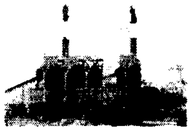
Appendix 1.1

Terms of Reference for ESIA



BOTSWANA POWER CORPORATION

PROJECT NO. 2006: MORUPULE B POWER STATION

TENDER 1050B/4

INVITATION TO TENDER

INCLUDING

TERMS OF REFERENCE FOR:

APPOINTMENT OF A CONSULTANT TO UNDERTAKE AN ENVIRONMENTAL & SOCIAL IMPACT ASSESSMENT STUDY FOR THE MORUPULE B POWER STATION PROJECT

MARCH 2007

TABLE OF CONTENTS

7. Detailed Terms of Reference

7.1 General

The Morupule B Power Station includes the construction and operation of a coal-fired power plant with a capacity of 600 MW (4x150 MW) together with any necessary affiliated infrastructure.

The international financing process for the Project requires an Environmental & Social Impact Assessment (ESIA) eligible for the national and international approval and acceptance.

Subject of the ESIA shall be the Project as well as any necessary affiliated infrastructure, excluding:

- the transmission line
- the water supply pipeline
- the water wellfield (for supply of raw process water)

It is expected that the investigation area for the ESIA and the issues to be considered in the ESIA will cover a radius of approx. 10,000 m. The definition of the investigation area is based on the "German Technical Guideline Air (TA Luft)". This guideline recommends an investigation area around a single point emission source in a radius of 50 times of the expected stack height. Considering a possible needed stack height of approx. 200 m, an investigation area of 10,000 m around the plant site seems to be appropriate.

The ESIA shall be prepared under the consideration of the applicable EIA guidelines of the World Bank and of the Republic of Botswana. The following documents shall be considered:

International:
- World Bank Operational Policy 4.01 (and annexes), dated January 1999, revised August 2004
- Pollution Prevention and Abatement Handbook of the WORLD BANK GROUP, dated July 1998
- Equator Principles, dated July 2006

National:
- Environmental Impact Assessment Act 2005
- Guideline for Conducting EIA Studies for the Energy Industry under the EIA Act 2005

The following documents will be made available to the Consultant:

- Topographical survey (under preparation)
- Geo-technical investigation (under preparation)
- Final scoping report, dated 21.12.2004
- Review report of final scoping report (under preparation)
- Existing soil investigation report, Morupule Power Project, Phase 2, Site Investigation Report, Revision November 1985
- Groundwater Pollution Monitoring at Morupule Power Station, Annual Report for 2005, Final
- Plant design criteria document

7.2 Project Boundary Limits and Interfaces

Beside the above defined ESIA investigation area, the project will have the following project boundary limits and interfaces:

- the transmission line (EIA finalised)
- the water wellfield (ESIA under execution)

This means, that the impact evaluation of the projects mentioned above will be part of the impact evaluation of the Project, but will be taken from the existing reports and from the report currently under preparation respectively.

The mentioned report for the transmission line will be handed-over to the Consultant during the kick-off-meeting.

The interim results of the ESIA for the water wellfield will be provided to the Consultant during the kick-off-meeting. The actual status and the status foreseen to be handed-over during the kick-off-meeting will be subject of a clarification to be provided by BPC to all Consultants.

7.3 Scoping & Public Consultation

A ESIA scoping exercise was executed in 2004 for the Project. The final scoping report, dated 21.12.2004, will be handed over to the Consultant during the kick-off-meeting.

Therefore, a new scoping exercise will not be necessary to be conducted by the Consultant.

The public was informed about the Project approximately 3 years ago. The Consultant is requested to update the project information by conducting public hearings. Two public hearing sessions should be executed:

- the first hearing session during the initial stage of the project (0-4 weeks)
- the second meeting after preparation and submission of the final report (date to be agreed between BPC and the Consultant)

Subject of the first hearing should be to inform the residents and inhabitants about the technical project components, the environmental baseline conditions and of the agreed scope of work.

Subject of the second meeting should be to inform the residents and inhabitants about the final results of the study and about the foreseen mitigation and monitoring measures.

The Consultant is requested to outline the lump sum fixed price for the public hearing sessions within the overall lump sum fixed price for the ESIA.

The consultation of public authorities should be done during the establishment of baseline conditions.

The Consultant is requested to quote for the preparation for the hearings but excluding meeting arrangements as this will be done by BPC.

7.4 Scope of Work

The ESIA shall be prepared considering the structure and content as outlined in World Bank Operational Policy OP 4.01 and its annexes and as outlined in the Botswana EIA Act 2005. In case of any discrepancies the World Bank OP 4.01 shall be the main reference document.

The scope of work shall consider the following tasks and subjects:

7.4.1 Investigation of applicable policy, legal and administrative framework

The Consultant shall investigate, collect and discuss the applicable policy, legal and administrative framework within which the ESIA will be carried out.

The task shall consider the applicable national and international requirements and shall identify the relevant international environmental agreements to which the Republic of Botswana is a party.

The Consultant shall discuss in detail the applicable and relevant national and international (e.g. World Bank, IFC and WHO) environmental limit values and standards and shall highlight the more stringent values which shall apply for the impact assessment.

7.4.2 Project description

The Consultant shall concisely describe the Project and the geographic, ecological, social and temporal context, incl. any offsite investments that may be required (e.g. dedicated pipelines, access roads, water supply, housing and product storage facilities.

The Consultant shall additionally describe the Project from the technical point of view. The project description shall consider the following issues as a minimum:

- Energy sources
- Transmission system
- General design and extent of electric power transmission
- General layout of facilities at project related development sites
- Flow diagrams for facilities, operations design basis, size and capacity
- Pre-construction activities, construction activities, operation and maintenance activities, staffing and support
- Process description for each project component and/or project unit (process diagrams, flow sheets etc. shall be used as appropriate)
- Input and output data shall be described per project component/unit as appropriate considering at least raw material utilization, expected waste amounts, expected air emissions etc.

7.4.3 Establishment of baseline conditions

The Consultant shall use the existing final scoping report and the review report of the final scoping report to get an overview about the existing baseline information. The Consultant shall use the exiting information for the purpose of study preparation and shall replace old information by available baseline information. This is especially necessary for baseline data which are outstanding and missing for the impact assessment. The baseline data collection shall describe the relevant physical, biological and socioeconomic conditions, including any changes anticipated before the project commences. The following issues shall be considered as a minimum:

- Topography and landscape
- Geology, hydrogeology and soil
- Meteorology and climate
- Fauna and flora
- Protected areas and sensitive habitats
- Land-use
- Water use
- Human health, including HIV/AIDS
- Socio-economy
- Noise
- Archaeology and cultural heritage
- Existing waste treatment and disposal facilities

The baseline data collection and assessment shall consider the proposed study area and shall discuss the appropriateness of the dimensions of the study area.

The Consultant shall take into account current and proposed development activities in the study area as well those which are not directly connected to the Project.

The data to be collected shall be relevant with respect to the Project location, the design, construction, operation.

The Consultant shall indicate the accuracy, reliability and sources of the data.

In case that any missing data could not be made available to the Consultant within a reasonable timeframe, the Consultant shall use reasonable assumptions.

For the determination of the baseline conditions, the Consultant shall undertake the following surveys:

Noise survey & assessment

The Consultant shall determine the existing baseline noise levels by collecting field measurements. Noise levels shall be monitored in terms of 15 minutes time weighted average Sound Pressure Level (SPL). A noise contour map shall be generated to present the results of the survey in comparison with the applicable noise limit values.

The necessary noise readings shall be done once per week over a timeframe of two weeks. The readings shall be done during day time and during night time considering a reasonable duration of the readings. Records shall be done during the measuring time to eliminate noise peeks later on. The Consultant is requested to obtain operational data from the existing Morupule Power Station to consider the operational load in the later discussion of the noise survey.

The readings shall be undertaken directly at the proposed fence boundary and at the nearest point of public contact.

The Consultant shall develop a methodology for the execution of the noise survey which shall include a description of the technical equipment, the software-program to be used, an estimation of the number of readings and locations of measurement points.

The Consultant is requested to highlight the noise survey & assessment component within the overall lump sum fixed price for the ESIA.

Ecological survey:

The Consultant is requested to carry out a walk-over survey with respect to the qualitative determination of the ecological value of the investigation area. The result of the survey shall be an indication of the sensitivity of the area with respect to the impacts of the Project on Flora and Fauna during construction and operation of the Project.

7.4.4 Environmental impact assessment

The Consultant is requested to predict and assess the project's likely positive and negative impacts on the physical, biological and socioeconomic conditions. The impact assessment shall consider as well the impacts to be caused by the waste generation, waste handling, treatment and disposal.

The impact assessment shall be done separately for the construction and operation phase of the Project. An indicative assessment of possible impact resulting from the decommissioning of the Project shall be done as well.

The impacts shall be predicted and assessed in qualitative terms and in quantitative terms for noise, groundwater quality and ambient air quality and shall address the short term, mid term and long term impacts as well as cumulative impacts.

The impacts to be caused by the transmission line and the water wellfield shall be taken from the existing EIA report respectively the EIA which is currently under preparation.

The impact assessment shall identify mitigation measures and any residual negative impacts that cannot be mitigated. Mitigation measures for the transmission line and the water wellfield project should not be considered. These measures are subject of the respective reports.

The impact assessment in qualitative terms shall be done by using the following point scale, the severity of the particular environmental impacts together with its general trend - that is negative or positive – shall be described. The evaluation scale shall be as follows:

Extent of impact:

■ ■ ■	=	high negative
■ ■	=	medium negative
■	=	low negative
o	=	nil
+	=	locally positive
++	=	regionally positive
+++	=	nationally positive

For the judgement of (international and national) standards the evaluation of impacts shall be done as follows:

Extent of impact	**Reason**
high	International and national standards are exceeded
medium	Between international and national standards, international and national standards are barely met
low	International and national standards are met

The Consultant could use as well other evaluation methods but these measures must be suitable and acceptable by international financing agencies and banks. The Consultant is responsible to ensure the appropriateness of other evaluation methods.

7.4.5 Air dispersion study and air quality assessment

The Consultant shall estimate and assess the relative contribution of the emissions caused by the Project to the ambient air ground level concentrations, particularly NOx, SO_2, CO and PM_{10}. The air quality assessment shall consider as well the impacts on the ambient air quality to be affected by the ash disposal site.

The air dispersion study shall be done by using international applicable and suitable software.

The existing ground level concentration for SO_2 could be made available by the Department of Waste Management and Pollution Control through BPC. The data has been confirmed to be available from 2002 (the year of installation of the measurement station). These data is going to be provided as daily averages.

Other data shall be collected by field measurements over a timeframe of 2 weeks. The Consultant is requested to provide a detailed strategy for the execution of the measurements, details of the measurement equipment and later analysis of the samples.

Necessary climate data could be obtained from meteorological stations at Gaborone, Francistown, Mahalapye, Letlhakane and Selibe Phikwe. The most suitable meteorological station shall be used. The Consultant shall coordinate and cooperate with the Department of Meteorological Services.

A GLC contour map shall be generated to present the assessment of the results of the survey separately for the mentioned parameter in comparison with the applicable ambient air limit values. A stack height of 200 m shall be considered for modeling purposes. The Consultant is requested to calculate a second and third GLC contour map and assessment for stack heights of 150 m and 300 m . The second and third air dispersion model run shall be quoted as an optional service.

The necessary air pollutant estimates for each point source will be made available by BPC as well as the locations of the pollution sources. The necessary deadline for submission of these data shall be included in the time schedule to be prepared by the Consultant.

The Consultant is requested to highlight the air dispersion study and air quality assessment component within the overall lump sum fixed price for the ESIA.

7.4.6 Archaeological assessment

The Consultant is requested to undertake an archaeological assessment to be executed by a certified and approved expert.

The assessment shall be done according to the national legal requirements.

7.4.7 Economic and socio-economic assessment

Arising from the final scoping report, the Consultant is requested to develop an economic and socio-economic assessment (incl. a social impact analysis).

This assessment shall:

- Evaluate the macro-economic impacts of the proposed Project
- Evaluate the cost and benefits of the Project to the extent possible in the specified timeframe of the Project. The evaluation should include the analysis of all externalities, such as 'hidden' environmental costs or costs to be borne by the society as a result of the project. This evaluation shall be done in qualitative terms and, wherever possible, in quantitative terms
- Evaluate the specific economic aspects of the proposed Project in the town of Palapye in qualitative terms
- Potential 'micro' socio-economic impacts including:
  - Population impacts, e.g. population changes, inflow and outflow of temporary workers, relocation of individuals and families, influence on development patterns
  - Community impacts, e.g. formation of attitudes towards the project skills development, opportunities for emerging contractors, development of small business opportunities with respect to the Project implementation
  - Individual and family level impacts, e.g. disruption in daily living and movement patterns, disruption in social networks
  - Perceptions in public health and safety, including HIV/AIDS
  - Job creation
  - Empowerment of the youth, women and the disabled

7.4.8 Analysis of alternatives

The Consultant shall systematically compare feasible alternatives to the proposed Project (site, technology, design and operation). The analysis shall describe as well the "without project" situation.

The analysis of alternatives shall be done in terms of their potential environmental impacts and the feasibility to mitigate these impacts. This section shall discuss the capital and recurrent cost of each alternative, their suitability and the institutional, training and monitoring requirements.

The Consultant shall quantify the environmental impacts for each alternative to the extend possible and shall attach economic values where feasible.

A statement shall be given describing the reason for selecting the particular project design. The Consultant shall justify the recommended emission levels and approaches to pollution prevention and abatement.

7.4.9 Environmental & social management plan

The Consultant is requested to develop and prepare an appropriate Environmental & Social Management Plan (ESMP). The ESMP shall consist of the following content and shall consider the construction phase and the operation phase of the Project:

- Mitigation measures
- Monitoring measures

- Institutional measures

The proposed measures shall be appropriate to eliminate adverse environmental and social impacts, offset them or reduce them to an acceptable level.

The ESMP shall include as well the necessary actions needed to implement these above mentioned measures.

The ESMP shall include the following components:

Mitigation Measures

The ESMP shall identify feasible and cost-effective mitigation measures that may reduce the potentially significant adverse environmental impacts to an acceptable level. The ESMP shall consider as well compensatory measures if mitigation measures are not expected to be feasible, cost-effective or sufficient.

Monitoring Measures

The ESMP shall include monitoring measures that will be sufficient to monitor and evaluate the mitigation of possible impacts.

The monitoring measures in the ESMP shall be linked to the impacts assessed in the ESIA report and the mitigation measures described in the ESMP.

The monitoring section of the ESMP shall provide a specific description and technical details of monitoring measures, including the parameters to be measured, methods to be used, sampling locations, the frequency of measurements, detection limits (if appropriate). The monitoring measurs shall define thresholds that will signal the need of corrective measures within the mitigation section of the ESMP.

The ESMP shall consider at least the following monitoring measures:

- Soil monitoring
- Groundwater monitoring
- Surface water monitoring (if necessary)
- Ambient air quality monitoring
- Stack emission monitoring

The Consultant is requested to review and assess the existing groundwater monitoring network and shall make necessary improvements, if needed, or shall confirm the existing network as appropriate for the Project.

The stack emission and the ambient air quality monitoring shall consider the greenhouse gas emission according to the Kyoto Protocol.

The ESMP shall include as well:

- reporting procedures
- capacity development and training procedures

The ESMP shall include a detailed cost estimation for each measure and an implementation schedule of the mitigation and monitoring measures to be implemented during construction and operation of the Project.

7.4.10 Structure of ESIA Report

The Consultant is requested to prepare the ESIA report in the following structure:

- Executive summary
- Policy, legal and administrative framework

- Project description
- Baseline data
- Environmental impacts
- Analysis of alternatives
- Environmental & social management plan
- Appendixes
  - List of ESIA report preparers
  - References
  - Record of meetings
  - Tables of relevant data
  - List of associated reports

7.5 Milestone Schedule

The available timeframe for the preparation of the ESIA shall be 8 weeks starting from the date of receipt of the commencement order by the selected Consultant.

An indicative time schedule is attached as annex no. A.2.

The Consultant shall consider the following dates and milestones and shall ensure his availability in case of contract award:

▪ Receipt of commencement order	30.04.2007
▪ Kick-Off-Meeting and Site Visit	07.05. – 09.05.2007
▪ Submission of Draft/Draft ESIA	25.06.2007

The Consultant is requested to modify the time schedule (annex no. A.2) as appropriate to demonstrate the compliance of the expected work within the specified timeframe.

7.6 Reporting

Progress Reports
The Consultant shall submit progress reports every two weeks to demonstrate the compliance of the work with the proposed time schedule. The submission of the progress reports shall be by e-mail. A template of the progress report shall be submitted together with the technical proposal.

The first progress report shall be submitted on the 14.05.2007.

ESIA Reports
The Consultant is requested to submit the following reports according to the specified timelines:

▪ Submission of Draft/Draft Report	25.06.2007
▪ Review of Draft/Draft Report by BPC and Fichtner	5 days
▪ Submission of comments to Consultant	29.06.2007
▪ Preparation of Draft/Final Report until	06.07.2007
▪ Receipt of Draft/Final Report by BPC	09.07.2007
▪ Review by Stakeholders	09.07. – 27.07.2007
▪ Receipt of comments from stakeholders	27.07.2007
▪ Submission of comments to Consultant	30.07.2007

- Preparation of Final Report by Consultant until 03.08.2007
- Submission of Final Report to BPC 03.08.2007
- Receipt of Final Report by BPC 06.08.2007

The following number of reports shall be submitted by the Consultant:

- Draft/Draft Report 5 hardcopies, 1 electronic copy
- Draft/Final Report 25 hardcopies, 1 electronic copy
- Final Report 10 hardcopies, 1 electronic copy

Botswana Power Corporation
Gaborone - Botswana

Expansion of Morupule Power Station

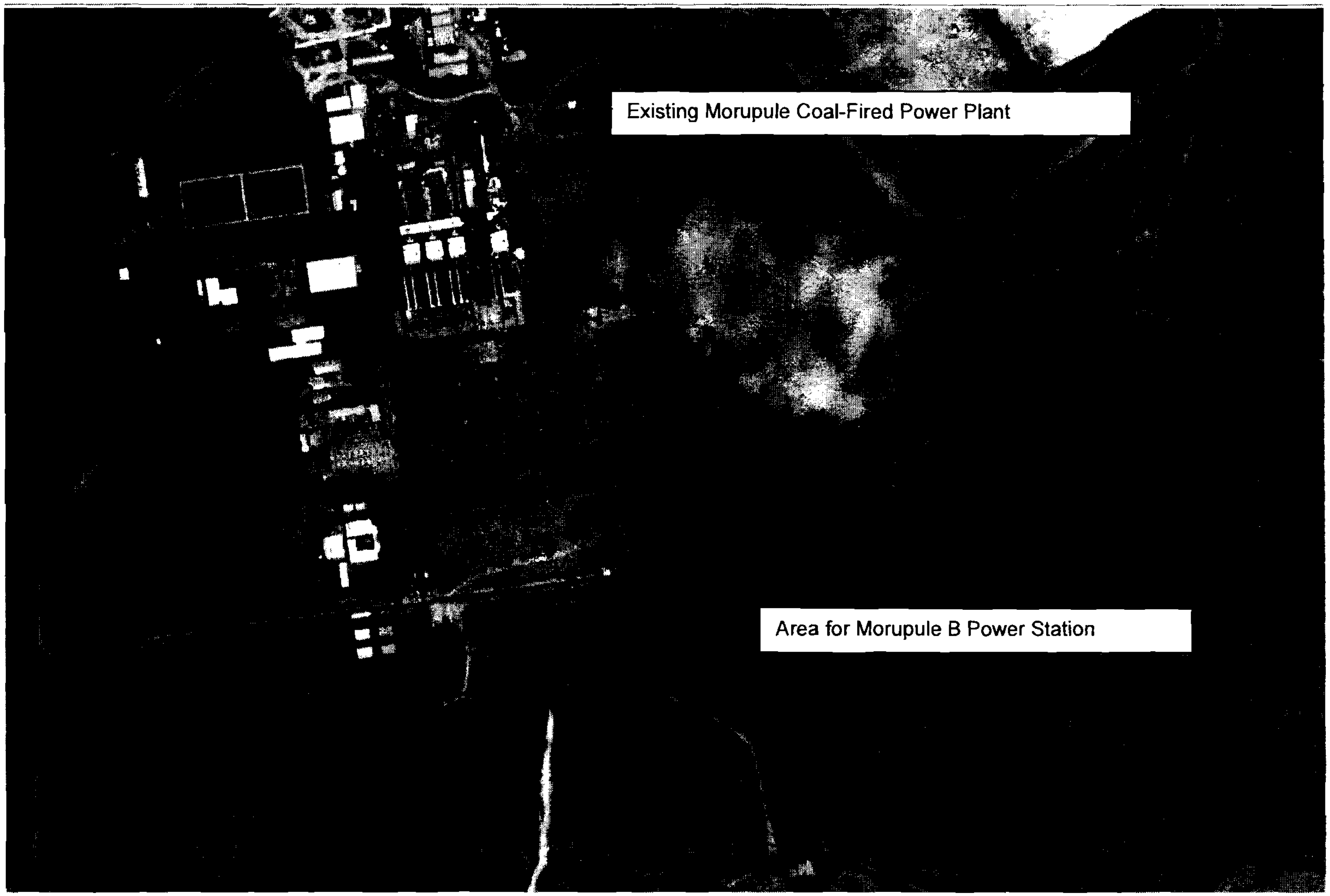
Project Name: Morupule B Power Station

Project No.: 2006

Tender No.: 1050B/4

Annex A.1
Location Overview

Annex A.1 – Location Overview



Appendix 1.2

DEA Approval of Terms of Reference for ESIA

Private Bag 0068
Gaborone
Botswana

Telephone. (267) 3902050
Telefax: (267) 3902051/ 3914687
Email envirobotswana@gov.bw
Web www.envirobotswana.gov.bw

Republic of Botswana

Department of Environmental Affairs

All Correspondence to be addressed to the Director

RE: DEA/BOD 7/9 XXI (150)

20th March 2007

Chief Executive Officer
Botswana power Corporation
P. O Box 48
Gaborone

Att: Mr. M. G. Badirwang:

RE: SCOPING REPORT AND TERMS OF REFERENCE FOR ENVIRONMENTAL IMPACT ASSESSMENT FOR THE PROPOSED EXPANSION OF MORUPULE B POWER STATIO

1. Reference is made to your letter ref: 2006, dated 16th March 2007 in which you submitted the scoping report and terms of reference for the Environmental Impact Assessment (EIA) study for the above project for our review.

2. We have evaluated the report and decided to approve the terms of reference on the condition that the Environmental Impact Statement (EIS) will be prepared in accordance with the approved structure as stipulated in the EIA Guidelines for Botswana (copy of which was provided to BPC on 16th March 2007 when comments were made on the draft terms of reference). The appointed Consultant (s) will therefore have to meet with the Department of Environmental Affairs to confirm and agree on the structure of the EIS at the beginning of the consultancy or before a draft EIS is submitted to the Department of Environmental Affairs for review and approval.

3. You will recall that during the meeting of the 16th March 2007, we advised BPC to issue the scoping report together with the terms of reference to prospective bidders but the revised terms of reference does not capture this. The scoping report provides a basis for the terms of reference and providing the scoping report to bidders together with the terms of reference would assist in their assessment of the magnitude of the scope of work and appropriately costing of the associated works to be done This would also level the playing field if the Consultant who undertook the scoping report would be allowed to tender for the EIA study, since they have access to background information contained in the scoping report.

Thank you

Yours faithfully

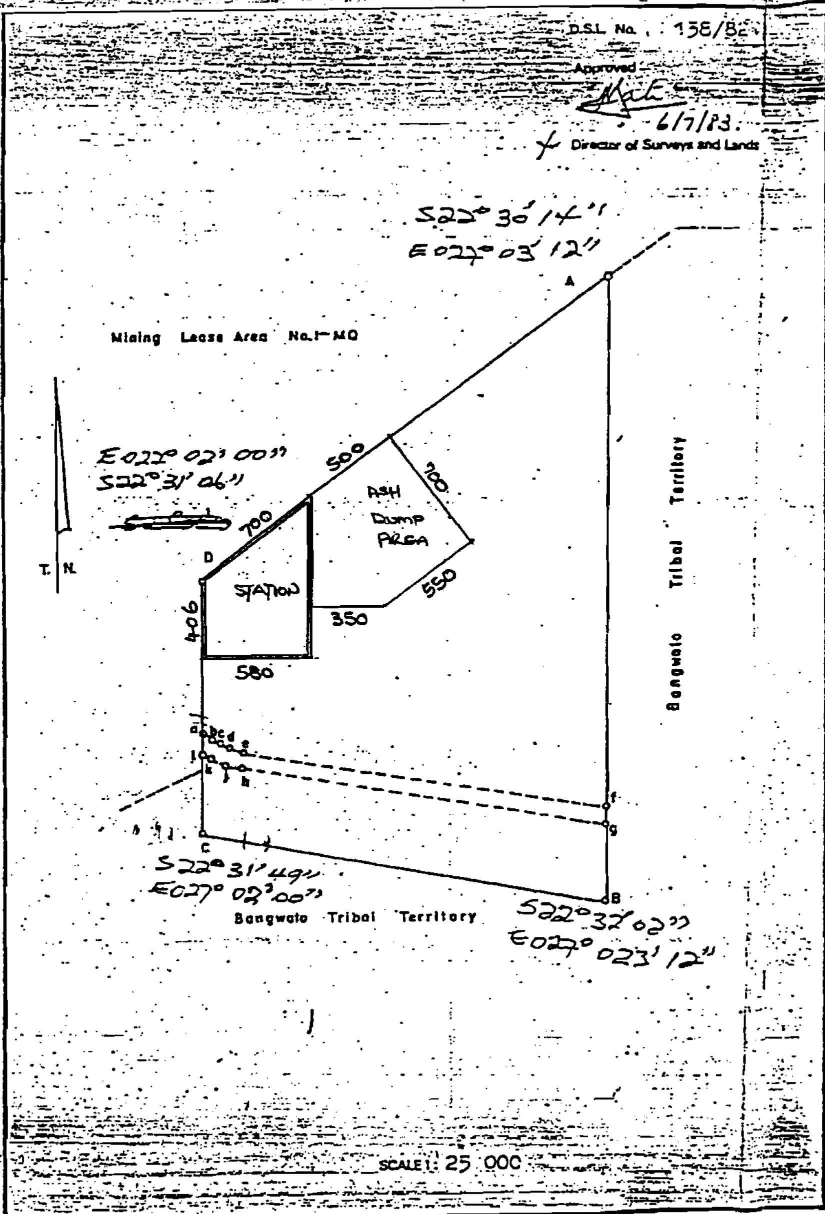
David Aniku
for/Director

An Environment Conscious and Friendly Nation.

Appendix 2

Survey Record

FARMIN.
35P 100



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B C	2 084.90	100 22 15	B	-5 488.74	+92 716.45
C D	1 337.00	179 44 52	C	-3 437.89	+92 341.13
D A	2 600.00	232 17 02	D	-3 432.01	+91 004.14
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e f	1 861.46	279 24 50	e	-3 652.35	+91 907.26
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k l	45.77	120 00 40	k	-3 475.63	+91 937.06
l a	106.98	179 45 00	l	-3 436.00	+91 914.17

Description of Beacons

A, B, C	: Half iron standard and cairn
D	: 50mm iron pipe in concrete
b, c, d, e, j, k, h	: 100mm guyed iron fence post
a, f, g, l	: 12mm iron peg

1. The figure A B C D A represents 476.6425 Hectares of land called

TRIBAL GRANT NO. 4-MQ

2. The figure a b c d e f g h j k l a represents a railway servitude of area 18.6888 Hectares situated on Tribal Grant No. 4-MQ

Situate in the Central Administrative District

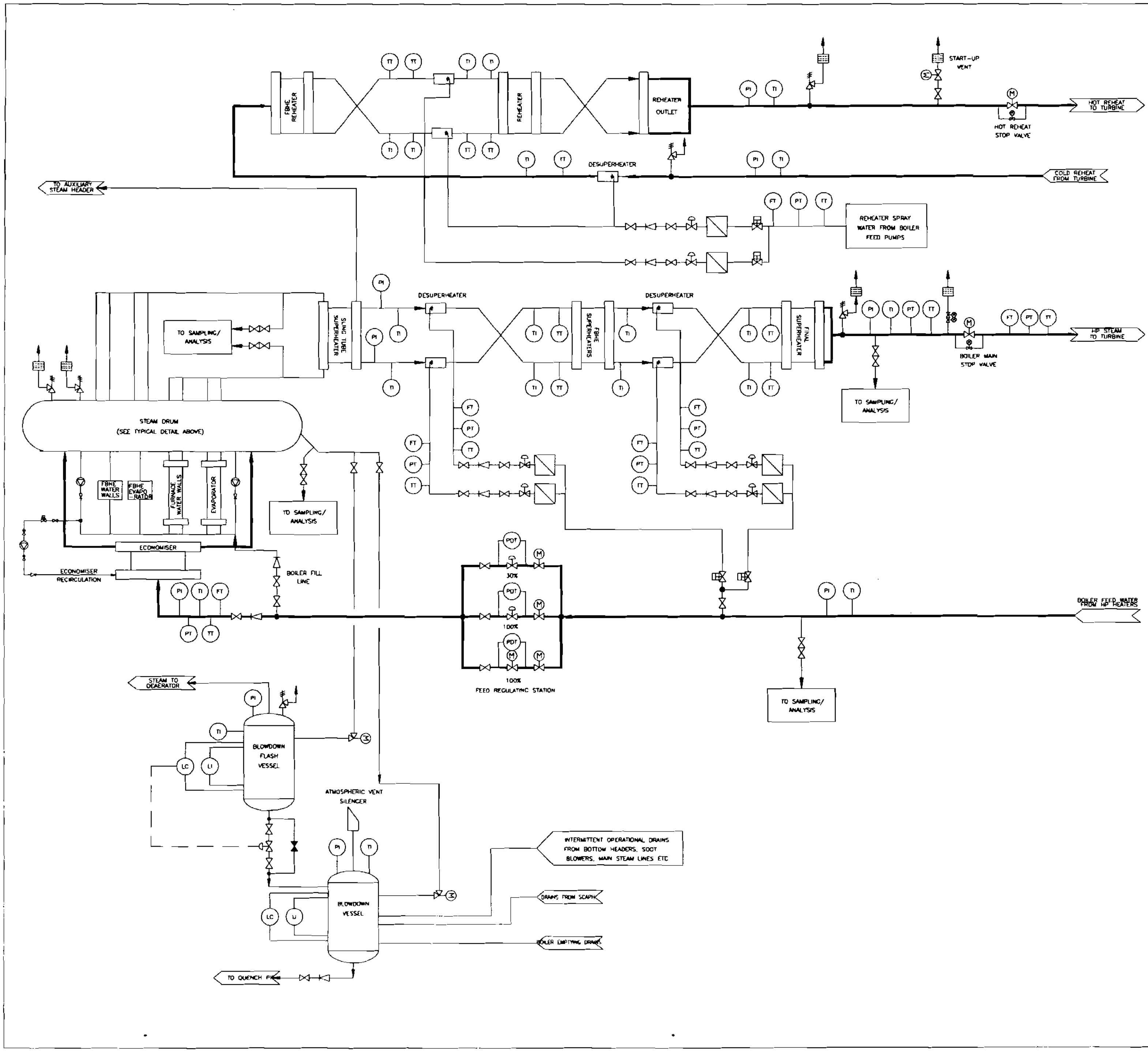
Surveyed in June and July 1982 by me (Sgd) R. J. Avenell
Land Surveyor

DEDUCTIONS FROM THIS DIAGRAM ARE MADE ON THE BACK HEREOF

This diagram is annexed to	The original diagram is No. annexed to No.	General Plan No. Survey Records No. 33/82 D.S.L. File No. T4, I460 Compilation Degree Square

Appendix 3.1

Flow diagram of steam flow



NOTES:

1. SCHEME SHOWN IN DRAWING IS INDICATIVE AND SHALL BE FINALIZED BASED UP ON SELECTED BOILER MANUFACTURE.

LEGENDS:

- PUMP
- STRAINER/FILTER
- SILENCER
- DESUPERHEATER
- ISOLATION VALVE
- NON RETURN VALVE
- RELIEF
- PISTON OPERATED
- (PI) PRESSURE INDICATOR
- (PT) PRESSURE TRANSMITTER
- (PDT) DIFFERENTIAL PRESSURE TRANSMITTER
- (TI) TEMPERTURE INDICATOR
- (TT) TEMPERTURE TRANSMITTER
- (LC) LEVEL CONTROLLER
- (LI) LEVEL INDICATOR
- (FT) FLOW TRANSMITTER
- SILENCER

	Date	Name	Note
D			
C			
B	24.04.07	GD	FOR TENDER PURPOSE
A	12.12.06	SAR	PRELIMINARY

FICHTNER

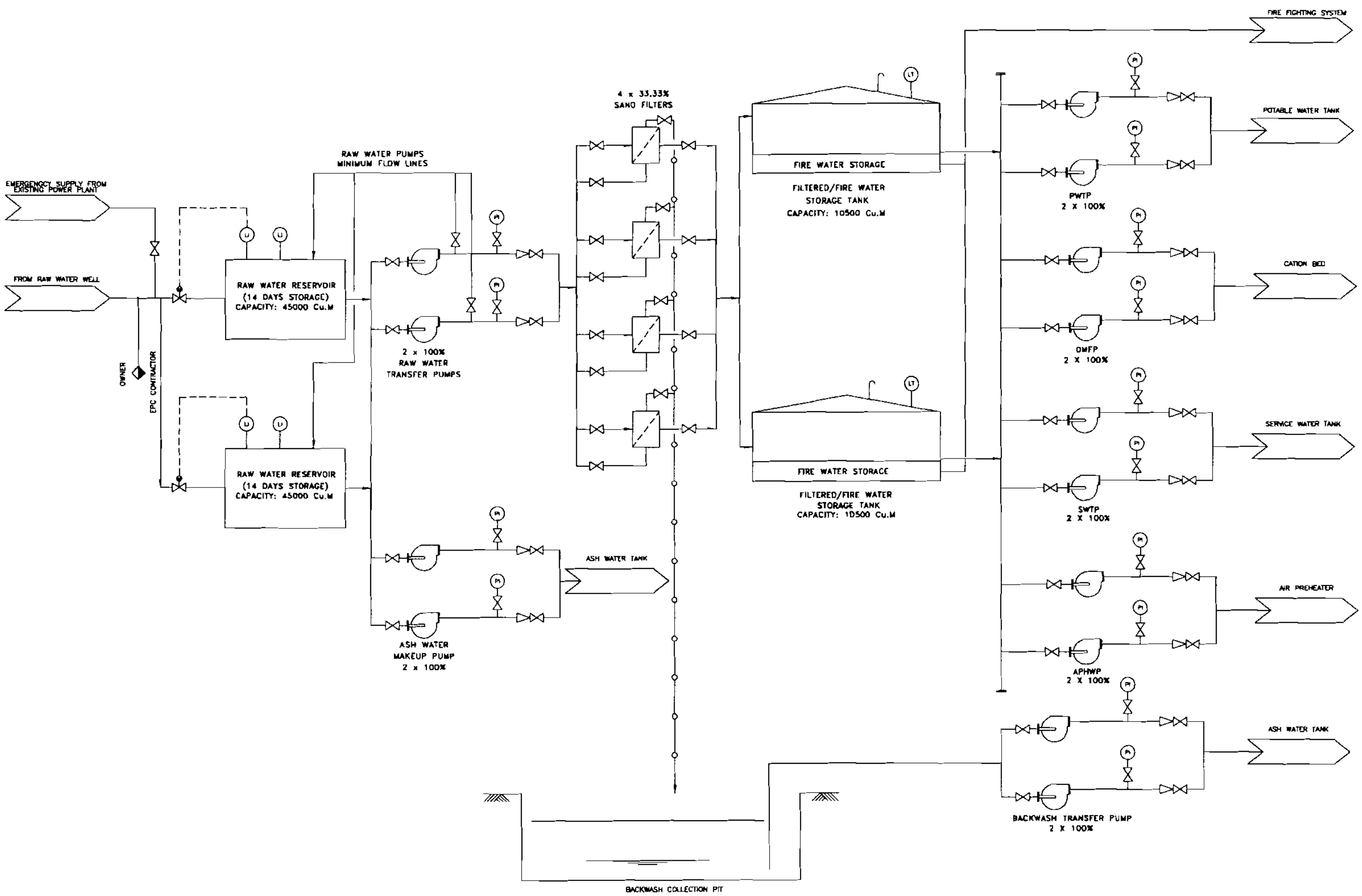
BOTSWANA POWER CORPORATION
PROJECT NO: 2006
PROJECT NAME:MORUPULE "B"

	Date	Name		Scale
Drawn	12.12.06	MSR	FLOW DIAGRAM	NTS
Checked	12.12.06	SAR	BOILER STEAM SYSTEM	Sheet 1 of 1
Supersedes				
Superseded by		Size A1	Project No 2006	File
System SG			DWG No. CNT-7776-M-002	

THIS CAD DRAWING MAY ONLY BE ALTERED WITH A CAD SYSTEM

Appendix 3.2

Flow diagram of raw water treatment



NOTES

1. THIS DRAWING IS THE BASIS FOR THE WATER TREATMENT SYSTEM DESIGN AND CONCEPTUAL MINIMAL AND THE EPC CONTRACTOR SHALL ADDITIONAL COMPONENTS
2. A DEAD STORAGE OF 1025 Cu.M IN EACH TANK IS CONSIDERED FOR FIRE FIGHTING SYSTEM

LEGEND:

1. DMFP - DM PLANT FEED PUMP
2. RWTP - RAW WATER TRANSFER PUMP
3. PWTP - POTABLE WATER TRANSFER PUMP
4. SWTP - SERVICE WATER TRANSFER PUMP
5. APHWP - AIRPREHEATER WASH PUMP
6. AWMP - ASH WATER MAKEUP PUMP
7. (PI) - PRESSURE INDICATOR
8. (LS) - LEVEL SWITCH
9. (LT) - LEVEL TRANSMITTER

Rev	Date	Name	Note
D			
C	31.05.07	MA	FOR TENDER PURPOSE
B	24.04.07	MA	FOR TENDER PURPOSE
A	12.12.06	MA	PRELIMINARY

FICHTNER

BOTSWANA POWER CORPORATION
PROJECT NO : 2006
PROJECT NAME : MORUPULE "B"

	Date	Name
Drawn	12.12.06	MSR
Checked	12.12.06	MA
Supersedes		
Superseded by:		

FLOW DIAGRAM
WATER TREATMENT
SYSTEM

Scale: NTS
Sheet: 1 of 2

Size: A1 | Project No.: 2006 | File:

System: WTP | Drawing No.: CNT-7776-M-009

THIS CAD DRAWING MAY ONLY BE ALTERED WITH A CAD SYSTEM

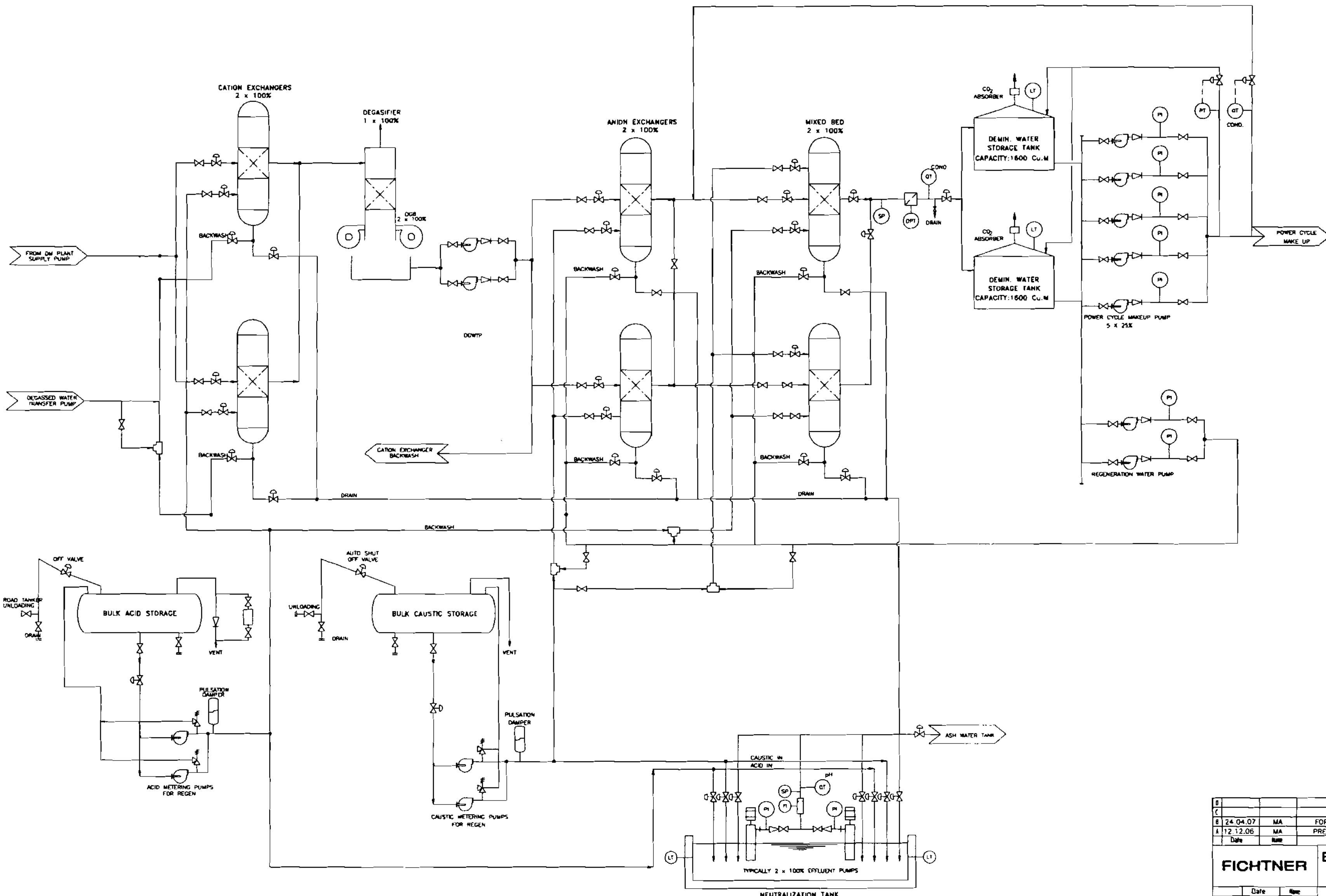
A0

NOTES

1. THIS DRAWING IS THE BASIS FOR THE WATER TREATMENT SYSTEM DESIGN AND CONCEPTUAL MINIMAL AND THE EPC CONTRACTOR SHALL PROVIDE ALL REQUIRED ADDITIONAL COMPONENTS.

LEGEND:

	ISOLATION VALVE
	NON RETURN VALVE
	DIAPHRAGM OPERATED
	RELIEF VALVE
	MIXING TEE
	CENTRIFUGAL PUMP
PI	PRESSURE INDICATOR
PT	PRESSURE TRANSMITTER
SP	SAMPLING POINT
LT	LEVEL TRANSMITTER
QT	CONCENTRATION TRANSMITTER
FI	FLOW INDICATOR
DPT	DIFFERENTIAL PRESSURE TRANSMITTER
COND.	CONDUCTIVITY
DGB	DEGASSED BLOWER
DGWTP	DEGASSED WATER TRANSFER PUMPS



Rev	Date	Name	Note
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C			
B	24.04.07	MA	FOR TENDER PURPOSE
A	12.12.06	MA	PRELIMINARY

FICHTNER

BOTSWANA POWER CORPORATION
PROJECT NO : 2006
PROJECT NAME : MORUPULE "B"

	Date	Name
Drawn	12.12.06	MSR
Checked	12.12.06	MA
Supersedes		
Superseded by		

FLOW DIAGRAM WATER TREATMENT SYSTEM

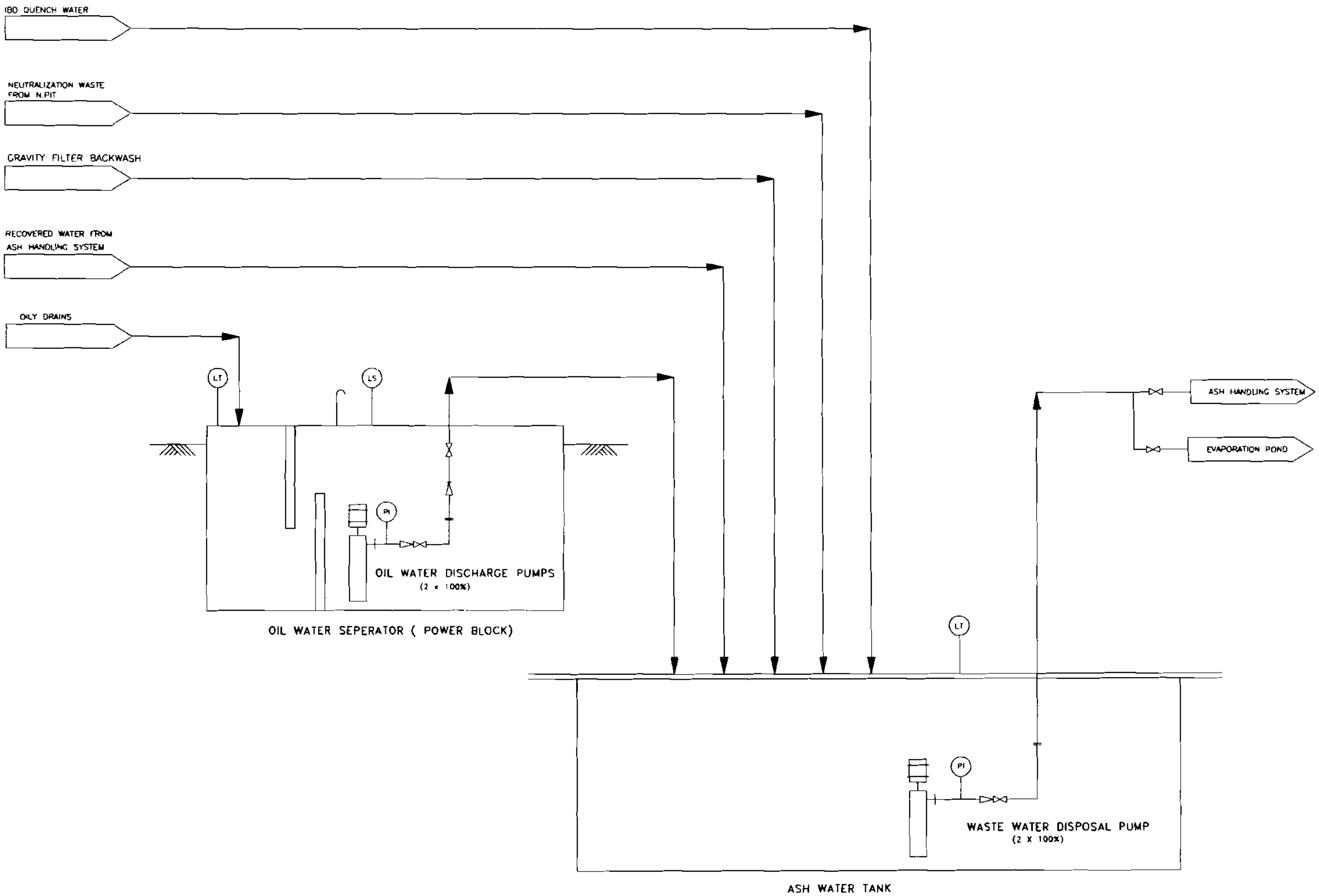
Scale NTS
Sheet 2 of 2
Size A1 | Project No. 2006 | File
System.WTP
Drawing No CNT-7776-M-009

THIS CAD DRAWING MAY ONLY BE ALTERED WITH A CAD SYSTEM

A0

Appendix 3.3

Flow diagram of wastewater treatment



NOTES:

1. THIS DRAWING IS THE BASIS FOR THE WASTE WATER TREATMENT SYSTEM DESIGN AND CONCEPTUAL MINIMAL AND THE EPC CONTRACTOR SHALL PROVIDE ALL REQUIRED ADDITIONAL COMPONENTS

SYMBOLS & LEGENDS

⋈	ISOLATION VALVE
▷	NON RETURN VALVE
LS	LEVEL SWITCH
LT	LEVEL TRANSMITTER
PI	PRESSURE INDICATER
	VERTICAL PUMP

Rev	Date	Name	Note
0			
C			
B	24.04.07	MA	FOR TENDER PURPOSE
A	12.12.06	MA	PRELIMINARY

FICHTNER

BOTSWANA POWER CORPORATION
PROJECT NO : 2006
PROJECT NAME : MORUPULE "B"

	Date	Name
Drawn	12.12.06	MSR
Checked	12.12.06	MA

Supersedes

Superseded by

FLOW DIAGRAM
WASTE WATER TREATMENT SYSTEM

Scale NTS

Sheet 1 of 1

Size A1 | Project No. 2006 | File

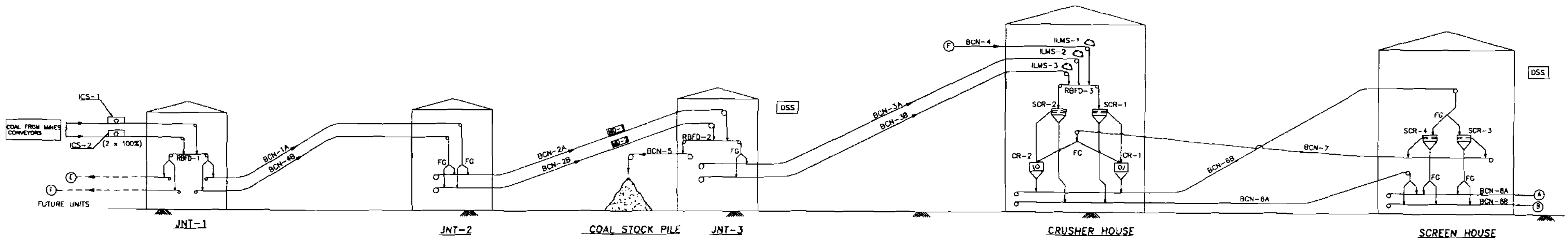
System WWTP | Drawing No CNT-7776-M-010

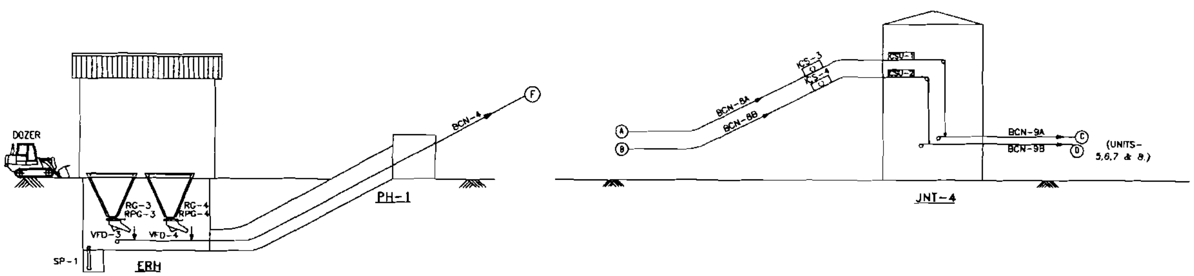
THIS CAD DRAWING MAY ONLY BE ALTERED WITH A CAD SYSTEM

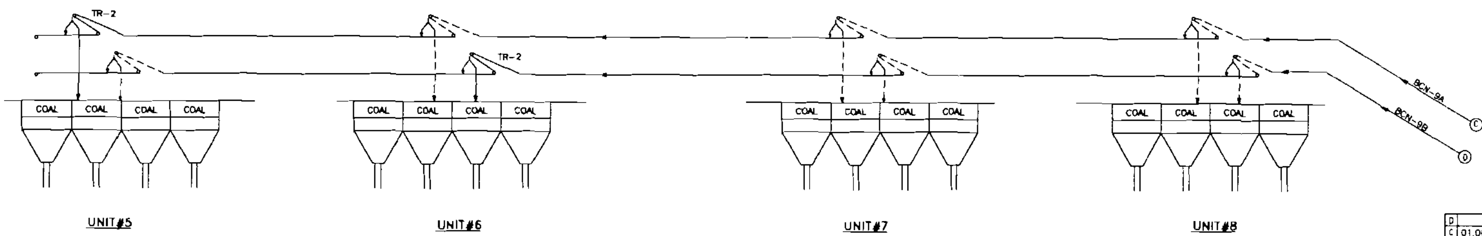
A0

Appendix 3.4

Flow diagram of coal handling system







NOTES

1. JUNCTION HOUSES INDICATED ARE TENTATIVE BIDDER TO CONFIRM THE EXACT REQUIREMENT
2. EQUIPMENTS SHOWN IN THE DRAWING ARE TENTATIVE BIDDER TO INDICATE THE EXACT REQUIREMENTS.
3. UPTO JNT-1 THE SYSTEM IS DESIGNED FOR 8x150MW BY CONSDERING FUTURE UNITS.
4. REQUIRED NO.OF DUST EXTRACTION, DUST SUPPRESSION SYSTEM SHALL BE PROVIDED
5. COAL FROM MINES IS ALSO IN THE SCOPE OF BIDDER.BIDDER TO PROVIDE DETAILED FLOW DIAGRAM AS PER REQUIREMENT.

SYMBOLS & LEGEND:

BCN	- BELT CONVEYOR
CR	- CRUSHER
CSU	- COAL SAMPLING UNIT
DSS	- DUST SUPPRESSION SYSTEM
ERH	- EMERGENCY RECLAIM HOPPER
FG	- FLAP GATE
ICS	- LIMESTONE INLINE CONVEYOR SCALE
ILMS	- LIMESTONE INLINE MAGNETIC SEPARATOR
JNT	- JUNCTION TOWER
MD	- LIMESTONE METAL DETECTOR
PH	- PENT HOUSE
RBFD	- REVERSIBLE BELT FEEDER
RG	- ROD GATE
RPG	- RACK & PINION GATE
SCR	- SCREEN
TR	- TRAVELING TRIPPER
VFD	- VIBRATION FEEDER

	Date	Name	Note
D			
C	01.06.07	TK	REVISED AS PER CLIENT'S COMMENTS
B	24.04.07	TK	FOR TENDER PURPOSE
A	08.12.06	TK	PRELIMINARY

FICHTNER

BOTSWANA POWER CORPORATION
PROJECT NO: 2006
PROJECT NAME:MORUPULE "B"

	Date	Name
Drawn	08.12.06	ECM
Checked	08.12.06	TK
Supersedes		
Superseded by		

FLOW DIAGRAM
COAL HANDLING SYSTEM

Scale: NTS
Sheet: 1 of 1

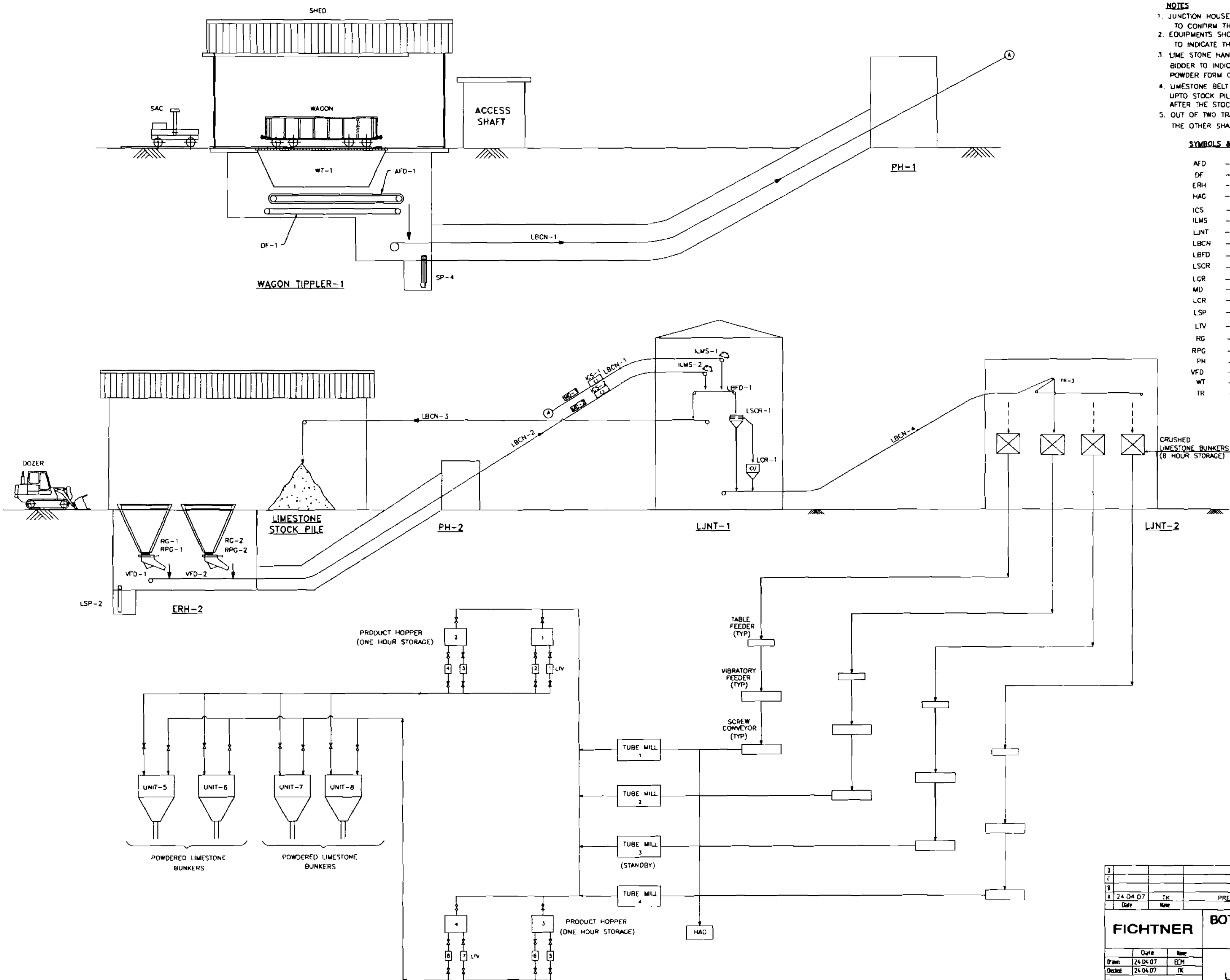
Size: A1 | Project No.: 2006 | File:

System: CHS | Drawing No.: CNT-7776-M-007A

THIS CAD DRAWING MAY ONLY BE ALTERED WITH A CAD SYSTEM

Appendix 3.5

Flow diagram of limestone handling system



NOTES

1. JUNCTION HOUSES INDICATED ARE TENTATIVE BIDDER TO CONFIRM THE EXACT REQUIREMENT
2. EQUIPMENTS SHOWN IN THE DRAWING ARE TENTATIVE BIDDER TO INDICATE THE EXACT REQUIREMENTS.
3. LIME STONE HANDLING SYSTEM INDICATED IS TENTATIVE. BIDDER TO INDICATE THE EXACT HANDLING SYSTEM FOR POWDER FORM OF LIMESTONE.
4. LIMESTONE BELT CONVEYOR CAPACITY SHALL BE DESIGNED UPTO STOCK PILE BY CONSIDERING 8x150MW. AFTER THE STOCK PILE CAPACITY SHALL BE DESIGNED FOR 4x150MW.
5. OUT OF TWO TRANSMITTER VESSELS ONE SHALL OPERATE AND THE OTHER SHALL BE STANDBY

SYMBOLS & LEGEND:

- AFD – APRON FEEDER
- DF – DRIBBLE FEEDER
- ERH – EMERGENCY RECLAIM HOPPER
- HAG – HOT AIR GENERATOR
- ICS – INLINE CONVEYOR SCALE
- ILMS – INLINE MAGNETIC SEPARATOR
- LJNT – LIMESTONE JUNCTION TOWER
- LBCN – LIMESTONE BELT CONVEYOR
- LBFD – LIMESTONE REVERSIBLE BELT FEEDER
- LSCR – LIMESTONE SCREEN
- LCR – LIMESTONE CRESHER
- MD – METAL DETECTOR
- LCR – LIMESTONE CRESHER
- LSP – LIMESTONE SUMP
- LTV – POWDERED LIME STONE TRANSMITTER VESSEL
- RG – ROD GATE
- RPG – RACK & PINION CATE
- PH – PENT HOUSE
- VFD – VIBRATION FEEDER
- WT – WAGON TIPPLER
- TR – LIMESTONE TRAVELING TRIPPER

Rev	Date	Name	Note
D			
C			
B			
A	24.04.07	TK	PRELIMINARY

FICHTNER

BOTSWANA POWER CORPORATION
PROJECT NO: 2006
PROJECT NAME:MORUPULE "B"

	Date	Name
Drawn	24.04.07	ECM
Checked	24.04.07	TK
Supervised		
Superseded by		
System	DIS	

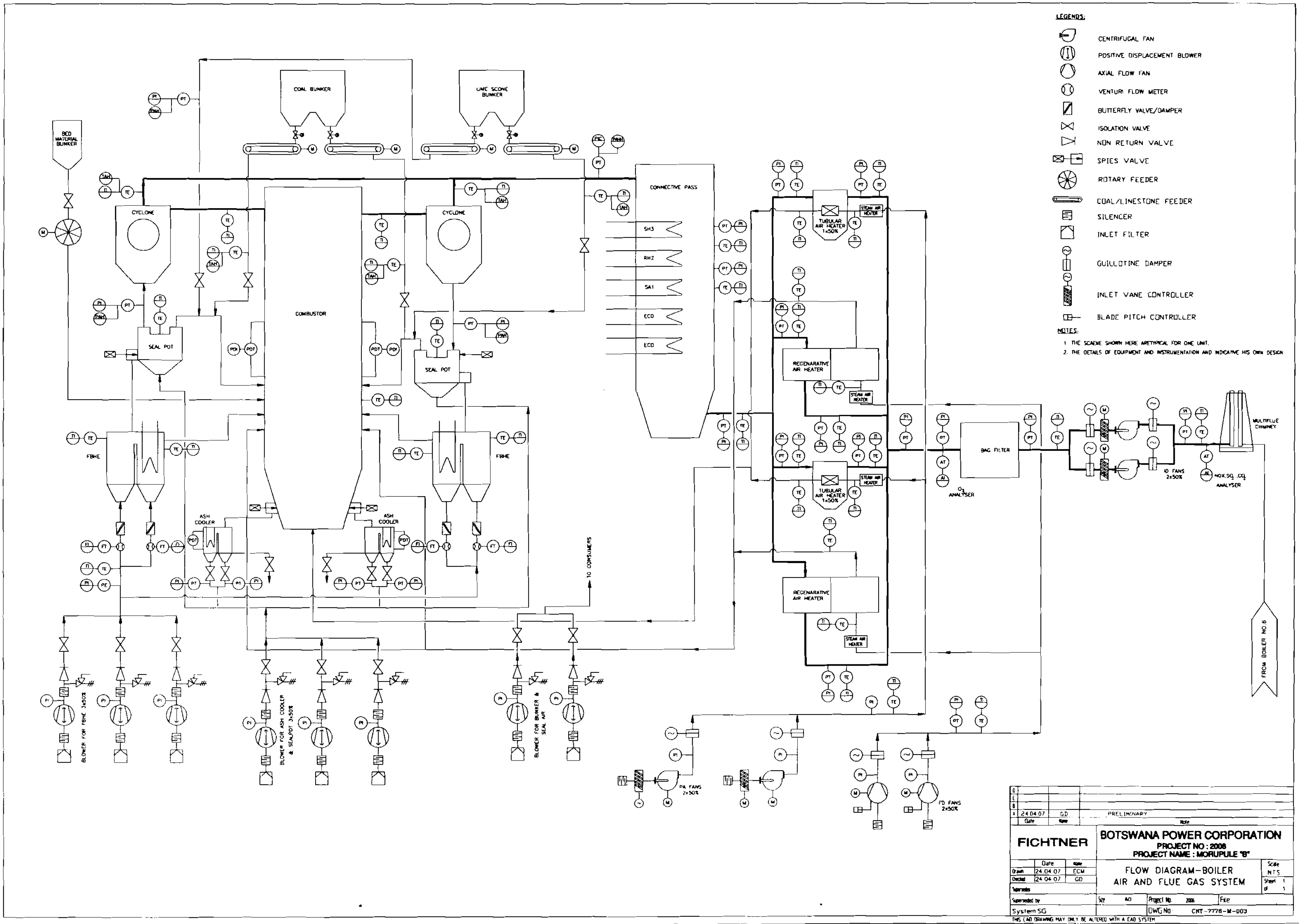
FLOW DIAGRAM
LIMESTONE HANDLING SYSTEM

Scale NTS
Sheet 1 of 1
Size A1 | Project No. 2006 | File
Drawing No CN1-7776-M-0078

THIS CAD DRAWING MAY ONLY BE ALTERED WITH A CAD SYSTEM

Appendix 3.6

Flow diagram of air and flue gas system



D			
C			
B			
A	24.04.07	GD	PRELIMINARY
	Date	Name	Note

FICHTNER

BOTSWANA POWER CORPORATION
PROJECT NO : 2006
PROJECT NAME : MORUPULE "B"

FLOW DIAGRAM-BOILER
AIR AND FLUE GAS SYSTEM

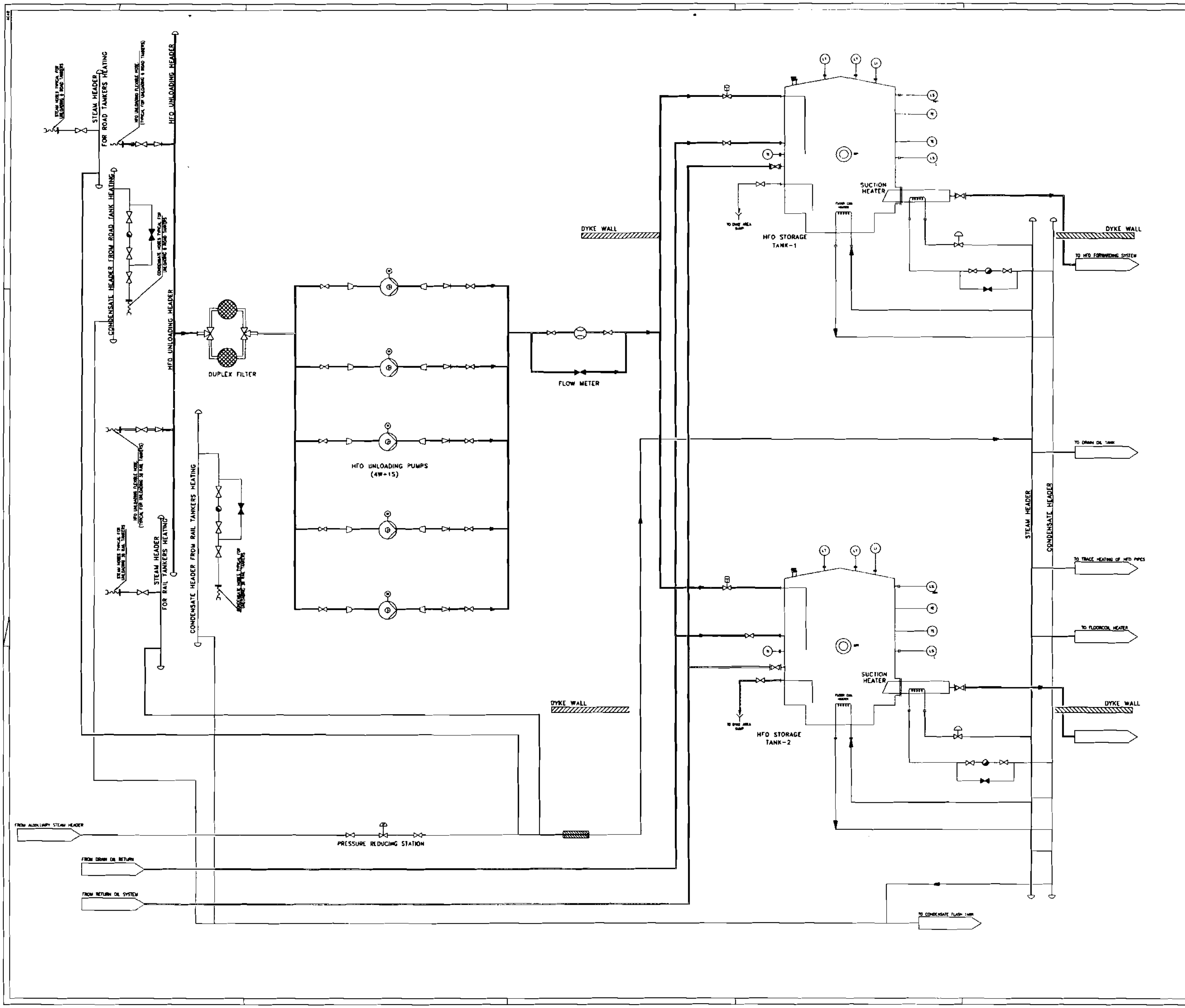
	Date	Name
Drawn	24.04.07	ECM
Checked	24.04.07	GD
Supersedes		
Superseded by		
System SG		

Scale NTS
Sheet 1 of 1
Size A0 | Project No. 2006 | File
DWG No. CNT-7776-M-003

THIS CAD DRAWING MAY ONLY BE ALTERED WITH A CAD SYSTEM

Appendix 3.7

Flow diagram of Fuel oil system



SYMBOLS & LEGENDS

- DUPLEX STRAINER
- MEASURING ORIFICE
- MOTOR OPERATED VALVE
- DIAPHRAGAM OPERATED VALVE
- SCREW PUMP
- NON RETURN VALVE
- ISOLATION VALVE
- PISTON OPERATED VALVE
- PNEUMATIC OPERATED VALVE
- HOSE
- LEVEL SWITCH
- LEVEL TRANSMITTER
- LEVEL INDICATOR
- TEMPERATURE INDICATOR
- TEMPERATURE ELEMENT

	Date	Name	Note
0			
C	01.08.07	GD	REVISED AS PER CLIENTS COMMENT
B	24.04.07	ZI	FOR TENDER PURPOSE
A	08.12.06	SSR	PRELIMINARY

FICHTNER

BOTSWANA POWER CORPORATION
PROJECT NO:
PROJECT NAME:MORUPULE "B"

