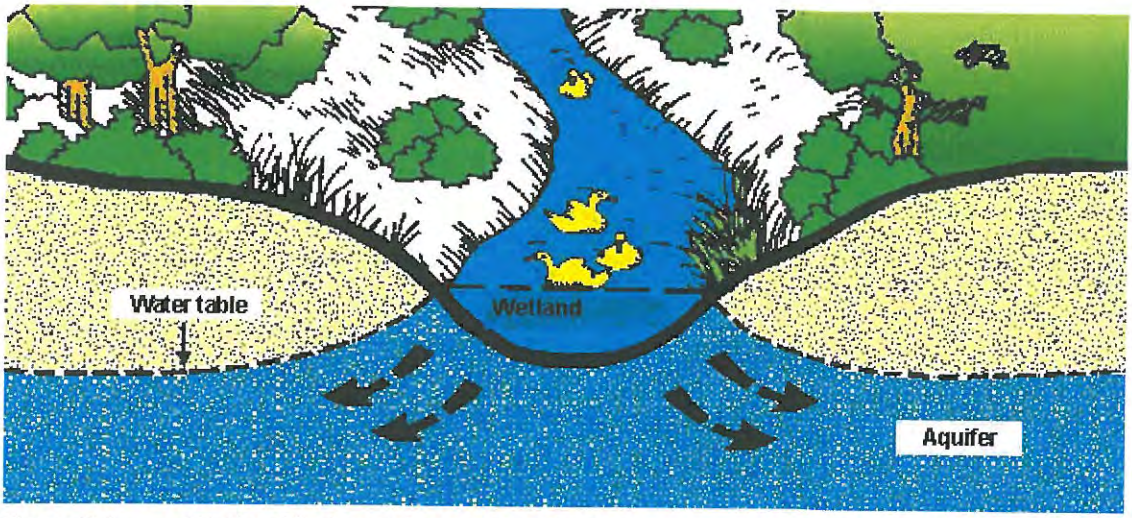


Figure 9.2 Wetland losing water to groundwater

10 CONCLUSION

The conclusion is based entirely on the evaluation of existing data from 9 boreholes with incomplete data in the study area, coupled with a hydrocensus. No new boreholes were drilled in this investigation.

The main conclusion derived from the study is that the potential impact of the proposed wetland rehabilitation on groundwater will be very little to none. Groundwater resources will actually benefit from the rehabilitation as a result of the elimination or reduction of potential sources of contamination by the rehabilitation exercise.

More specific findings of the study include the following:

- The baseline groundwater conditions (groundwater level and water quality) at the site could not be determined due to inadequate existing data. New boreholes will be required to generate the requisite information.
- Groundwater has potential to act as conduit for contaminants from outside sources to the wetland.
- The hydraulic relationship between groundwater and the wetland could not be determined due the lack of boreholes in the vicinity of the wetland to determine the water-table gradient; hence groundwater flow direction.

11 RECOMMENDATION

The investigation provided a preliminary understanding of the groundwater situation at the site.

To this end, the following recommendations are made:

- Site and drill at least six monitoring boreholes adjacent to the wetland. Approximate positions of the monitoring boreholes are shown in Figure 11.1, and the approximate locations are given Table 11.1. These positions were selected to intercept groundwater flow from potential sources of contamination; mainly residential areas, industrial areas, and mining disposal facilities.
- The boreholes should be located outside the 1:100 year flood line or at least 100 metres away from the edge of a natural drainage channel if the location of the flood line is not known.
- The siting of the boreholes should use geophysical survey techniques to increase the chances of intersecting geological structures that influence groundwater flow at the site. Electromagnetic horizontal profiling is recommended in this regard.
- Geophysical surveys lines should be placed parallel to the wetland in order to intersect fracture zones oriented perpendicular to the wetland. These fracture zones channel groundwater from outside to the wetland.
- Boreholes should be drilled to maximum depth of between 30 and 50 metres, or at least 25 metres below the water-table.

- At least three boreholes spread over the entire area of interest should be pump-tested to determine hydraulic parameters of aquifers at the site, to be used later in groundwater modelling. A 12 hour constant rate test is recommended.
- Groundwater from the new monitoring boreholes should be sampled quarterly, and water levels measured monthly.
- Water quality parameters to be monitored should include, but not limited to the following: pH, EC, TDS, Ca, Mg, Na, K, Fe, Mn, Cu, Pb, Zn, Cd, Cr, Cl, SO_4, F, NO_3, PO_4, CO_3, and HCO_3.
- A groundwater flow and transport model should be developed for the site. The model will be used to predict potential long-term impacts of groundwater on the wetland. The potential impacts to be simulated include migration of contaminants from outside sources to the wetland.
- The estimated cost of the proposed activities is given in Table 11.3.

Table 11.1: Approximate location of the proposed monitoring boreholes

BH ID	Latitude	Longitude
BH 1	26.201765°	27.904926°
BH 2	26.221146°	27.929229°
BH 3	26.213188°	27.942151°
BH 4	26.242358°	27.911847°
BH 5	26.250095°	27.894840°
BH 6	26.271059°	27.885230°

Table 11.2 Cost estimate for recommended activities

Item	Description	Unit	Rate	Quantity	Cost
1	Borehole siting	Borehole	3,500.00	6	21,000.00
2	Borehole drilling	Borehole	30,000.00	6	180,000.00
3	Pumping test	Borehole	15,000.00	3	45,000.00
4	Groundwater Sampling and laboratory analysis	Borehole	2,500.00	6	15,000.00
5	Groundwater flow and transport modelling	Hours	1,000.00	64	64,000.00
6	Data analysis and report	Hours	1,000.00	40	325,000.00
TOTAL					**325,000.00**
14%VAT					**45,500.00**
GRAND TOTAL					**370,500.00**

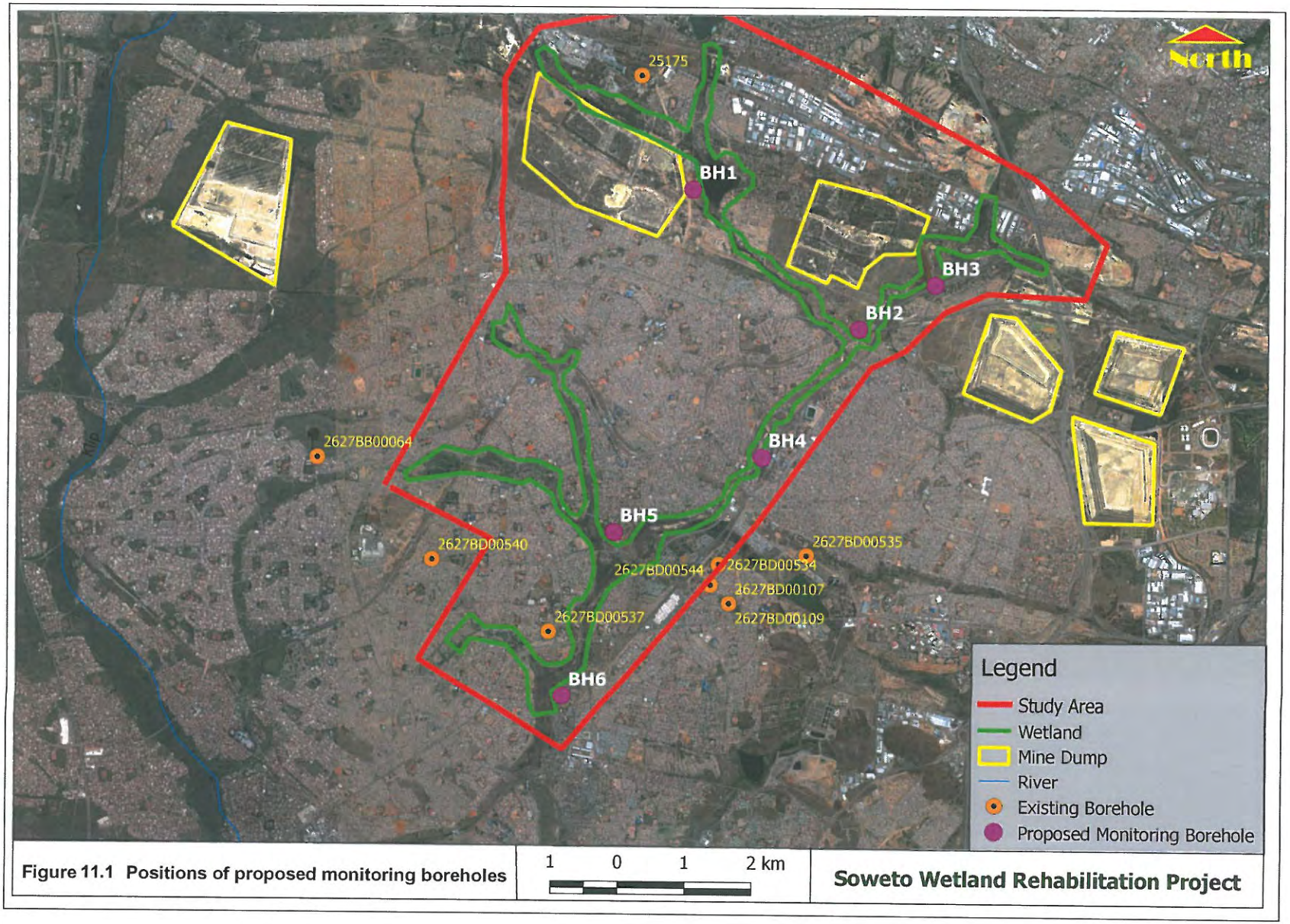


Figure 11.1 Positions of proposed monitoring boreholes

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APPENDIX I

Academic Qualifications

South African Council for Natural Scientific Professions

This is to certify that

Andrew Mavurayi

400032/98

Has been registered in terms of section 11 of the Natural Scientific Professions Act, 1993 as a

Professional Natural Scientist

SACNASP

26.06.98
Pretoria

President

Registrar

UNIVERSITY OF LONDON

ANDREW MAVURAYI

of

UNIVERSITY COLLEGE LONDON

having completed an approved course of study in

HYDROGEOLOGY

as an Internal Student in the Faculty of SCIENCE

and passed the prescribed examinations has this

day been admitted by the Senate to the degree of

MASTER OF SCIENCE

20 DECEMBER 1989

Vice-Chancellor

UNIVERSITY OF ZIMBABWE

FACULTY OF SCIENCE

Degree of Bachelor of Science General

WE HEREBY CERTIFY THAT ANDREW MAVURAYI

having attended an approved course of full-time study and having satisfied the Examiners, has this day been awarded Degree of Bachelor of Science General.

Vice-Chancellor

Dean

Registrar

Date 12 TH DECEMBER, 1984.

Johannesburg City Parks and Zoo

Geohydrological Impact Assessment for the Rehabilitation of Wetlands in the Klip Middle Water Management Unit in Soweto Within the Johannesburg Municipality, Gauteng Province

Report Ref: 2016/ENV006

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Prepared for

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Water & Environmental Consultancy
Water recognises no borders

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EXECUTIVE SUMMARY

INTRODUCTION

The City of Johannesburg intends to rehabilitate several wetlands in Soweto and convert them into recreational parks for the residents. Waters Without Frontiers cc was appointed by Lebone Engineering on behalf of Johannesburg City Parks and Zoo to undertake a geohydrological impact assessment for proposed rehabilitation of wetlands in Klip Middle Water Management Unit in Soweto within the Johannesburg Municipality, Gauteng Province. The wetlands are located within residential, industrial and previously mined areas; all of which have potential to contaminate groundwater.

OBJECTIVE

The main objective of the study was to assess the potential impact of the proposed rehabilitation of the wetland on groundwater in the Klip Middle Water Management Unit in Soweto, and to recommend management options to mitigate or remedy the impact.

METHODOLOGY

The investigation was based entirely on the evaluation of existing data, no new boreholes were drilled and neither were any groundwater samples collected for water quality analysis. The data evaluation was complemented by hydrocensus that sought to identify existing boreholes in the study area

CONCLUSION

The conclusion is based entirely on the evaluation of existing data from 9 boreholes with incomplete data in the study area, coupled with a hydrocensus. No new boreholes were drilled in this investigation.

The main conclusion derived from the study is that the potential impact of the proposed wetland rehabilitation on groundwater will be very little to none. Groundwater resources will actually benefit from the rehabilitation as a result of the elimination or reduction of potential sources of contamination by the rehabilitation exercise.

More specific findings of the study include the following:

- The baseline groundwater conditions (groundwater level and water quality) at the site could not be determined due to inadequate existing data. New boreholes will be required to generate the requisite information.
- Groundwater has potential to act as conduit for contaminants from existing sources to the wetland.
- The hydraulic relationship between groundwater and the wetland could not be determined due the lack of boreholes in the vicinity of the wetland to determine the water-table gradient; hence groundwater flow direction.

RECOMMENDATION

The investigation provided a preliminary understanding of the groundwater situation at the site.

To this end, the following recommendations are made:

- Site and drill at least six monitoring boreholes adjacent to the wetland. Approximate positions of the monitoring boreholes are shown in Figure 11.1, and the coordinates given Table 11.1. These positions were selected to intercept groundwater flow from potential sources of contamination; mainly residential areas, industrial areas, and mining disposal facilities.
- The boreholes should be located outside the 1:100 year flood line or at least 100 metres away from the edge of a natural drainage channel if the location of the flood line is not known.
- The siting of the boreholes should use geophysical survey techniques to increase the chances of intersecting geological structures that influence groundwater flow at the site. Electromagnetic horizontal profiling is recommended in this regard.
- Geophysical surveys lines should be placed parallel to the wetland in order to intersect fracture zones oriented perpendicular to the wetland. These fracture zones channel groundwater from outside to the wetland.
- Boreholes should be drilled to maximum depth of between 30 and 50 metres, or at least 25 metres below the water-table.
- At least three boreholes spread over the entire area of interest should be pump-tested to determine hydraulic parameters of aquifers at the site, to be used later in groundwater modelling. A 12 hour constant rate test is recommended.
- Groundwater from the new monitoring boreholes should be sampled quarterly, and water levels measured monthly.
- Water quality parameters to be monitored should include, but not limited to the following: pH, EC, TDS, Ca, Mg, Na, K, Fe, Mn, Cu, Pb, Zn, Cd, Cr, Cl, SO_4, F, NO_3, PO_4, CO_3, and HCO_3.
- A groundwater flow and transport model should be developed for the site. The model will be used to predict potential long-term impacts of groundwater on the wetland. The potential impacts to be simulated include migration of contaminants from outside sources to the wetland.
- The estimated cost of the proposed activities is given in Table 11.3.

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1.1 BACKGROUND

The City of Johannesburg intends to rehabilitate several wetlands in Soweto and convert them into recreational parks for the residents. Waters Without Frontiers cc was appointed by Lebone Engineering on behalf of Johannesburg City Parks and Zoo to undertake a geohydrological impact assessment for proposed rehabilitation of wetlands in Klip Middle Water Management Unit in Soweto within the Johannesburg Municipality, Gauteng Province. The wetlands are located within residential, industrial and previously mined areas; all of which have potential to contaminate groundwater.

1.2 ASSUMPTIONS AND LIMITATIONS

The main assumption was that groundwater exists at the site based on characteristics of similar geological setup in other parts of the country.

The main limitation was the lack of groundwater data from existing boreholes in and around the site. New boreholes will need to be drilled in order to generate site specific data.

2 OBJECTIVE

The main objective of the study was to assess the potential impact of the proposed rehabilitation of the wetland on groundwater in the Klip Middle Water Management Unit in Soweto, and to recommend management options to mitigate or remedy the impact.

3 SCOPE OF WORK

The scope of work will include but not limited to the following:

- Desktop study – collection and review of existing groundwater data to create preliminary understanding of the groundwater regime at the site. This represents a scoping exercise to determine if further activities such siting and drilling of additional boreholes to augment data will be necessary;
- Hydrocensus - field verification of existing boreholes and groundwater related features such as wetlands and springs;
- Establishment of the extent of groundwater use in adjacent areas
- Determination of the current geohydrological environment, hence establish prevailing groundwater conditions against which impacts will be measured;
- Identification of geological structures that influence groundwater flow; such as faults, fracture zones and dykes;
- Assessment of surface water and groundwater interaction;

- Compilation of all the relevant data and recommendations in a report, structured in such a way that it can be incorporated into the integrated water use licence application document.

4. SITE DESCRIPTION

4.1 LOCATION

The wetland under investigation is located in Soweto in the Klip Middle Water Management Unit (WMU). This Water Management Unit is roughly bounded by Koma Road on the south-west, Elias Motsoaledi on the west, Main Reef Road on the north and Klip Valley Road on the south east. The location of the study area is shown Figure 4.1, and the site layout is shown in Figure 4.2.

4.2 TOPOGRAPHY AND DRAINAGE

The study area is situated in the Klip Middle Water Management Unit, which in turn is located in Quaternary Catchment C22A. The topography of the study area is characterised by flat to gently rolling terrain. The prominent morphological features in the area are the artificial mine dumps from previous mining activities, which rise to about 50-60 metres above ground. Ground elevation ranges from 1580 metres above sea level at the southern tip of the wetland to about 1720 metres at the top of the mine dumps. Figure 4.3 shows the topography of the study area, as well as surface water flow directions. Drainage is ultimately to the south into the Klip River.

4.3 CLIMATE

Johannesburg receives about 604mm of rain per year, with most rainfall occurring during summer as short thunderstorms. It receives the lowest rainfall (0mm) in July and the highest (113mm) in January. The average midday temperatures for Johannesburg range from 16.6°C in June to 26.2°C in January. The region is the coldest during July when the mercury drops to 0.8°C on average during the night. Weather charts for the study area shown in Figure 4.4.

4.4 LAND USE

The study area is located in a predominantly residential area in Soweto. The northern section of the study area consist of old mine dumps and industry. Soweto is the most populous black urban residential area in South Africa with a population of approximately a million residents. It consists of both formal and informal settlements.

Figure 4.1 Location of the study area

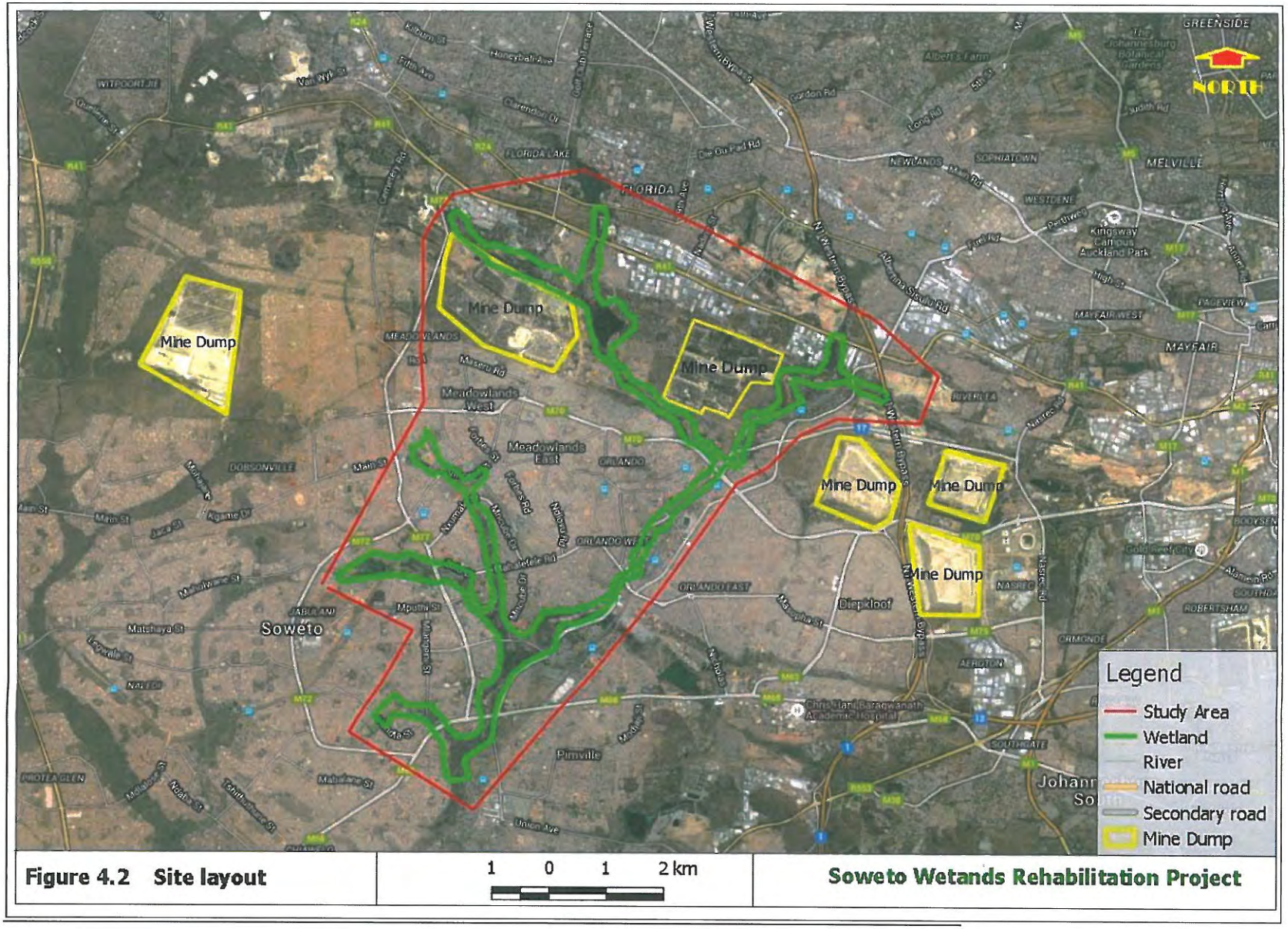


Figure 4.2 Site layout

Soweto Wetands Rehabilitation Project

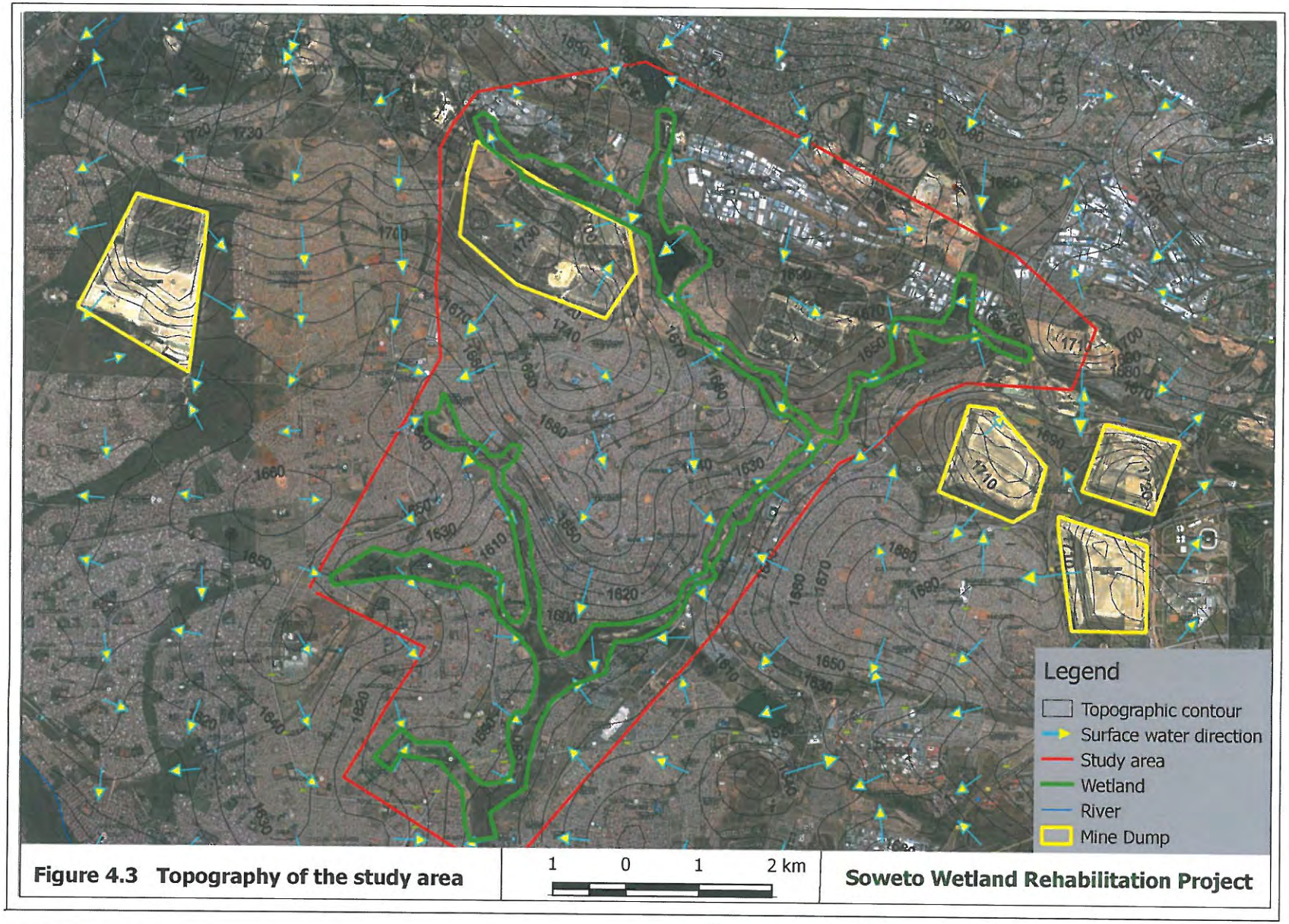
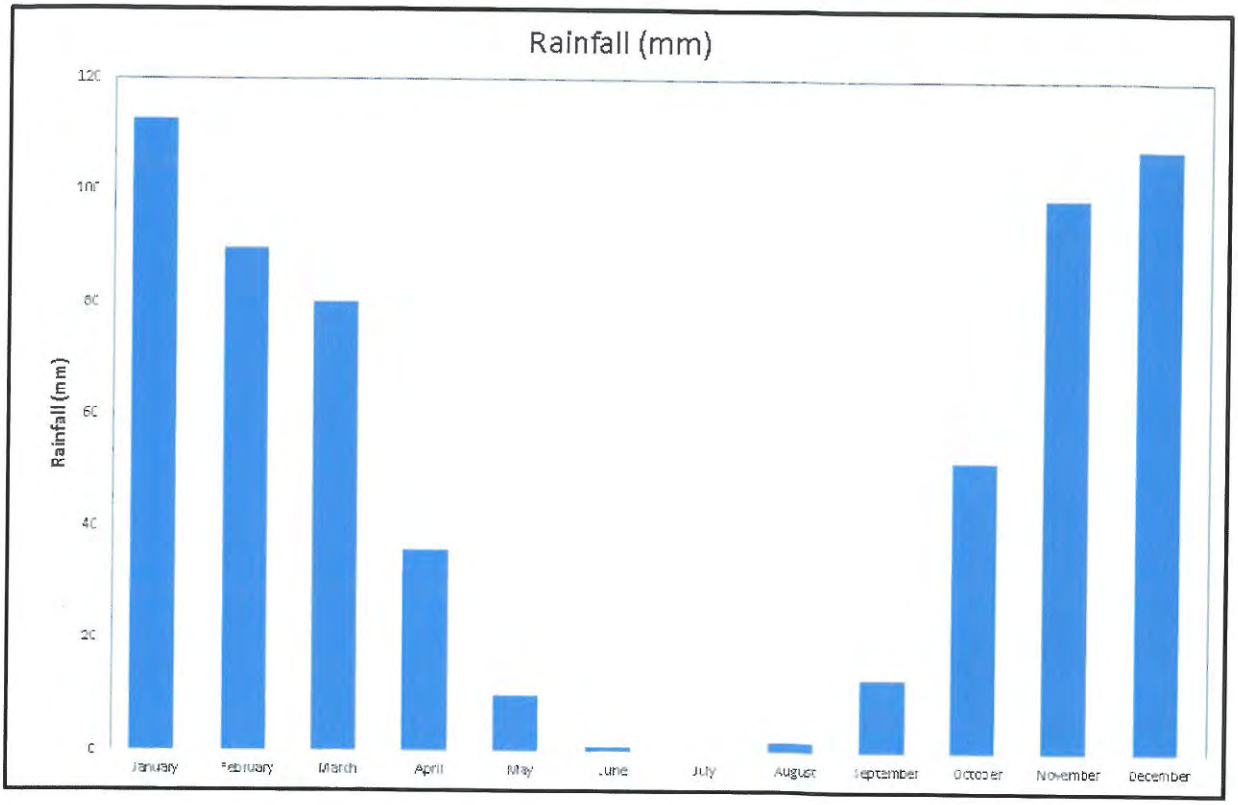


Figure 4.3 Topography of the study area



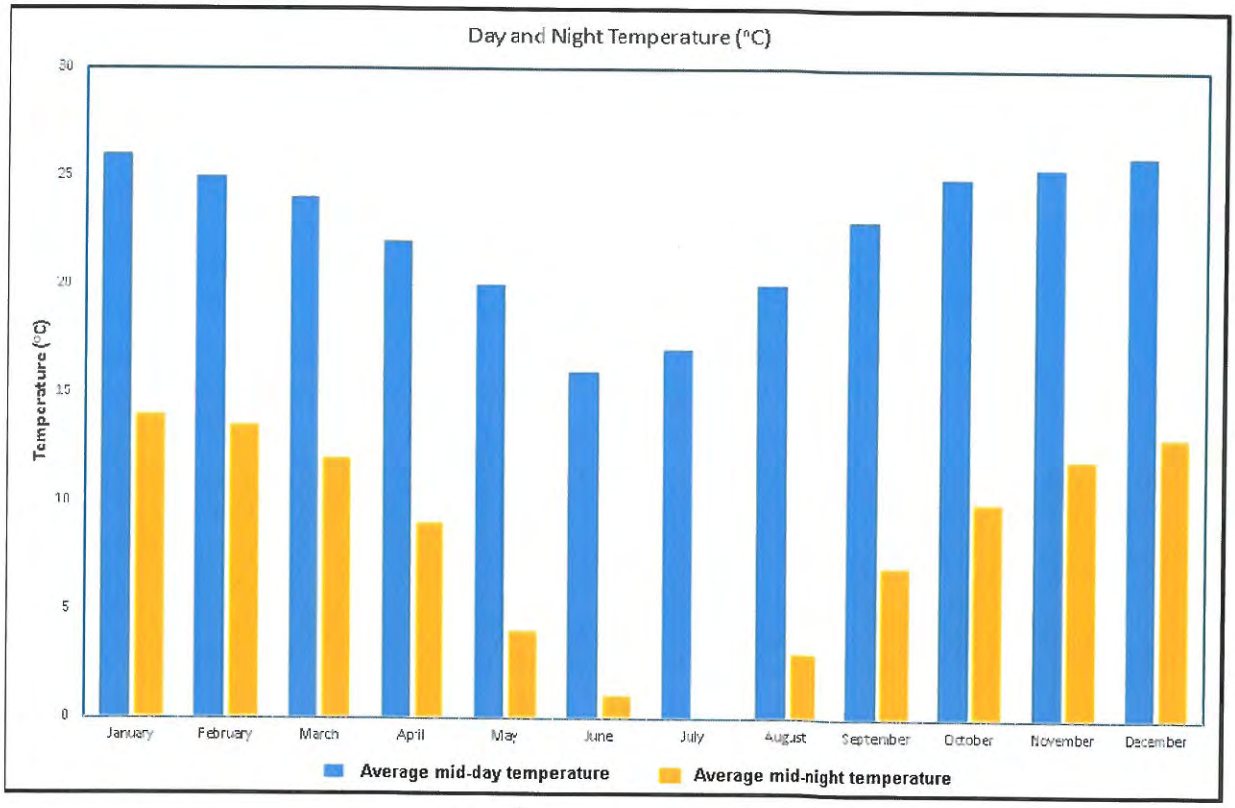


Figure 4.4 Climate graphs

5 GEOLOGICAL SETTING

The regional lithostratigraphical sequence in the project area is given in Table 5.1, a simplified geological map is shown in Figure 5.1. The oldest rocks in the region belong to the Archean Basemen complex represented by the Halfway House granites. These were followed upward by sedimentary rocks of the Witwatersrand, then andesite intrusion of the Ventersdorp. The sequence is completed by the deposition Transvaal followed by the Karoo.

Locally the site is underlain by the andesite of the Ventersdorp Group in the south and, and quartzite, conglomerate and shale of the Transvaal Group in the northern section. These rocks have been intruded by late Karoo dolerite dykes and sills.

Table 5.1 Stratigraphical Sequence in the area

Ma	Erathem (geological period)	Lithology	Stratigraphy		
			Formation	Group	Complex: Super-group
230	Mesazoic	Dolerite	Intrusive		Karoo
	Paleozoic	Sandstone, shale & Coal	Vryheid formation	Ecca Group	
570		Tillite, mudstone, sandstone		Dwyka	
	Valian	Dolomite	Malamani	Chuniespoort	Transvaal
2560		Quartzite, Conglomerate	Black Reef		
	Randian	Andesite	Alanridge	Kliprivier	Ventersdorp
		Sandstone, Conglomerate		Central Rand Group	Witwatersrand Super-group
3090		Quartzite, shale		West Rand Group	
	Swazian	Granite, gneiss	Halfway House	Basement Complex	Basement Complex

Rocks highlighted in blue are present in the study area

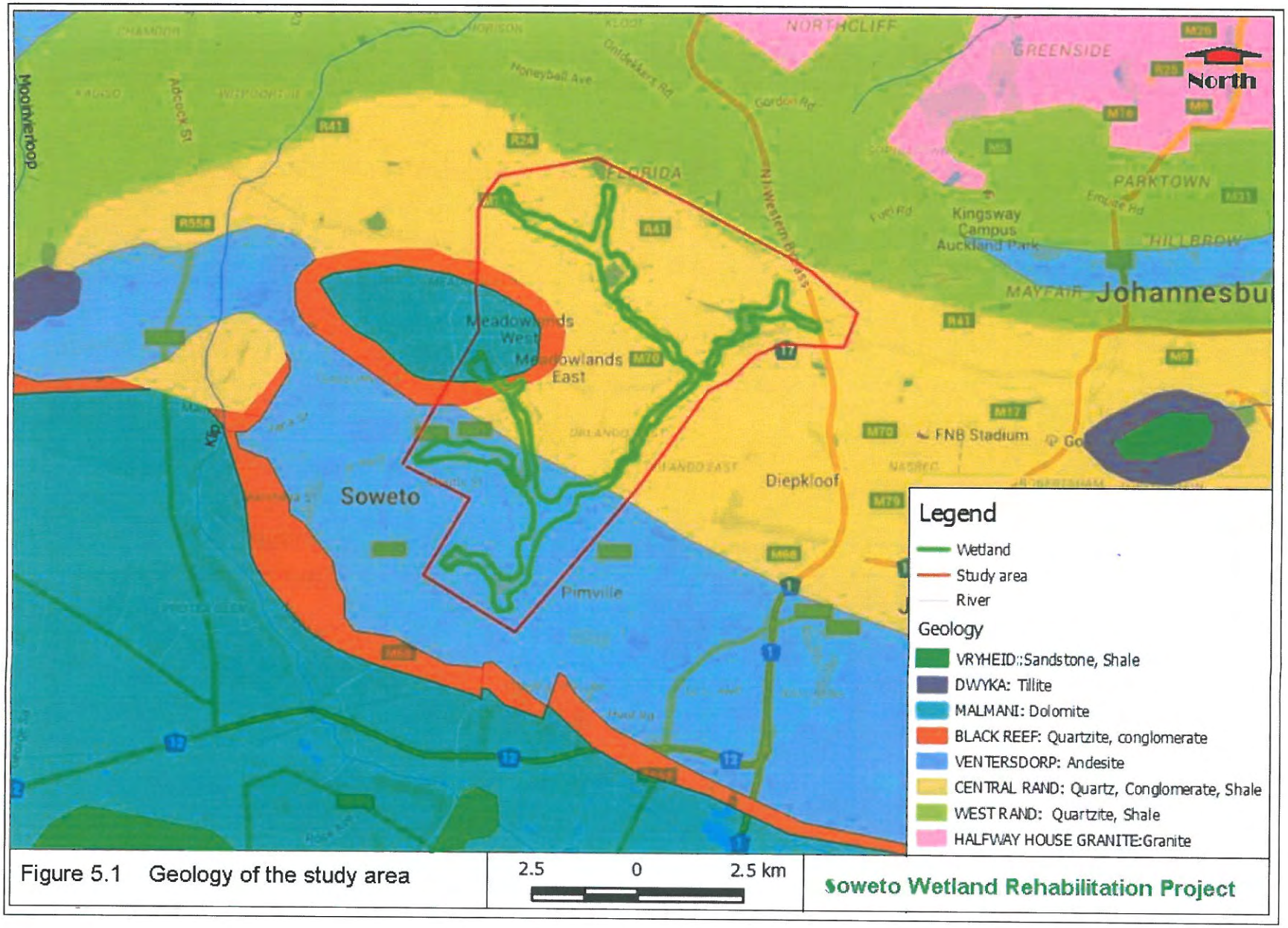


Figure 5.1 Geology of the study area

6 GEOHYDROLOGICAL SETTING

The study area is underlain by predominantly the both sedimentary (shale, sandstone and conglomerate) and igneous rocks (andesite). These rocks possess low primary permeability and porosity. Groundwater occurrence is generally associated with fractures and joints developed along bedding planes in former, weathering and fracturing in the later. Contact zones between dolerite intrusions and the country rocks represent especially good aquifers due to the presence of shrinkage fractures that developed as the dolerite magma rapidly cooled on contact with the cooler country rocks. The groundwater potential in the area is classified as low; with borehole yields generally less than 2 L/s, (Barnard, 2000). However, high yields are occasionally obtained on lithological contact zones described earlier.

Groundwater recharge in the study area is estimated at 95 mm per annum. The harvest potential of the area, which indicates the maximum volume of groundwater that can sustainably be abstracted per square kilometre per annum, is estimated at 11 200m^3/km^2/annum (Vegter, 1995).

7 INVESTIGATION

The investigation was based entirely on the evaluation of existing data, no new boreholes were drilled, and neither were any groundwater samples collected for water quality analysis.