	Date	Name
Drawn	08.12.06	MSR
Checked	checked date	SSR
Approved		
Superseded by		

FLOW DIAGRAM FOR
HEAVY FUEL OIL UNLOADING
AND STORAGE SYSTEM

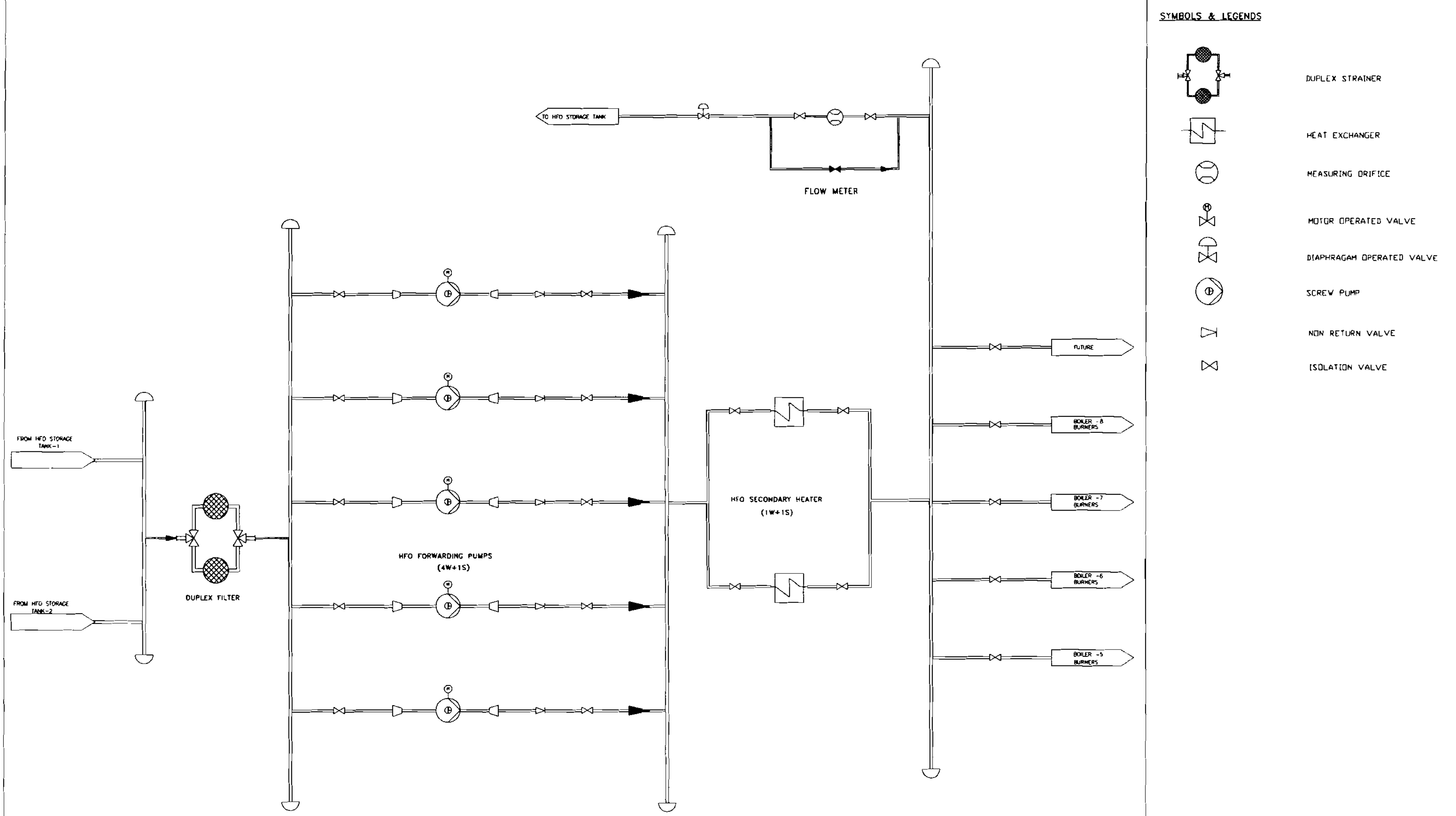
Scale: NTS
Sheet: 7 of 4

Size: A0 | Project No.: 2006 | File:

System: FOS | Drawing No.: CNT-7778-M-006

THIS CAD DRAWING MAY ONLY BE ALTERED WITH A CAD SYSTEM

A0



Rev	Date	Name	Note
D			
C			
B	24.04.07	ZI	FOR TENDER PURPOSE
A	08.12.06	SSR	PRELIMINARY

FICHTNER

BOTSWANA POWER CORPORATION
PROJECT NO: 2008
PROJECT NAME:MORUPULE "B"

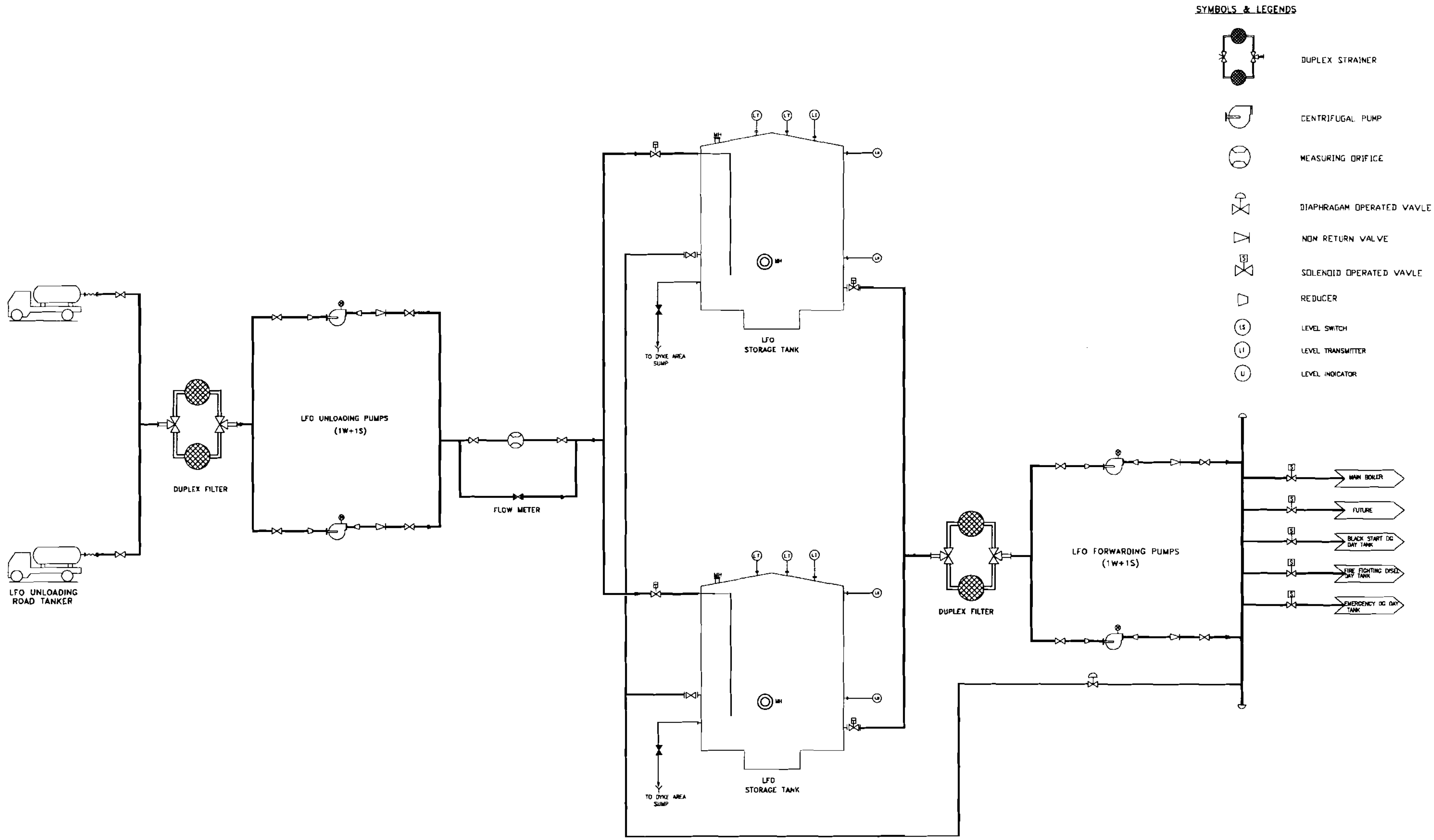
	Date	Name
Drawn	08.12.06	MSR
Checked	checked date	SSR
Supersedes		
Superseded by		

FLOW DIAGRAM
FOR HEAVY FUEL OIL
FORWARDING SYSTEM

Scale NTS
Sheet 2 of 4

Size A1 | Project No 2006 | File
System FOS | Drawing No CNT-7776-M-006

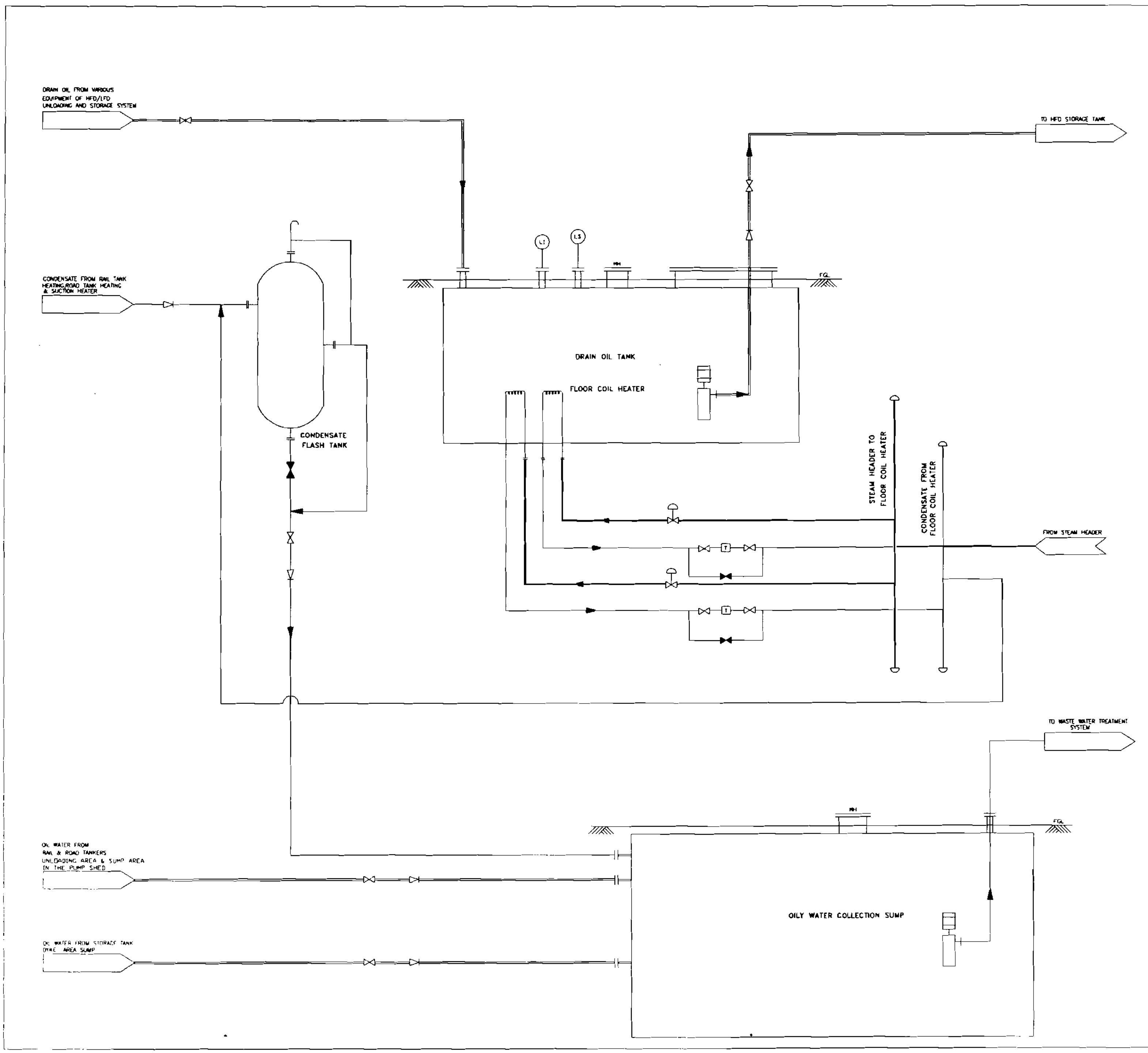
THIS CAD DRAWING MAY ONLY BE ALTERED WITH A CAD SYSTEM



D			
C	01.06.07	GD	REVISED AS PER CLIENTS COMMENT
B	24.04.07	ZI	FOR TENDER PURPOSE
A	08.12.06	SSR	PRELIMINARY
	Date	Name	Note

FICHTNER	BOTSWANA POWER CORPORATION PROJECT NO: 2006 PROJECT NAME:MORUPULE "B"			
	Date	Name	FLOW DIAGRAM FOR LIGHT FUEL OIL UNLOADING, STORAGE FORWARDING SYSTEM	Scale: NTS
Drawn	08.12.06	MSR		Sheet:3 of 4
Checked	checked date	SSR		
Supersedes				
Superseded by			Size A1	Project No.: 2006	File:
System: FOS				Drawing No: CNT-7776-M-006

THIS CAD DRAWING MAY ONLY BE ALTERED WITH A CAD SYSTEM



SYMBOLS & LEGENDS

- VERTICAL CENTRIFUGAL PUMP
- THERMODYNAMIC TRAP
- DIAPHRAGAM OPERATED VAVLE
- NON RETURN VALVE
- ISOLATION VALVE
- LEVEL SWITCH
- LEVEL INDICATOR

D			
C			
B	24.04.07	ZI	FOR TENDER PURPOSE
A	08.12.06	SSR	PRELIMINARY
	Date	Name	Note

FICHTNER

BOTSWANA POWER CORPORATION
PROJECT NO: 2006
PROJECT NAME:MORUPULE "B"

FLOW DIAGRAM FOR DRAIN OIL, CONDENSATE AND OILY WATER COLLECTION SYSTEM

	Date	Name
Drawn	08.12.06	MSR
Checked	checked date	SSR
Supersedes		
Superseded by		
System	FOS	

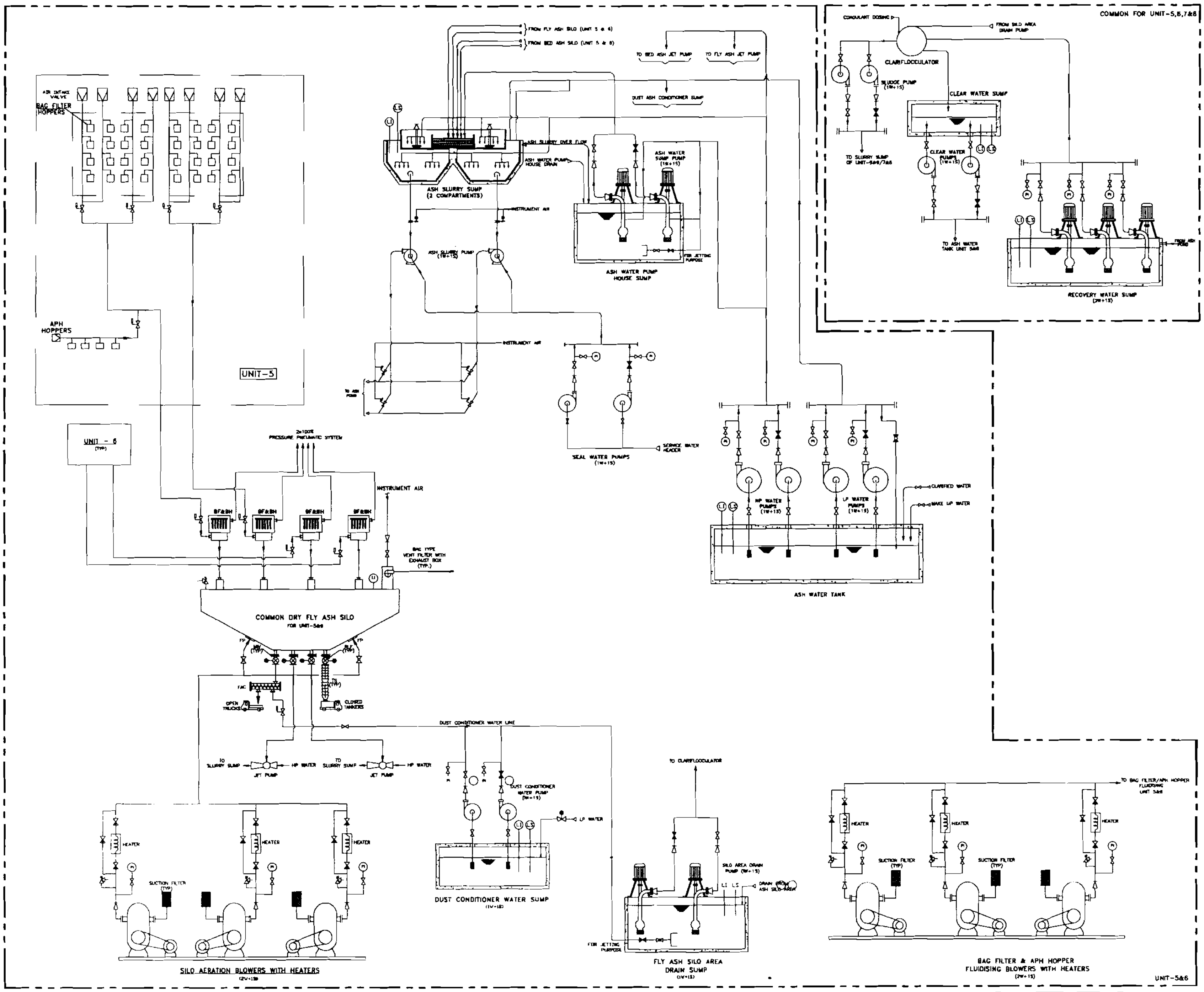
Scale NTS
Sheet 4 of 4

Size A1 | Project No. 2006 | File
Drawing No: CNT-7776-M-006

THIS CAD DRAWING MAY ONLY BE ALTERED WITH A CAD SYSTEM

Appendix 3.8

Flow diagram of Ash handling system



NOTES:

1. NUMBER AND TYPE OF VALVES AND INSRUMENTS WILL BE FINALISED DURING DETAIL ENGINNERING.
2. FLOW THROUGH EACH FLY ASH EVACUATION LINE CONNECTED TO ASH HOPPERS WILL BE EQUAL
3. NUMBER OF BAG FILTER HOPPER, AIR PREHEATER & DUCT HOPPERS WILL BE PROVIDED AS PER REQUIREMENT.
4. UNIT-5 & 6 WILL BE SIMILAR TO UNIT-7 & 8
5. IF PRESSURE PNEUMATIC SYSTEM IS ENVISAGED, CLOSED COOLING WATER SYSTEM SHALL BE PROVIDED.(WITH AIR COOLED)
6. BIDDER SHALL OFFER EITHER DRY/WET DISPOSAL SYSTEM FOR THE BED & COARSE ASH SYSTEM

LEGENDS:-

TS - TELESCOPIC CHUTE
MIV - MANUAL ISOLATION VALVE
RLF - ROTARY LOCK FEEDER
FAC - FLY ASH DUST CONDITIONER
BF&BH - BAG FILTER & BUFFER HOPPER
FP - FLUIDISING PAD
APH - AIR PREHEATER

SYMBOLS:-

- PNEUMATIC OPERATED KNIFE GATE VALVE
- ISOLATION VALVE (OPENED)
- ISOLATION VALVE (CLOSED)
- MATERIAL HANDLING VALVE
- ROTARY LOCK FEEDER
- NON RETURN VALVE
- SAFETY VALVE
- BALL VALVE(OPENED)
- BALL VALVE(CLOSED)
(PI) - PRESSURE INDICATOR
(LI) - LEVEL INDICATOR
(LS) - LEVEL SWITCH

	Date		Note
B	24.04.07	FG	FOR TENDER PURPOSE
A	01.12.06	SSR	PRELIMINARY

FICHTNER

BOTSWANA POWER CORPORATION
PROJECT NO : [illegible]
PROJECT NAME : MORUPULE "B"

	Date	Name
Drawn	1.12.2006	SK
Checked	1.12.2006	SSR

FLOW DIAGRAM
ASH HANDLING SYSTEM

Scale NTS
Sheet 1 of 1

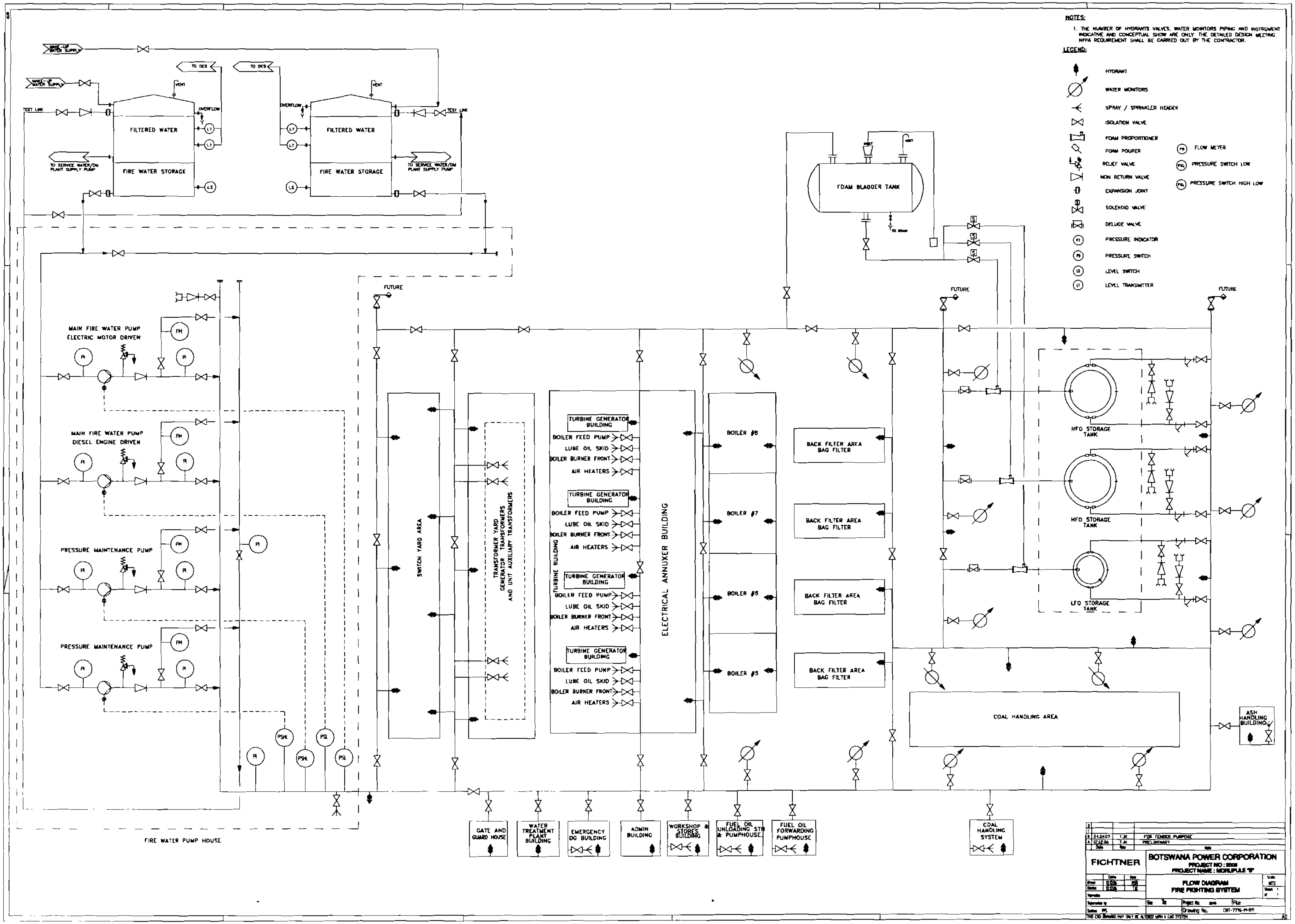
Size A0 | Project No. [illegible] | File
System AHS | Drawing No. CM-7776-M-008

THIS CAD DRAWING MAY ONLY BE ALTERED WITH A CAD SYSTEM

A0

Appendix 3.9

Flow diagram of Fire fighting system


NOTES:
1. THE NUMBER OF HYDRANTS VALVES, WATER MONITORS PIPING AND INSTRUMENT INDICATIVE AND CONCEPTUAL SHOW ARE ONLY. THE DETAILED DESIGN MEETING NFPA REQUIREMENT SHALL BE CARRIED OUT BY THE CONTRACTOR.
LEGEND:
HYDRANT
WATER MONITORS
SPRAY / SPRINKLER HEADER
ISOLATION VALVE
FOAM PROPORTIONER
FOAM POURER
RELIEF VALVE
NON RETURN VALVE
EXPANSION JOINT
SOLENOID VALVE
DELUGE VALVE
PRESSURE INDICATOR
PRESSURE SWITCH
LEVEL SWITCH
LEVEL TRANSMITTER
FLOW METER
PRESSURE SWITCH LOW
PRESSURE SWITCH HIGH LOW
MAKE-UP WATER SUPPLY
TEST LINE
TO DCS
VENT
OVERFLOW
FILTERED WATER
FIRE WATER STORAGE
TO SERVICE WATER/DM PLANT SUPPLY PUMP
FOAM BLADDER TANK
TO DRAIN
FUTURE
MAIN FIRE WATER PUMP
ELECTRIC MOTOR DRIVEN
MAIN FIRE WATER PUMP
DIESEL ENGINE DRIVEN
PRESSURE MAINTENANCE PUMP
FIRE WATER PUMP HOUSE
SWITCH YARD AREA
TRANSFORMER YARD
GENERATOR TRANSFORMERS
AND UNIT AUXILIARY TRANSFORMERS
TURBINE BUILDING
TURBINE GENERATOR BUILDING
BOILER FEED PUMP
LUBE OIL SKID
BOILER BURNER FRONT
AIR HEATERS
ELECTRICAL ANNUXER BUILDING
BOILER #8
BOILER #7
BOILER #6
BOILER #5
BACK FILTER AREA BAG FILTER
HFO STORAGE TANK
LFO STORAGE TANK
COAL HANDLING AREA
ASH HANDLING BUILDING
GATE AND GUARD HOUSE
WATER TREATMENT PLANT BUILDING
EMERGENCY DG BUILDING
ADMIN BUILDING
WORKSHOP & STORES BUILDING
FUEL OIL UNLOADING STN & PUMPHOUSE
FUEL OIL FORWARDING PUMPHOUSE
COAL HANDLING SYSTEM
B 24.04.07 TJK FOR TENDER PURPOSE
A 12.12.06 TJK PRELIMINARY
FICHTNER
BOTSWANA POWER CORPORATION
FLOW DIAGRAM
FIRE FIGHTING SYSTEM
Scale NTS
Sheet 1 of 1
Drawing No. CNT-7776-M-011
THIS CAD DRAWING MAY ONLY BE ALTERED WITH A CAD SYSTEM
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Appendix 4.1

Hydrogeological report

EXECUTIVE SUMMARY

Water Surveys Botswana (Pty) Ltd was commissioned by Ecosurv to assess potential impacts on ground (and surface) water that may result from the expansion of the BPC facilities at Morupule with the introduction of a new power generation plant to be known as the Morupule B Power Station.

The scope of work carried out is summarised below:

- Baseline hydrological and hydrogeological study
- Impact identification, interpretation and analysis
- Proposed mitigation measures

The study revealed that the soils and aquifer immediately around the power station location are considered to be of moderate vulnerability. A network of boreholes around the existing Power Station is currently used to monitor groundwater and the water quality results from these represent the background water quality from which to judge any impacts made from the new development. The existing power plant does not appear to have significantly impacted on the water resources in the area albeit for a rise in sulphate concentrations. However expansion of the power plant will increase the potential risk of water pollution. Clearly there is a need to protect both the groundwater and surface water from contamination. Pollution prevention on site should be very rigorous to ensure that any potential pollutants are mitigated. However it is also felt equally important to try to conserve water as much as possible particularly though the use of sustainable means such as recycling. There appears to be potential therefore to mitigate pollution potential and at the same time allow considerable reduction in water usage by the collection and reuse of water. By constructing impermeable lagoons for the main waste streams (ash and the general wastewater sewage system) the wastewater from the site can be contained and then treated and reused. This can have a beneficial effect for the existing site as the existing evaporation pond is not sealed and thus presents a possible pathway for contaminants to the environment. Consideration should be given to designing the new sealed lagoons large enough to receive all the waste streams from both the existing and the new site. As much surface water run off from the site as possible should be collected and reused.

Impermeable bunding of all chemical, coal and fuel stores will be required. Absorbent material capable of dealing with accidental spillages etc should be stored on site. Action plans for dealing with pollution incidents should be made a priority and all staff should have awareness training on what to do and who to contact in case of an incident which might lead to environmental damage. Oil interceptors should be placed on drainage routes and these facilities should be regularly maintained. Drainage routes should be regularly inspected for blockages and any potential contaminant transport - oily sheens etc. It is not thought that the power station will have any impact on river flows in the Lotsane River or be likely to impact water quality there. This will further be mitigated if all surface water is collected on site as recommended above.

Monitoring boreholes will need to be drilled to assess whether the development is causing any pollution. As there is already a network of boreholes monitoring the present site it is felt that 5 new boreholes will be sufficient. These will need to be sampled on a monthly basis, and the results forwarded to the Department of Geological Surveys and the Water Apportionment Board in the form of an annual report.

Table of Contents

Figures and Tables

Figures

Tables

1 INTRODUCTION

Water Surveys Botswana (Pty) Ltd was commissioned by Ecosurv to assess potential impacts on ground (and surface) water that may result from the expansion of the BPC facilities at Morupule with the introduction of a new power generation plant to be known as the Morupule B Power Station.

The scope of work carried out is summarised below:

- Baseline hydrological and hydrogeological study
- Impact identification, interpretation and analysis
- Proposed mitigation measures

1.1 Background

The Botswana Power Corporation (BPC) has experienced an unprecedented yearly increase in demand for electricity averaging 10% per annum. The current generation capacity of the existing Morupule Power station is 132 MW and the demand for electricity within Botswana currently exceeds the available generation capacity. Morupule Power Station contributes about 30% of the electricity requirements of the country. The balance of about 70% is met through imports from other countries, mainly South Africa. The shortage of surplus power generation capacity in Southern African is affecting Botswana's power imports. Consequently, Botswana must either find an alternative source or pay more for imported power.

A feasibility study carried out in 2004 concluded that the most suitable option for the rapidly developing Botswana economy was to expand the existing power station at Morupule. BPC has since made a decision to implement the expansion option.

The expansion option includes the construction and operation of Morupule B Power Station which will be a coal-fired, steam turbine driven thermal plant with a capacity of 600 MW (4 units of 150 MW each) together with necessary associated infrastructure. It is understood that an additional 600 MW will be installed at a later date (Morupule C), after an add-on feasibility study has been completed, bringing the aggregate to 1200 MW. The Morupule C is not part of this study.

This Environmental Impact Assessment (EIA) deals with the Morupule B Power Station Development (600 MW) development which will be a turn key project undertaken within the current lease area for the BPC Morupule Power Station. The location of the new station will be east of the existing station although the final site is yet to be decided. The project will thus benefit from the proximity of the existing coal supplies and transport infrastructure. Approximately 2.6 million tonnes of coal per annum will be supplied to the plant through a conveyor belt from the adjacent Morupule Colliery. The current Paje Wellfield approximately 80 km north-west of the existing plant, which supplies the existing plant, is being expanded to augment water supply to the existing station and to supply the proposed Morupule B Power Station.

The water supply (well field and supply pipeline), the expansion of the Morupule Colliery and the transmission line for the electrical grid connection are understood to be undergoing separate EIAs and, as such, these aspects of the development are specifically excluded from the scope of the project. The findings of these EIAs will however be incorporated into this ESIA where possible.

Construction of the Morupule B Power Station is expected to be undertaken over 3 years with the new plant being commissioned between January and October 2010.

1.2 Project Objective

The broad project objective is understood to be as follows:

- Preparation of an environmental and social impact assessment for the Morupule B Power Station Project, with the EIA to meet national requirements and those of the World Bank financing agency.
- This stand-alone specialist report to represent the findings of the hydrological and hydrogeological study. This hydrogeological report being essentially a desk-top study review of background baseline information with the findings presented below in the following sections, and a review of potential pollutant sources and possible mitigation options to prevent environmental impacts from the new development.

1.3 Location and Access

The existing BPC Morupule Power Station is located in the Central District and lies some 5 kilometres west of Palapye village immediately north of the main road from Palapye to Serowe (Figure 1). Serowe village some 30 km further west is the administrative centre of the Central District and has Government, District and Tribal Administration Offices.

A railway spur links both the power plant and Morupule colliery to the main north-south railway line from Gaborone to Francistown.

A site plan of the existing power station and colliery together with the perceived new area for Morupule B is presented in Figure 2. The existing plant area mainly consists of power generation plant, administrative buildings, water treatment plant, water reservoir, coal stockpiles, ash disposal site (Ash Lagoon), evaporation ponds, school, and a golf course. The new area designated for Morupule B is basically undisturbed ground with only bush tracks as access.

1.4 Physiography, Soils & Vegetation

The soils of the study area are mainly aeolian, derived from the weathering of the Ntane Sandstone Formation, which outcrops along the Serowe escarpment. They are mainly orange coloured, fine grained sandy silty loams (1990 Ministry of Agriculture FAO/BOT/85/011). The dominant soil types within the area of the Power Plant are Ferralic Arenosols and Arenic Ferric Luvisols (<3% clay), whereas southwards along the axis of the Lotsane River Calcaric Cambisols and Orthic Luvisols predominate. These soil types are displayed in Figure 3 - Soils Map.

The geotechnical report by Schwartz Tromp and Associates (2007) confirms the soil on site as 'Dry, orange brown blotched off white, loose to medium dense, porous, fine sand.- Aeolian' to a depth generally between 1.5 - 2.0 m becoming more medium grained with depth to about 4 m. Beneath this is a calcrete/ferricrete layer.

The soil is well to very well drained, and consequently does not retain any significant water moisture. As a result there do not seem to be any associated lines of drainage around the site.

The power plant lies within the Lotsane River catchment area, which is characterised by gently rolling flat plains. The power plant lies at a ground elevation of ~ 950mamsl. The topographic gradient is to the southeast as shown on the contoured elevation map (Figure 2).

The ephemeral Lotsane River (incised 2 - 3 m below the surrounding peneplain), is the major river in the area and drains from west to east and rises at the Serowe escarpment some 30 km west of the Power Plant. The Morupule River, a tributary of the Lotsane River, drains from north to south and is located some three kilometres west of the power plant and colliery site. The deeply incised nature of the Lotsane also suggests little contribution to flow from the surrounding area. The main flow is a result of drainage from the Serowe escarpment.

The lack of topographical features is clearly shown in the satellite image, which has been draped on the digital terrain model for the area, thus providing the quasi 3-dimensional image shown in Figure 4.

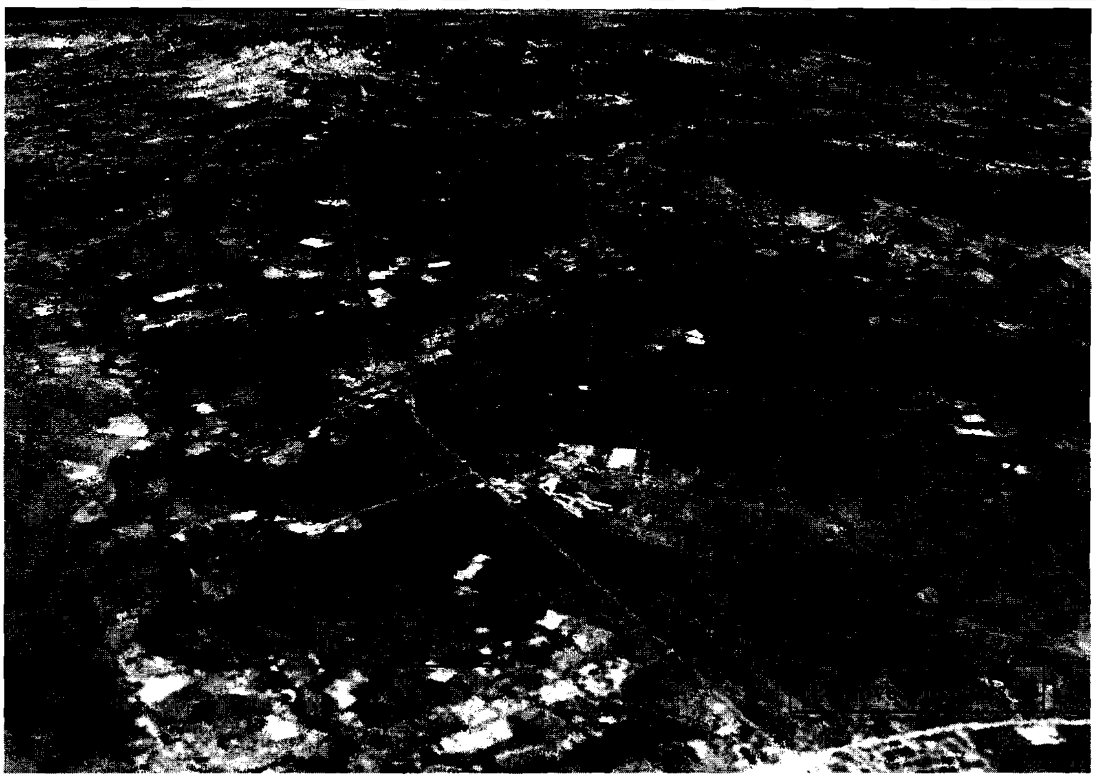


Figure 4 - 3 Dimensional satellite image showing lack of any distinctive topographical features

Vegetation around Palapye consists predominantly of Mopane Bushveld vegetation and scrub savanna (thorn trees). However due to the ephemeral nature of the rivers, a more diverse vegetation is also supported in an intermittent manner closer to the main channels. Some phreatophytic species (trees surviving on groundwater) have been reported to produce such high rates of evapotranspiration that groundwater levels have been depleted by several metres (DWA 2004).

1.5 Climate

The climate of the study area is typical of semi-arid regions, with relatively cold, dry winters and hot wetter summers.

Climatological data is regularly monitored by BPC, which includes rainfall, temperature and wind direction/speed. These details are made available to the Department of Mines, who record the results in annual Air Pollution Control Reports. Annual rainfall averages show temporal and spatial variation, which is typical of arid / semi-arid environments. The prevalent wind directions at the Power Station are easterly and northeasterly.

Rainfall data from the power station for the years 1989 – 2006 have been assessed and are presented in Table 1 and graphically in Figure 5. The mean annual precipitation for these years is 371 mm and ranges from a minimum of 111 mm in the year 1992 to a maximum of 661 mm in the particularly heavy rainfall *'Cyclone Eline'* year, which caused extensive flooding in Mozambique in 2000. The hydrometeorological analysis of the area indicated moderate to severe drought conditions with the occurrence of below normal rainfall during 1990, 1992-1994, 1997, 1999, 2002-2003, and 2005. The mean monthly precipitation data shown in Figure 6 indicates that the main rainfall occurs between November and March. The seasonal rainfall totals are presented in Table 2.

The characteristics of the rainfall are important in terms of groundwater recharge. High-intensity, short-duration rainfall is a feature of the area (as in the majority of Botswana). Rainfall intensity is a measure of how much rain falls over a specified time period. The more intense the rainfall the more likely it is to create surface run off thus potentially filling pans or depressions and thereby creating conditions conducive to groundwater recharge. The rainfall intensity/duration curves for Palapye (the closest available to the Morupule site) are shown in Figure 7 (taken from the Botswana National Water Master Plan Review 2006). They show intensity against recorded time periods over which the rainfall intensity was maintained. It is clear that the more intense the rain is, the less long it is likely to occur for - hence the graphs curve downwards as duration increases. The figures for Palapye show the maximum 100 year return value as being 132 mm/hr. When compared to other stations in the area (Serowe and Orapa for example) it appears that there is a trend of higher rainfall intensity to the north where Orapa has a maximum of 172 mm/hr and Serowe a maximum of 146 mm/hr.

Table 1 - Monthly Rainfall Totals (mm) 1989-2006, Morupule Power Station.

Year	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Yearly Total
1989-90	0	17.0	76.0	16.8	6.8	45.2	43.3	12.4	8.5	0.0	0	0	364.2
1990-91	0	0.2	11.5	86.1	85.8	74.0	126.0	0	0	37.2	0	0	214.0
1991-92	0	27.0	42.3	89.5	34.3	0	7.6	0	0	0	0	0	481.8
1992-93	0	28.3	16.5	24.3	37.0	42.6	0	0	0	0	10.0	0	111.0
1993-94	0	0	97.0	105.3	38.0	37.0	9.0	0	4.0	0	0	0	291.9
1994-95	0	0	52.4	53.0	6.5	124.6	107.1	3.5	10.0	0	0	0	193.4
1995-96	0	7.0	96.0	126.0	169.0	197.5	24.0	0	9.7	0	42.0	0	480.7
1996-97	0	4.0	105.0	63.0	47.0	55.0	131.0	2.5	0	0	0	0	614.2
1997-98	9.0	0	39.0	81.0	138.0	16.0	32.0	94.0	0	0	0	0	364.5
1998-99	0	19.6	25.9	79.5	57.5	0	4.0	21.5	0	0	0	0	405.0
1999-00	0	57.9	49.4	129.2	179.0	270.0	29.0	20.0	15.0	28.0	0	0	319.5
2000-01	0	7.0	26.0	86.5	29.0	129.0	114.0	30.0	0	0	0	0	660.5
2001-02	20.0	40.0	169.5	78.5	34.0	1.0	0	13.0	0	13.0	0	3.0	610.0
2002-03	9.0	26.0	30.0	25.1	22.0	136.0	30.0	0	0	13.0	0	0	154.1
2003-04	0	0	0	75.0	173.3	70.4	121.6	63.0	0	0	0	0	276.0
2004-05	0	40.5	18.0	88.0	72.0	15.1	57.5	51.0	0	0	0	0	574.8
2005-06	0	0	0	0	117.5	136.6	60.3	8.0	0	0	0	0	195.6
Mean	2.2	16.1	50.3	71.0	73.3	79.4	52.7	18.8	2.8	5.3	3.1	0.2	371.2

Table 2 – Seasonal Rainfall Totals (mm) 1989-2006

Year	Wet Season (September to April)	Dry Season (May to August)
1988-89	236.9	0
1989-90	217.5	17.5
1990-91	383.6	8.5
1991-92	200.7	37.2
1992-93	148.7	0
1993-94	286.3	10
1994-95	347.1	4
1995-96	619.5	10
1996-97	407.5	51.7
1997-98	409	0
1998-99	208	0
1999-00	734.5	0
2000-01	421.5	43
2001-02	356	16
2002-03	278.05	13
2003-04	503.3	0
2004-05	342.05	0
2005-06	322.4	0

Figure 5. Annual Rainfall, Morupule Power Station Area, BPC.

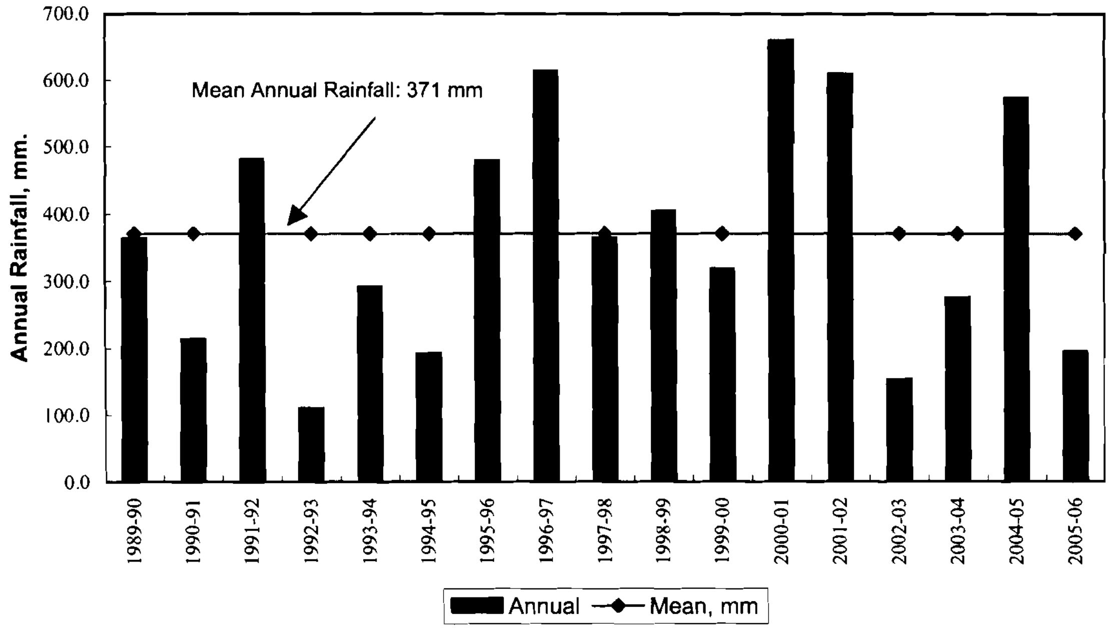


Figure 6. Mean Monthly Rainfall, Morupule Pwer Station Area, BPC.

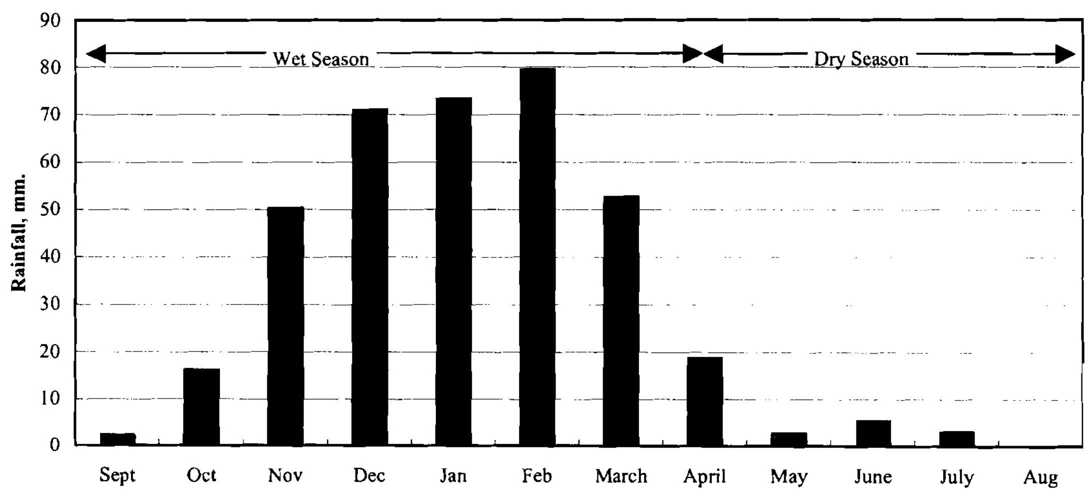
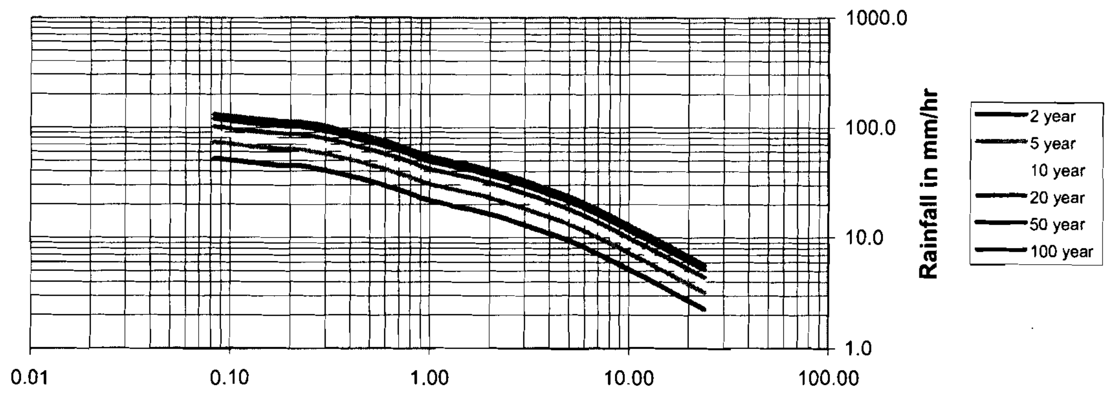


Figure 7 - Rainfall Intensity for Palapye



1.6 Evapotranspiration

Potential evapotranspiration is in the order of 900-1500 mm/year (Lubczynski 2000) three to four times the annual rainfall. Generally, monthly rainfall totals are consistently exceeded by potential evapotranspiration. This would indicate that recharge is seldom ever really possible. However due to extreme rainfall conditions that occur in short duration and high intensity, on a daily basis rainfall can exceed potential evapotranspiration and lead to a groundwater recharge particularly through transport via preferential flow paths (old tree roots, animal burrows, etc) (Selaolo 1998, SGAB 1988).

1.7 Geology

The geology of the area where the Morupule B power plant is to be constructed is essentially shales and mudstones of the Lotsane Formation overlain by relatively thin (10 - 20 m) Kalahari Beds. Beneath the Lotsane Formation (~100 mbgl) are the fractured quartzites of the Tswapong Formation, which outcrop as the western escarpment of the Tswapong Hills some 20 km to the southeast. To the west black shales with mudstones and siltstones of the Karoo Supergroup sediments unconformably overlie the Lotsane Mudstones. These rocks form the eastern edge of the South East Central Kalahari Karoo Sub Basin (Smith 1984), where a succession of conglomerates, shales and sandstones occur to around 300 m in thickness. Within these sequences lie the coal seams that provide the fuel for the power station.

Table 3 shows the complete stratigraphic sequence using accepted terminology after Smith (1984) and Figure 8 shows the geology of the study area.

Table 3 - Stratigraphy in the Serowe Area

AGE	SUPERGROUP	GROUP	FORMATION	LITHOLOGICAL DESCRIPTION
CAINOZOIC		Kalahari	Kalahari Beds	soil, sand, calcrete, silcrete and clay
			Tuli Dyke Swarm	Dolerite dyke and sill intrusive event
MESOZOIC	KAROO	Stormberg Lava	Serwe Pan	Massive amygdaloidal flood basalt extrusion
		Lebung	Ntane Sandstone	Aeolian sandstone. Medium to fine grain with minor mudstone intercalations becoming fluvial to base
			Mosolotsane	Fluvial red beds. Siltstones and fine grained sandstone
		Beaufort	Tlhabala	Non-carbonaceous mudstones and siltstones with minor sandstones
		Ecca	Serowe	Siltstones, mudstones with minor sandstones, limestones and vitrinite coal seams
			Morupule	Carbonaceous shales and dull coal seams with minor sandstones
			Kamokata	Coarse clastic fluvio-deltaic sediments
			Makoro	Post glacial lacustrine argillaceous mudstones and siltstones
		Dwyka	Dukwi	Base of Karoo sequence tillites, shales, varved siltstones and mudstones
PROTEROZOIC	WATERBERG			Dolerite dyke and sill intrusions
		Palapye	Shoshong	Conglomerate and sandstone with banded ironstones, dolomite and quartzite
			Lotsane	Variegated shales and mudstones
			Tswapong	Massive to flaggy purple quartzites
			Moeng	Argillites pink shales and micaceous siltstones with minor limestone
			Selika	Volcanic tuffs and coarse grained sandstones/quartzites
ARCHAEAN	BASEMENT	Limpopo Mobile Belt		Granite gneiss and amphibolite

1.8 Hydrogeology

From a hydrogeological viewpoint, the Kalahari Beds immediately below the new site can be considered a very minor aquifer. The mudstones and shales of the Lotsane Formation beneath, unless significantly fractured (which does not seem likely in the area according to the results of the Geotechnical Report - Schwartz Tromp and Associates 2007), do not contain usable amounts of groundwater and are almost certainly a barrier to the downward migration of water. Likewise to the west the mudstones and shales of the Karoo sequence cannot be considered a significant aquifer. Only the fractures within the quartzitic Tswapong Formation are capable of providing significant quantities of groundwater, and it is these rocks that have been tapped historically for the supply of Palapye via the Palapye Wellfield, which is located some 15 km to the south east of the power station.

Groundwater flow, what little there is, will mirror the topography away from the power station site to the southeast towards Palapye. Thus there is potential for any surface contaminants that might percolate down to the shallow surface aquifer to thus be able to migrate off site towards Palapye within the Kalahari Beds. There seems little possibility that groundwater will penetrate any significant depth into the mudstones of the Lotsane Formation.

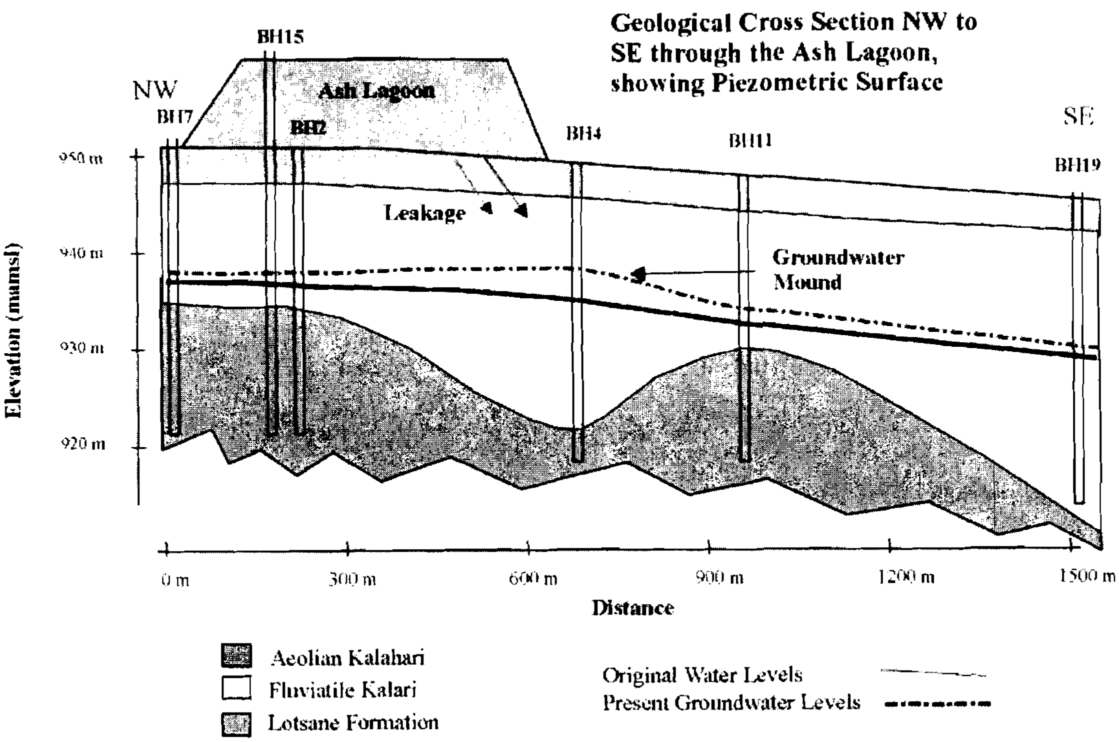
2 BACKGROUND DATA AND VULNERABILITY CHARACTERISATION

Following construction of the existing Morupule Power Station, it was realised that the activities there could potentially lead to impacts to the environment particularly relating to groundwater. As a result the existing power station has a network of groundwater monitoring boreholes around the site. These are monitored (sampled and dipped) on a monthly basis and the resulting analysed data is forwarded, in the form of a yearly audit, to the Department of Geological Surveys (DGS) and the Water Apportionment Board (WAB). It is this data that has provided the most useful source of baseline data on the groundwater at site.

A geotechnical study has been carried out for the proposed Morupule B Power Station and the depth of groundwater noted. No other hydrogeological information was obtained. However sufficient data probably already exists from the present groundwater monitoring (which has been carried out over the last 20 years at the existing site) to characterize the baseline status of the water environment at the site.

The most recently available Morupule Power Station Annual Groundwater Monitoring Audit Reports have therefore been scrutinized. These are extensive in their detail of the current situation as related to the area immediately surrounding the current power station. Data provided from the groundwater monitoring teams at BPC has also been accessed which includes both water levels and water quality. Historical data from previous reports has been examined to compare the present situation with the past and potentially highlight changes or impacts on the environment that have occurred as a result of previous activities at site.

Indeed the hydrogeological cross section shown in Figure 9 below (adapted from Aqualogic 2006 Groundwater Audit Report) indicates that a groundwater mound has developed beneath the present Ash Lagoon due to seepage from that area. This has the potential to cause the movement of contaminants away from the Ash Lagoon towards the southeast.



Source: Morupule Groundwater Audit 2006 Aqualogic

Figure 9 - Hydrogeological Cross Section through current Ash Lagoon Site

Other sources of data have been the soils report from 1985 and the Geotechnical Reports. The 1:125,000 geology map for the area (2227C – Palapye), the 1:250,000 Soil map and the 1:500,000 Hydrogeological Map for the area have also been used to collate baseline background data.

2.1 Aquifer Vulnerability

To examine the potential for groundwater impact, it is important to firstly assess and understand the vulnerability of the setting. Groundwater vulnerability is a function of the physical circumstances at a particular location and provides a measure of the ease with which unacceptable effects upon groundwater can occur.

Awareness of an aquifer's vulnerability to pollution or other detriment will offer protection to the regional resource preserving it for future exploitation. Aquifer vulnerability is assessed on the basis of physical, biological and chemical characteristics of geological and soil layers above the aquifer and can be presented as zones of differing vulnerability on maps.

A vulnerability assessment does not specifically aim at protecting, say, a wellfield but is directed towards establishing protection policy for water resources in general. Protection of existing wellfield boreholes is addressed by individual protection zoning around boreholes. However in the case of the Morupule B power plant, there are no protection zones within a 10 km radius, the closest wellfield being the Palapye Wellfield to the south east of Palapye itself.

2.2 Vulnerability Assessment

The characteristics of the strata and soils, which separate the saturated aquifer from the land surface, are of prime consideration.

Three factors are used to assess the vulnerability of groundwater resources to a given hazard:

- **Nature of the soil horizon**
- **Nature of strata above the saturated aquifer (in the unsaturated zone)**
- **Depth of the unsaturated zone**

The above criteria form a practical, scientifically based methodology for constructing primary land surface zoning providing the framework to mount a groundwater protection policy.

2.3 Nature of the Soil Zone

Risk from diffuse polluting activities (for example coal piles, waste ash piles, pesticide/fertilizer application) depends upon the attenuating characteristics of the soil. The biologically active soil zone can be very efficient at eliminating or attenuating pollutants. For a point source contaminant (say a spillage of material in a small area) the pollutant tends to overwhelm the attenuation characteristics of the soil and thus renders the potential protection inoperative. This is generally true for the semi-arid conditions persisting in Botswana where the soil zone is normally relatively thin and often fairly fragile.

Three general soil vulnerability classes (high, medium and low) are generally accepted as a starting point for vulnerability classification based on the physical and biological properties of the soil to prevent and/or attenuate downwards movement of contaminants. These classifications were originally proposed by the United States Environment Protection Agency in the 1970's and were adopted by the National Rivers Authority (now the Environment Agency) in the UK for their water resource protection zone modelling. The same vulnerability modelling rationale was used in Botswana in 1993, under the auspices of the Department of Water Affairs (Protection Zone Study (PZS) - DWA 1993), to demarcate soils and sub surface characteristics.

CLASS 1	High Vulnerability Soils
	Soils with little or no ability to attenuate diffuse pollutants and in which non-adsorbed diffuse pollutants and liquid discharges will leach rapidly.
CLASS 2	Soils of Intermediate Vulnerability
	Soils with moderate ability to attenuate diffuse, non-adsorbed pollutants but will possibly allow pollutants to penetrate the soil layer.
CLASS 3	Soils of Low Vulnerability
	Soils unlikely to allow the penetration of pollutants and within which water movement is largely horizontal, or have large capacity to attenuate pollutants.

The principal soil groups encountered in Botswana are described below based on definitions from the Soil Mapping and Advisory Services, Botswana - (1990).

'S' Soils	'S' soils are developed on coarse-grained **Sedimentary** rocks (ie. generally sandstones) and generally attain a maximum depth of around 150 200 cm. Soil texture is loamy fine to coarse sand. Clay often occurs lower in the profile but all S type soils are well to excessively drained. S type soils have been designated as Class 1 high vulnerability soils.
'A' Soils	Developed on **Alluvial** sands and are generally moderately deep to deep (>150cm) brown sandy loams to clay. They are poorly to moderately drained. The higher clay/organic content and deeper profile characterises them as having Class 2 vulnerability.
'B' Soils	Soils on **Basic** igneous rocks (Stormberg Basalt) which are shallow or very shallow (<50cm) well-drained sandy loam to clay. The thin profile results in a Class 1 vulnerability designation.
'C' Soils	Highly **calcareous** with >40% $CaCO_3$ content developed on shallow calcrete or limestone. The soils are very shallow (<10 cm), well-drained sandy loams classified as lithosols - calcaric regosols.

Soil vulnerability zoning is regarded to be of only relatively minor importance in overall resource protection in Botswana since the soils are generally thin and easily disturbed.

At the Morupule location only the first soil types (type S) is particularly relevant. The relative positions of the various different soil types was shown earlier in Figure 3.

The geotechnical study (Schwartz Tromp and Associates 2007) has also provided confirmatory evidence of the soils and depths at the site. These have been tabulated and are presented from that report in Table 4 overleaf:

Table 4 - Table of Soil Characteristics at Morupule B Power Station

TH01	6,0		3,3		6,0+	6,0	NP	NE
TH04	4,8		2,0		4,8+	4,8	NP	NE
TH06	9,5		8,6		9,5+	9,5	NP	NE
TH07	6,1*		6,1+		NP	NP	NP	NE
TH08	10,2		9,3	9,9	10,2+	10,2	NP	NE
TH09	6,0		5,2		6,0+	NE	6,0	NE
TH10A	6,0		6,0		6,0+	NE	6,0	NE
TH11A	3,4		3,4		3,4+	NE	3,4	NE
TH12A	7,2	0,8	5,3		7,2+	7,2	NP	NE
TH13A	5,0		4,8		5,0+	4,8	5,0	NE
TH14	7,1		5,5		7,1+	NE	7,1	NE
TH15	9,1		7,0		9,1+	7,0	9,1	NE
TH16	5,8		4,8		5,8+	4,8	5,8	NE
TH18	9,0		7,8		9,0+	NE	9,0	NE
TH19A	7,0		6,8		7,0+	NE	7,0	NE
TH20	8,4		5,2		8,4+	5,2	8,4	NE
TH21	4,0		4,0		4,0+	4,0	NP	NE
TH23	5,2		3,4		5,2+	5,2	NP	NE
TH24	4,2		4,2		4,2+	4,2	NP	NE
TH25	4,4		4,2		4,4+	4,4	NP	NE
TH27	16,3		9,1	9,6	16,3[2]+	NE	NP	NE
TH28	12,0		10,5		12,0+	12,0	NP	NE
TH29	5,5	0,1	5,5		5,5+	5,5	NP	NE
TH35	11,3		5,3		11,3+	7,0	10,3	NE
TH35A	6,5		5,5		6,5+	5,5	~6,0	NE
TH36	4,6		3,9		4,6+	3,9	4,6	NE
TH36A	4,4		3,9		4,4+	3,9	4,4	NE
TH37	4,2		4,1		4,2+	NE	4,1	NE
TH38	12,2		4,3		12,2+	6,8	(4,3 to 6,8)	NE

Key provided on the next page

Key :

*	-	*Not at refusal*
1	-	*Ferricrete / calcrete formed within the basal aeolian soils and/or possibly in upper residual soils*
2	-	*Residual sandstone / shale*
NP	-	*Not Proven*
NE	-	*Not Encountered*

Positions of Trial Pits can be located in the full Geotechnical Report

Note:

- *All trial holes drilled with a 750mm diameter flight using a Williams LDH piling rig*
- *Trial holes TH35 to TH38 deepened with 450mm auger flight below refusal of 750mm diameter flight*
- *Sidewall collapse occurred in trial holes TH04, TH10A, TH12A and TH23*

From the evidence of the soil map for Botswana and the soil descriptions from Table 4 it is concluded that all the soils within the proposed development area at Morupule B can be classified as S Type Soils - moderate to deep well drained red to strong brown fine sands to loamy fine sands from coarse grained sedimentary rocks. As such they would be classified as Class I high vulnerability soils.

They provide little opportunity for biological or physiochemical attenuation of pollutants and allow rapid access to underlying strata.

2.4 Nature of Strata above Saturated Aquifer

As for soils three types of strata which form the unsaturated zone or confining layer to the saturated aquifer are generally defined for vulnerability assessment based upon the physical, chemical and biological nature. These definitions based on UK Environment Agency standards were adopted in the DWA PZS 1993 Study.

Aquifers - Types A and B

- Type A - Major aquifers which are highly permeable and productive, normally with the presence of significant fracturing. These are highly vulnerable.
- Type B - Minor aquifers, fractured or potentially fractured rocks with low primary permeability. Layered strata of variable permeability also fall into this category. This category has moderate vulnerability depending upon the presence of fracture zones.

Non-Aquifer - Type C

- Rocks of very low permeability which do not contain groundwater in exploitable quantities. However few rocks are totally impermeable.

The aeolian layer of sandy silty loams overlies mainly calcretes and ferricretes of the Kalahari Beds (which in turn overlie the Lotsane Formation rocks). Table 5 below is a summary of the rock types encountered during the geotechnical study. The Kalahari sediments themselves consist generally of a geological matrix which is capable of retaining and transmitting groundwater and has therefore been classified for the purpose of this study as a *Minor Aquifer - Type B.*

The underlying Lotsane Formation unit, which is unlikely to retain or transmit groundwater, has been classified for the purpose of this study as *Non Aquifer - Type C vulnerability* as has the Karoo Formation unit to the west (again classified as *Non Aquifer - Type C vulnerability.)*

2.5 Depth of Unsaturated Zone

The unsaturated zone of an aquifer can play an important role in attenuating pollutants through physical, chemical and biological processes and by acting as a delay mechanism. The latter benefit is of most importance in pollutants that biodegrade. The time taken for the pollutant to reach the groundwater may be sufficient to completely biodegrade the hazard.

The groundwater at the site is generally between 10 – 15 m based on evidence from the current monitoring borehole and the core holes drilled as part of the geotechnical study. This depth allows for a moderate degree of protection. However as shown above in Figure 9 there is potential for long term leakage into the groundwater from a saturated area like the Ash Lagoon. Thus surface contaminants can over time be transported to groundwater via the unsaturated zone. Leakage from the Ash Lagoon already at site has caused a rise in groundwater contours immediately below the site of around 3.5 m over the last ten years (Figure 9). However this mound of water does not appear to have moved significantly off site and the relatively small degree of rise (average 35 cm a year) shows that movement of groundwater is slow in both the saturated and unsaturated zones.

Table 5 - Summary of Cored Borehole Information and Rock Depths

BH01	28,0	4,87	4,97	13,8	21,5	21,5	12,83 (Pz)
BH02	27,0	3,62	8,7	15,18	22,16	22,16	13,0
BH03	21,0	6,0	7,3	18,7		18,7	10,65 (Pz)
BH04	25,0	3,75		12,03	19,53	19,53	16,58
BH05	18,0	4,36		16,36	16,8 *	16,8	14,32
BH06	22,5	8,3		14,07	18,0	18,0	15,0
BH07	25,5	4,65		13,0	14,5	14,5	2,85[3](Pz)
BH08	23,1	5,7		16,2	17,0?	17,0	10,3
BH09	18,6	7.6		10,35	15,83	15,83	13,85
BH10	15,0	4,45		10,5	10,74	10,74	1,0[3]
BH17	24,5	4,75		20,25?	20,7	20,7	15,3
BH18	21,0	7,6		14,15	16,2	16,2	16,57

Key on the next page

Key :

NP - *Not Proven*

* - *Residual Sandstone?*

Pz - *Piezometer installed to monitor groundwater level*

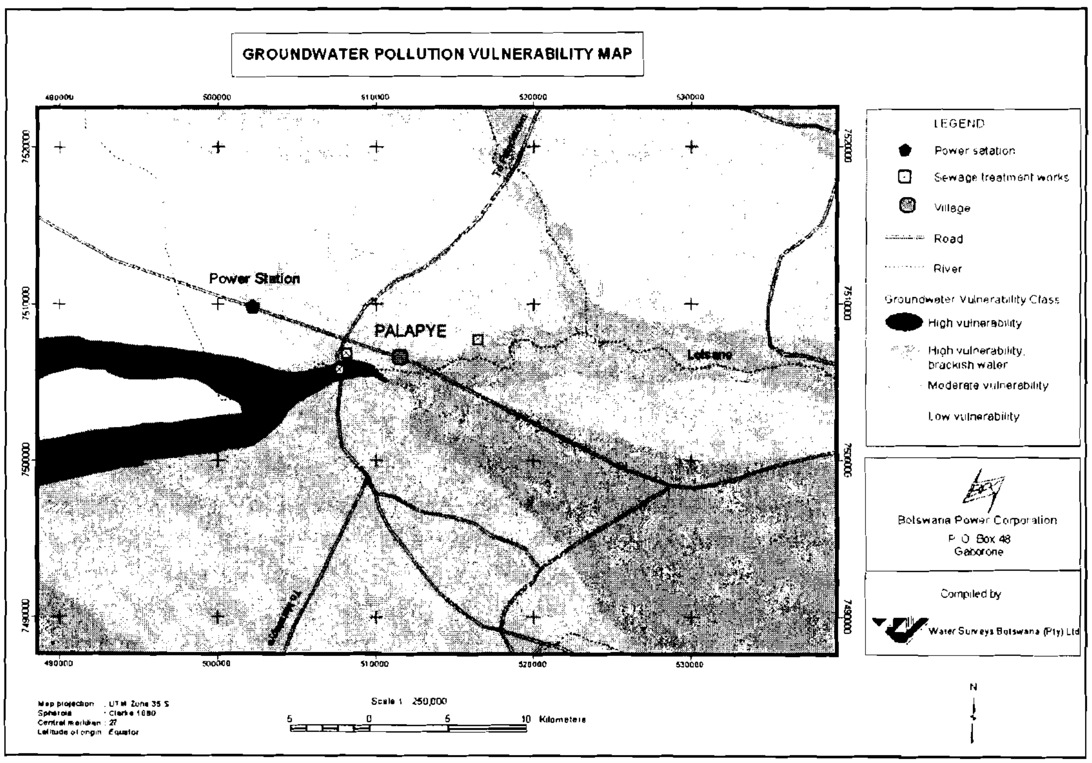
Note - *Piezometer in BH07 is possibly blocked, groundwater level of 16,65m measured alongside piezometer before gravels placed*

1 - *Calcrete (including ferricrete where present) is variable in consistency through the profile occurring as medium dense through dense ferruginised and cemented sands to very soft rock and better calcret*

2 *Groundwater levels were measured immediately after completion of drilling and repeated later to allow water levels to stabilize*

3 *Shallow groundwater reading - borehole probably collapsed and/or blocked with drilling fluids*

Based on the information gathered and the assessment of vulnerability according to the criteria listed in section 2.2 of this report, a vulnerability map based on soils and geology for the Morupule site and surrounding area has been produced and is presented below. The main site, including the proposed site for the Morupule B Power Station, lies within a moderate vulnerability setting whilst to the west the vulnerability becomes lower over the coal bearing Karoo Formation.



3 EVALUATION CRITERIA

The general method of assessing contamination or potential contamination worldwide has moved away from standards to site specific objectives. The model is now source - pathway - receptor. Generally the worst case scenario (or worst case receptor) is to judge whether groundwater at a location out outside a site is fit for human consumption (ie is it potable?). In reality this is a harsh measure but it is the one often adopted. In Botswana there are three Classes of Acceptable Drinking Water from ideal - Class I - rarely achieved especially in groundwater, Class II - Acceptable and Class III Max Allowable. Beyond that the water is unclassified and generally described as unfit for human consumption. However in many places in Botswana, the only source of available water is often Class III or above. One thing Botswana is not short of is salty and saline water.

The relevant concentrations for the three water Classes described above is given below in Table 6.

Table 6 - Botswana Water Quality Guidelines (BOS 32:2000)

Parameter	Unit	Class I (Ideal)	Class II (Acceptable)	Class III (Maximum allowable)
pH at 25°C		6.5 to 8.5	5.5 to 9.5	5.0 to 10
Conductivity at 25°C	µS/cm	700	1500	3100
TDS	mg/l	450	1500	2000
Na	mg/l	100	200	400
Ca	mg/l	80	150	200
Mg	mg/l	30	70	100
K	mg/l	25	50	100
Fe	mg/l	0.03	0.3	2
Cl	mg/l	100	200	600
SO4	mg/l	200	250	400
NO_3	mg/l	45	45	45

Whilst these standards are suitable for the long-term supply of potable water, they are stringent standards for judging the quality of shallow groundwater in a minor aquifer within an industrial context. However for the time being they probably represent the best way for assessing the current situation and determining the consequences of possible impacts.

4 BASELINE SITUATION

No new information was gained on the quality of groundwater from the geotechnical study. Therefore the most recent water quality conditions as measured by BPC in their existing monitoring boreholes must be used as the baseline condition. These conditions may represent a groundwater already impacted to a certain extent by the current power station activities. Figures 10 and 11 show the current situation for Total Dissolved Solids (TDS), Chloride (Cl), Sodium (Na) and Sulphate (SO_4) in the form of contour plots.

This shows TDS in the area of the proposed new power station in the range 1250 - 1500 mg/l, SO4 in the range 200 to 800 mg/l and Cl in the range 250 - 300 mg/l. It is better to try to present the data in this format (as a range) rather than as a single value. A single value may not be representative of the whole area and water quality would probably vary over the year according to water levels and rainfall/recharge effects.

However the worst-case situation, as represented by the highest concentration most recently analysed, must in theory be the bench mark as such a concentration already exists. Any increase in concentration beyond this would represent a deterioration in water quality. Any reduction would represent an improvement. However clearly the source of contaminants may already exist off site and so great care will need to be taken to monitor deterioration resulting from the current activities at the existing site and any activities at the new site.

Curiously the sulphate concentration at the monitoring borehole furthest from the Ash Lagoon (which would be considered a potential source of sulphate) has the highest value of any in the entire monitoring network. This may represent a localised nature source (gypsum or other material) within the Kalahari sediments. Table 7 below shows the highest existing concentrations already present within the area of the new site and therefore represents baseline conditions.

The table also compares the present existing concentrations with the drinking water standards (the only groundwater standards available in Botswana). As discussed above these are very stringent standards to use in the context of this project and they are not always met in naturally occurring shallow groundwater in the Kalahari Beds regardless of whether there was an existing industrial area close by (the current power station) or not.

Table 7 - Present Concentrations found in Groundwater close to the Morupule B site

[illegible]	[illegible]	[illegible]
Chloride	350 mg/l	Above Class II but below Class III
Sulphate	800 mg/l	Above Class III
Carbonate	350 mg/l	Above Class II but below Class III
Nitrate	15 mg/l	In Class I
Sodium	150 mg/l	In Class I
Potassium	10 mg/l	In Class I
Calcium	200 mg/l	Class III
Ammonia	5 mg/l	Above Class III
Iron	5 mg/l	Above Class III
Total Dissolved Solids	1500 mg/l	Above Class II below Class III
Trace Elements in Total (Pb, Cr, As, V and Co)	<0.02 mg/l	Not all applicable but very low concentrations - for Pb 0.01, for Ar 0.01, for Co 1 mg/l, for Cr 0.05 mg/l

5 POTENTIAL ENVIRONMENTAL IMPACTS

Detailed final engineering designs for the new Morupule B Power Station are not yet available. In this regard however, it is assumed that by and large the design and mode of operation for the new power station will be similar to that of the existing site. Therefore noted experiences and environmental issues relating to the existing site were considered in the identification and evaluation of the possible impacts that might accrue from the development of the proposed Morupule B Power Station.

Pollution is an emotive word and tends to cause a range of reactions and opinions, some of which can raise exaggerated concerns. It is also import to realise that for the release of any substances to have an impact on the environmental regime not only does there need to be a source (ie: leakage, spillage, etc), there also has to be a pathway or conduit for that source to move down, and finally there needs to be a receptor for the contaminant source to impact upon. Accordingly prior to discussion of pollution impacts it is necessary to consider firstly what, if any, source materials may be present or may result from this type of development, which might be considered a risk, should it or they be released to the environment. Secondly it is necessary to then examine whether any pathways exist via which any potential contaminant might travel and evaluate what mechanisms exist for these potentially impacting materials to move off site and then final on whom or what they will then be likely to impact upon.

Basically without leakage, spillage or bad house keeping of any potentially polluting materials on site, in a properly engineered environment (with proper safeguards) there should be no source material available to migrate from site. **Pollution Control** on site is therefore the key area of importance. Alternatively removing the pathway or routes for any contamination to leave the site eliminates the potential risk altogether. Conversely operations or developments, which open up new pathways, are a considerable risk. Although it will be of necessity to consider one off potential problems (accidents releasing spillages etc), the general infrastructure and day to day management control of the waste streams at site are likely to be of more importance as they represent a constant potential hazard.

5.1 Potential Contaminant Sources

Historically the only potential sources of contamination identified from the existing power station relate to the disposal of the ash from the coal combustion in the boilers and the disposal of the general wastewater sewerage system at site. The issue of the storage of coal and other potential contaminants - hydrocarbons, oils, tars etc also needs to be considered, but these do not appear to have caused a problem within the existing power plant site. There is a 'live' coal storage area on the present site and this potentially offers an opportunity for contaminant leakage after heavy rainfall. Also the construction phase (albeit more short term) needs to be evaluated to see whether any activities will be likely to occur which may impact on the water environment

Ash Disposal

At the present site, the waste fly ash is mixed with water to form a slurry which is pumped to the Ash Lagoon where the water drains out leaving a hard compacted dry mound of dried fly ash. There has historically been no retention of liquid, which has thus been able to leach into the groundwater. It is assumed that a similar operation will take place at the new site although it is envisaged that the base of the lagoon area will be engineered to be impermeable to downward migration of leachate. However this wet disposal of ash is not the only method available. At some other power stations in Southern Africa fly ash is transported by conveyor belt after having been 'wetted' (20% moisture) to improve transportation and handling quality and minimise dust. Thus the amount of water used is considerably less and this method might be considered as a potentially more environmentally friendly way of transporting the waste stream.

Waste Water System

The site sewage system drains to a series of septic tanks and the discharge from the septic tanks (via an oil interceptor) flows into an oxidation pond for final treatment. The main function of the oxidation pond is the removal of pathogens and nutrients (especially nitrogen). Waste stabilization (oxidation) pond technology is a most cost-effective wastewater treatment technology for the removal of pathogenic micro-organisms. It is particularly well suited for a country like Botswana because the intensity of the sunlight and temperature are key factors for the efficiency of the removal processes.

Hydrocarbons

Any fuels and hydrocarbons stored on site represent a potential pollution threat. Heavy fuel oils are used in ignition of the boilers and other oils, lubricants and petrol and diesel tanks on site offer a potential threat.

Losses occurring from the storage tanks and supply pipe lines are generally not obvious, particularly if the tanks are below ground, so unless they are so large that discrepancies are noted in stock control, they are generally ignored. Usually, small differences are put down to evaporation or changes in volume due to temperature differences. Breaks in the supply lines due to passage of heavy vehicles and uneven settlement of the soil will constitute a hazard as will spills occurring when the tanks/vehicles etc are being refilled.

In an area of shallow groundwater (like the situation at the Power Station) hydrocarbons often form a surface on the water and move according to the contours of the water. A proportion may be attenuated by the soil and by the unconsolidated and consolidated geology, by adsorption to the soil or rock particles or even by evaporation into the soil gas or rock pores, but leaching by influent water can remobilise much of it.

The action of soil bacteria can ultimately result in the oxidation of the hydrocarbons to carbon dioxide and water but this is dependent on aerobic, moist, biologically active soil and this type of soil horizon does not occur at the Power Station location.

Serious contamination can also result from spillages of chlorinated hydrocarbons such as some cleaning fluids and degreasing solvents. These compounds are generally very mobile and unlike petroleum products, are more dense than water. They sink to the base of the aquifer and, by dissolution in the groundwater at low concentrations, can cause very long term contamination.

Coal Stock Piles

Instances of rainfall causing contaminated surface water run off from coal storage heaps have been recorded in Europe and the USA leading to rises in hardness and sulphates in groundwater, as well as increases in some trace elements - arsenic, cobalt, lead, molybdenum. However at the Morupule site this does not seem to have been a particularly significant problem. There are groundwater monitoring boreholes situated to measure the evidence of any contamination and to date very little evidence of impact has been recorded around the coal stock pile areas.

Sulphate levels have possibly risen slightly from 100 mg/l to 150 mg/l. However hardness (as measured by $CaCO_3$) seems to be constant at about 250 mg/l, which is consistent with the background $CaCO_3$ levels. For the new site the coal storage is likely to be considerably larger as three to four times more power is to be produced. The potential for contamination from a larger coal stock pile is consequentially assessed as being more likely to be an environmental issue with the enlarged power plant site as compared to the existing site.

5.2 Contaminant Migration

From the data in the most recent 2006 Morupule Power Station Annual Groundwater Monitoring Audit Report, it appears that there is a certain degree of groundwater movement away from the Ash Lagoon which has been measured both by a rise in water levels to the south west and slightly elevated sulphate levels (sulphate being one of the main constituents of the fly ash and one of the least retarded during the movement of water through both the unsaturated and saturated zones).

The exact mechanism of recharge (infiltration of water) from the surface to groundwater is still subject to debate. Two systems are generally proposed, one being a piston like surge of moisture once the evapotranspiration losses and soil moisture deficits have been overcome, with the other being a more heterogeneous system with short cuts in the process, via preferred pathways or macro-pores (abandoned root channels, fissures) with subsequently some recharge moving more quickly than the rest.

However clearly there is some recharge of groundwater from the Ash Lagoon. The rise in water levels over the last ten years immediately close to the Ash Lagoon site has been recorded as 3.5 m. This is an average of 35 cm per year assuming a quasi 'steady state' scenario has been achieved. Taking a range of between 20 - 30% dry porous space within the unsaturated zone (as suggested by Freeze and Cherry 1979) and a distance of between 10 - 15 m to travel vertically from the lagoon, simplistic calculation suggests a leakage velocity in the order of 6 - 9 cm/yr. This ties in quite well with the 2×10^{-4} mm/d hydraulic leakage conductivity in the unsaturated zone suggested by Aqualogic during the 2005 groundwater modelling using a head different of 10 - 20 m caused by the lagoon giving an average travel velocity in the unsaturated zone of 2 - 4 cm/yr. Clearly these are hypothetical calculations but they do at least provide an order of magnitude of the speed of the moisture flow.

Sulphate cannot be considered a particularly severe contaminant but is a good 'marker' because of its conservative nature. The background levels of sulphate in the area historically seem to have been around the 50 - 100 mg/l level but some samples from the site show levels in the range 200 - 800 mg/l. In contrast the BOS 32:2000 Drinking Water Standards for Class I water is 200 mg/l but for Class III Waters (maximum allowable for drinking water) the permissible level rises to 400 mg/l. Analysis for other trace elements which might have greater toxicity have only recently been started and as yet have not been detected in any significant quantities (total below detection limits of 0.02 mg/l) and the need for organic sampling has been taken on board by BPC but the results from the first sampling are yet to have been carried out. It does not appear that significant organic contamination has occurred as BPC have an oil/water separator which skims the surface of the waste stream before entry into the evaporation ponds. If organic material is noticed as a sheen on the surface of the pond then a boom is placed across to absorb this. However the larger the generating plant, the larger the potential problem may become.

Review of recent steady state computer modelling of the site (Aqualogic 2006) has indicated that a potentially conservative contaminant like sulphate could move off site within the saturated groundwater at a rate of 20 cm/day not allowing for any retardation effects (adsorption, diffuse, absorption etc). This modelling, although necessarily a little simplistic as the number of unknown variables was large, was a useful attempt to try to obtain a quantitative rather than qualitative finding. A lot of the data on which the modelling was based was estimated, as no values of transmissivity or storage are available which would normally form the basis of a computer model. Neither is there any pumping of water in the local area so there are no transient groundwater levels to calibrate the model with. Thus the estimated result obtained must be considered with a degree of caution.

The possibility of attempting to model the new site is not appropriate as similarly no hard hydrogeological data is available, nor is there any contaminant source to model. Subsequently if a pollutant source were to be identified in the future it might then be considered.

Evaporation Ponds

The wastewater and sewage from the site flows to a series of septic tanks with the outflow via an oil separator to a large oxidation pond. The oxidation pond dealing with the sewage and waste waters on site appears to be a very appropriate form of disposal.

Although the ponds are not lined, water levels beneath the ponds have actually reduced over time by around 0.5 – 1 m (during the last 10 years). The reason for this has been attributed to the luxurious growth of vegetation and trees around the ponds which have intensified the natural evapotranspiration processes. However there has been a small rise in the concentrations of chemical parameters measured in boreholes monitoring the groundwater around the evaporation ponds albeit these rises are small. For example concentrations of sulphate, sodium and chloride have appeared slightly higher than background (in the general range of 150 - 200 mg/l). This can probably be attributed to the waste water stream as these are likely to contain higher than naturally occurring sulphates and salts generated from the processes on site and run off picking up waste material. However the levels are not high and nitrate levels, the obvious marker for leakage from a sewage evaporation pond, are generally low (less than 10 mg/l), which appears to indicate little significant leakage.

The other immediately apparent pollutant sources on site would appear to be fuel stores both solid and liquid, lubricants, oils, tars etc and other chemicals and waste products on site.

Thus the only potential for contaminants to leave site will be airborne as droplets in the smoke and steam. These will be vapours with a potentially high acid content - sulphuric acid.

Migration of Contaminants via Moisture in the Air

The issue of 'acid' rain and the potential to cause environmental damage and pollution outside the immediate sphere of influence is a complex one. The dramatic effects that have been caused by this acid rain in Europe, America and Russia are well documented. It is not certain how much an impact this will have in the Morupule B context.

Test cases from other countries have been reviewed to judge whether this is likely to be significant from the increased size of the new power plant.

Most evidence available relates to soils. The three general conclusions reached are:

Important plant nutrients are mobilized and leached from the soil, therefore decreasing the availability to plants for growth.

The microbial community is altered by the lower pH created by acid rain. It harms decomposer microbes that recycle nutrients and mycorrhozal fungi that aid in nutrient uptake by plants.

Acid soils contain elevated concentrations of aluminum, hence impairing root activity. That is, it may limit root uptake of calcium and magnesium, thus creating nutrient deficiencies. At high levels of soil acidity, aluminum can also released to the surface water and groundwater. The bulk of research points to evidence showing the effects of acid rain on soil is generally dependent on the ions in the soil. The ions related to either plant growth or lack of it are calcium (Ca^{2+}) and magnesium (Mg^{2+}) as well as the cation hydrogen (H^{+}). These ions are the nutrients needed by plants. . At the same time as these important tree nutrients such as calcium, magnesium and potassium are leached out of the soil there is an increase in toxic metals, coupled with a decrease in the uptake of nutrients which has an adverse effect on trees' growth and health. The buffer capacity of most soils has so far prevented much acid contamination of groundwater, but the capacity of soils to store and neutralize large amounts of cation acids is almost impossible once the capacity for retention is exhausted. In the case at Morupule the absence of any significant aquifer close to the site tends to indicate that sulphur dioxide emissions (and hence acid rain) is not likely to be a significant issue.

5.3 Water Usage

A further groundwater environmental impact, which although not strictly part of this study, is already occurring at the BPC Paje Wellfield some 80 km to the north west of Morupule. Here each year around 650,000 m^3/yr of groundwater is abstracted for use at the current power plant. This abstraction is estimated to rise to around 2 Mm^3/yr. This water is 'lost' from the environment basically as steam, cooling water evaporation, waste product with no recycled end product.

This is a large amount of water and costs BPC a considerable amount of money to pump and transport. A positive environmental impact that can come about as a result of the development of Morupule B is one of 'relative' cost saving and environmental saving as a result of a much more concentrated effort to look for ways to conserve and reuse water. This topic is discussed more fully within the mitigation section below.

6 IMPACT ASSESSMENT

The different facets of the new power plant, which have potential to cause impact to the water environment, are now assessed. These include the shorter-term development phase as well as the longer-term waste disposal activities.

Firstly the construction phase of the new power station will involve the influx of machinery and equipment with the consequent need for fuel and chemicals. Construction materials will be stored on site. There is the short term risk of accidents, spillages, leakages and one off potential pollution incidents.

Then there are the longer term pollutant risks - the on going need to dispose of ash from the boilers and waste water stream resulting from the running of the proposed new Morupule B Power Station.

Although 'Environmental Protection' is the key for eliminating pollution potential (and this will need to be the case for the new development) there is at the same time an opportunity for improvements in the existing infrastructure and a chance to rethink some of the previously installed waste stream practices.

For example it is assumed that the disposal of ash from the boilers is likely to follow the same method as currently employed at the existing site. The ash will be slurried and pumped to an ash lagoon. This area therefore represents a potential pollutant loading. Leaching of the liquid portion of the slurry into the ground can occur. However this not only represents a contaminant risk but is also a waste of a precious resource - the water. Therefore although the ash represents an environmental risk, it also represents a potential positive impact if the water can be reused.

However the possibility of a different ash disposal method (a drier method) involving only the wetting of the ash to aid transport characteristics and to suppress dust should be considered. This process involves much less water and thus reduces the leachate potential. However run off caused by rainfall will still need to be controlled.

A similar situation is considered to be the case for the sewage system/oxidation pond. The wastewater produced in the new plant will obviously be a potential threat to ground and surface waters. The present oxidation ponds are an affective method of treating the current waste stream although seen (by some) as potentially damaging to the environment because they are not lined. However when the water has been fully treated within the pond it does not present such a hazard and could then potentially be reused - thus providing a positive impact. This is not happening at the current site and therefore represents an improvement in water management obtainable from the new site.

All drainage from the site and from coal storage areas also represents a potential hazard. Chemical and fuel stores can leach material into the general drainage system thus arriving unwontedly at the evaporation pond or potentially bypassing this treatment and escaping into the environment.

The various pollutant risks without the completely self contained sealed drainage are shown below with the relevant intensity, extent, duration and probabilities in Table 8.

Table 8 - Prediction of Impacts before Mitigation

[illegible]	Nature	Intensity	Extent	Duration	Probability	Confidence	Comment
On Groundwater as a result of:							
Construction							
Soils impacted by ground works, spillages/oils/concrete with potential for leaching into groundwater	Negative	Medium	Local	Short Term	High	Medium	Almost inevitably this will occur, but the construction is a short term activity
Discharge of pollutant liquids as result of incident/accident infiltrating into groundwater	Negative	Medium/ High	Local	Short Term	Medium	Medium	Accidents can happen. Serious incident - Fuel bowser overturns - potential for causing serious effects
Ash Waste Stream							
Ash slurried with water before disposal. This waste stream has high sulphate and calcium loadings in the leachate and other potential trace elements. Leachate can impact groundwater and the waste product remains on site after the life time of the plant.	Negative	High	Regional	Long Term	High	High	This waste stream is certain, therefore confidence and probability high. Sulphate is not readily removed from groundwater - therefore long term regional impact possible. Waste product remains after site closure.
Sewage Waste Stream							
All other waste products from the plant including sewage, drainage, waste from chemical processes, leakages and spillages. A wide range of products with potential to contaminate groundwater.	Negative	Medium	Regional	Long Term	High	High	This waste stream is certain, therefore confidence and probability high. - long term regional impact possible
Coal Storage							
High sulphate and hardness ($CaCO_3$) leachate potential. Long term storage inevitable - remains an issue for life of site.	Negative	Medium	Local/ Regional	Long Term	Medium	Medium	The coal is not a waste stream as the ash is. Problem will only occur as a result of rainfall. Therefore less certainty about occurrence/impact.

Coal Combustion							
Acid rain causing precipitation of materials away from the power plant.	Negative	Low	Regional	Long Term	Medium	Low	Uncertain how this will impact. Evidence from other countries shows that this happens but confidence in impact low.
Chemical Fuel Storage							
Chemicals and hydrocarbons capable of causing groundwater contamination are stored on site - Spillages, leakage, drainage and run off issues	Negative	Low	Regional	Long Term	Low	High	These materials inevitably on site. Accidents can mobilise contaminant. High confidence but uncertain probability of occurrence of accident.
Site Drainage/Run Off/Water Reuse							
Water Reuse - not only saves resources but can also alleviate groundwater pollution by removing source of contamination.	Positive	Medium	Local	Long Term	Medium	Medium	Water reuse seen as positive impact. Can only be used locally within the power station.
On Surface Water as a result of							
Construction							
Soils impacted by ground works, spillages/oils/concrete with potential for draining into surface water	Negative	Low	Local	Short Term	Low	Medium	Less likely to impact surface water as limited drainage potential in the sandy soils around the power station
Discharge of pollutant liquids as result of incident/accident infiltrating into surface water	Negative	Medium	Local	Short Term	Low	Medium	Less likely to impact surface water as limited drainage potential in the sandy soils around the power station
Ash Waste Stream							
Ash slurried with water before disposal. Waste water can impact surface water even after the life time of the plant. High sulphates and other trace elements	Negative	Medium	Local/ Regional	Long Term	Medium	Medium	Waste material will remain on site after closure of power plant. Drainage pathways may develop to transport material off site
Sewage Waste Stream							

All other waste products from the plant including sewage, drainage, waste from chemical processes, leakages and spillages. A wide range of products with potential to contaminate surface water.	Negative	Medium	Local/ Regional	Long Term	Medium	Medium	As the waste is in liquid form has potential to transport material to surface water
Coal Storage							
High sulphate and hardness ($CaCO_3$) leachate potential. Long term storage inevitable - remains an issue for life of site.	Negative	Low	Local/ Regional	Long Term	Low	Medium	Less likely to impact surface water as limited drainage potential in the sandy soils around the power station
Chemical Fuel Storage							
Chemicals and hydrocarbons capable of causing contamination are stored on site - Spillages, leakage, drainage and run off issues	Negative	Medium	Local/ Regional	Long Term	Low	Medium	Less likely to impact surface water as limited drainage potential in the sandy soils around the power station
Site Drainage/Run Off/Water Reuse							
Water Reuse - removes surface water resources	Negative	Medium	Local	Long Term	Medium	Medium	Limited drainage but removing water from the environmental cycle means less water available for surface flow

7 MITIGATION

Having assessed the potential sources of pollutants and their potential impacts, it is in some ways difficult to realistically argue that the new power station (Morupule B) will be likely to pose a particularly significant pollutant risk to groundwater since retrospectively the existing power station (with little efforts made at containment of potentially polluting by products) has not been a cause of groundwater pollution - no significant impacts have been noted other than a relatively small rise in sulphate concentrations in groundwater immediately next to the ash disposal lagoon. However the development will increase the size of the area and number of people working there. This will have a contributory effect on the amount of coal and chemical storage. It will also increase the amount of burnt coal ash to be disposed of. These are the activities which are likely to have the most potential for consequent impact.

However mitigation measures have been assessed and are discussed below. The mitigation measures that will be suggested in this section have an additional benefit in that they will potentially produce positive impacts for other parts of the environment.

It is proposed that the pathways via which potential contaminants could leave the site and thus impact the environment be severed thus removing all risks.

For example if the ash lagoon is a sealed unit with a self contained drainage system then the water previously released to the environment via groundwater will be retained and can actually be recycled and reused thus saving resources (which would otherwise have to be pumped from the BPC Wellfield at Paje some 80 km to the north west). Thus the potential contaminant threat is eliminated whilst the wider environment benefits. Alternatively a different method of disposal would greatly reduce the impact. That is if the waste fly ash was disposed of 'dry' - that is to say with only minimal wetting to allow handling and reduce dust impact - then there would be far less risk of groundwater impact as there would be virtually no leachate potential. The only risk being rainfall infiltration into the waste heap but this could be managed by engineering the heap to allow run off to be controlled.

Likewise by sealing the base of the oxidation ponds there is no subsequent risk to groundwater and positive impacts can be obtained by reusing the end waters. Since the present system is not sealed it is therefore considered prudent to examine possibilities of rerouting the existing system into a new sealed pond thereby saving further water and reducing current risks. The size of the new facility should be designed with this possibility in mind.

The sealing of all drainage and collection (rain water harvesting) of all clean surface run off and roof water, together with the recycling of all waster waters will not only eliminate potential for groundwater contamination but will also resolve any surface water discharge issues. There will be extremely limited surface water run off from site thus reducing the pathway for any significant surface transportation of pollutants.

Run off from coal storage (which for the new site should be on an impermeable surface) should be routed for collection at the evaporation ponds and hence back into the system for reuse. A completely self sealed drainage and run off collection system should be at the top of the design scope of the project. It is proposed that the existing pond no 3 - which is supposed to be used for storm water collection - could prove the ideal site for an expanded and improved oxidation pond for the whole power plant complex. An additional site could be used for the storm water surge created by particularly large storm events and for the collection of roof drainage from buildings and run off from car parks.

Thus the mitigation proposal is the same for all activities (other than construction) that being the drainage from all areas is collected and drains to a central oxidation pond area for treatment and subsequent reuse on the site particularly as water for slurrying with the ash, landscaping and other non potable uses.

Where possible during construction all materials should be stored on an impermeable bunded surfaces within a secure location. These bunded areas could be a surface required within the final power plant complex or could be a temporary enclosure. Spills, leaks and fueling operations should be contained within this location with drainage leading to a sump which can contain spillages should any occur. Good management of construction traffic and impermeable parking areas for tankers etc should reduce risks of accidents causing environment impact.

The fully mitigated consequences are shown in Table 9 whilst the overall environmental consequences and confidence predictions are presented as Table 10 .

Table 9 - Mitigated Risks

On Groundwater as a result of:							
Construction							
Soils impacted by ground works, spillages/oils/concrete with potential for leaching into groundwater	Negative	Medium	Local	Short Term	High	Medium	Almost inevitably this will occur, but the construction is a short term activity
Discharge of pollutant liquids as result of incident/accident infiltrating into groundwater	Negative	Medium/ High	Local	Short Term	Medium	Medium	Accidents can happen. Serious incident - Fuel bowser overturns - potential for causing serious effects
Mitigation - (impermeable bases to storage areas - good traffic management system)	Negative	Low	Local	Short Term	Medium	Medium	Having impermeable storage areas with sealed drainage and accident prevention measures can not eliminate all risks. However the risks can be reduced.
Ash Waste Stream							
Ash slurried with water before disposal. This waste stream has high sulphate and calcium loadings in the leachate and other potential trace elements. Leachate can impact groundwater and the waste product remains on site after the life time of the plant.	Negative	High	Regional	Long Term	High	High	This waste stream is certain, therefore confidence and probability high. Sulphate is not readily removed from groundwater - therefore long term regional impact possible. Waste product remains after site closure.
With Mitigation - (Sealed Drainage to Collection Sump and hence Reuse)	Positive	Low	Local	Long Term	High	High	Scaled drainage removes environmental threat and creates potential for water saving - thus a small positive environmental benefit.
Sewage Waste Stream							
All other waste products from the plant including sewage, drainage, waste from chemical processes, leakages and spillages. A wide range of products with potential to	Negative	Medium	Regional	Long Term	High	High	This waste stream is certain, therefore confidence and probability high. - long term regional impact possible

contaminate groundwater.							
With Mitigation - (Sealed Drainage to Evaporation Pond for Treatment and subsequent Reuse)	Positive	Medium	Regional	Long Term	High	High	The treatment process afforded by the evaporation pond is very suitable for Botswana. If the evaporation pond is sealed (not currently the case) this removes the environmental threat and all the liquid waste streams flow to it, the treated water will be a substantial resource for the Power Station and save resources being drawn from the more distant Paje Wellfield.
Coal Storage							
High sulphate and hardness ($CaCO_3$) leachate potential. Long term storage inevitable - remains an issue for life of site.	Negative	Medium	Local/ Regional	Long Term	Medium	Medium	The coal is not a waste stream as the ash is. Problem will only occur as a result of rainfall. Therefore less certainty about occurrence/impact.
With Mitigation - (Sealed Drainage to Evaporation Ponds with subsequent Treatment and Reuse)	Positive	Low	Local	Long Term	High	High	Sealed drainage to central collection area removes risk and produces a small positive impact - water saving/reuse
Chemical Fuel Storage							
Chemicals and hydrocarbons capable of causing groundwater contamination are stored on site - Spillages, leakage, drainage and run off issues	Negative	Low	Regional	Long Term	Low	High	These materials inevitably on site. Accidents can mobilise contaminant. High confidence but uncertain probability of incident occurring.
With Mitigation - (Sealed Drainage to Evaporation Ponds with subsequent Treatment and Reuse)	Negligible	Low	Local	Long Term	High	High	Sealed drainage should be able to eliminate the risks posed by accidents/spillages
Site Drainage/Run Off/Water Reuse							
Water Reuse - not only saves resources but can also alleviate groundwater pollution by removing source of contamination.	Positive	Medium	Local	Long Term	Medium	Medium	Water reuse seen as positive impact. Can only be used locally within the power station.
No mitigation required.							

On Surface Water as a result of							
Construction							
Soils impacted by ground works, spillages/oils/concrete with potential for draining into surface water	Negative	Low	Local	Short Term	Low	Medium	Less likely to impact surface water as limited drainage potential in the sandy soils around the power station
Discharge of pollutant liquids as result of incident/accident infiltrating into surface water	Negative	Medium	Local	Short Term	Low	Medium	Less likely to impact surface water as limited drainage potential in the sandy soils around the power station
With Mitigation - (Local containment drainage to cope with spills)	Negligible	Low	Local	Short Term	Low	Medium	Measures to capture chemical leaks should reduce risk to environment.
Ash Waste Stream							
Ash slurried with water before disposal. Waste water can impact surface water even after the life time of the plant. High sulphates and other trace elements	Negative	Medium	Local/ Regional	Long Term	Medium	Medium	Waste material will remain on site after closure of power plant. Drainage pathways may develop to transport material off site
With Mitigation (Sealed internal drainage - no run off)	Positive	Medium	Local	Long Term	High	High	Reduced risks of transport of material off site with consequent water saving
Sewage Waste Stream							
All other waste products from the plant including sewage, drainage, waste from chemical processes, leakages and spillages. A wide range of products with potential to contaminate surface water.	Negative	Medium	Local/ Regional	Long Term	Medium	Medium	As the waste is in liquid form has potential to transport material to surface water
With Mitigation (Sealed internal drainage - no run off)	Positive	High	Local/ Regional	Long Term	High	High	All drainage of potentially contaminated water to treatment pond, all 'clean water' to collection pond for reuse
Coal Storage							
High sulphate and hardness ($CaCO_3$) leachate potential. Long term storage inevitable - remains an issue for life of site.	Negative	Low	Local/ Regional	Long Term	Low	Medium	Less likely to impact surface water as limited drainage potential in the sandy soils around the power station
Chemical Fuel Storage							

Chemicals and hydrocarbons capable of causing contamination are stored on site - Spillages, leakage, drainage and run off issues	Negative	Medium	Local/ Regional	Long Term	Low	Medium	Less likely to impact surface water as limited drainage potential in the sandy soils around the power station
With Mitigation (Sealed internal drainage - no run off)	Negligible	Low	Local	Long Term	Medium	High	Sealed drainage should remove risk of contaminants moving off site.
Site Drainage/Run Off/Water Reuse							
Water Reuse - removes surface water resources	Negative	Medium	Local	Long Term	Medium	Medium	Limited drainage but removing water from the environmental cycle means less water available for surface flow

Table 10 - Significance Rating

On Groundwater as a result of:					
Construction	Low	Probable	Low	Medium	
With Mitigation - impermeable storage areas	Low	Improbable	Low	Medium	Mitigation will reduce risks to acceptable levels
Ash Waste Stream	Medium	Highly Probable	Medium	High	
With Mitigation - (Sealed Drainage to Collection Sump)	Negligible	Highly Probable	Low	High	Mitigation should remove risk and produce a positive impact - water saving
Sewage Waste Stream/Evaporation Pond	Medium	Probable	Medium	High	
With Mitigation - (Sealed Drainage to Collection Sump)	Negligible	Probable	Low	High	Mitigation should remove risk and produce a positive impact - water saving
Coal Storage	Low	Probable	Low	Medium	
With Mitigation - (Sealed Drainage to Collection Sump)	Negligible	Probable	Low	High	Mitigation should remove risk and produce a positive impact - water saving
Chemical Storage	Medium	Probable	Medium	Medium	
With Mitigation - (Sealed Drainage to Collection Sump)	Negligible	Probable	Low	High	Mitigation will reduce risks to acceptable levels
Site Drainage/Run Off Water Reuse	Positive	Probable	Medium	High	

7.1 General House Keeping and Accident Procedures

Proper 'house keeping' at site should prevent significant spillage and leakage. However accident procedures particularly relating to spillages etc should be reviewed and a list of actions to be carried out should an incident occur should be produced.

For pollution prevention measures regarding chemical /fuel storage the following mitigation statements are general and simplistic but will help prevent major incidents.

Fuel/Chemical Storage

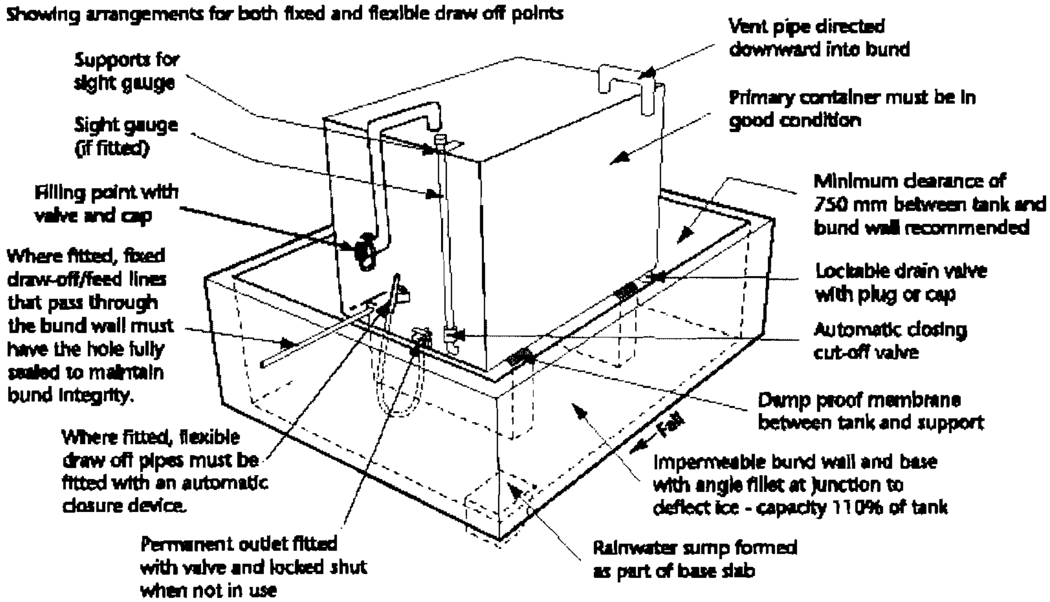
All tanks containing liquids whose spillage could be harmful to the environment should be bunded.

Bunds should in general:

- be impermeable and resistant to the stored materials
- have no outlet (that is, no drains or taps) and drain to a blind collection point
- have pipework routed within bunded areas with no penetration of contained surfaces
- be designed to catch leaks from tanks or fittings
- have a capacity greater than 110 percent of the largest tank or 25 percent of the total tankage
- be subject to regular visual inspection and any contents pumped out or otherwise removed under manual control after checking for contamination
- where not frequently inspected, be fitted with a high-level probe and an alarm as appropriate
- have fill points within the bund where possible or otherwise provide adequate containment

A schematic demonstrating these key features is shown below as Figure 12

Figure 12 Open Bunded Oil Tank Schematic



Source - Environment Agency, UK

Good Management Practice

An effective system of management is a good technique for ensuring that all appropriate pollution prevention and control techniques are delivered reliably and on an integrated basis.

Effective operational and maintenance systems should be employed on all aspects of the process whose failure could impact on the environment, in particular there should be:

• documented procedures to control operations that may have an adverse impact on the environment

• a defined procedure for identifying, reviewing and prioritising items of plant for which a preventative maintenance regime is appropriate

• documented procedures for monitoring emissions or impacts

• a preventative maintenance programme covering all plant, whose failure could lead to impact on the environment, including regular inspection of major 'non productive' items such as tanks, pipework, retaining walls, bunds ducts and filters

The maintenance system should include auditing of performance against requirements arising from the above and reporting the result of audits to top management. It is recommended that formal quarterly inspections be carried out at the power station. The reports should be formally delivered to senior management who should sign for acceptance of them and act upon their recommendations and findings.

Competence and training

Training systems, covering the following items, should be in place for all relevant staff which covers

- awareness of the activity and their work activities;
- awareness of all potential environmental effects from operation under normal and abnormal circumstances
- awareness of the need to report deficiencies in storage conditions
- prevention of accidental emissions and action to be taken when accidental emissions occur

8 MONITORING AND AUDITING

As a result of the development there will be a need to produce a groundwater quality monitoring audit of the new site. It is thought likely that this can be incorporated as an extension of the existing yearly audit produced by BPC for the current power plant. This however will have to be agreed between BPC and the DGS and WAB.

Monitoring boreholes will need to be drilled to establish baseline conditions and to monitor any potential deterioration in groundwater quality. These should encircle the site both upstream and downstream. As a similar monitoring network system already exists around the old site, an extension of this network it is not thought to be too onerous a process. It will probably be sufficient to introduce 5 new boreholes. Three should be drilled to the south and southeast and east of the final new power plant site as these directions represent the likely flow of groundwater. One should be drilled to the north (to act as a background control and to try to differentiate any contaminant flow emanating from the existing power plant) and one to the west to try to assess any groundwater arriving from the evaporation and oxidation ponds area. Siting of these boreholes will only be possible once the design and infrastructure of the new power plant has been finalised.

As at present these boreholes will be required to be dipped and sampled on a monthly basis. Basic analysis should consist of the major inorganic determinands within BOS32: 2000 namely:

TDS, Conductivity, NH_4, Ca, Cl, F, Hardness as $CaCO_3$, Mg, NO_3, NO_2, K, Na, SO_4, and Zn. Other trace elements as are currently carried out within BPC's laboratory as well as Total Organic Carbon should also be analysed for.

9 CONCLUSIONS AND RECOMMENDATIONS

Having assessed the potential sources of pollutants it is difficult to argue that the new power station (Morupule B) will be likely to pose a particularly significant pollutant risk to groundwater since retrospectively the existing power station (with little efforts made at containment of potentially polluting by products) has not been a cause of groundwater pollution - no significant impacts have been noted other than a relatively small rise in sulphate levels in groundwater immediately adjacent to the Ash Lagoon disposal site. However the development will increase the size of the area and number of people working there. This will have a contributory effect on the amount of coal and chemical storage and the waste generated. It will also increase the amount of burnt coal ash to be disposed of. These are the activities which are likely to have the most potential for consequent impact.

Concerns have been made regarding the potential for leakage from the oxidation pond currently used at site. Any new sewage system for the new site should drain to a lined evaporation pond to ensure that there is no leakage to groundwater.

It is considered desirable that the existing sewage system be redirected to flow into this new evaporation pond scheme so the new scheme should be designed with this in mind. This will help mitigate impacts from the existing site.

The oxidation pond treatment is very appropriate for Botswana's climate and it is further recommended that the treated water from the pond be reused on site - particularly for the slurrying of the ash stream. This will create a positive environmental gain as less water will be required from the Paje Wellfield.

The new facility for the disposal of ash (new Ash Lagoon) should also have an enclosed drainage system. The drainage from the lagoon should either be re-circulated within the lagoon until evaporation has been achieved or redirected to the new oxidation pond. Consideration for an alternative waste disposal method requiring less water should be examined. The possibility of disposing of the ash 'dry' (or only slighted wetted) should be assessed.

A much greater degree of reuse/recycling of water should be made at the new site. Treated water from the evaporation pond can be reused back in the plant for mixing with ash or other uses (irrigation of grass areas etc). The use of wetland technology could be also be considered for the removal of potential contaminants within the waste water systems and for the creation of an improved vegetative and wildlife area.

The drainage of surface water off site in the case of the severe rainfall will need to be addressed by the new design. At present there is a surface water lagoon at the existing site for such events but it does not appear to function effectively. The retention of water on site will remove the pathway for contaminants off site and the water stored can be reused back in the plant. This again is seen as having a positive impact as water consumption from the distant BPC Paje Wellfield can be reduced.

As a general comment as much as possible of all site drainage should be self contained or rain water harvested for reuse within the new plant. Water usage at the old site is large and the provision of new water resources is expensive and detrimental to the environment in general. It is recommended that all surface water and roof and car park run off be collected (possibly in one of the current evaporation ponds currently not fully utilised) for re use on the site.

Any coal storage areas also need to have self-contained drainage with potential reuse of surface water run off.

All potentially contaminated water should be routed to the new oxidation ponds for treatment and subsequent reuse.

The possibility of the spread of contaminants by rainfall from the smoke produced by coal burning has been reviewed by a desktop study of other locations worldwide. It seems unlikely that the new development will have a significant effect on the water environment.

General house keeping issues at site will need to be fully addressed. Storage of hydrocarbons and chemicals will require proper spillage and leakage protection. Bunds and the use of leakage detectors are considered vital for such storage areas (tanks, etc).

Wastes not appropriate for disposal into the waste water stream - ie used oils, greases - should be collected at a separate area and recycled if possible or disposed off site. Staff should be trained to know what wastes are to be collected and where the correct waste disposal area is.

Monitoring boreholes will need to be drilled to establish baseline conditions and to monitor any potential deterioration in groundwater quality. These should encircle the site both upstream and downstream. As such a monitoring network has already been established around the existing power plant it is not thought that many new boreholes will be necessary. Three should be drilled to the south, southeast and east of the final new power plant site as these directions represent the likely flow of groundwater. One to the north (to act as a background control and to try to differentiate any contaminant flow emanating from the existing power plant) and one to the west to try to assess any groundwater arriving from the current oxidation and evaporation pond area. Siting of these boreholes will only be possible once the design and infrastructure of the new power plant has been finalised.

10 STATEMENT OF EXPERTISE

Mr. Hiley is a senior Hydrogeologist at Water Surveys Botswana and has some 16 years experience as a hydrogeologist of which 6 have been in Botswana. He has recently been involved in an EIA for the Botswana Meat Commission in Lobatse and has also recently finished writing the groundwater section of the Botswana National Water Master Plan Review. He was a member of the EIA team for the new international airport expansion project in Maun and carried out the water resource impact study for the new copper mine at Dukwi for Africa Copper. He has also recently completed the final wellfield report including simulated abstraction from Orapa wellfield for Debswana. Mr. Hiley is currently working on a conjunctive use water supply project for the DWA in the Bobonong area. Previously to working as a Senior Consultant for WSB he worked for Government in the UK in the regulatory sector (the Environment Agency). .

KEY QUALIFICATIONS:

EDUCATION: MSc Groundwater Engineering, Newcastle University 1990-91

PCGE Mathematics, Bath University 1984-85

BSc Engineering Science, Durham University 1976-79

EXPERIENCE

2001 - Present Senior Hydrogeologist – Water Surveys Botswana

Recent projects:

Botswana National Water Master Plan review.

EIAs for BMC in Lobatse and for the Maun International Airport Expansion

Debswana - Orapa Wellfield 6 and 7 Studies

Water Resource/Impact Assessment of the Dukwe (Bushman) Copper Mine

DWA - Bobonong Groundwater Investigation.

1999 - 2001 Area Hydrogeologist - Environment Agency River Seven Area

SSSI's (Sites of Special Scientific Interest). - Wetland Area of the River Severn Estuary.

Contaminated land and Landfill sites impacts

Risk Assessment Identification of suitable burial sites for foot and mouth outbreak in 2000

1997 - 1999 Hydrogeologist/Groundwater Modeller - Environment Agency

1994 - 1997 Hydrogeologist- Waste Regulations - Norfolk County Council

1992 - 1994 Hydrogeologist - Geraghty and Miller International

1991 – 1992 Hydrogeologist/modeller Anglican Water Company

Full CV provided as Appendix I

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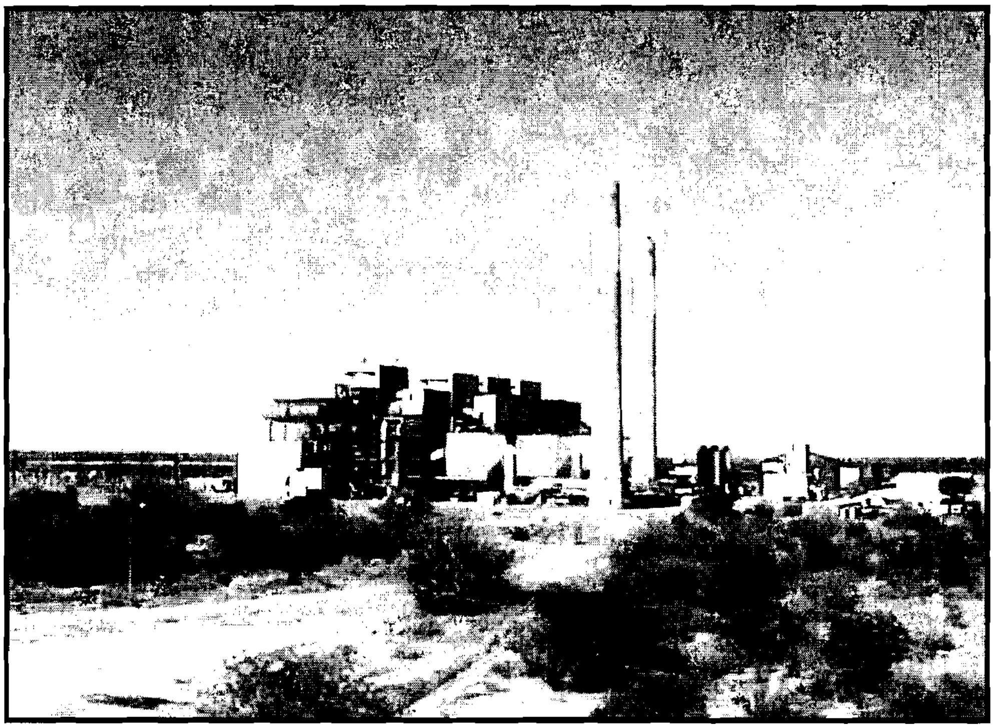
Appendix 4.2

Ecological and land use report

BOTSWANA POWER CORPORATION

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT STUDY FOR THE MORUPULE B POWER STATION PROJECT



Ecological and Land Use Report

Prepared by Ecosurv Environmental Consultants

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ABBREVIATIONS AND ACRONYMS

AI	Artificial Insemination Camp
AIA	Archaeological Impact Assessment
BID	Background Information Document
BPC	Botswana Power Corporation
BSAP	Biodiversity Strategy and Action Plan
CBNRM	Community Based Natural Resource Management
CO	Carbon Monoxide
DEA	Department of Environmental Affairs
DWA	Department of Water Affairs
DWMPC	Department of Waste Management and Pollution Control
DWNP	Department of Wildlife and National Parks
EIA	Environmental Impact Assessment
EIAA	Environmental Impact Assessment Act
EMP	Environmental Management Plan
ESIA	Environmental and Social Impact Assessment
ESS	Expanded Scoping Study
GIS	Geographic Information System
GPS	Geographical Positioning System
HIA	Heritage Impact Assessment
I&APs	Interested and Affected Parties
IBAs	Important Bird Areas
IUCN	The World Conservation Union
L	Litre
M	Metres
Mbgl	Metres below ground level
mg	Milligrams
MOA	Ministry of Agriculture
MW	Megawatts
NDP	National Development Plan
NGOs	Non-governmental Organisations
NMMAG	National Museum, Monuments and Art Gallery
NOx	Nitrogen Oxide
NRSE	New Renewable Sources of Energy
PM	Particulate Matter
PPP	Public Participation Programme
PRA	Participatory Rural Appraisal
RIAM	Rapid Impact Assessment Matrix
QA	Quality Assurance
SEA	Strategic Environmental Assessment
SIA	Social Impact Assessment
SO_2	Sulphur Dioxide
SOER	State of Environment Report
STIs	Sexually Transmitted Infections
ToR	Terms of Reference
UTM	Universal Transverse Mercator

1. EXECUTIVE SUMMARY

This Environmental and Social Impact Assessment (ESIA) deals with the Morupule B Power Station Development (600 MW) development which will be a turn key project undertaken within the current lease area for the BPC Morupule Power Station.

Methodology

The general ecology of the area has been described. The time of year made it difficult to identify plants particularly the herbaceous ones.

Land use and habitats were mapped off the 2003 black and white 1:80,000 aerial photography.

Sensitivity of communities and habitats to development were generated through assigning the land uses and habitats with biodiversity, sensitivity and density values.

The policy and planning framework outlined the environmental parameters and international obligations such as those under the United Nations Framework to Combat Climate Change.

The Baseline

Baseline covered

- Climate, particularly wind and temperature.
- Per capita carbon emissions which indicate that increased power generation from coal will greatly increase the national per capita emissions.
- Geology and soils, the implications of which is that Aeolian sands reduce the probability of archaeological remains being found on site.
- Topography and hydrology (three rivers pass to the south and west of the site, these are seasonal rivers, one of which, the Lotsane is an important river. Plans to dam the river downstream of the power station are currently underway).
- Plant ecology showed that the site is predominantly made up of a common habitat (Sandveld bush). To the south and west there is riverine vegetation which has been severely degraded due to clearing for arable agriculture.

Habitats within 10 km of the site are recorded in the table below:

Habitat Type	Area (ha)	%
Disturbed	3073	9.80
Drainages with bush	3660	11.67
Mopane woodland	1	0.00
Outcrop	745	2.38
River floodplain	1473	4.70
Riverine Woodland	873	2.78
Rock outcrop	4	0.01
Sandveld	20628	65.78
Sandveld & pan soils	32	0.10

Sandveld with emergent Acacia	588	1.87
Sandveld with emergent trees	284	0.91
Total Area (ha)	31361	

- There are few concerns about threat to rare or endangered plants within the lease area or within the area affected by SO_2 emissions.
- Birds are of concern due to the presence of an Important Bird Area to the East of the site which is one of the last remaining nesting sites in Botswana of the Cape Vulture.
- Land use within a 10 km radius was mapped and is predominantly livestock grazing, arable lands areas and urban (as indicated in the table hereunder)
- The site is situated approximately 4 km from the developed edge of Palapye which is the third largest town in the Central district holding 26,293 people (Population census 2001).

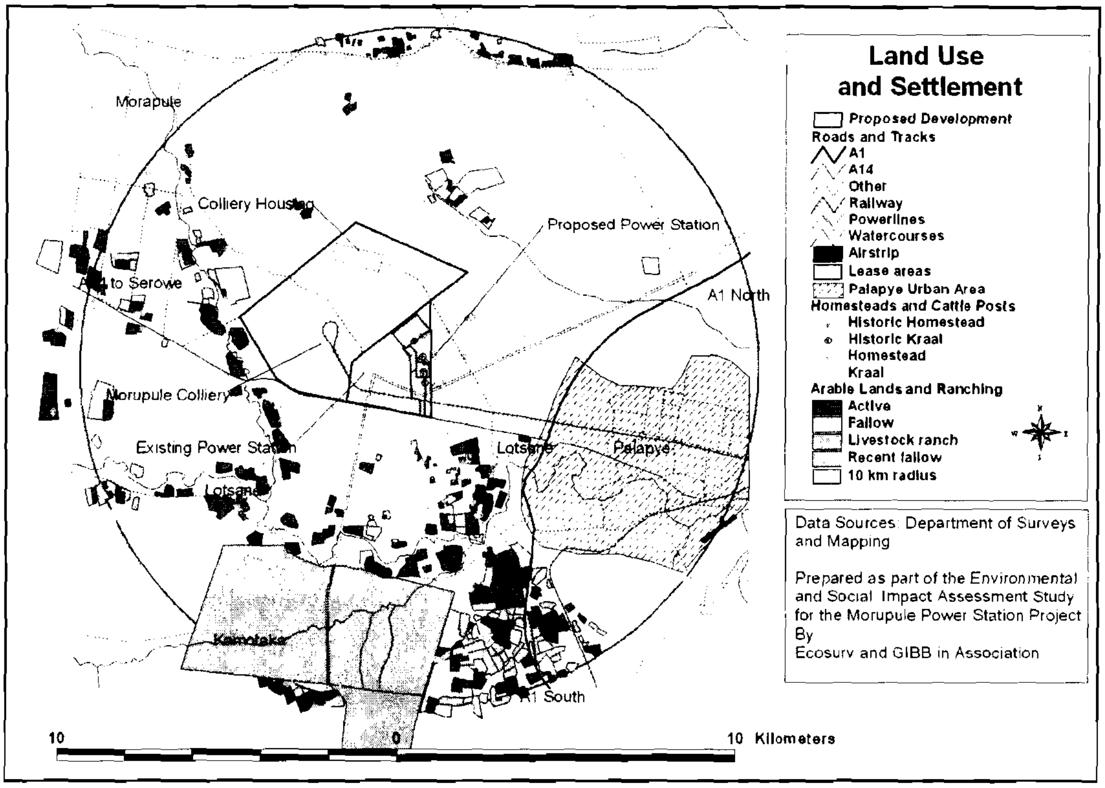
Area and percentages of various land use activities within 10 km of the proposed development.

L.U. Type	**Areas (ha)**	**% of Radius**	**% of Developed**
Total Area within 10 km (ha)	31,416	100	26
Total Developed Land	8,160	26	na
Cultivated (%)	2,661	8.5	32.6
Disturbed (%)	96	0.3	1.2
Urban (%)	2,860	9.1	35.1
Mine & Power (%)	106	0.4	1.5
Morupule Al Camp (%)	2,424	7.7	29.7
Wildlife (Morupule) (%)	1,689	5.4	na
Communal Grazing (%)	21,579	68.6	na

Note:

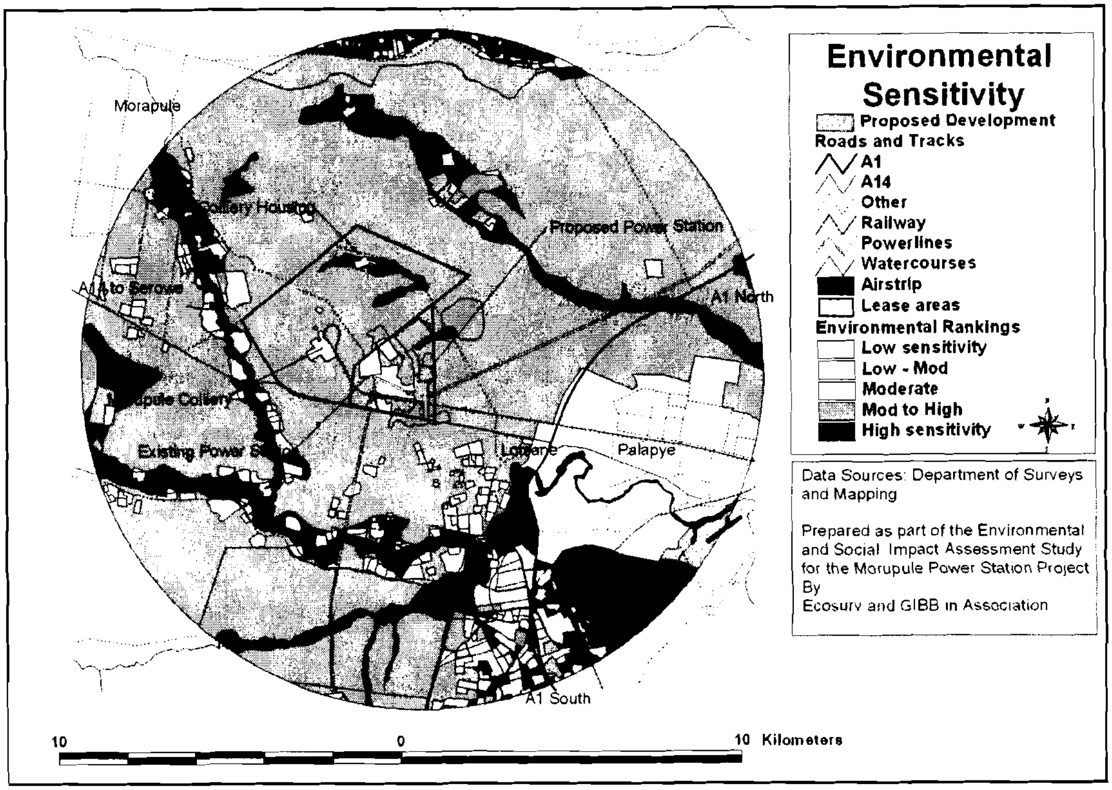
na: not applicable

Distribution of arable agriculture in the area surrounding the proposed development



- Within the 10 km radius of the proposed development about 68% of the land is available for traditional livestock production with an additional 8% fenced for Animal Health and Production activities.
- Dry land farming is a common land use practice in the area. Fields are near the national upper average size, being just larger than 6ha on average.
- Environmental Sensitivity: The environmental variables were combined and an overall sensitivity map prepared. It is clear from the map that the riverine woodlands, the western edge of the Tswapong (near Palapye) and the rocky outcrops in the Colliery area are the habitats of most concern.

Environmental Sensitivity of habitats within 10 km of the proposed development



Conclusions and Recommendations

- This study has indicated that there are few ecological issues relating to the establishment of the plant on the present site. The area is in a common habitat with no known rare, endangered or endemic plant species known to occur on the site.
- Land use in the immediate surroundings is generally low density with a number of points of high density such as the colliery and colliery housing. There is a school which falls within the zone subject to annual levels of SO_2 in excess of the national objectives for air quality. The same school will be subject to the upper acceptable limits of noise from a combination of the power station and the adjacent road. Land Board and the Physical planners must be made aware of the power station impact zones. This will allow for suitable land allocation and planning.
- There are limits to the existing knowledge of the effect of SO_2 and acid rain on indigenous vegetation and the crops growing in the surroundings, this limits the predictability of the results and makes it difficult to quantify the impacts. The issue is that many species of plant benefit from low doses of Sulphur whilst other such as beans and pines are affected at relatively low levels of exposure.

2. INTRODUCTION

This Environmental and Social Impact Assessment (ESIA) deals with the Morupule B Power Station Development (600 MW) which will be a turn key project undertaken within the current lease area for the BPC Morupule Power Station. The location of the new station will be due east of the existing station although the actual position of the site is still to be decided. The project will thus benefit from the proximity of the existing coal supplies and transport infrastructure.

3. APPROACH AND METHODOLOGY

The general ecology of the area has been described in the Final Scoping Report (2004). Since 2004, there has been considerable progress within Botswana in relation to availability of information, environmental objectives and strategies. For example, the Biodiversity Strategy and Action Plan (Ecosurv & IUCN, 2005) have a stocktaking, which identified known rare and endangered species and areas of concern. This information has been reviewed in order to augment the information presented in the Final Scoping Report (2004).

The time of year made it difficult to identify plants particularly the herbaceous ones. No systematic collection of plants was made. A review of the potential rare, endangered or endemic plants was undertaken (Annexure 2).

Land use and habitats were mapped off the 2003 black and white 1:80,000 aerial photography. The ecological and land use assessments have worked closely with the GIS component to carry out mapping of plant communities and settlement and assess them in relation to the air dispersion modelling undertaken as part of the air quality impact assessment.

Sensitivity of communities and habitats to development were generated through assigning the land uses and habitats mapped from the 1:80,000 aerial photography with biodiversity sensitivity, settlement density and land-use (Table 1 and Table 1).

Table 1: Environmental Values incorporated

Environmental Variables	Rankings	Explanation
Environmental		
Biodiversity	3	Known rare or endangered plants
	2	Habitat of high diversity
	1	Habitat of moderate diversity
	0	Habitat of low diversity
Vulnerability to proposed development	3	Vulnerable due to location in high SO_2 deposition area
	2	Vulnerable to moderate SO_2 deposition area
	1	Vulnerable to low SO_2 deposition area
	0	No SO_2 concerns
Disturbance	3	Undisturbed habitats
	2	Partially disturbed habitats
	1	Cleared agriculture
	0	Cleared or developed
Wetlands (Seasonal)	2	

Wetlands (sporadic) e.g. pans, floodplains	1	

Table 2: Social Values Incorporated

Land Use Variable	Rankings	Explanation
Settlement Density	3	Urban
	2	Settlements and Isolated homesteads (buffered 200m)
	0	No settlement
Landuse	3	Residential & Schools
	2	Arable agriculture (active and recent fallow)
	1.5	Old fallow arable lands
	1	Livestock

These values were combined in the GIS to generate the sensitivity maps.

Impact of SO_2 emissions and noise on land use and environment was generated by combining the air dispersion modelling contours from the air quality impact assessment and the noise contours from the noise impact assessment with the GIS mapping.

4. PLANNING FRAMEWORK

4.1 NATIONAL ENVIRONMENTAL OBJECTIVES

4.1.1 STATE OF THE ENVIRONMENT REPORT (SOER)

The SOER (DEA, 2002) was aimed at informing the nation and decision makers about the state of the national natural resources. The report is thematically structured and deals with issues specifically relevant to this project, namely:

- Socio-economic: Rural poverty is seen as a major cause of environmental degradation. HIV/AIDS is considered one of the factors reducing life expectancy.
- Land: Land pollution form poor waste disposal and management particularly from dumping of building rubble and degradation due to soil extraction practices.
- Biodiversity: Air quality was not identified as a cause of biodiversity loss.
- Climate Change: This is of concern particularly with the potential that global warming will increase temperatures and decrease rainfall
- Water: Groundwater depletion is a major concern as recharge is limited and much water abstraction is “mining”.

4.1.2 BIODIVERSITY STRATEGY AND ACTION PLAN

The BSAP encourages sustainable and wise use of resources and provides a framework of activities designed to improve the way biodiversity is conceived, utilized and conserved.

The goal of the Biodiversity Strategy and Action Plan is to contribute to the long-term health of Botswana’s ecosystems and related species, and to encourage sustainable and wise use of resources through the provision of a framework of specific activities designed to improve the way biodiversity is perceived, utilised and conserved.

4.2 APPLICABLE ENVIRONMENTAL POLICIES AND LAWS

4.2.1 ENVIRONMENTAL IMPACT ASSESSMENT ACT (2005)

The Department of Environmental Affairs (DEA) is the environmental authority responsible for all the ESIAactivities in Botswana. The Act states that environmental impact assessments should be undertaken to assess potentially adverse environmental and socioeconomic effects of planned developmental activities (projects, programmes and policies) and to provide mitigation measures and a monitoring and evaluation process where necessary. The Act also provides for retrospective EIAs, i.e. an environmental assessment of existing activities.

4.2.2 POLICIES AND LEGAL REQUIREMENTS FOR EMISSIONS, SOLID AND LIQUID WASTE

Atmospheric Pollution (Prevention) Act, 1971

This Act provide for the prevention of the pollution of the atmosphere by enabling the Minister to declare any area as a 'controlled area '(includes all urban areas) and the carrying on of industrial processes in these areas and for matters incidental thereto. The main aim of the Act is to control the emission of 'objectionable matter', i.e. controlling a very wide -range of different forms of atmospheric emissions produced by an extremely wide range of processes.

The Air Pollution Control annual report of 2004 states that: "Under the Act, industrial processes capable of releasing airborne contaminants into the atmosphere are required to have a valid Air Pollution Registration Certificate (APRC) or permit in order to operate. The application for the APRC is made in a prescribed form that provides for a detailed description of the following:

- The process including quantities and quality of raw materials
- Air pollution abatement measures to be undertaken

The Department of Waste Management and Pollution Control (DWMPC) is responsible for the monitoring of air quality in Botswana. The Department has set up objectives; Botswana Air Quality Objectives (BAQO) for concentration of criteria pollutants (Table 1) as the emissions standards. These define the maximum amount of pollutant that can be present in outdoor air without compromising the health of the public.

Table 3: Botswana Air Quality Objectives (BAQO) for the concentration of criteria pollutants

Pollutant		Standard Value
Particulate matter (TS)	Annual average	100 µg/m3
	Monthly average	200 µg/m3
Sulphur Dioxide (SO_2)	Annual average	80 µg/m3
	Monthly average	160 µg/m3
	24 hour average	90 % of hourly observations to be less than 300 µg/m3
Carbon Monoxide (CO)	8 hour average	10 000 µg/m3
	1 hour average	40 000 µg/m3
Nitrogen Dioxide (NO2)	Annual average	100 µg/m3
	Monthly	200 µg/m3

	average	
	1 hour average	400 µg/m3
Ozone (O3)	8 hour average	157 µg/m3
	1 hour average	235 µg/m3

Public Health Act 1981
The Public Health Act provides for a wide range of public health measures, including prohibition of pollution by liquid waste and odour nuisance.

Waste Management Act (1998)
The Waste Management Act deals with the collection, disposal and re-use or recycling of all types of solid waste. The Act outlines the roles of central and local government and the requirements for industries and institutions.

This Act makes provision for the regulation and management of controlled waste (waste defined as household, industrial, commercial, clinical or hazardous) in order to minimise pollution and prevent harm to human, animal and plant life. It also prescribes that the Basel Convention applies for the regulation of trans-boundary movement of hazardous wastes.

The Act has the following implications for BPC management of solid waste:
- Disposal of solid waste and fly ash require registration

Botswana Strategy for Waste Management (2001)
The most important objectives of this strategy are:
- Preservation, protection and improvement of the quality of the environment
- Contribution towards the protection of human health
- Ensuring prudent and rational utilisation of the natural resources

Water Act (1967)
The Act provides for the ownership, protection and rights of use of 'public water'. It imposes duties to return water to its origin where it is reasonable practicable, i.e. to return water to that body of water from which it was taken to a stream or such other body of water. The Water Act specifies that water resources need to be returned of a quality closest to the quality of the abstracted water so that it does not cause injury either directly or indirectly to the biodiversity. There are standards developed by Botswana Bureau of Standards for wastewater discharge into the environment.

Archaeology and Cultural Heritage
The Monuments and Relics Act (2001, as amended) calls for the protection of the environment, where possible in places where developments are proposed. Section 18 of the Monument and Relics Act prohibits any interference, change of place of origin, alteration, and destruction of monuments, relics of artefacts. Section 19 of the same act however allows for mitigation of the above mentioned in case they appear where proposed developments will affect or have started. Note needs to be made that mitigation may only be carried out by persons of recognized credentials either by the National Museum of Botswana or an equivalent institution. This is in acknowledgement to the fact that while monuments and relics are important, the contemporary societies' developmental needs may also need to be prioritised. As such, the Acts (Environmental & Monument and Relics) call for developmental interventions to be carried out in both an environmentally and culturally sensitive way.

4.3 CONVENTIONS AND PROTOCOLS

4.3.1 UNITED NATIONS FRAMEWORK TO COMBAT CLIMATE CHANGE (UNFCCC)

The Convention on Climate Change sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. It recognizes that the climate system is a shared resource whose stability can be affected by industrial and other emissions of carbon dioxide and other greenhouse gases. The Convention enjoys near universal membership, with 191 countries having ratified.

Under the Convention, governments:

- gather and share information on greenhouse gas emissions, national policies and best practices
- launch national strategies for addressing greenhouse gas emissions and adapting to expected impacts, including the provision of financial and technological support to developing countries
- cooperate in preparing for adaptation to the impacts of climate change

The Convention entered into force on 21 March 1994.
(http://unfccc.int/essential_background/convention/items/2627.php)

4.3.2 KYOTO PROTOCOL

The Protocol falls under the UNFCCC. The objective of the protocol is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[1]

As of December 2006, a total of 169 countries and other governmental entities have ratified the agreement (representing over 61.6% of emissions from Annex I countries).[2][3] Notable exceptions include the United States and Australia. Other countries, like India and China, which have ratified the protocol, are not required to reduce carbon emissions under the present agreement. The ratification by Russia on 18 November 2004 satisfied the "55%" clause and brought the treaty into force, effective February 16, 2005. (http://en.wikipedia.org/wiki/Kyoto_Protocol).

China, India, and other developing countries were not included in any numerical limitation of the Kyoto Protocol because they were not the main contributors to the greenhouse gas emissions during the industrialization period that is believed to be causing today's climate change. However, even without the commitment to reduce according to the Kyoto target, **developing countries do share the common responsibility that all countries have in reducing emissions**.

4.4 DEVELOPMENT PLANS

4.4.1 NATIONAL OBJECTIVES (NDP 9 AND VISION 2016)

The Long Term Vision for Botswana, Vision 2016, states that renewable resources are to be used at a rate that is in balance with their regeneration capacity, and that non-renewable resources are used efficiently so that their depletion is exchanged for enhanced physical and labour capital. The Vision also states that key natural resources are to be equitably distributed and that communities which contribute to the management of these resources should benefit from them.

The implications of the national policy and the national vision for the development of Morepule B Power Station and increase in power production:

- Power/Energy production should not disrupt social harmony in the area,
- Natural resource base should be used suitably; and
- Environmental degradation must be prevented.

4.4.2 CENTRAL DISTRICT DEVELOPMENT PLAN 6: 2003 2009:

The study area falls under the Central District Development Plan 6: 2003-2009, having previously been under Plan 5. Various areas of support have been highlighted in the DDP 6, in the form of the Rural Village Electrification Programme, the increased pressure to use alternative energy sources (other than wood), the support for the use of coal as an energy source etc. This provides a firm base for the development of the Morupule B power station.

In terms of environmental aspects, air pollution and water pollution are the two predominant factors, relevant to the expansion, which should be taken cognisance of. Although the mining of coal is not directly part of this scoping, the harvesting of natural resources must be undertaken in accordance with the National Conservation Strategy (1990) – "so that the beneficial interactions are optimised and the harmful environmental side effects are minimised."

4.4.3 PALAPYE DEVELOPMENT PLAN

The station falls within the Palapye Development Plan (1995- 2015) and so should comply with the development objectives of this plan. The plan describes the expansion of Palapye and has identified the area on the northern side of the Serowe Palapye road to be reserved for industrial use, the area south of this road has been left for the future development of agriculture.

A sewage system is to be designed and implemented although this is to cater for the already built up area of the town. The Morupule Power Station should aim at either getting connected to the sewage system or follow the Department of Sanitation and Waste Managements Guidelines and Waste Strategy for the disposal of solid and liquid waste. The planning principles, which are followed by the plan detailing the preservation of environmentally sensitive areas such as rivers, banks, wellfields, agricultural and forest lands.

The Palapye Development Plan is presently being updated and will be completed early in 2008.

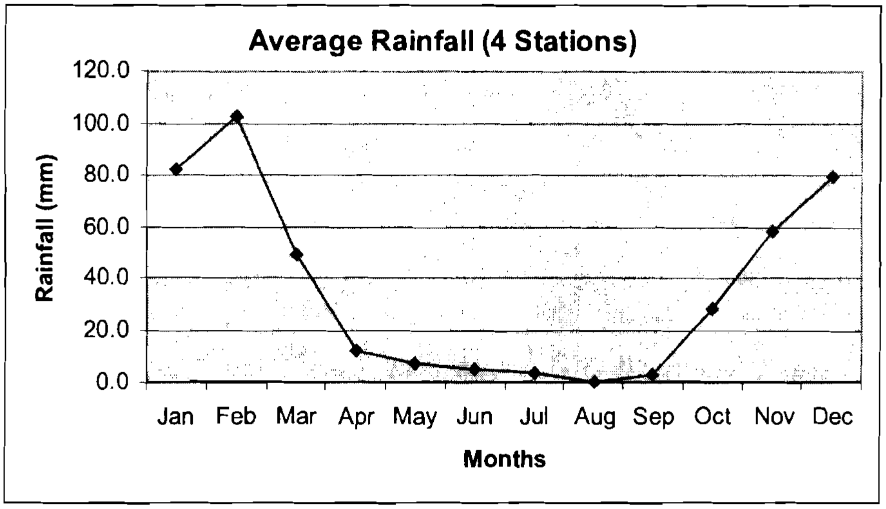
5. BASELINE

5.1 ABIOTIC

5.1.1 CLIMATE

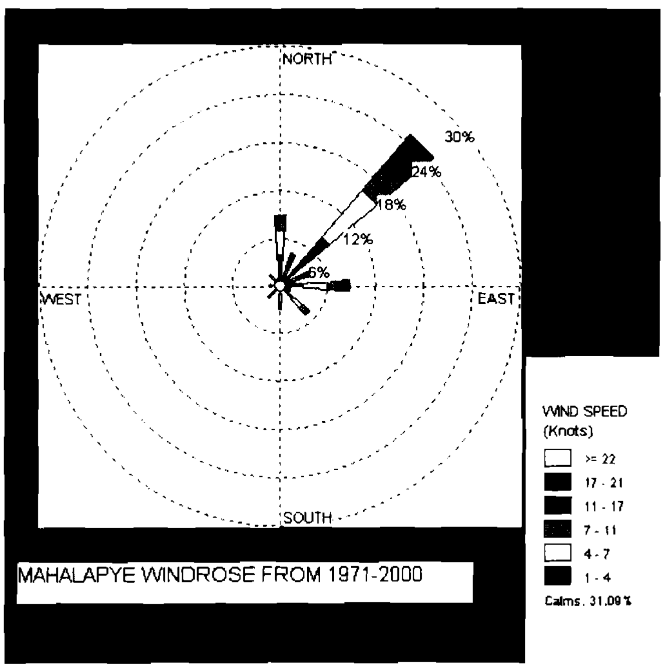
The climate of the study area is semi-arid, with cool dry winters and warm summers. Mean annual rainfall is 371mm, most of which falls between September and April (approximately 90%). The majority of the rain falls with high intensity in brief storms that last anywhere from a couple of minutes to about 4 days.