To achieve the objective of the study the following activities were undertaken:

7.1 DESKTOP STUDY

The investigation commenced with a desktop study in which existing data and information pertaining to groundwater characteristics at the site were gathered and analysed. Sources of information and data included the following:

- National Groundwater Archive of the Department of Water and Sanitation,
- Published geological reports and maps,
- Published geohydrological reports and maps,
- Consultant's reports provided by the client,

7.2 HYDROCENSUS

The desktop study was complemented by a hydrocensus in which existing boreholes and other groundwater related features such as springs and wetlands were identified within the study area.

The hydrocensus sought to:

- Provide a feel of the study area.
- Identify existing water points (boreholes, springs, wetlands, etc.) in the area.
- Assess groundwater use in the study area.
- Where accessible, collect groundwater samples and measure water levels in the boreholes

7.3 INTERVIEWS

During the desktop study and the hydrocensus, interviews were conducted with interested and affected people around the site to establish issues relating to their groundwater resources.

8 DISCUSSION OF FINDINGS

8.1 DATA EVALUATION

Groundwater haracterization was based on the evaluation of existing boreholes mainly from the **N**ational **G**roundwater **A**rchive (**NGA**) of the **D**epartment of Water and Sanitation (**DWS**). A total of nine (9) existing boreholes were identified from the NGA in the vicinity of the study area. Information on the boreholes is given in Table 8.1. The positions of the boreholes are shown in Figure 8.1. None of the boreholes could be located in the field; this being attributed to the age of most of the boreholes which were drilled between 1936 and 2001. Residential houses have sprouted where these boreholes existed. Their information, however, still gives a good idea of the groundwater situation in the area.

Table 8.1 Information on the existing borehole

Borehole ID	Latitude	Longitude	BH Depth (m)	Water Level (m)	Water Strike (m)	Blow Yield (L/s)	Date	Geology
2627BD00537	-26.26137	27.88383	84		84		2001/03/13	Dolomite
2627BD00109	-26.2575	27.91078	61	3.35	55	0.2	1938/05/24	Diabase
2627BD00107	-26.25749	27.91078	28		20	0.2	1936/06/13	Lava/Shale
2627BD00544	-26.25498	27.908		55	60	0.4		
2627BD00534	-26.25221	27.90925	79	12	57	5.0	1987/07/07	Quartzite
2627BD00540	-26.25165	27.86633	84		13	0.1	2001/03/15	Dolomite
2627BD00535	-26.25098	27.92239	31		30	1.3	1988/06/02	Quartzite
2627BB00064	-26.23804	27.84911	49		70		1983/12/20	Quartzite
25175	-26.18665	27.89744	86		30	3.0	1973/01/13	Shale/Quartzite /dolomite

8.2 GROUNDWATER QUANTITY

Data from the existing boreholes in the study area indicate borehole yields ranging from 0.1 to 5 L/s, with an average yield of 1.5 L/s, as analysed from 7 boreholes. Water strike depth ranges from 13 to 60 metres blow surface, with an average depth of 42 metres, as analysed from 9 boreholes. High yields are associated with well-developed fractures and fissures in the bedrock; usually associated with lithological contacts. The depth of the majority of the boreholes lies between 28 and 86 metres below surface.

Figure 8.1 Positions of existing boreholes | **Soweto Wetland Rehabilitation Project**

8.3 GROUNDWATER LEVEL

Groundwater level data were evaluated from 3 boreholes, which incidentally occur close to each other. These boreholes show water level ranging from 3.5 to 55 metres below surface. Such variation of water level in boreholes located in such close proximity to each other would suggest that the boreholes are tapping different and hydraulically unconnected aquifers. The shallow water level of between 3.5 and 10 metres in two of the boreholes indicate a water-table lying higher than the water level in the wetland; resulting in groundwater following and contributing to the wetland. This remains to be confirmed by drilling boreholes adjacent to the wetland.

Lack of adequate water level elevation data precluded the construction of a piezometric surface map that would show the groundwater flow patterns at the site. Under these circumstances, it is assumed that the water-table mimics surface topography; hence groundwater flows from topographic highs towards topographic lows. Estimated groundwater flow patterns at the site are shown in Figure 8.2.

8.4 GROUNDWATER QUALITY

Groundwater quality could not be evaluated due to lack of data. New boreholes will have to be drilled to generate such information.

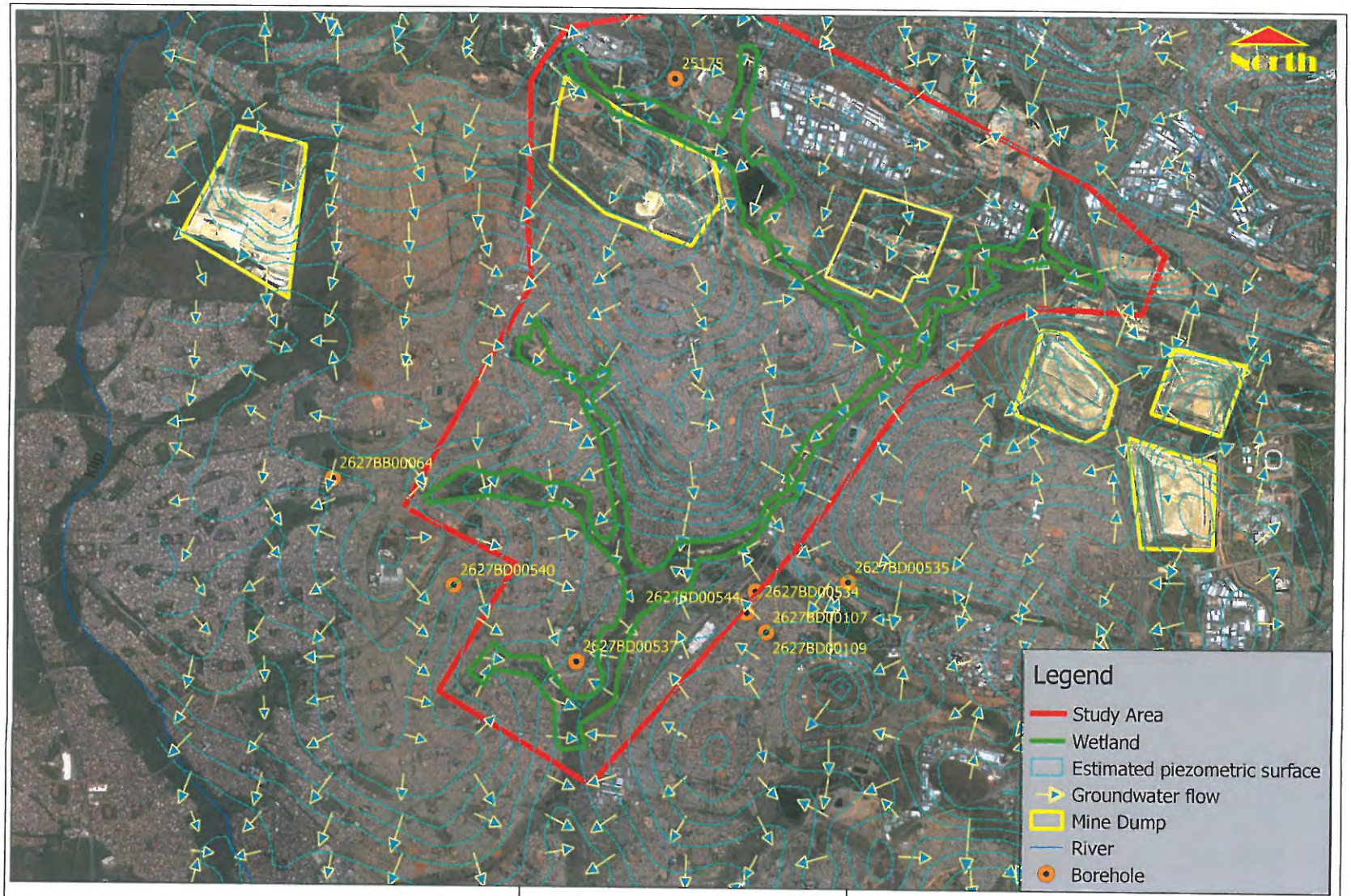


Figure 8.2 Groundwater flow patterns

Soweto Wetland Rehabilitation Project

9 ASSESSMENT OF IMPACT PROPOSED ACTIVITY ON GROUNDWATER RESOURCES

9.1 PRESENT STATUS OF WETLAND SYSTEM

The wetland system under investigation has been highly modified from its natural state by human activities around it. The site is located in a predominantly residential area, but also close to old mine dumps and industrial area. The major impacts on the wetland system include, amongst others illegal dumping, sewage leakages, overgrazing and tramping by livestock, unsustainable reed harvesting, erosion due to increased storm-water from paved areas and sedimentation. The ecological status of the wetland has significantly deteriorated (Personal communication with wetland specialist). The wetland is therefore no longer pristine. The current study seeks to rehabilitate the wetland to a functional ecological system; but not necessarily to its original state.

9.2 ASSESSMENT OF IMPACT ON GROUNDWATER RESOURCES

The current study seeks to identify potential impacts of the proposed wetland rehabilitation on groundwater resources. The rehabilitation exercise aims at cleaning up the wetland by eliminating or minimising all potential sources of deleterious effect on the wetland. The proposed activities will have very little or no negative impacts on groundwater resources. As a matter of fact, groundwater resources will benefit from the rehabilitation of the wetland as a result of the elimination of potential sources of contamination around the site.

The main threat to groundwater resources are the existing sources of contamination at the site, and these have nothing to do with the proposed rehabilitation activities. These include:

- Residential areas: Leakage from the sewage system and storm water drainage.
- Industrial activities: Leakage from sewage system and illegal discharge of toxic effluent.
- Old mine dumps: Seepage of leachate into underlying aquifers.
- Illegal dumping. Seepage of leachate into underlying aquifers.

The main concern relates to the discharge of contaminated groundwater into the wetland. This impact is governed by the wetland's hydraulic relationship with groundwater. If groundwater level elevation in the vicinity of the wetland is higher than the water level in the wetland, then groundwater will flow towards and discharge into the wetland; and if groundwater level elevation is lower, water will flow from the wetland to the aquifer. These scenarios are illustrated in Figures 9.1 and 9.2 respectively. Available groundwater data suggest that both scenarios may exist in the study area. This will have to be confirmed by drilling monitoring boreholes adjacent to the wetland.

Groundwater abstraction in the vicinity of the wetland has potential to lower water level and flow in the wetland. However, no groundwater abstraction was observed during the hydrocensus.

In summary, the current status of groundwater in terms of both water levels and water quality at the site is unknown due to lack of data.

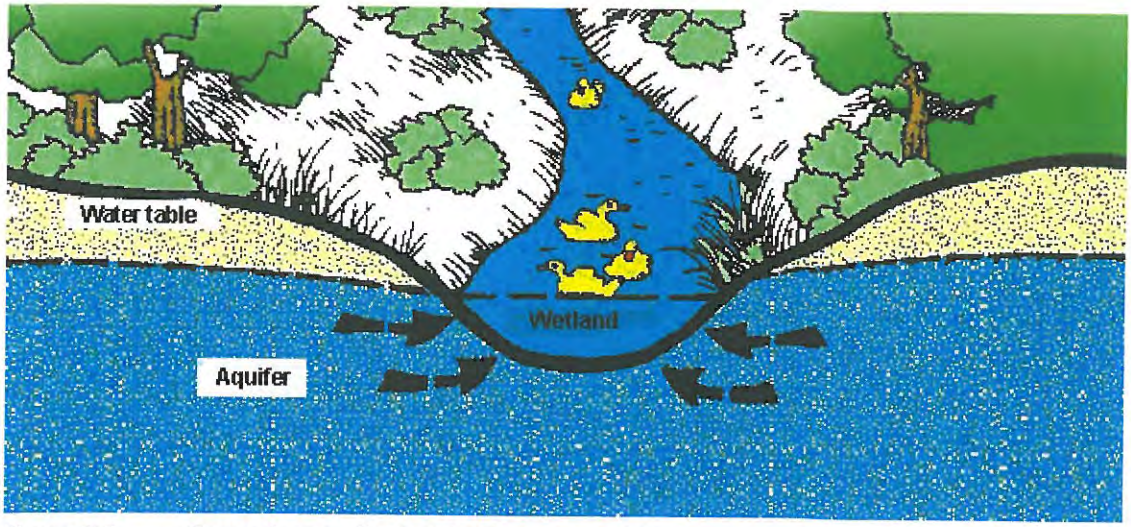


Figure 9.1 Groundwater discharging into a wetland

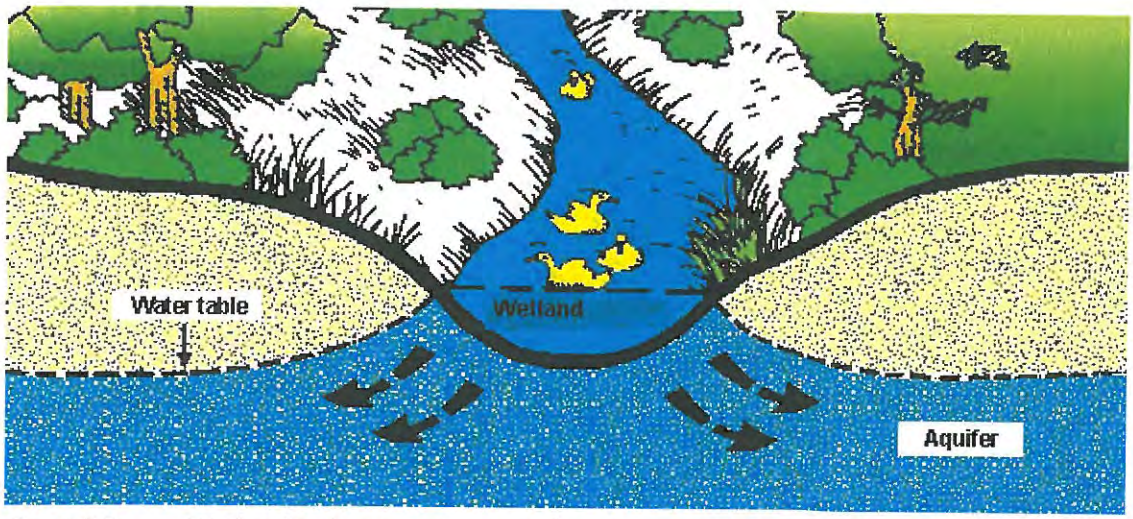


Figure 9.2 Wetland losing water to groundwater

10 CONCLUSION

The conclusion is based entirely on the evaluation of existing data from 9 boreholes with incomplete data in the study area, coupled with a hydrocensus. No new boreholes were drilled in this investigation.

The main conclusion derived from the study is that the potential impact of the proposed wetland rehabilitation on groundwater will be very little to none. Groundwater resources will actually benefit from the rehabilitation as a result of the elimination or reduction of potential sources of contamination by the rehabilitation exercise.

More specific findings of the study include the following:

- The baseline groundwater conditions (groundwater level and water quality) at the site could not be determined due to inadequate existing data. New boreholes will be required to generate the requisite information.
- Groundwater has potential to act as conduit for contaminants from outside sources to the wetland.
- The hydraulic relationship between groundwater and the wetland could not be determined due the lack of boreholes in the vicinity of the wetland to determine the water-table gradient; hence groundwater flow direction.

11 RECOMMENDATION

The investigation provided a preliminary understanding of the groundwater situation at the site.

To this end, the following recommendations are made:

- Site and drill at least six monitoring boreholes adjacent to the wetland. Approximate positions of the monitoring boreholes are shown in Figure 11.1, and the approximate locations are given Table 11.1. These positions were selected to intercept groundwater flow from potential sources of contamination; mainly residential areas, industrial areas, and mining disposal facilities.
- The boreholes should be located outside the 1:100 year flood line or at least 100 metres away from the edge of a natural drainage channel if the location of the flood line is not known.
- The siting of the boreholes should use geophysical survey techniques to increase the chances of intersecting geological structures that influence groundwater flow at the site. Electromagnetic horizontal profiling is recommended in this regard.
- Geophysical surveys lines should be placed parallel to the wetland in order to intersect fracture zones oriented perpendicular to the wetland. These fracture zones channel groundwater from outside to the wetland.
- Boreholes should be drilled to maximum depth of between 30 and 50 metres, or at least 25 metres below the water-table.

- At least three boreholes spread over the entire area of interest should be pump-tested to determine hydraulic parameters of aquifers at the site, to be used later in groundwater modelling. A 12 hour constant rate test is recommended.
- Groundwater from the new monitoring boreholes should be sampled quarterly, and water levels measured monthly.
- Water quality parameters to be monitored should include, but not limited to the following: pH, EC, TDS, Ca, Mg, Na, K, Fe, Mn, Cu, Pb, Zn, Cd, Cr, Cl, SO_4, F, NO_3, PO_4, CO_3, and HCO_3.
- A groundwater flow and transport model should be developed for the site. The model will be used to predict potential long-term impacts of groundwater on the wetland. The potential impacts to be simulated include migration of contaminants from outside sources to the wetland.
- The estimated cost of the proposed activities is given in Table 11.3.

Table 11.1: Approximate location of the proposed monitoring boreholes

BH ID	Latitude	Longitude
BH 1	26.201765°	27.904926°
BH 2	26.221146°	27.929229°
BH 3	26.213188°	27.942151°
BH 4	26.242358°	27.911847°
BH 5	26.250095°	27.894840°
BH 6	26.271059°	27.885230°

Table 11.2 Cost estimate for recommended activities

Item	Description	Unit	Rate	Quantity	Cost
1	Borehole siting	Borehole	3,500.00	6	21,000.00
2	Borehole drilling	Borehole	30,000.00	6	180,000.00
3	Pumping test	Borehole	15,000.00	3	45,000.00
4	Groundwater Sampling and laboratory analysis	Borehole	2,500.00	6	15,000.00
5	Groundwater flow and transport modelling	Hours	1,000.00	64	64,000.00
6	Data analysis and report	Hours	1,000.00	40	325,000.00
TOTAL					**325,000.00**
14%VAT					**45,500.00**
GRAND TOTAL					**370,500.00**

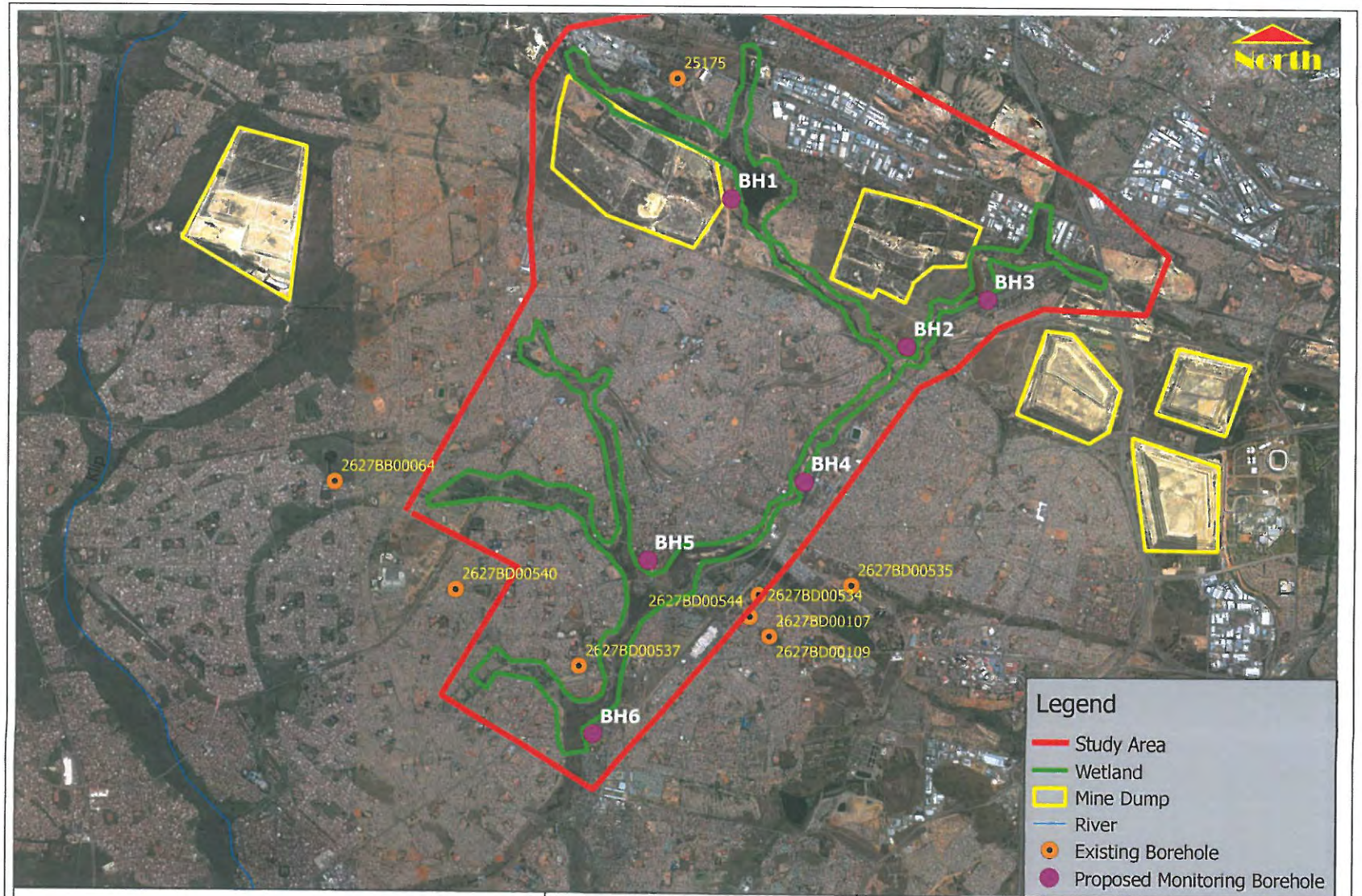


Figure 11.1 Positions of proposed monitoring boreholes

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APPENDIX I

Academic Qualifications

South African Council for Natural Scientific Professions

This is to certify that

Andrew Mavurayi

400032/98

Has been registered in terms of section 11 of the Natural Scientific Professions Act, 1993 as a

Professional Natural Scientist

SACNASP

26.06.98
Pretoria

President

Registrar

UNIVERSITY OF LONDON

ANDREW MAVURAYI

of

UNIVERSITY COLLEGE LONDON

having completed an approved course of study in

HYDROGEOLOGY

as an Internal Student in the Faculty of SCIENCE

and passed the prescribed examinations has this

day been admitted by the Senate to the degree of

MASTER OF SCIENCE

20 DECEMBER 1989

Vice-Chancellor

UNIVERSITY OF ZIMBABWE

FACULTY OF SCIENCE

Degree of Bachelor of Science General

WE HEREBY CERTIFY THAT ANDREW MAVURAYI

having attended an approved course of full-time study and having satisfied the Examiners, has this day been awarded Degree of Bachelor of Science General.

Vice-Chancellor

Dean

Registrar

Date 12 TH DECEMBER, 1984.

APPENDIX G.3 BIODIVERSITY ASSESSMENT SPECIALIST REPORT

Sazi
Environmental Consulting

BIODIVERSITY ASSESSMENT REPORT FOR CITY PARKS AND ZOO'S ENVIROMENTAL STUDIES IN KLIP MIDDLE SOWETO WITHIN THE CITY OF JOHANNESBURG MUNICIPALITY, GAUTENG PROVINCE.

MAY 2016

Title:	BIODIVERSITY ASSESSMENT REPORT FOR THE KLIP MIDDLE SOWETO WITHIN THE CITY OF JOHANNESBURG MUNICIPALITY, GAUTENG.
Author:	Aphiwe-Zona Dotwana
Reviewed by:	Lufuno Nemakhavhani
Status of report:	FINAL
Document control	IN000046/2016
First Issue:	May 2016

Approved by:

.....

Nonkanyiso Zungu, Pr.Nat.Sci (Reg. No. 400194/10)

Specialist Ecologist/Wetland specialist

Date: 23 June 2016

environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

DETAILS OF SPECIALIST AND DECLARATION OF INTEREST

	(For official use only)
File Reference Number:	12/12/20/ or 12/9/11/L
NEAS Reference Number:	DEA/EIA
Date Received:	

Application for integrated environmental authorisation and waste management licence in terms of the-

(1) National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended and the Environmental Impact Assessment Regulations, 2014; and

(2) National Environmental Management Act: Waste Act, 2008 (Act No. 59 of 2008) and Government Notice 921, 2013

PROJECT TITLE

City Parks and Zoo's Environmental Studies that will be undertaken in Klip Middle Soweto and Upper Rietspruit, within the City of Johannesburg Municipality

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Indemnity

This report is based on survey and assessment techniques which are limited by time and budgetary constraints relevant to the type and level of investigation undertaken. The findings, results, observations, conclusions and recommendations given in this report are based on the author's best scientific and professional knowledge as well as information available at the time of study. Therefore the author reserves the right to modify aspects of the report, including the recommendations, if and when new information may become available from ongoing research or further work in this field, or pertaining to this investigation.

Although the author exercised due care and diligence in rendering services and preparing documents, she accepts no liability, and the client, by receiving this document, indemnifies the author against all actions, claims, demands, losses, liabilities, costs, damages and expenses arising from or in connection with services rendered, directly or indirectly by the author and by the use of this document.

EXECUTIVE SUMMARY

i. INTRODUCTION

SAZI Environmental Consulting cc was appointed by Lebone Engineering on behalf of Johannesburg City Parks and Zoo to undertake a biodiversity (fauna and flora) assessment study for the management of water catchments and sources, namely, water conservation and preservation of the ecological reserve and the goal of reduced water pollution in Johannesburg's Water Management Units within the City of Johannesburg Municipality. The site assessment was undertaken in May 2016 and the purpose was to assess the biodiversity status and ecological sensitivity of the study areas.

ii. METHODOLOGY

Data sources from the literature consulted and used for the execution of this study included: IUCN, NFEPA, NPAES, CBA and ESA for Gauteng, SIBIS.

Lists of mammals and reptiles which are likely to occur at the site were derived based on distribution records from the literature and various spatial databases (SANBI's SIBIS and BGIS databases).

An ecological sensitivity map of the site was produced by integrating the information collected on-site with the available ecological and biodiversity information available in the literature and various spatial databases.

iii. RESULTS

- Vegetation

The project site is located within the Grassland Biome of South Africa with approximately two percent currently conserved (Le Roux, 2002). The site traverses the Carltonville Dolomite Grassland, Soweto Highveld Grassland and the Tsakane Clay Grassland. The grasslands of South Africa are important both in terms of their terrestrial and river biodiversity, and the services they provide to most of South Africa's human population. This importance is increasingly being recognised, and the National Grasslands Biodiversity Program (a

partnership between the private sector, government and non-governmental organisations to secure and sustain biodiversity in the Grassland biome) is an example of this increasing recognition. Within the assessment area, Grassland species were identified.

- Vertebrates

A number of herds of *Bos taurus* (Cattle), *Capra aegagrus* (Goats), *Equus africanus asinus* (Donkeys), *Equus cabalus* (Horses) were observed grazing along sections of the river. *Canis lupus familiaris* (Dogs) were also observed at various sections along the river.

- Invertebrates

A variety of invertebrates were observed on site during the time of assessment; such as the *Limenitis arthemis*, *Papilio demodocus, Neptis laeta* and *Danaus plexippus*.

- Avifauna

A diversity of avifauna species was observed on site during the time of assessment along the Klipspruit River. Avifauna species observed on site included *Passer melanurus* (Cape sparrow), *Bubulcus Ibis (*Cattle egret*), Ardea herodias* (Blue heron), *Ardea cinerea* (Grey heron), *Threskiornis aethiopicus* (African sacred ibis), *Bostrychia hagedash* (Hadeda ibis), *Vanellus Armatus* (Blacksmith lapwing), *Alopochen aegyptica* (Egyptian goose), Anas erythrorhyncha (Red-billed teal),*Columba livia domestica* (Feral pigeon) and *Patagioenas fasciata* (Band-tailed pigeon). *Gallus gallus domesticus* (Chickens) were also observed in houses near the river.

- Red data species and critical biodiversity

According to the Gauteng C-Plan the study area lies within both a Critical Biodiversity Area and an Ecological Support Area (Figure 5). This means that even though no red data or threatened species were observed during the time of assessment, due diligence and care must be undertaken to identify species of importance that may occur in this area at any time.

- Sensitivity

The study area is regarded to as that of **High** sensitivity. It is designated High sensitivity status based on the following:

- According to NFEPA, the study area contains wetland areas as seen in the figure below;
- The study area contains a highly polluted river (Klipspruit River) and wetlands which cannot endure any more pollution;
- The study area constitutes the Endangered Tsakane Clay Grassland;
- The wetlands provide numerous human benefits for residents such as grazing land for livestock, flood attenuation, recreational activities etc.;
- Although alien invasive species were observed at various sections of the study area, indigenous vegetation was dominant;
- The river provides habitat for a variety of indigenous avifauna species.

iv. RISK FACTOR AND RECOMMENDATION

Individuals of protected species within the development footprint, if found, should be translocated to a safe area on the property. A permit obtainable from the Department of Agriculture, Forestry and Fisheries (at a national level) and the Gauteng Department of Agricultural and Rural Development (provincial level), is required before any protected species may be interfered with. The details of the impacts and recommendations are included in the report.

v. CONCLUSION

This report has illustrated and described the fauna and flora of the Klip-Middle Soweto Water Management Unit and the impacts on the river, wetlands and biodiversity. The major impacts on the wetland and river vegetation were found to be illegal dumping due to over population, overgrazing and trampling by livestock, unsustainable reed harvesting, erosion, gabion collapse and sedimentation among other impacts. The report has also included rehabilitation methods that can be used to re-establish vegetation and for the recovery of the system as a whole. In order for all the rehabilitation methods described to successfully work, follow up maintenance is crucial. Three categories of solutions were suggested and described in this

report i.e. heavy systems (including concrete structures such as gabions and river mattresses), light systems (including erosion control fences, treating footpaths with mulches), and soil bioengineering techniques (use of a variety of plant species without any inert materials). Of the rehabilitation techniques described, vegetation can reduce any conditions causing slope and river bank instability and erosion in general. Lastly, rehabilitation measures must be suitable for animal and plant communities so as to ensure that a full rehabilitation of our natural ecosystems can occur.

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DEFINITION OF TERMS

Alien species: The alien species are species which is originated from foreign country.

Assessment Criteria: The environmental impacts are assessed with mitigation measures (MM) and without mitigation measures (WMM).

Biodiversity: Biodiversity is the variety of plant and animal life in the world or in a habitat.

Biome: A major biotic unit consisting of plant and animal communities having similarities in form and environmental conditions, but not including the abiotic portion of the environment.

Confidence: The confidence level can be classified as medium during the construction phase. However, the confidence level becomes low during the operational phase.

Conservation: Conservation is the management of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations.

Duration: The period of time during which something continues.

Ecosystem: Organisms together with their biotic environment, forming an interacting system, inhabiting an identifiable space.

Ecosystem services: Activities that help to maintain an ecosystem but are not directly part of energy flows and nutrient cycles. Examples include pollination, dispersal, population regulation, and provision of clean water and the maintenance of liveable climates (carbon sequestration).

Endangered: A taxon is endangered when it is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future.

Endemic: An 'Endemic Species' is one that is only found in that region and nowhere else in the world. As such they are of conservation concern because they are not widespread and may be confined to only one or two protected areas.

Exotic: a species introduced either accidentally or deliberately by human actions into places beyond its natural geographical range.

Intensity: The intensity of the development can be categorized as medium since the impacts of the activity will alter the environment due to increased disturbance of the site by heavy machinery.

IUCN: International Union for Conservation of Nature.

Probability: Is a way of expressing knowledge or belief that an event will occur or has occurred.

Red Data: A list of fauna and flora species that require environmental protection.

Significance with and without mitigation: The significance without mitigation is medium; meaning that the impact of the development is of moderate importance and is considered to have a medium negative impact. The significance with mitigation is low, meaning that the negative impact of the operation is of importance but is reduced by the mitigation measures.

Species diversity: A measure of the number and relative abundance of species (see biodiversity).

Species richness: The number of species in an area or habitat.

NFEPA: National Freshwater Ecosystem Priority Areas.

NPAES: National Protected Areas Expansion Strategy.

CBA: Critical Biodiversity Area.

ESA: Ecological Support Area.

SIBIS: SANBI Integrated Biodiversity Information System.

WMU: Water Management Unit

1. INTRODUCTION

As the persistent drought conditions continue to affect South Africa, water shortages have been reported across the country with the Gauteng Province, Limpopo Province and KwaZulu-Natal Province being the most affected. Rand Water which provides water to the municipalities of Gauteng including Johannesburg Water which distributes water to the areas within the City of Johannesburg Municipality has given a warning of low levels of reservoirs in the province. To reduce the pressure imposed on water supply, Rand Water has at the time of compiling this report placed the Gauteng Province under level 2 water restrictions. This entails that residents and businesses are to refrain from watering of gardens between 6am and 6pm, no filling of swimming pools and no using of hoses to wash cars or paved areas. This highlights the urgent need for the conservation of water resources to ensure access to a sustainable and reliable water resource for South Africa. With the City committing to the conservation of its sustainable resources in its Growth Development Strategy (GDS) will ensure that the City is doing its part to prevent further impacts on our water resources and preventing similar water shortage crises that we are currently experiencing.

In addition to this broader national challenge outlined above, the environmental aspects associated with the current high rate of development within the Johannesburg Metropolitan areas has contributed to the pollution of vulnerable Water Management Units (WMU) within the City of Johannesburg municipality and further put pressure on the already stressed water infrastructure. The expansion of urban development has resulted in a loss of valuable riverine environment, with diversions and illegal weirs, encroachments, channelization and the construction of roads, bridges and culverts across rivers, resulting in their deterioration. In addition, the increased intensity of storm water runoff from urbanized catchments as well as increased pollutant loads is placing additional pressure on rivers which cannot always sustain such impacts. This leads to flooding, bacteriological pollution, chemical pollution, litter, exotic vegetation, bad visual impact, odour and sediment and obviously needs to be addressed.

This project will address some of these pressing issues, as part of its support to the GDS goals, which advocate for Management of Water Catchments and Sources, namely, water conservation and preservation of the ecological reserve and the goal of reduced water pollution. WMUs play a role in the management of storm water as they act as receivers of storm water diverted through the storm water drains from the city streets to the water units. The wetlands within the WMU serve as a natural filtration system. The Water Management Unit (WMU) to be covered in this particular project is the Klip Middle Soweto Water Management Unit.

SAZI Environmental Consulting cc was appointed by Lebone Engineering on behalf of Johannesburg City Parks and Zoo to undertake a biodiversity (fauna and flora) assessment study for the management and rehabilitation of water catchments and sources, namely, water conservation and preservation of the ecological reserve and the goal of reduced water pollution in Johannesburg's Water Management Units within the City of Johannesburg Municipality. The site assessment was undertaken in May 2016 and the purpose was to assess the biodiversity status and ecological sensitivity of the study area.

1.1 TERMS OF REFERENCE

The terms of reference for the current study were as follows:

- To undertake a vegetation survey on site and, to identify and provide species lists;
- To identify possible Red Data floral and faunal species and important habitat that may occur within the proposed site;
- To provide a desktop faunal survey of the area;
- To provide an indication of the relative conservation importance and ecological function of the study area in terms of flora and fauna; and
- Identify measures to reduce the impacts, and/or measures to optimise or enhance possible benefits to biodiversity.

1.2 LIMITATIONS AND ASSUMPTIONS

The major potential limitation associated with the project is the narrow temporal window allocated for sampling. Ideally, a site should be visited during seasons optimal for the identification of the full complement of plant and animal species present in an area. However, this is rarely possible due to time and cost constraints and therefore, the representation of the species sampled at the time of the site visit should be critically evaluated.

Another limitation is that regarding some of the plant species that have no foliage above ground, and for all practical purposes disappear during the dry season when they are dormant, and only reappear after the annual spring rains, some birds migrate; insect and small mammals are inactive and bullfrogs are buried deep in winter.

To overcome these limitations, the site visit took place in the autumn season. This season is marked by slow rainfall and warm sunshine which are both favourable for plant and animal life. Animals have not gone into hibernation during this season and the warm temperatures during the day warm the ground making it softer and more yielding to plants. According to Pooley (2005), many herbaceous plants in winter die back and reptiles hibernate (Jacobsen, 2005) while many amphibians are still out to mate in the autumn rainfall (Du Preez & Carruthers, 2009).

Therefore, the fauna and flora assessment undertaken by SAZI in autumn offers a representative sample of the species diversity on site as the time of assessment offers optimal conditions for fauna and flora observation. As such no additional site visits are necessary in other seasons as most fauna and flora will either be in hibernation or dormant.

The lists of fauna and flora for the site were based on those observed at the site as well as those likely to occur in the area based on their distribution and habitat preferences. This represents a sufficiently conservative and cautious approach which takes the study limitations into account.

2. GENERAL LOCATION AND LANDUSE

The Water Management Unit (WMU) to be covered in this particular project is the Klip-Middle Soweto Water Management Unit. This Water Management Unit is roughly bounded by Koma Road on the south-west, Elias Motsoaledi on the west, Main Reef Road on the north and Klip Valley Road on the south east. The area in which the Water Management Unit flows (Soweto) is predominantly used for residential purposes (with both formal and informal structures) (figure 1). Soweto is the most populous black urban residential area in South Africa with a population of approximately a million residents. There are various industrial areas and shopping centres within Soweto. Figure 2 illustrates the general location of the assessment site.

Figure 1: General land use in Soweto is residential

Figure 2: Study site (area of interest and assessment in blue)

3. METHODOLOGY

3.1 DATA SOURCING AND REVIEW

A literature review and a GIS desktop exercise preceded the site visit so as to identify fauna and flora that may occur during the site visit. During the site visit, samples of vegetation were taken and photographs taken for identification. Data sources from the literature that were consulted and used where necessary in the study include the following:

3.1.1 VEGETATION

Vegetation types and their conservation status were extracted from the South African National Vegetation Map (Mucina and Rutherford, 2006) as well as the National List of Threatened Ecosystems (2011), where relevant. Critical Biodiversity Areas (CBA's) for the site and surroundings were extracted from the Fine Scale Conservation Plan of Gauteng. Information on plant and animal species recorded for the project site were extracted from the SABIF/SIBIS database hosted by SANBI. The IUCN conservation status of the species in the list was also extracted from the database and is based on the Threatened Species Programme, Red List of South African Plants (2014). Important catchments and protected areas expansion areas were extracted from the National Protected Areas Expansion Strategy (NPAES) (2008). The following books (but not limited to) were used to identify flora species observed on site: Field guide to trees of Southern Africa (van Wyk & van Wyk, 2013), Guide to grasses of Southern Africa (van Oudtshoorn, 2012), Photo guide of wildflowers of South Africa (Manning, 2012), Guide to plant families of southern Africa (Koekemoer, Steyn & Bester, 2014), A field guide to wildflowers of KwaZulu-Natal and the Eastern region (Pooley, 2005).