Figure 1: Average monthly rainfall for weather stations in the surrounding area (Source: DMS)



Winds are predominantly from a north and north-easterly direction, with winds from the south-easterly direction being associated with thunderstorms (in summer months) and cold fronts (during winter months). Calm conditions account for approximately 30% of the year. October has been seen to have the highest wind speeds with thunderstorms creating wind speeds of up to 25m/sec whilst the mean annual wind speeds vary between 2.5 and 3.5 m/sec.

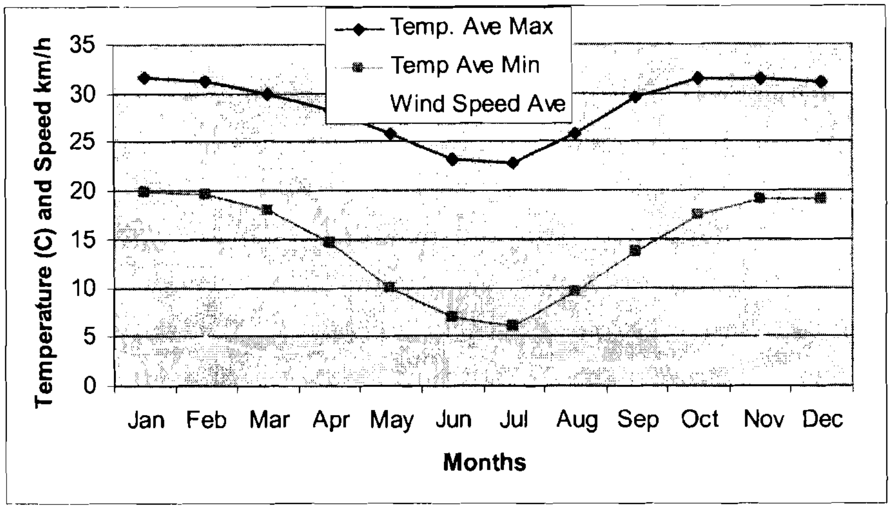
Figure 2: Wind roses for Mahalapye (Source DMS)



Potential evapo-transpiration exceeds the mean annual rainfall.

Temperatures are on average lowest in June- July. This is a period when temperature inversion may occur particularly in the hours between 02:00 and 06:00 which have the average lowest wind speeds.

Figure 3: Temperatures for the BPC station at Morupule



Concerns:

- During moderate to high wind events coal dust will be distributed downwind affecting conditions for people and plants.
- Temperature inversion events correlate with the lowest wind events indicating potential for high levels of SO_2 in down slope areas. These are expected in June and July during early morning hours.
- Low annual average rainfall indicates considerable need to manage and conserve water resources.

5.1.2 CARBON EMISSIONS

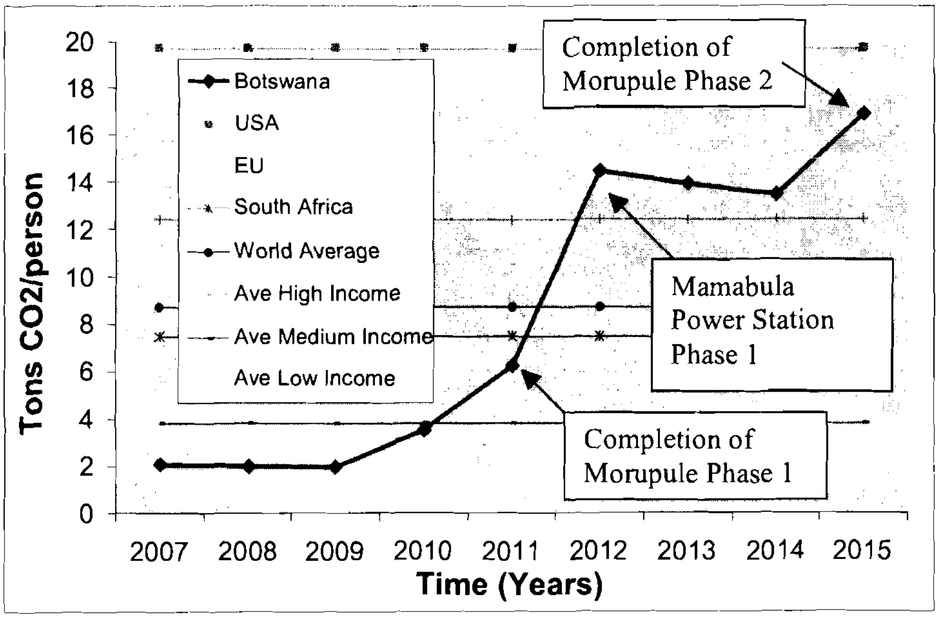
Per capita carbon emissions in tons per person per year was calculated from the 2003 energy statistics (CSO, 2003) and converted using international conversion figures from the united nations. These figures were then converted to 2007 and beyond using population growth rates of 3.9% (CSO). Botswana's present CO_2 emissions are approximately 2 tons CO_2 emissions per person per year. This figure excludes the carbon cost of imported electrical power but includes present coal production and use, all fuels, gas and firewood.

If one looks at these figures in relation to the average for middle income countries which is 3.8 tons and China which is now 2.9 tons, Botswana appears to be doing well in limiting its carbon emissions.

Adding the carbon emissions from the proposed Phase One 600MW power station causes the country's figures jump to just above the world average CO2 emissions level of 8.7 tons. If one adds coal use for the first phase 1,200 MW Mmamabula[1] project, Botswana will exceed the average EU per capita emission levels of 15 tons per person. Then, if one includes the future Morupule C Power Station Development of an additional 600 MW, Botswana will have one of the worlds highest per capita emission levels at nearly 17 tons per person per year. To place this in perspective RSA, Africa's highest producer of carbon, has a level of 7.5 tons and USA has the world's highest levels at 19.7 tons.

[1] Mmamabula Power Station Development has a number of phases and is envisaged to expand to 5,400MW.

Figure 4: Predicted CO_2 emissions for Botswana 2007 - 2015



Concerns:

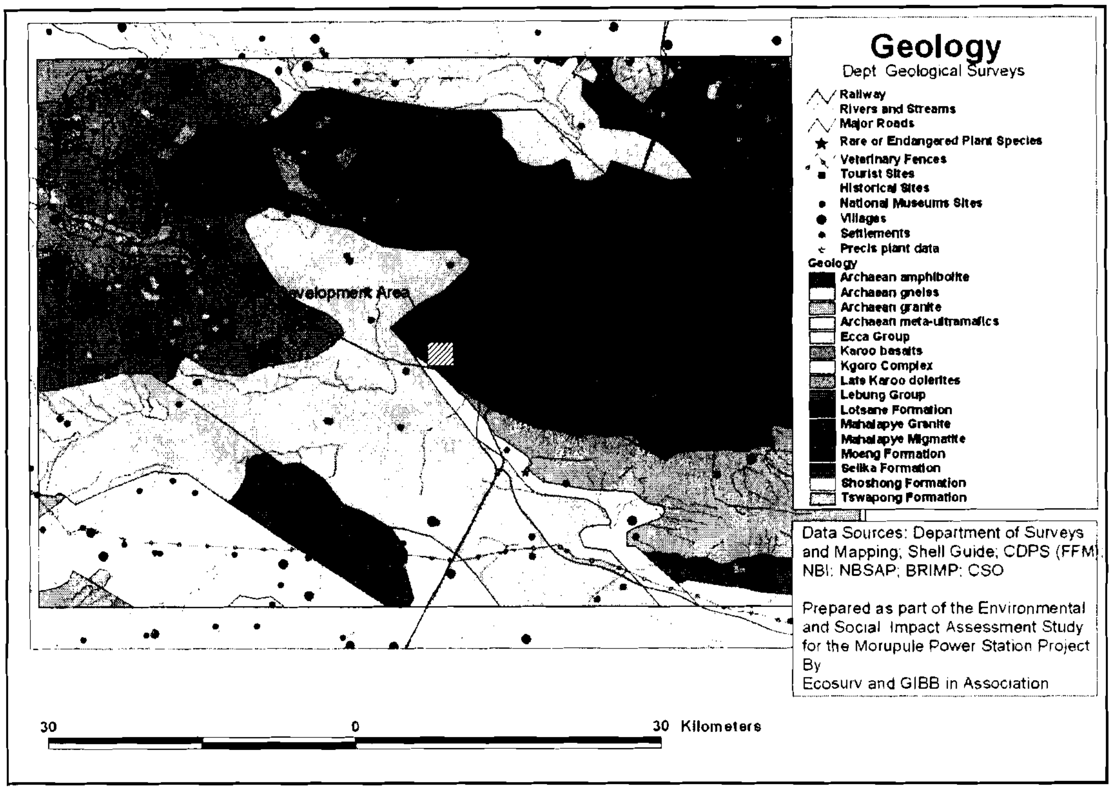
- With regard to the UNFCCC and the Kyoto Protocol, Botswana will be failing to meet the spirit of the convention and failing in her common responsibility in reducing emissions
- The Morupule B Power Station Development will bring Botswana close to South Africa's emission levels (South Africa has the highest per capita carbon emissions in Africa).

5.1.3 GEOLOGY

The area is situated on a Karoo Supergroup and the Palapye group, the former being responsible for major coal seems and sandstones whilst the latter the sandy shale and siltstone from the Lotsane formation. Much of these rock groups are easily weathered to a clay-rich soil, which is exposed in the Lotsane River Bed (Figure 5).

The Geotechnical Report reported transported aeolian (windblown) soils which blanket the site, underlain by cemented sands and calcrete overlying varicoloured siltstone, probably of the Lotsane Formation (Schwartz Tromp and Assoc. draft dated July 2007)

Figure 5: Geology of Palapye (Source, national 250,000 Geological Map)



5.1.4 SOILS

The study area falls within the Ferralic Arenosols (ARo35) soil unit. Arenosols being the most common soil type within the district and generally range between a sand and loamy sand of varied texture. The sandy nature of these soils generally provides well-drained soils of low fertility/quality. The site is overlain with moderate to deep sands. The survey carried out by Schwartz Tromp and Associates (2007) indicated an Aeolian layer of sand of between 2-9 metres deep averaging around 5.5 m which overlay a band of ferrocrete / calcrete. Siltstones are found below the ferrocrete.

Other factors, which play a role in the soil quality, include drainage, depth, slope, and texture. In terms of erosion both wind and water erosion hazards have been rated as being high in the site area (Central District Integrated Land Use Plan, CCI/Landflow, 2000).

Concerns/Issues

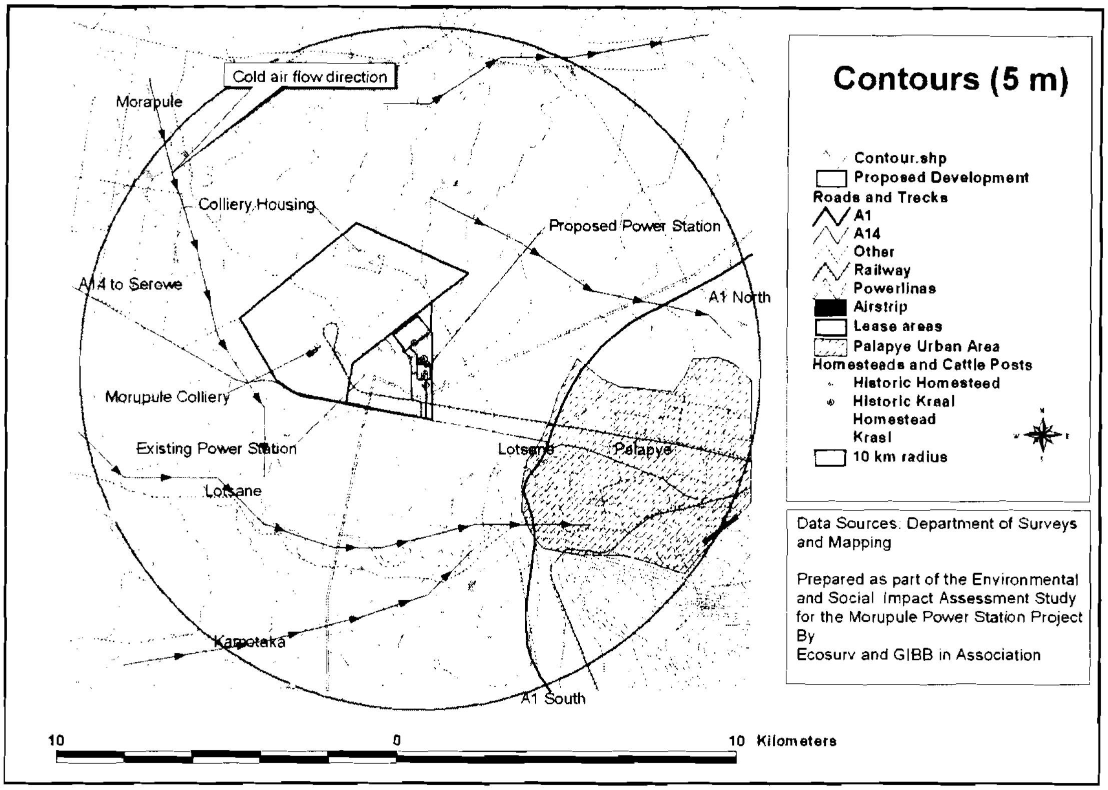
- The sandy soil overburden of aeolian origin will reduce the likelihood of archaeological sites being affected by the proposed development.
- Due to the sand, extensive gravel fill may be required. This will result in the extraction of gravels from borrows. This needs to be monitored for compliance to the Mines and Minerals Act and the EIA Act.

5.1.5 TOPOGRAPHY

The area is in general flat with the main landscape variation being that of the Tswapong hills which lie roughly 10 km east-south-east of the site. Two small "koppies" exist to the north of the site situated on the Colliery property. The Colliery village is situated at one of these two outcrops.

The area has a gentle gradient running in a southeasterly direction, based on the topographic maps of the area, although the site itself is situated on generally level ground.

Figure 6: Contours (5m) and expected flow of cold air (Source Surveys and Mapping)



Concerns:

- During low wind events and temperature inversions, SO_2 levels along the drainages could be high affecting natural vegetation, arable crops and people residing in the scatted homesteads.

5.1.6 HYDROLOGY

For the purpose of this study there are three ephemeral rivers that run within ten kilometres of the site, which are of importance. The Morupule River which feeds into the Lotsane River being the closest, approximately 3km from the site whilst the Lotsane River being approximately 10km south of the site. The Kamotaka River flows into the Lotsane River from the west. The Lotsane River is one of the major ephemeral rivers in the Limpopo basin. The catchment of these rivers is situated to the west with Kalahari-Limpopo watershed forming the western boundary. The Lotsane flows into the Limpopo on the Botswana and South African border. There are plans to establish a dam for domestic water supply on the Lotsane River downstream of Palapye.

Numerous boreholes have been drilled (9 in total although only 5 seem to be functional) around the study area in an attempt to monitor any pollution that may be caused by the existing power station and associated activities. Samples are taken from these boreholes on a monthly basis and their chemistry is analysed. Much of the hydrology and hydrogeology has been covered in the annual reports undertaken by Water Surveys Botswana (Monitoring of groundwater pollution) and Aqualogic (2006).

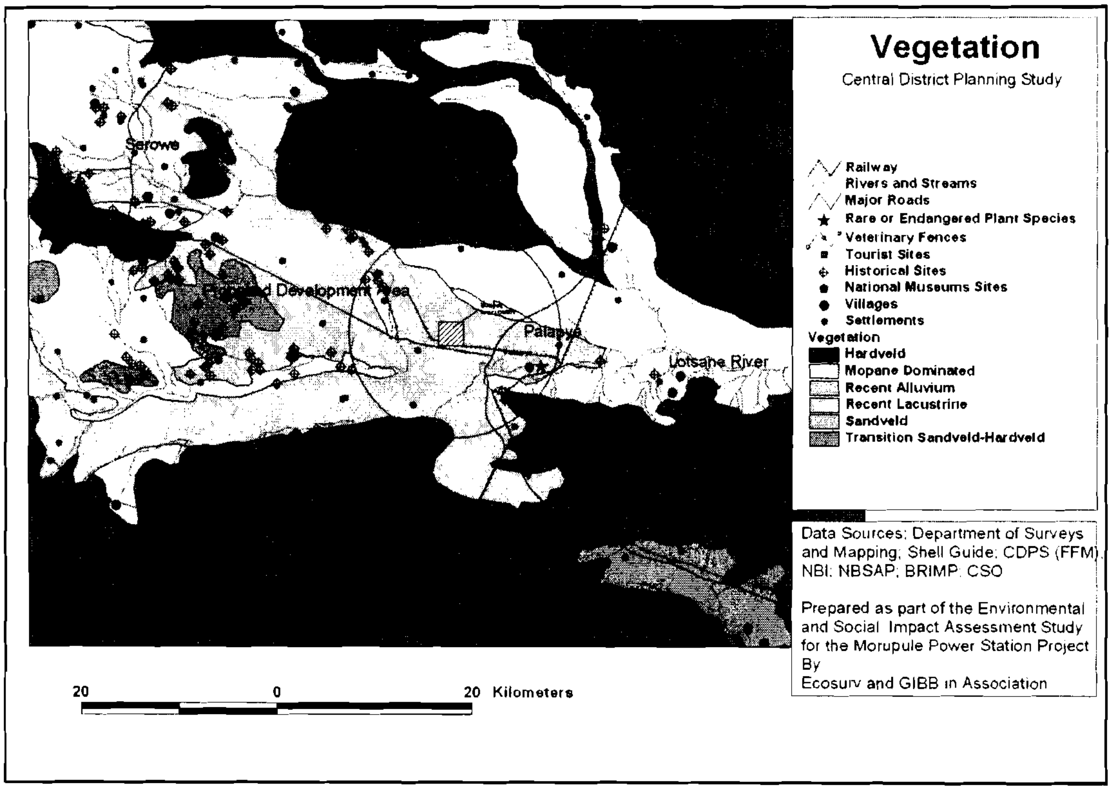
5.2 BIOTIC

5.2.1 PLANT ECOLOGY AND PLANT COMMUNITIES

This vegetation description and definition of plant communities is derived from the Central District Planning Study (Environmental Consultants, 1992). Detail has been added from field observations and data from the available literature.

The Central District Planning Study describes the area as comprising of two vegetation types, *Burkea/Ochna* Savannah and *Acacia erioloba* Savannah. The former being associated with deep well drained ferrallic sandy soils with this vegetation type grading into type 14, *Colophospermum mopane* on sandy soils, in the areas south of the Makagdikgadi. Type 6 is dominated by three tree species namely *Acacia erioloba, Terminalia sericea*, and *Lonchocarpus nelsii* with the occurrence of these species being dependant on either the depth of sand or the amount of silcrete or calcrete in the soil profile (General vegetation mapping Figure 7).

Figure 7: Plant Communities as mapped in the CDPS (1992)



Both vegetation types are Savannah type systems. Type 6 being variable between an open woodland to savannah with low shrubs and sparse trees dominating extensive areas.

Some vegetation occurs on the ash dams, with most species being exotic species. The most commonly occurring species is *Nicotiana sp*, which is a small blue-green bush, which produces a yellow flower, and is found throughout the ash dams in the coarse ash, which is used to make the dam walls. Some of the other species include Pepper trees and Castor oil plants.

Some of the floral species identified within the proposed development area have been listed below.

Table 4: Plant species identified within the proposed development area

Tree Species	Grasses, Herbs, Flowers
Acacia erioloba (Camel Thorn)	*Hibiscus sp.*
Acacia mellifera (Hook thorn)	*Ipomea sp.*
Burkea africana (Wild Syringa)	*Tribulus terrestris*
Combretum hereroense (Russet Bush Willow)	*Ocimum canum*
Dichrostachys cinerea (Sickle Bush)	*Nicotiana sp.*
Grewia sp. (Raisin Bush)	*Acrotome inflata*
Peltophorum africanum (African Wattle)	*Sansevieria sp.*
Rhus sp. (Rhus)	*Momordica balsamina*
Schinus molle (Pepper tree)	*Lagenaria seciraria*
Terminalia sericea (Silver Cluster leaf)	*Cucumis metuliferus*
Ziziphus mucronata (Buffalo thorn)	*Vernonia sp.*
Melia azedarach(Exotic Syringa)	*Ricinus communis*

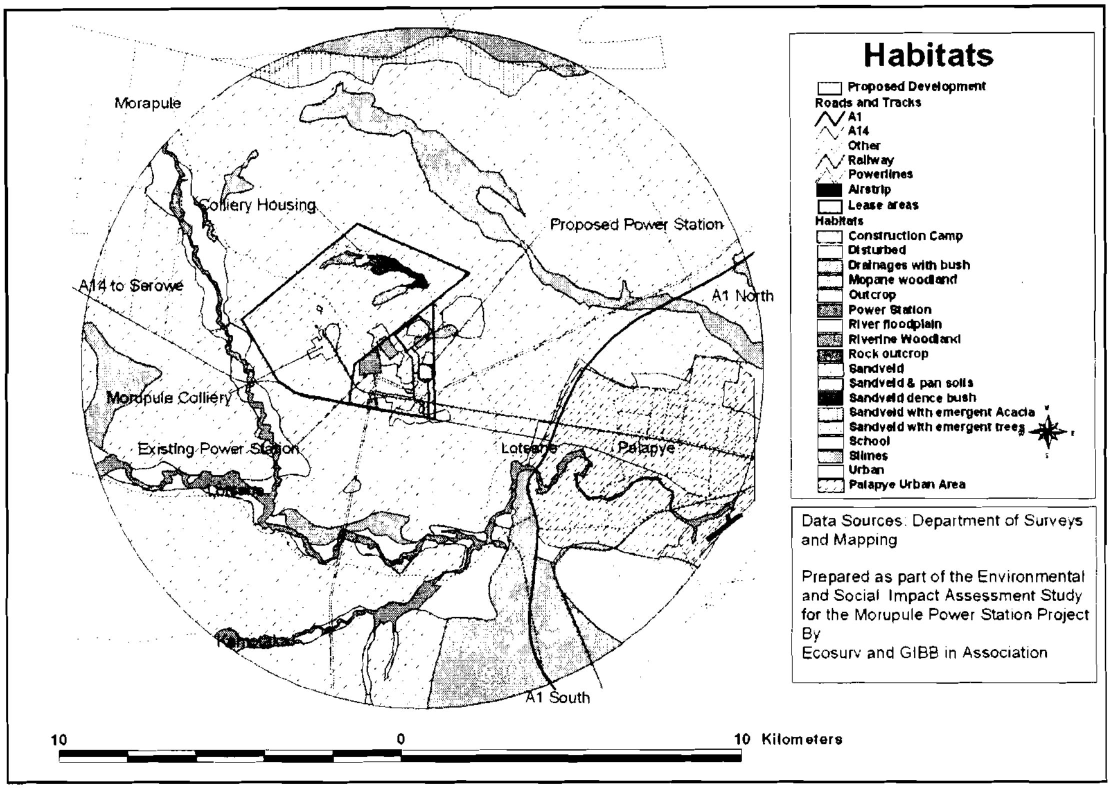
Within the 10 km radius of the site the habitats are dominated by sandveld and riverine habitats (Table 5 and Figure 8).

Riverine habitat has been greatly modified due to the practise of establishing arable agriculture in the river floodplains. At least 20 % of the riverine habitat is severely degraded.

Table 5: Habitats within 10 km of the site

Habitat Type	Area (ha)	%
Disturbed	3073	9.80
Drainages with bush	3660	11.67
Mopane woodland	1	0.00
Outcrop	745	2.38
River floodplain	1473	4.70
Riverine Woodland	873	2.78
Rock outcrop	4	0.01
Sandveld	20628	65.78
Sandveld & pan soils	32	0.10
Sandveld with emergent Acacia	588	1.87
Sandveld with emergent trees	284	0.91
Total Area (ha)	31361	

Figure 8: Major habitats within 10 km of the proposed development



Floral Biodiversity

Although the site of the proposed power station and slurry dams has low plant species diversity, the surrounding areas have been highlighted as being host to important species, namely in the Tswapong hills area. In terms of biological diversity within Botswana the area is seen as being high in species richness, and plant diversity (BSAP Stocktaking Report, Final Draft, 2003).

The Royal Botanical Gardens Kew indicates that Botswana currently has 43 species on its national Red Data list. Of these, 13 are confirmed as threatened (critically endangered, endangered or vulnerable) and 22 are of uncertain status. There are an estimated 15 endemic species in Botswana, which are vulnerable due to their limited distribution. None of these species are known to occur at the site.

The National Botanical Institute (RSA) has identified one plant species classed as "vulnerable" on rocky areas to the east of the site (near Palapye). This is *Adenium oleifolium,* of the Apocynaceae Family. This plant is a succulent shrub and not found at the power station site. A list of rare or endangered plants and those that have some potential to occur on or near the proposed development is contained in Annexure 2.

During the EIA of the North South Carrier and follow up work, J. Burgess (Environmental Consultants, 1996) located a well developed stand of *Pterocarpus rotundifolia* subspecies *rotundifolia.* These were located on the rocky hills to the immediate south of Palapye and will not occur at the site.

Concerns

- Loss of vegetation down wind of all coal storage facilities due to coal dust pollution.

- Clearing of the site for construction and construction camp will result in loss of vegetation of low conservation status.
- Expansion of ash dams will result in the loss of vegetation.
- Spills from fly ash dam could damage the surrounding vegetation as pH levels are between 10 – 14.
- The closest area of high diversity lies to the north in the Morupule Colliery concession area (at the Colliery housing site). Important species have also been identified in the surrounding areas (Tswapong Hills and the ridge near Palapye).
- Fire could also be considered a potential risk from exploration activities in areas where grass cover exists.
- It is clear from aerial photography that the coal dump creates a coal dust plume downwind for about 400 m affecting an area of about one km^2. This is due to the system of dropping coal into stacks from a height allowing wind action to carry all fines downwind.
- Similarly, SO_2 levels in excess of the national air quality objectives may reduce plant growth.

Sulphur Dioxide and Habitats

Air dispersion modelling carried out by Airshed Planning Professionals (2007) indicates that when Morupule B is operating together with the existing power station, the daily maximum and annual average air quality objectives set for Botswana will affect similar areas of about 14,600 ha. Of this, 106 ha are already disturbed and the rest is all sandveld bush, a very common habitat.

The picture is different for the daily maximum and annual average standards set by the World Bank. The 50 micrograms/annum limit covers about 1,000 ha more area than the 80 micrograms (Botswana Objective). The increase includes riverine habitats of about 990 ha in addition to the sandveld habitat. (Table 6).

Table 6: Area of habitats potentially affected by proposed SO_2 emissions

Sum of AREA	Daily Maximum		Annual Average		
TYPE	150 micrograms max daily (WB)	300 micrograms max daily (Botswana)	50 micrograms /annum (WB)	80 micrograms /annum (Botswana and WB)	Grand Total (ha)
Construction Camp	6	6	6	6	24
Disturbed	89	70	71	68	298
Drainages with bush	38				38
Mopane woodland	1				1
Existing Power Station	37	3	37	2	79
River floodplain	218		66		284
Riverine Woodland	164		2		166
Sandveld	3,089	331	893	240	4553
Sandveld & pan soils	27				27
Sandveld with emergent trees	178	64	94	43	379
School	13	13	13	13	52
Slimes	17	0	17		34
Urban	0				0
Total (ha)	3,877	487	1199	372	5935

Concerns:

- Impact of SO_2 emissions on riverine and urban habitats

5.2.2 AVIFAUNA AND WILDLIFE

Birds

Based on the maps produced by the Biodiversity Strategy and Action Plan Project the area is known to hold approximately between 460 –500 bird species. In terms of importance the Tswapong hills have been identified as being an Important Bird Area (IBA), which does not have any formal protection. The Tswapong hills are host to large breeding populations of Palaearctic migrants and are thus given the status of being an IBA. Although the site is not situated on these hills it is within ten kilometres of the western edge of them. Of the species occurring in the Tswapong hills, the Cape Vulture, *Gyps coprotheres* is a species of global conservation concern (Lincoln, Fishpool, and Evans – Important Bird Areas in Africa and Associated Islands 2001). At present an estimated 300 breeding pairs exist. In terms of threats to the species, relevant to the project, electricity pylons have been identified as being a cause of death for larger birds both by electrocution and collisions. A description of the IBA is annexed (Annexure 1).

Tyler (2001) published the waterbird counts for wetlands within the Palapye area, these are summerised below,

Table 7: Lecha Lodge Dam, Palapye. A small newly constructed dam at a lodge at Palapye. The dam covers ca. 4 ha. Counted once, in July 2000

No	Species	July (1)
008	Little Grebe	7
055	Reed Cormorant	3
062	Grey Heron	2
084	Black Stork	1
107	Hottentot Teal	4
108	Red-billed Teal	4
258	Blacksmith Plover	2
	TOTAL	23
	No. Species	7

Table 8: Lemonwe (Limone) Pan, southwest of Palapye. An ephemeral pan, over 1 km in length and ca. 9 km from the Lotsane River. Counted, partially, and only once, in July 2000 when it was still very full.

No	Species	July (1)
102	Egyptian Goose	12
108	Red-billed Teal	100+
115	Knob-billed Duck	3
116	Spurwinged Goose	15
228	Red-knobbed Coot	50+
	TOTAL	180
	No. Species	5

The presence of wetlands and associated storks, herons, ducks and geese will increase the likelihood of bird mortalities due to collisions.

Invertebrates

Little is known about the invertebrate populations throughout Botswana and the study area is no exception. Two subspecies of butterflies were however identified in the Scoping study as being endemic to the Tswapong hills (these were not named).

Faunal Biodiversity
Based on the Fauna priority area generated for the country by the Biodiversity Strategy and Action Plan project the area is situated in an area ranked as "Average". This ranking would be based on the level of protection to Biodiversity (BD) in the area (no formal conservation measures exist i.e. site is not situated in a protected area) against the numbers of species and diversity of species in the area (areas with no protection but high diversity would be ranked as being high priority areas).

A list of reptiles, amphibians and mammals known to exist in the area is appended (Annexure 3).

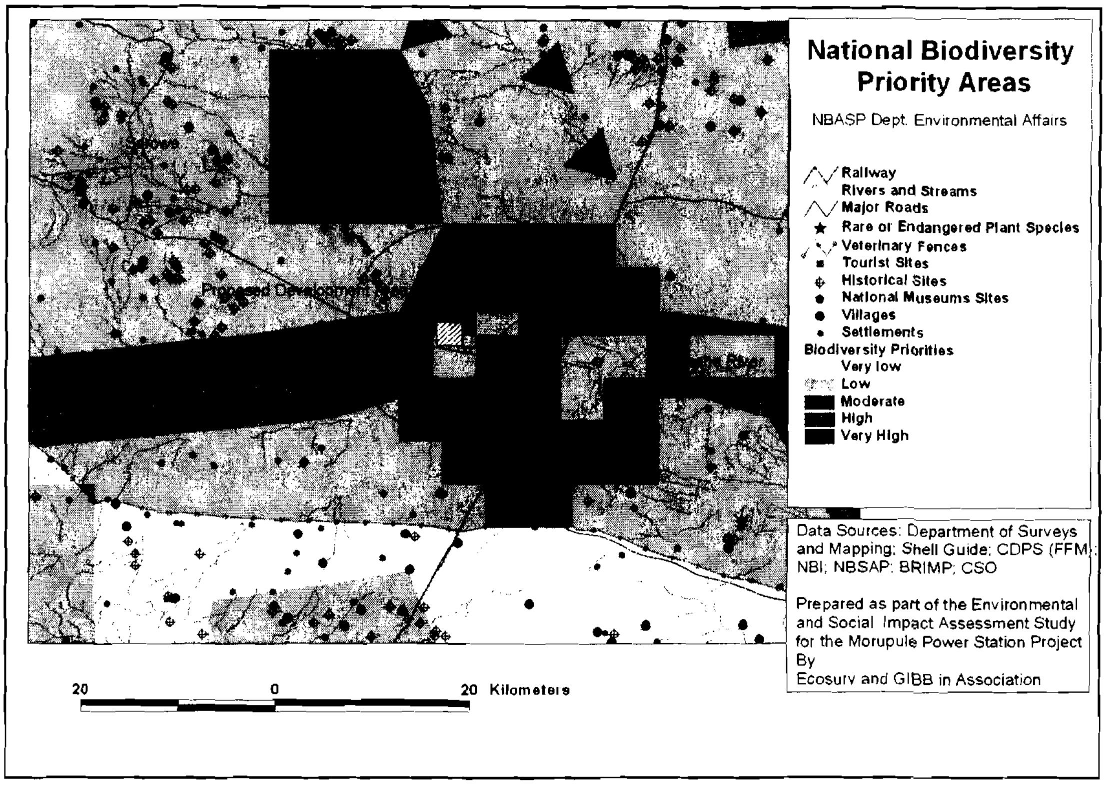
Concerns

- The new power station will result in an increase in number of power lines, increasing the likelihood of both collisions and electrocutions of Cape Vultures.
- Increased human presence will negatively impact on the small populations of antelope occurring around the study area.
- Expansion of the fly ash dams will result in a loss of habitat for various bird and wildlife species.

5.2.3 BIOLOGICAL DIVERSITY

The area as a whole has been identified as having a high threat level to biodiversity. Due to this high threat level and the relatively high species richness the surrounding area has been given a relatively high biodiversity conservation index. This is not necessarily within the site itself but rather in the surrounding areas.

Figure 9: Regional biodiversity priority areas (Source NBSAP)



5.3 LAND USE

The site is situated approximately 4km from the edge of Palapye which is the third largest town in the Central district holding 26,293 people (Population census 2001). Various cattle posts occur around the site with one small "squatter" settlement to the north east of the site on the BPC lease area. Adjacent to the site, on BPC lease area, near the main road lies a school and small community including workshops and some housing. The housing is to be removed due to presence of asbestos in the wall and roof materials. Directly north of the site lies the Colliery village and to the northeast is the colliery.

Within the surrounding area there are a number of land use practices. These include:

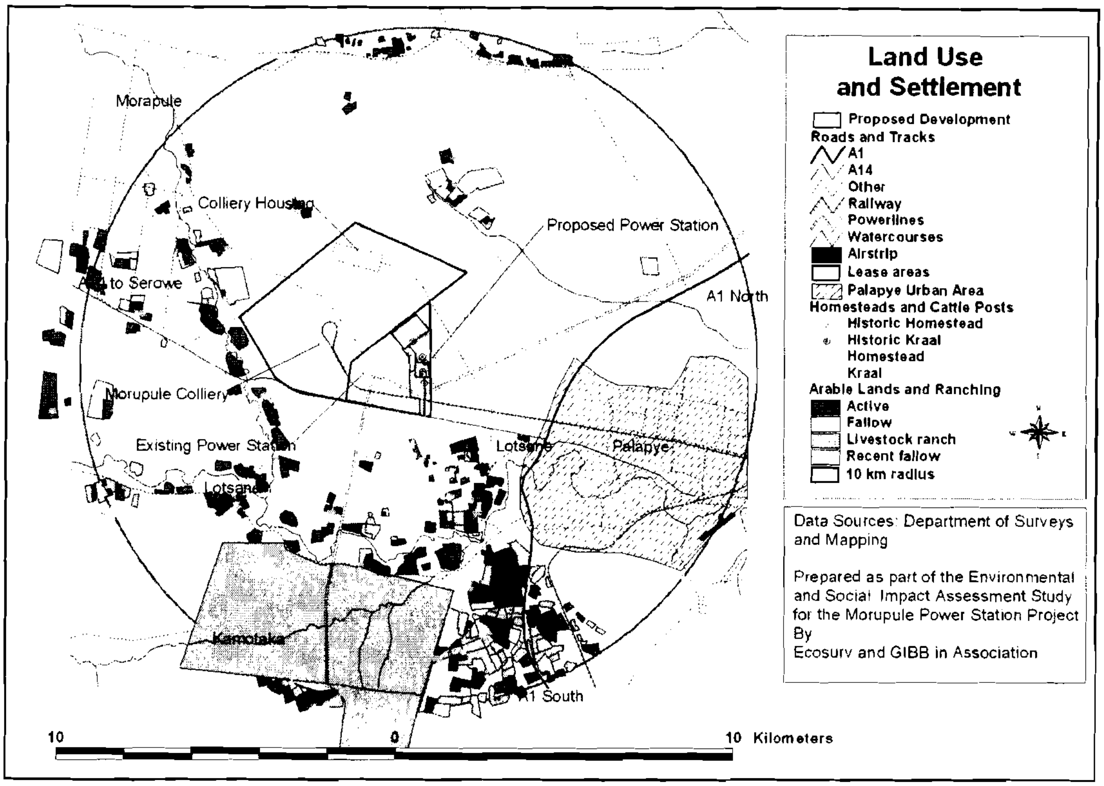
- Arable agriculture
- Livestock production
- Urban development (mainly housing)
- Land developed for mining and power production

Table 9: Area and percentages of various land use activities within 10 km of the proposed development.

L.U. Type	Areas (ha)	% of Radius	% of Developed	Comment
Total Area within 10 km (ha)	31,416	100	26	26% of the area within 10 km is developed
Total Developed Land	8,160			
Cultivated (%)	2,661	8.5	32.6	Includes active, recent fallow and fallow lands areas
Disturbed (%)	96	0.3	1.2	Areas cleared e.g. borrow pits
Urban (%)	2,860	9.1	35.1	Palapye urban area falling within 10 km of power station
Mine & Power (%)	106	0.4	1.5	Modified areas within leases including slimes
Morupule AI Camp (%)	2,424	7.7	29.7	Fenced rangeland
Wildlife (Morupule) (%)	1,689	5.4	na	Fenced game management area
Communal Grazing (%)	21,579	68.6	na	Undeveloped rangeland

Most of the lands areas are on the fluvial soils of the three main drainages, the Lotsane, the Morupule and the Kametaka as indicated in Figure 10.

Figure 10: Distribution of arable agriculture in the area surrounding the proposed development



Concerns

- Arable lands lie both downwind and down contour of the site. During still air events SO_2 levels may exceed recommended exposure for people and crops. Particularly affected are bean crops.
- High density housing of Palapye 4 km to the east. Ca 2,000ha of housing fall within the predicted 150 maximum daily exposure threshold level set by the World Bank (current scenario or with Morupule B?). None of the urban housing falls above the national air quality objectives for sulphur dioxide.
- Approximately 29 homesteads lie within the 150 micrograms/day threshold set by World Bank.
- A primary school located 1.6 km downwind of the proposed site will be exposed to SO_2 levels in excess of the national and World Bank SO_2 objectives(current scenario with Morupule B).

5.3.1 URBAN AND RESIDENTIAL

There are three main types of residential area within the 10 km radius secondary impact zone ; these are:

1. Homesteads linked to lands areas and cattle post (approximately 163 homesteads of which 16 fall within the area exceeding the 40 decibel evening noise limit (current scenario with Morupule B));
2. Formal housing for Morupule Colliery staff (11.2 ha with about 30 households) do not fall within the high noise impact area of > 40 DB nor is it affected by sulphur dioxide (current scenario with Morupule B).
3. Urban Palapye which has both traditional and modern housing (2,860 ha of urban area fall within the 10 km radius).

Concerns

- 16 homesteads (representing approximately 65 people) fall within the area that may exceed 40 decibels sound limit at night (current scenario with Morupule B).

5.3.2 MINING

Morupule Colliery is owned and operated by Debswana, a partnership between the government of Botswana and De Beers. Founded in 1973 to supply the nearby Bamangwato Concessions Ltd copper and nickel mine, operations have expanded considerably since then to supply a number of regional power plants and industries, especially the nearby Morupule Power Station.

The coalfield is composed of four main seams, only one of which, the No. 1 Seam, is currently being mined subsurface using slope mining. The No. 1 Seam has an average height of 8.5 meters (28 ft), and is located at an average depth of 80 meters (260 ft) below surface. Production over a recent 7-year stretch averaged 877,000 tons per year. (http://en.wikipedia.org/wiki/Morupule_Colliery).

The coalfield is immense and contains good quality coal, with overall reserves of over 9 billion tons. Production has increased steadily over the years from 145 000 tons per annum in 1973. A total of 984 838 tons of coal were mined and 964 555 tons were sold during the year 2005.

A number of key industries in Botswana depend on coal supply from Morupule. More than half of the mine's current annual production is supplied directly by overland conveyor to the adjacent Morupule Power Station, while the BCL Mine at Selebi-Phikwe and the Botswana Ash plant at Sua Pan remain major customers. Coal is also supplied to the Botswana Meat Commission, Botswana Breweries, Foods Botswana, Makoro Bricks and two coal distributors. The Colliery has also been able to penetrate the SADC market and is currently supplying graded coal to Zimbabwe, Zambia and the Democratic Republic of Congo.

The Colliery has over 250 employees, over 97 % of whom are citizens of Botswana (http://www.debswana.com/Debswana.Web/About+Debswana/Investments/Morupule+Colliery/).

Concerns

- The Colliery housing is located just 3.6 km NNE of the power station and employees may be exposed for short periods to SO_2 levels in excess of the limits (current scenario with Morupule B).
- Similarly the Colliery is located 2.75 km from the proposed development site. Exposure levels may exceed the legal threshold for short periods (current scenario with Morupule B).
- Cumulative effects of SO_2 emissions from both power stations.

5.3.3 LIVESTOCK

Communal grazing livestock farming is the largest practiced land use in the area as well as within the district with over 65% of the district being under this land use practice (Central District Planning Study – 1992). Cattle, goats and sheep are common to the area, which is situated in a communal grazing area. Little management occurs with regards to farming practices and overgrazing.

Within the 10 km radius of the proposed development about 68% of the land is available for traditional livestock production with an additional 8% fenced for commercial livestock production {there is a partially disused Artificial Insemination (AI) camp belonging to the

Ministry of Agriculture (MOA), called Leupala, in the southern part of the 10 km radius}. Immediately west of the 10 km radius is another AI camp called Moupule which is still operated by MOA.

Livestock carrying capacities are presently 7ha/LSU and the number of livestock within the 10 km radius are estimated as indicated in Table 9 (MoA Livestock Crush Figures supplied September 2007).

Table 10: Crush figures for the area falling within the 10 km radius (Source MoA, DAHP, Veterinary Officer Serowe)

Crush	Cattle	Sheep	Goats	Horses	Donkeys	Dogs and Cats
Bollantoko	78	7	26	1	0	4
Botepetepe	352	80	197	4	70	26
Lewele	1194	146	522	0	175	50
Masama	840	29	388	0	22	42
Totals	2464	262	1133	5	267	122

Based on the aerial photography assessment there are at least 163 homesteads within the area all of which will have livestock as an important component of their livelihoods.

Concerns

- Impact of SO_2 deposition on livestock forage is not known. In the EU they have found both positive and negative effects depending on the prevailing Sulphur levels in the soils and the tolerance of plant species to SO_2 exposure. There is little data on the impact of SO_2 on plant species indigenous to Botswana.

5.3.4 GAME RANCHING (WILDLIFE CONSERVATION AND FARMING)

Morupule Colliery has game fenced its lease area and is developing the wildlife population through protection and stocking.

5.3.5 ARABLE AGRICULTURE

Dry land farming is seen to be a common land use practice in the area with this practice accounting for approximately 11% of the total area within the district (Central District Planning Study – 1992). Soil fertility and water resources being the determining factors with regards to the distribution of this land use practice. The majority of the lands areas are situated in close proximity to the Morupule River. Some lands areas exist on the southern side of the road towards Palapye.

Fields are near the national upper average size, being just larger than 6ha. The total number of lands areas identified from the aerial photography analysis was 435 (Table 12). Distribution of the lands areas along drainages and near to Palapye can be seen in Figure 10.

The main crops grown in the Palapye area are sorghum, maize, cowpeas, sweet-reed, groundnuts and melons[2]. Average yields for these crops are low as indicated in Table 11.

Table 11: Yields of common crops (Source: National Master Plan for Agricultural Development, MoA, 2000)

[2] Information supplied by the Crop Production Officer, Serowe

Crop	Yield in kg/ha & Estimated average Yields for Palapye
Sorghum	Max yield sandy soils 4,000 kg/ha, maximum yield on fine medium soils 4,600 kg/ha. Average yield on sandy soils 2,060 kg/ha.
Maize	4,400 to 5,500 kg/ha. Average yield on sandy soils 1,550 kg/ha.
Cowpeas	1,000 to 1,200 kg/ha. Average yield on sandy soils 470 kg/ha.
Pearl millet	1,500 to 1,730 kg/ha. Average yield on sandy soils 610 kg/ha
Watermelon	30,000 – 40,000 kg/ha. Average yield on sandy soils 15,100 kg/ha.

Table 12: Average size of lands areas and number identified within 10 km of the development

Status	Average Size	Count	National Average
Active	6.12	244	4 to 6 ha
Recent fallow	6.06	91	na
Fallow	na	100	na
Total lands areas within 10 km of the development		435	na

There are no croplands that fall into areas exposed to SO_2 levels higher than the national daily average SO_2 limit of 80μg/m^3. About 230 ha of arable lands fall within the World Bank threshold of 150 micrograms max daily exposure.

Table 13: Areas of arable land falling into areas above World Bank thresholds

Count	Area (ha)	SO_2 Levels
28	230	150 micrograms max daily (WB)
0	0	80 micrograms/annum (WB)

Concerns

- Although arable agricultural production is low, it remains an important part of the rural economy and should not be threatened by SO_2 emissions.
- Bean crops particularly sensitive to SO_2

6. DEFINED EVALUATION CRITERIA

1. There are at present no Botswana Bureau of Standards for SO_2 emissions although the Department of Waste Management and Pollution Control has air quality objectives of:
    - 90 % of hourly observations to be less than 300 μg/m^3 over 24-hour average
    - Annual arithmetic mean < 80 μg/m^3
    - Monthly arithmetic mean < 80 μg/m^3

7. IMPACT IDENTIFICATION, ASSESSMENT AND MITIGATIONS

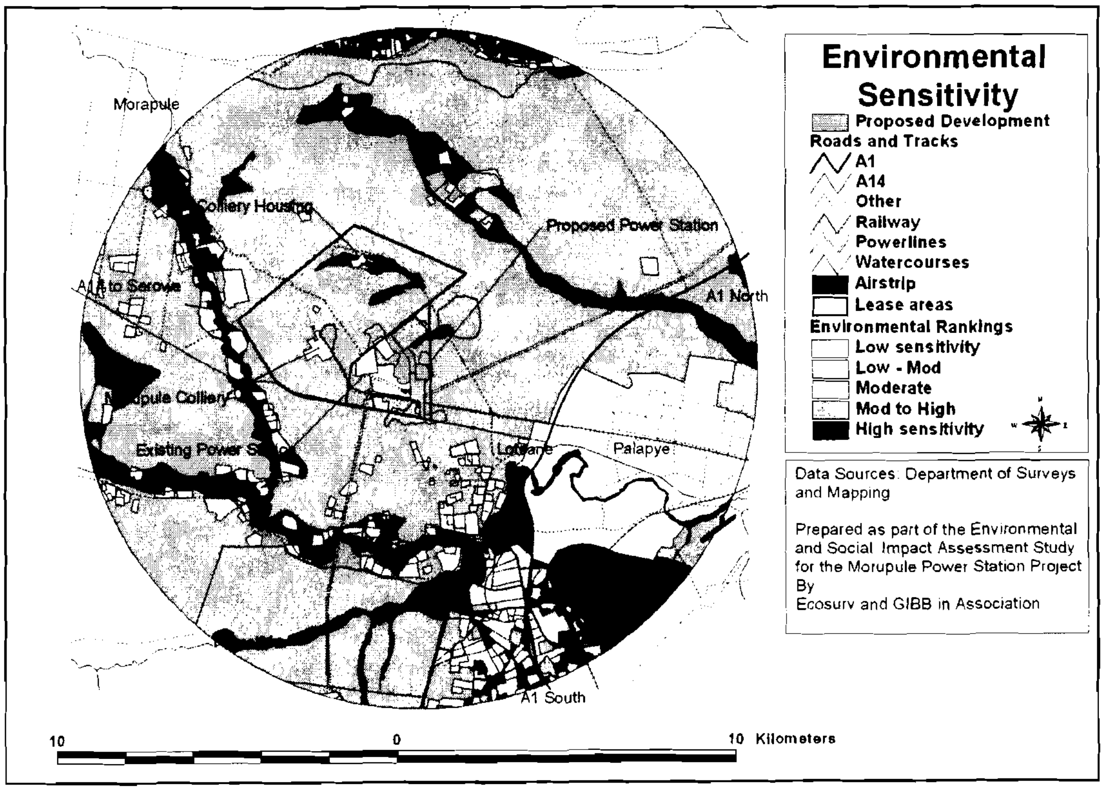
7.1 AREAS OF CONCERN

The mapping of habitats, land use, arable agriculture and settlement patterns have been used to identify areas of concern.

7.1.1 ENVIRONMENTAL SENSITIVITY

The environmental variables were combined and an overall sensitivity map prepared. It is clear from the map that the riverine woodlands, the western edge of the Tswapong (near Palapye) and the rocky outcrops in the Colliery area are the habitats of most concern.

Figure 11: Environmental Sensitivity of habitats within 10 km of the proposed development

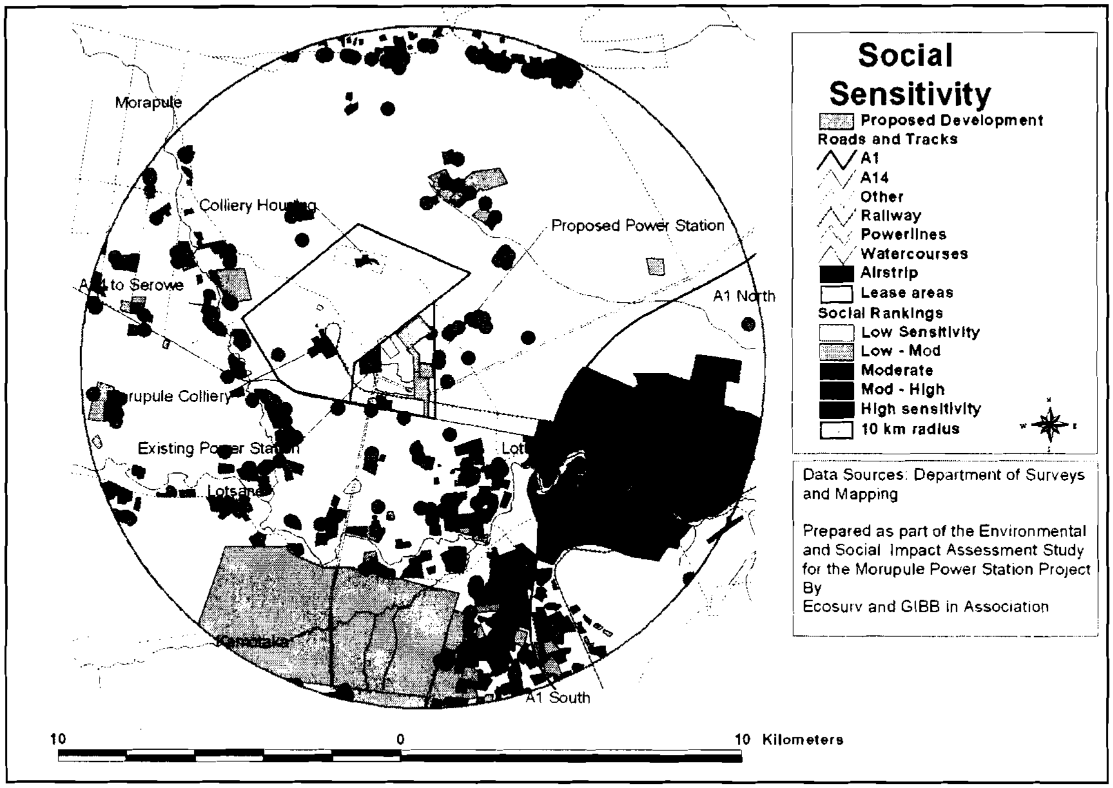


7.1.2 SOCIAL SENSITIVITY

The human distribution (density and land uses) were used to indicate areas of most concern relating to the development and related emissions. The results indicate that south and east lie the areas of most concern. This is largely due to the distribution of people.

To the north west are the fewest social concerns, with the Morupule Colliery housing being of most concern.

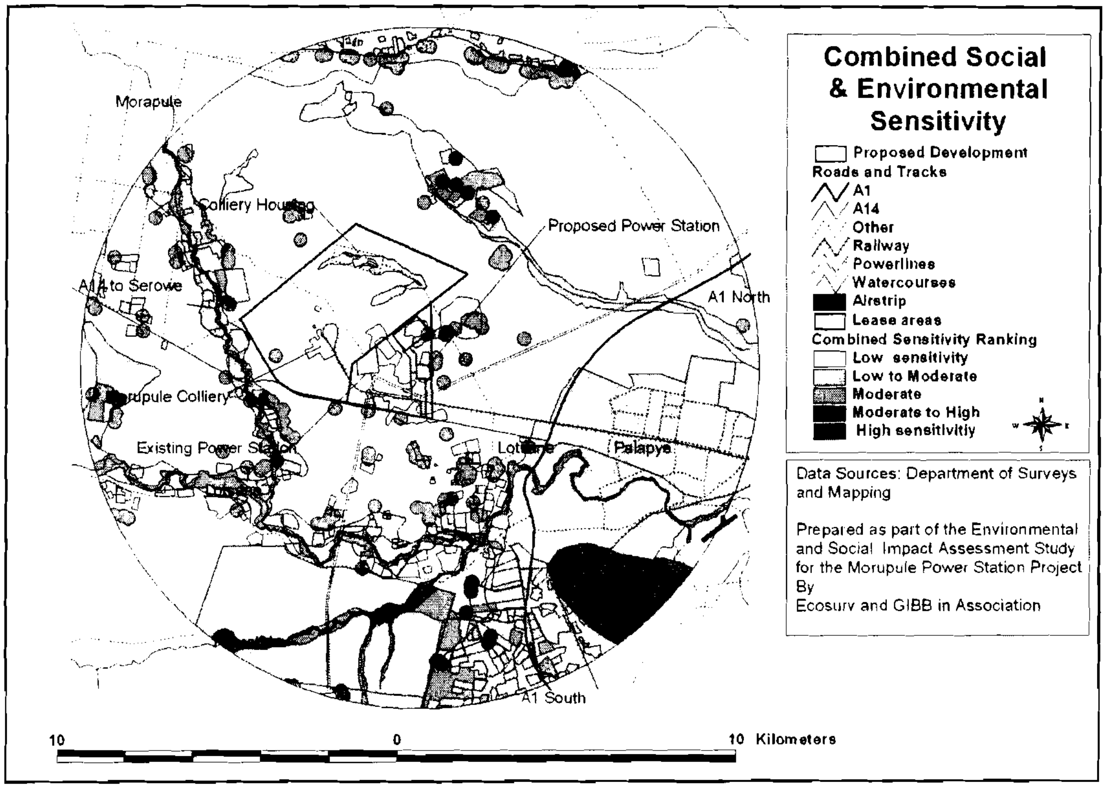
Figure 12:Social sensitivity of communities within 10 km of the proposed development



7.1.3 COMBINED SENSITIVITY

When the two sets of data are combined, the emphasis of sensitive areas remains similar to the social sensitivity indicating that people are using the more sensitive and high biodiversity environments.

Figure 13: Social and environmental sensitivity to development combined



7.2 IMPACT QUANTIFICATION AND RANKING

Impacts have been ranked according to recognised impact assessment methodology provided by GIBB Botswana. The tables indicate impacts, ranking, mitigations and post mitigation rankings.

Table 14: Environmental and Land Use Impacts, ranking and mitigation during Construction[3]

Activity	Aspect	Impact	Mitigation	Nature	Cumulative	Non-Reversibility	Irreplaceable Resource	Intensity	Extent	Duration	Consequence rating	Probability	Confidence	Significance
Abiotic														
Establishment of the site	Excavation of large volumes of gravel	Loss of habitat		Negative	Low	Medium	No	High	Local	Long-term	Medium	Highly probable	Medium	Medium
Establishment of the site	Excavation of large volumes of gravel	Loss of habitat	Sites used for abstraction to be registered with Mines and have a valid EIA. to be (located on low impact areas	Negative	Low	Medium	No	Medium	Local	Medium-term	Medium	Probable	High	Low
Biotic														
Clearing of site and construction camp	Removal of vegetation	Loss of sandveld vegetation		Negative	Low	Medium	No	High	Local	Medium-term	Low	Highly probable	High	Low
Clearing of site and construction camp	Removal of vegetation	Loss of sandveld vegetation	Use of existing damaged areas for Construction camp. Minimise area cleared at site by careful marking of extent and maintaining as much local vegetation as possible	Negative	Low	Medium	No	?	Local	Medium-term	Low	Highly probable	High	Low
Construction	Bush fires	Loss of grazing in Colliery lease area and surrounding grasslands		Negative	Medium	Low	No	Low	Regional	Short-term	Low	Highly probable	Medium	Low
			No fires outside of construction camp. Firebreak around camp, awareness during induction	Negative	Medium	Low	No	Low	Local	Short-term	Low	Probable	High	Low
Construction site and camp	Noise and human presence	Disturbance of wildlife	Entire lease area	Negative	Medium	Low	No	Medium	Local	Short-term	Low	Highly probable	High	Low

[3] The pre-mitigation impact is assessed in the first line of the table for each impact. The second line of the table for each impact refers to the post-mitigation impact.

		presence												
				Induction course for construction crews	Negative	Medium	Low	No	Medium	Local	Short-term	Low	Highly probable	High	Unchanged
	Slimes disposal	Clearing of habitat for flyash storage	Loss of sandveld habitat		Negative	Low	High	No	High	Local	Long-term	Medium	Highly probable	High	Medium
				None										Unchanged
Land Use														
	Establishment of the site	Excavation of large volumes of gravel	Loss of arable lands and grazing	Area and location is not known	Negative	Medium	Medium	No	High	Regional	Long-term	Medium	Highly probable	Medium	Medium
	Establishment of the site	Excavation of large volumes of gravel	Loss of arable lands and grazing	Sites to be located on low impact areas	Negative	Low	Medium	No	Medium	Local	Medium-term	Medium	Highly probable	High	Low

Table 15: Environmental and Land Use impacts, rankings and mitigation - during Operation

Activity	Aspect	Impact	Mitigation	Nature	Cumulative	Non-Reversibility	Irreplaceable Resource	Intensity	Extent	Duration	Consequence rating	Probability	Confidence	Significance
Abiotic														
All sections	High levels of water usage in an arid environment	Groundwater depletion and drawdown		Negative	High	High	Yes	High	Regional	Long	High	High	Medium	High
All sections	High levels of water usage in an arid environment	Groundwater depletion and drawdown	Water reduction technology, recycling, ability of station to use variable water quality	Negative	High	High	Yes	High	Regional	Long	High	High	Medium	High
Burning of coal	CO2 emission	Global warming		Negative	Medium	Medium	Yes	Low	National	Long	High	High	High	High
Burning of coal	CO2 emission	Global warming	Use of low CO2 emissions technology	Negative	Low	Medium	Yes	Low	National	Long	High	Medium	High	High
Biotic														
Coal storage	Dispersal of coal dust downwind of coal storage	Loss of habitat (about 1.6 km^2		Negative	Low	Medium	No	Medium	Local	Medium	Low	Definite	High	Low
Coal storage	Dispersal of coal dust downwind of coal storage	Loss of habitat	Mechanism for dampening or cleaning coal before transport to store site	Negative	Low	Medium	No	Low	Local	Medium	Low	Improbable	Medium	Low
Ash dams	Clearing and disposal of high pH material	Loss of sandveld habitat		Negative	Low	High	No	High	Local	Long	High	Definite	High	Medium
Ash dams	Clearing and disposal of high pH material	Loss of sandveld habitat	None											Unchanged
Power generation	High SO_2 levels during temperature inversions along drainage lines	Reduced grass productivity, reduced crop productivity	Area, tons crops	Negative	Low	Low	No	Low	Regional	Long	Medium	Improbable	Low	Low

Power generation	High SO_2 levels during temperature inversions along drainage lines	Reduced grass productivity, reduced crop productivity	SO_2 scrubbers	Negative	Low	Low	No	Low	Local	Long	Low	Improbable	Low	Low
Burning of coal	SO2 deposition on habitats of concern	Loss of species diversity on outcrops in Colliery lease area and Palapye ridge	Species	Negative	Low	Medium	No	Low	Regional	Long	Medium	Improbable	Low	Low
Burning of coal	SO_2 deposition on habitats of concern	Loss of species diversity on outcrops in Colliery lease area and Palapye ridge	SO_2 scrubbers	Negative	Low	Medium	No	Low	Local	Long	Low	Improbable	Low	Low
Supporting powerline infrastructure	Electrical cables	Loss of Cape Vultures due to electrocution		Negative	High	High	Yes	High	National	Long	High	Probable	Low	High
Supporting powerline infrastructure	Electrical cables	Loss of Cape Vultures due to electrocution	Quantification of losses. Identify localities of mortalities, identify concern areas etc.	Negative	High	High	Yes	Medium	National	Long	Medium	Probable	Medium	Medium
Land Use														
Burning of coal	SO_2 deposition in high density housing area	Human health impacts such as asthmatic attacks	Colliery housing 3.6 km NNW and Palapye 4 km.E	Negative	Medium	Low	No	Low	Regional	Long	Medium	Probable	Medium	Medium
Burning of coal	SO_2 deposition in high density housing area	Human health impacts such as asthmatic attacks	SO_2 scrubbers	Negative	Medium	Low	No	Low	Regional	Long	Medium	Probable	Medium	Medium
Burning of coal	SO_2 levels in Colliery and Power Station work environments	362 persons working at existing power station, estimated additional 240 plus in the Colliery		Negative	Low	Low	No	Low	Regional	Long	Medium	Probable	Medium	Medium
Burning of coal	SO_2 levels in Colliery and Power Station	362 persons working at existing power station, estimated	SO_2 scrubbers	?	?	?	?	?	?	?	?	?	?	?

	work environments	additional 240 plus in the Colliery												
Burning of coal	SO_2 levels in school to south of Colliery	School pupils exposed to SO_2 levels in excess of ?		Negative	Low	Medium	No	Medium	Local	Long	Medium	High	Medium	High
Burning of coal	SO_2 levels in school to south of Colliery	School pupils exposed to SO_2 levels in excess of ?	If SO_2 levels cannot be brought below national thresholds, close the school	?	?	?	?	?	?	?	?	?	?	?
Burning of coal	SO_2 levels in arable agricultural lands	Croplands with SO_2 levels in excess of the national objective	?ha of active lands areas will be exposed to SO_2	Negative	Low	Low	No	Low	Regional	Long	Medium	Improbable	Low	Low
Burning of coal	SO_2 levels in arable agricultural lands	Croplands with SO_2 levels in excess of the national objective	SO_2 scrubbers	?	?	?	?	?	?	?	?	?	?	?
Power generation	Noise within 2200 m of station will exceed night time levels of 40 DB	High noise levels affecting sleep	16 homesteads within the 40 DB limit	Negative	Medium	Low	No	Medium	Regional	Long	Medium	High	High	Medium
Power generation	Noise within 2200 m of station will exceed night time levels of 40 DB	High noise levels affecting sleep	Advise Land Board and Palapye Physical Planners on zonation.	Negative	Medium	Low	No	Medium	Regional	Long	Medium	High	High	Medium

8. MITIGATION OF IMPACTS

In addition to the mitigation measures identified in the tables, there is need to mitigate raptor impacts due to an increased transmission network.

Electrocution on power lines is one of many human-caused mortality factors that affect raptors. Cost-effective and relatively simple raptor-safe standards for power line modification and construction have been available for over 25 years. To control raptor electrocutions in the future, the industry must increase information sharing and technology transfer, increase efforts to retrofit lethal power poles, and above all ensure that every new and replacement line constructed incorporates raptor-safe standards at all phases of development.

Collisions:

Requirements
- Systematic monitoring and recording of mortalities;
- Mapping of vulture flight routes and potential conflict areas;
- Attachment of orange spheres in critical areas;
- New power line corridors to avoid sensitive areas and wetlands;
- Kite and H towers are responsible for a "disproportionate" number of electrocutions. This is if birds can perch on the pylon and wipe beaks on the lines;
- Power industry must increase information sharing and technology transfer;
- Ensure that every new and replacement line constructed incorporates raptor-safe standards at all phases of development.

Sources: Lehman, 2001; Hebet et al, 1995

9. MONITORING AND AUDITING

A brief survey for rare and endangered plants in the area exposed to SO_2 levels in excess of the national air quality objectives is required after the rainy season.

10. CONCLUSIONS AND RECOMMENDATIONS

This study has indicated that there are few ecological issues relating to the establishment of the plant on the present site. The area is in a common habitat with no known rare, endangered or endemic plant species known to occur on the site.

Land use in the immediate surroundings is generally low density with a number of points of high density such as the colliery and colliery housing. There is a school which falls within the zone subject to annual levels of SO_2 in excess of the national objectives for air quality. The same school will be subject to the upper acceptable limits of noise from a combination of the power station and the adjacent road. Land Board and the Physical planners must be made aware of the power station impact zones. This will allow for suitable land allocation and planning.

There are limits to the existing knowledge of the effect of SO_2 and acid rain on indigenous vegetation and the crops growing in the surroundings, this limits the predictability of the results and makes it difficult to quantify the impacts. The issue is that many species of plant benefit from low doses of Sulphur whilst others such as beans and pines are affected at relatively low levels of exposure.

11. SUPPORTING DOCUMENTATION

The specialist Mr. D. Parry states that this assessment was carried out independently of the client and that I have no vested or other interests in the outcome of the study. I am also qualified to address all ecological and land use issues and provide professional remote sensing services.

12. REFERENCES

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13. ANNEXURE 1: TSWAPONG HILLS IBA

Fishpool L. and Evans M. 2001 (eds) Important Bird Areas in Africa and associated islands; Priority sites for conservation. Birdlife Conservation Series N. 11.

Site description
The Tswapong Hills lie in the hardveld of eastern Botswana, east of the town of Palapye. They arise from a sandy plain dominated by mopane woodland. The hills, which extend for 67 km in an east-west direction, are mainly sandstone and on the steeper slopes the vegetation is dominated by Croton. There are gorges with precipitous cliffs and seasonal streams, and exposed rock faces around the edge of the hills and along some watercourses.

Birds
Gyps coprotheres currently breeds at three sites within the Tswapong Hills. The species has probably bred there for well over a century but the existence of some former and current breeding sites, Machibaba and Kukubye at Lerala, and Manong Yeng, was not documented until 1976. The Machibaba site was abandoned in 1984. In the same year breeding sites at Bonwalenong and Sebale were discovered; Seolwane was colonized in 1986, but the colony here dwindled and finally disappeared in 1990 whilst that at Kukubye suffered a similar fate due to direct persecution. In the 1980s, the number of breeding pairs increased from 240 in 1984 to 325 in 1992, although the total number of birds appeared to be declining. Bonwalanong, having undergone a large increase since 1989, was the most important breeding site in 1992, with over 200 pairs, and Manong Yeng then supported around 90 pairs. Nine nests were also found at Kukubye in 1992. As of 2001, the decline in numbers of *Gyps coprotheres* appears to have halted.

Conservation issues
Direct persecution and disturbance have affected breeding sites in the Tswapong Hills. Continuing increases in the population and extent of villages have contributed to the abandonment of small breeding sites. Predation by *Aquila verreauxi* is a cause of some nest losses. Although there is no evidence that a shortage of food or accidental poisoning are causing serious losses, there is concern about the small number of immature birds seen at breeding colonies. This may be due to a high mortality rate of young birds or alternatively young birds may emigrate from the area. In 1996, the Kalahari Conservation Society embarked upon a community-based conservation project in the Tswapong Hills to help local people to use the area in a sustainable way and to develop the hills as a conservation area, thereby deriving direct income from tourism or tourist-based industries. A veld product and vegetation survey of the hills was also undertaken in early 1996.