3.1.2 FAUNA

Lists of mammals, reptiles and amphibians which are likely to occur on the site were derived based on distribution records from the literature and various spatial databases (SANBI's SIBIS and BGIS databases).

Literature consulted includes Jacobsen (2005) and Alexander and Marais (2007) for reptiles, Du Preez and Carruthers (2009) for amphibians, Friedmann and Daly (2004) and Stuart & Stuart (2015) for mammals. Sasol Birds of Southern Africa (Sinclair, Hockey, Tarboton & Ryan, 2011) was used for Avifauna identification.

Apart from the literature sources, additional information on reptiles was extracted from the SARCA web portal, hosted by the ADU, http://vmus.adu.org.za.

The faunal species lists provided are based on species which are known to occur in the broad geographical area, as well as a preliminary assessment of the availability and quality of suitable habitat at the site. The conservation status of each species is also listed, based on the IUCN Red List Categories and Criteria version 2014.2 and where species have not been assessed under these criteria, the CITES status is reported where possible.

3.2 SENSITIVITY MAPPING & ASSESSMENT

An ecological sensitivity map of the site was produced by integrating the information collected on-site with the available ecological and biodiversity information available in the literature and various spatial databases. This includes delineating the different habitat units identified in the field and assigning sensitivity values to the units based on their ecological properties, conservation value and the observed presence of species of conservation concern. The ecological sensitivity of the different units identified in the mapping procedure was rated according to the following scale:

Low – Areas of natural or transformed habitat with a low sensitivity where there is likely to be a negligible impact on ecological processes and terrestrial biodiversity. Most types of development can proceed within these areas with little ecological impact.

Medium- Areas of natural or previously transformed land where the impacts are likely to be largely local and the risk of secondary impact such as erosion low. These areas usually comprise the bulk of habitats within an area. Development within these areas can proceed with relatively little ecological impact provided that appropriate mitigation measures are taken.

High – Areas of natural or transformed land where a high impact is anticipated due to the high biodiversity value, sensitivity or important ecological role of the area. These areas may contain or be important habitat for faunal species or provide important ecological services such as

water flow regulation or forage provision. Development within these areas is undesirable and should only proceed with caution as it may not be possible to mitigate all impacts appropriately.

Very High – Critical and unique habitats that serve as habitat for rare/endangered species or perform critical ecological roles. These areas are essentially no-go areas from a developmental perspective and should be avoided as much as possible.

In some situations, areas were also classified between the above categories, such as Medium-High, where it was deemed that an area did not fit well into a certain category but rather fell most appropriately between two sensitivity categories.

3.3 CRITICAL BIODIVERSITY AND ECOLOGICAL SUPPORT AREAS (EAS's)

A Gauteng Conservation Plan (C-Plan 3.3) was used to determine the ecological status of the study area. Landscape features associated with ESAs (termed spatial surrogates for ESAs) that are essential for the maintenance and generation of biodiversity in sensitive areas and that require sensitive management were incorporated into C-Plan 3. Spatial surrogates included dolomite, rivers, wetlands, pans, corridors for climate change and species migration, ridges and low cost areas for Gauteng (received from Dr. S. Holness).

3.4 SITE VISIT

The site visit took place in May 2016. During the site visit, all sensitive features present within and around the proposed development area were noted and recorded. A full plant species list for the site was developed and all fauna observed were recorded.
The presence of sensitive habitats within the site such as wetland features and rivers were noted in the field and recorded on a GPS.

Searches were undertaken specifically for Red List plant species (according to SANBI and GDARD) and any other species with potential conservation value (according to GDARD). Historical occurrences of threatened plant species were obtained from the South African National Biodiversity Institute and GDARD. For all threatened plant species that may occur along the proposed site, a rating of the likelihood of it occurring is given as follows:

- **LOW**: no suitable habitats occur on site / habitats on site do not match habitat description for species;

- **MEDIUM**: habitats on site match general habitat description for species (e.g. grassland), but detailed microhabitat requirements (e.g. rocky grassland on shallow soils overlying dolomite) are absent on the site or are unknown from the descriptions given in the literature or from the authorities;
- **HIGH**: habitats found on site match very strongly with the general and microhabitat description for the species (e.g. rocky grassland on shallow soils overlying dolomite); and
- **DEFINITE**: species found on site.

All exotic species categorised as alien invaders or weeds (as listed in Alien and Invasive Species List, 2014) were recorded.

4. RESULTS (VEGETATION)

The study area is located within the Grassland Biome of South Africa (Mucina & Rutherford, 2006). The area where the site is located comprises of areas with both natural habitat and transformed habitat of which the majority of the area is highly transformed. Three vegetation types occur within the area; the Tsakane Clay Grassland, Carleton Dolomite Grassland and the Soweto Highveld Grassland. The majority of the site lies within the Tsakane Clay Grassland. According to Mucina et al. (2006), the Tsakane Clay Grassland is endangered with 1.5 % conserved and more than 60 % transformed by urbanisation, cultivation, dam building and mining. Mucina et al. (2006) describe the Tsakane Grassland as a vegetation type that occurs on flat and slightly undulating low hills and plains. *Brachiaria serrata, Cynodon dactylon, Acanthospermum austral* and *Anthospermum* species dominate the majority of this vegetation type with a variety of other grasses such as *Themeda triandra, Heteropogon contortus, Elionurus musticus* and a number of *Eragrostis* species and forbs . The most prominent forbs within this vegetation type include the families of Asteraceae, Rubiceae, Malvaceae, Lamiceae and Fubaceae. Disturbance within the Tsakana Clay Grassland leads to an increase in the abundance of the grasses *Hyparrhenia hirta* and *Eragrostis chloromelas.*

Appendix 2 includes a list of species (vegetation) which have been used to prioritise conservation in Gauteng while appendix 3 provides a list of threatened birds in Gauteng. However, none of the listed threatened vegetation and bird species were identified on this particular site.

Mucina & Rutherford (2006) list the following as important taxa occurring in the Tsakane Clay Grassland:

- **Grasses**

Brachiaria serrata, Cynodon dactylon, C. hirsutus, Digitaria ternata, Elionurus muticus, Panicum maximum, Cymbopogon pospischilii, Eragrostis (chloromelas, patentipilosa, racemose, plana), Heteropogon contortus, Microchloa caffra, Hyparrhenia hirta, Setaria nigrirostris, Trachypogon spicatus, Abildgaardia ovata, Andropogon schirensis, Cymbopogon caesius, Diheteropogon amplectens, Melinis nerviglumis, Panicum gilvum, Setaria sphacelata, Themeda triandra.

- **Herbs**

Vernonia oligocephala, Acanthospermum austral, Ajuga ophrydis, Eriosema salignum, Euryops transvaalensis subsp. *transvaalensis, Gerbera viridifolia, Helichrysum nudifolium var. nudifolium, H, rugusolum, Hermannia depressa, Lotononis macrosepala, Nidorella hottentotica, Pentanisia prunelloides* subsp. *latifolia, Peucedanum caffrum, Rotheca hirsute, Selago paniculata, Senecio coronatus, S. inornatus, Sonchus nanus, Aspidoglossum ovalifolium, Hypoxis rigidula* var. *pilosissima, Striga asiatica.*

- **Low shrubs**

Anthospermum rigidum subsp. pumilum, Chaetacanthus setiger, Tephrosia capensis var. acutifolia, Thesium impeditum.

- **Small trees**

Acacia caffra, Acacia karroo, Celtis Africana, Protea caffra, Zanthoxylum capense, Ziziphus mucronata.

4.1 VEGETATION IDENTIFIED ON SITE

The majority of the site consists of grassland and disturbed areas with bare ground and rocky outcrops surrounded by built-up area. Roads and bridges also cross the site. The site mainly consists of a herbaceous layer dominated by grasses as well as sporadic tree species and a discontinuous layer of shrubs. A number of species identified on the site were alien species. Alien invaders are plants that are of exotic origin and invade areas that were previously pristine

or invade ecological niches (Bromilow, 2001). However, not all weeds are exotic in origin but more often than not, they grow aggressively and are the most opportunistic in an ecosystem. Consequently, most often they are the most noticeable and dominant within an area. Ground disturbances such as mining, urbanisation, roads, trampling and excavations often lead to the dominance of exotic species. The majority of the site is used as a residential area as well as for grazing livestock. Through anthropogenic activities within the Soweto vegetation type, a number of exotic and weed species were identified on site. Figure 3 below gives a general view of the site. A plant species list recorded during the assessment is provided as Appendix 1. A total of 64 species were recorded during the assessment of which 20 are declared weeds or invader plants (Table 1). The proportion of exotic and declared weeds or invader species is high (31 %), a reflection of high levels of disturbance and transformation in the study area.

Figure 3: General overview of the site with rocky outcrops

4.1.1 GRASSES AND REEDS

See appendix 1 for a list of grasses and reeds observed on site.

4.1.2 HERBS

See appendix 1 for a list of herbs observed on site.

4.1.3 TREES AND SHRUBS

See appendix 1 for a list of trees and shrubs observed on site.

4.1.4 DECLARED WEEDS AND INVADERS

Concern is growing over the way in which alien/exotic plants are invading large areas within South Africa. Invasive species are a major threat to the ecological functioning of natural systems as well as the productive use of the land, and should ideally be removed if they are serving no ecological function. In terms of the amendments to the regulations under the National Environmental Management: Biodiversity Act, 2004 (Act no. 10 of 2004) – Alien and Invasive Species (AIS) Regulations which became law on 1 October 2014, landowners are legally responsible for the control of invasive alien plants on their properties. There are currently 198 alien species listed as declared weeds and invaders, and have been divided into three categories (Henderson, 2001):

- Category 1 plants are prohibited and must be controlled;
- Category 2 plants (commercially used plants) may be grown in demarcated areas proving that there is a permit and that steps are taken to prevent their spread; and
- Category 3 plants (ornamentally used plants) may no longer be planted; existing plants may remain, as long as all reasonable steps are taken to prevent the spreading there of, except within the flood line of watercourses and wetlands.

The assessed area had alien invasive species infestations at various points. The area was surrounded by a number of alien invasive tree and shrub species such as *Eucalyptus camaldulensis, Solanum mauritanum, Solanum sisymbriifolium* and *Salix* species as well as locations infested by stands of various invasive herbs such as *Datura ferox, Canna indica, Ipomoea purpurea* and *Cirsium vulgare.* These species should be controlled to prevent further

infestation. Table 1 below gives a list of alien and invasive species observed on site.

Table 1: alien and invasive plants observed on site

SCIENTIFIC NAME	COMMON NAME	INVADER CATEGORY
Eucalyptus camaldulensis	Red Gum	Category 1b in riparian zones
Melia azedarach	Seringa	Category 1b Category 3 in urban areas
Morus alba		Category 3
Datura stramonium	Thorn Apple	Category 1b
Datura ferox	Thorn Apple	Category 1b
Arundo donax	Spanish Reed	Category 1b
Pinus sp.	Pine	Category 2
Solanum sisymbriifolium	Wild tomato	Category 1b
Agave sisalana	Sisal	Category 2
Salix babylonica	Weeping willow	Category 2
Solanum mauritianum	Bugweed	Category 1b
Canna indica	Canna lilly	Category 1b
Cirsium vulgare	Bull thistle	Category 1b
Ipomoea purpurea	Common Morning Glory	Category 1b
Ipomoea carnea	Bush morning glory	Category 1b
Pennisetum clandestinum	Kikuyu grass	Category 1b
Pennisetum setaceum	Fountain grass	Category 1b
Cortaderia selloana	Pampas grass	Category 1b
Tagetes minuta	Tall khakiweed	Declared weed category 1
Cynodon dactylon	Couch grass	Declared weed category 2

Due to the high abundance of alien species, their competitive advantage resulting from their primary ecological strategy, these species are able to colonise new areas rapidly and out-compete existing indigenous vegetation.

Bearing this in mind, there are a number of considerations that will be required when undertaking the rehabilitation of the disturbed wetlands. These considerations will ensure that the current value of the wetland and river system is not adversely impacted following rehabilitation.

4.1.5 MEDICINAL PLANT SPECIES

South Africa is home to a diversity of cultural groups all of which utilise plant species for some purpose. A number of these species are highly prized for their traditional healing properties; especially for "*muthi*" (they have ethno-medicinal value). An estimated 28 million people in South Africa consume about 19 500 tonnes of medicinal plant material per annum (Mander, 1998). The Gauteng Province alone has around 1 049 plant taxa utilised for medicinal properties, 31 % of the total estimated number of ethno-medicinal plants in South Africa (Arnold et al, 2002). It is therefore imperative that the population demographics of these species (especially the more conspicuous and sought-after species) be closely monitored and utilised in a sustainable manner. Although most of these plant species are regionally widespread and abundant, some of the more economically important species should be envisaged as high priority conservation entities (Pooley, 1998).

During the site assessment, a variety of plant species with medicinal properties were observed. These include:

- *Eucalyptus camaldulensis*: the oil found in the leaves of this tree can be used as an antiseptic and for relieving coughs and sore throats;
- *Datura ferox*: although very poisonous, the juice from this herb can be used to treat hair loss and dandruff by applying it over the scalp;
- *Tagetes minuta*: this herb can be used to treat inflammation;
- *Melia azedarach*: known medicinal uses of this tree include treating leprosy, scrofula and is also used as an antiseptic for sores and ulcers;
- *Ipomoea purpurea*; the seed of this herb is used in the treatment of oedema, oliguria and constipation.

4.2 FAUNA (VERTEBRATES)

Reduction in fauna numbers and occurrence in the Gauteng Province can be attributed to the introduction of alien and invasive plants that do not offer a variation in plant communities, with most of the plant species being unpalatable.

The Water Management Unit flows through Soweto which is primarily used for residential purposes with various sections within Soweto and adjacent the wetlands and rivers used for grazing. Quite a number of the households kept domestic animals in their homes and most often than not, it was observed during the site assessment that these animals roamed around

the township and grazed along the rivers. A number of herds of *Bos taurus* (cattle), *Capra aegagrus* (Goats), *Equus africanus asinus* (Donkeys), *Equus cabalus* (Horses) were observed grazing along sections of the river and directly on wetlands. *Canis lupus familiaris* (Dogs) were also observed at various sections along the river.

Fauna observed on site are indicated on Table 2 below.

Table 2: Fauna observed on site

	*Capra aegagrus hircus* (Goats)
	*Equus africanus asinus* (Donkeys)

	*Equus caballus* (Horses)

4.2.1 AVIFAUNA

A diversity of avifauna species was observed on site during the time of assessment along the Klipspruit River and associated wetland areas. Avifauna species observed on site included *Passer melanurus* (Cape sparrow), *Bubulcus Ibis (*Cattle egret*), Ardea herodias* (Blue heron), *Ardea cinerea* (Grey heron), *Threskiornis aethiopicus* (African sacred ibis), *Bostrychia hagedash* (Hadeda ibis), *Vanellus Armatus* (Blacksmith lapwing), *Alopochen aegyptica* (Egyptian goose), Anas erythrorhyncha (Red-billed teal),*Columba livia domestica* (Feral pigeon), *Lanius collaris* (Common fiscal) and *Patagioenas fasciata* (Band-tailed pigeon). *Gallus gallus domesticus* were also observed in houses located on the river banks.

Table 3 presents some of the avifauna observed on site at the time of assessment.

Table 3: Avifauna observed on site

	*Passer melanurus* (Cape sparrow)
	*Ardea herodias* (Blue heron)
	*Ardea cinerea* (Grey heron)

	*Threskiornis aethiopicus* (African sacred ibis)
	*Bostrychia hagedash* (Hadeda ibis)

	*Vanellus Armatus (Blacksmith lapwing)*
	*Anas erythrorhyncha* (red-billed teal)

With regards to reptiles, none were observed during the time of assessment.

4.2.2 INVERTEBRATES

Invertebrates belonging to the class of insects in the order Lepidoptera and the family Acrididae were observed during the site visit. The *Limenitis arthemis* (commonly known as the white admiral), *Papilio demodocus* (Citrus swallowtail), *Neptis laeta* (Common sailor butterfly), *Danaus plexippus* (African monarch butterfly), were observed on site (Table 4).

Table 4: Invertebrates observed on site

	*Limenitis arthemis*

5. RED DATA SPECIES

According to the IUCN Red Data database, Threatened species are species that are facing a high risk of extinction. Any species classified in the IUCN categories of Critically Endangered, Endangered or Vulnerable is a threatened species (Figure 4).

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 of Extinct in the Wild (EW), Regionally Extinct (RE), Near Threatened (NT), Critically Rare, Rare, Declining and Data Deficient - Insufficient Information (DDD).

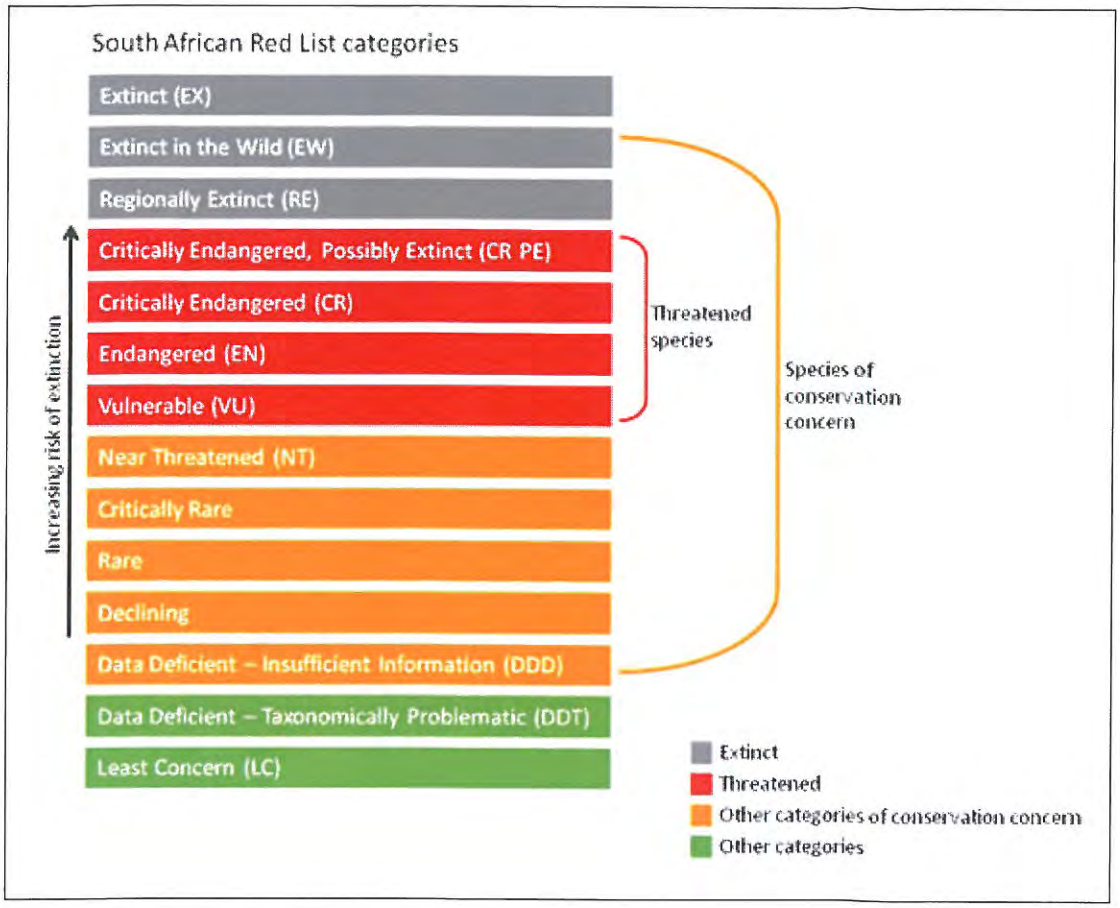


Figure 4: IUCN Red data categories

No red data species were observed on site. In addition, no species of conservation value were identified on site.

6. SENSITIVITY

6.1 GAUTENG CONSERVATION PLAN

The Gauteng Conservation Plan (C-Plan), 2014 incorporates plants, birds, mammal, reptile and invertebrate data that are regarded as threatened according to the Red Data Book class. These attributes were included in the systematic conservation plans in South Africa. In addition, the Gauteng C-Plan 3.3 includes near threatened and rare species.

According to the Gauteng C-Plan the study area lies within both a Critical Biodiversity Area and an Ecological Support Area (Figure 5). This means that even though no red data or threatened species were observed during the time of assessment, due diligence and care must be undertaken to identify species of importance that may occur in this area at any time. Figure 5 below indicates the study area in relation to the Gauteng Conservation Plan.

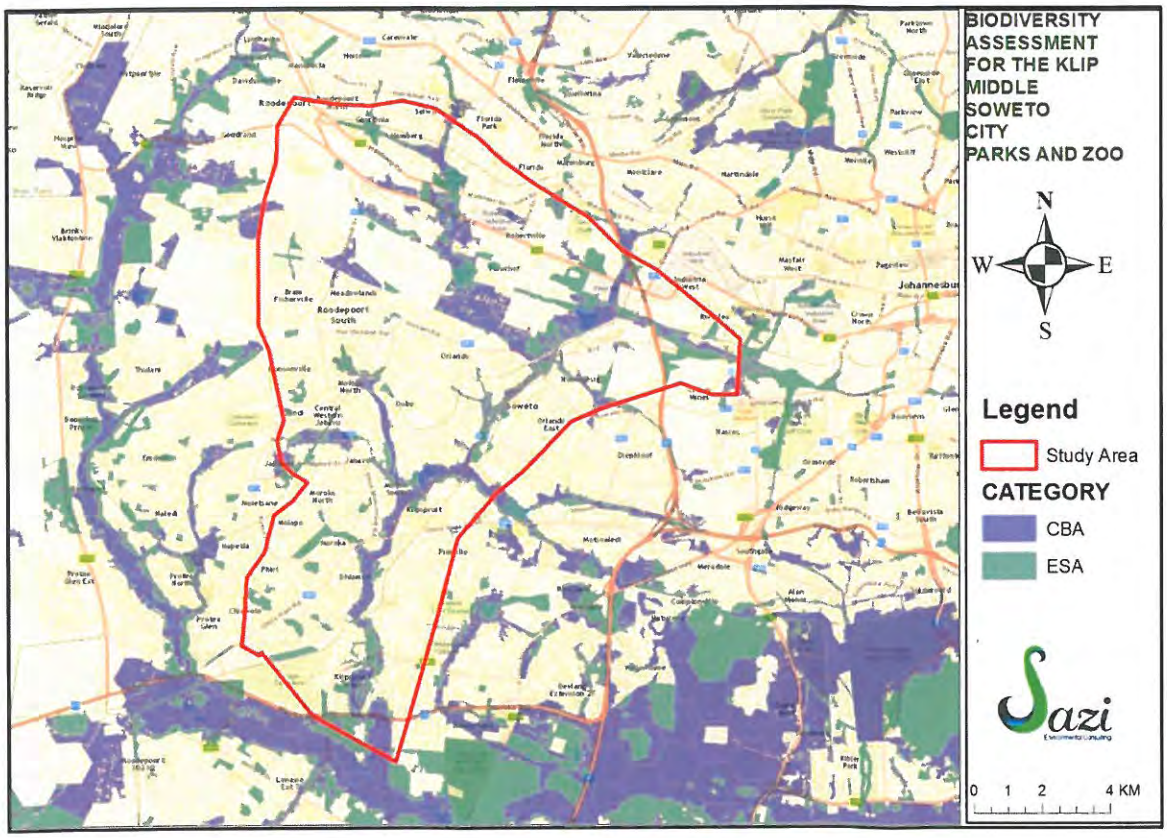


Figure 5: Study area within a Critical Biodiversity Area and Ecological Support Area

6.2 THREATENED ECOSYSTEM

The study area falls under the Tsakane Clay Grassland of South Africa. This Grassland vegetation type is Endangered.

Three ecosystem types occur within the assessment area; Critical (CR), Endangered (EN) and Vulnerable (VU) as indicated in Figure 6 below. A Critical Biodiversity Area is an area necessary for meeting biodiversity targets for ecological processes, ecosystems and species and the majority of the assessed area lies within a Critical Ecosystem.

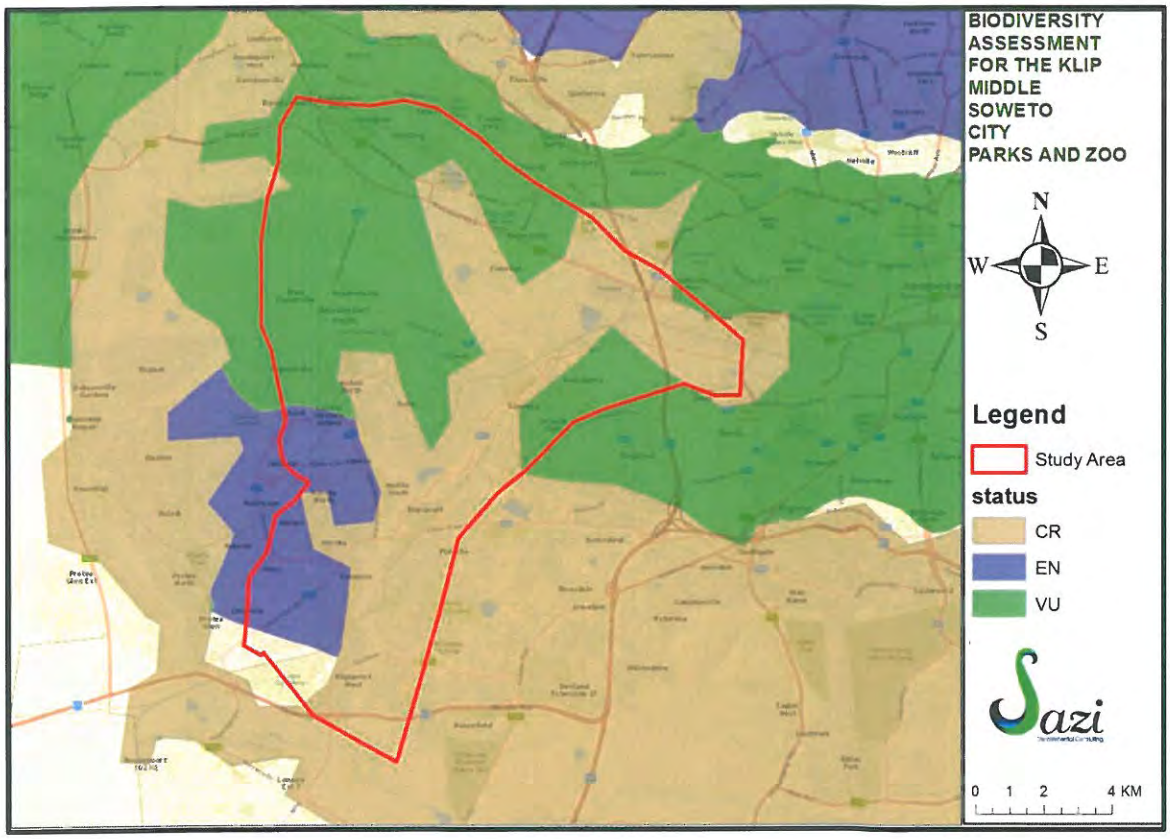


Figure 6: Ecosystem status within the assessment area

6.3 SENSITIVE AREAS WITHIN ASSESSMENT SITE

The study area is regarded to as that of **High** sensitivity. It is designated High sensitivity status based on the following:

- According to NFEPA, the study area contains wetland areas as seen in the figure below;
- The study area contains a highly polluted river (Klipspruit River) and wetlands which cannot endure any more pollution;
- The study area constitutes the Endangered Tsakane Clay Grassland;
- The wetlands provide numerous human benefits for residents such as grazing land for livestock, flood attenuation, recreational activities etc.;
- Although alien invasive species were observed at various sections of the study area, indigenous vegetation was dominant;
- The river provides habitat for a variety of indigenous avifauna species.

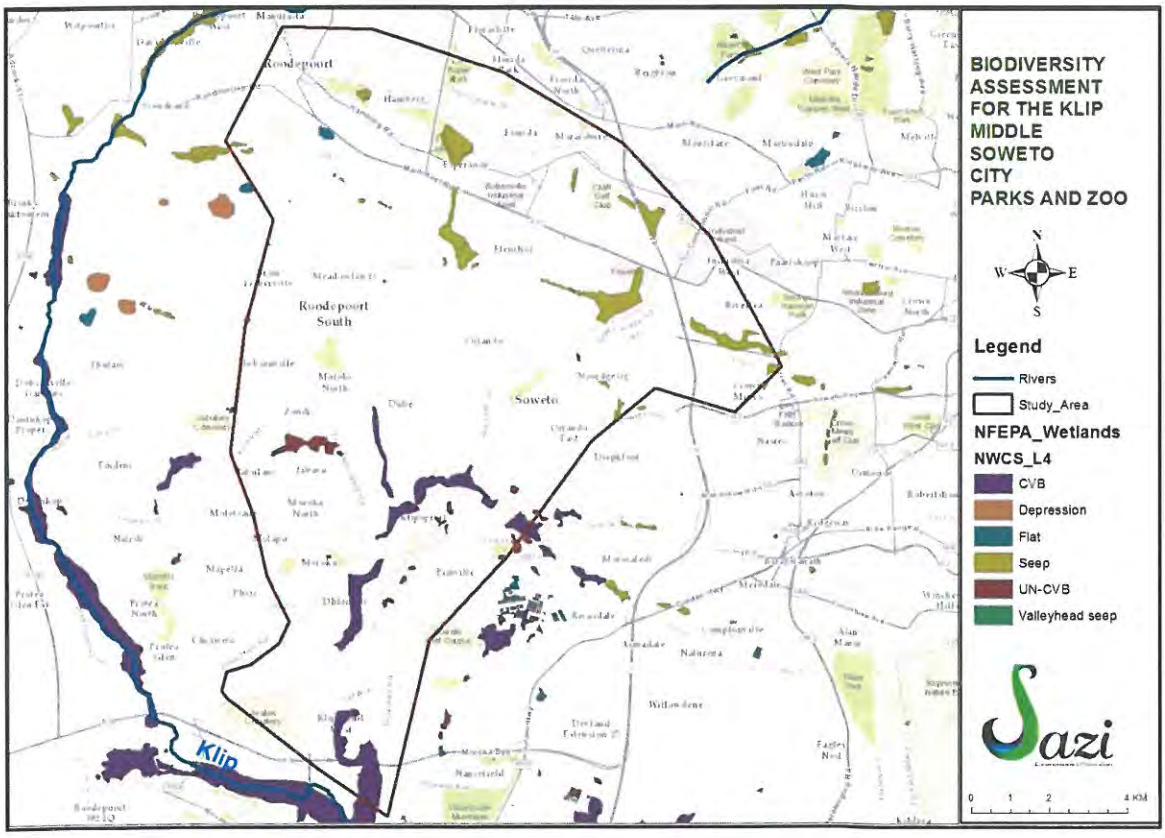


Figure 7: Sensitive areas within the assessment area

7. BIODIVERSITY MANAGEMENT PLAN FOR KLIP-MIDDLE SOWETO WATER MANAGEMENT UNIT

The Klipspruit River meanders through the heart of Soweto and is the main river flowing through Soweto. It is one of the few rivers that have large wetlands in Johannesburg. Many of the wetlands in Soweto are in a poor state as observed through a detailed assessment. In order for the wetlands in the Klipspruit River to be rehabilitated to a state where they are once again able to perform their functions, a Biodiversity Management Plan is a necessity. This Management Plan focuses on flora and fauna management and rehabilitation of the wetlands as vegetation and associated animal species are indicators of healthy and properly functioning wetlands. The overall aim of the Plan is that the vegetation of the Klipspruit River wetlands returns to a healthy state to be able to perform functions such as flood attenuation and trapping of pollutants and sediment. Fauna also needs to return to the wetlands for ecological and aesthetic value. Within this broad aim, the following management objectives have been identified as a guide to the implementation of the Plan:

7.1 MANAGEMENT OBJECTIVES

1. To promote the recovery of indigenous vegetation, to ensure that each indigenous species persists in the long term within the wetlands of Klipspruit;
2. To reduce the current levels of threats and risks to the biodiversity of the Klipspruit wetlands;
3. To improve and maintain the extent of indigenous vegetation, including quality, functionality and connectivity for priority species in the Klipspruit;
4. To ensure no indigenous species or ecological communities become threatened;
5. To improve the baseline information of biodiversity along the Klipspruit River and associated wetlands; and
6. To inform and encourage community support in the implementation of the plan.

8. LEGISLATIVE CONTEXT

South African environmental law chronicles the legal rules in South Africa concerning the philosophical, economic, and social and statute issues raised by the pursuit to protect and

conserve the environment in the country. The environmental law in South Africa incorporates natural resource conservation and utilisation as well as development and land use planning. Enforcement issues are also considered. The primary acts that relate to the Klipspruit Biodiversity Management Plan are described below:

NATIONAL ENVIRONMENTAL MANAGENENT ACT, 1998 (Act no. 107 of 1998)

This act provides the underlying framework for environmental law in South Africa. The legislation in the act provides for environmental management in the country.

THE NATIONAL ENVIRONMENTAL MANAGEMENT BIOIDVERSITY ACT, 2004 (Act no. 10 of 2004)

The purpose of the National Environmental Management Biodiversity Act (NEMBA) is to provide for the management and conservation of South Africa's biodiversity within the framework of the National Environmental Management Act (107 of 1998). This includes: the protection of species and ecosystems; the sustainable use of indigenous biological resources; the fair and equitable sharing of benefits arising from bioprospecting involving indigenous biological resources; and the establishment of a South African National Biodiversity Institute.

THE NATIONAL WATER ACT, 1998 (Act no. 36 of 1998)

The act contains comprehensive provisions for the protection, use, development, management, conservation and control of South Africa's water resources. It is the principal legal requirement relating to water resources management in South Africa.

THE NATIONAL ENVIRONMENTAL MANAGEMENT WASTE ACT, 2008 (Act no. 59 of 2008)

The purpose of the act is, "To reform the law regulating waste management in order to protect health and the environment by providing reasonable measures for the prevention of pollution and ecological degradation and for securing ecologically sustainable development; to provide for institutional arrangements and planning matters; to provide for national norms and standards for regulating the management of waste by all spheres of government; to provide for specific waste management measures; to provide for the licensing and control of waste management activities; to provide for the remediation of contaminated land; to provide for the national waste information system; to provide for compliance and enforcement; and to provide for matters connected therewith."

9. CURRENT STATUS OF THE KLIP-MIDDLE SOWETO MANAGEMENT UNIT

The Klipspruit and associated wetlands are in a bad state mainly due to pollution of the wetlands and river itself. All wetlands and sections of the river are in an acceptable state, especially around Moroka Dam, Dobsonville, Orlando West, Kliptown area, Diepkloof, Jabavu and Meadowlands East. The following section provides a description of the current status of the Klipspruit River and wetlands.

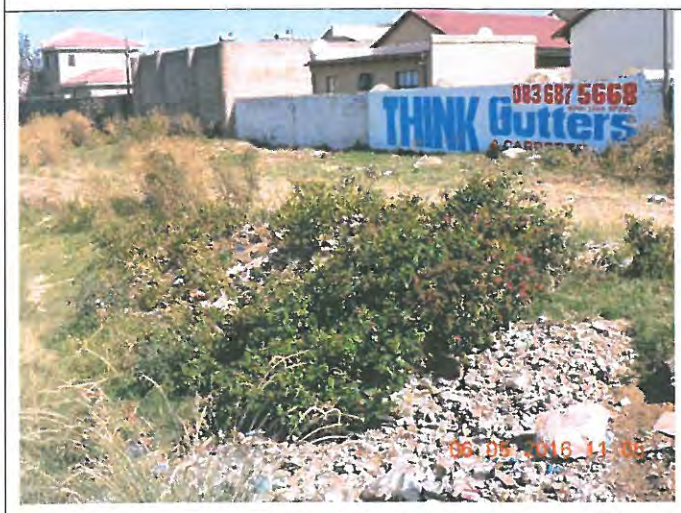
9.1. ORLANDO WEST PARK SECTION OF WMU

This section of the Klipspruit River has part of a channelled valley-bottom wetland in it. It is located at the following coordinates; -26, 22816 S and 27,921929 E. The following table (table 5) describes the condition of this section of the Klipspruit.

Table 5: Current impacts at Orlando West Park section of WMU

	At this point, there was an informal housing settlement in which livestock farming was practised. The household farmed cattle, goats, chickens and pigs. This household is situated at the banks of the Klipspruit River on the riparian zone of the wetland. This has negative effects on the river and associated wetlands as there was evidence of trampling on the wetland vegetation. There was also cow dung on the vegetation as well as in the water.
	Along the wetland and river, there were large sections of eroded banks especially on the right hand bank. The left hand bank

	was vegetated with few and small sections eroded.
 	The riverbed and riparian zone were covered in a thick, black oily substance that appeared similar to sludge. This substance was found throughout this section of the river with algal blooms mixed with this oily substance dominant as you move along the river. The water had a distinct pungent smell. In such conditions, in such dirty water, it would be difficult for most fauna to survive. In addition, vegetation on the riparian zone has been covered with this substance and consequently, it cannot grow healthily.

	Along the river there were boulders present that hindered water flow and disabled some vegetation from growing successfully. The dark substance was very apparent and stuck on the boulders at this point.
	A major problem identified during the site assessment was extreme pollution in the form of illegal dumping in the river and wetland. The water was polluted with paper, plastic, bottles, cans, clothes and electronics. The riparian zone and water had high levels of litter. This has negative implications for vegetation as the litter has toxins that seep into the soil impeding growth and also affecting ground water.
	The river riparian zone and seasonal zone of the wetland were infested with stands of invasive weeds such as *Tagetes minuta* as well as invasive species such as the bush morning glory (pictured).