Key species

A1	*Gyps coprotheres*	Breeding (Pairs)	Non-breeding
A4ii	*Gyps coprotheres*	300	600+

14. ANNEXURE 2: RARE AND ENDANGERD PLANT SPECIES OF BOTSWANA (ECOSURV/IUCN, BSAP, 2005)

Note: the species in italics are the only species that may occur in or near the development site

Family	Taxon	IUCN Category	Full IUCN Status	Notes
Data Deficient				
Apocynaceae sensu lato	Ceropegia floribunda N.E.Br.	Data Deficient	DD	Suspected Endemic. According to PRECIS, endemic to Botswana. The type locality is Khwebe Hills. Suspected to also occur in Namibia but this has not been confirmed. May possibly occur in South Africa, but again, this cannot be confirmed.
Asteraceae	Arctotis rogersii S.Moore	Data Deficient	DD	Could be endemic to Botswana, but may be a synonym or may occur further north. Reported that this may be a garden hybrid which occurs in the Cape (South Africa) but this cannot be confirmed. The taxonomic status of this species is uncertain.
Asteraceae	Arctotis serpens S.Moore	Data Deficient	DD	Could be endemic to Botswana, but may be a synonym or may occur further north. Reported that this may be a garden hybrid which occurs in the Cape (South Africa) but this cannot be confirmed. The taxonomic status of this species is uncertain.
Asteraceae	Erlangea remifolia Wild & G.V.Pope	Data Deficient	DD	Suspected Endemic. According to PRECIS, endemic to Botswana. Based on the number of herbarium collections, is reported to be common. However, this could well be an artefact since the collections could perhaps have been mistakenly identified as E. misera, a common species
Asteraceae	Rennera laxa (Brem. & Oberm.) Kallersjo	Data Deficient	DD	Suspected Endemic. According to PRECIS, known only from Botswana.
Cyperaceae	Eleocharis cubangensis H.E.Hess	Data Deficient	DD	Endemic to the Okavango River, and currently known only from Namibia and Botswana.
Eriospermaceae	Eriospermum linearifolium Baker	Data Deficient	DD	Endemic; Could be endemic to Botswana, but may be a synonym or may occur further north. Recorded from the Okavango and Chobe area. Not known from Namibia.
Eriospermaceae	Eriospermum seineri Engl. & Krause	Data Deficient	DD	Endemic; Not recorded in Namibia. Suspected to be endemic to Botswana, but may be a synonym or may occur further north.
Fabaceae	Acacia hebeclada DC subsp. tristis A.Schreib.	Data Deficient	DD	Has down-turned pods, and a small proportion of the global population is distributed in Botswana. It is found in the northwestern corner of Botswana. Mostly, it is known from Namibia and a few plants extend into Botswana in the fossil river valleys.
Mesembryanthemaceae	Nananthus aloides (Haw.) Schwant.	Data Deficient	DD	Suspected Endemic. Known from border area of the Nossob River. The herbarium descriptions of the distribution of this species are unclear, and therefore it cannot be confirmed if the species also occurs in Namibia and South Africa.
Mesembryanthemaceae	Nananthus margaritiferus L.Bolus	Data Deficient	DD	No herbarium records exist for this species in Botswana. Also known from Namibia where it is legally protected.
Orchidaceae	Habenaria pasmithii G.Will.	Data Deficient	DD	In Botswana, it is known only from the Okavango (type locality). Known from a second collection in Mwinilunga (Zambia). Apparently known only from these disjunct localities. Probably a case of being under-collected or misidentifications of other taxa
Orchidaceae	Zeuxine africana Rchb.f.	Data Deficient	DD	Extremely rare in southern Africa, but widespread across Africa. In Botswana, known only from the Moremi Nature Reserve, as well as other localities in the north of Botswana such as Xobega Lediba. Flowers in July to August.
Poaceae	Aristida wildii Melderis	Data Deficient	DD	Suspected Endemic. Could be endemic to Botswana, but may be a synonym or may occur further north (unlikely to occur in the Caprivi). Found in areas of Botswana that are generally rocky.
Poaceae	Panicum coloratum L.Mant. var. makarikariense Gooss.	Data Deficient	DD	Endemic; The variety is regarded by some as being taxonomically invalid. Localities of this plant beyond Botswana are instances where the species was introduced. In Botswana, it is known from the north (Makarikari Pan) and the southeast (Gaborone).
Poaceae	Panicum gilvum Launert	Data Deficient	DD	Also known from Namibia and South Africa. In Botswana, it is known from the north in seasonal water pans. Probably under-collected and widespread.
Poaceae	Panicum pilgerianum (Schweick.) Clayton	Data Deficient	DD	In Botswana, it is known from the north (Samedupe Bridge) and the southeast (Content Farm). It is also found in Namibia, in seasonally flooded areas, growing in water. Altitude of about 1050 m. Probably under-collected and widespread.
Poaceae	Sporobolus bechuanicus Gooss.	Data Deficient	DD	Endemic; According to PRECIS, known from fewer than five collections and occurring only in Botswana. However, reported to be very common in pans

				of Makgadigadi and Lepepe. The main centre of distribution is central Botswana.
Rosaceae	Grielum cuneifolium Schinz	Data Deficient	DD	The type is from Lydenburg in South Africa. The species does not occur in Namibia. It has a restricted global distribution.
Santalaceae	Thesium dissitum N.E.Br.	Data Deficient	DD	Suspected Endemic. According to PRECIS, known only from Botswana.
Scrophulariaceae	Jamesbrittenia concinna (Hiern) Hilliard	Data Deficient	DD	Suspected Endemic. According to PRECIS, known only from Botswana.
Scrophulariaceae	Jamesbrittenia integerrima (Benth.) Hilliard	Data Deficient	DD	Suspected Endemic. According to PRECIS, known only from Botswana.
Lower Risk				
Acanthaceae	***Barleria matopensis S.Moore***	Lower Risk–Least Concern	LR-lc	No herbarium record of it being collected in Botswana, and also not in PRECIS. However, observed in the wild in Botswana. The distribution of this species in Botswana represents a small proportion of the global population.
Acanthaceae	Blepharis bainesii S.Moore ex C.B.Clarke	Lower Risk–Least Concern	LR-lc	Known from gypsum substrate in southeastern Botswana. Reported to have been observed several times in the vicinity of Matloutsi(e). Also known from southwestern Zimbabwe. However, not found in the former Transvaal area of South Africa.
Cyperaceae	Pycreus okavangensis Podlech	Lower Risk–Least Concern	LR-lc	Nondescript, small plant. Widespread in northwest Botswana occurring throughout the lower delta, on the Chobe River and near a pan in the Kalahari. Also recorded in Namibia and possibly Angola and Zambia. The species has a wide distribution range.
Euphorbiaceae	Jatropha botswanica Radcl.-Sm.	Lower Risk–Least Concern	LR-lc	Endemic. According to PRECIS, known only from Botswana. This species is fairly well protected since it occurs on black clay which is unarable and generally avoided by developments or human settlements. Currently known only from two localities.
Capparaceae	***Boscia foetida Schinz subsp. minima Toelken***	Lower Risk–Near Threatened	LR-nt	The varietal status of this species represents plants shorter than 30 cm that are cushion-like. It is suspected that this dwarf form could be a growth form as a result of overgrazing. It may be rare, but it is certainly not threatened in Botswana.
Fabaceae	Acacia hebeclada DC subsp. chobiensis (O.B.Mill.) A.Schreib.	Lower Risk–Near Threatened	LR-nt	Multi-stemmed tree-shrub. Found in riverbanks or sandbanks close to the northern border of Botswana but only for a limited distance downstream. The species is safe where it occurs, but its numbers and the size of its habitats are exceedingly small
Pedaliaceae	Harpagophytum procumbens (Burch.) DC. ex Meisn.	Lower Risk–Near Threatened	LR-nt	No subspecies or varieties of this species is in use in Botswana. High-value export product for its medicinal properties. More valued than H. zeyheri since the active ingredient is more concentrated. Could become threatened due to reckless harvesting
Pedaliaceae	Harpagophytum zeyheri Decne.	Lower Risk–Near Threatened	LR-nt	No subspecies or varieties of this species is in use in Botswana. High-value export product for its medicinal properties. Far more accessible than H. procumbens since it is fairly common along the roadsides of eastern Botswana. High levels of recruitment.
Vulnerable				
Apocynaceae sensu lato	***Adenium oleifolium Stapf***	Vulnerable	VU B1B2ce	Sought after by collectors and used as a medicinal plant. Ointment made from the plant is used for snake and scorpion bites, and a root extract is used for tonics and treating fevers. Rare and definitely requires protection. Is also found in the San Kalahari.
Apocynaceae sensu lato	***Hoodia lugardi N.E.Br.***	Vulnerable	VU A1de	This species has been subsumed as H. currorii, but this name is not in use in Botswana. In Botswana, the distribution of this taxon is an east-west belt spanning 600 km. Found in the Kglagadi Game Reserve. Several localities have been lost due to diamond exploration and mining.
Apocynaceae sensu lato	Huernia levyi Oberm.	Vulnerable	VU D2	Found in Zimbabwe, Zambia and Namibia (from Mpilila Island in Caprivi). This species is restricted to the Zambezi River drainage area and is uncommon in Botswana. The species has a narrow distribution range and straddles the borders of the four countries.
Apocynaceae sensu lato	***Orbeopsis knobelii (E.Phillips) L.C.Leach***	Vulnerable	VU D1D2	First described in Molepolole. This species is uncommon and difficult to locate in the wild. The subpopulations are very small and disjunct in Botswana. Found on Kalahari sands. Also known from South Africa, Namibia and elsewhere.
Lythraceae	Nesaea minima Immelman	Vulnerable	VU D2	Endemic. Known only from the moist grassy area of the Zwezwe Flats floodplain in Botswana.
Orchidaceae	Ansellia africana Lindl.	Vulnerable	VU A1ad	This is the only epiphytic orchid in Botswana. All orchids are rare in Botswana and therefore, are usually collector's items amongst ecotourists. Frequently observed in cultivation. Wide distribution throughout Africa, but certainly threatened in Botswana.
Orchidaceae	Eulophia angolensis (Rchb.f.) Summerh.	Vulnerable	VU A1ad	Large, showy orchid that grows in peaty ground in perennial and seasonal swamp. In possible danger due to collectors. Flowers from late October to December. Widespread in Angola, Zambia, Tanzania, Uganda and so forth.
Orchidaceae	Eulophia latilabris	Vulnerable	VU	Large, showy orchid that grows in peaty ground in perennial and seasonal

	Summerh.		A1ad	swamps. In danger due to collectors. Flowers from late October to December. Widespread in West Tropical Africa.
Portulacaceae	Anacampseros rhodesiaca N.E.Br.	Vulnerable	VU A1ad	Uncommon in Botswana as this species is at the end of its westren distribution range. It is found close to the border near Francistown, and then extends easterly into Zimbabwe. Has a cryptic, rare habitat in Botswana; known from accessible crevices
Sapindaceae	Erythrophysa transvaalensis I.Verd.	Vulnerable	VU D1D2	The first and only record for Botswana was collected in Shoshong in 1993. Known from the former western Transvaal (South Africa) where it is condered rare. Also known from Zimbabwe (possibly Matopos). The habitat of this species is rocky wooded hills.
Endangered				
Apocynaceae sensu lato	Adenium boehmianum Schinz	Endangered	EN D	Very distinctive-looking plant. Apparently known from only a single Botswana field observation in the hills of Kuke Ghanzi; no herbarium records for this species. Known only from a few individuals.
Apocynaceae sensu lato	***Orbea tapscottii (I.Verd.) L.C.Leach***	Endangered	EN A1ac	Also known from South Africa. In Botswana, collected in Pitsane Pan, but a recent survey failed to find it there again; the area has been heavily overgrazed. Other known localities of this species (near Gaborone and Molepolole) have been decimated due to overgrazing.
Euphorbiaceae	Euphorbia venteri L.C.Leach ex R.Archer & S.Carter	Endangered	EN C2a	Suspected Endemic Only two subpopulations recorded in Botswana from a gypsum substrate. These subpopulations are extremely disjunct (one in the north, the other in the south) and occur close to the border of eastern Botswana.

15. ANNEXURE 3: REPTILES, AMPHIBIANS AND SMALL MAMALS RECORDED FOR THE PALAPYE AREA

Sources: Reptiles and amphibians (Auerbach, 1987); rodents (De Graaf, 1981); other mammals (Smithers, 1983)

Reptiles and Amphibians

Common Name	Scientific Name	Comments
Angolan Shovel-snout	Prosymna angolensis Boulenger	The internasal is single and forms a thin band. 1 preocular, 1 postocular (rarely 2) 5-7 upper labials usually with the 3rd and 4th entering the orbit.
Bushveld Rain Frog, Common Rain Frog Common Blaasop	Breviceps adspersus Peters	Eye moderately large. Dark brown to grey or yellow above, with variable markings.
Cape Sand Frog, Tremolo Sand Frog, Striped Burrowing frog	Tomopterna cryptotis (Boulenger)	The subarticular tubercles of the first finger are single, and the inner metatarsal tubercle is more than 140% of the length of the 2nd toe
Mountain or Leopard Tortoise, Eastern Leopard Tortoise	Geochelone Pardalis babcocki (Loveridge)	Tawny yellow to brown with dark areolae.
Serrated Tortoise, Kalahari Tortoise, Kalahari Geometric Tortoise, Toothed Cape Tortoise, Kuhl's Tortoise	Psammobates oculifer (Kuhl)	The beak is hooked and tricuspid, and the jaw surfaces more or less serrated.
Tropical House Gecko, Common or Moreau's Gecko	Hemidactylus mabouia mabouia	Tail with about ten dark bands. Grey to pale red-brown or almost white with darker bands and sometimes scattered spots or blotches or the back
Common Cape Gecko, Smith's Cape Gecko, Smith Kaapse geitijie, Kasspse diktoongetjie	Pachydactylus capensis capensis (smith)	Variegated above with white and dark spots, pale buff to reddish brown or grey, sometimes with stripes through the eye and nostril.
Peter's Spotted Gecko, Spotted Thick-toed Gecko.	Pachydactylus punctatus punctatus Peter	Grey to brown above, with small darker spots or blotches usually arranged serially in irregular transverse or longitudinal patterns.
Bibron's Gecko, Bibron's Thick-toed Gecko.	Pachydactylus bibrobii Smith	Two dark streaks on either side of the head, one passing through the eye and one above from the nostril to the border of the eye.
Lygodactylus Gray	Common or Cape Dwarf Gecko	The throat and belly of breeding males is reportedly bright yellow.
Wahlberg's or Velvety House Gecko.	Homopholis wahlbergii	The iris of the eye is bronze with dark purple venation.
Wahlberg's Ground Gecko	Colopus wahlbergii wahlbergii Peters	A few clawed males have been recorded. In males the enlarge scales on the base of the tail above the vent are more prominent while they may be whole absent in females.
Tree Agama, Black-necked Agama, Black-necked Tree Agama	Agama atricollis Smith	Body flattish, covered in small keeled scales larger on the back than laterally.
Kalahari Agama, Kalahari Spiny Agama Tropical Spiny Agama.	Agama aculeate aculeate Merrem	Reddish-brown with transverse markings, sometime with bands or chevrons of spots and blotches fading to a yellow ground pattern.
Peters Spiny Agama, Zambezi Spiny Agama Tropical Spiny Agama	Agama aculeate armata Peters	This sub-species is apparently a smaller, eastern form.

Speckled-bellied Skink	Mabuya striata punctatissima (Smith)	The flanks are dark with scattered pale spots.
Cape Three-striped or Three-striped Skink, House Lizard Three-lined	Mabuya capensis (gray)	Ventrum uniform yellow to grey. Tail from one and a third to one and a half times length of body.
Common Variegated Skink, Variable Skink	Mabuya varia (Peters)	Ear- opening oval, oblique, with 3-5 short broad and bluntly-p0inted lobules on anterior border
Sundeval's Skink, Sundeval's Writhing Skink.	Lygosoma sundevallii sundevallii (/Smith)	Both eye-lids present. When alarmed these lizards move in a writing, almost serpentine fashion – the limbs are much reduced.
Yellow-throated. Plated-lizard.	Gerrhosaurus flavigularis Wiegmann	The back may be uniform, or may have additional spots, squares and/or a pale-edged vertebral steak.
Jones' Girdled Lizards, Jones' Arboreal Girdled Lizard, Lowveld Girdled Lizard.	Gordylus Laurenti	Tail relatively short and stout for the genus. Head distinctly tri-angular from above.
Shoshong Hills Flat Lizard	Platysaurus intermedius nigrescens ;Broadley 1980/1981	Chest and belly white with a blue-black patch mesially which may be absent, limbs with blue-grey infuscation, tail pale orange towards base, fading to buff.
Ornate Sandveld or Scrub Lizard.	Nucras taeniolata ornate Gray	+Tail about twice the length of head and body with strongly-keeled scales.
Black and-yellow Sand lizard	Heliobolus Fitzinger	The legs are spotted and the tail is yellow to red
Ocellated Sand Lizard	Pedioplanis lineoocellata lineoocellata (Dumeril & Bibron)	Ventrum white and salmon-pink beneath the hind-limbs and tail males
Rough-scaled Sand Lizard, Mozambique Rough-scaled Sand Lizard	Ichnotropis squamulosa Peter	The tail is about double in the length of the head and body.
Western Worm Lizard, Peter's Round-snouted Amphisbaenian, Kalahari Roundsnouted Amphisbaenian	Zygaspis quadrifrons (Peters)	Purplish to pinkish-brown above, darker towards the tail and fleshy-pink below
Delalande's Blind Snake, Pink Earth Snake.	Typhlops lalandei Schlegel	The belly is similar or paler with patches of yellow to pink interspersed, or uniformly lighter than dorsum
Peter's Worm-, Thread-, Scaly-fronted or Glossy Worm-Snake.	Leptotyphlops scutifrons scutifrons (Peters)	Tail longer than broad, 19-30 sub-caudals. Black, dark-brown or shades of rust above, sometimes paler ventrally, often with pale-edged scales
Common or Brown House Snake, Lineated House Snake, African Lined Snake.	Lamprophis fuliginosus (Boie)	Uniform brown above , sometimes with lighter spots or stripes on neck. Two distinct light lines on head viewed laterally, one runs from the rostral along the upper labials, and the other from the rostral above the eye
Cape Wolf Snake, Common Wolf Snake	Lycophidion capense capense (Smith)	The species id divided into several sub-species.
Southern Striped-bellied Sand or Grass –Snake. Stripe-Bellied Sun, Grass or Sand Snake, yellow-bellied Sand Snake.	Psammophis subtaeniatus subtaeniatus (Peters)	The stripes break up anteriorly to series of spots or bars on the neck and head. The lips are white, flecked with black, and the chin yellowish fading to a distinct bright yellow band which runs down the belly bounded on either side by thin black stripes.
Olive Grass Snake, Hissing Sand- or Grass snake, Short-snouted Grass Snake, African Beauty Snake, Sun	Psammophis sibilans brevirostris Peters	The belly is uniform white, sometimes with dots, streaks or speckles forming thin stripes on the margins of the ventrals

Snake.		
Cape Centipede-eater or Black-headed Snake. Black-headed or Cape Centipede-eater	Aparallactus capensis Smith	Red to brown dorsally with a black head and collar on the nape of the neck.
Common Purple-glossed Snake	Amblyodipsas polylepis polylepis	Glossy black above with a distinct purplish sheen dorsally and ventrally
Cape Centipede-eater or Black-headed Snake, Black-headed or Cape Centipede-eater.	Aparallactus capensis Smith	Red to brown dorsally with a black head and collar on the nape of the neck.
Angolan Green Snake, Spotted or Variegated Bush Snake, Green Bush Snake, Spotted, Speckled or Variegated Wood Snake.	Philothanmnus angolensis Bocage	Ventrum pale green to yellow-green, darkening posteriorly.
Spotted or Variegated Bush Snake, Green Spotted, Speckled or variegated Wood Snake.	Philothamnus semivariegatus semivariegatus	Ventrals and sub-caudals sharply angular, distinctly keeled and notched laterally.
Eastern Tiger Snake	Telescopus semiannulatus semiannulatus	Head very distinct from neck, flattish with large eyes and vertically elliptical pupils.
Southern or Cape Vine, Twig-, or Bird-snake.	Thelotornis capensis capensis (Smith)	The body is varying shades of grey to brown, with white, brown and black speckles and blotches.
Common, Rhombic or African Egg-eating Snake, Scaled Snake, Rough-skinned Snake	Dasypeltis scabra (Linnaeus)	Most specimens have a distinct 'V' shape on the neck, often held to be characteristic of adders.
Shield or Shield-nosed Snake	Aspidelaps scutatus scutatus (Smith)	The rostral is from two-fifths to a little over half as broad as the head and forms an obtuse angle separating the internasals
Egyptian, banded, black, Brown, Rock, Bushveld Cobra or South-eastern Egyptoam Cpnra	Naja haje annulifera Peters	The anterior band usually encircles the body
Horned Adder, Horned Puff-adder, Side winding Adder, common Single-horned Adder.	Bitis caudalis (Smith)	The dark markings may be pale centered
Common or African Puff-adder	Bitis Arietans arietans (merrem)	Variable marked with chevrons, bands or bars of black to grey on orange to grey brown with additional patches of grey to white forming dark rhombs with light borders

Rodents of the Palapye Area

Common Name	Scientific Name	Comments
Cape Ground Squirrel	Xerus inauris (Zimmermann. 1780)	A white lateral stripe from shoulder to hip and small ears. The eyes are prominent, head broad, with a dull whitish line above and below each eye. The front of the face, the hands, feet and belly are white.
Bush Squirrel, yellow-footed Squirrel, Smith's Bush Squirrel	Paraxerus cepapi (A. Smith, 1836)	The fur is short, soft and close. The tail is darkened by the presence of three black bands on the individual hairs while the limbs are a more richly coloured buffy-yellow. The claws are curved and sharp. The back of the ears is dark brown.

Springhare	**Pedetes capensis** (Forster, 1778)	The head is blunt, with ears long and narrow, thinly haired apically, naked inside with a well-developed tragus which probably keeps sand out of the meatus while the animal is burrowing. The ears are brownish. The eyes are well developed. The vibrissae area long while longish hairs also occur on the eyelids
Cape Porcupine	Hystrix africaeaustralis (Peters, 1852)	They are stout, heavily built animals with blunt, rounded heads and small eyes situated far back, and coats of thick cylindrical spines covering the body behind the shoulders, sparsely intermingled with ordinary hairs.
Common Molerat, Hottentot Molerat	Cryptomys hottentotus (Lesson, 1826)	It is small to medium sized, cinnamon-buff to clay-coloured dorsally, slightly paler below .
Hairy-footed Gerbil, South African Pygmy Gerbil, Lesser Gerbil	Gerbillurus paeba (A Smith 1836)	The back is pencilled with liver-brown hairs, while the lower surface, including the chin and inner surface of the limbs, is pure white (plate 4) The tail is the same colour as the back, being of slightly lighter hue and towards the tip may hairs have an amber-brown tint.
Bushvek Gerbil, Peters' Gerbil	Tatera leucogaster (Peters, 1852)	The Bushveld Gerbil is pale orange-buffy dorsally and pure white on the chin, throat, ventral surface, limbs, hands and feet. Lower back darkened by an admixture of hairs with black tips.
Highveld Gerbil, Brants' Gerbil	Tatera brantsii	The chin, throat and ventral surface are pale cream to dull white or yellowish-white (Plate 4) The ears are brown and thinly covered with hair. The tail is reddish-brown above with black hair intermixed and is about as long as the head-body measurement.
Short-tailed Gerbil, Namaqua Gerbil	Desmodillus auricularis (a. Smith, 1834)	It is a short and stockily built medium-sized gerbil, the untufted tail comprising approximately 78%. The tail is pale brown above and reddish white below.
Pouched Mouse	Saccostomus campestris Peters, 1846	The tail is short (less than half the total head-body length), thinly bristled, brown above and white below.
Grey Pygmy Climbing Mouse, Dark-eared Climbing Mouse, Grey Tree Mouse	Dendromus melanotis A. Smith, 1834	The fur is soft and thick. The upper and lateral parts of the head, the neck, body and the upper surfaces of the extremities are ashy-grey with a rufous or rusty tint, more clearly visible on the anterior parts.
Woosnam's Desert Rate	Zelotomys woosnami (Schwann, 1960)	A white line runs from the muzzle to the inner sides of the forelimbs. The dorsal surfaces of the hands and feet are white, the fur not extending over the claws.
Red Veld Rat	Aethomys (Aethomys) chrysophilus (De Winton 1897)	The cheeks, throat, flanks and thighs are paler. The distal parts of both hands and feet are pure white, covered with fine, small hairs.
Namaqua Rock Mouse	Aethomys (Micaelamys) nanaquensis (A. Smith, 1834)	The belly hairs are white to the roots or may be grey to the base with greyish-white or grey tips. The fur is fairly long and soft. The chin, lower neck, throat and limbs are also white.
Tree Rat	Thallomys paedulcus	The fur is soft and well dressed, giving the animal a neat appearance. The black mark on the face, extending from the nose to the eye and spreading in a more diffuse manner in the direction of the ear, is very conspicuous in this species. The chin, throat and entire belly portion are pure

		white, gradually merging into the darker coloration of the upper parts along the flanks.
Multimammate	Praomys (Mastomys) natalensis (A Smith, 1834)	The fur of the species is moderately long and comparatively soft to the touch. The dorsal colour is buffy, suffused with black hairs.
Pygmy Mouse	Mus (Leggada) minutoides A. Smith, 1834	The dorsal colour is a brownish-buff, darkening somewhat along the midline through an admixture of black hairs The white belly is sharply demarcated from the flanks. The ears are of a moderate size, rounded and nearly naked, a little darker along their margins.
Spiny Mouse	Acomys spinosissimus Peters, 1852	The colour of the spiny coat is normally smoky-grey which gradually fades to a reddish brown as the moult approaches. The lower surface of the body is pure white.
Rock Dormouse	Gra[hiurus (Claviglis) Platyops Thomas, 1897	A whitish tail tip is usually broadly tipped with white.
Woodland Dormouse	Graphiurus (Claviglis) murinus (Desmarest, 1822)	The general colour dorsally is mouse-grey. The fur is soft and thick, dark slaty at the base with ashy-brown tips. The ears are large, rounded and not profusely haired.

Mammals (excluding ungulates) (Source: Smithers, 1983)

Common Name	Scientific Name & IUCN Status	Comments
Reddish-grey musk shrew	Crocidura cyanea (duvernoy, 1838)	The colour of the upper parts of the body in the western C.c cyanea is paler than those from the eastern parts of the Subregion and is grey with a wash of reddish-brown. The upper surfaces of the feet in both are distinctly, lighter in colour than the upper parts of the body and both have long hairs present on the third to seven eighths of the basal section of the tail
Lesser red musk shrew	Crocidura hirta (peters, 1852	Musk shrews, C. hirta, have a total lenghth of about 1.3 cm with talls that are about half the length of the head and body and a tails of about 16.0g The under parts are silvery-grey, usually with a yellow or fawn tinge At a spring moult the new fur is darker
South African hedgehog	Erinaceus frontalis A. Smith, 1831	The spiny coat extends from the forehead, round behind the ears and covers the whole of upper parts of their bodies.
Short-snouted elephant-shrew	Elephantulus brachyrhynchus (A. Smith, 1836)	Adults have a total length of about 21 cm, with tails shorter or about the same length as the length of the head and body and a mass of about 44,0 g. The under parts are white, the upper surface of the tail deep brown in the darker specimens to yellowish-grey in the lighter, the under surfaces pale
Bushveld elephant-shrew	Elephantulus intufi	The upper parts of the body of specimens from the Transvaal are yellowish-buffy in colour with a tendency to be dark down the mid-back caused by the long black hairs, which are scattered throughout the coat, lying irregularly in juxtaposition The flanks are paler, and the under parts and chin white, the grey bases of the hair showing through.
Rock elephant-shrew	Elephantulus myurus LC	The upper parts of the body are buffy-grey, greyer towards the rump. The flanks are paler than the upper parts and greyer. The head is buffy-grey, the forehead washed with a paler buff. The eyes conspicuously ringed with white. The ears are brown with a fringe of white hairs on their inner margin.
Egyptian free-tailed bat	Tadarida (Tadarida) aergyptiaca (E. Geoffroy, 1818)	The wing and interfemoral membranes are a translucent light brown, the fur of the under parts spreading thickly but narrowly on to the wing membranes where it is generally the same colour as that on the under parts, but in some cases lighter and in exceptional l cases white. The rounded ears are set closely together on the top of the head, the ear tragus larger than in the subgenera Chaerephon or Mops and not concealed by the antitragus.
Schreibers' long-fingered bat	Miniopterus schreibersii (Kuhl, 1819)	The upper parts are very dark brown, the under parts slightly lighter, especially towards the lower belly, The ears are small for the size of the body and have rounded ends.
Rusty bat	Pipistrellus rusticus (Tomes, 1861)	The colour of the upper parts is a pale rusty , the under parts a shade lighter in colour and tinged with grey. The wing and interfemoral membranes are dark in nearly black the former with a narrow white border.
Cape serotine bat	Eptesicus capensis	The female are larger than the male with a total length of about 8.0cm, the females 9.0 cm with tails of about 3.0cm and 3.5 cm respectively. The colour of the upper parts is a yellowish-brown, in darker and lighter shades, the

		individual hairs black at the base with narrow tips of various shades of yellowish-brown. The wing and interfemoral membranes are blackish-brown.
Yellow house bat	Scotophilus dinganii (A. Smith, 1833)	The colour of the upper parts is variable, ranging from a light olive-brown or a greyish-olive to a rich reddish-brown. The under parts may be bright yellow, ochre-yellow or much paler, almost off-white, with or without yellow on the flanks.
Common slit-faced bat	Nycteris thebaica	The upper parts of the body are buffy-brown, the base of their hair slate-grey, the hairs on the sides of the neck and head with buffy bases. The under parts of the body are buffy on off-white. The long ears and the wing membranes light brown.
Darling's horseshoe bat	Rhinolophus darlingi k. Andersen, 1905	There is some variation in the colour of the upper parts, the majority of specimens being drab grey, but others slightly browner, the colour of the under parts following the colour of the upper parts, but much lighter in colour, a light dove-grey..
Lesser bushbaby	Galago senegalensis E Geoffroy, 1796 LC	The have small rounded heads with short muzzles, very large round eyes with vertical pupils and large, naked, membranous ears which can be folded back against the sides of their heads. The have a thick pelage of soft, light grey or grey-brown fur on the upper parts of the body.
Chacma babbon	Papio ursinus (Kerr, 1792)	The upper parts of the limbs are yellowish, the hands blackish, The tail is dark brown from the base to the tip, partly with tinged with yellow.
Vervet monkey	Cercopithecus pygerythrus (F. Cuvier, 1821)	The face is covered with short black hair and the forehead has a transverse band of pure white hair The hair of the side whiskers is long, white in white in front and speckled grey towards the back where it sweeps back from the cheeks to nearly cover the ears
Pangolin	Manis temminckii (Smuts, 1832) NT	The head is small, the muzzle pointed and covered with small scales which continue forward of the eyes. The sides of the face to the back of the large, vertical, elongated ear openings are naked. The eyelids have a few fringing hairs, the ear openings have fluggy, soft hair inside and there are scattered curly hairs on the skin of the under parts.
Scrub hare	Lepus saxatilis	The upper parts are grizzled greyish or buffy. The general colour of the upper parts is imparted to them by the colour of the penultimate band of grey or buffy on the hairs of the guard coat. The forehead conforms in colour to that of the upper parts
Common mole rat	Cryptomus	The colour of the upper parts varies from cinnamon-buff to clay-coloured.
Porcupine	Hystrix africaeaustralis Peters 1852	The porcupine occurs in south-western Uganda; south-eastern Kenya; Ruanda, in most of Tanzania and on Zanzibar Island, as well as in all the other countries south of this to the borders of the Subregion.
Springhare	Pedetes capensis (Forster, 1778)	They have short, round heads with noticeably large eyes and conspicuous, long, rather narrow , upstanding, roundly pointed ears.
Woodland dormouse	Graphiurus (Claviglis) murinus (Desnarestm#, 1822)	The bushy tail is shorter than the length of the head and body. The hair on the upper surface graduates in length from the base, where it is the same length as on the upper parts of the body to about 18mm long towards the tip..
Ground squirrel	Xerus inauris	The round squirrel is a purely terrestrial species

		about 45 cm in overall length with a tail about half this length and an average mass of about 600 g, although individuals of up to 1000 gare known.
Tree squirrel	Paraxerus cepapi	The colour of the head may be the same as the remainder of the upper parts or may contrast with these in various shades of rusty-yellow.
Woosnam's desert rat	Zelotomys woosnami	The tail is white above and below, slightly darker towards the tip in specimens from the southern parts of their range, pure white in those from the northern parts
Desert pygmy mouse	Mus indutus (Thomas, 1910)	The flanks and rump lack the black tipped hairs. The under parts are white, the white extending upwards to just below the eyes and along the flanks to the hind legs.
Multimammate mouse	Praomys (Mastomys) natalensis	Multimammate mice have a total length of about 24 cm with tails that are about the same length as the length of the head and body and a mass of about 65.0 g
Tree mouse	Thallomys paedulcus (Sundevall, 1847)	The skull has no particular features that mark it from the murid type, although the teeth are small and the bullae large, usually over 6 mm in greatest diameter in adults. (meester, Davis & Coetzee, 1964).
Namaqua rock mouse	Aethomys namaquensis (A. Smith 1934)	The hair on the under parts may be pure white or, particularly on the upper chest and flanks, the hairs may have grey bases imparting a greyish colour to these sections of the under parts.
Red veld rate	Aethomys chrysophilus (de Winton, 1897	The flanks are lighter in colour than the upper parts and the under parts are greyish, the individual hairs with grey bases and white tips.
Short-tailed gerbil	Desmodillus auricularis	The tail is the same colour as the upper parts of the body or slightly lighter, in the darker coloured specimens it is broadly dark-tipped.
Hairy footed gerbil	Gerbillurus paeba (A Smith, 1836)	The tail is the same colour as the upper parts, in the greyer specimens it is darker along the top and is longer than the head and body.
Bushveld gerbil	Tatera leucogaster	Generally they are reddish-brown to orange-buffy on the upper parts and pure white on the chin, throat, and the remainder of their under parts, with white hands and feet.
Highveld gerbil	Tatera brantsii	The colour of the upper parts varies from a pallid light rufous-brown. In central Botswana they are pallid, in the southwest distinctly reddish, and in the southeast distinctly darker.
Pouched mouse	Saccostomus campestris	The colour of the upper parts is grey, or grey tinged brown.
Grey climbing mouse	Dendromus melanotis	The long tail is dark above and lighter in colour on the under surface. The ears are dark in colour with a white patch at the anterior base of the ear.
Aardwolf	Proteles cristatus LC	The hair of the guard coat, on the remainder of the body, is shorter than on the crest and is rather sparse. Body is given to the coat mainly by the dense, soft, crinkled underfur, the hairs of which area silvery-white at the bases, buffy or yellowish-white at the tips.
Brown hyaena	Hyaena brunnea NT	The head, neck and shoulders are massive, the extra mass carried by the fore legs being shown in the size of the fore feet which are much larger than the hind, a feature which marks clearly in the spoor.
Spotted Hyaena	Crocuta crocuta NT	The immense power of the muscles of the neck and for quarters is best appreciated when an individual is seen running off a kill carrying the hind leg of a wildebeest or other heavy section of

		a carcass high off the ground.
Cheetah	Acinonyx jubatus VU C2a(i)	The body of the cheetah is slender and is held high off the ground on the long thin legs. Their heads are distinctly rounded, their muzzles very short, the relatively small rounded ears set widely apart from each other. Occasionally found in the area.
Leopard	Panthera pardus LC	The tail which is over half the length of the head and body, is spotted or rosetted on top and, corresponding with the lighter colour of the under parts of the body, lighter in colour underneath, usually white or off-white.
Caracal	Felis caracal (Schreber, 1776) LC	Their tails are short, only some 27% of the total, length or 36% of the length of the heard and body.
African wild cat	Felis silvestris cafra	The chin and throat are white, the chest is white, washed with pale rufous, the lower chest and belly are pale reddish. Lighter or near white towards the anus.
Bat-eared fox	Otocyon megalotis	Characteristic features are the enormous ears, up to 13 cm long and 10 cm around the base, the broadly black tipped, bushy tail, and the black limbs.
Vulpes chama	Cape fox	The have five digits on the front feet and four on the hind.
Black-backed jackal	Canis mesomelas	The characteristic features of the black-backed jackal which distinguish it from its close relative, the side-striped, are the dark saddle on its back, which runs from the nape of the neck to the base of the tall, the black, bushy tail and reddish flanks and limbs
Honey badger	Mellivara capensis LC	The saddle, which extends from ear to ear across the top of the head narrows slightly on the back of the neck, then widens out at the level of the belly, narrowing to a point at the base of the tail or in some individuals extending slightly on to the top of the tail itself.
Striped polecat	Ictonyx striatus	The under parts and limbs are jet black. The hair on the upper parts is long and silky. The hair on the white bands is pure white throughout its length, and on the black parts of the body, jet black.
African civet	Civettictis civetta LC	The sides of the body from the chest to the base of the tail have a distinct pattern of black markings on a greyish or whitish background
Small-spotted genet	Genetta genetta Linnaeus, 1758	The background colour of the body varies from almost pure white in specimens from the western drier parts of the range to white tinged with buff or off-white from the eastern parts .
Large-spotted genet	Getta tigrina	There are two white or off-white patches under the eyes and brown or dark brown patch at the base of the vibrissae.
Suricate	Suricata suricatta LC	The under parts, from the upper chest to the base of the tail, are very sparsely, haired, the dark coloured skin showing through, giving them a dark appearance. The hair itself is, however, silvery-buffy or off-white.
Selous' mongoose	Paracynictis selousi LC	The soft hair is short on the face and head, barely reaching a length of about 15 mm increasing in length towards the rump where it reaches about 40 mm.
Yellow mongoose	Cynictis penicillata	Yellow mongoose have five digits on the front feet and four on the hind feet
Slender mongoose	Galerella sanguinea	The hair of the black tip is long and projects up to 5 cm beyond the end of the vertebrae of the tail
Banded mongoose	Mungos mungo	In both especially on the head and shoulders, the

		coat is distinctly grizzled continues on to the tail which is tipped black in the darker specimens, dark brown in the lighter.
Dwarf mongoose	Helogale parvula Sundervall, 1846 LC	The hair on the tail is similar to that on the upper parts and about the same length or slightly longer at about 18 mm, except at the base of the tail where it is slightly longer
Rock dassie	Procavia.capensis	The limbs are short and sturdy. The fore foot has four digits, the outer digit the shortest, each digit with a flat nail. Found to the east on the Tswapong hills.

Status
EX = Extinct
EW = Extinct in the wild
CR = Critically endangered
EN = Endangered
VU = Vulnerable
NT = Near threatened
LC = Least concern
DD = Data deficient

Appendix 4.3

Air quality impact report

Project done on behalf of:
ARCUS GIBB (Pty) Ltd

AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED MORUPULE B POWER PLANT NEAR PALAPYE IN BOTSWANA

Report No.: APP/07/AG 01 Rev 1

DATE: ***October 2007***

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REPORT DETAILS

Reference	APP/07/AG-01
Status	Final Report, Revision 1
Report Title	Air Quality Impact Assessment for the proposed Morupule B Power Plant near Palapye in Botswana.
Date Submitted	October 2007
Client	ARCUS GIBB (Pty) Ltd
Prepared by	Hanlie Liebenberg-Enslin, MSc RAU (now University of Johannesburg) Cobus Olivier, BSc Hons (University of Pretoria)
Notice	Airshed Planning Professionals (Pty) Ltd is a consulting company located in Midrand, South Africa, specializing in all aspects of air quality, ranging from nearby neighbourhood concerns to regional air pollution impacts. The company originated in 1990 as Environmental Management Services, which amalgamated with its sister company, Matrix Environmental Consultants, in 2003.
Declaration	Airshed is an independent consulting firm with no interest in the project other than to fulfil the contract between the client and the consultant for delivery of specialised services as stipulated in the terms of reference.
Copyright Warning	With very few exceptions, the copyright in all text and other matter (including the manner of presentation) is the exclusive property of Airshed Planning Professionals (Pty) Ltd. It is a criminal offence to reproduce and/or use, without written consent, any matter, technical procedure and/or technique contained in this document.
Acknowledgements	The authors would like to express their sincere appreciation for the effort from Paul Furniss of ARCUS GIBB for obtaining the relevant emissions information required to complete this study. We also want to thank Martha Kelesitse and Modiri Badirwang from the BPC for supplying the relevant information. Itumeleng Kgololo from Ecosurv is also thanked for providing a site layout map.

EXECUTIVE SUMMARY

1. INTRODUCTION

Airshed Planning Professionals (Pty) Ltd was appointed by ARCUS GIBB (Pty) Ltd to do an air quality assessment of the proposed Morupule B Power Plant in Botswana. The proposed Morupule B Power Plant will include the construction of a 600 MW (4x150 MW) power plant near the town of Palapye. Associated processes to be developed in support of the power generation plant include materials transfer points, new roads, storage piles and an additional ash dump. Morupule B will be located directly adjacent to the existing Morupule Power Plant.

The main pollutants of concern from power generation facilities include particulate matter (specifically PM10), sulphur dioxide (SO_2), oxides of nitrogen (as NO_2) and carbon monoxide (CO). Heavy metals are associated with the emitted particulate emissions with the main concerning ones being lead and mercury. Other substances include Hydrogen Sulphide (H_2S), Sulphuric Acid (H_2SO_4), Total Reduced Sulphur (S), and Fluorides.

The main objective of this investigation was to determine the possible impacts of the proposed operations on the surrounding environment and human health, with specific reference to cumulative impacts referencing background sources already impacting on the area.

1.1 Terms of Reference

As is typical of ESIA's the study components will include a baseline assessment, an impact assessment and a recommendation and management plan section.

1.1.1 Baseline Assessment

- The legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and dustfall classifications.

- Collation and assessment of existing information and identification of information gaps. The availability of the following data and information were specifically taken into account:
  - Meteorological data characteristic of the airflow and atmospheric stability regime of the study area. .
  - Identification of types of air pollutants likely to be released given the power station operations (i.e. stack releases, fugitive emissions from the ash disposal site, storage piles, materials handling and vehicle activity).
  - Identification of other sources of emissions within the region. The existing Morupule Power Station was included and other sources in the region identified
  - Ambient air pollution monitoring data recorded in the vicinity of the proposed power station (where available) was used to characterise the baseline air quality for the purpose of informing the projection of cumulative pollutant concentrations. Ambient measurements of particulate matter (PM10), sulphur dioxide (SO_2) and nitrogen oxides (NO_x) were of interest.
  - Identification of sensitive receptors near and around the site of the proposed power station.
  - Landuse information for the study area was included.

- Provided an indication of the issues, concerns and red flags related to air quality that may occur due to the proposed power station and ash dams.

- Collated and analysed meteorological data form various surface stations within the region of the proposed power station.

- Use was made of a suitable dispersion model for the assessment of the proposed power station on the surrounding environment and human health.

- All relevant background sources were included to provide the base case for the evaluation of the proposed power station impacts and also to assure the assessment of cumulative impacts. The regional US.EPA CALPUFF model was used.

1.1.2 Impact Assessment

- Emissions and source parameters for the proposed Morupule B Power Station was provided by the design engineers. Fugitive emissions deriving from the ash disposal site, materials handling operations and vehicle entrainment from roads were quantified by Airshed.

- Dispersion simulations of ambient particulate and gaseous concentrations and dust fallout from the power plant and associated infrastructure (i.e. ash disposal site etc), for both *routine* operating conditions (no information on *upset* conditions was available) were undertaken using the regional US.EPA CALPUFF model. Three modelling scenarios was included, namely:
  - Scenario 1 - Stack height of 150m;
  - Scenario 2 - Stack height of 200m;
  - Scenario 3 - Stack height of 300m.

- Analysis of dispersion modelling results from the proposed Power Station operations.

- Evaluate the acceptability of predicted air pollutant concentrations and increments in such concentrations, projected to occur in the vicinity of identified sensitive receptor sites, given local and international air quality limits.

1.1.3 Air Quality Management Plan

- Review of existing and proposed abatement measures taking into account international best practice controls. Development of an Air Quality Management Plan included the following:
  - Source prioritisation based on source contributions to total emissions and air quality related impact potentials;
  - Identification of cost-optimised mitigation and management measures for priority sources;
  - Determination of suitable timeframes, responsibilities, performance indicators and targets for selected mitigation and management measures;
  - Development of a suitable ambient monitoring network, including:
    - determine the best location for an ambient monitoring station;
    - determine the pollutants to be monitored;
    - specifications on the frequency of calibration of the equipment by accredited independent companies;:
    - details of data capture;

- processing and telemetry at the station; and,
- reporting frequency and format.

- Recommendation of emission controls and management measures to be taken into account in the project design phase in order to minimise the potential for air quality impacts.

1.2 Project Assumptions and Limitations

Since the project is still in the design phase, not all required information was available for the current assessment. Certain assumptions had to be made and these together with the information limitations are listed as follows:

- Incomplete meteorological data was available from the meteorological station located at the Morupule Power Plant. Historical data for the months of November 1997, May 1998, August 2000 and May to June 2007 were available. Since the dispersion model requires as a minimum one year of hourly average meteorological data, use was made of the simulated three-dimensional CALMET dataset. These simulated meteorological data is regarded to provide a reasonable identification of the regional dispersion potential. Due to the lack of any other data, this was assumed adequate for the impact assessment.
- Limited background ambient air quality data was available from both the on-site monitoring station and the Department of Waste Management and Pollution Control (DWMPC) monitoring station (situated at the Morupule Colliery). Ambient SO_2 data was available from the DWMPC monitoring station for the second half of 1999 and 2001, and for the full year of 2000, 2005 and 2006. The data availability was however poor ranging from 37% to 60% for the periods measured. Data availability of more than 80% is required.
- Sources originally identified to have a possible impact on the background concentrations in the vicinity of Morupule B Power Plant included Matimba and the proposed Matimba B Power Plants. However, given that these stations are ~130 km away and based on the findings for the Mmamabula Energy Project EIA, it was regarded to have an insignificant contribution to the ambient air quality within the region of the Morupule B Power Plant.
- Emission rates were based on the design specifications as provided by the Fichtner technical documentation. Information for the quantification of emissions was only available for the boiler stack, and limited to particulates (assumed to be PM10), SO_2 and NO_x. Further, information was provided on the coal and ash content, the storage piles and discard dump. Vehicle entrainment on the on-site roads was based on information obtained from the scoping report done in 2004.
- The air quality assessment is seen as a preliminary health risk assessment by screening the predicted impacts against relevant ambient air quality guidelines and standards.
- The tender scope stipulated that a two week ambient monitoring campaign was to be conducted. This was not done given that a two week period was regarded too short to obtain any useful background information for the purpose of the current study. Instead the background concentrations were simulated.

1.3 Evaluation Criteria

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality guideline values indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guidelines and standards are normally given for specific averaging periods.

For the Morupule B Power Plant project three sets of criteria were referenced namely the World Bank Guidelines (WBG), the World Health Organisation (WHO) and Botswana's air quality legislation. The WBG guidelines provided guidance on acceptable emission limits for Thermal Power Plants and General Ambient Air Quality. The WHO has recently (October 2005) revised their ambient air quality guidelines for criteria pollutants. Botswana's legislation also provides ambient air quality guidelines for various pollutants and was given preference in the impact assessment.

2. BASELINE ASSESSMENT

3.1 Site Description

Botswana is situated in the centre of the Southern Africa Plateau at a mean altitude of 1,000 m above sea level. The majority of the country is flat with gentle undulations. The topography in the immediate vicinity of the Morupule and Morupule B Power Plants is fairly flat.

There are mainly two towns located in close proximity to the proposed development. The town of Palapye is located approximately 5 km east-southeast of Morupule and Serowe village is situated ~35 km to the northwest. The main activities surrounding the power plant area is primarily agricultural with the Morupule Colliery located approximately 5 km to the northwest.

3.2 Dispersion Modelling Methodology

The CALMET/CALPUFF suite of models was used due to the lack of comprehensive on-site meteorological data. CALMET simulates a three dimensional meteorological profile for the study area using more than one surface weather station and upper air data. Hourly average meteorological data, including wind speed, wind direction and temperature was used, and mixing heights were estimated for each hour, based on prognostic equations, while night-time boundary layers were calculated from various diagnostic approaches. Wind speed and solar radiation were used to calculate hourly stability classes.

CALMET was used to simulate the wind field within the study area. The meteorology was modelled for an area covering 104 km (east-west) by 104 km (north-south) with the three dimensional wind field modelled at five levels for 43,264 receptor points. No upper air data is recorded within Botswana and use was therefore made of South African Weather Services ETA-model data for upper air recordings. Surface meteorological parameters were taken from various monitoring stations including Mahalapye, Sir Seretse Khama, and Selebi-Phikwe in Botswana and the South African Weather Services station at Lephalale.

3.2.1 Dispersion Potential of the Site

The vertical dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume is able to rise), and determining the development of the mixing and inversion layers. Precipitation is important to air pollution studies since it represents an effective removal mechanism of atmospheric pollutants.

A single point from the simulated CALMET model close the Morupule B Power Plant was extracted as representative of on-site meteorological conditions. The prevailing wind field at the Morupule Power Plant site was predicted to be predominantly from the northeast with fairly strong winds (between 5 m/s and 15 m/s) associated with it. Frequent winds were also evident from the east-northeast and east. Calm conditions were predicted to occur for 6.3% of the time.

Temperature maximums generally occur during the October-March months, with June and July months experiencing the lowest temperatures. At Mahalapye a temperature of 35°C during 2004 was only exceeded for 46.4 hours of the year (0.5%). .

Most of the rainfall occurs between the months of October and March, with the dry season in April continuing until September.

3.3 Existing Sources of Emissions

The main sources of emissions within the region include the existing Moropule Power Plant and the Morupule Colliery. In addition agricultural activities, vehicle entrainment on unpaved roads, domestic fuel burning and biomass burning add the specifically particulate emissions. To a lesser extent, sources such as vehicle tailpipe emissions impact on the proposed site and surrounding.

An ambient monitoring station is in place at Morupule Power Station measuring SO_2 and PM10 concentrations. The data availability from this data set was however poor. The highest hourly SO_2 concentrations recorded were during the years 1999 and 2000 with a distinct decrease in the measured ground level concentrations during 2001, 2005 and 2006. The highest hourly concentrations measured every month exceeded the EC standard of 340 $\mu g/m^3$ during 1999 (June, September and October) and 2000 (February and March). The highest daily average concentrations measured over the entire period was 311 $\mu g/m^3$ exceeding the WBG guideline (150 $\mu g/m^3$). On an annual average the concentrations varied over the years between 6.35 $\mu g/m^3$ (2005) and 20.5 $\mu g/m^3$ (1999).

Only 1 month (June 2007) of PM10 ambient concentration data was available for analysis. Also it was unclear if the recordings were for 1-hour twice daily. The concentrations were on average between 16.4 $\mu g/m^3$ and 27.7 $\mu g/m^3$.

4. IMPACT ASSESSMENT

4.1 Background Simulations

Background concentrations were simulated to determine the existing levels of SO_2, NO_2 and PM10 in the region. The main sources contributing to the ambient air quality within the vicinity of the proposed Morupule B Power Station is the current Morupule Power Station and the Morupule Coal Mine. The other main sources, i.e. Matimba and Matimba B Power Stations are too far away to have a significant influence on the background concentrations at Morupule Power Plant. No information was available on the Morupule Coal Mine and this source was also excluded from the simulations.

The emissions from the current Morupule Power Plant was quantified based on information obtained in the technical documents for the proposed Morupule B Power Plant and the original scoping study conducted by Airshed in 2004. The current Morupule Power Plant comprised of four 33 MW. Aside from the boiler stacks, fugitive emissions derive from vehicle entrainment on the unpaved road between the power plant and the ash dump, wind blown dust from the storage piles and ash dump, and materials transfer points.

The highest predicted ambient concentrations from the current Morupule Power Plant operations are provided in Table 1 for SO_2, NO_2 and PM10.

Table 1: Predicted SO_2, NO_2 and PM10 *baseline* concentrations due to the Morupule Power Plant (exceedances of air quality guidelines are highlighted)

Averaging Period	Standard/ Guideline (µg/m³)	MAX GLC		PALAPYE		SEROWE	
		Max Conc (µg/m³)	Fraction of GL	Max Conc (µg/m³)	Fraction of GL	Max Conc (µg/m³)	Fraction of GL
Sulphur Dioxide (SO_2)							
Highest hourly	350(d)	4683.6	**13.4**	690.0	**2.0**	43.0	0.1
Highest 24-hour average	300(a)	557.9	**1.9**	70.0	0.2	7.4	0.02
	150(b)		**4.5**		0.6		0.1
	50(c)		**11.2**		**1.4**		0.1
Annual average	80(a)(b)	155.2	**1.9**	3.5	0.0	0.9	0.01
	30(c)		**3.1**		0.1		0.02
Nitrogen Dioxide (NO_2)							
Highest hourly	400(a)	164.0	0.4	25.0	0.1	1.9	0.00
	200(c)		0.8		0.1		0.01
Highest 24-hour average	150(b)	19.6	0.1	2.6	0.02	0.3	0.002
Annual average	100(a)(b)	5.5	0.1	0.1	0.001	0.04	0.0004
	40(c)		0.1		0.00		0.001
Particulates (PM10)							
Highest 24-hour average	150(b)	366.6	**5.2**	3.4	0.05	1.2	0.017
	100(c)		**3.7**		0.03		0.012
Annual average	200(a)	189.2	0.9	0.2	0.2	0.1	0.3
	50(b)(c)		**3.8**		0.004		0.001

Notes:

(a) Botswana guideline (90% of observed to be less than 300 µg/m³)
(b) World Bank (WBG) Thermal Power Guidelines
(c) World Health Organisation (WHO) Interim Target-2 (IT-2)
(d) European Community (EC) hourly standard

Abbreviations:

GLC – ground level concentration (this is the maximum concentration)
GL – Guideline
Max Conc – Maximum Concentration

4.2 Morupule B Power Plant Dispersion Modelling Results

The impact assessment included the construction, operational closure phases of the proposed project. An emissions inventory for all primary and secondary sources of emissions for the proposed Morupule B Power Plant operations was established. The new plant will comprise of a power generating plant with two stacks associated with it. Fugitive sources will include materials handling operations (loading, tipping and off-loading), conveyor transfer points, vehicle entrainment, and wind erosion from exposed storage piles and the ash dump. The ash dump will be an extension of the existing Morupule ash dump.

All point source emissions were calculated based on the technical information provided in the FICHTNER reports for the Power Station design. The design of the proposed Morupule B Power Plant was based on the emission limits stipulated by the WBG for new Thermal Power Plants. Fugitive emissions were quantified using design data and predictive emission factor equations published by the US-EPA (EPA, 1996). In addition, use was made of the National Pollutant Inventory (Npi) compiled by the Australian Government (ANPI, 2001). No local emission factors are available. Fugitive dust emission rates will be estimated for PM10 (i.e. particles <10 µm) and total suspended particulate (TSP).

Dispersion simulations were conducted for all sources associated with the proposed Morupule B Power Plant. Three scenarios were included in the modelling including stack heights of 150 m, 200 m and 300 m. Since ambient air quality guidelines and standards are applicable to the assessment of off-site, community exposures, cumulative impacts were predicted by including the baseline modelled concentrations. Isopleth plots were generated for the various pollutants reflecting all relevant averaging periods for which ambient air quality guidelines and standards exists.

The highest predicted ambient concentrations from the proposed Morupule B Power Plant operations are provided in Table 2 for SO_2, NO_2 and PM10. This includes the ambient concentrations resulting from the existing Morupule Power Plant.

Table 2: Predicted SO_2, NO_2 and PM10 future concentrations due to the Morupule and Morupule B Power Plants (exceedances of air quality guidelines are highlighted)

Averaging Period	Stack Height	Standard/ Guideline (µg/m³)	MAX GLC		PALAPYE		SEROWE	
			Max Conc (µg/m³)	Fraction of GL	Max Conc (µg/m³)	Fraction of GL	Max Conc (µg/m³)	Fraction of GL
Sulphur Dioxide (SO_2)								
Highest hourly	150 m	350(d)	4,707.03	**13.45**	950.00	**2.71**	98.00	0.28
	200 m		4,706.55	**13.45**	940.00	**2.69**	91.00	0.26
	300 m		4,683.60	**13.38**	937.00	**2.68**	76.00	0.22
Highest 24-hour average	150 m	300(a)	581.36	**1.94**	95.00	0.32	16.50	0.06
		150(b)		**4.65**		0.76		0.13
		50(c)		**11.63**		**1.90**		0.33
	200 m	300(a)	577.88	**1.93**	89.00	0.30	14.70	0.05
		150(b)		**4.62**		0.71		0.12
		50(c)		**11.56**		**1.78**		0.29
	300 m	300(a)	559.26	**1.86**	82.00	0.27	12.50	0.04
		150(b)		**4.47**		0.66		0.10
		50(c)		**11.19**		**1.64**		0.25
Annual average	150 m	80(a)(b)	189.16	**2.36**	6.30	0.08	2.40	0.03
		30(c)		**3.78**		0.13		0.05
	200 m	80(a)(b)	181.68	**2.27**	5.90	0.07	2.30	0.03
		30(c)		**3.63**		0.12		0.05
	300 m	80(a)(b)	169.06	**2.11**	5.30	0.07	2.20	0.03
		30(c)		**3.38**		0.11		0.04
Nitrogen Dioxide (NO_2)								
Highest hourly		400(a)	164.90	0.41	34.00	0.09	3.90	0.01

Averaging Period	Stack Height	Standard/ Guideline (µg/m³)	MAX GLC		PALAPYE		SEROWE	
			Max Conc (µg/m³)	Fraction of GL	Max Conc (µg/m³)	Fraction of GL	Max Conc (µg/m³)	Fraction of GL
		200(b)(c)		0.82		0.17		0.02
Highest 24-hour average		150(b)	20.59	0.14	3.50	0.02	0.72	0.005
Annual average		100(a)	6.74	0.07	0.23	0.002	0.10	0.001
		40(b)(c)		0.17		0.01		0.002
Particulates (PM10)								
Highest 24-hour average		150(b)	2,377.30	**33.96**	23.00	0.33	7.80	0.11
		100(c)		**23.77**		0.23		0.08
Annual average		200(a)	1,232.13	**6.16**	1.80	0.29	0.62	0.003
		50(b)(c)		**24.64**		0.04		0.01

Notes:

(a) Botswana guideline (90% of observed to be less than 300 µg/m³)
(b) World Bank (WBG) Thermal Power Guidelines
(c) World Health Organisation (WHO) Interim Target-2 (IT-2)
(a) European Community (EC) hourly standard

Abbreviations:

GLC – ground level concentration (this is the maximum concentration)
GL – Guideline
Max Conc – Maximum Concentration

4.2 Significance Rating

The significance of the predicted impacts from the proposed Morupule B Power Plant in addition to the existing Morupule Power Plant was assessed based on the significance rating criteria provided by ARCUS GIBB. Table 3 provides the significance rating allocated.

Table 3: Significance Rating

Impact	Stack	Consequence	Probability	Significance	Confidence
Sulphur Dioxide (SO_2)	150 m	Medium	Highly Probable	HIGH	Medium
Nitrogen Dioxide (NO_2)		Medium	Highly Probable	LOW	Medium
Particulates (PM10)		Medium	Highly Probable	MEDIUM	Medium
Mitigated					
Sulphur Dioxide (SO_2)	200 m	Medium	Highly Probable	HIGH	Medium
	300 m	Medium	Highly Probable	HIGH	Medium
Nitrogen Dioxide (NO_2)		Low	Probable	LOW	Medium
Particulates (PM10)		Low	Probable	LOW	Medium

5. CONCLUSIONS

The main findings from this investigation may be summarised as follows:

5.1 Baseline Assessment

- The main pollutants associated with coal-fired power plants include sulphur dioxide (SO_2), particulate matter (TSP, PM10 and PM2.5), oxides of nitrogen (NO_x), carbon monoxide (CO). In addition heavy metals are associated with particulate emissions and are likely to include (but are not limited to) arsenic, cadmium, nickel, mercury and lead. Information was only available for the criteria pollutants of SO_2, NO_2, and PM10.

- Simulated background concentrations only included the current Morupule Power Station emissions. The influence from Matimba A and Matimba B power stations (~139 km to the east-southeast) and Selebi-Phikwe Smelter (~101 km to the northeast), were regarded too distant to have a noticeable impact on the background around Morupule Power Plant.
  - SO_2 predicted concentrations were high, exceeding the EC hourly standard at Palapye but only for 7 hours throughout the year (24 hours is allowed). Highest 24-hour predictions indicated ground level concentrations ranging between 7 µg/m³ and 70 µg/m³ at the sensitive receptors of Palapye and Serowe with annual averages between 0.9 µg/m³ and 3.5 µg/m³. Palapye reflected the highest SO_2 concentrations.
  - Highest hourly NO_2 concentrations predicted at Palapye was 25 µg/m³ and 2 µg/m³ at Serowe. Daily averages ranged between 0.3 µg/m³ and 2.6 µg/m³ with annual averages well within compliance at all sites (between 0.03 µg/m³ and 0.13 µg/m³).
  - Predicted concentrations of PM10, also indicated very low ground level concentrations from the Morupule Power Plant with concentrations ranging between 1.2 µg/m³ and 3.4µg/m³ over highest daily averages, and 0.06 µg/m³ and 0.2 µg/m³ over annual averages.

5.2 Impact Assessment of the proposed Morupule B Power Plant

For the operational phase, the predicted ground level concentrations included background concentrations from the Morupule Power Plant.

- The main sources of emissions from the power plant is the boiler stack, comprising >99% of all SO_2, NO_x, PM10, CO, and VOC emissions. Information was only available on the criteria pollutants of SO_2, NO_2 and PM10. Sulphur dioxide (SO_2), oxides of nitrogen (NO_x) and PM10 emission rates were based on the WBG emission limits for thermal power plants as provided in the technical documentation provided. Thus, the emission rates complied with the WBG requirements. Fugitive emissions derive from materials handling operations (such as coal tipping and limestone tipping), wind blown dust from storage piles and the ash dump and vehicle entrained dust from on-site roads.

- Dispersion modelling was conducted for three stack scenarios, i.e. 150 m, 200m and 300m. All other stack parameters such as temperature, exit velocities and emission rates were assumed to remain the same.

- Highest hourly SO_2 concentrations were screened against the EC standard (350µg/m³) and exceeded at Palapye for all three stack heights (i.e. 150m, 200m and 300m). The number of hours exceeding the EC hourly standard at Palapye were 13 based on the 150 m stack but reduced to 10 hours with the 200m stack and with the 300 m stack down to 6 hours (EC allows 24 hours). SO_2 predicted ground level concentrations for highest daily averages showed compliance with the Botswana and WBG guidelines at Palapye and Serowe, but exceeded the WHO_IT2 guideline at Palapye. This was true for all three stack heights, with a marginal decrease between 150m and 300m. Over an annual average none of the guidelines were exceeded at any of the residential areas for all three stack heights. The impacts on vegetation were screened against the critical level for agricultural crops, forest trees and natural vegetation where the concentrations around Palapye exceeded this threshold. The EC and UK limit to protect ecosystems were not exceeded at the areas outside the power plant.

- Predicted ground level concentrations from a stack height of 150m for NO_2 complied with the Botswana, WBG and WHO guidelines at both residential areas. Highest daily and annual averages reflected compliance with the selected guidelines off-site and at all residential areas. Given the compliance with NO_2 ambient air quality standards from a 150m stack height, the 200m and 300m were not included. This mainly has reference to SO_2 concentrations.

- PM10 concentrations were screened against the WBG, WHO and Botswana guidelines for highest daily and annual averages. The simulated ground level concentrations were well within the relative guidelines at all sensitive receptors for both averaging periods. Only close to the site did the PM10 concentrations exceeded the highest daily guidelines. This is primarily due to the fugitive dust form materials handling, wind erosion form the ash dump and vehicle entrained dust from the roads.

- Given the three stack scenarios (i.e. 150m, 200m and 300m) it can be concluded that an increase in stack height will not result in significant changes on predicted SO_2 ground level concentrations. This is due to the elevated background SO_2 concentrations..

- The significance of the predicted ground level concentrations was rated to be HIGH for SO_2 irrespective of the stack height. NO_2 was given a LOW significance since no exceedances of the ambient air quality guidelines were predicted with PM10 (unmitigated) at a MEDIUM significance. Should mitigation measures be applied to the fugitive sources the significance of particulate concentrations could reduce to a significance rating of LOW.

It should be noted that the existing Morupule Power Plant is the main contributing source of SO_2 ground level concentrations. SO_2 emissions from the current Morupule Power Plant comprise between 56% and 74% of the SO_2 concentrations predicted at Palapye, with the new Morupule B Power Plant making up the rest.

Closure Phase

- *Incremental* impacts due to rehabilitation and demolition activities to be undertaken during the closure phase are of low significance.

- *Cumulative* impacts due to rehabilitation and demolition activities, taking into account background particulate concentrations are more significant.

- No significant aspects should occur during the closure and post-closure phases given the implementation of rehabilitation strategies during the operational phase of the power plant.

6. RECOMMENDATIONS

The Morupule B Power Plant design aimed to ensure compliance with WBG stack emission limits. These emission limits did however not result in compliance with the WBG ambient air quality guidelines, specifically at sensitive receptors. It was therefore recommended that the proposed Morupule B Power Plant be designed according to the design specifications used for the air quality impact assessment for PM10 and NO_2. The design should however be improved for SO_2 emissions since the WBG emission limit results in non-compliance off-site. This can be done by:

- Washing the coal to ensure a reduction in the sulphur content of the coal; and/or,
- Desulphurisation unit to be implemented to reduce SO_2 emissions (Flue gas desulphurisation (FGD) is one control option available to reduce SO_2 emissions).

The PM10 predicted ground level concentrations (even though within compliance at the sensitive receptors) increased 7 times with the introduction of the new power plant. It is therefore recommended that these emissions be reduced by:

- Water sprays or chemical suppressants on the unpaved roads;
- Water sprays or chemical suppressants on all material transfer points; and,
- Vegetation cover on the ash dumps (existing and future) to reduce the potential for wind blown dust.

6.1 Performance Indicators

Key performance indicators against which progress may be assessed form the basis for all effective environmental management practices.

Source based performance indicators were recommended to include the following:

- Implement an online stack monitor at the boiler stack to measure SO_2 and NO_x emissions. This will eliminate the concern regarding isokenetic sampling only representing intermittent measurements and the uncertainty surrounding mass balance calculations. These continuous measurements will also provide a solid foundation for WBG emission standards compliance assessment.
- Conduct Isokenetic stack sampling at all the remaining point sources at least once a year. This is to ensure that the dust collectors are working according to design specifications. A contractor can be used for this purpose.
- Source based performance indicators for the storage piles and ash dump would include vegetation cover density to be 80% on the entire slope up to 1 m from crest, and dustfall immediately downwind to be <1 200 $mg/m^2/day$.
- Dustfall in the immediate vicinity of the road perimeter should be less than 1,200 $mg/m^2/day$ for all unpaved haul roads on the plant site.
- The absence of visible dust plume at all material transfer points would be the best indicator of effective control equipment in place. In addition the dustfall in the immediate vicinity of various sources should be less than 1,200 $mg/m^2/day$.

Receptor based performance indicators were recommended to include the following:

- Continuation of the existing ambient monitoring station throughout the life of the project. This ambient station should be calibrated at least once every six months to ensure accurate and continuous data capturing. This would also prove invaluable information on the effectiveness of the mitigation measures and control equipment and should future expansions be planned.
- Implementation of a dust fallout monitoring network to be placed at the following locations:
    - 1 directional dust fallout bucket next to the unpaved road from the plant to the ash dump;
    - 5 directional dust fallout buckets around the existing and proposed ash dumps;
    - 1 directional dust fallout bucket near each of the main materials transfer points; and,
    - 1 directional dust fallout bucket down wind (i.e. to the southwest) of the coal and lime storage piles.

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Airshed	Airshed Planning Professionals (Pty) Ltd
APCS	Air Pollution Control System
APIA	Air Pollution Impact Assessment
APPA	Atmospheric Pollution (Prevention) Act, Act 18 of 1971
BPC	Botswana Power Corporation
C	Carbon
$CaCO_3$	Calcium Carbonate
CH_4	Methane
CIC	CIC Energy Corporation
CO	Carbon Monoxide
CO_2	Carbon Dioxide
EC	European Commission
EMP	Environmental Management Programme
FGD	Flue Gas Desulphurization
I&AP	Interested and Affected Parties
m^3	Cubic metre
MW	Megawatts
MWe	Megawatt electric
NO_2	Nitrogen Dioxide
OECD	Organisation for Economic Co-operation and Development, European Community
PM10	Particulate Matter with an aerodynamic diameter of less than 10μ
PM2.5	Particulate Matter with an aerodynamic diameter of less than 2.5μ
PPM	Parts per Million
ROM	Run Off Mine
SA	South Africa
SO_2	Sulphur Dioxide
tpd	Tons Per Day
TSP	Total Suspended Particles
μ	Microns
μg	Micrograms
US-EPA	United States Environmental Protection Agency
WBG	The World Bank Group
WHO	The World Health Organisation

Air Quality Impact Assessment for the Proposed Morupule B Power Station near Palapye in Botswana

1 INTRODUCTION

The Botswana Power Corporation (BPC) proposes the construction of a new coal fired Power Station near the existing Morupule Power Station at Palapye in Botswana to cater for the growing power demand (Figure 1-1). Morupule B Power Station will be 600 MW (4x150 MW) in comparison to the existing Morupule Power Station of 132 MW. Morupule B will be located directly adjacent to the existing power plant.

The proposed Morupule B Power Plant will be an independent plant and be constructed in phases. The power plant design will be based on the latest state-of-the-art technology. Phase I will include 4 150 MW nominal capacity units each with a coal fired boiler connected to a steam turbine generator along with required auxiliaries. Phase II will include additional unites of the same design to reach an ultimate capacity of about 1,200 MW. This assessment only focused on Phase I.

Airshed Planning Professionals (Pty) Ltd was appointed by ARCUS GIBB (Pty) Ltd to undertake the specialist air quality study. The main objective of the air quality assessment is to determine the state of the current air quality in the area and assess the impact of the proposed Morupule B Power Plant on the surrounding environment and human health.

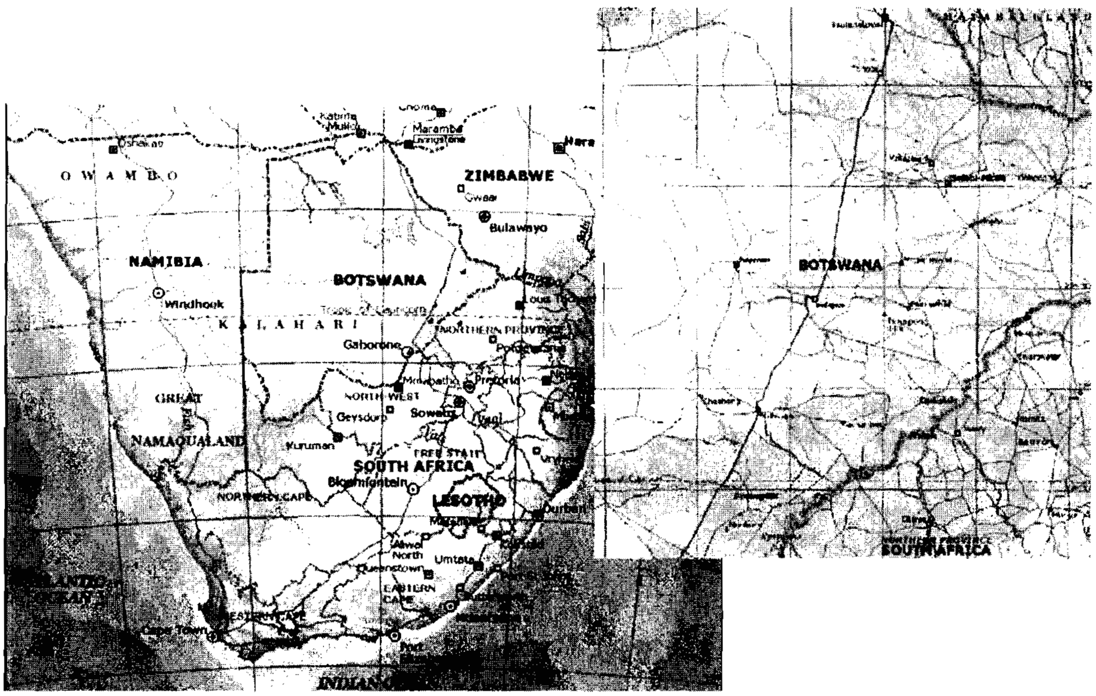

Figure 1-1: Location of the Morupule Power Plant and the proposed Morupule B Power Plant near Palapye in Botswana.

1.1 Terms of Reference and Methodological Overview

As is typical of ESIA's the study components will include a baseline assessment, an impact assessment and a recommendation and management plan section.

1.1.1 Baseline Assessment

- The legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and dustfall classifications with specific reference to the Botswana legislation, the new South African legislation and the World Bank (WBG) requirements have been addressed. Other organisations such as the World Health Organisation (WHO), US.EPA, the European Commission (EC) and United Kingdom (UK) legal requirements have also been referenced. Greenhouse gas emissions have not been included in the assessment due to the lack of detailed information.

- Collation and assessment of existing information and identification of information gaps. The availability of the following data and information were specifically taken into account:
    - Meteorological data characteristic of the airflow and atmospheric stability regime of the study area. Information from various meteorological stations in Botswana was included for determining the on-site dispersion potential (i.e. Gaborone, Francistown, Mahalapye, Letlhakane and Selibe Phikwe).
    - Identification of types of air pollutants likely to be released given the power station operations, including stack releases and fugitive emissions from the ash disposal site, storage piles, materials handling and vehicle activity. The World Bank (WBG) guidelines for new Thermal Power Plants were referenced.
    - Identification of other sources of emissions within the region. The existing Morupule Power Station was included and other sources in the region identified. Attention was paid to trans-boundary pollution sources such as Matimba Power Station and the approved Matimba B Power Station in South Africa, located approximately ~130 km to the southeast of the proposed Morupule B Power Station. These sources were however regarded to be too far away to influence the area surrounding Morupule.
    - Ambient air pollution monitoring data recorded in the vicinity of the proposed power station (if available) was used to characterise the baseline air quality for the purpose of informing the projection of cumulative pollutant concentrations. Ambient measurements of particulate matter (PM10), sulphur dioxide (SO_2) and nitrogen oxides (NO_x) were of interest.
    - Identification of sensitive receptors near and around the site of the proposed power station. Cognisance was given to both human health concerns and sensitive environments (i.e. vegetation impacts, animals).
    - Landuse information for the study area suitable for identifying the proximity of receptors sensitive to increments in air pollutant concentrations (e.g. residential areas, hospitals, schools, sensitive ecosystems) to the existing power station.

- Provided an indication of the issues, concerns and red flags related to air quality that may occur due to the proposed power station and ash dams.

- Collated and analysed meteorological data form various surface stations within the region of the proposed power station. This included data from Gaborone, Mahalapye and other nearby Botswana stations in the region. No upper air data is recorded in Botswana and use was made of mathematical calculations for upper air meteorological conditions. Such data was obtained from the South African Weather Services.

- Use was made of a suitable dispersion model for the assessment of the proposed power station on the surrounding environment and human health. The US.EPA approved CALMET/CALPUFF suit of models was used to provide for the regional modelling of background sources and since Langrarian Puff model is better suited for the simulation of very tall stacks. The CALMET model was used to simulate a three dimensional wind field over the study area. Input to the model included all collated meteorological data and the upper air data, land use information and topography data. A single point was extracted from the simulated CALMET data to serve as an on-site weather station for use in the project.

- All relevant background sources were included to provide the base case for the evaluation of the proposed power station impacts and also to assure the assessment of cumulative impacts. The regional US.EPA CALPUFF model was used. Such background sources included:
  - Existing Morupule Power Station;
  - Matimba Power Station near Lephalale in South Africa (approximately 130km to the southeast) was excluded from the dispersion modelling due to the distance away from the Morupule Power Plant;
  - Other mines or industries in close proximity to the proposed Power Station were to be included but no detailed information was available and hence was omitted from the study. The only mine in the region is the Morupule Colliery;
  - Domestic fuel burning from informal settlements was also intended to be included but no data on the use of coal and wood was available.

1.1.2 Impact Assessment

- Emissions and source parameters for the proposed Morupule B Power Station was provided by the design engineers. Airshed evaluated the emissions inventory and assessed the proposed emission rates against the emission limits provided by the World Bank (WBG) to ensure compliance. The emissions rates were however based on the emission limits of the World Bank and hence no compliance assessment was necessary. Fugitive emissions deriving from the ash disposal site, materials handling operations and vehicle entrainment from roads were quantified by Airshed.

- Dispersion simulations of ambient particulate and gaseous concentrations and dust fallout from the power plant and associated infrastructure (i.e. ash disposal site etc), for both *routine* operating conditions (no information on *upset* conditions was available) were undertaken using the regional US.EPA CALPUFF model. Three modelling scenarios was included, namely:
  - Scenario 1 - Stack height of 150m;
  - Scenario 2 - Stack height of 200m;
  - Scenario 3 - Stack height of 300m.

- Analysis of dispersion modelling results from the proposed Power Station operations, including:
  - Assessment of the predicted incremental ground level concentrations (Morupule B Power Station only); and,
  - Assessment of the predicted cumulative ground level concentrations (existing and proposed sources).

- Evaluate the acceptability of predicted air pollutant concentrations and increments in such concentrations, projected to occur in the vicinity of identified sensitive receptor sites, given local and international air quality limits.

1.1.3 Air Quality Management Plan

- Review of existing and proposed abatement measures taking into account international best practice controls. Development of an Air Quality Management Plan included the following:
  - Source prioritisation based on source contributions to total emissions and air quality related impact potentials;
  - Identification of cost-optimised mitigation and management measures for priority sources;
  - Determination of suitable timeframes, responsibilities, performance indicators and targets for selected mitigation and management measures;
  - Development of a suitable ambient monitoring network, including:
    - determine the best location for an ambient monitoring station;
    - determine the pollutants to be monitored;
    - specifications on the frequency of calibration of the equipment by accredited independent companies;:
    - details of data capture;
    - processing and telemetry at the station; and,
    - reporting frequency and format.

- Recommendation of emission controls and management measures to be taken into account in the project design phase in order to minimise the potential for air quality impacts.

1.2 Site Description

Botswana lies in the centre of the Southern Africa Plateau at a mean altitude of 1,000 m above sea level. The majority of the country is flat with gentle undulations. The topography in the immediate vicinity of the Morupule B Power Plant is fairly flat ranging from 940 metres above mean sea level (mamsl) in the southeast to 1136 mamsl in the northwest. The larger area (including Gaborone) ranges between 1,035 (west) and 756 mamsl (east), thus a 279 m decline over a 240 km distance.

1.3 Sensitive Receptors

The town of Palapye is located approximately 5 km east-southeast of the current Morupule Power Plant. The proposed Morupule B Power Plant will be located directly east of the existing plant. Serowe village is situated ~30 km to the northwest of the current and proposed power plants. To the northwest is the coal mine which supplies the power station with the coal required in order to generate electrical power. The power station is surrounded by farming communities. It lies in the catchment area of a very important river, Lotsane, which is earmarked for damming by the Ministry of Minerals Energy and Water Affairs (see Figure 1-2).

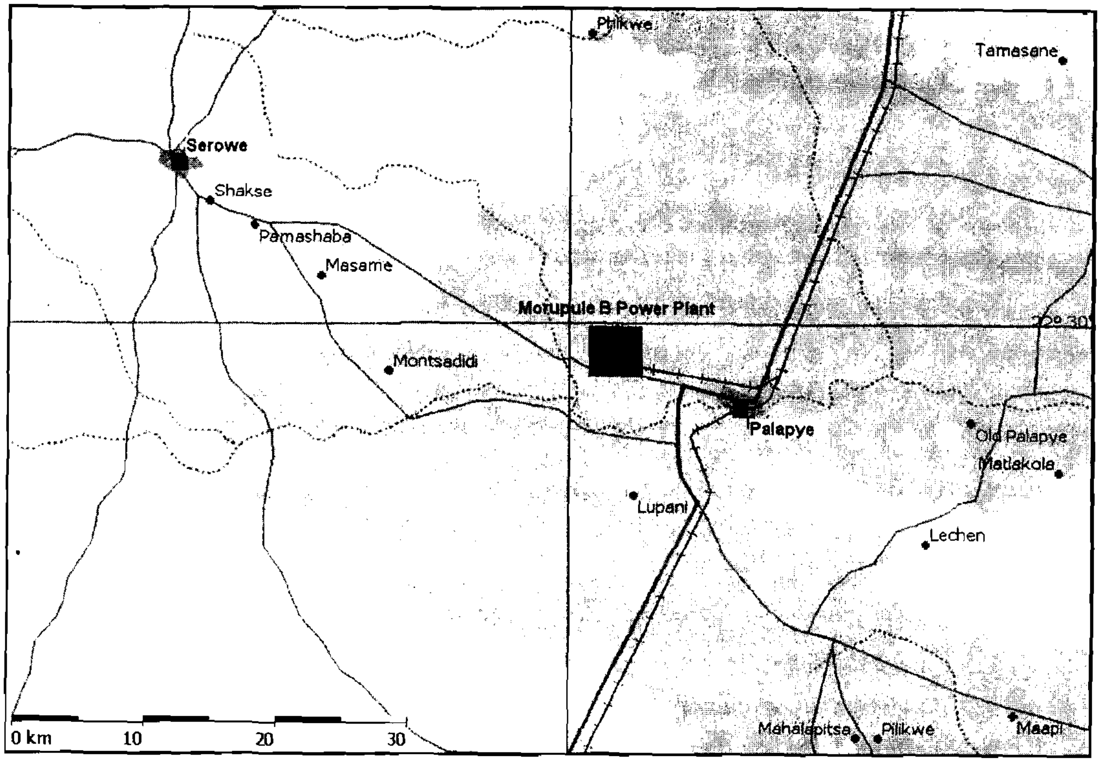

Figure 1-2: Location of sensitive receptors in the vicinity of the Morupule and Morupule B Power Plants

1.4 Limitations and Assumptions

The following assumptions were made during the assessment of the study. Cognisance should also be taken of the limitations associated with the data and models used.

- Incomplete meteorological data was available from the meteorological station located at the Morupule Power Plant. Historical data for the months of November 1997, May 1998, August 2000 and May to June 2007 were available. Since the dispersion model requires as a minimum one year of hourly average meteorological data, use was made of the simulated three-dimensional CALMET dataset. These simulated meteorological data is regarded to provide a reasonable identification of the regional dispersion potential. Due to the lack of any other data, this was assumed adequate for the impact assessment.
- Limited background ambient air quality data was available from both the on-site monitoring station and the Department of Waste Management and Pollution Control (DWMPC) monitoring station (situated at the Morupule Colliery). Ambient SO_2 data was available from the DWMPC monitoring station for the second half of 1999 and 2001, and for the full year of 2000, 2005 and 2006. The data availability was however poor ranging from 37% to 60% for the periods measured. Data availability of more than 80% is required.
- Sources originally identified to have a possible impact on the background concentrations in the vicinity of Morupule B Power Plant included Matimba and the proposed Matimba B Power Plants. However, given that these stations are ~130 km away and based on the findings for the Mmamabula Energy Project EIA, it was regarded to have an insignificant contribution to the ambient air quality within the region of the Morupule B Power Plant.

- Emission rates were based on the design specifications as provided by the Fichtner technical documentation. Information for the quantification of emissions was only available for the boiler stack, and limited to particulates (assumed to be PM10), SO_2 and NO_x. Further, information was provided on the coal and ash content, the storage piles and discard dump. Vehicle entrainment on the on-site roads was based on information obtained from the scoping report done in 2004.
- The air quality assessment is seen as a preliminary health risk assessment by screening the predicted impacts against relevant ambient air quality guidelines and standards.
- The tender scope stipulated that a two week ambient monitoring campaign was to be conducted. This was not done given that a two week period was regarded too short to obtain any useful background information for the purpose of the current study. Instead the background concentrations were simulated.

1.5 Outline of the Report

The report is outlined as follows:

Section 2	-	Legal requirements, including the specifications of the Botswana Legislation, the World Bank Requirements and the World Health Organisation specifications. Both emission limits and ambient air quality standards/guidelines are referenced and discussed.
Section 3	-	The selection of an appropriate dispersion model and the modelling methodology are discussed in this section.
Section 4	-	Description of the climate and dispersion potential of the site.
Section 5	-	Baseline characterisation based on the current Morupule Power Plant operations and all measured ambient air quality data to date and predicted background concentrations.
Section 6	-	Emissions quantification, dispersion modelling and impact assessment of the proposed Morupule B Power Plant operations. It also includes the two alternative stack height predictions.
Section 8	-	Qualitative assessment of the closure and post-closure phases.
Section 9	-	Management measures identified for the Morupule B Power Plant.

2 LEGISLATION AND AMBIENT AIR QUALITY CRITERIA

Prior to assessing the impact of the operations at Morupule and Morupule B Power Plants, reference needs be made to the environmental regulations and guidelines governing the emissions and impact of such operations. The World Bank guidelines as published in the Pollution Prevention and Abatement Handbook 1998 provides guidance on what is regarded as internationally acceptable emission limits and ambient air quality standards for thermal power stations and mines. Botswana also has legislation on air quality control in the form of the Atmospheric Pollution (Prevention) Act of 1971.

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality guideline values indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guidelines and standards are normally given for specific averaging periods. These averaging periods refer to the time-span over which the air concentration of the pollutant was monitored at a location. Generally, five averaging periods are applicable, namely an instantaneous peak, 1-hour average, 24-hour average, 1-month average, and annual average. The application of these standards varies, with some countries allowing a certain number of exceedances of each of the standards per year.

Reference is made to the ambient air quality guidelines as stipulated by the Botswana legislations, in addition to the World Bank specifications and the World Health Organisation guidelines. Since South Africa (a neighbouring country) is also a developing country and has recently revised its ambient air quality standards, these were also included as reference.

2.1 Review of the Current Air Pollution Legislative Context

The Department of Waste Management and Pollution Control is responsible for air quality and its control in Botswana. The legislation in force is the Atmospheric Pollution (Prevention) Act, Act 18 of 1971. The operational principle is that of "best practicable means" carried over from the British Alkali Act of 1863.

Persons wishing to carry on an industrial process capable of or causing the emission into the atmosphere of objectionable matter (Smoke, noxious or offensive gases, vapours, fumes, grit and dust) shall apply for a registration certificate before starting erection of such a process plant. The application is to be lodged with the Air Pollution Control Officer in the prescribed form and is to be accompanied by prescribed information. The Air Pollution Control Officer appointed under the Act must be satisfied that "best practicable means" ("having regard to local conditions and circumstances, the prevailing extent of technical knowledge and the cost likely to be involved") for pollution control is applied before issuing such a permit.

The Botswana authorities have set guidelines for ambient air quality in residential areas. These are listed in the relevant tables under Section 2.3. The standards are in general less onerous than the standards in developed countries.

2.2 World Bank Requirements

The World Bank Pollution Prevention and Abatement Handbook 1998 provide guidelines on ambient air quality and emission limits for specific process (i.e. Thermal Power Plants and Coal Mines). Ambient standards provide the maximum allowable level of a pollutant in the receiving environment whereas emission standards set the maximum amount of pollutant that may be released.

Ambient air quality standards should be set once an agreement has been reached on the environmental quality objectives that are desired and the cost that society is willing to accept in order to meet the set objectives. Typically the set of ambient air quality standards aim to protect human health but lately ambient standards for the protection of ecosystems have been established by some countries. Emission standards on the other hand may be established in terms of what can be achieved with available technology or in terms of the impacts resulting from the emissions (World Bank, 1999).

The World Bank has developed a set of guidelines and standards for specific process (including Thermal Power Plants and Coal Mines) and for individual pollutants (such as particulates, sulphur dioxide and oxides of nitrogen).

2.3 Emission Limits

2.3.1 Emission Limits for Large Coal-fired Combustion Plants

Emission limits specified by the World Bank for large coal-fired combustion plants is given in Table 2-1 (World Bank, 1998). EC emission limits, documented in *Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emission of certain pollutants into the air from large combustion plants,* differentiate between existing and new plants. Such emissions limits are summarised in Tables 2-2 and 2-3 respectively.

Table 2-1: World Bank emission limits for coal-fired combustion plants (World Bank, 1998)

Particulates	Sulphur Dioxide	Nitrogen Oxides, as NO_2
50 mg/Nm^3 for units ≥50 MWe input 100 mg/Nm^3 for units <50 MWe)	Not to exceed 2000 mg/Nm^3	750 mg/Nm^3 (260 nanograms per Joule (ng/J)

Table 2-2: EC emission limits for existing(a) solid fuel combustion plants, expressed in mg/Nm^3 (O_2 content 6%) (EC Directive 2001/80/EC)

Particulates	Sulphur Dioxide	Nitrogen Oxides, as NO_2
100 mg/Nm^3	2000 mg/Nm^3	750 mg/Nm^3

Notes:
(a) Emission limits applicable to existing plants and new plants which submitted a full request for a license before 27 November 2002 provided that the plant is put into operation no later than 27 November 2003.

Table 2-3: EC emission limits for new(a) solid fuel combustion plants, expressed in mg/Nm³ (O_2 content 6%) (EC Directive 2001/80/EC)

Particulates	Sulphur Dioxide	Nitrogen Oxides, as NO_2
30 mg/Nm³	200 mg/Nm³(b)	600 mg/Nm³

Notes:
(a) Emission limits applicable to new plants other than those plants which submitted a full request for a license before 27 November 2002 and began operations no later than 27 November 2003.
(b) Where the emission limit value cannot be met due to the characteristics of the fuel, installations must achieve 300 mg/Nm² SO_2, or a rate of desulpurisation of at least 92% must be achieved in the case of plants with a rated thermal input of less than or equal to 300 MWth.

The SO_2 emission limits stipulated by the World Bank and the EC for existing operations is significantly more stringent than the maximum permissible limit specified by the Botswana authorities for the Morupule Power Station's current boiler operations (i.e. 3293 mg/Nm³)(Watson *et.al.*, 2004)..

2.4 Ambient Air Quality Standards and Guidelines

It is recommended that the design of the power station should comply with the Botswana guidelines and the WBG (WBG are more stringent than the Botswana guidelines). Reference is further made to the World Health Organisation (WHO) and European Community (EC) ambient air quality guidelines as an indication to international best practice where applicable. It should be noted that these guidelines were developed for first world conditions with different social-economic drivers than what is the case in Botswana.

2.4.1 Suspended particulate matter

Air quality guidelines for particulates are given for various particle size fractions, including total suspended particulates (TSP), inhalable particulates or PM10 (i.e. particulates with an aerodynamic diameter of less than 10 μm), and respirable particulates of PM2.5 (i.e. particulates with an aerodynamic diameter of less than 2.5 μm). Although TSP is defined as all particulates with an aerodynamic diameter of less than 100 μm, and effective upper limit of 30 μm aerodynamic diameter is frequently assigned. PM10 and PM2.5 are of concern due to their health impact potentials. As indicated previously, such fine particles are able to be deposited in, and damaging to, the lower airways and gas-exchanging portions of the lung.

The focus of suspended particulate matter is mainly on the size fractions less than 10 μm due to the health effects associated with the fine dust fractions. The ambient air quality guidelines and standards for PM10 are given in Table 2-4.

During the 1990s the World Health Organisation (WHO) stated that no safe thresholds could be determined for particulate exposures and responded by publishing linear dose-response relationships for PM10 and PM2.5 concentrations (WHO, 2005). This approach was not well accepted by air quality managers and policy makers. As a result the WHO Working Group of Air Quality Guidelines recommended that the updated WHO air quality guideline document contain guidelines that define concentrations which, if achieved, would be expected to result in significantly reduced rates of adverse health effects. These guidelines would provide air quality managers and policy makers with an explicit objective when they were tasked with setting national air quality standards. Given that air pollution levels in developing countries frequently far exceed the recommended WHO air quality guidelines (AQGs), the Working Group also proposed interim targets (IT) levels, in excess of the

WHO AQGs themselves, to promote steady progress towards meeting the WHO AQGs (WHO, 2005). The air quality guidelines and interim targets issued by the WHO in 2005 for particulate matter are given in Tables 2-5 and 2-6.

Table 2-4: Air quality guidelines and standards for inhalable particulates (PM10).

Authority	Maximum 24-hour Concentration (µg/m³)	Annual Average Concentration (µg/m³)
Botswana Guidelines	100(monthly) (a)	200(a)
World Bank (General Environmental Guidelines)	70(b)	50(b)
World Bank (Thermal Power Guidelines)	150(c)	50(c)
Proposed South African Standards (based on the SANS:1929,2004)	75(d)	40(d)
World Health Organisation	150(e) 100(f) 75(g) 50(h)	70(e) 50 (f) 30(g) 20 (h)
European Community (EC)	50(i)	30(j) 20(k)

Notes:
(a) Provided by the National Environmental Laboratory Botswana
(b) World Bank, 1999. Pollution Prevention and Abatement Handbook (www.worldbank.org). Ambient air conditions at property boundary.
(c) World Bank, 1999. Pollution Prevention and Abatement Handbook (www.worldbank.org). Ambient air quality in Thermal Power Plants.
(d) SANS 1929 - South African National Standard - Ambient Air Quality - Limits for common pollutants. Also proposed South African Standards as published in the Government Gazette of 9th June 2006.
(e) WHO interim target-1 (IT-1). World Health Organisation air quality guidelines global update 2005.
(f) WHO interim target-2 (IT-2). World Health Organisation air quality guidelines global update 2005.
(g) WHO interim target-3 (IT-3). World Health Organisation air quality guidelines global update 2005.
(h) WHO guideline (AQG). World Health Organisation air quality guidelines global update 2005.
(i) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2005. Not to be exceeded more than 25 times per calendar year. (By 1 January 2010, no violations of more than 7 times per year will be permitted.)
(j) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2005
(k) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2010

Table 2-5: WHO air quality guideline and interim targets for particulate matter (annual mean) (WHO, 2005)

Annual Mean Level	PM10 (µg/m³)	PM2.5 (µg/m³)	Basis for the selected level
WHO interim target -1 (IT-1)	70	35	These levels were estimated to be associated with about 15% higher long-term mortality than at AQG
WHO interim target -2 (IT-2)	50	25	In addition to other health benefits, these levels lower risk of premature mortality by approximately 6% (2-11%) compared to WHO-IT1
WHO interim target – 3 (IT -3)	30	15	In addition to other health benefits, these levels reduce mortality risks by another approximately 6% (2-11%) compared to WHO-IT2 levels.
WHO air Quality Guideline (AQG)	20	10	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to PM2.5 in the American Cancer Society (ACS) study (Pope *et al.*, 2002 as cited in WHO 2005). The use of the PM2.5 guideline is preferred.

Table 2-6: WHO air quality guideline and interim targets for particulate matter (daily mean) (WHO, 2005)

Annual Mean Level	PM10 (µg/m³)	PM2.5 (µg/m³)	Basis for the selected level
WHO interim target -1 (IT-1)	150	75	Based on published risk coefficients from multi-centre studies and meta-analyses (about 5% increase of short-term mortality over AQG)
WHO interim target -2 (IT-2)	100	50	Based on published risk coefficients from multi-centre studies and meta-analyses (about 2.5% increase of short-term mortality over AQG)
WHO interim target – 3 (IT -3)	75	37.5	Based on published risk coefficients from multi-centre studies and meta-analyses (about 1.2% increase of short-term mortality over AQG)
WHO air Quality Guideline (AQG)	50	25	Based on relation between 24-hour and annual levels

Notes:
* 99th percentile (3 days/year)
** for management purposes, based on annual average guideline values; precise number to be determined on basis of local frequency distribution of daily means

2.4.2 Sulphur Dioxide

Sulphur dioxide is damaging to the human respiratory function. Exposure to sulphur dioxide concentrations above certain threshold levels increases the prevalence of chronic respiratory disease and the risk of acute respiratory illness. Due to it being highly soluble, sulphur dioxide is more likely to be adsorbed in the upper airways rather than penetrate to the pulmonary region.

Ambient air quality guidelines and standards referenced for purposes of this study are given in Table 2-7. The WHO and general environment WBG guidelines are not linked to allowable frequencies of exceedences, with the EC standards indicating allowable incidence exceedances for hourly and daily averages. The WBG does however indicate frequency of exceedances for power plants in degraded airsheds. Even though the ambient air quality at the Morupule site is not regarded to fall into this category (see Section 5), these requirements were referenced to provide a more informed understanding of potential impacts. In the formulation of the WHO goals, the lowest observed level at which adverse health effects are observed to occur as a result of a particular pollutant is identified *and a margin of safety added.* Margins of safety are included to account for uncertainties in, for example, extrapolating health effects from animals to humans or from small human sample group to entire populations.

It is important to note that the WHO air quality guidelines (AQGs) published in 2000 for sulphur dioxide have recently been revised (WHO, 2005). Although the 10-minute AQG of 500 µg/m³ has remained unchanged, the previously published daily guideline has been significantly reduced from 125 µg/m³ to 20 µg/m³. The previous daily guideline was based on epidemiological studies. WHO (2005) makes reference to more recent evidence which suggests the occurrence of health risks at lower concentrations. Although WHO (2005) acknowledges the considerable uncertainty as to whether sulphur dioxide is the pollutant responsible for the observed adverse effects (may be due to ultra-fine particles or other correlated substances), it took the decision to publish a stringent daily guideline in line with the precautionary principle. The WHO (2005) stipulates an annual guideline is not needed for the protection of human health, since compliance with the 24-hour level will assure sufficiently lower levels for the annual average. Given that the 24-hour WHO AQG of 20 µg/m³ is anticipated to be difficult for some countries to achieve in the short term, the WHO (2005) recommends a stepped approach using interim goals as shown in Table 2-7.

Table 2-7: Ambient air quality guidelines and standards for sulphur dioxide for various countries and organisations

Authority	Maximum 1-hourly Average (µg/m³)	Maximum 24-hour Average (µg/m³)	Annual Average Concentration (µg/m³)
Botswana guidelines (a)	-	300(a)	80
World Bank (General Environmental Guidelines)	-	125(b)	50(b)
World Bank (Thermal Power Guidelines)	-	150(c)	80(c)
Proposed South African Standards (based on the SANS:1929,2004)	350(d)	125(e)	80(e)
World Health Organisation	-	125(f) 50(g) 20(h)	10-30(i)
European Community (EC)	350(j)	125(k)	20(l)

Notes:
(a) Provided by the National Environmental Laboratory Botswana. 90% of observed to be less than 300 µg/m³
(b) World Bank, 1999. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air conditions at property boundary.
(c) In airsheds with significant level of pollution, an Airshed will be classified as having moderate air quality if the annual mean does not exceed 50 µg/m³ or the 98th percentile of 24-hour mean values over a period of a year is below 150 µg/m³. World Bank, 1999. Pollution Prevention and Abatement Handbook (www.worldbank.org). Ambient air quality in Thermal Power Plants.
(d) Proposed South African Standards as published in the Government Gazette of 9th June 2006
(e) SANS 1929 - South African National Standard - Ambient Air Quality - Limits for common pollutants. Also proposed South African Standards as published in the Government Gazette of 9th June 2006
(f) WHO interim target-1 (IT-1). World Health Organisation air quality guidelines global update 2005. operations.
(g) WHO interim target-2 (IT-2). World Health Organisation air quality guidelines global update 2005.
(h) WHO guideline (AQG). World Health Organisation air quality guidelines global update 2005
(i) Represents the critical level of ecotoxic effects (issued by the WHO for Europe); a range is given to account for different sensitivities of vegetation types (WHO, 2000).
(j) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 24 times per calendar year).
(k) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 3 times per calendar year).
(l) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limited value to protect ecosystems. Applicable two years from entry into force of the Air Quality Framework Directive 96/62/EC.

Table 2-8: WHO air quality guidelines and interim guidelines for sulphur dioxide (WHO, 2005)

	24-hour Average Sulphur Dioxide (µg/m³)	10-minute Average Sulphur Dioxide (µg/m³)
WHO interim target-1 (IT-1) (2000 AQG level)	125	-
WHO interim target-2 (IT-2)	50(a)	-
WHO Air Quality Guideline (AQG)	20	500

Notes:
(a) Intermediate goal based on controlling either (i) motor vehicle (ii) industrial emissions and/or (iii) power production; this would be a reasonable and feasible goal to be achieved within a few years for some developing countries and lead to significant health improvements that would justify further improvements (such as aiming for the guideline).

2.4.3 Oxides of Nitrogen

Human respiratory tract irritation represents a direct effect of NO_x exposures. Due to it being relatively insoluble (relative to sulphur dioxide), NO_2 can penetrate deep into the lungs where tissue damage occurs. Effects of NO_2 exposure include alveolar tissue disruption and obstruction of the respiratory bronchioles. Long-term effects of exposure include increased potentials for lung infections (Koenig, 2000).

Human respiratory tract irritation represents a direct effect of exposure to NO_x. Nitrogen dioxide is less soluble than sulphur dioxide and can thus penetrate deep into the lungs where tissue damage occurs. Adverse effects due to acute NO_2 exposure, such as pulmonary edema usually do not show up until many hours after the exposure has ended. The WHO gives the lowest observed adverse effect level of hourly NO_2 exposures to be in the order of 190 to 300 ppb (365 to 565 μg/m^3). The standards and guidelines are given exclusively for NO_2 concentrations in Table 2-9.

Table 2-9: Ambient air quality guidelines and standards for NO_2

Authority	Maximum 1-hourly Average (μg/m³)	Maximum 24-hour Average (μg/m³)	Maximum 1-month Average (μg/m³)	Annual Average Concentration (μg/m³)
Botswana guidelines	400(a)	-	200(a)	100(a)
World Bank (General Environmental Guidelines)	-	150 (as NO_x)(b)	-	-
World Bank (Thermal Power Guidelines)	-	150(c)	-	100(c)
Proposed South African Standards (based on the SANS:1929,2004)	200(d)	-	-	40(d)
World Health Organisation	200(e)	-	-	40(e)
European Community (EC)	200(f)	-	-	40(f)

Notes:
(a) Provided by the National Environmental Laboratory Botswana
(b) World Bank, 1999. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air conditions at property boundary.
(c) World Bank, 1999. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air quality in Thermal Power Plants.
(d) SANS 1929 - South African National Standard - Ambient Air Quality - Limits for common pollutants. Also proposed South African Standards as published in the Government Gazette of 9th June 2006
(e) WHO guidelines (AQG). World Health Organisation air quality guidelines global update 2005.
(f) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Averaging times represent the 98th percentile of averaging periods; calculated from mean values per hour or per period of less than an hour taken throughout the year; not to be exceeded more than 18 times per year. This limit is to be complied with by 1 January 2010

2.4.4 Carbon Monoxide

Carbon monoxide poisoning occurs as a result of tissue hypoxia (lack of oxygen). On inhalation, CO can bind reversibly to hemoglobin with a 200-fold greater affinity than oxygen. CO thus reduces the oxygen carrying capacity of the blood with its effects being first observed in organs and tissues with high oxygen consumption (e.g. brain and heart). Symptoms of CO poisoning are confusion, nausea, headache, dizziness, fatigue, drowsiness and coma, sometimes resulting in death (Koenig, 2000). Ambient air quality guidelines and standards issued for Botswana, the World Bank and the World Health Organisation for carbon monoxide are given in Table 2-10.

Table 2-10: Ambient air quality guidelines and standards for carbon monoxide

Authority	Maximum 1-hourly Average (µg/m³)	Maximum 8-Hour Average (µg/m³)
Botswana guidelines	40 000(a)	10 000(a)
World Bank	-	-
World Health Organisation	30 000(b)	10 000(b)
Proposed South African Standards (based on the SANS:1929,2004)	30 000(c)	10 000(c)

Notes:
(a) Provided by the National Environmental Laboratory Botswana
(b) WHO Guidelines for the protection of human health (WHO, 2000).
(c) SANS 1929 - South African National Standard - Ambient Air Quality - Limits for common pollutants. Also proposed South African Standards as published in the Government Gazette of 9th June 2006

2.4.5 Ozone

Ozone is one of the most toxic pollutants regulated under ambient air quality guidelines and standards. Exposure to sufficient quantities can cause severe damage to lung tissues and impair defences against bacteria and viruses. Lung function changes are concentration dependent, increasing with increasing depth of breathing. Chronic exposures to ozone may result in premature ageing of the lungs. Health effects associated with ozone exposures include increased incidence and severity of asthma attacks and increased pulmonary resistance. High exposure levels are associated with impaired carbon monoxide diffusion capacity, headaches and possible acute bronchiolitis. Air quality guidelines and standards for ozone are given in Table 2-11.

Table 2-11: Ambient air quality guidelines and standards for ozone

Authority	Maximum 8-hourly Average (µg/m³)
Botswana guidelines	-
World Bank	-(a)
World Health Organisation	240(b) 160(c) 100(d)
Proposed South African Standards	120(e)

Notes:
(a) World Bank, 1999. Pollution Prevention and Abatement Handbook (www.worldbank.org) states that in the long term ground-level ozone concentrations should not exceed the guidelines recommended by WHO. In the interim countries should set ambient standards for ground-level ozone that take into account the benefits to human health and to sensitive ecosystems; the concentration levels achievable by pollution prevention and control measures; and the costs involved in meeting the standards
(b) WHO High level. World Health Organisation air quality guidelines global update 2005.
(c) WHO interim target-1 (IT-1). World Health Organisation air quality guidelines global update 2005.
(d) WHO guideline (AQG). World Health Organisation air quality guidelines global update 2005.
(e) SANS 1929 - South African National Standard - Ambient Air Quality - Limits for common pollutants. Also proposed South African Standards as published in the Government Gazette of 9th June 2006

2.4.6 Air Quality Standards for Heavy Metals

Air quality guidelines and standards are issued by various countries and organisations for lead including the WHO (Table 2-12).

Table 2-12: Ambient air quality guidelines and standards for lead

Authority	Maximum 1-month(Quarterly) Average (µg/m³)	Annual Average (µg/m³)
Botswana guidelines	-	-
World Bank	-	-
World Health Organisation	-	0.5(a)
Notes: (a) WHO Guidelines for the protection of human health (WHO, 2000).		

There is also an increasing trend towards the specification of air quality limits for certain other metals. The limits published by the WHO for cadmium, manganese, mercury and vanadium are summarised in Table 2-13. No air quality limits have been set for such metals in Botswana or the WBG to date.

Table 2-13: Ambient air quality target values issued by the WHO 2000 for metals.

Pollutant	Guideline Value (for the total content in the PM10 fraction averaged over a period of 12 months) (µg/m³)
Cadmium	0.001- 005(a) 0.01– 0.02(b)
Manganese	0.15
Mercury	1
Vanadium	1(24-hours)
Notes: (a) rural areas. (b) urban areas.	

2.4.7 Vegetation Exposures to Air Pollution

2.4.7.1 Sulphur Dioxide

High concentrations of SO_2 over short periods may result in acute visible injury symptoms. Such symptoms are usually observed on broad-leaved plants as relatively large bleached areas between the larger veins which remain green. On grasses acute injury, usually caused by exposures to sub-lethal long-term intermittent episodes of relatively low concentrations, may be observed as general chlorosis of the leaves (Lacasse and Treshow, 1976). This visible injury may decrease the market value of certain crops and lower the productivity of the plants. Sulphur dioxide impairs stomatal functioning resulting in a decline in photosynthetic rates, which in turn causes a decrease in plant growth. Reduction in plant yields can occur, even in the absence of visible foliar symptoms (Mudd, 1975). Relationships between plant injury and SO_2 dosages are given in Table 2-14.

Species that are sensitive to SO_2 include spinach, cucumber and oats. These species may show decreases in growth at concentrations of 0.01 to 0.5 ppm (26 to 1309 µg/m³) (Mudd, 1975). Visible SO_2 injury can occur at dosages ranging from 0.05 to 0.5 ppm (131 to 1309 µg/m³) for 8 hours or more (Manning and Feder, 1976). Maize, celery and citrus show much less damage at these low concentrations (Mudd, 1975).

Table 2-14: Injury to plants due to various doses of Sulphur Dioxide[(1)]

[illegible]	[illegible]	[illegible]
Visible foliar injury to vegetation in arid regions	26179	2 hr
Coverage of 5% of leaf area of sensitive species with visible necrosis[(2)]	1309 – 2749	1 hr
visible injury to sensitive vegetation in humid regions	2618	5 min
Coverage of 5% of leaf area of sensitive species with visible necrosis[(2)]	785 – 1571	3 hr
visible injury to sensitive vegetation in humid regions	1309	1 hr
visible injury to sensitive vegetation in humid regions	524	3 hr
Visible injury to sensitive species	131 – 1309	8 hrs
Decreased growth in sensitive species	26 – 1309	-
Coverage of 5% of leaf area of sensitive species with visible necrosis[(2)]	524 – 680	6 - 8 hrs
Yield reductions may occur	524	monthly mean
Growth of conifers and yield of fruit trees may be reduced	262	monthly mean
Yield reductions may occur	209	annual mean
Growth of conifers and yield of fruit trees may be reduced	131	annual mean
Critical level for agricultural crops, forest trees and natural vegetation[(3)]	79	24-hrs
Critical level for agricultural crops[(3)]	26	annual mean
Critical level for forest trees and natural vegetation [(3)]	21	annual mean

Notes:
[(1)]References: Laccasse and Treshow, 1976; Mudd, 1975; Manning and Feder, 1976; Harrison, 1990; Godish, 1991; Ferris, 1978
[(2)]Resistant species found to have threshold levels at three times these concentrations.
[(3)]Refer to critical levels used by the United National Economic Commission for Europe to map exceedence areas. These represent levels at which negative responses have been noted for sensitive receptors.

Air quality criteria issued by the EC, UK and WHO for the protection of ecosystems against sulphur dioxide exposures are summarised in Table 2-15.

Table 2-15: Thresholds specified by certain countries and organisations for vegetation and ecosystems

[illegible]	[illegible]	[illegible]
Sulphur dioxide	annual average	10 - 30 μg/m^3 **(a)** 20 μg/m^3 **(b)**

Notes: **(a)** Represents the critical level for ecotoxic effects issued by the WHO for Europe; a range is given to account for different sensitivities of vegetation types
(b) EC and UK limit value to protect ecosystems

2.4.7.2 Oxides of Nitrogen

Direct exposure to NO_x may cause growth inhibitions in some plants (Table 2-167). Higher concentrations of NO_x are usually needed to cause injury than for other pollutants such as ozone and sulphur dioxide. Chronic injury, such as chlorosis, may be caused by long-term exposures to relatively low concentrations of nitrogen dioxide but are reversible on young leaves. Acute injury is observed as irregularly shaped lesions that become white to tan, similar to those produced by SO_2. Sensitive plants to NO_x include beans and lettuce, whereas citrus and peach trees are rated as having an intermediary sensitivity. NO_x may also impact indirectly on plants since the oxidation of NO_2 to nitric acid contributes to acid rain problems. Acid rain serves to increasing the leaching of base cations from most soils in affected areas, resulting in the change in the acidity of the soils.

Table 2-16: Injury to plants caused by various dosages of NO_2.

[illegible]	Concentration [illegible]	Duration of [illegible]
foliar injury to vegetation	3774	4 hr
slight spotting of pinto bean, endive, and cotton	1887	48 hr
subtle growth suppression in some plant species without visible foliar markings	943	10-20 days
decreased growth and yield of tomatoes and oranges	472	growing season
reduction in growth of Kentucky bluegrass	189	20 weeks
References: (Ferris, 1978; Godish, 1990; Harrison, 1990; Quint *et al.*, 1996).		

Critical levels for NO_x, used by the United National Economic Commission for Europe to map exceedence areas, are given as 30 µg/m^3 for annual means and 95 µg/m^3 for a 4-hour mean for agricultural crops, forest trees and natural and semi-natural vegetation. Air quality criteria issued by the EC and UK for the protection of vegetation against nitrogen oxide exposures are summarised in Table 2-17.

Table 2-17: Thresholds specified by certain countries and organisations for vegetation and ecosystems

[illegible]	[illegible]	Threshold [illegible]
nitrogen oxides (NOx)	annual average	30 µg/m^3 **(a)**
(a) EU limit value specifically designed for the protection of vegetation		

3 DISPERSION MODELLING METHODOLOGY

Not more than 2 consecutive months of on-site meteorological data was available for use in the dispersion simulations. Since a minimum of 1 year of meteorological data is required for dispersion modelling purposes (to ensure the seasonal variability in dispersion potential is accounted for) on-site meteorological data was simulated. The CALMET/CALPUFF suite of models was used for this purpose. CALMET simulates a three dimensional meteorological profile for the study area using more than one surface weather station and upper air data. Hourly average meteorological data, including wind speed, wind direction and temperature was used, and mixing heights were estimated for each hour, based on prognostic equations, while night-time boundary layers were calculated from various diagnostic approaches. Wind speed and solar radiation were used to calculate hourly stability classes.

3.1 Dispersion Simulation Methodology

Dispersion models compute ambient concentrations as a function of source configurations, emission strengths and meteorological characteristics, thus providing a useful tool to ascertain the spatial and temporal patterns in the ground level concentrations arising from the emissions of various sources. Increasing reliance has been placed on ground level air pollution concentration estimates from models as the primary basis for environmental and health impact assessments, risk assessments and determining emission control requirements. In the selection of a dispersion model it is important to understand the complexity of the dispersion potential of the area (i.e. the terrain and meteorology), and the potential scale and significant of potential effects (i.e. other sources that might have an influence the ground level concentrations). Care was therefore taken in the selection of a suitable dispersion model for the task at hand.

Due to the limited background air quality information available for the area, the simulation of background concentrations was necessitated. The sources identified as potential impacting sources in the region of the proposed power plant were two power stations located ~100 km to the east and ~111 km north-northeast. Thus a dispersion model that could predict over a wide area was required. In addition, the closest meteorological station to site is 50 km away.

The CALMET/CALPUFF suite of models was chosen for this purpose. CALMET simulates a three dimensional meteorological profile for the study area using more than one surface weather station and upper air data. Hourly average meteorological data, including wind speed, wind direction and temperature was used, and mixing heights were estimated for each hour, based on prognostic equations, while night-time boundary layers were calculated from various diagnostic approaches. Wind speed and solar radiation were used to calculate hourly stability classes.

Most regulatory dispersion models, such as the widely used Industrial Source Complex (ISC) model and the relatively new AERMOD model, are based on the steady-state plume assumption, with meteorological inputs for these models assuming a horizontally uniform flow field. Usually the winds are derived from a single point measurement, which is often made at a nearby non-complex terrain site. The meteorological processors for the regulatory models do not adjust the winds to reflect terrain effects. The steady-state flow fields either do not or only partially reproduce the terrain-induced spatial variability in the wind field. In addition to which, the straight-line trajectory assumption of the plume models cannot easily handle curved trajectories associated with terrain-induced deflection or channelling. These limitations of plume models can significantly affect the models ability to correctly represent the spatial area of impact from sources in complex terrain, in addition to the magnitude of the peak values in certain instances.

CALPUFF is a regional Lagrangian Puff model suitable for application in modelling domains of 50 km to 200 km. Due to its puff-based formulation the CALPUFF model is able to account for various effects, including spatial variability of meteorological conditions, dry deposition and dispersion over a variety of spatially varying land surfaces. The simulation of plume fumigation and low wind speed dispersion are also facilitated.

CALPUFF requires as a minimum the input of hourly average surface meteorological data. In order to take full advantage of the model's ability to simulate spatially varying meteorological conditions and dispersion within the convective boundary layer it is, however, necessary to generate a three-dimensional wind field for input to the CALPUFF model. The CALMET model may be used to generate such a three-dimensional wind field for input to the CALPUFF model.

The CALMET meteorological model contains a diagnostic wind field module that includes parameterized treatments of terrain effects, including slope flows, terrain channelling and kinematic effects, which are responsible for highly variable wind patterns. CALMET uses a two-step procedure for computing wind fields. An initial guess wind field is adjusted for terrain effects to produce a Step 1 wind field. The user specifies the vertical layers through which the domain wind is averaged and computed, and the upper air and surface meteorological stations to be included in the interpolation to produce the spatially varying guess field. The Step 1 (initial guess) field and wind observational data are then weighted through an objective analysis procedure to produce the final (Step 2) wind field. Weighting is undertaken through assigning a radius of influence to stations, both within the surface layer and layers aloft. Observational data are excluded from the interpolation if the distance between the station and a particular grid point exceeds the maximum radius of influence specified (EPA, 1995; Scire and Robe, 1997; Robe and Scire, 1998).

By using CALMET and CALPUFF in combination it is possible to treat many important complex terrain effects, including spatial variability of the meteorological fields, curved plume trajectories, and plume-terrain interaction effects. Maximum hourly average, maximum daily average and annual average concentrations were simulated through the application of CALPUFF, using as input the relevant emissions data and the three-dimensional CALMET data set.

3.1.1 Model Accuracy

Comparisons between CALPUFF results, and results generated by the Industrial Source Complex Model Short Term version 3 (ISCST3) model, have shown that CALPUFF is generally more conservative (Strimatis et al., 1998). The ISC model (and similarly AERMOD) typically produces predictions within a factor of 2 to 10 within complex topography with a high incidence of calm wind conditions. When applied in flat or gently rolling terrain, the U.S.EPA (EPA 1995) considers the range of uncertainty of the ISC to be -50% to 200%. CALPUFF predictions have been found to have a greater correlation with observations, with more predictions within a factor of 2 of the observations when compared to the ISC model (Strimatis et al., 1998). It has generally been found that the accuracy of off-the-shelf dispersion models improve with increased averaging periods. The accurate prediction of instantaneous peaks are the most difficult and are normally performed with more complicated dispersion models specifically fine-tuned and validated for the location. The duration of these short-term, peak concentrations are frequently limited to a few minutes and on-site meteorological data are then essential for accurate predictions.

3.2 Dispersion Model Data Requirements

3.2.1 Receptor Locations and Modelling Domain

The meteorology was modelled for an area covering 104 km (east-west) by 104 km (north-south) with the three dimensional wind field modelled at five levels for 43,264 receptor points. The regular Cartesian receptor grid selected has a resolution of 500 m by 500 m. Figure 3-1 shows the modelling domain with the weather stations included. The main existing sources of emissions are also indicated to illustrate the basis of the model domain selection. The modelling domain was selected for the purpose of including all meteorological stations and upper air data.

Thus, based on the necessity to simulate the on-site meteorology and dispersion potential, the Calpuff/Calmet suite of models was deemed the most suitable for the task at hand.

3.2.2 Meteorological Data Inputs

CALMET was used to simulate the wind field within the study area. Upper air data required by CALMET include pressure, geopotential height, temperature, wind direction and wind speed for various levels. No upper air monitoring stations are located within the region with the nearest South African Weather Services (SAWS) station being located in Irene, Gauteng (~460 km to the southeast). No upper air data is recorded within Botswana. Use was therefore made of ETA-model data for upper air recordings obtained from the SAWS.

Daily data calculated for 3-hourly intervals were obtained for five sounding levels. The initial guess field in CALMET was therefore determined as a combined weighing of surface winds at four monitoring stations, vertically extrapolated using Similarity Theory (Stull, 1997) and upper air winds. Hourly average meteorological data was obtained from the South African Weather Services station at Lephalale (~139 km south-southeast), from the ETA data point (~100 km southeast) and from the three Botswana weather stations, viz. Mahalapye (70 km south-southwest), Sir Seretse Khama (~247 km south-southwest) and Selebi-Phikwe (101 km to the northeast) (see Figure 3-1).

The CALMET meteorological model requires hourly average surface data as input, including wind speed, wind direction, mixing depth, cloud cover, temperature, relative humidity, pressure and precipitation. The mixing depth is not readily measured and needed to be calculated based on readily available data, viz. temperature and predicted solar radiation. The daytime mixing heights were calculated with the prognostic equations of Batchvarova and Gryning (1990), while night-time boundary layer heights were calculated from various diagnostic approaches for stable and neutral conditions.

A three dimensional meteorological data set for the region was output by the CALMET model for application in the CALPUFF model. This data set parameterised spatial (horizontal and vertical) and temporal variations in the parameters required to model the dispersion and removal of pollutants, including: vertical wind speed, wind direction, temperature, mixing depths, atmospheric stability, and atmospheric turbulence. Meteorological parameters were projected at various heights above the ground, viz.: 20m, 200m, 500m, 1500m, and 3000m. In projecting vertical changes in the wind field, temperature (etc.) it was possible to accurately parameterise the atmospheric conditions characteristic of within valley layers, transitional layers and atmospheric layers located above the terrain. The three-dimensional data set was generated for the most recent year 2004 and comprised hourly averages for each parameter, thus providing information for each time interval required by the non-steady state CALPUFF dispersion model

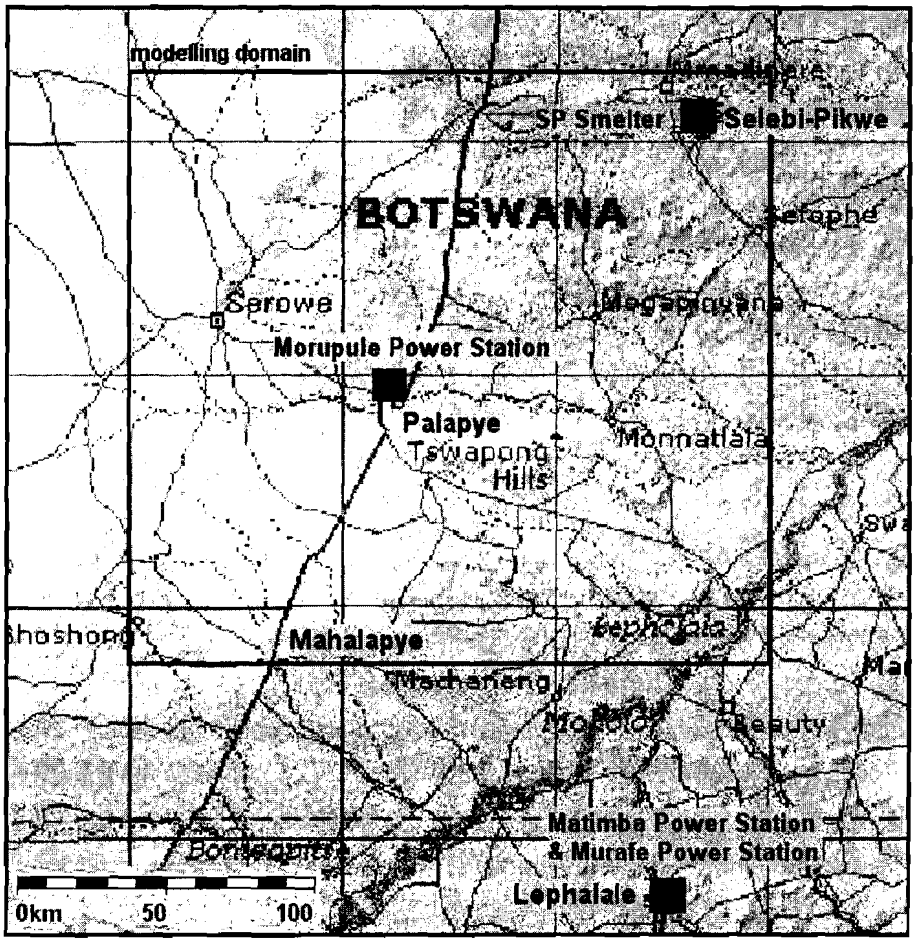

Figure 3-1: Selected modelling domain for the proposed Morupule B Power Plant to ensure the inclusion of all available meteorological data.

4 CLIMATOLOGY AND ATMOSPHERIC DISPERSION POTENTIAL

4.1 Atmospheric Dispersion Potential of the Region

The meteorological characteristics of a site govern the dispersion, transformation and eventual removal of pollutants from the atmosphere (Pasquill and Smith, 1983; Godish, 1990). The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field and atmospheric stability. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction, and the variability in wind direction, determines the general path pollutants will follow, and the extent of cross-wind spreading (Shaw and Munn, 1971; Pasquill and Smith, 1983; Oke, 1990).

Pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field. Spatial variations, and diurnal and seasonal changes, in the wind field and stability regime are functions of atmospheric processes operating at various temporal and spatial scales (Goldreich and Tyson, 1988). Atmospheric processes at macro- and meso-scales need therefore be taken into account in order to accurately parameterise the atmospheric dispersion potential of a particular area.

4.1.1 Meso-Scale Atmospheric Dispersion Potential

The analysis of meteorological data observed for the site provides the basis for the parameterisation of the meso-scale ventilation potential of the site, and to provide the input requirements for the dispersion simulations. Parameters that need to be taken into account in the characterisation of meso-scale ventilation potentials include wind speed, wind direction, extent of atmospheric turbulence, ambient air temperature and mixing depth. A comprehensive data set for at least one year of detailed hourly average wind speed, wind direction and temperature data are needed for the dispersion simulations.

Not more than 2 months consecutive data was available for the site based on the on-site meteorological station at Morupule Power Plant. In order to provide a general description of the dispersion potential of the site, reference was made to meteorological stations in the region. The Department of Meteorological Services in Botswana were kind enough to provide data for Gaborone, Mahalapye and Selebi-Phikwe for inclusion into the study. Meteorological data was also obtained from the South African Weather Services for Lephalale. The locations of the weather stations are indicated in Figure 3-1. Sir Seretse Kama Airport is located near Gaborone approximately 247 km to the south-southwest of the site. Mahalapye and Selebi-Phikwe are also located some distance away, with Mahalapye ~ 70 km south-southwest and Selebi-Phikwe 101 km away (northeast). Lephalale on the South African side is ~139 km to the south-southeast of the proposed site.

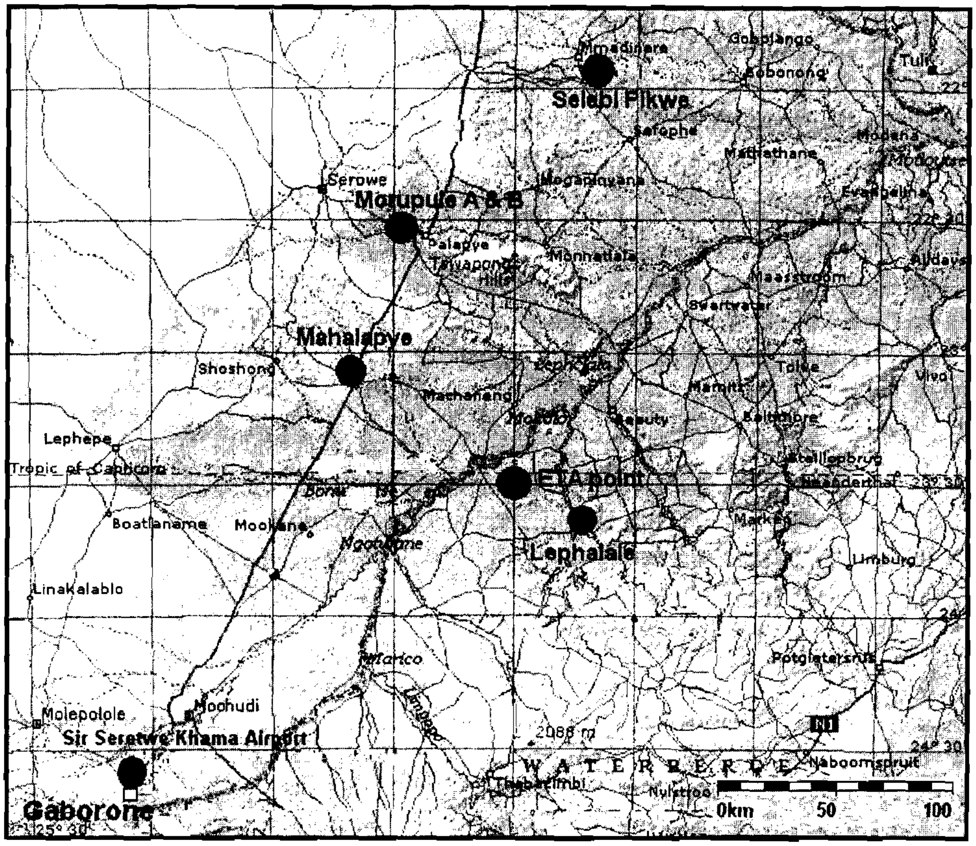

Figure 4-1: Location of meteorological stations included in the current study.

Upper air meteorological data generated by the South African Weather Service (SAWS) using the ETA model were also purchased for a point in the region to provide the required input data for the atmospheric dispersion modelling to be conducted during the air quality impact assessment component of the project. Meteorological data was obtained for the years 2004 and 2005 from the mentioned stations with the availability from each station provided in Table 4-1. The 2006 meteorological data was not fully captured at the date of this study.

Table 4-1: Data availability for surface and upper air meteorological data for the period 2005.

Data	Station	Data availability for 2004	Data availability for 2005
Surface data	Sir Seretse Kama Airport [a]	79%	74%
	Mahalapye [b]	22%	60%
	Selebi-Phikwe [b]	65%	55%
	Lephalale	100%	100%
Upper Air Data	ETA	N.A.	74%

Notes:
[a] Data for the period January to October available.
[b] January to November, 05h00-20h00.

Sir Seretse Kama Airport located just outside of Gaborone had no data available for November and December 2005. Mahalapye had data recorded for the period January to November 2005 but only from 05h00 to 20h00. The same period of data was recorded at Selebi-Phikwe however less useable data was available.

4.1.1.1 Surface Wind Field

The vertical dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness.

Wind roses comprise 16 spokes which represent the directions from which winds blew during the period. The colours reflect the different categories of wind speeds, the grey area, for example, representing winds of 1 m/s to 3 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. For the current wind roses, each dotted circle represents 5% frequency of occurrence. The figure given in the centre of the circle described the frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s.

Wind roses from the simulated wind field for the site are presented in Figure 4-2. These wind roses serve to provide the prevailing wind field for the region and indicate the average wind speeds that dominated the period of concern. Day-time and night-time wind roses provide an indication of the diurnal variation on average within the area. Figure 4-4 provides the seasonal variation as simulated for the area. Although one year of meteorological data is not ideal (three years' data is usually considered necessary to capture all variations) the data provides a fair representation of the presence of prevalent wind directions and speeds in the area and in the light of the flat topography of the area is applicable to the project site. The wind regime of the study area largely reflects the synoptic scale circulation.

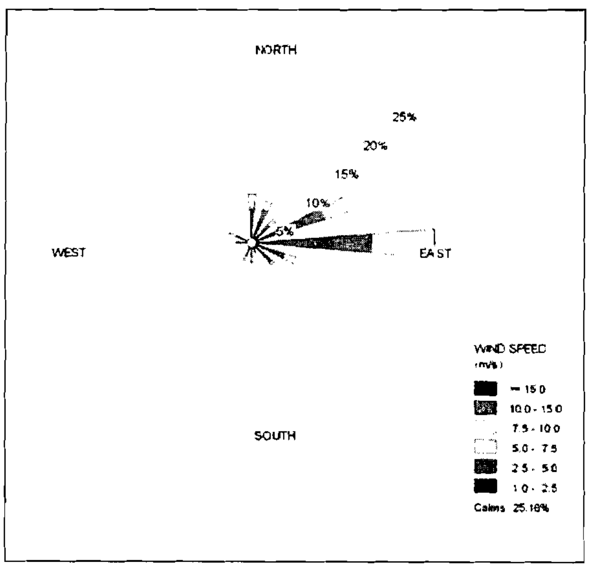

Figure 4-2: Wind rose reflecting the 2 months on-site meteorological data (May to June 2007)

The two months of on-site meteorological recorded data indicated the prevailing wind field to be from the east and east-northeasterly sector. These winds are also characterised by strong wind velocities exceeding 5 m/s 26% of the time in the two months. These months are not representative of the average prevailing wind direction or wind speeds and the most windy months are typically during the period August to November.

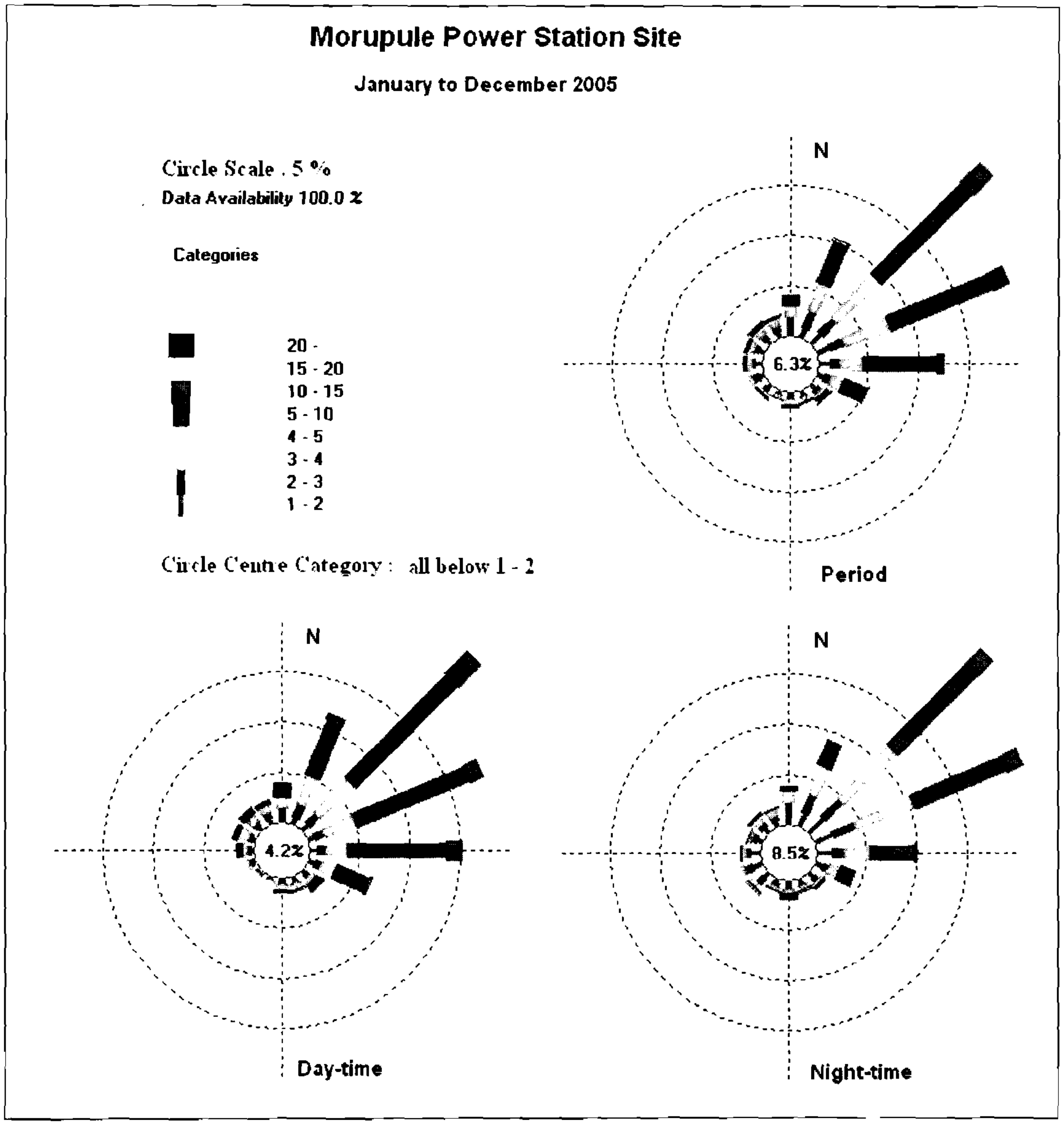

Figure 4-3: Day-time, night-time and period average wind roses for the simulated on-site wind field for the period 2005

Figure 4-3, based on the simulated wind field shows the prevailing wind direction to be from the northeasterly sector with frequent wind also from the east and east-northeast on average. Very little wind flow was observed from the northwesterly and southwesterly sectors. This is due to the continental high pressure, which persists over the region, in combination with the tropical easterly systems which influence the flow field during much of the year. The winds are also associated with strong winds, exceeding 5 m/s for 41% of the time. Calm conditions were predicted to occur for 6.3%

of the time. Similar wind flow is indicated for day-time and night-time conditions, with higher percentage calms during the night (8.5%) as is typical of night-time conditions. There is a decrease in winds from the east during the night with an increase of flow from the northeast.

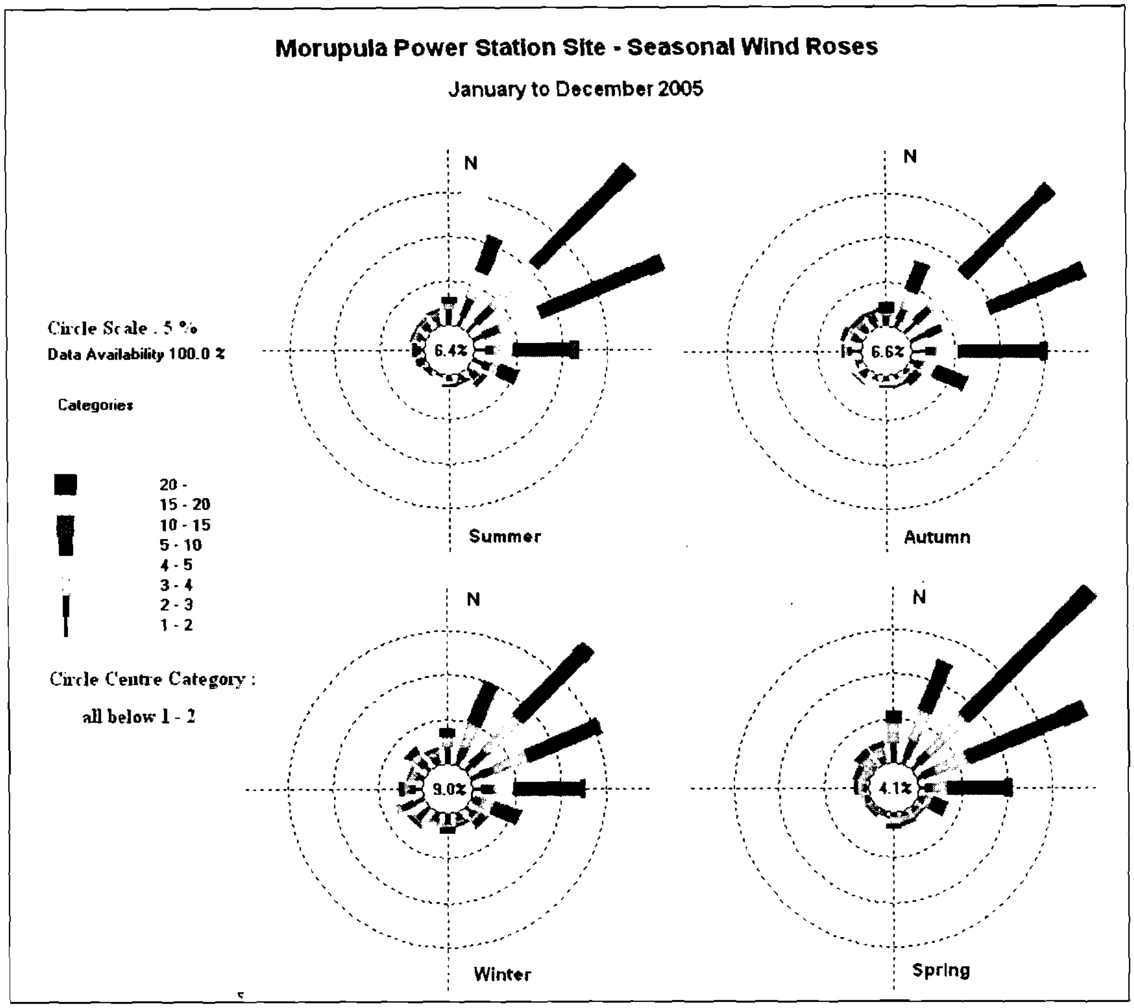

Figure 4-4: Seasonal-average wind roses for the simulated on-site wind field for the period 2005.

Although the northeasterly winds dominate for all four seasons the frequency of occurrence of these winds vary. During winter, the percentage of northeasterly winds decreases due to the northward shift of the high-pressure belt. East-northeasterly and northeasterly winds increase in frequency during summer months, with the continental high pressure and tropical easterlies having resumed their influence over the region.

4.1.1.2 Temperature Profile

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume is able to rise), and determining the development of the mixing and inversion layers.

The nearest meteorological recordings was at Mahalapye. The long-term maximum and minimum monthly average ambient temperatures recorded at the Mahalapye monitoring site during the 1991 to 1999 period are given in Table 4-2. Temperature maximums generally occur during the October-March months, with June and July months experiencing the lowest temperatures. Only small inter-annual variations in temperature ranges were noted for the period for which data were available. At Mahalapye a temperature of 35°C during 2004 was only exceeded for 46.4 hours of the year (0.5%).

Table 4-2: Long-term maximum and minimum monthly temperatures for Mahalapye.

	Ambient temperature (°C) (average over 1991 to 1999)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Spt	Oct	Nov	Dec
Maximum	31.3	31.6	30.5	28.6	25.9	23.4	22.7	25.4	29.8	31.2	31.2	31
Minimum	20.1	19.8	18.3	14.6	10.3	6.7	6.5	9.4	14.5	17.6	19.4	19.4

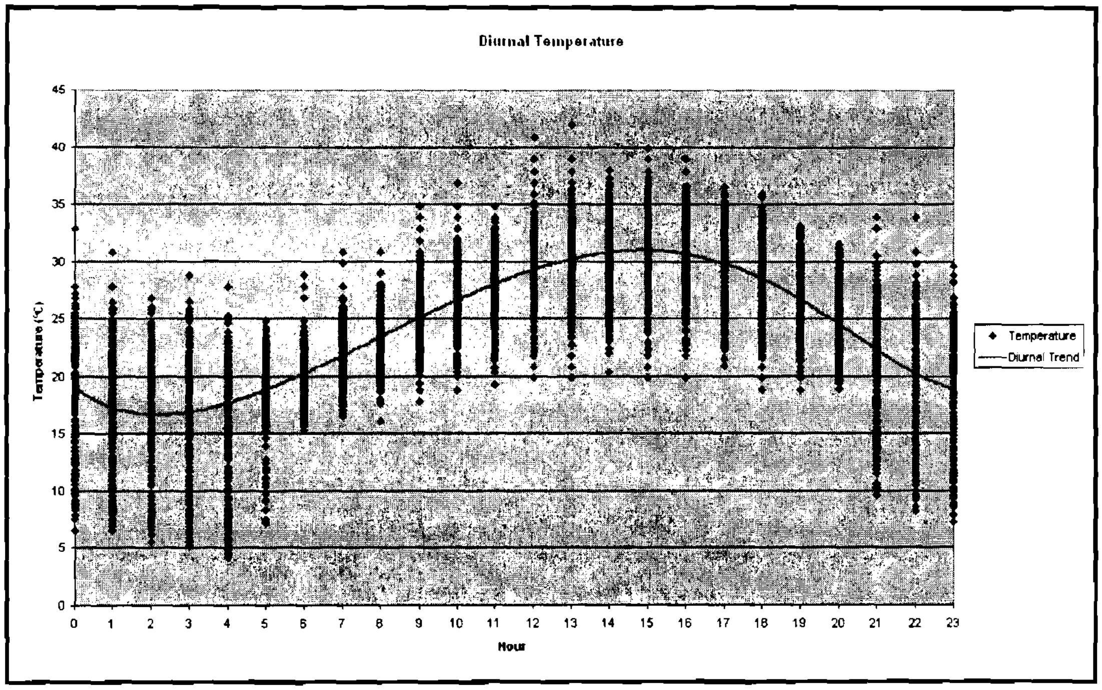

Figure 4-5: Diurnal temperature variation based on simulated data for Morupule for the year 2005.

Figure 4-3 shows the temperature profile for Morupule for 2005 as was simulated with CALMET. The hourly temperature data clearly shows the decrease in temperature during the winter months. The diurnal trends as reflected in Figure 4-7 clearly show the highest temperatures during the early afternoon and the lowest temperatures just before sunrise.

4.1.1.3 Rainfall and Evaporation

Most of the rainfall occurs between the months of October and March, with the dry season commencing around April and continuing until September. Maximum, minimum and mean monthly average precipitation for the period January 1991 to December 2002 is depicted in Figure 4-5. The annual average rainfall recorded at the study site for this period is 445 mm. Rainfall recorded for the station placed at the Mmamabula station totals 121mm for the period 7 September through to 14 December 2006.

Precipitation is important to air pollution studies since it represents an effective removal mechanism of atmospheric pollutants. Due to the relatively low rainfall experienced, and the long period for which little or no rainfall occurs, wet deposition is anticipated to be relatively unimportant in the removal of pollutants from the study area.

Evaporation is a function of ambient temperature, wind and the saturation deficit of the air. Evaporation rates have important implications for the design and implementation of effective dust control programmes as part of the mining project. High levels of evaporation occur as a result of the high levels of solar radiation experienced. The annual total evaporation is observed to be in the range of ~2523 mm. Total monthly evaporation rates range between ~122 mm and ~303 mm (Figure 4-6). The low temperatures and absence of rainfall during winter months is offset by the large uninterrupted incidence of sunshine. Rising temperatures in September and October, accompanied also by the windiest conditions of the year, result in increased evaporation rates during these months.

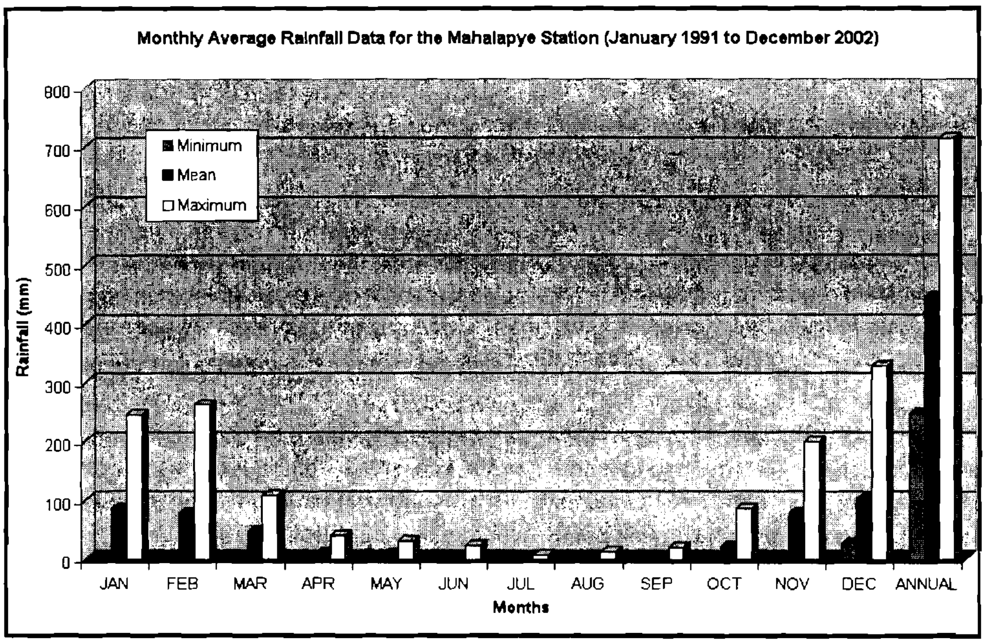

Figure 4-6: Maximum, minimum and mean monthly rainfall recorded for the period January 1991 to December 2002.