	At various points of the wetland and river area, dead birds were observed. These avifauna species lay dead just outside the water on the permanent zone of the wetland. Their death may be attributed to the poor water quality of the Klipspruit which could be very toxic for birds and other fauna.
	Overgrazing was also observed on a large scale on the seasonal and temporal zone of the wetland.

9.2 KLIPSPRUIT VALLEY ROAD SECTION OF WMU

This section of the Klipspruit River flows behind a group of houses (located at coordinates -26, 245495 S; 27,899972 E). The wetland at this point was highly vegetated with *Phragmites australis*. However, there were stands of weeds and invasive species on the seasonal and temporary zone of the wetland. There was a lot of construction debris and it appeared that the temporary zone of the wetland was recently excavated or graded rather. The temporary zone of the wetland was used as an illegal dumping site with people actively dumping as the assessment was taking place. There were also many brick making companies near the wetland which could explain the high levels of rubble observed on the temporary zone of the wetland. There was also a very strong odour from the water at this point. The table below illustrates some of the impacts on vegetation.

Table 6: Current impacts at Klipspruit Valley Road section of WMU

	The construction debris on temporary zone where it appears vegetation has been cleared for illegal dumping.
	Residents actively dumping on vegetation.
	Stands of *Tagetes minuta, Ipomoea purpurea* and *Ipomoea carnea* (weeds and alien invasive species) on seasonal zone of wetland.

	Temporary zone of wetland excavated with vegetation removed.

9.3 KLIPSPRUIT VALLEY ROAD TO CHRIS HANI ROAD SECTION OF WMU

This is a large wetland section along the Klipspruit Valley Road that goes past Chris Hani Road. It is located at coordinates -26, 151064 S; 27, 534582 E. This wetland area was assessed and found to be fairly healthy with regards to vegetation. The vegetation was abundant especially in the permanent and seasonal zone. There was a strong presence of weeds (*Tagetes minuta and Conyza species)* on the seasonal and temporary zone. On closer observation of the river, there was evidence of undercutting as many reeds and trees had fallen over with exposed roots. There was minimal erosion on the river bank (this needs attending to before it worsens). The temporary zone at this point had a rocky landscape with rocky outcrops. The area as a whole was used for grazing as there were groups of individuals tending to goats. There was also a large garden (which had been ploughed with furrows approximately 1 m deep) present in the seasonal zone extending to the temporary zone. There was also evidence of burning of vegetation in the temporary zone near the garden. There was evidence of crop farming in the garden. The major impact in this section was the amount of litter deposited on the temporary zone. The temporary zone appeared to be used for illegal dumping. In addition there were sections of the seasonal and temporary zone that showed signs of overgrazing (frequent areas of bare ground, large amounts of dung). There were also sections with high levels of sedimentation (-26, 256519 S; 27,891401 E). Sedimentation has detrimental effects such as burial of bottom-dwelling organisms. Sedimentation has negative impacts such as the loss of important and sensitive habitat, loss of wetlands, and loss of submerged vegetation. There were also human faeces on the seasonal zone. The landscape of the temporary zone showed signs of disturbance with rocky outcrops and boulders. The

water was also polluted with algae and debris such as tyres and plastics. The table (Table 7) below describes the impacts on vegetation at this point.

Table 7: Current impacts at Klipspruit Valley Road to Chris Hani Road section of WMU

	Illegal dumping in seasonal zone.
	Illegal dumping on wetland edge.

	Sedimentation
 	River bank erosion

	Boulders on temporary zone of wetland. These boulders flatten vegetation and hinder its growth.
	Water with algae and tyres.

9.4 THOKOZA PARK/MOROKA DAM

Thokoza Park is located at -26, 263267 S; 27,880685 E. Moroka Dam is located at -26, 261818 S; 27,875713 S.

Thokoza Park is a park in Soweto used for recreational purposes and aesthetic value. The park is somewhat maintained but pollution in the form of litter is extensive. During the time of assessment, the park was fully packed with residents who either were having celebrations, drinking, playing soccer of or just walking through the park. The number of people at the park was large and this maybe one of the causes of the high levels of litter at the park. With regards to the river flowing through the park, the water was very dirty with a distinct bad odour. The water had algae. Algae in general and algal blooms can have detrimental effects on wetland fauna and fauna. Algae can block out sunlight to under water grasses. Some algal species

can also produce chemicals that are toxic to humans and aquatic life. Algae also produce offensive smells. Algal blooms also use up a large amount of oxygen when they decay which can suffocate aquatic life. The water was polluted with litter, erosion of river banks was observed, gabion collapse was also observed which appeared to lead to more erosion of soil and vegetation. The water also had a dark green colour. The river bank was dominated by the alien invasive *Salix* species and *Solanum* species. The round culverts used to channel the water through the park are clogged with litter and this presents an ecological imposition to fauna and flora as they are unable to pass through these culverts. People at the park also urinated in the water and surrounding vegetation. Table 8 below depicts the conditions at Thokoza Park.

Table 8: Current impacts at Thokoza Park section of WMU

	Round culverts blocked with litter, posing a threat to ecological connectivity for fauna and flora.
	People urinating in the water.

	Erosion
	Collapsed gabions
	Dirty water with algae and litter.

Moroka Dam (an artificial dam created in 1960).

The construction of the dam itself was and still is a major impact on vegetation. Natural vegetation that occurred in the location of Moroka Dam was removed, consequently leading

to habitat degradation and fragmentation. The current state of the Moroka Dam is poor. The channel feeding into the dam is heavily polluted with litter (illegal dumping). The Rockville area of the Moroka Dam is mainly residential with households practising livestock farming. Around the dam, a trip of goats was observed grazing on the permanent and seasonal zone of the wetland as well as donkeys. There was a fetid smell from the water. Alien invasive species were also present in the seasonal zone of the wetland area. The water flowing into Morkoa dam had algae. Erosion was minimal. There were, however, *Salix* species along this channel and in some sections around Moroka Dam.

The channel feeding the dam is channelized and flows in-between houses. This channel is heavily polluted with litter. There was also man-made crossings placed over vegetation.

The following table (Table 9) depicts the state at Moroka Dam area.

Table 9: Current impacts at Moroka Dam section of WMU

	Algae with black soot
	Alien invasive species in permanent zone of wetland

 	Algal bloom in channel feeding into Moroka Dam
	Pollution in seasonal zone of wetland

	Livestock grazing in seasonal zone (goats)
	Donkeys grazing in temporary zone
	River channelized and polluted with litter. The creation of this channel has degraded vegetation and increased erosion. The channel also has sedimentation in progress.

9.5 MOFOLO PARK SECTION OF WMU

The assessed section of the WMU at this point also flows past, Nhlapo Road, Xuma Street and Mahalefele road. The wetland area is located at -26, 241491 S; 27, 89025 E. The impacts on vegetation at this point included; illegal dumping (construction debris and household litter as well as carcasses) that has flattened and degraded vegetation, alien invasive species that were present in clumps as well as human faeces in the temporary zone of the wetland. There was also evidence of burning on the vegetation in the seasonal zone of the wetland at this point. There was also presence of sedimentation. The table (Table 10) below describes the impacts on vegetation at this point.

Table 10: Current impacts at Mofolo Park section of WMU

	Construction debris and litter on seasonal zone of wetland
	Burning on temporary zone of wetland

	Carcasses on temporary zone of wetland
	Alien invasive and weed infestation on seasonal and temporary zone
	Sedimentation

9.6 JABAVU SECTION OF WMU

This section of the WMU consisted of a large wetland area adjacent to the river (-26, 239247 S; 27, 87292 E). The river channel is itself eroded at various sections. The area is also used as an illegal dumping site as there were large amounts of litter in the water as well as in the permanent and seasonal zones of the wetland. There were also large amounts of animal dung in the whole wetland area. The wetland area had clumps of weeds and invasive species. Collapsed gabions were also observed along the river banks as well as collapsed concrete walk ways across the river. These walkways have flattened vegetation and contributed to the eroded banks. Gabions have also collapsed into the river impeding water flow and hindering vegetation growth. Across this wetland area, the river flows through a culvert under a railway line. On the other side of the railway line is a wetland area. At this section (-26, 238839 S; 27, 871249 E), there is an informal settlement adjacent to the wetland. Here, there is a lot of alien invasion as well as litter. There were also sections where gully erosion had taken place.

Table 11 below depicts the impacts at this point of the WMU at Jabavu area.

Table 11: Current impacts at Jabavu area of the WMU

	Alien invasive *Bidens pilosa* on seasonal zone of wetland

	Alien invasive *Salix species* with weed invader *Tagetes minuta* on river bank and permanent zone of wetland
	Collapsed walkway on river and vegetation
	Erosion

	
	Debris impeding water flow
	Animal dung

	Informal settlement (far end of photograph) and *Tagetes minuta* (-26, 238839 S; 27, 871249 E)
	Gullies forming (-26, 238839 S; 27, 871249 E)

9.7 KLIPTOWN SECTION OF WMU

At this section of the WMU is the Kliptown informal settlement. The river flows behind this informal settlement and is heavily polluted. The wetland is also behind the settlement. Residents don't have sanitation services and as a result, they dump litter in the river, dump dirty water into the wetland and relieve themselves in the river as the mobile toilets provided by the government have reached full capacity. The vegetation in the wetland is polluted with litter, and water with soap and other detergents. There is a bad odour from the wetland water. There is also dirty, polluted water streaming from the shacks into the wetland and river area. The WMU at this section is found at coordinates -26, 274883 S; 27, 884905 E.

The table (table 12) below describes the conditions with a negative impact on fauna and flora.

Table 12: Current impacts at Kliptown section of WMU

	Dirty water streaming from the informal settlement into the wetland
	Litter in the form of plastics, fabric, papers and more
	Illegal dumping

	Dirty water and litter in seasonal zone of wetland

9.8 DOROTHY NYEMBE PARK (MEADOWLANDS EAST)

At this point the river flows through Dorothy Nyembe Park (-26. 222794 S; 27. 876948 E). The park is maintained to a certain degree. However, the wetland within the park is polluted with litter. There are also collapsed gabions along the banks and riparian zone. The permanent zone was also eroded. There was also a leaking sewage pipe installed above the tributary leading into the park which was leaking into the river and on vegetation. Alien invasive species were also observed on the riparian zone and permanent zone of the wetland. There was also presence of algal blooms as well as sedimentation. There were also goats grazing in the park and outside the park. Table 13 below illustrates the impacts on the wetland vegetation at Dorothy Nyembe Park.

Table 13: Current impacts at Dorothy Nyembe Park section of WMU

	Leaking sewage pipe above tributary feeding into Dorothy Nyembe Park
	*Solaunum mauritianum* (alien invasive species) on banks of tributary leading to Dorothy Nyembe Park
	Erosion and sedimentation at Dororthy Park entrance

	Erosion on right hand bank. Erosion at this point begins from this point **(-26. 222053 S; 27. 874101 E)** and continues all along the route.
	Channelized section of river feeding Dorothy Nyembe wetland from entrance of park. Litter and erosion prevalent.
	Collapsed gabion structures.

Table 14: Current impacts at Diepkloof section of WMU

 	Heaps of animal carcasses being burnt
	Foamy water with algae

	*Datura ferox* (alien invasive species dominant in seasonal and temporary zone)
	Animal trampling in permanent and seasonal zone
	Household practising livestock farming on permanent and seasonal zone of wetland

	Degraded landscape with litter and animal carcasses

9.10 FLEURHOF DAM

The Fleurhof dam is located between Meadowlands Soweto and Florida in Roodepoort at coordinates -26°12'11.88" S; 27° 54'29.91" E. The dam was built about 110 years ago on the upper Klipspruit. During the time of assessment the Dam water appeared clear at the top. The reed area within the dam was small and sporadic. There were different species of ducks swimming in the dam. However, there was litter (tyres, and few plastic bags on the edges of the dam). The dam was also surrounded by mine dumps, slimes dams and tailings dam. It is therefore not far-fetched to suspect that run-off from the mine areas affects the Fleurhof Dam water. A water quality test would need to be performed to confirm this. There was also construction of residential flats next to the dam. This may also have negative effects on the dam and dam life. The dam construction itself could have had lasting environmental impacts. A dam holds back sediments that would naturally replenish downstream ecosystems. When a river is deprived of its sediment load, it seeks to recapture it by eroding the downstream river bed and banks (which can undermine bridges and other riverbank structures). Riverbed incision caused by erosion will also lower groundwater tables along a river, lowering the water table accessible to plant roots. Table 15 below describes the impacts at Fleurhof dam. When taking a closer look at the dam water, reddish sediment was observed in the dam and in a channel flowing into the dam. The channel flowing into the dam was infested by weeds and alien vegetation. The red sediment could be alkaline waste from the tailings dams nearby.

Table 15: Current conditions at Fleurhof dam

	Mine dumps located behind the dam
	Construction of residences in close proximity to the dam
	Red sediment

10. SUMMARY OF IMPACTS FOR KLIP-MIDDLE SOWETO WMU

The main sources of pollution for wetlands are overcrowding and a lack of sanitation facilities in informal settlement areas of Soweto. Overflowing and leaking sewers are also an endemic problem in most areas and compromise water quality. In most cases, run-off water carries the pollution to storm water drains and, in turn, to dams. Paving and hardened surfaces increase run-off water into rivers and wetlands. Missing and corroded manhole covers result in litter and rubble getting into the storm water systems which block the sewers and cause them to overflow into storm water culverts. Sources of industrial pollution also play a major role in the degradation of the wetlands and rivers of Soweto. Many of Soweto's wetlands are in a shocking state. The pollution is astounding because people still use them as a dumping ground for their building material and domestic waste and animal carcasses. Many people in Soweto seem not to understand the value and importance of wetlands and only view them as empty pieces of land where they can plough mealies or graze their cattle. One of the major troubling issues of the degraded and polluted wetlands is that local children swim in the dirty wetlands. This is a health hazard as people continue to pollute these areas. The unsustainable harvesting of wetland reeds is also a major wetland vegetation issue in Soweto as hawkers harvest reeds year round in order to make furniture to sell and make a living.

11. BIODIVERSITY MANAGEMENT THROUGH REHABILITATION

With the rehabilitation of the Klip-Middle Soweto WMU wetland sites, restoration to a pre-settlement state should not be attempted. Instead, the rehabilitation should focus on establishing a dense and protective plant cover as well as stabilisation of erosion, improving water quality and flow for aquatic and terrestrial fauna. Degradation cannot be "fixed" overnight and the results of degradation vary from patches of unvegetated soil to gully and reel erosion. Soil permeability and chemistry vary from site to site and they influence which plants will or will not grow on a particular site. Rehabilitation plans and designs must then be site specific. Using the correct plants for revegetation is crucial. For any rehabilitation to be successful, the cause of degradation (e.g. extensive illegal dumping, trampling, overgrazing, unsustainable harvesting and unmaintained stabilisation structures) must be removed or significantly reduced. All the sites under observation are part of residential areas. It is important to design practical and affordable rehabilitation plans to ensure implementation in these areas. It is also important to note that wetland and river rehabilitation are slow processes dependent on

climatic conditions and timeous follow up maintenance of soil erosion control structures and treatments. If these are not done, then rehabilitation will fail with money being wasted.

11.1 REHABILITATION TECHNIQUES

The points assessed along the Klip-Middle Soweto WMU had similar impacts with variations at some points. The major impacts on the watercourses on all points include: extensive illegal dumping, severe erosion on river banks and wetlands, sedimentation and silting, dominance of alien invasive species in seasonal and temporary zones of wetland, collapsed gabions, pipes and old sewage outfall pipes, woody debris and concrete structures impeding water flow, animal trampling of wetland and river soil and vegetation, overgrazing, unsustainable reed harvesting and human disturbance (people residing on river banks). The following rehabilitation methods are recommended:

- **Mulching**

Slopes to be rehabilitated need to be stabilised with a layer of geotextile then seeded making them ready for mulching. The sources of mulch are easy to find and save costs. In some of the sites, Acacia species such as Acacia Karoo are abundant and these thorn trees are a valuable renewable resource and if carefully harvested, will leave no visible impact or have any adverse ecological impacts. Alien Eucalyptus trees which were present in sections of the Water Management Unit can also be sourced and used. Mulch from these trees must however be applied when dry as the leaves and branches have a chemical impact on soil. Spanish reed (*Arundo donax)* is another potential source for mulching. Adequate mulch material needs to be available at all times. Harvesting of the trees can be done by cutting every third or fourth tree or large shrub about 300mm above ground so as to ensure that the habitat is not too drastically changed. All the cut branches of trees to be used as mulch must be fed through a motorised chip mulch machine which must be set to produce a rough mulch consisting of bits approximately 100-150mm long to form a dense mat on the surface. A layer of about 60 to 100mm should be a suitable layer of mulch but this needs to be tested on site to confirm whether it is suitable. It is important to note that a great deal of mulch will be required. It is also important to appreciate that the temporary loss of thorn trees and other shrubs is valuable for the rehabilitation work and that the cut trees will resprout with time.

Mulching can be implemented at the Orlando West section of the WMU and the Klipspruit Road to Chris Hani Road section of WMU.

- **Erosion Control Fences**

These comprise of simple low wire netting and jute geotextile fences with a thick mulch layer which can trap and slow run-off water and become a beneficial vegetated belt across degraded landscapes or stabilise small drainages and dongas. These fences can be used on slopes to treat small rills. These fences must be used with mulch for effective water control and microclimate creation. Fences with mulch check water flow and stabilise small dongas. When placing these mulched fences, it is imperative to work around existing vegetation. To check big runoff flows, fences can be placed in series. These fences are recommended because they slow down the speed of destructive runoff water, they act as windbreaks by trapping windblown dust and seeds, they are quick to install, they allow water to pass through at a slow rate but plant litter and silt remain behind thus helping reconstruction of topsoil.

Erosion control fences can be installed by unskilled labour by following these steps:

1. A sturdy low fence of iron standards and wire netting is made across the flow of water and spaced approximately 3-5m apart;
2. A thick layer of mulch is then placed over the full length of the fence;
3. Geotextile must always be used together with wire netting;
4. On steeper slopes, the fences are installed netting in series down the slope.

The erosion control fences can be applied at the following sections of the WMU:

- Orlando West section;
- Klipspruit Valley Road to Chris Hani Road section;
- Diepkloof section; and
- Jabavu section.

- **Stone gabions and river mattresses**

Traditional stone gabions have a place in any rehabilitation plan and are especially useful for rehabilitating degraded drainage channels and donga systems. Gabions are wire mesh boxes, baskets or containers filled with rock to prevent soil erosion and to retain soil particles. Gabions are normally used together with geotextiles to reduce water velocities and to re-capture river

bed sediment in rivers and streams. River mattresses or flat gabions are extensively used in river courses where soil erosion is a problem over a sloped or flat area in need of protection against soil loss or scour. Gabions should only be used if a sufficient source of stone is available nearby. The availability of material close to the erosion system to be treated will determine the type of gabion or barrier that is used. It is not sensible or productive to transport stones over great distances, with great costs, instead of searching and using alternative materials closer to the work site. Stones should be considered as animal habitat. In any natural environment either terrestrial or aquatic, when you turn over a stone it is safe to assume that an amazing variety of invertebrates will be found under those stones including ants, beetles, slugs, spiders and centipedes. These invertebrates together with microscopic soil organisms are the architects and engineers of soil. To construct and enrich the soil they need moisture, protection from predators and the sun which is provided by the rocks they live under.