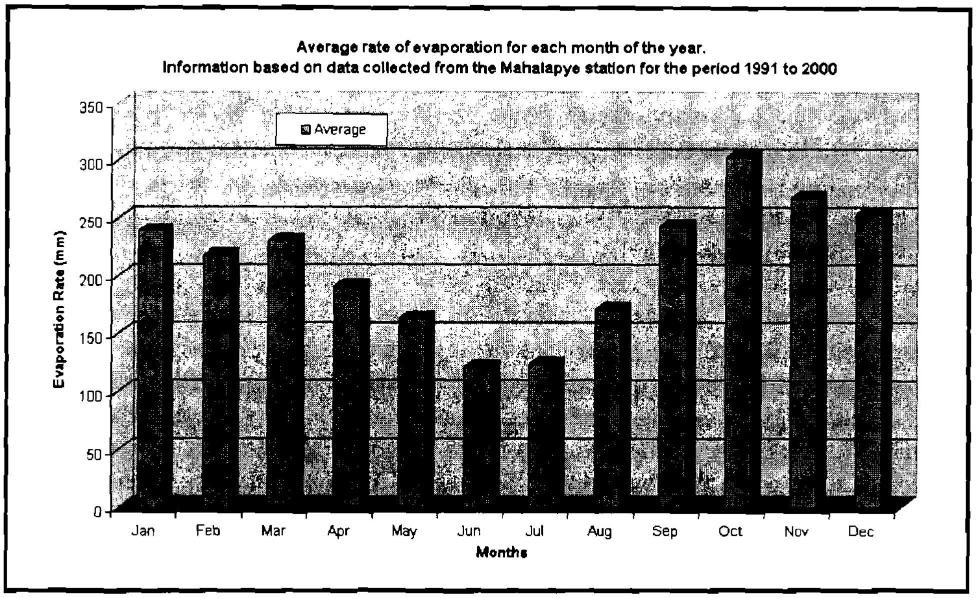

Figure 4-7: Total monthly evaporation (mm) observed at Mahalapye.

4.1.1.4 Atmospheric Stability

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. This layer is directly affected by the earth's surface, either through the retardation of flow due to the frictional drag of the earth's surface, or as result of the heat and moisture exchanges that take place at the surface. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the extension of the mixing layer to the lowest elevated inversion. Radiative flux divergence during the night usually results in the establishment of ground based inversions and the erosion of the mixing layer.

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 4-3. The hourly standard deviation of wind direction, wind speed and predicted solar radiation were used to determine hourly-average stability classes.

Table 4-3: Atmospheric Stability Classes

Designation	Stability Class	Atmospheric Condition
A	Very unstable	calm wind, clear skies, hot daytime conditions
B	Moderately unstable	clear skies, daytime conditions
C	Unstable	moderate wind, slightly overcast daytime conditions
D	Neutral	high winds or cloudy days and nights
E	Stable	moderate wind, slightly overcast night-time conditions
F	Very stable	low winds, clear skies, cold night-time conditions

The atmospheric boundary layer is normally unstable during the day as a result of the turbulence due to the sun's heating effect on the earth's surface. The thickness of this mixing layer depends predominantly on the extent of solar radiation, growing gradually from sunrise to reach a maximum at about 5 to 6 hours after sunrise. This situation is more pronounced during the winter months due to strong night-time inversions and slower developing mixing layer. During the night a stable layer, with limited vertical mixing, exists. During windy and/or cloudy conditions, the atmosphere is normally neutral.

For elevated releases, the highest ground level concentrations would occur during unstable, daytime conditions. The wind speed resulting in the highest ground level concentration depends on the plume buoyancy. If the plume is considerably buoyant (high exit gas velocity and temperature) together with a low wind, the plume will reach the ground relatively far downwind. With stronger wind speeds, on the other hand, the plume may reach the ground closer, but due to increased ventilation, it would be more diluted. A wind speed between these extremes would therefore be responsible for the highest ground level concentrations. In contrast, the highest concentrations for ground level, or near-ground level releases would occur during weak wind speeds and stable (night-time) atmospheric conditions.

5 BASELINE CHARACTERISATION

The identification of existing sources of emission in the region and the characterisation of existing ambient pollutant concentrations is fundamental to the assessment of the potential for cumulative impacts and synergistic effects given the proposed operation and its associated emissions.

5.1 Existing sources of Atmospheric Emissions In the region

A comprehensive emissions inventory has not been completed for the region to date. The establishment of such an inventory was not within the scope of the current study. Instead source types present in the area and the pollutants associated with such source types were noted with the aim of identifying pollutants which may be of importance in terms of cumulative impact potentials. Sources identified as possibly impacting on air quality in the region include, but are not limited to:

- Industrial operations (stack, vent and fugitive emissions)
- Fugitive emissions from mining operations
- Vehicle tailpipe emissions from national and main roads
- Household fuel combustion (particularly coal and wood used by smaller communities)
- Biomass burning (veld fires in agricultural areas within the region)
- Various miscellaneous fugitive dust sources (agricultural activities, wind erosion of open areas, vehicle-entrainment of dust along paved and unpaved roads).

5.1.1 Industrial Sources and Power Generation

At present the only operational power plant in the area is the current Morupule Power Plant near Palapye. The Matimba Power Plant located near Lephalale in South Africa is the only other power plant in the larger region, located approximately 139 km to the south-southeast. The proposed Matimba B power plant has been approved for construction by the South African authorities. In addition, a new power plant at Mmamabula (~111 km south-soutwest) of Morupule is proposed for development. The EIA process for this plant is on-going. A Nickel Smelter is operational at Selebi-Phikwe (101 km to the northeast).

The power stations are large sources of sulphur dioxide. Sulphur dioxide oxidises in the atmosphere to particulate sulphate at a range of between 1 and 4% per hour. Fine particulate sulphate has been used to trace the transportation of power station plumes across the Southern African sub-continent.

The Morupule Power Plant has a nominal capacity of 132 MW and comprises of four boilers venting to 3 stacks. The emissions and potential impacts from this plant are discussed in more detail further on in Section 5.3.

The existing Matimba Power Plant near Lephalale is a dry cooled, coal fired pulverised power station comprising six 665 MW units, representing a total capacity of 3990 MW and a total net maximum generation capacity of 3690 MW. The power station is located in the Waterberg coal field and is supplied with coal form the Grootgeluk Colliery located to the west of the Power Station. Matimba B Power Plant is an approved proposed power plant of similar design with a capacity of 4800 MW and with a thermal efficiency of up to 40%. The project will comprise a power plant and associated coal stockpile, conveyor belts, an ash dump and transmission lines. The plan was approved without desulphurisation required even though it should be built as to fit an FDG unit.

An air quality impact assessment was conducted for the proposed Matimba B project as part of an EIA process. The air quality study assessed existing ambient monitoring data within the region, predicted baseline concentrations and the proposed impacts due to the expansion. The main findings of the EIA given uncontrolled emissions were as follows:

- It was concluded that the addition of 3 new 800 MW PF units with no sulphur dioxide abatement in place would result in significant increases in the magnitude, frequency and spatial extent of non-compliance with SA standards. A further 3 units would more than double the magnitude and spatial extent of non-compliance, whilst resulting in a 3 to 4 fold increase in the frequency of exceedence of air quality limits. The extension of the height of the stack by 30 m, from 220 m to 250 m, was not sufficient to negate the need for considering abatement measures. The area of impact (exceeding the South African standards for SO_2) from the Matimba B Power Plant (with 6 new 800 MW PF units with no sulphur dioxide abatement in place) in addition to the Matimba Power Plant covered an area of ~20 km to the west-southwest.

The proposed Mmamabula Energy Project will comprise a 2,700 MW nominal capacity plant. The design of the power plant was based on World Bank requirements and will include Pulverized Coal (PC) Boilers, air-cooled condensers and Flue Gas Desulphurisation (FGD) units. The coal mine is proposed to comprise of an underground and opencast mining operations and will provide coal directly to the power station.

5.1.2 Mining Operations in the Region

Mining operations represent potentially significant sources of fugitive dust emissions (PM2.5, PM10 and TSP) with small amounts of NO_x, CO, SO_2, methane, and CO_2 being released during blasting operations. Fugitive dust sources associated with mining activities include blasting and drilling operations, materials handling activities, vehicle-entrainment by haul vehicles and wind-blown dust from waste dumps and stockpiles.

Experience has shown that fugitive dust emissions due to on-site operations are typically only of concern within 3 km of the mine boundary. This is the reason for the current manner in which atmospheric emissions are treated for mining operations. Dust suppression methods that are most frequently used in local mining operations include the wet suppression and the chemical stabilization of haul roads and storage piles, and the vegetation or rock cladding of tailings impoundments.

Except for the Morupule Mine, no mines are operational within the area. Even though the mining expansion operations were excluded from the scope of work, existing operations may contribute to the ambient background particulate emissions in the region.

5.1.3 Vehicle Tailpipe Emissions

Air pollution from vehicle emissions may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly into the atmosphere, and secondary, those pollutants formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The significant primary pollutants emitted by motor vehicles include carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (HCs), sulphur dioxide (SO_2), oxides of nitrogen (NO_x), particulates and lead. Secondary pollutants include: nitrogen dioxide (NO_2), photochemical oxidants (e.g. ozone), HCs, sulphur acid, sulphates, nitric acid, nitric acid and nitrate aerosols. Toxic hydrocarbons emitted include benzene, 1.2-butadiene, aldehydes and polycyclic aromatic hydrocarbons (PAH). Benzene represents an aromatic HC present in petrol, with 85% to 90% of benzene emissions emanating from the exhaust and the remainder from evaporative losses.

Vehicle tailpipe emissions are also localised sources and unlikely to have impacts far-field. The roads in the vicinity of the proposed Morupule B Power Plant are not associated with high traffic volumes and unlikely to be a main source of air pollution in the region. The national road to Francistown is approximately 5 km to the east-southeast.

5.1.4 Household Fuel Combustion

Domestic coal combustion has been identified, based on both qualitative and quantitative observations, as being potentially the greatest source of airborne particulates within poor urban residential areas in South Africa. Quantitative indirect source apportionment of particulate, SO_2 and NO_x concentrations confirmed the predominance of the contribution of domestic coal combustion emissions to airborne particulate concentrations (Annegarn and Kneen, 1994). Coal burning emits a large amount of gaseous and particulate pollutants including sulphur dioxide, heavy metals, total and respirable particulates including heavy metals and inorganic ash, carbon monoxide, polycyclic aromatic hydrocarbons, nitrogen dioxide and benzo(a)pyrene. Pollutants arising due to the combustion of wood include respirable particulates, nitrogen dioxide, carbon monoxide, polycyclic aromatic hydrocarbons, particulate benzo(a)pyrene and formaldehyde. Particulate emissions from wood burning within South Africa have been found to contain about 50% elemental carbon and about 50% condensed hydrocarbons (Terblanche *et al.*, 1992).

The amount of coal consumed for domestic use in Botswana is not known and the emissions resulting from domestic fuel burning could not be established.

5.1.5 Agricultural Activities

The main activity within the Morupule region is farming, both small and localised to large commercial farms.

Crop farming and mixed crop farming include land tilling operations, fertiliser and pesticide applications, and harvesting. By applying fertiliser and pesticides use are typically made of vehicles (tractors) driving on unpaved roads and exposed soil. Land tilling include dust entrainment on exposed surfaces, wind blown dust and scraping and grading type activities resulting in fugitive dust releases. Both particulate matter (PM) and gaseous air emissions (mainly NO, NO_2, NH_3, SO_2 and VOCs) are generated from the application of nutrients as fertilizers or manures (EPA, 1999). There are primarily 3 harvesting operations resulting in particulate emissions: (1) crop handling by the harvest machine, (2) loading of the harvested crop into trucks, and (3) transport by trucks in the field. Particulate matter, composed of soil dust and plant tissue fragments (chaff), may be entrained by wind (EPA, 1995).

Cattle farms are also significant sources of fugitive dust especially when feedlots are used and the cattle trample in confined areas. Pollutants associated with dairy production for instance include ammonia (NH_3), hydrogen sulphide (H_2S), Methane (CH_4), Carbon dioxide (CO_2), Oxides of Nitrogen (NO_x) and odour related trace gasses. According to the U.S.EPA, cattle emit methane through a digestive process that is unique to ruminant animals called enteric fermentation. The calf-cow sector of the beef industry was found to be the largest emitter of methane emissions. Where animals are densely confined the main pollutants of concern include dust from the animal movements, their feed and their manure, ammonia (NH_3) from the animal urine and manure, and hydrogen sulphide (H_2S) from manure pits.

Organic dust includes dandruff, dried manure, urine, feed, mold, fungi, bacteria and endotoxins (produced by bacteria, and viruses). Inorganic dust is composed of numerous aerosols from building, materials and the environment. Since the dust is biological it may react with the defence system of the respiratory tract. Odours and VOCs associated with animal manure is also a concern when cattle are kept in feedlots. The main impact from methane is on the dietary energy due to the reduction of carbon from the rumen. Dust and gas levels are higher in winter or when ever animals are fed, handled or moved (http://www.cdc.gov/nasd/docs).

5.1.6 Biomass Burning

Crop-residue burning and general wild fires (veld fires) represent significant sources of combustion-related emissions associated with agricultural areas. Emissions are greater from sugar cane burning that for savannas wild fires due to sugar cane areas being associated with a greater availability of available material to be burned. The quantity of dry, combustible matter per unit area is 25 ton per hectare for sugar cane, whereas it is on average 4.5 ton per hectare for savannas areas.

Biomass burning is an incomplete combustion process with carbon monoxide, methane and nitrogen dioxide being emitted during the process. About 40% of the nitrogen in biomass is emitted as nitrogen, 10% remains in the ashes and it is assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds. The visibility of smoke plumes from vegetation fires is due to their aerosol content.

5.1.7 Fugitive Dust Sources

Fugitive dust emissions may occur as a result of vehicle entrained dust from local paved and unpaved roads, and wind erosion from open areas. The extent of particulate emissions from the main roads will depend on the number of vehicles using the roads and on the silt loading on the roadways. The extent, nature and duration of agricultural activities and the moisture and silt content of soils is required to be known in order to quantify fugitive emissions from this source. The quantity of wind blown dust is similarly a function of the wind speed, the extent of exposed areas and the moisture and silt content of such areas.

The pollutants listed above are released directly by sources and are therefore termed 'primary pollutants'. 'Secondary pollutants' which form in the atmosphere as a result of chemical transformations and reactions between various compounds include: NO_2, various photochemical oxidants (e.g. ozone), hydrocarbon compounds, sulphur acid, sulphates, nitric acid and nitrate aerosols.

5.2 Ambient Monitored Data

5.2.1 Ambient Air Quality Data within the greater Botswana

The Department of Waste Management and Pollution Control (DWM&PC) states that 17 stations are "continuously measuring the levels of the different air pollutants" (Mmolawa, 2004). Francistown is indicated as the location of two of these stations where nitrogen oxides and sulphur oxides are being measured. The Morupule Colliery is another site where SO_2 is measured. The locations of the other sites were not indicated. The locations chosen for the Francistown measurement sites (Blue Jacket Street in the city centre and the City Council depot in the industrial area) confirm that the intention of these stations is to measure pollution related to industry and traffic in urban areas. The diurnal variation in nitrogen oxides values at the city centre station indicates a typical urban traffic-related pattern albeit at a relatively low level, with values of approximately 15-20 $\mu g/m^3$ total nitrogen oxides during the morning and afternoon traffic peak, and values below 5 $\mu g/m^3$ in the early morning hours. Similarly, monthly averages of sulphur dioxide range between 0 and 26 $\mu g/m^3$, with the highest hourly value ever measured being 401 $\mu g/m^3$.

Research has been carried into the background ozone concentration over Southern Africa (Zunckel *et al.* 2004, van Tienhoven *et al.* 2006). Values were measured at a number of stations in South Africa, Namibia and Botswana. Strong seasonal and diurnal variations occur; springtime maxima over Botswana are similar to those over the industrialised Highveld of South Africa at 40-60 $\mu g/m^3$ and this sometimes continues into early summer. These maxima are reached early in the day and may continue at high levels for up to 10h. It is thought that the seasonal maximum coincides with the spring growth in vegetation (with an increase in biogenic hydrocarbons as ozone precursors being emitted) and nitrogen emissions from soil wetting. Biomass burning during winter and early spring is probably also involved.

There is similar evidence that background levels for suspended particulate matter are high at certain times of the year, mainly due to biomass burning. During the SAFARI 2000 research project over Southern Africa, two flights through the atmospheric boundary layer over Botswana in August gave an average concentration of 139 $\mu g/m^3$, with a very clear biomass burning fingerprint in terms of the content of organic solids (47%) and semi-volatile organic compounds (33%) (Eatough *et al* 2003).

5.2.2 On-site Ambient Monitored Data

The DWM&PC ambient monitoring station located at the Morupule Colliery has been operational since 1999 and measures SO_2. An annual monitoring station is also located on-site at the Morupule Power Station. The latter monitors SO_2 and PM10. The ambient monitored data from the DWM&PC monitoring station was provided for inclusion into this project. Due to various technical difficulties experienced over the years, the recorded data is not very comprehensive. Table 5-1 provides the data availability over the recorded periods for SO_2. Outliers have been removed from the dataset to provide a more representative and accurate dataset. In general a minimum of 80 % data capture is required to achieve minimum data quality assurance for data manipulation and summary. Data for ambient PM10 concentrations were obtained from the on-site monitoring station but was only available for the month of June 2007, reflecting two readings per day (i.e. 7 AM and 2 PM).

Despite the poor data availability, these ambient measurements were included into the current assessment to provide an indication of the background SO_2 and PM10 concentrations. Figure 5-1 provides the ambient SO_2 concentrations for the various monitoring periods, with Table 5-2 reflecting the highest hourly recorded SO_2 concentrations and annual averages. The one month of measured PM10 concentrations are provided in Table 5-3.

Table 5-1: Percentage sulphur dioxide data capture and data availability at the Morupule Power Plant ambient monitoring station.

[illegible]	Monitoring Period				
	1999	2000	2001	2005	2006
Data recorded	June - Dec	Jan - Dec	June - Dec	Jan - Dec	Jan - Dec
Data Availability	60%	37%	62%	46%	44%

Table 5-2: Highest hourly and annual average SO_2 concentrations for the various periods.

Averaging Period	SO_2 concentrations (µg/m³)				
	1999	2000	2001	2005	2006
Highest hourly	794.8	704.7	344.80	156.56	280.20
Annual	20.5 (a)	14.29	14.46 (a)	6.35	17.00

Notes:
(a) Covered only a period of 6 months.

The highest hourly SO_2 concentrations recorded were during the years 1999 and 2000 with a distinct decrease in the measured ground level concentrations during 2001, 2005 and 2006.

No hourly Botswana or World Bank guideline for SO_2 concentrations exists and reference was made to the European Community (EC) hourly standard of 350 µg/m³. The highest hourly concentrations measured every month exceeded this guideline during 1999 (June, September and October) and 2000 (February and March). The years 2001, 2005 and 2006 reflected lower maximum SO_2 concentrations on average with no exceedances of the EC hourly standard indicated for these periods.

Compliance with the Botswana 24-hour guideline (90% of observed data need to be less than 300 µg/m³) was assessed on the available data. The 24-hour average concentrations for the months provided (over the period 1999, 2000, 2001, 2005 and 2006) exceeded the Botswana guideline for 1 day out of 1,523 days (thus <1% of the time). The highest daily average concentrations measured over the entire period was 311 µg/m³. The highest daily average SO_2 concentrations measured for each year were 125 µg/m³ (1999), 311 µg/m³ (2000), 57 µg/m³ (2001), 142 µg/m³ (2005), and 192 µg/m³ (2006). When compared against the WBG guideline (150 µg/m³), the highest SO_2 concentrations exceeded these guidelines in 1999 and 2006.

On an annual average the concentrations varied over the years between 6.35 µg/m³ (2005) and 20.5 µg/m³ (1999). It should be noted that in 1999 only 6 months of data were recorded with a data availability of 60% and 2005, even though for a full year had a data availability of only 42%. All the annual average concentrations were shown to comply with the Botswana annual guideline and WBG annual guideline of 80 µg/m³.

It is clear from the data available that the current Morupule Power Station is the main contributing source of SO_2 emissions. The station is situated within the prevailing wind field and should thus reflect elevated sulphur dioxide concentrations when the wind is blowing from a southeasterly, south-southeasterly and easterly direction respectively.

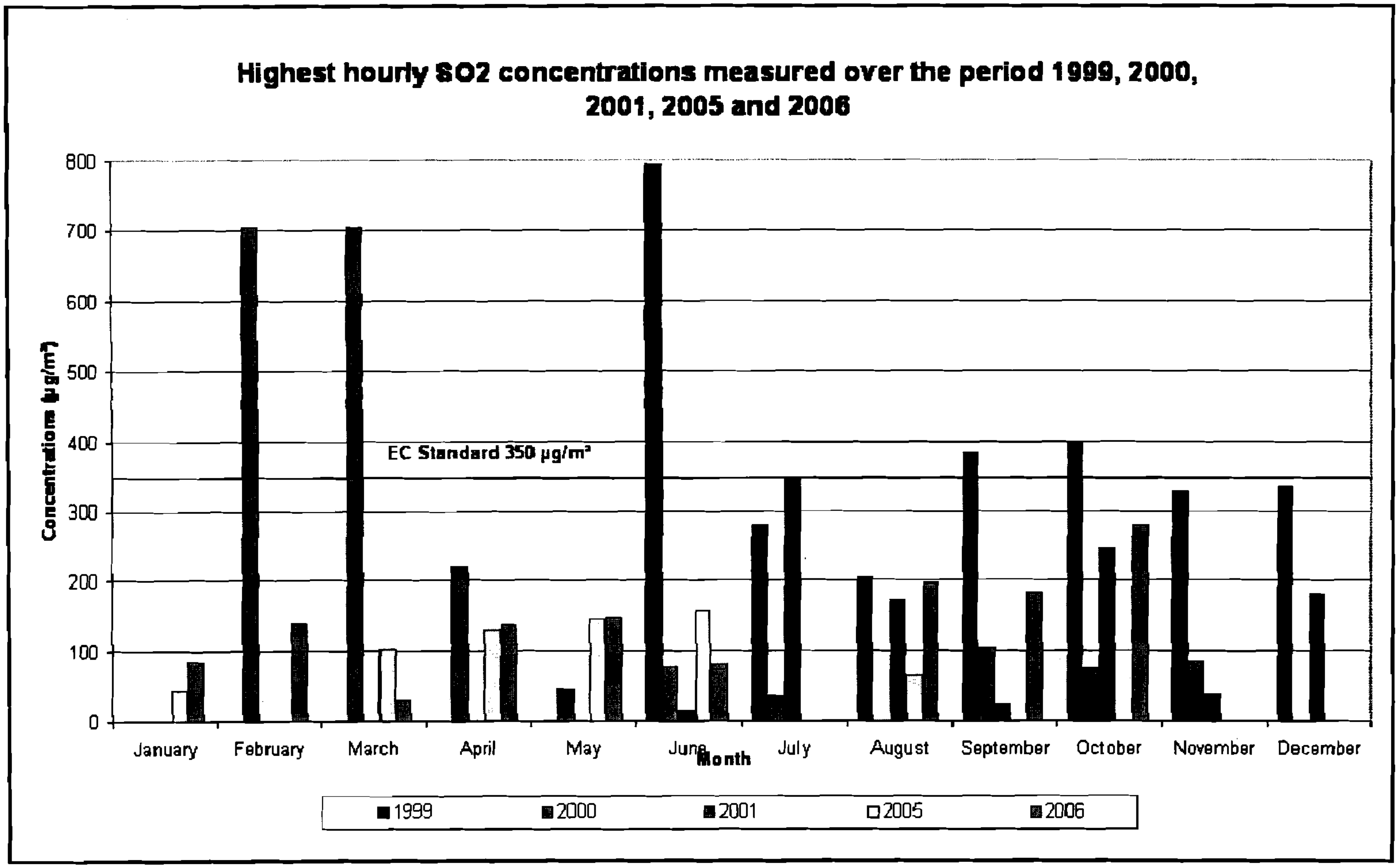

Figure 5-1: Hourly ambient monitored SO_2 concentrations for the period 1999, 2000, 2001, 2005 and 2006.

Table 5-3: Recorded PM10 concentrations at the Morupule Power Plant

Date	PM10 Ambient Concentrations (µg/m³)	
	07H00	14H00
2007/06/01	32	84
2007/06/02	Defective	Defective
2007/06/03	Defective	Defective
2007/06/04	Defective	Defective
2007/06/05	Defective	Defective
2007/06/06	Defective	Defective
2007/06/07	Defective	Defective
2007/06/08	Defective	Defective
2007/06/09		
2007/06/10		
2007/06/11	Defective	39
2007/06/12	12	32
2007/06/13	13	16
2007/06/14	13	6
2007/06/15	8	7
2007/06/16	Weekend	Weekend
2007/06/17	Weekend	Weekend
2007/06/18	0	43
2007/06/19	46	40
2007/06/20	0	20
2007/06/21	0	32
2007/06/22	0	20
2007/06/23	Weekend	Weekend
2007/06/24	Weekend	Weekend
2007/06/25	Weekend	Weekend
2007/06/26	86	23
2007/06/27	2	26
2007/06/28	12	30
2007/06/29	6	13
2007/06/30	Weekend	Weekend

It was unclear from the data set provided if the PM10 data was merely recorded for 1-hour twice daily. The concentrations were on average between 16.4 µg/m³ and 27.7 µg/m³.

5.3 Predicted Baseline Concentrations

The main sources contributing to the ambient air quality within the vicinity of the proposed Morupule B Power Station is the current Morupule Power Station and the Morupule Coal Mine. The other main sources, i.e. Matimba and Matimba B Power Stations are too far away to have a significant influence on the background concentrations at Morupule Power Plant. This is based on the predicted ground level concentrations as part of the Matimba B EIA.

5.3.1 Morupule Power Station Emissions Inventory

The Morupule Power Station is situated approximately 5 km from the residential settlement of Palapye. To the northwest is a coal mine which supplies the power station with the coal required in order to generate electrical power. The power station comprises of four boilers. Gaseous emissions from each boiler are routed through electrostatic precipitators before being vented to dedicated stacks (flues occupying a chimney).

5.3.1.1 Emissions from Boiler Stacks

The emissions from the current Morupule Power Plant was quantified based on information obtained in the technical documents for the proposed Morupule B Power Plant and the original scoping study conducted by Airshed in 2004. In addition, stack monitored data for SO_2 was provided for the years 2004 and 2005 and the data for 2005 (most recent) was used.

The current Morupule Power Plant comprised of four 33 MW units to make up the total nominal capacity of the plant of 132 MW. The source parameters are provided in Table 5-4 with Table 5-5 presenting the measured SO_2 emission rates from the four boiler units. The calculated emissions rates for NOx, CO, CO_2, PM10, methane and nitrous oxides are provided in Table 5-6. No information was available on the auxiliary stacks, but these are generally in use only for limited times and for short durations.

Table 5-4: Stack parameters of the Morupule Power Plant (as per flue)

No of Stacks(a)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Volumetric Flow Rate (m^3/s)	Temperature (K)
2	100	2.2	13.9	52.8	334.85

Notes:
(a) Three flues are combined in the west stack and one flue in the east stack. Information obtained from an application for registration certificates provided for the three flues emitting through west chimney (Watson *et.al.*, 2004).

Table 5-5: In-stack sulphur dioxide monitoring data from the boiler units at the Morupule Power Station for the year 2005.

Boiler Units	Minimum		Maximum		Average(a)	
	mg/Am³	g/s	mg/Am³	g/s	mg/Am³	g/s
Boiler Unit 1	1,039.00	54.90	5,461.00	288.55	3,587.95	189.58
Boiler Unit 2	1,079.00	57.01	4,832.00	255.32	2,788.14	147.32
Boiler Unit 3	1,022.00	54.00	5,960.00	314.92	3,536.79	186.88
Boiler Unit 4	1,039.00	54.90	5,461.00	288.55	3,587.95	189.58

Notes:
(a) The average measured emission rates for SO_2 for each flue was used as input to the dispersion model.

Table 5-6: Calculated emission rates reflected for all four flues at the Morupule Power Station

Pollutant	Emission Concentration (mg/Nm³)	Emission Rate (g/s)
Particulates (as PM10)(a)	392.90	20.76
Oxides of Nitrogen (NO_x)(b)	4,755.63	251.28
Carbon monoxide (CO)(b)	76.65	4.05
Methane (CH_4)(b)	9.08	0.48
Carbon dioxide (CO_2)(b)	590,657.97	31,209.45
Nitrous Oxide (N_2O)(b)	13.44	0.71

Notes:

(a) From scoping report (Watson et.al., 2004) based on the total of all four flues, assuming mitigation is in place.

(b) From scoping report (Watson et.al., 2004) based on the total of all four flues, calculated

5.3.1.2 Fugitive emissions from materials handling operations

In the quantification of fugitive dust releases use was made of the predictive emission factor equations published by the US-EPA (EPA, 1996). In addition, use was made of the National Pollutant Inventory (Npi) compiled by the Australian Government (ANPI, 2001). The emission factors used in the current study, and assumptions made in their application, are described below. No local emission factors are available. Fugitive dust emission rates will be estimated for PM10 (i.e. particles <10 µm) and total suspended particulate (TSP).

Materials handling operations at the Morupule Power Plant include:

- Coal is transported to the plant from the mine by conveyer whereby it is tipped to a temporary storage pile.
- Stored coal is transferred from the temporary storage pile and routed to the plant to be burnt.
- The fly ash that is produced is stored in two silos on site. Some of this material is transferred to trucks, which remove the product from the site for reuse. The remaining fly ash is transferred from the silo's by pipeline (as slurry) to the ash dumps situated northeast of the plant.

The quantity of dust which will be generated from such loading and off-loading operations will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature (moisture content) and volume of the material handled. Fine particulates are most readily disaggregated and released to the atmosphere during the material transfer process, as a result of exposure to strong winds. Increases in the moisture content of the material being transferred would decrease the potential for dust emissions, since moisture promotes the aggregation and cementation of fines to the surfaces of larger particles.

Equation 1 as depicted and discussed in Appendix A was used to calculate the emission rates from tipping. The equation for tipping (Equation 1) takes into account the influence of wind speeds on the material being tipped, whereas the emission factors applied to loading and off-loading are single valued emission factors merely accounting for the amount of material handled (i.e. kg of dust per ton of material handled). The Australian NPi recommends the same equation as for tipping to be applied to excavators, shovels and front-end loaders. The tipping equation was applied to all material transfer actions. The quantity of dust generated from the materials handling operations identified was based on the amount of material stored and retrieved each month. Where no site-specific information was available use was made of the US.EPA AP42 documentation on similar processes. Material transfer for each type of operation is given in Table 5-7.

Table 5-7: Materials handling operations at Morupule Power Plant

Material Transfer points	Material Transferred (tonnes per hour)(a)	Moisture content of Material (%)(b)
Coal from mine to storage pile	400.00	2.5
Temporary Storage Pile to power plant	200.00	2.5
Fly ash transferred	51.50	0.4
Notes: (a) From scoping report (Watson et.al.,2004) (b) From Morupule B Power Plant technical information on coal and ash analysis		

The particle size multiplier varies with aerodynamic particle sizes and is given as a fraction of TSP. For PM30 the fraction is 74%, with 35% of TSP given to be equal to PM10, and the PM2.5 fraction is 11% of TSP (EPA, 1998a). Hourly emission factors, varying according to the prevailing wind speed, were used as input in the dispersion simulations. Moisture content for ash and coal was taken from the EPC documents as provided by FICHTNER for Morupule B and assumed to be the same since it will be from the same mine.

5.3.1.3 Fugitive emissions resulting from wind blown dust

Significant emissions arise due to the mechanical disturbance of granular material from open areas and storage piles. Parameters which have the potential to impact on the rate of emission of fugitive dust include the extent of surface compaction, moisture content, ground cover, the shape of the storage pile, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture contents, whether due to precipitation or deliberate wetting, promote the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. Surface compaction and ground cover similarly reduces the potential for dust generation. The shape of a storage pile or disposal dump influences the potential for dust emissions through the alteration of the airflow field. The particle size distribution of the material on the disposal site is important since it determines the rate of entrainment of material from the surface, the nature of dispersion of the dust plume, and the rate of deposition, which may be anticipated (Burger, 1994; Burger et al., 1995).

The main sources of wind erodable dust at Morupule Power Plant are the ash dump, and the coal storage pile. A temporary coal storage pile was also considered. An hourly emissions file was created for each of these source groups. The calculation of an emission rate for every hour of the simulation period was carried out using the ADDAS model. This model is based on the dust emission model proposed by Marticorena and Bergametti (1995). The model attempts to account for the variability in source erodibility through the parameterisation of the erosion threshold (based on the particle size distribution of the source) and the roughness length of the surface.

In the quantification of wind erosion emissions, the model incorporates the calculation of two important parameters, viz. the threshold friction velocity of each particle size, and the vertically integrated horizontal dust flux, in the quantification of the vertical dust flux (i.e. the emission rate). The equations used are discussed in Appendix A (Equations 2 and 3).

Information regarding the nature of the source, the percentage of exposed surface area and the type of material was obtained from the technical information as provided for the Morupule B Power Plant. No source specific information pertaining to clay percentage or particle size data was available and use was made of information from the Matimba B EIA. Where no parameter information (i.e. height, dimensions, etc.) was available on the storage piles, the size was assumed to be equal to the amount (cubic metres) of material received over a monthly average. The information on the different storage piles for is listed in Table 5-8 and includes the size, height and volume of each source.

Table 5-8: Source parameter information used for the quantification of wind blown dust

Sources	Length (m)	Width (m)	Height (m)	Moisture Content (%)	Clay Content (%)(d)	Bulk Density (kg/m³)
Contingency Coal Storage Pile (a)	152.20	152.2	2	2.5	4.96	1,000
Temporary Coal Storage Pile (b)	73.50	73.5	2	2.5	4.96	1,000
Ash dump cells (c)	500	150	10	2.5	1.05	771(d)

Notes:

(a) based on 1 month supply as stipulated in the scoping report (Watson *et.al.*, 2004)
(b) based on 1 week supply as stipulated in the scoping report (Watson *et.al.*, 2004)
(c) two cells active as stipulated in the scoping report (Watson *et.al.*, 2004)
(d) from Matimba B EIA information (Scorgie *et.al.*, 2006)

Table 5-9: Particle size distribution data used for the wind blown sources

Ash Particle Size		Coal Particle Size	
µm	fraction	µm	fraction
600	0.0472	75	0.28
404.21	0.0269	45	0.16
331.77	0.0296	30	0.2
272.31	0.0336	15	0.07
223.51	0.0404	10	0.1
183.44	0.0503	5	0.05
150.57	0.0609	2.5	0.07
123.59	0.0687	1	0.07
101.44	0.0728		
83.26	0.0739		
68.33	0.072		
56.09	0.0669		
46.03	0.0607		
37.79	0.0537		
31.01	0.0471		
25.46	0.0407		
17.15	0.0628		

Ash Particle Size		Coal Particle Size	
µm	fraction	µm	fraction
14.08	0.0528		
7.78	0.0285		
3.53	0.0105		
Notes: from Matimba B EIA information (Scorgie *et.al.*, 2006)			

5.3.1.4 Fugitive emissions resulting form vehicle entrainment on unpaved roads

The unpaved road from the Morupule Power Plant to the ash dump is likely one of the main sources of fugitive emissions from the plant. It was assumed that dust suppression would be applied in the form of water sprays. Vehicle-entrained dust emissions from unpaved haul roads could be a significant source of fugitive dust.

The unpaved road size-specific emission factor equation of the US.EPA, used in the quantification of emissions for the current study, is given in Appendix A, Equation 4. In addition to traffic volumes, emissions also depend on a number of parameters which characterise the condition of a particular road and the associated vehicle traffic. Such parameters include average vehicle speed, mean vehicle weight, average number of wheels per vehicle, road surface texture, and road surface moisture (EPA, 1996). For the Morupule operations, the amount of ash to be hauled from the plant was applied.

The haul road lengths and total vehicle kilometres travelled per day for are provided in Table 5-10. A silt loading of 8.4% was used in the calculations based on generic US.EPA values.

Table 5-10: Parameters from unpaved roads at Morupule Power Plant

Road length (m)	Road width (m)	Truck weight (ton)	Average speed (km/hr)	Number of trucks	Amount of ash removed (tpd)	VKT/day
300	10	7	30	3	336	38.4
Notes: (a) VKT/day – Vehicle kilometres travelled per day						

5.4 Simulated Baseline Ambient Air Quality

Atmospheric dispersion modelling was undertaken for the existing Morupule Power Plant using the CALPUFF modelling suite recommended for regulatory use by the US-EPA (further detail pertaining to the modelling is outlined in Section 3), to determine background concentrations. Emissions resultant from sources more than 100 km away (i.e. Matimba A, Matimba B, and Selebi-Phikwe Smelter) was regarded not to have a noticeable impact at the Morupule site. Smaller contributing sources such as vehicles, agriculture, domestic fuel burning, and fugitive emissions were not quantified and do not form part of the baseline concentrations presented in this section.

Ambient air quality guidelines are applicable to the assessment of off-site, community exposures (rather than occupational exposures). In assessing compliance of current baseline operations emphasis was placed on:

- the *magnitude* of the exceedance (i.e. extent to which pollutant concentrations exceed the permissible limit value);
- the *frequency* of exceedance (i.e. how many times, given as hours or days a year, air quality limit values are exceeded); and
- the *spatial extent* of exceedances (i.e. the area over which frequencies of exceedance are expected to occur.)

Concentrations are presented in Tables 5-11, 5-12 and 5-13 for SO_2, NO_2 and PM10 predicted ground level concentrations at referenced receptor areas. These tables reflect the maximum ground level concentrations (irrespective of where it occurred) and the sensitive receptor areas of Palapye and Serowe are included as an indication of community exposures.

The plots for SO_2, NO_2 and PM10 are provided after each table. It should be noted that the plots reflecting hourly and daily averaging periods contain only the maximum predicted ground level concentrations, for those averaging periods, over the entire period for which simulations were undertaken. It is therefore possible that even though a high hourly or daily average concentration is predicted to occur at certain locations, that this may only be true for one hour or one day during the year. Typically for short-term predictions the second highest concentrations would be extracted, hence these predictions can be seen as a conservative approach.

5.4.1 Sulphur Dioxide Concentrations

Table 5-11 depicts the simulated concentrations for the specified locations. Highest hourly, daily and annual isopleth plots for *routine* operations are illustrated as Figures 5-2, 5-4 and 5-6, respectively. Frequency of exceedance plots are provided for hourly SO_2 exceedance in Figure 5-3 and for daily in Figure 5-5.

Table 5-11: Predicted SO_2 *baseline* concentrations due to the Morupule Power Plant (exceedances of air quality guidelines are highlighted)

Averaging Period	Standard/ Guideline (µg/m³)	MAX GLC		PALAPYE		SEROWE	
		Max Conc (µg/m³)	Fraction of GL	Max Conc (µg/m³)	Fraction of GL	Max Conc (µg/m³)	Fraction of GL
Highest hourly	350(d)	4683.6	**13.4**	690.0	**2.0**	43.0	0.1
Highest 24-hour average	300(a)	557.9	**1.9**	70.0	0.2	7.4	0.02
	150(b)		**4.5**		0.6		0.1
	50(c)		**11.2**		**1.4**		0.1
Annual average	80(a)(b)	155.2	**1.9**	3.5	0.0	0.9	0.01
	30(c)		**3.1**		0.1		0.02

Notes:

(a) Botswana guideline (90% of observed to be less than 300 µg/m³)

(b) World Bank (WBG) Thermal Power Guidelines

(c) World Health Organisation (WHO) Interim Target-2 (IT-2)

(d) European Community (EC) hourly standard

Abbreviations:

GLC – ground level concentration (this is the maximum concentration)

GL – Guideline

Max Conc – Maximum Concentration

- The maximum predicted ground level concentrations exceeded all the relevant ambient air quality guidelines for all three averaging periods (i.e. Botswana, WBG and WHO). The maximum concentration occurred near field to the source 800m to the west of Morupule Power Station.
- Highest hourly predicted SO_2 concentrations exceeded the EC standard at Palapye and the WHO IT-2 guideline over a 24-hour average. The guidelines for highest daily averages as provided by Botswana and the WBG were not exceeded at Palapye (5 km away). Neither did the annual average concentrations exceed any of the guidelines.
- The allowable frequency of exceedance according to the EC hourly standard of 350 $\mu g/m^3$ is 24 hours per calendar year. Based on the predicted hourly concentrations at Palapye, 7 hours exceeded the EC standard.
- At Serowe, none of the ambient air quality guidelines or standards was exceeded for any of the averaging periods. The highest hourly concentration was 10% of the EC standard and the daily was 20% of the WHO IT-2 guideline.

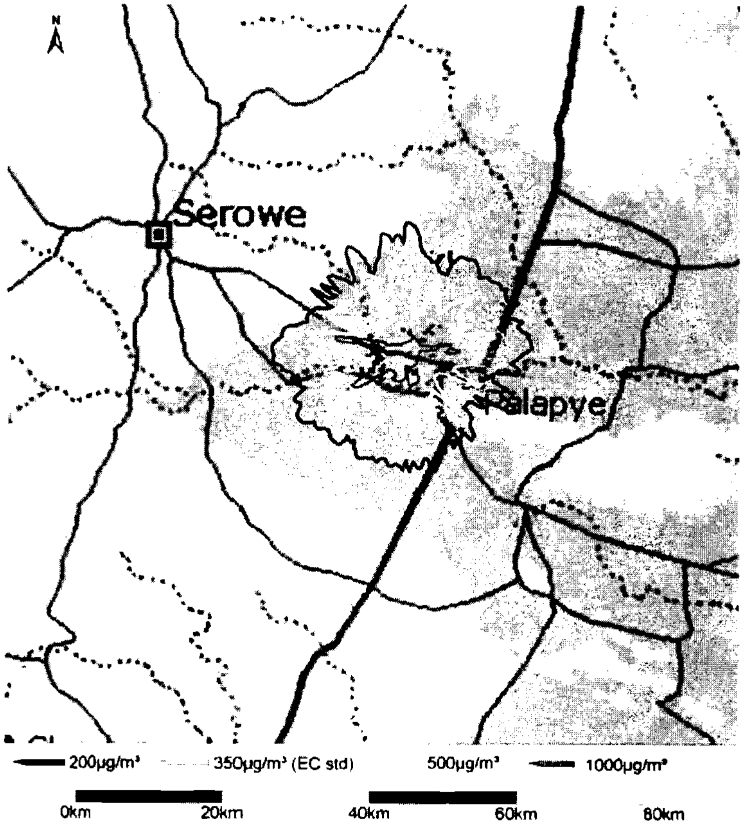

Figure 5-2: Highest hourly SO_2 predicted ground level concentrations due to baseline conditions

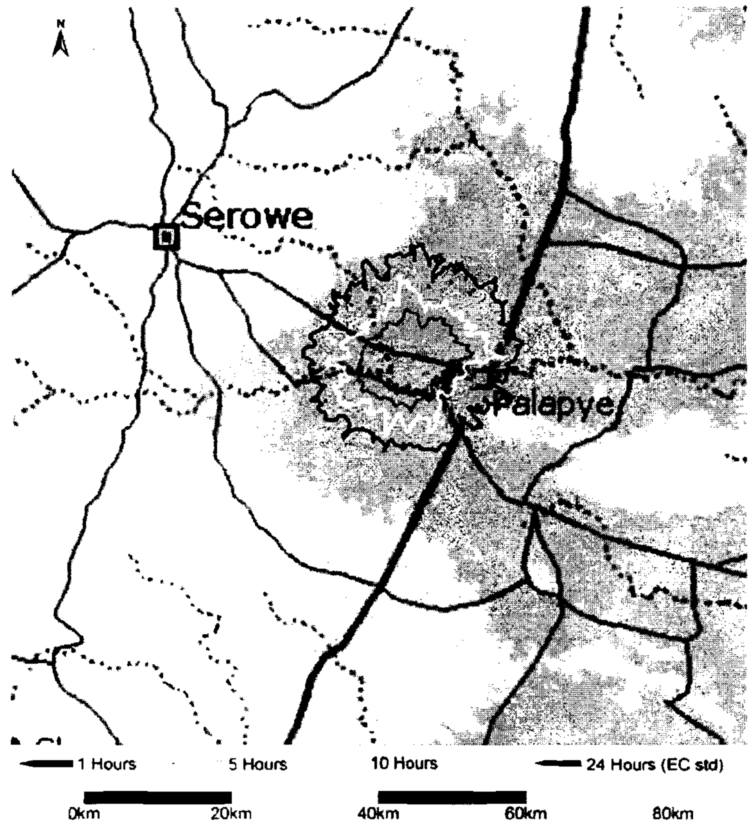

Figure 5-3: Frequency of exceedance of the hourly SO_2 predicted ground level concentrations (based on the EC allowable exceedance of the 350 µg/m³ of 24 hours per year) - baseline

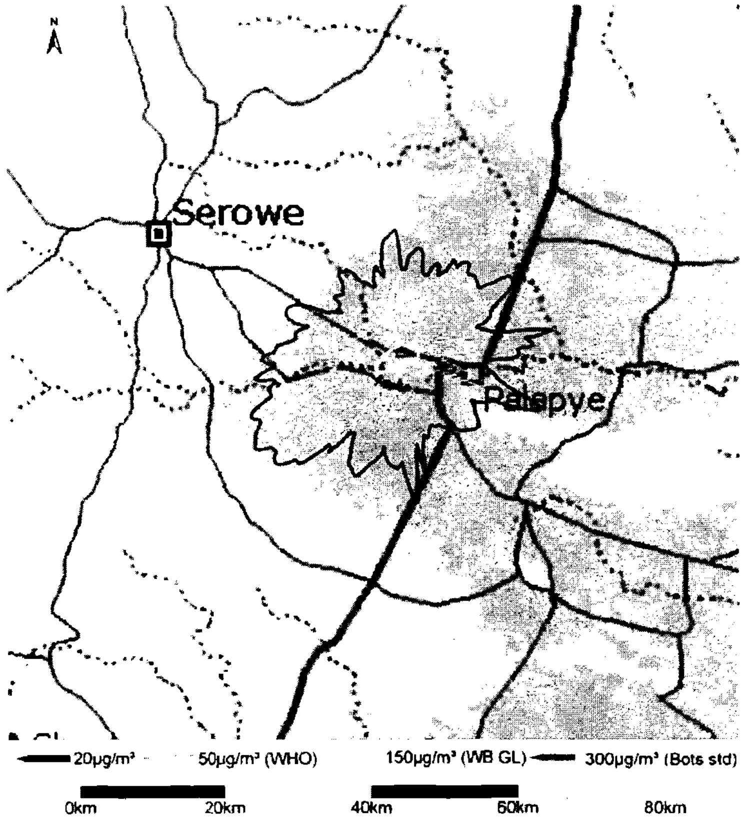

Figure 5-4: Highest daily average SO_2 predicted ground level concentrations due to baseline conditions

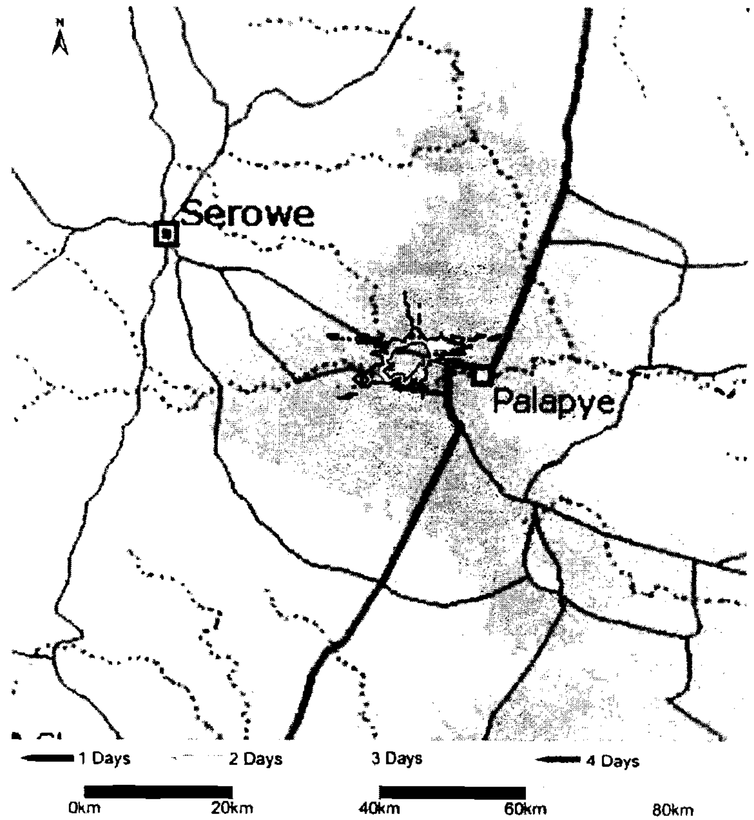

Figure 5-5: Frequency of exceedance of the daily SO_2 predicted ground level concentrations (based on the EC allowable exceedance of the 125 µg/m³ of 3 days per year) - baseline

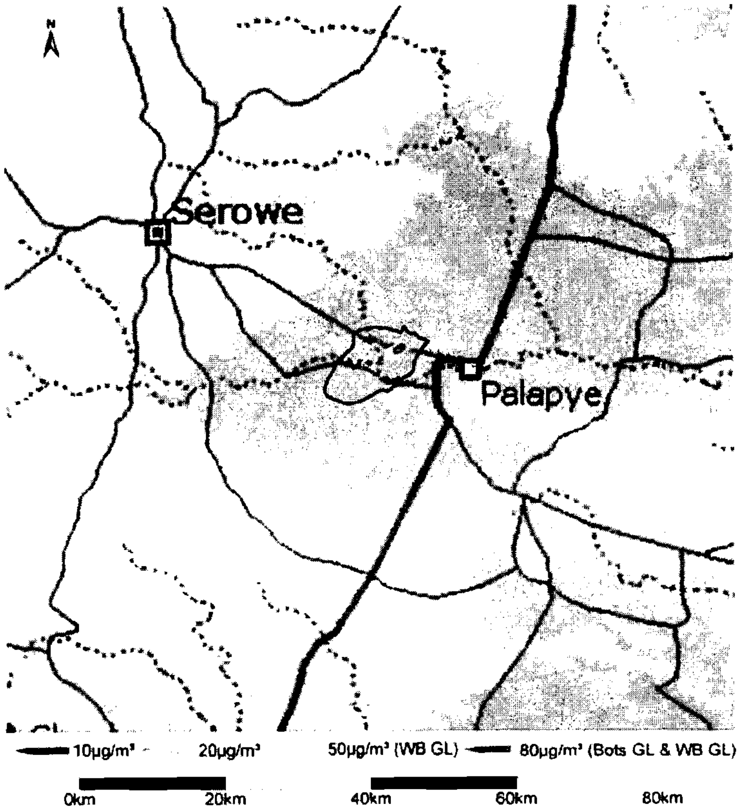

Figure 5-6: Annual average SO_2 predicted ground level concentrations due to baseline conditions.

5.4.2 Nitrogen Dioxide Concentrations

Predicted ground level concentrations for Nitrogen Dioxide (NO_2) are provided in Table 5-12 for maximum, and at the sensitive receptors of Palapye and Serowe. The predicted NO_2 concentration plots are provided in Figures 5-7, 5-8, and 5-9 for highest hourly, highest daily and annual averages, respectively.

- The maximum ground level concentration for highest hourly averages was predicted to comply with the Botswana, WBG and WHO guidelines. Highest daily and annual average predictions were also well within the respective guidelines. The maximum zone of impact was predicted to be near field to the source, approximately 769 m to the west of Morupule Power Station.
- All predicted NO_2 ground level concentrations were low and well within the respective guidelines at the two sensitive receptors (Palapye [5 km away] and Serowe). Even highest hourly concentrations were less than 30% of the WBG and WHO guideline at Palapye and less than 2% at Serowe.

Table 5-12: Predicted NO_2 baseline concentrations due to the Morupule Power Plant (exceedances of air quality guidelines are highlighted)

Averaging Period	Standard/ Guideline (µg/m³)	MAX GLC		PALAPYE		SEROWE	
		Max Conc (µg/m³)	Fraction of GL	Max Conc (µg/m³)	Fraction of GL	Max Conc (µg/m³)	Fraction of GL
Highest hourly	400(a)	164.0	0.4	25.0	0.1	1.9	0.00
	200(c)		0.8		0.1		0.01
Highest 24-hour average	150(b)	19.6	0.1	2.6	0.02	0.3	0.002
Annual average	100(a)(b)	5.5	0.1	0.1	0.001	0.04	0.0004
	40(c)		0.1		0.00		0.001

Notes:

(a) Botswana guideline

(b) World Bank Thermal Power Guidelines

(c) World Health Organisation Air Quality Guideline (AQG)

Abbreviations:

GLC – ground level concentration (this is the maximum concentration)

GL – Guideline

Max Conc – Maximum Concentration

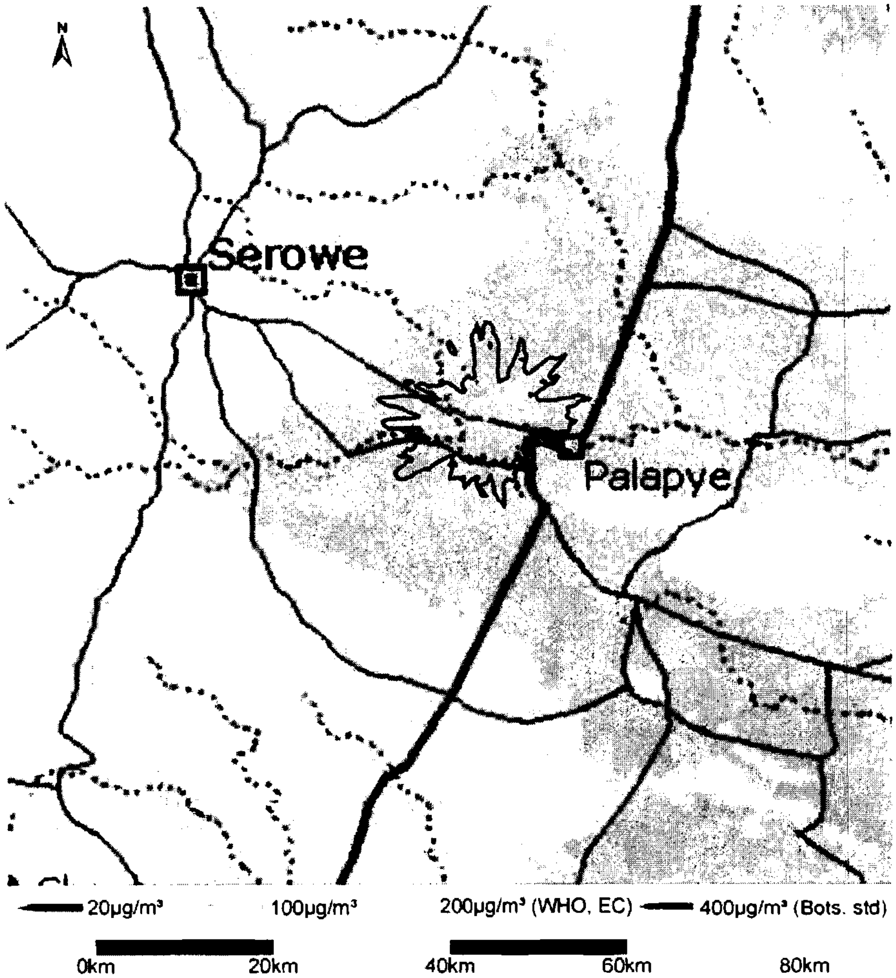

Figure 5-7: Highest hourly NO_2 predicted ground level concentrations due to baseline conditions

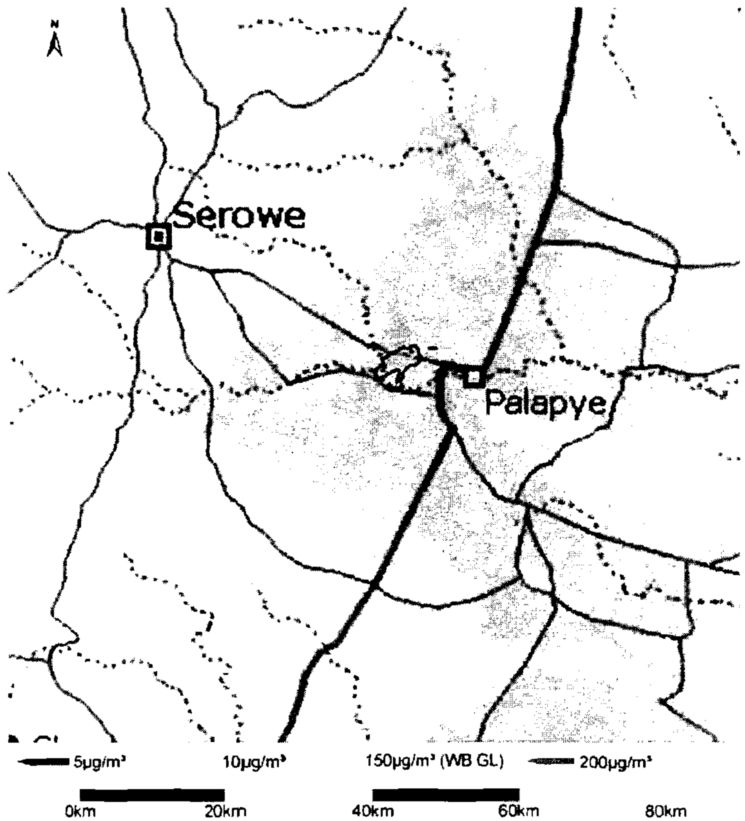

Figure 5-8: Highest daily average NO_2 predicted ground level concentrations due to baseline conditions

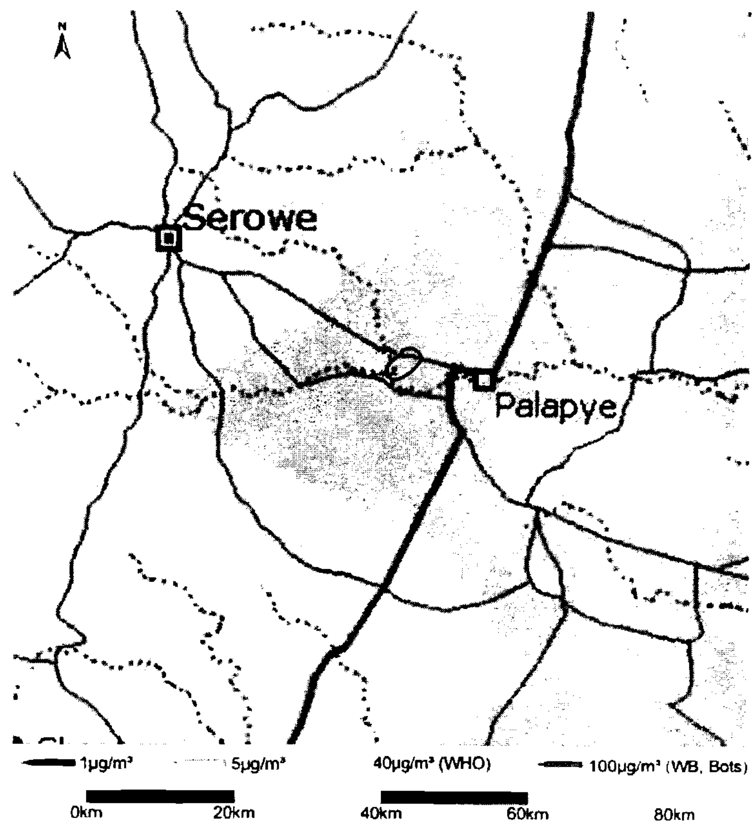

Figure 5-9: Annual average NO_2 predicted ground level concentrations due to baseline conditions

5.4.3 *Particulate (as PM10) Concentrations*

Predicted ground level concentrations of PM10 included all sources at Morupule, i.e. stacks, vehicle entrainment on roads, wind blown dust from the storage piles and ash dump and materials handling operations. These concentrations are provided in Table 5-13 with the contour plots in Figures 5-10 and 5-11 for highest daily and annual averages, respectively.

Table 5-13: Predicted PM10 *baseline* concentrations due to the Morupule Power Plant (exceedances of air quality guidelines are highlighted)

Averaging Period	Standard/ Guideline [illegible]	MAX GLC		PALAPYE		SEROWE	
		Max Conc	Fraction	Max Conc	Fraction	Max Conc	Fraction
Highest 24-hour average	150(b)	366.6	**5.2**	3.4	0.05	1.2	0.017
	100(c)		**3.7**		0.03		0.012
Annual average	200(a)	189.2	0.9	0.2	0.2	0.1	0.3
	50(b)(c)		**3.8**		0.004		0.001

Notes:

(a) Botswana guideline (90% of observed to be less than 300 µg/m³)
(b) World Bank Thermal Power Guidelines
(c) World Health Organisation Interim Target-2 (IT-2)

Abbreviations:

GLC – ground level concentration (this is the maximum concentration)
GL – Guideline
Max Conc – Maximum Concentration

- Since the plant boundary of the site was not clear, the maximum ground level concentrations occurred on-site near the source of emissions (less than 500 m from the Morupule Power Station). The highest concentrations were predicted to exceed both the daily and annual guidelines as reflected by the WBG and WHO. Botswana only has monthly average guidelines and annual average guidelines. The Botswana annual average guideline was matched and the WBG and WHO exceeded.
- At Palapye the predicted PM10 concentrations were low and well within the respective guidelines for highest daily and annual averages. Even lower ground level concentrations were predicted at Serowe, falling well within the respective guidelines for both averaging periods.

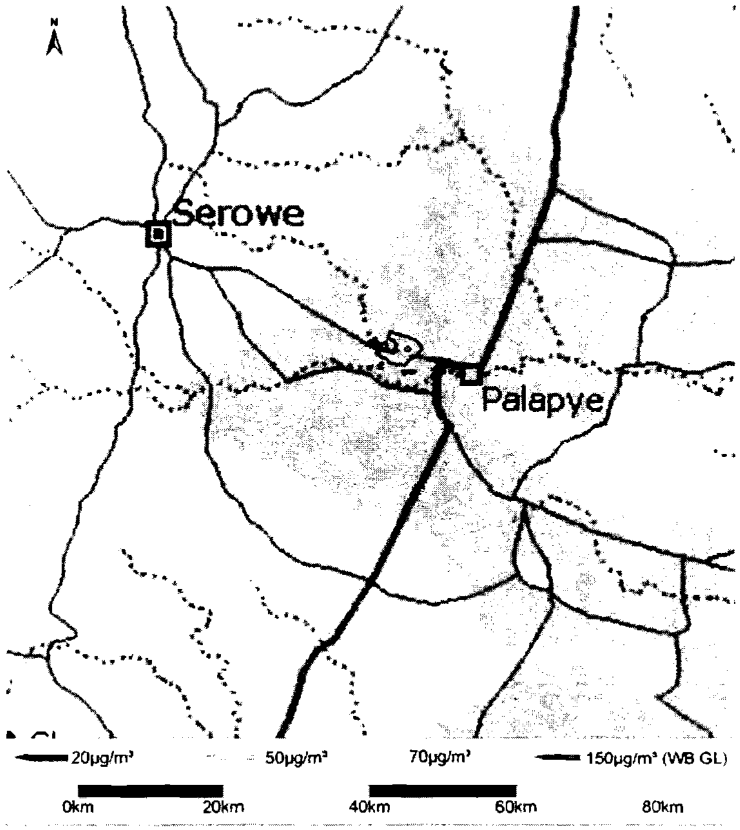

Figure 5-10: Highest daily average PM10 predicted ground level concentrations due to baseline conditions

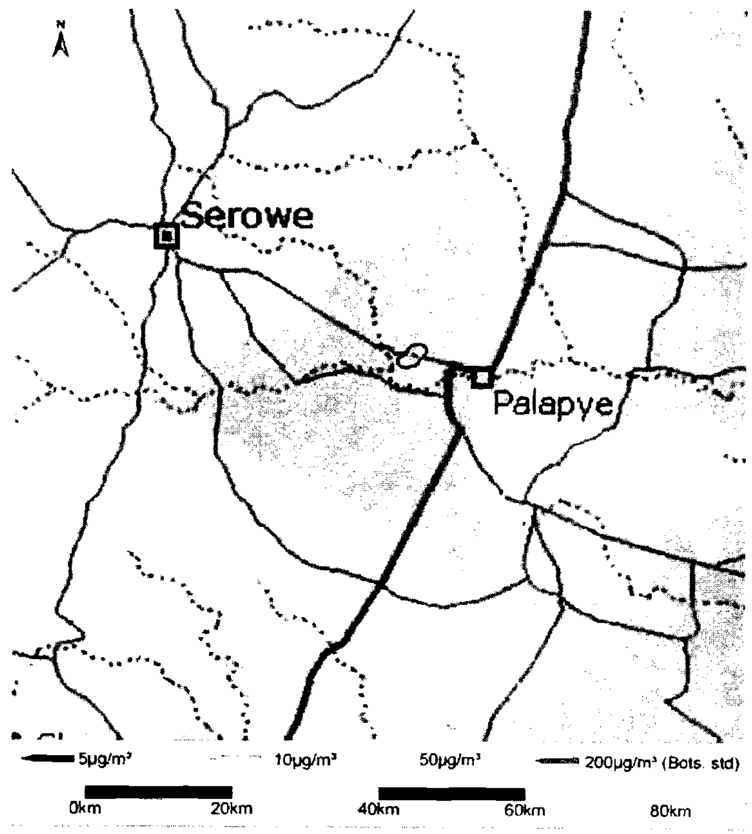

Figure 5-11: Annual average PM10 predicted ground level concentrations due to baseline conditions

6 IMPACT ASSESSMENT FOR THE PROPOSED MORUPULE B POWER PLANT

An emissions inventory for all primary and secondary sources of emissions for the proposed Morupule B Power Plant operations has been established. The emissions inventory forms the basis for assessing the impact of gaseous and particulate emissions from the processes on the receiving environment. The establishment of an emissions inventory comprises the identification of emission sources, and the quantification of each source's contribution to ambient air pollution concentrations.

The nature and significance of air quality impacts associated with the proposed operations at Morupule B forms the focus of the current section. The approach adopted in this section includes the identification of sources of emissions and types of pollutants released, determination of pertinent source parameters, establishment of particle size distributions and chemical compositions of particle emissions, and quantification of each source's emissions.

6.1 Identification of Environmental Aspects and Impact Criteria

The identification and quantification of emissions are divided into point sources and fugitive sources. Fugitive sources are defined as sources where the emission releases are not discharged to the atmosphere in a confined flow stream (EPA, 1992).

The proposed Morupule B Power Plant will obtain coal from the existing Morupule Coal Mine (approximately 5 km away). The new plant will therefore primarily comprise of a power generating plant with two stacks associated with it. Smaller point sources will include an auxiliary stack but this will be an intermittent source of emissions, only operational during short time intervals. Fugitive sources will include materials handling operations (loading, tipping and off-loading), conveyor transfer points, vehicle entrainment on internal roads, and wind erosion from exposed storage piles and the ash dump. The ash dump will be an extension of the existing Morupule ash dump.

The main source of gaseous emissions at the Morupule B Power Plant will be the boiler stacks emitting SO_2, NO_2, PM10, CO, CO_2, VOCs and metals (associated with the particulates from the ash). Other pollutants associated with power generation but expected to occur in small quantities include Hydrogen Sulphide (H_2S), Sulphuric Acid (H_2SO_4), Total Reduced Sulphur (S), Fluorides and heavy metals such as Lead (Pb), Mercury (Hg), Arsenic (As), Barium (Ba), Bismuth (Bi), Cobalt (Co), Chromium (Cr), Copper (Cu), Gallium (Ga), Germanium (Ge), Nickel (Ni), Niobium (Nb), Rhiobium (Rb), , Selenium (Se), Thorium (Th), Tin (Sn), Tungsten (W), Uranium (U), Vanadium (V), Yiddium (Y), Zinc (Zn) and Zirconium (Zr).

6.2 Quantification of environmental impacts

6.2.1 Primary Source Emission Estimation

All point source emissions were calculated based on the technical information provided in the FICHTNER reports for the Power Station design. Emissions were calculated using conceptual engineering data and emission factors published by the US-EPA (EPA, 1996).

The stack parameters according to the design specifications are listed in Table 6-1 with the quantified emission rates for the various pollutants in Table 6-2. The design for the proposed Morupule B Power

Plant was based on World Bank Group specifications for Thermal Power Plants (see Section 2.3). No information was available on the quantities of emissions to be released from the auxiliary stack(s).

Table 6-1: Parameters for the proposed Morupule B Power Plant.

Stack Parameters	Number/ Value(a)	Units
No of Stacks	1	
Stack Height	150(b)	m
Stack inner diameter	5.69(c)	m
Stack exit velocity	25.00	m/s
Stack volumetric flow rate	636.57(c)	Nm^3/s
Stack exit temperature	200	°C
Elevation of site	950	mamsl
Operational times	7884	hours
Availability	90%	

Notes:
(a) Information obtained from the EPC documents as provided by FICHTNER
(b) Two alternative scenarios were also included for 200m and 300m stack heights
(c) Calculated based on the emissions information provided for SO_2 and the stack exit velocity

Table 6-2: Emission rates for the proposed Morupule B Power Plant based on design criteria

Pollutants	Emission Rates		
	mg/Nm^3(a)	(tpd)	(g/s)
Particulates (as PM10)	50	2.75(b)	31.83
Sulphur Dioxide (SO_2)	2000	110	1,273.15
Oxides of Nitrogen (NO_x)	750	41.25(b)	477.43

Notes:
(a) Design criteria emission limits based on WBG guidelines for new Thermal Power Plants
(b) Calculated based on the emission limits and the calculated stack volumetric flow rate

No information was available to quantify other emissions likely to derive from the proposed power plant. Heavy metal associated with the coal and ash content were analysed and supplied by FICHTNER. The percentage metal content in the coal and ash are provided in Table 6-3. The average percentage between the ash and coal was applied to the PM10 emission rate.

Table 6-3: Emission rates for the various Heavy Metals associated with Coal.

[illegible] Boiler Stack [illegible]	[illegible] Coal (a) [illegible]	[illegible] Ash (a) [illegible]	Emission Rate(b) [illegible]
Silica	42.9	44.9	13.97
Aluminium	18.7	26.3	7.16
Iron	6.96	9.02	2.54
Titanium	1.61	1.9	0.56
Phosphorus	7.07	0.96	1.28
Calcium	6.36	8.37	2.34
Magnesium	3	2.4	0.86
Sodium	0.9	0.7	0.25
Potassium	0.43	0.22	0.10

[illegible]	[illegible]	[illegible]	[illegible]
Sulphur as SO_3	10.5	4.53	2.39
Manganese	ND	ND	ND
Notes: ND – No Data (a) based on coal and ash analysis (b) applied to the PM10 emission rate			

6.2.2 Fugitive Source Emissions Quantification

Fugitive dust, generated from materials handling operations, wind erosion, and vehicle-entrainment from unpaved roads, is classified as *routine* emissions and is fairly constant throughout the year. All the operations were assumed to be continuous for 365 days per year for 24 hours of the day.

The same methodology as followed in the baseline section for the quantification of fugitive emissions was applied for the future operations (see Section 5.3.1).

6.2.2.1 Materials Handling Operations

Coal from the Morupule Mine will be transferred to the Morupule B Power Plant via conveyor where it will be tipped into a coal storage bund. Limestone will arrive by truck and off-loaded at the limestone storage pile for use in the SO_2 scrubbers. Ash from the boilers will be loaded into a truck and dumped at the ash dump. The amount of material transferred at each point is provided in Table 6-4.

The same emission factor equation for materials handling operations as used for the baseline operations (see Section 5.3.1.3) was used in the quantification of emissions for the Morupule B operations (Equation 1 as depicted and discussed in Appendix A).

The particle size multiplier varies with aerodynamic particle sizes and is given as a fraction of TSP. For PM30 the fraction is 74%, with 35% of TSP given to be equal to PM10, and the PM2.5 fraction is 11% of TSP (EPA, 1998a). Hourly emission factors, varying according to the prevailing wind speed, were used as input in the dispersion simulations. Moisture content for coal and ash was taken from the EPC reports. No moisture information was available for the limestone and a generic value of 1% as provided by the US-EPA in the section pertaining aggregate handling and storage piles for coal mining operations was used (EPA, 1998a).