When constructing gabions, the correct shape, height and foundation of a gabion is crucial and planning is necessary as the cost of failure is very high. Gabions should be used when absolutely necessary when the problem cannot be solved with a cheaper and faster method. For the assessed watercourse points of the WMU in Soweto, gabions are necessary for bank stabilisation and halting erosion as many of the riverbanks assessed were eroded and unstable.

Gabions can be constructed and installed by following the steps below. It is necessary however to investigate the construction and installation of gabions on river banks and watercourses in depth as the following steps are a simpler guideline:

1. First a trench is dug into the donga floor/river banks/slopes and sides;
2. The trench is then lined with wire netting and the gabion is constructed with stones;
3. The wire netting is then closed at the correct height over the gabion;
4. Geotextile is lined on the upstream side of the gabion to trap silt and plant material.

Important sections of the WMU that are in need of gabion structures are found in table 16 below:

Table 16: WMU sections in need of gabion structures for erosion control

	
Various sections on the Klipspruit Valley Road to Chris Hani Road are eroded and need gabion support	Gabion baskets can be used to stabilise banks
	
The Jabavu section also has various points needing gabion structures	Box gabions can be used to stabilise river banks

The Jabavu section highly eroded and in need of gabion support structures

Gabion mattress can be useful at this particular slope as it is slanting

Gabion collapse at the Jabavu section

Gabion baskets are more durable

Gabion collapse and erosion at Dorothy Nyembe Park	Gabion mattress can be useful at this particular slope as it is slanting

- **Sediment control**

Sediment is a pollutant in its own right, causing turbidity in the water that limits light penetration and prohibits healthy plant growth on the river bed. Sediment also covers much of the river bed with a blanket of silt that smothers life. By covering up gravel and cobble, sediment destroys the spawning grounds and habitat of desirable fish species. Finally, sediment is an important carrier of a critical pollutant: phosphorus. This nutrient stimulates excessive algae growth in the water column. When the algae decompose, it depletes dissolved oxygen from the water, reducing the quality of life forms that are able to survive.

Many of the assessed points had high levels of sedimentation. The following methods are recommended to control and manage sedimentation. The following methods are cost-effective and easy to install:

1. Silt fence: it is a woven geotextile fabric fence with hardwood stakes attached. It is designed to trap silt behind the fabric;
2. Gravel bags: Used to filter large silt particles or reduce flow velocity;
3. Within the assessed points, sedimentation is caused by fallen trees and concrete structures such as pipes that have collapsed into the watercourse. These need to be removed to reduce sedimentation.

The following table (Table 17) depicts how gravel bags can be utilised at some of the sections of the WMU.

Table 17: Utilisation of gravel bags in some sections of WMU

 Sedimentation at Dorothy Nyembe Park	 Use of gravel bags to combat sedimentation
 Sedimentation at Klipspruit Valley Road to Chris Hani section of WMU	 Use of gravel bags to combat sedimentation

- **Treating footpaths**

Footpaths were observed at various points of the assessed sections of the wetland and river. Treating footpaths is a simple technique for preventing soil erosion and rehabilitating degraded landscapes. Mulching is used in treating footpaths as it protects the soil and creates favourable conditions for plant establishment. This method is suitable for flat surfaces and moderate slopes. Most footpaths across watercourses are flat. When applying this method, it important not to remove any rooted plants in the paths. Water flow along the path also needs to be halted. Footpaths need to be rehabilitated because they channel runoff water and become dongas if not treated. Top soil and valuable water is lost along eroding paths and numerous

networks of paths contribute to drying out of soil. Treating footpaths is cost-effective as no engineering equipment is necessary and unskilled labour can be used. This necessitates the rehabilitation of footpaths by following the steps below:

1. Hard capped soil along the paths can be loosened by using simple equipment such as a broad fork or mattock pick;
2. Jute geotextile (soil saver) is cut and laid along the paths;
3. The covered paths are then given a fairly thick mulch;
4. A complete treated footpath is the result.

- **Preventing Overgrazing and animal trampling**

The first step in preventing overgrazing of wetlands is ensuring that the grazing capacity of the wetland is not exceeded. On average, the grazing capacity of a wetland is 1.5 times higher than non-wetland areas although this depends on many factors such as the water regime and species composition of the wetland. In an area like Soweto where regular monitoring of grazing in wetlands is not possible, a fixed rotational grazing system of 14 days in and 24 days out of the wetland must be applied. Another important aspect in preventing overgrazing in wetlands is to discontinue all grazing when soils are waterlogged (as this is when erosion begins) until waterlogging seizes. When rotational grazing is applied, this means that trampling will also be minimised.

- **Invasive alien species control**

Invasive alien plants, animals and microbes are organisms that are imported or introduced into countries where they outcompete indigenous species. In South Africa, invasive alien species are the biggest threat to biodiversity and cost the country billions of Rands in damage every year. They pose not only a threat to biological diversity but to water security as well as the ecological functioning of natural systems. In South Africa, 198 plants have been characterised as invasive. The removal of invasive alien species also increase water yield which is necessary in a water scarce municipality such as City of Johannesburg. A range of methods can be used to control invasive alien plants. These include:

1. Mechanical methods: burning or removing of alien invasives, felling;
2. Chemical Methods: using herbicides that are environmentally friendly;

3. Biological control: the use of species-specific diseases and insects from the country of origin of the alien plant;
4. Integrated control: the use of the combination of all three methods mentioned above. In most cases, this type of approach is necessary in preventing enormous impacts.

Mechanical methods are recommended in the removal of invasive alien plant species in the Klip-Middle Soweto Water Management Unit because these methods have been found to be the most successful and safest for the environment. Although they may be time consuming in larger areas and labour intensive, they are the safest. Also, the assessed points in this Water Management Unit are not very big for the use of mechanical methods. Chemical methods are easier to apply but may have unwanted effects on water resources. Although biocontrol methods have been proven to be safe and host-specific, they do not completely exterminate populations of their host plants because few host plants always survive. Biocontrol also works slowly by comparison to other techniques and take at least 5 years on average to establish successfully before attacking its host and damaging it.

An integrated approach of mechanical and chemical methods may be the best option for quick and effective invasive alien species eradication. For trees on slopes these options can be utilised:

1. Basal bark: Application of suitable herbicide in diesel can be undertaken to the bottom 250mm of the stem. These applications should be by means of a low pressure droplet spray from a narrow angle sloid cone nozzle;
2. Hand pull: Grip the young plant by hand low done and pull (gloves are recommended);
3. Ring barking: Bark must be removed from the bottom of the stem to height of 0.75-1.0m. All bark must be removed to below ground level for best results. Where clean de-barking is not possible due to crevices in the stem or exposed roots are present, a combination of bark removal basal stem treatments should be carried out. Bush knives or hatchets should be used for debarking;
4. Frill: angled cuts downwards into the cambium layer can be made using an axe or bush knife through the bark in a ring. Ensure to effect the cuts around the entire stem and apply herbicide into the cuts.

For this control programme for alien vegetation, follow up control (control of root suckers, coppice growth etc.) and maintenance control (annual control to sustain low alien plant numbers) are compulsory.

Invasive alien control techniques that can be utilised in this Water Management Unit include the following:

- Most trees across the Management Unit can be felled and removed using chainsaws, bowsaws and brushcutters;
- The hand pull methods can be used to removed small shrubs and herbs such as the *Solanum mauritianum;*
- The assessed points had a number of mature alien invasive tree species that cannot be eradicated mechanically only. An integrated method is necessary for such trees as *Eucalyptus, Melia azedarach, Salix babylonica* etc. Felling and treating stumps with herbicide and follow-up removal of seedlings is essential. Biocontrol to reduce seed output is also crucial.
- The removal of weeds and alien invasive species in the permanent, seasonal and temporary zone of the wetland is imperative. Species such as *Tagetes minuta, Ipomoea purpurea, Canna indica, Solanum mauritianum, Salix* species (among others) were observed in the permanent and seasonal zone of the wetland. This has negative implications for the wetland as most of these species are alien invasives and drain the water in these zones which is essential for the survival of the wetland. Weeds also indicate that these zones are degrading. Removal of alien invasives and weeds in these zones is of primary importance. (See appendix 1 for a list of species occurring in different zones of the wetland).

- **Soil bioengineering techniques**

The most important objective of any rehabilitation programme is to establish a permanent and dense cover of soil protecting plants as quickly as possible. Soil bioengineering techniques refer to the use of a variety of plant species without any artificial materials. It is imperative that locally occurring plants are utilised as they have the best survival chance of conditions in degraded areas. All sowing (planting) must be followed by some form of micro-habitat treatment such as mulching with local plant material, surface geotextile or moisture capturing hollows. Seeding and sowing onto eroded sites only will NOT be successful. The priority in revegetation of riparian zones is the stabilisation of watercourse banks and channel plug development. It is for this reason that it is important to deliberately select and place plants with vigorous rooting growth characteristics that will accelerate natural plant succession. It is preferable to plant once the wet season has started as this eliminates the need for frequent watering. An alternative to seed germination is the uprooting of small seedlings between 40 mm to 10 mm high from an area where they are many. Small seedlings are likely to transplant more successfully than large ones.

The following (but not limited to) are a selection of plants suitable for bank stabilisation in rivers and wetlands and channel plug development:

1. *Cyperus papyrus*
2. *Typha capensis*
3. *Phragmites australis*
4. *Setaria megaphylla*
5. *Cynodon dactylon*
6. *Imperata cylindrica*
7. *Leersia hexandra*
8. *Stenotaphrum secundatum*
9. *Acroceras macrum*
10. *Hermarthria altissima*

The herbaceous plants can be planted either by digging out clumps with a spade, planting as whole plant or splitting into slices or separate rhizomes and planting into trenches on the streambank or channel floor at ½ to 1 m spacing.

Trees are also suitable for bank stabilisation and channel plug development. The following trees (but not limited to) are recommended:

1. *Acacia karroo*
2. *Acacia robusta*
3. *Bridell micrantha*
4. *Celtis Africana*
5. *Buddlej saiviifoia*
6. *Ficus sur*
7. *Ficus natalensis*
8. *Crombretum erythrophyllum*
9. *Ficus trichopoda*
10. *Halleria lucida*

The propagation of the tree seedling is as follows:

1. Remove flesh covering from fresh seeds and plant to depth of seed diameter. Seed material should be of local origin;
2. Treat harsh leguminous seeds by pouring boiling water over seeds in a bowl and allow to cool for 24 hours;
3. Maybe planted from cuttings or truncheons-treated with root inducing hormone.

- **Addressing illegal dumping**

Most of the sites were polluted with litter and other aquatic and terrestrial debris. There was also chemical pollution affecting the watercourses such as toxic chemicals from soap used by people to do their laundry as well as human faeces observed at various points of the management unit and collapsed or overflowing sewage drains that need urgent attendance. Soaps and sewage (faeces) contain phosphates and nitrates that are harmful to water quality and thus harmful to aquatic life.

It will be difficult to address illegal dumping as it is prevalent and common in Soweto. The Soweto area is huge with a lot of informal settlements springing up daily and unfortunately as a consequence, sanitation services are unable to be provided for all. The amount of litter and waste produced daily in these areas is more than the municipality can collect daily. Without sanitation services, most residents utilise the rivers and wetlands for domestic purposes and for relieving themselves. Suggested measures are as follows:

1. All rivers and parks should have no dumping signs (although these have proved ineffective);
2. There should be cleaners and caretakers appointed at various sections of the management unit;
3. River clean ups should be more frequent;
4. Penalties and fines should be charged for non-compliance.

- **Unsustainable reed harvesting**

Most of the Soweto residents are poor and unemployed. As a result, there were hawkers on most street corners. There were a variety of hawkers selling tables, chairs, placemats and baskets during the time of assessment. On enquiry of one of the manufacturers selling placemats about the material he uses to make them, the reply was bulrushes. When comparing the number of hawkers selling this type of furniture to the amount of bulrushes observed at the assessed points, there are simply too many people harvesting them. In light of this fact, the following measures should be taken:

1. There should be times set aside for harvesting so that the reeds will have time to regrow;
2. There should be yields agreed upon;

3. There should be fines for illegal and over-harvesting;

However, these suggestions may not be practical as there are no reed police or law enforcement. The only way to ensure wetland survival is through educating the people around these wetlands on their importance and value.

11.2 LABOUR

All of the rehabilitation methods presented in this assessment can be established and installed using unskilled workers who can be trained on-the-job and carefully supervised. The installations are not technically demanding but need to be properly installed to be effective. With the exception of the gabion construction and placement, most the methods require only a few employees (not more than 10).

11.3 MATERIALS

The rehabilitation methods presented were designed with cost-effectivity in mind. Scrap wire and wire netting can be used to make the fences. Jute geotextile (soil-saver) is affixed to the ground by hammering sharpened sections of old wooden fencing droppers into the material. Stone gabion construction requires fabricated wire gabion or wire netting to enclose the stones. Any wire netting used for fencing is suitable but if netting is especially purchased then it is advisable to utilize fully galvanized material. Rough wood chip obtainable from sawmills is the best mulch to use and material such as hay or sawdust is not advisable to use as it blows away in the wind.

11.4 IMPACT ASSESSMENT

The assessment of possible impacts during the rehabilitation stage was done through the establishment of a standardised and internationally recognised methodology to assess the significance of the potential environmental impacts of the proposed rehabilitation activities. The significance of the impacts was determined through the following:

For each impact, the SEVERITY (size or degree), DURATION (time scale) and EXTENT (spatial scale) are used to determine the CONSEQUENCE of the impact. The table below illustrates the list of rehabilitation activities that could have an impact on biodiversity. Following this table is table 19 which illustrates the mitigation measures for the environment affected by the rehabilitation activities.

Table 18: impact assessment for environmental impacts

ACTIVITIES	IMPACTS	ASPECTS AFFECTED	PHASE	SIGNIFICANCE RATING			TYPICAL MITIGATION MEASURES
Mulching of slopes and banks (Stabilisation of slopes using geotextile; seeding slopes to get them ready for mulching; Harvesting of trees for mulching, Layering slopes with mulch)	Trampling, damage to topsoil, tree felling, nutrient overload, weed contamination	Water quality, soil integrity, riparian vegetation	Rehabilitation		Without mitigation	With mitigation	Use of organic mulches only (based on wood products); careful harvesting of trees for mulch; mulch from trees is to be applied when dry so as to eliminate chemical impact on soil; when harvesting for mulch, every third or fourth tree or large shrub will be cut at 30 mm above ground so as not to change the habitat too drastically; cutting down of trees (especially indigenous trees) is
				Severity	Low	Low	
				Duration	Short term	Short term	
				Extent	Localised	Localised	
				Consequence	Low	Low	
				Probability	Low	Low	
				Significance	Low	Low	
				Status	Positive	Positive	

				Confidence	High	High	temporary loss as the trees will resprout with time. Monitoring of alien invasion or weed encroachment after mulching process.
				Reversibility	Fully reversible	Fully reversible	
				Loss of resource	Low	Low	
				Degree to which the impact can be mitigated	High	High	
				Nature of cumulative impact	Not expected to result in cumulative impacts		
Installation of erosion control fences	Impact posed by damage to bank and slopes through excavation of topsoil for Installation of metal stakes for fence (iron standard fence and wire netting) by digging holes on ground or slope; trampling	Top soil will be susceptible to erosion; run-off of soil during rain events that may cause sedimentation, poor water quality, riparian vegetation disturbed	Rehabilitation	Severity	Low	Low	Fences will be used with mulch for effective water control and microclimate creation; when placing mulched fences, the work will be done around existing vegetation; trampled sections will quickly regrow.
				Duration	Short term	Short term	

				Extent	Localised	Localised	
				Consequence	Low	Low	
				Probability	Low	Low	
				Significance	Low	Low	
				Status	Negative	Negative	
				Confidence	High	High	
				Reversibility	Fully reversible	Fully reversible	
				Loss of resource	Low	Low	
				Degree to which the impact can be mitigated	High	High	
				Nature of cumulative impact	Not expected to result in cumulative impacts		
Stone Gabions construction and installation	Dredging for installation of gabions; trampling; excavation of soil and vegetation, impeding of water flow	Riparian zone banks and vegetation; flow regime; sedimentation; water quality, habitat loss for invertebrates and microscopic	Rehabilitation	Severity	Moderate	Low	Gabions preferably used with geotextiles to reduce water velocities and to recapture river bed sediment; during construction of gabion structures, the correct height, shape and foundation will be relevant

		organisms living under rocks					to site being rehabilitated; qualified engineers will be consulted on appropriate gabion structures and installations; microscopic organisms and invertebrates will obtain new habitat under rocks within habitat; once gabions are installed properly, vegetation will regrow and sedimentation and erosion will cease.
				Duration	Low	Low	
				Extent	Localised	Localised	
				Consequence	Low	Low	
				Probability	Medium	Medium	
				Significance	Medium	Medium	
				Status	Negative	Negative	
				Confidence	Medium	Medium	
				Reversibility	Fully reversible	Fully reversible	
				Loss of resource	Low	Low	
				Degree to which the	High	High	

				impact can be mitigated			
				Cumulative impacts	Not expected to result in cumulative impacts		
Installation of River mattress	Dredging for installation of gabions; trampling; excavation of soil and vegetation.	Riparian zone banks and vegetation; flow regime; sedimentation; water quality.	Rehabilitation	Severity	Medium	Low	River Mattresses preferably used with geotextiles to reduce water velocities and to recapture river bed sediment; during construction of river mattress structures, the correct height, shape and foundation will be relevant to site being rehabilitated; qualified engineers will be consulted on appropriate river mattress structures and installations; once river mattresses are installed properly, vegetation will regrow and sedimentation and erosion will cease.
				Duration	Low	Low	
				Extent	Localised	Localised	
				Consequence	Low	Low	
				Probability	Medium	Medium	
				Significance	Medium	Medium	
				Status	Negative	Negative	
				Confidence	Medium	Medium	
				Reversibility	Fully reversible	Fully reversible	
				Loss of resource	Low	Low	
				Degree to which the impact can be mitigated	High	High	
				Cumulative impacts	Not expected to result in cumulative impacts		

Sediment control using silt fence	Impact posed by damage to bank and slopes through excavation of topsoil for Installation of wood stakes for fence by digging holes on ground or slope; trampling	Top soil will be susceptible to erosion; run-off of soil during rain events that may cause sedimentation, poor water quality, riparian vegetation disturbed, flow regime disturbed; trenching	Rehabilitation	Severity	Low	Low	When installing the fence tree roots are present then installation needs to be done around the roots so that they are not cut down; slope gradient will be considered; soil type must also be considered; inspection and monitoring required after installation.
				Duration	Short term	Short term	
				Extent	Localised	Localised	
				Consequence	Low	Low	
				Probability	Low	Low	
				Significance	Low	Low	
				Status	Negative	Negative	
				Confidence	High	High	
				Reversibility	Fully reversible	Fully reversible	
				Loss of resource	Low	Low	