Table 6-4: Materials handling operations at Morupule B Power Plant

Material Transfer points	Material Transferred (tonnes per hour)(a)	Moisture Content of Material (%)(a)
Coal from mine to coal bunker	296.80	2.5
Tip at limestone storage pile	18.00	1.0
Fly ash transferred	81.62	0.4
Notes: (b) from Morupule B Power Plant technical information on coal and ash analysis		

6.2.2.2 *Wind Erosion from Exposed Areas*

The same equations and methodology for wind erodable dust was applied to the sources associated with Morupule B Power Plant. A coal and a limestone storage pile will be located near the power plant. The proposed ash dump will be located adjacent to the existing Morupule ash dump.

Information regarding the nature of the source, the percentage of exposed surface area and the type of material was not available and various assumptions were made. The ash dump dimensions were based on the footprint from the maps provided by Ecosurv for the project layout. The heights were determined by assuming the maximum design volumes as obtained from the EPC reports on the ash dump design. Additional information required for the estimation of emission rates from wind erosion is particle density and bulk density. No particle size distribution information was available and use was made of the particle size analysis done for the Matimba EIA (Scorgie *et.al.*, 2006) and similar sources at other coal mines in South Africa (i.e. for the discard dump). Coal densities were provided by the EPC documents but the ash density was taken from the Matimba EIA. The information on the different storage piles for is listed in Table 6-5 and includes the size, height and volume of each source.

Table 6-5: Source parameter information used for the quantification of wind blown dust

Sources	Length (m)	Width (m)	Height (m)	Moisture Content (%)	Clay Content (%)(b)	Bulk Density (kg/m^3)
Coal Storage Pile	92.46	92.46	2.5	2.5	4.96	1,000
Limestone Storage Pile	81.00	81.00	2	1.0	4.96	1,000
Ash dump extension (a)	1,845	675.00	10	0.4	13.45	771(b)

Notes:
(a) taken from the map provided by Ecosurv
(c) Based on 1 month of limestone supply
(d) from Matimba B EIA information (Scorgie *et.al.*, 2006)

6.2.2.3 *Vehicle Entrainment on Unpaved Roads*

Similar to the baseline operations, it was assumed that the ash from the Morupule B Power Plant will be removed via truck and taken to the ash dump. The road between the plant and ash dump was assumed to be unpaved.

The unpaved road size-specific emission factor equation of the US.EPA, used in the quantification of emissions for the current study, is given in Appendix A Equation 3. The haul road lengths and total vehicle kilometres travelled per day for all proposed Morupule B Power Plant truck activities are provided in Table 6-7. .

Table 6-6: Parameters from unpaved roads at Morupule B Power Plant

Road length (m)	Road width (m)	Truck weight (ton)	Average speed (km/hr)	Number of trucks	Amount of ash removed (tpd)	VKT/day
3,360	10	60	30	2	1,959	32.6

Notes: VKT/day – Vehicle kilometres travelled per day

6.3 Dispersion Simulation Results

Dispersion simulations were conducted for all sources associated with the proposed Morupule B Power Plant. Three scenarios were included in the modelling including stack heights of 150 m, 200 m and 300 m. Aside from the stack heights, all other parameters were taken to remain the same. Given that the main pollutant of concern from the power plant stacks is SO_2, the stack height scenarios were only simulated for SO_2. Thus, SO_2 predictions were used as the indicator for the influence stack height will have on the ground level concentrations.

Since ambient air quality guidelines and standards are applicable to the assessment of off-site, community exposures, cumulative impacts were predicted by including the baseline modelled concentrations (see Section 5.4). PM10 and gaseous concentrations predicted to occur at neighbouring residential areas were therefore calculated as a percentage of the relevant guidelines and standards for the purpose of compliance assessment. Reference was made to the guidelines issued by Botswana and to the World Bank Group (WBG), World Health Organisation (WHO) and European Community (EC).

Isopleth plots were generated for the various pollutants reflecting all relevant averaging periods for which ambient air quality guidelines and standards exists. It should be noted that the isopleth plots reflects the highest predicted ground level concentrations/depositions for that averaging period, over the entire period for which simulations were undertaken. It is therefore possible that even though a high hourly or daily concentration is predicted to occur at certain locations, that this may only be true for one hour or one day during the entire period of operation.

6.3.1 Sulphur Dioxide Concentrations

Table 6-7 depicts the simulated concentrations for the specified locations. Highest hourly, daily and annual isopleth plots for operations at a 150 m stack are illustrated as Figures 6-1, 6-7 and 6-13, respectively. Frequency of exceedance plots are provided for hourly SO_2 exceedance in Figure 6-4, 6-5 and 6-6 for the three stack heights and for daily in Figure 6-10, 6-11 and 6-12.

- The highest predicted ground level concentrations exceeded all the relevant guidelines and standards for hourly, daily and annual averaging periods. This was based on a design stack height of 150 m. The maximum concentration predicted was very close to the Morupule Power Station impacting ~800 m to the west.
- The highest predicted ground level concentrations from SO_2 emissions from the 150 m stack height at a sensitive receptor were predicted to occur at Palalpye, exceeding the hourly EC standard and WHO IT-2 guideline for highest daily averages. Compared to the Botswana guideline, and the WBG guideline for highest daily averages, the predicted SO_2 concentrations were within compliance, both at Palapye and Serowe. Similarly, no exceedances of the annual average guidelines were indicated.
- The zone of eceedance for highest hourly predictions (EC standard) covered approximately a radius of ~10 km around the power plant site (see Figure 6-4). Thus, the area of exceedance strenched for approximately 5 km to the west, east, north and south.
- With the increase in stack heights to 200m and 300m, very little difference was noted in the cumulative (i.e. including Morupule Power Station) maximum predicted ground level concentrations. The predicted ground level concentrations at Palapye reduced by 1%

between the 150 m stack and the 200m stack and by a further 0.4% when increased to 300 m. The incremental impacts from the three stack heights did however indicate a significant reduction between 200 m and 300 m. The predicted maximum concentrations from the proposed Morupule B Power Station in isolation were 1,315 µg/m³ at 150 m, 978 µg/m³ at 200 m and 740 µg/m³ at 300 m. Thus a reduction in ground level concentrations of 26% will be achieved by increasing the stack height from 150 m to 200 m and a further 24% reduction by increasing it to 300 m. With the background concentrations included (i.e. Morupule Power Station) the reduction is less noticeable. This is due to the background concentrations contributing between 37% and 98% of the cumulative ground level concentrations.

- The number of hours exceeding the EC hourly standard of 350µg/m³ at Palapye were 13 based on the 150 m stack but reduced to 10 with the 200m stack and with the 300 m stack down to 6. The EC allows 24 hours of exceedance.

Table 6-7: Predicted SO_2 future concentrations due to the Morupule and Morupule B Power Plants (exceedances of air quality guidelines are highlighted)

Averaging Period	Stack Height	Standard/ Guideline (µg/m³)	MAX GLC		PALAPYE		SEROWE	
			Max Conc (µg/m³)	Fraction of GL	Max Conc (µg/m³)	Fraction of GL	Max Conc (µg/m³)	Fraction of GL
Highest hourly	150 m	350(d)	4,707.03	**13.45**	950.00	**2.71**	98.00	0.28
	200 m		4,706.55	**13.45**	940.00	**2.69**	91.00	0.26
	300 m		4,683.60	**13.38**	937.00	**2.68**	76.00	0.22
Highest 24-hour average	150 m	300(a)	581.36	**1.94**	95.00	0.32	16.50	0.06
		150(b)		**4.65**		0.76		0.13
		50(c)		**11.63**		**1.90**		0.33
	200 m	300(a)	577.88	**1.93**	89.00	0.30	14.70	0.05
		150(b)		**4.62**		0.71		0.12
		50(c)		**11.56**		**1.78**		0.29
	300 m	300(a)	559.26	**1.86**	82.00	0.27	12.50	0.04
		150(b)		**4.47**		0.66		0.10
		50(c)		**11.19**		**1.64**		0.25
Annual average	150 m	80(a)(b)	189.16	**2.36**	6.30	0.08	2.40	0.03
		30(c)		**3.78**		0.13		0.05
	200 m	80(a)(b)	181.68	**2.27**	5.90	0.07	2.30	0.03
		30(c)		**3.63**		0.12		0.05
	300 m	80(a)(b)	169.06	**2.11**	5.30	0.07	2.20	0.03
		30(c)		**3.38**		0.11		0.04

Notes:
(a) Botswana guideline (90% of observed to be less than 300 µg/m³)
(b) World Bank (WBG) Thermal Power Guidelines
(c) World Health Organisation (WHO) Interim Target-2 (IT-2)
(e) European Community (EC) hourly standard

Abbreviations:
GLC – ground level concentration (this is the maximum concentration)
GL – Guideline
Max Conc – Maximum Concentration

- Irrespective of stack height, all predicted SO_2 ground level concentrations were well below the respective guidelines and standards at Serowe.
- The area exceeding the highest daily guidelines was ~800 m from Morupule Power Plant and 8 km to the southwest when compared to the WBG guidelines.
- Over an annual average, only the maximum ground level concentrations exceeded the relevant guidelines. This was predicted to be right at the plant, less than 1 km from the source. With an increase in stack height to 200m a reduction of 16% would be achieved at Palapye and at 300m the overall improvement will be 40%.
- For SO_2 various guidelines have been determined for the protection of vegetation in general and in some cases more specific (i.e. fruit trees). All these guidelines are specified for various averaging periods ranging from 5 minutes to annual averages. When the 24-hour (daily average) critical level for agricultural crops, forest trees and natural vegetation of 79µg/m³ is compared against, the maximum predicted ground level concentrations at the area around Palalpye are exceeded. One of the more stringent of the annual average guidelines is the EC and UK limit value to protect ecosystems of 20 µg/m³. Predicted annual averages at the sensitive receptors were well within this guideline.

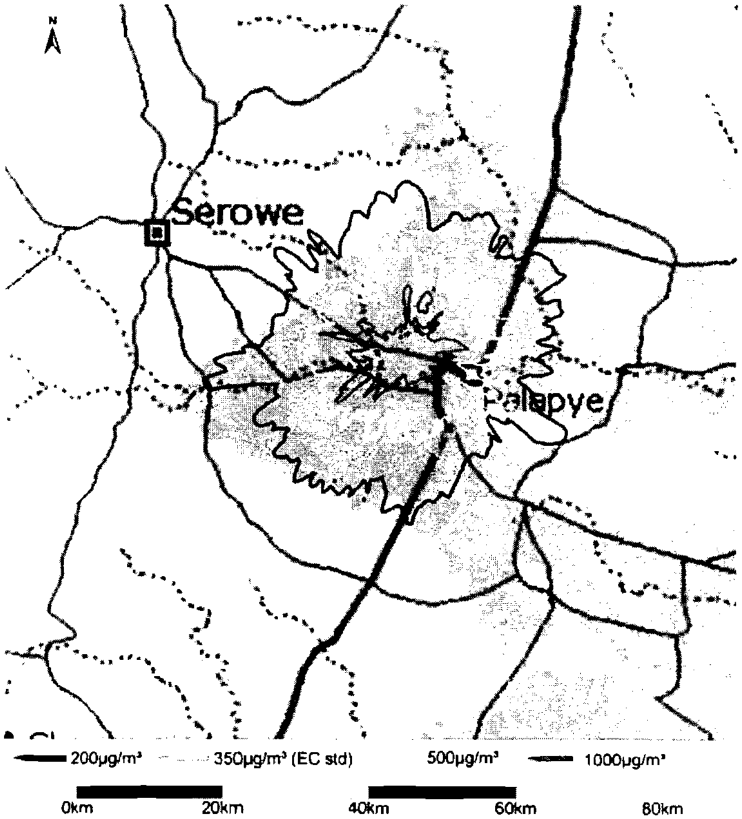

Figure 6-1: Highest hourly SO_2 predicted ground level concentrations due to future operational conditions (150 m stack height)

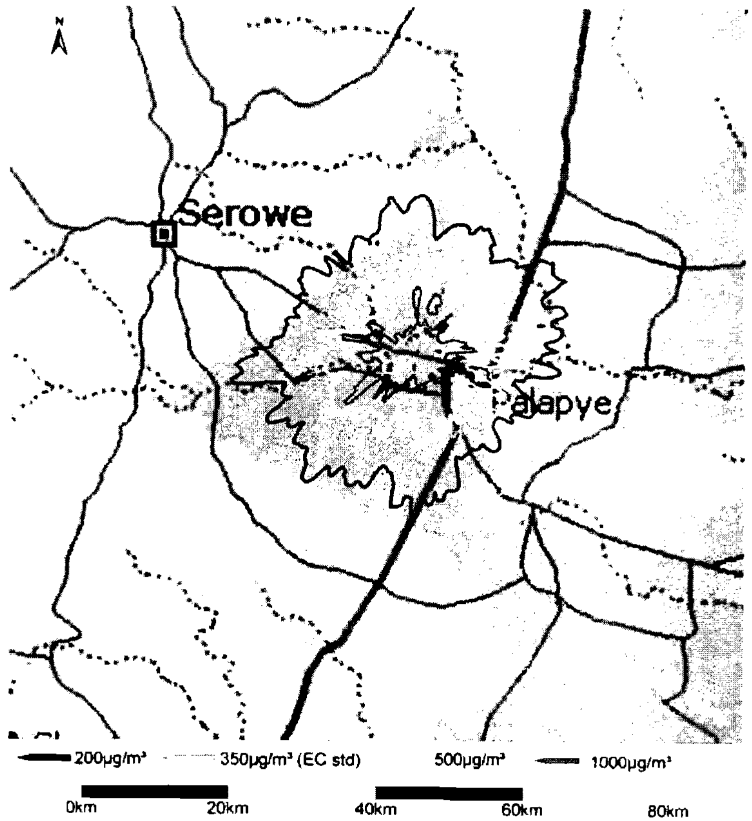

Figure 6-2: Highest hourly SO_2 predicted ground level concentrations due to future operational conditions (200 m stack height)

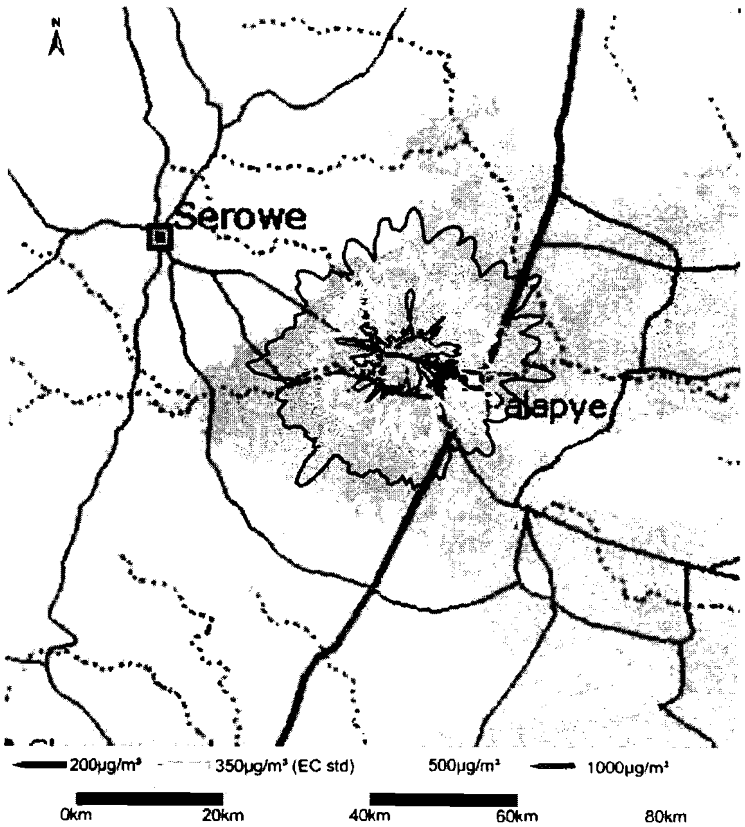

Figure 6-3: Highest hourly SO_2 predicted ground level concentrations due to future operational conditions (300 m stack height)

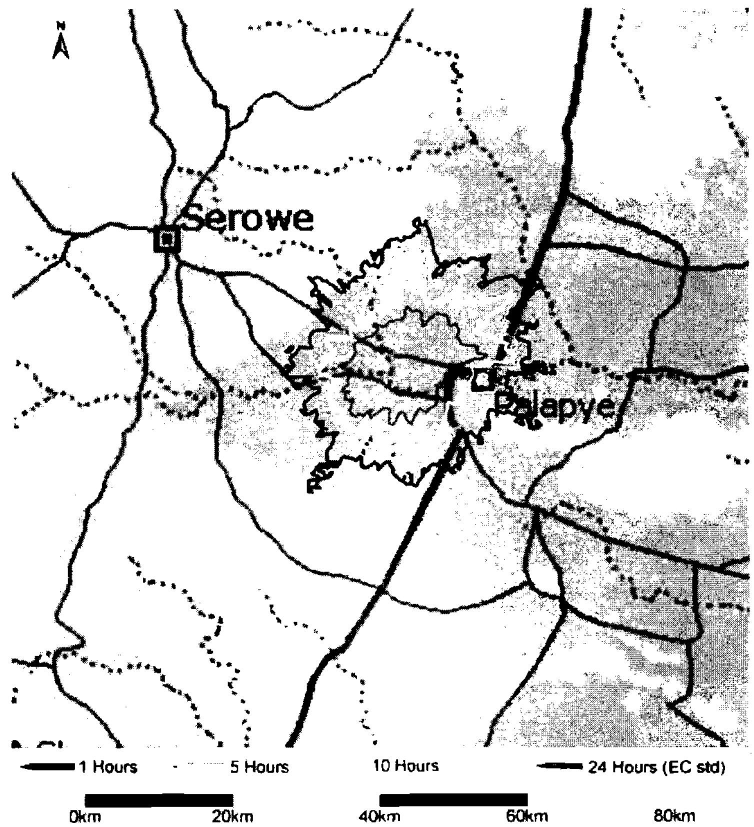

Figure 6-4: Frequency of exceedance of the hourly SO_2 predicted ground level concentrations (based on the EC allowable exceedance of the 350 µg/m³ of 24 hours per year) - future at 150 m stack height

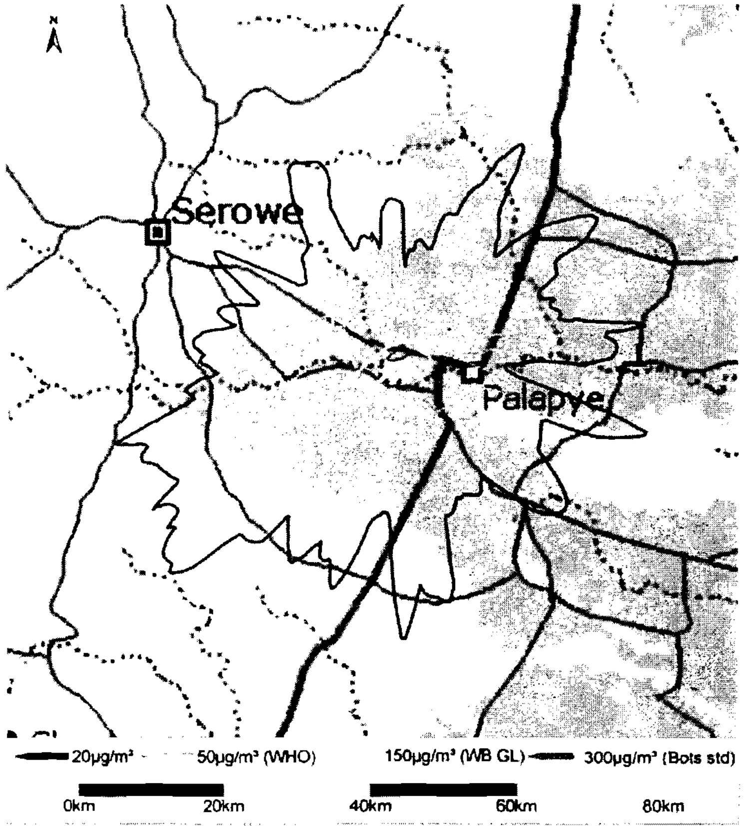

Figure 6-5: Highest daily average SO_2 predicted ground level concentrations due to future operational conditions at 150 m stack height

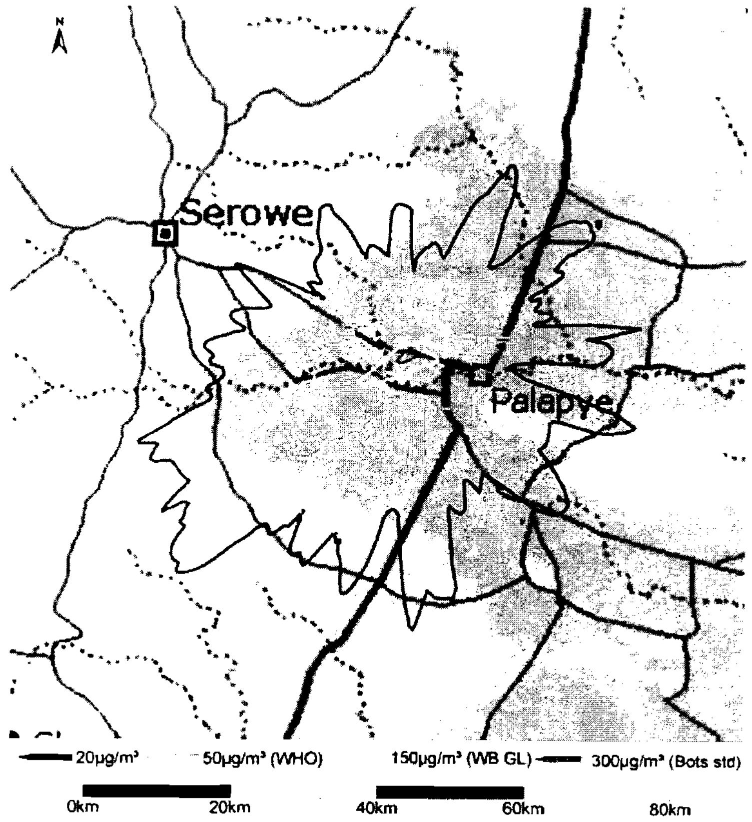

Figure 6-6: Highest daily average SO_2 predicted ground level concentrations due to future operational conditions at 200 m stack height

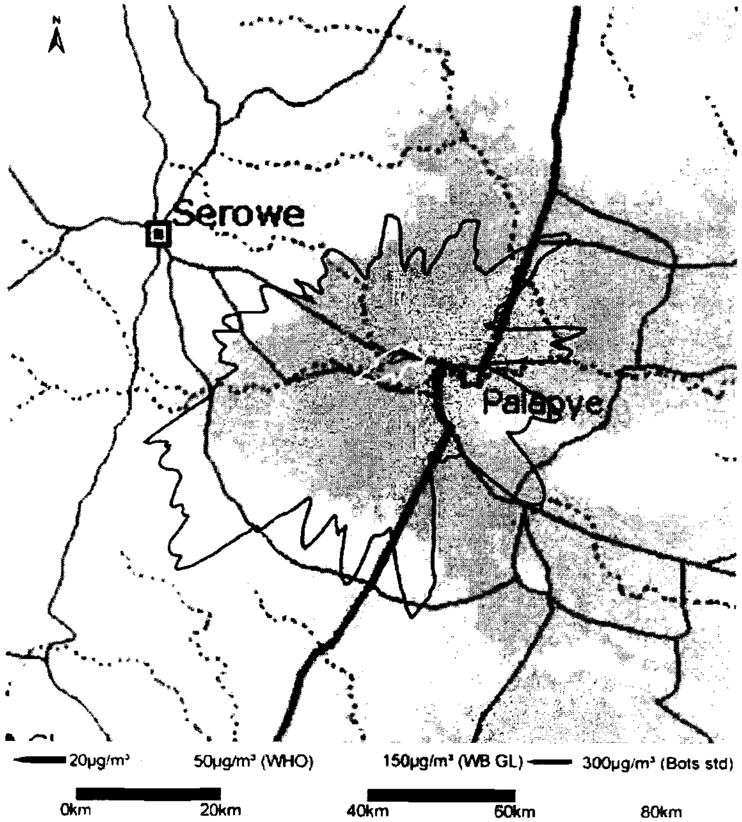

Figure 6-7: Highest daily average SO_2 predicted ground level concentrations due to future operational conditions at 300 m stack height

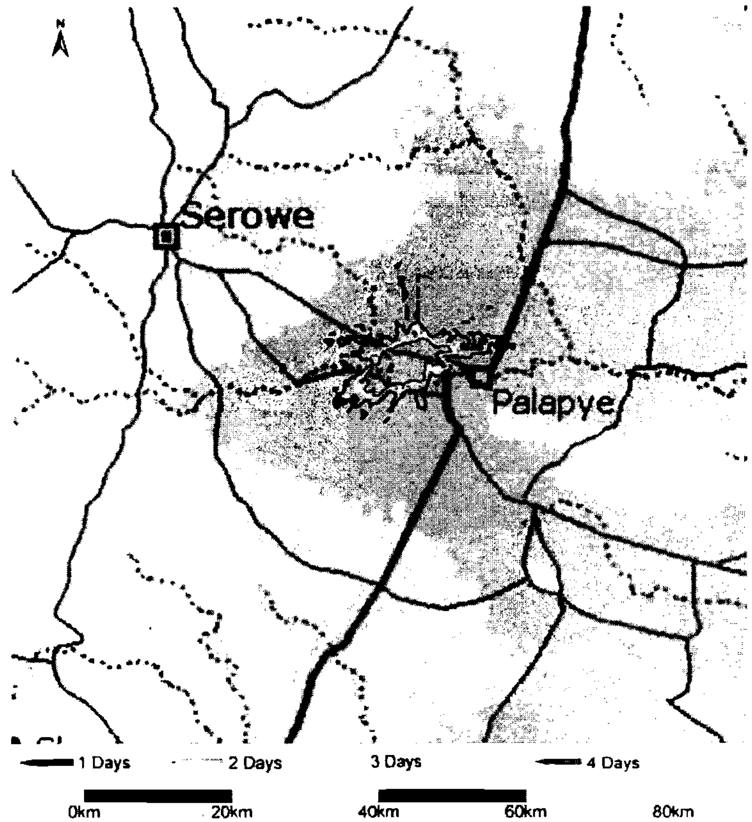

Figure 6-8: Frequency of exceedance of the daily SO_2 predicted ground level concentrations (based on the EC allowable exceedance of the 125 µg/m³ of 3 days per year) – future based on 150 m

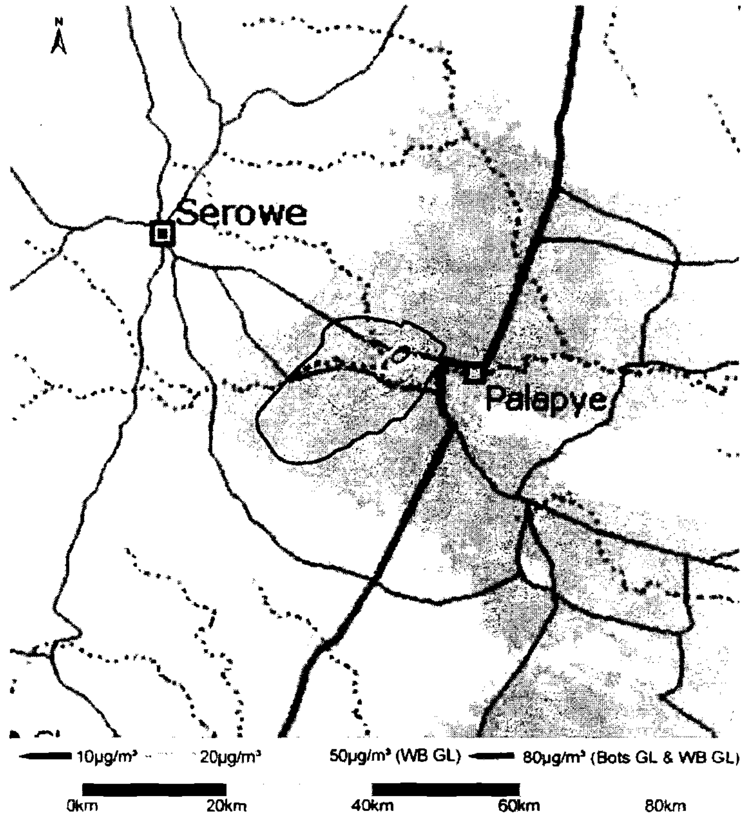

Figure 6-9: Annual average SO_2 predicted ground level concentrations due to future operational conditions 150 m stack height

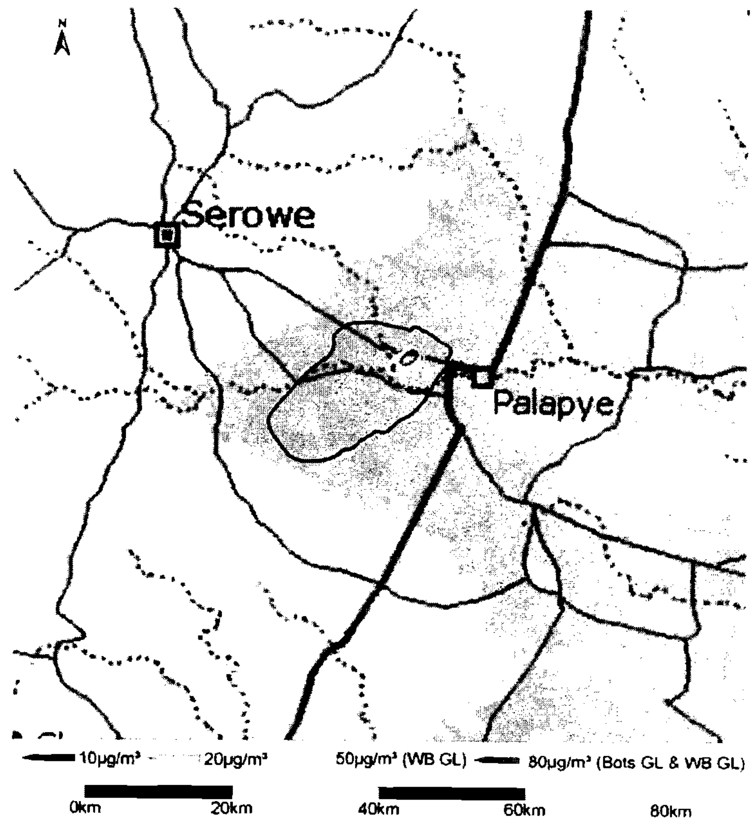

Figure 6-10: Annual average SO_2 predicted ground level concentrations due to future operational conditions 200 m stack height

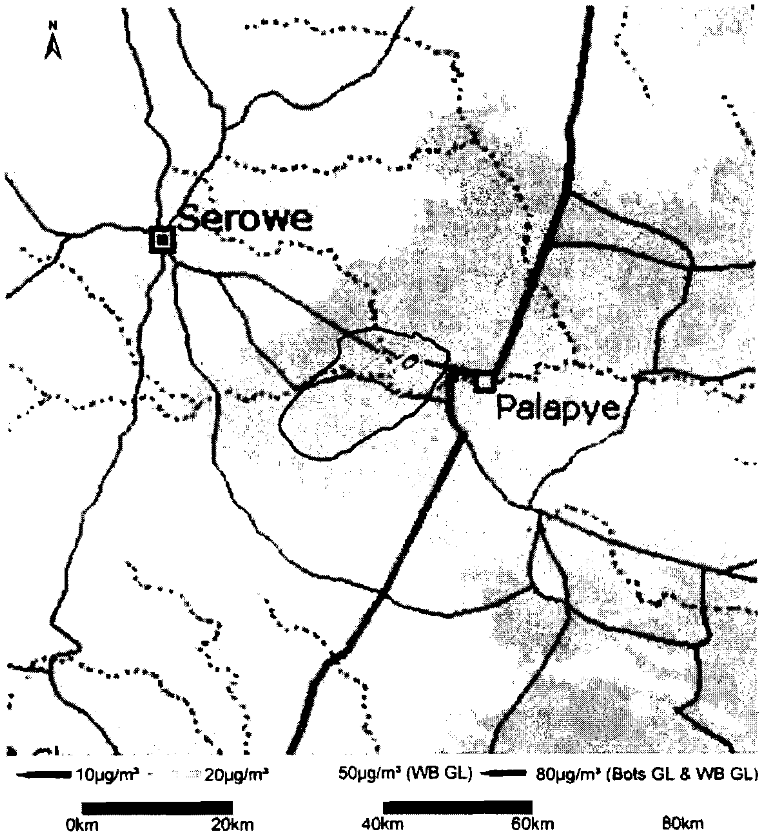

Figure 6-11: Annual average SO_2 predicted ground level concentrations due to future operational conditions 300 m stack height

6.3.2 Nitrogen Dioxide Concentrations

A synopsis of the hourly, daily and annual simulated concentrations for the referenced locations is depicted in Table 6-8. Isopleth plots illustrating the spatial extent of the modelled pollutant are illustrated in Figures 6-14, 6-15 and 6-16 for hourly, daily and annual concentrations from the 150 m stack respectively.

- A maximum hourly ground level concentration of 165 µg/m³ was predicted for operations from the Morupule B Power Plant and Morupule Power Plant. This concentration did not exceed the WBG, the WHO guideline or the Botswana guideline. Interestingly, the concentration is very similar to the baseline predicted maximum ground level concentration.
- The daily concentration was not in exceedance of any of the guidelines. The annual concentrations complied with the Botswana, the WB and WHO guidelines for general ambient conditions. As can be depicted from the isopleth plots the maximum ground level concentration is located in close proximity to the source but extends outside the plant boundaries.
- The highest hourly operations resulted in compliance of the nominated Botswana, the WBG and the WHO guidelines at both Palapye and Serowe. At both sensitive receptors the predicted concentrations were within the WBG daily guideline. Similar to the highest ground

level concentrations, none of the sensitive receptors were in exceedance of the WB, WHO or Botswana guidelines for annual averages.

- The significance of an exceedance at a single receptor point is defined by the number of times in a year the referenced guideline or standard is exceeded. In Europe 18 hours exceedance of the 200 µg/m³ ambient concentration limit is allowed whereas the 99th percentile (1% of the time) would result in 88 hours of exceedance allowed. Predicted NO_2 concentrations did not exceed any of the standards or guidelines.
- The European Union (EU) has stipulated a guideline of 30 µg/m³ over an annual average for the protection of vegetation from NO_2 impacts. Compared to this guideline the predicted ground level NO_2 concentrations were well below this threshold and thus no negative impacts on vegetation is expected.

Table 6-8: Predicted NO_2 *future* concentrations due to the Morupule and Morupule B Power Plants (exceedances of air quality guidelines are highlighted)

Averaging Period	Standard/ Guideline (µg/m³)	MAX GLC		PALAPYE		SEROWE	
		Max Conc (µg/m³)	Fraction of GL	Max Conc (µg/m³)	Fraction of GL	Max Conc (µg/m³)	Fraction of GL
Highest hourly	400(a)	164.90	0.41	34.00	0.09	3.90	0.01
	200(b)(c)		0.82		0.17		0.02
Highest 24-hour average	150(b)	20.59	0.14	3.50	0.02	0.72	0.005
Annual average	100(a)	6.74	0.07	0.23	0.002	0.10	0.001
	40(b)(c)		0.17		0.01		0.002

Notes:

(a) Botswana guideline

(b) World Bank Thermal Power Guidelines

(c) World Health Organisation Air Quality Guideline (AQG)

Abbreviations:

GLC – ground level concentration (this is the maximum concentration)

GL – Guideline

Max Conc – Maximum Concentration

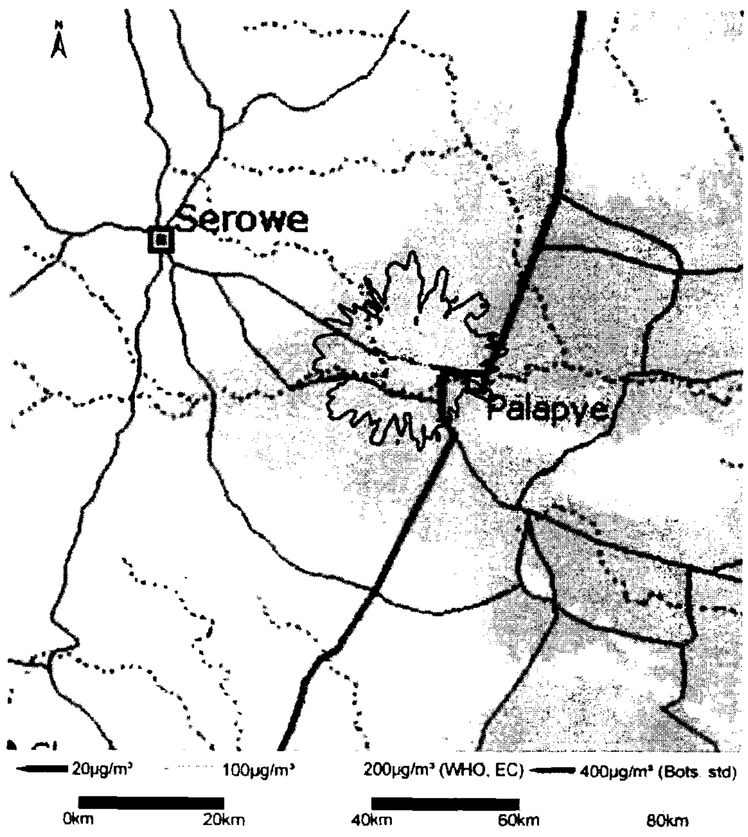

Figure 6-12: Highest hourly NO_2 predicted ground level concentrations due to future operational conditions (150 m stack)

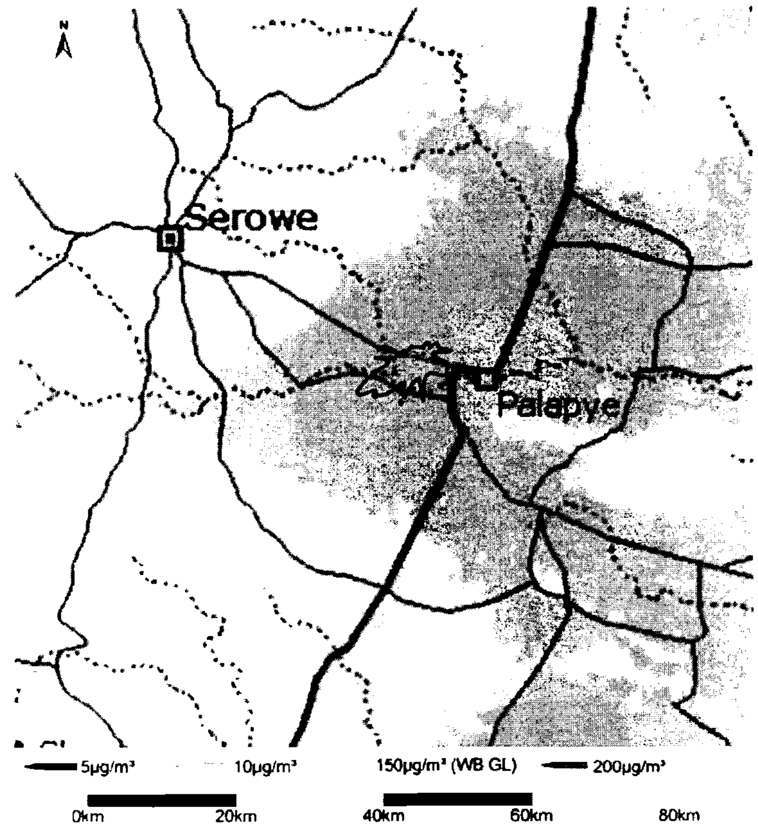

Figure 6-13: Highest daily average NO_2 predicted ground level concentrations due to future operational conditions (150 m stack)

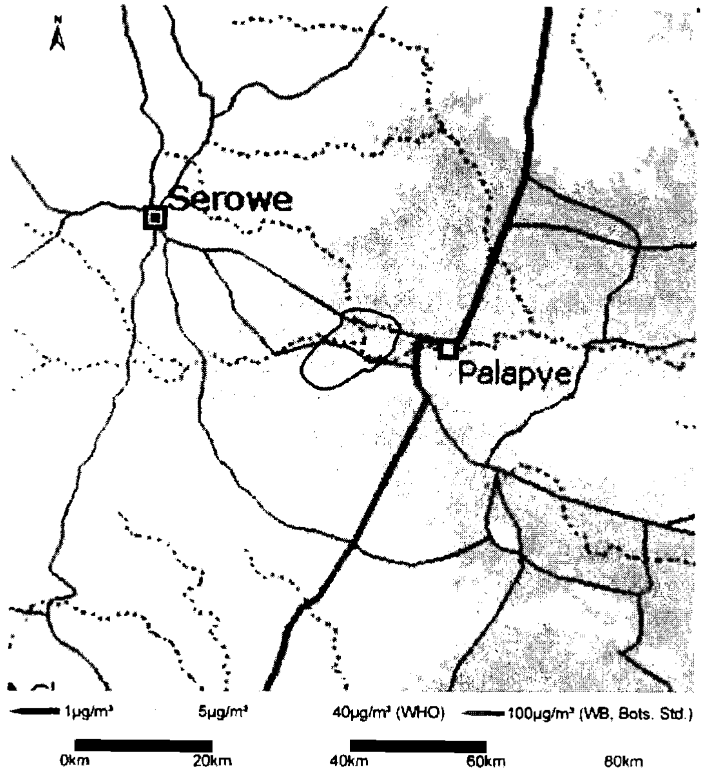

Figure 6-14: Annual average NO_2 predicted ground level concentrations due to future operational conditions (150 m stack)

6.3.3 Particulate (as PM10) Concentrations

The concentrations simulated at the referenced receptor points are depicted in Table 6-9. These concentrations reflect emissions from all sources, including the current Morupule and the proposed Morupule B. Concentrations were referenced against the relevant guidelines as a fraction, thus where this value is greater than one an exceedance of the relevant guideline in indicated. The spatial representation of PM10 concentrations are illustrated in Figures 6-17 and 6-18 for daily and annual concentrations respectively.

- PM10 concentrations exceeded the referenced daily and annual guidelines (i.e. Botswana, WB and WHO) for the maximum ground level concentration. Due to the low level of release of the main particulates sources (i.e. materials handling, wind blown dust and vehicle entrainment), the maximum predicted impact was expected to be within close proximity of the plant.
- The area exceeding the WBG guideline for highest daily PM10 concentrations extended for approximately 2.5 km from the site. The exceedance of the annual average Botswana guidelines is within an area of a few hundred meters from the source and ~1 km radius when compared to the WBG and WHO annual guidelines.
- At the sensitive receptors of Palapye and Serowe, the predicted highest daily ground level PM10 concentrations were well within the relevant guidelines with the highest (at Palapye)

being 33% of the WBG guideline. Similarly, none of the annual average guidelines were exceeded at any of the two sensitive receptors.

It should be noted that the predicted PM10 concentration only reflected sources from the existing and proposed power plants and not from the proposed mining operations.

Table 6-9: Predicted PM10 baseline concentrations due to the Morupule and Morupule B Power Plants (exceedances of air quality guidelines are highlighted)

Averaging Period	Standard/ Guideline	MAX GLC		PALAPYE		SEROWE	
		Max Conc	Fraction	Max Conc	Fraction	Max Conc	Fraction
Highest 24-hour average	150(b)	2,377.30	**33.96**	23.00	0.33	7.80	0.11
	100(c)		**23.77**		0.23		0.08
Annual average	200(a)	1,232.13	**6.16**	1.80	0.29	0.62	0.003
	50(b)(c)		**24.64**		0.04		0.01

Notes:

(a) Botswana guideline (90% of observed to be less than 300 µg/m³)
(b) World Bank General Environmental Guidelines
(c) World Health Organisation Interim Target-2 (IT-2)

Abbreviations:

GLC – ground level concentration (this is the maximum concentration)
GL – Guideline
Max Conc – Maximum Concentration

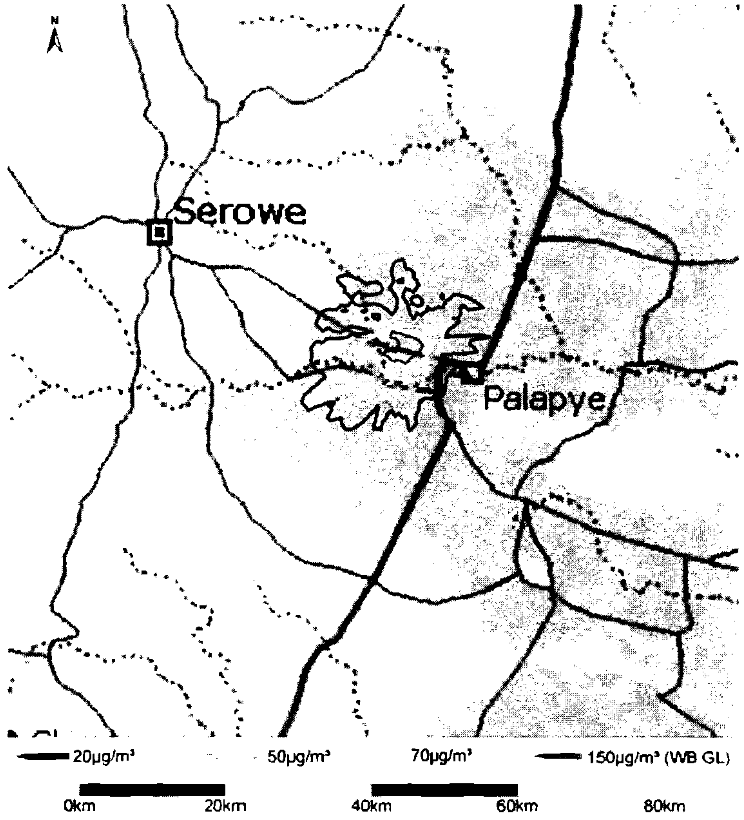

Figure 6-15: Highest daily average PM10 predicted ground level concentrations due to future operational conditions (150 m stack)

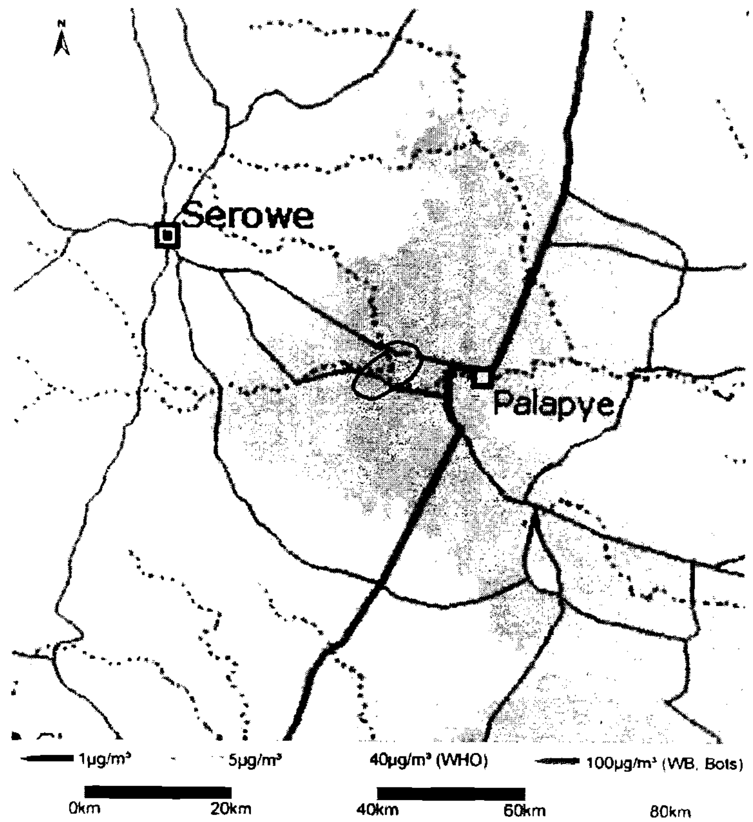

Figure 6-16: Annual average PM10 predicted ground level concentrations due to future operational conditions (150 m stack)

6.4 Significance rating of the Proposed Morupule B Power Plant operations

As for the proposed Morupule B Power Plant, the significance of atmospheric emissions estimated to emanate from activities during the operational phase was determined based on the impact assessment matrices provided by ARCUS GIBB. Results from the significance rating are illustrated below with Table 6-10 provide the Classification information with the Consequence rating given in Table 6-11. Table 6-12 is the Significance rating of the predicted impacts.

Fugitive dust emissions were quantified assuming no mitigation measures to be in place. Since the main sources resulting in off-site particulate impacts included the fugitive dust sources, a mitigated scenario for particulates were also evaluated. This scenario assumed water prays at material transfer points, chemical suppressant on the roads and vegetation of the side slopes of the ash dumps (see Section 8.2.3). The emissions of SO_2 and NO_2 were based on design criteria, including Best Available Control Technology (BACT). For SO_2 however, increasing the stack height was simulated as mitigation options.

Table 6-10: Classification of Impact

Impact		Nature	Intensity	Extent	Duration	Probability	Confidence
Sulphur Dioxide (SO_2)	150 m	Negative	Medium	Regional	Long-term	Highly Probable	Medium
Nitrogen Dioxide (NO_2)		Negative	Low	Local	Long-term	Highly Probable	Medium
Particulates (PM10)		Negative	Medium	Local	Long-term	Highly Probable	Medium
Mitigated							
Sulphur Dioxide (SO_2)	200 m	Negative	Medium	Regional	Long-term	Highly Probable	Medium
	300 m	Negative	Medium	Regional	Long-term	Highly Probable	Medium
Nitrogen Dioxide (NO_2)		Negative	Low	Local	Long-term	Probable	Medium
Particulates (PM10)		Negative	Low	Local	Long-term	Probable	Medium

Table 6-11: Consequence Rating

Impact		Nature	Consequence	Probability	Confidence
Sulphur Dioxide (SO_2)	150 m	Negative	Medium	Highly Probable	Medium
Nitrogen Dioxide (NO_2)		Negative	Low	Highly Probable	Medium
Particulates (PM10)		Negative	Medium	Highly Probable	Medium
Mitigated					
Sulphur Dioxide (SO_2)	200 m	Negative	Medium	Highly Probable	Medium
	300 m	Negative	Medium	Highly Probable	Medium
Nitrogen Dioxide (NO_2)		Negative	Low	Probable	Medium
Particulates (PM10)		Negative	Low	Probable	Medium

Table 6-12: Significance Rating

Impact		[illegible]	Probability	[illegible]	[illegible]
Sulphur Dioxide (SO_2)	150 m	Medium	Highly Probable	HIGH	Medium
Nitrogen Dioxide (NO_2)		Medium	Highly Probable	LOW	Medium
Particulates (PM10)		Medium	Highly Probable	MEDIUM	Medium
Mitigated					
Sulphur Dioxide (SO_2)	200 m	Medium	Highly Probable	HIGH	Medium
	300 m	Medium	Highly Probable	HIGH	Medium
Nitrogen Dioxide (NO_2)		Low	Probable	LOW	Medium
Particulates (PM10)		Low	Probable	LOW	Medium

7 IMPACT ASSESSMENT: CLOSURE PHASE

All activities will have ceased by the closure phase of the project. The main source of air pollutants namely the power station will have ceased once closure has been reached. This will obviously result in a positive impact on the surrounding environment and human health. The potential for impacts during the closure phase will therefore depend on the extent of rehabilitation efforts of the mining operations and the discard dump and ash dump and thus ultimately the rehabilitation efforts during operation.

7.1 Identification of Environmental Aspects

Aspects and activities associated with the closure phase of the proposed project are listed in Table 7-1.

Table 7-1: Activities and aspects identified for the closure phase

CLOSURE PHASE	
[illegible]	Activity
Fugitive dust	Demolition and stripping away of all buildings and facilities
Fugitive dust	Topsoil recovered from stockpiles for rehabilitation and revegetation of surroundings
Fugitive dust	Wind blown dust from ash dumps
Fugitive dust	Degradation of paved roads resulting in unpaved road surfaces

The following conclusions are drawn:

- *Incremental* impacts due to rehabilitation and demolition activities to be undertaken during the closure phase are of low significance.
- *Cumulative* impacts due to rehabilitation and demolition activities, taking into account background particulate concentrations are more significant.

No significant aspects should occur during the closure and post-closure phases given the implementation of rehabilitation strategies during the operational phase of the power plant. This will include the covering and vegetation of the discard dump and ash dump side walls and surface areas. It is therefore assumed that the potential for fugitive dust impacts will have been rendered negligible (and proven to be so) through comprehensive rehabilitation prior to closure being granted for these facilities.

7.2 Overview of Dust Control Measures for Exposed Surfaces

The main recommendation is that rehabilitation and mitigation is continuous throughout the life off the project in order to result in the minimal effort to apply final rehabilitation strategies.

Dust control measures for open areas can consist of wet suppression, chemical suppressants, vegetation, wind breaks, etc. Wet suppressants and chemical suppressants are generally applied for short storage pile durations. For long-term control measures vegetation frequently represents the most cost-effective and efficient control. Vegetation cover retards erosion by binding the soil with a root network, by sheltering the soil surface and by trapping material already eroded. Sheltering occurs by reducing the wind velocity close to the surface, thus reducing the erosion potential and volume of material removed. The trapping of the material already removed by wind and in suspension in the air is an important secondary effect. Vegetation is also considered the most effective control measure in terms of its ability to also control water erosion. In investigating the feasibility of vegetation types the following properties are normally taken into account: indigenous plants; ability to establish and regenerate quickly; proven effective for reclamation elsewhere; tolerant to the climatic conditions of the area; high rate of root production; easily propagated by seed or cuttings; and nitrogen-fixing ability. The long-term effectiveness of suitable vegetation selected for the site will be dependent on the nature of the cover.

The paved road infrastructure should be maintained to ensure fully covered surfaces by closure phase. This is to ensure the minimisation of vehicle entrained dust on unpaved roads.

8 AIR QUALITY MANAGEMENT MEASURES FOR THE MUROPULE B POWER PLANT

An air quality impact assessment was conducted for the proposed Morupule B Power Plant near Palapye in Botswana. The main objective of this study was to determine the significance of the predicted impacts from the proposed operations on the surrounding environment and on human health.

8.1 Conclusions

The main findings from this investigation may be summarised as follows:

8.1.1 Baseline Assessment

- The main pollutants associated with coal-fired power plants include sulphur dioxide (SO_2), particulate matter (TSP, PM10 and PM2.5), oxides of nitrogen (NO_x), carbon monoxide (CO). In addition heavy metals are associated with particulate emissions and are likely to include (but are not limited to) arsenic, cadmium, nickel, mercury and lead. Information was only available for the criteria pollutants of SO_2, NO_2, and PM10.

- The recorded on-site meteorological data at Morupule proved to be incomplete (less than 1 year) and could not be used in the current assessment. A three dimensional wind field for the area was simulated using the CALMET three dimensional meteorological model and the wind field for the site predicted. The prevailing wind field at the Morupule Power Plant site was predicted to be predominantly from the northeast with fairly strong winds (between 5 m/s and 15 m/s) associated with it. Frequent winds were also evident from the east-northeast and east.

- Ambient monitoring results from the on-site ambient SO_2 monitoring station indicated hourly averages exceeding the EC standard of 350 µg/m³ during 1999 and 2000 with no exceedances during 2001, 2005 and 2006. Only one day throughout the entire period assessed exceeded the Botswana daily guideline of 300 µg/m³. On an annual average the concentrations ranged between 6.35 µg/m³and 20.5 µg/m³. Particulate concentrations (as PM10) data was only available for one month (June 2007) reflected as twice daily readings. The PM10 concentrations were on average between 16.4 µg/m³ and 27.7 µg/m³.

- Simulated background concentrations only included the current Morupule Power Station emissions. The influence from Matimba A and Matimba B power stations (~139 km to the east-southeast) and Selebi-Phikwe Smelter (~5 km to the northeast), were regarded too distant to have a noticeable impact on the background around Morupule Power Plant.
    - SO_2 predicted concentrations were high, exceeding the EC hourly standard at Palapye but only for 7 hours throughout the year (24 hours is allowed). Highest 24-hour predictions indicated ground level concentrations ranging between 7 µg/m³ and 70 µg/m³ at the sensitive receptors of Palapye and Serowe with annual averages between 0.9 µg/m³ and 3.5 µg/m³. Palapye reflected the highest SO_2 concentrations.
    - Highest hourly NO_2 concentrations predicted at Palapye was 25 µg/m³ and 2 µg/m³ at Serowe. Daily averages ranged between 0.3 µg/m³ and 2.6 µg/m³ with annual averages well within compliance at all sites (between 0.03 µg/m³ and 0.13 µg/m³).

- Predicted concentrations of PM10, also indicated very low ground level concentrations from the Morupule Power Plant with concentrations ranging between 1.2 µg/m³ and 3.4µg/m³ over highest daily averages, and 0.06 µg/m³ and 0.2 µg/m³ over annual averages.

8.1.2 Impact Assessment of the proposed Morupule B Power Plant

For the operational phase, the predicted ground level concentrations included background concentrations from the Morupule Power Plant.

- The main sources of emissions from the power plant is the boiler stack, comprising >99% of all SO_2, NO_x, PM10, CO, and VOC emissions. Information was only available on the criteria pollutants of SO_2, NO_2 and PM10. Sulphur dioxide (SO_2), oxides of nitrogen (NO_x) and PM10 emission rates were based on the WBG emission limits for thermal power plants as provided in the technical documentation provided. Thus, the emission rates complied with the WBG requirements. Fugitive emissions derive from materials handling operations (such as coal tipping and limestone tipping), wind blown dust from storage piles and the ash dump and vehicle entrained dust from on-site roads.

- Dispersion modelling was conducted for three stack scenarios, i.e. 150 m, 200m and 300m. All other stack parameters such as temperature, exit velocities and emission rates were assumed to remain the same.

- Highest hourly SO_2 concentrations were screened against the EC standard (350µg/m³) and exceeded at Palapye for all three stack heights (i.e. 150m, 200m and 300m). The number of hours exceeding the EC hourly standard at Palapye were 13 based on the 150 m stack but reduced to 10 hours with the 200m stack and with the 300 m stack down to 6 hours (EC allows 24 hours). SO_2 predicted ground level concentrations for highest daily averages showed compliance with the Botswana and WBG guidelines at Palapye and Serowe, but exceeded the WHO_IT2 guideline at Palapye. This was true for all three stack heights, with a marginal decrease between 150m and 300m. Over an annual average none of the guidelines were exceeded at any of the residential areas for all three stack heights. The impacts on vegetation were screened against the critical level for agricultural crops, forest trees and natural vegetation where the concentrations around Palapye exceeded this threshold. The EC and UK limit to protect ecosystems were not exceeded at the areas outside the power plant.

- Predicted ground level concentrations from a stack height of 150m for NO_2 complied with the Botswana, WBG and WHO guidelines at both residential areas. Highest daily and annual averages reflected compliance with the selected guidelines off-site and at all residential areas. Given the compliance with NO_2 ambient air quality standards from a 150m stack height, the 200m and 300m were not included. This mainly has reference to SO_2 concentrations.

- PM10 concentrations were screened against the WBG, WHO and Botswana guidelines for highest daily and annual averages. The simulated ground level concentrations were well within the relative guidelines at all sensitive receptors for both averaging periods. Only close to the site did the PM10 concentrations exceeded the highest daily guidelines. This is primarily due to the fugitive dust form materials handling, wind erosion form the ash dump and vehicle entrained dust from the roads.

- Given the three stack scenarios (i.e. 150m, 200m and 300m) it can be concluded that an increase in stack height will not result in significant changes on predicted SO_2 ground level concentrations. This is due to the elevated background SO_2 concentrations.

- The significance of the predicted ground level concentrations was rated to be HIGH for SO_2 irrespective of the stack height. NO_2 was given a LOW significance since no exceedances of the ambient air quality guidelines were predicted with PM10 (unmitigated) at a MEDIUM significance. Should mitigation measures be applied to the fugitive sources the significance of particulate concentrations could reduce to a significance rating of LOW.

It should be noted that the existing Morupule Power Plant is the main contributing source of SO_2 ground level concentrations. SO_2 emissions from the current Morupule Power Plant comprise between 56% and 74% of the SO_2 concentrations predicted at Palapye, with the new Morupule B Power Plant making up the rest.

8.1.2.1 Closure Phase

- *Incremental* impacts due to rehabilitation and demolition activities to be undertaken during the closure phase are of low significance.
- *Cumulative* impacts due to rehabilitation and demolition activities, taking into account background particulate concentrations are more significant.
- No significant aspects should occur during the closure and post-closure phases given the implementation of rehabilitation strategies during the operational phase of the power plant.

8.2 Site Specific Management Objectives

The main objective of Air Quality Management measures for the proposed Morupule B Power Plant is to ensure that all operations at the power plant will be within compliance with the requirements of the Botswana government and WBG. In order to define site specific management objectives, target control efficiencies need to be defined for each of the main sources of pollution to ensure acceptable cumulative ground level concentrations.

8.2.1 Source ranking

8.2.1.1 Operational Phase

Operations resulting from the power plant would result in emissions of SO_2, NO_2, particulates (PM10, PM2.5 and TSP), CO, VOCs, H_2S, H_2SO4 and various heavy metals. The main source of emissions (for all pollutants) and impacts (for all gaseous compounds) was the boiler. The main pollutant of concern from the power generation process based on predicted ground level concentrations was SO_2.

The main sources of fugitive dust emissions from the plant operations will be wind blown dust from the ash dump and vehicle entrainment form the unpaved roads.

8.2.1.2 Closure Phase

The potential for impacts during closure phase are dependent on the extent of demolition and rehabilitation efforts during closure and on features which remain (viz. the ash dam). It was assumed that the potential for fugitive dust impacts due to these sources could be rendered negligible (and proven to be so) through comprehensive rehabilitation prior to closure.

8.2.2 Target Control Efficiencies

8.2.2.1 Operational Phase

It is recommended that the proposed Morupule B Power Plant be designed according to the design specifications used for the air quality impact assessment for PM10 and NO_2. The design should however be improved for SO_2 emissions since the WBG emission limit results in non-compliance off-site. This can be done by:

- Washing the coal to ensure a reduction in the sulphur content of the coal; and/or,
- Desulphurisation unit to be implemented to reduce SO_2 emissions.

The PM10 predicted ground level concentrations (even though within compliance at the sensitive receptors) increased 7 times with the introduction of the new power plant. It is therefore recommended that these emissions be reduced by:

- Water sprays or chemical suppressants on the unpaved roads;
- Water sprays or chemical suppressants on all material transfer points; and,
- Vegetation cover on the ash dumps (existing and future) to reduce the potential for wind blown dust.

8.2.2.2 Closure Phase

- Wind erosion from ash dump – 100% control efficiency through vegetations or rock cladding or chemical capping of side slopes and surface.

8.2.3 Identification of Suitable Pollution Abatement Measures

8.2.3.1 Power Generation

The Morupule B Power Plant design aimed to ensure compliance with both WBG stack emission limits. These emission limits did however not result in compliance with the WBG ambient ambient air quality guidelines, specifically at sensitive receptors. Flue gas desulphurisation (FGD) is one control option available to reduce SO_2 emissions are provided below.

The FGD processes are designed to remove SO_2 from the flue gas of combustion installations. The processes such as the wet scrubbing process are based on the reaction of the SO_2 with an alkaline agent added as solid or as suspension/solution of the agent in water to form respective salts. In secondary reactions SO_3, fluorides and chlorides are also removed. By using the Lime/Limestone Wet Scrubbing technology, pollutants are removed form the flue gas by chemical reactions with an alkaline liquid (suspension of calcium compounds in water). The main waste product from this process is gypsum. The wet scrubbing process represents about 90% of the total FGD-equipped electrical capacity installed in European OECD countries. Facilities are in operation at combustion units using hard coal, lignite and oil with sulphur contents from about 0.8 to more than 3.0 wt.-%. Other fossil fuels (such as peat) are presently rarely used at combustion plants with a thermal capacity >= 300 MW. The SO_2 reduction efficiency is > 90 %.

The influence of FGD- and de-NO_x-units on heavy metal emissions has been investigated mainly in the frame of mass balance studies. Wet Scrubbing -FGD-units remove a further fraction of particulate matter in flue gas in addition to dust control. Particle bound elements are removed by FGD-units with an efficiency of about 90%. In FGD-units, in particular wet-units, the gaseous compounds can additionally condense on particulate matter, which are mainly removed in the pre-scrubber. With regard to gaseous elements, various studies have shown reduction efficiencies of 30% - 50% for mercury (Hg) and 60% - 75 % for selenium (Se). Lime contributes over 90% of the input of arsenic (As), cadmium (Cd), lead (Pb) and zinc (Zn) to the FGD.

The abatement of mercury (Hg) emissions is influenced indirectly by de-NO_x-units. A high dust SCRunit improves mercury (Hg) removal in a subsequent FGD-unit using a lime scrubbing system. The SCR-unit increases the share of ionic mercury (HgCl2) to up to 95%, which can be washed out in the pre-scrubber of the FGD-unit.

Particulate emission reduction is usually achieved using abatement equipment. Electrostatic precipitators (ESPs) and fabric filters (FFs) are widely used on boilers. Cyclones (particularly multi-cyclones) can be found on smaller grate-fired boilers. Most pulverised coal fired power station boilers use ESPs although fabric filters are becoming more common.

Flue gas desulphurisation (FGD) plant can also help reduce particulate emissions from pulverised coal-fired boilers. Wet limestone FGD systems retrofitted to existing plant are generally located downstream of existing ESPs and can provide a further stage of particulate reduction. Dry lime injection FGD systems incorporate a FF for sorbent capture and PM removal.

8.2.3.2 Vehicle Entrainment on Unpaved Roads

Vehicle entrained dust from unpaved road surfaces would result in high impacts near the source and off-site during both construction and operational phase without mitigation in place. It is therefore recommended that mitigation measures be considered on all unpaved haul roads and unpaved access roads.

Three types of measures may be taken to reduce emissions from unpaved roads: (a) measures aimed at reducing the extent of unpaved roads, e.g. paving, (b) traffic control measures aimed at reducing the entrainment of material by restricting traffic volumes and reducing vehicle speeds, and (c) measures aimed at binding the surface material or enhancing moisture retention, such as wet suppression and chemical stabilization (EPA, 1987; Cowhert *et al.*, 1988; APCD, 1995). It is standard practice at most mines to utilise water trucks on the unpaved roads.

An empirical model, developed by the US-EPA (EPA, 1996), was used to estimate the average control efficiency of certain quantifies of water applied to a road. The model takes into account evaporation rates and traffic.

$$C = 100 - \left(\frac{0.8pdt}{i}\right)$$

where,

c = average control efficiency (%)
d = average hourly daytime traffic rate (hr^{-1})
i = application intensity (litres per m^2)
t = time between applications (hr)
p = potential average hourly daytime evaporation rate (mm/hr)

It was estimated that water sprays resulting in at least 85% control efficiency would be a requirement to result in a significant reduction in ground level concentrations from all on-site unpaved roads. The amount of water needed to ensure 85% control efficiency on the various haul roads can be calculated using the equation provided together with site specific evaporation data and rainfall information.

Botswana in general is a water scarce country and watering is not considered to the best option for dust suppression. It is therefore proposed that the Morupole B Power Plant rather apply chemical suppressants to the unpaved roads and access roads. Various products are on the market ensuring the containment of dust on road surfaces such as Dust-a-Side (DAS) or Dustex. Dustex is a Lignosulphonate and DAS (Dust-a-side) is a bitumen. DAS has been successfully used at Sishen Iron Ore mine in the Northern Cape, South Africa (also a water scarce area) and according to literature the control efficiency can be as high as 90%.

The control efficiency of vacuum and broom sweepers is dependent on: sweeper design and maintenance, the frequency of sweeping, the nature of the area being swept, and the particle size distribution of the dust on the roadway. Until recently, the control efficiency of vacuum sweepers was given as being generally in the range of 0% - 60% (Table 8-1). Other options include water flushing which will be dependant on the availability of water.

Table 8-1: Control efficiencies for control measures for paved and treated roads

Paved Road Control Measures	Estimated PM10 Control Efficiency	Reference
General road cleaning	35%(a)	Cowherd *et al.* 1988
Vacuum sweeping	0% - 58% 30% - 60%(b) 46%(c) 34%(d)	Cowherd and Kinsey 1986 Calvert *et al.* 1984 Eckle and Trozzo 1984 Cowherd *et al.* 1988
'Improved' vacuum sweeping	37%(d)	Cowherd *et al.* 1988
Broom sweeping	25% to 30%(e)	Cowherd *et al.* 1988, EPA 1992
Water flushing	69-0.231 V (f)(g)	Cowherd and Kinsey 1986
Water flushing followed by sweeping	96-0.263V (f)(g)	Cowherd and Kinsey 1986

Notes:

(a) Represents the upper bound on efficiencies obtained in practice since no redeposition after cleaning was considered in the estimation of the control efficiency.
(b) Refers to control efficiency provided by efficiency designed and well maintained vacuum sweepers.
(c) Control efficiency for particulates with an aerodynamic diameter of less than 30 µm (PM30).
(d) Estimated based on measured initial and residual < 63 µm loadings on urban paved roads.
(e) Maximum (initial) instantaneous control efficiencies with the efficiency decreasing after cleanup.
(f) Water applied at 2.173 litres per m^2.
(g) V = number of vehicle passes since application.

8.2.3.3 *Wind Erosion*

The largest impacting source would be wind erosion from the ash dump. With no controls on the slopes and on the surfaces of the ash dump, high impacts would be experienced off-site. It is recommended that the walls of the ash dump be vegetated or covered up to 1 m from the top throughout the life of mine. The vegetation cover should be such to ensure at least 80% control efficiency for the walls. The surface areas should be kept wet, if feasible. A water spraying system could be implemented on the surface of the ash dump covering the outer perimeter of the dump, spraying water when wind exceeds 4 m/s. Experience has shown that the threshold wind velocity of local gold mine tailings impoundments generally accords with a wind speed of ~4.5 m/s (Mitzelle *et al.*, 1995), which corresponds with a threshold friction velocity of ~0.24 m/s. Thus it was assumed that similar principles would apply to the wind erodibility of ash dumps. In addition, screens could be installed on the crest of the ash dump walls mainly to act as wind breaks and to reduce the potential for dust deposition on the vegetated side walls, hence curbing the growth of the grass. The workable surface (disturbed surface) of the ash dump should be kept as small as possible to reduce the exposed surface.

It should be noted that the wind erosion equations are very sensitive to clay percentage, moisture content and particle size distribution of the material. It is therefore recommended that samples be taken and analysed for clay and moisture content, and particle size distribution as soon as the mine and power plant is in operation. The emissions should then be re-quantified and the simulation redone for inclusion into the management plan.

Topsoil piles and the initial storage pile for overburden (the opencast mine will follow a backfill method) should be vegetated completely to ensure as little as possible disturbance of the areas.

8.3 Performance Indicators

Key performance indicators against which progress may be assessed form the basis for all effective environmental management practices. In the definition of key performance indicators careful attention is usually paid to ensure that progress towards their achievement is measurable, and that the targets set are achievable given available technology and experience.

Performance indicators are usually selected to reflect both the source of the emission directly and the impact on the receiving environment. Ensuring that no visible evidence of wind erosion exists represents an example of a source-based indicator, whereas maintaining off-site dustfall levels to below a certain threshold represents an impact- or receptor-based performance indicator. Source-based performance indicators have been included in regulations abroad. The Queensland Environmental Management Overview Strategy (QDPI, 1988), for example, states that erosion rates must not be higher than 40 t/hectare/year and that the depths of drills and gullies be limited to less than 30 cm. The ambient air quality guidelines and standards given for respirable and inhalable particulate concentrations by various countries, including Botswana, represent receptor-based objectives.

8.3.1 Specifications of Source Based Performance Indicators

- It is recommended that an online stack monitor be implemented at the boiler stack to measure SO_2 and NO_x emissions. This will eliminate the concern regarding isokenetic sampling only representing intermittent measurements and the uncertainty surrounding mass balance calculations. These continuous measurements will also provide a solid foundation for WBG emission standards compliance assessment.
- Isokenetic stack sampling should be conducted at all the remaining point sources at least once a year. This is to ensure that the dust collectors are working according to design specifications. A contractor can be used for this purpose.
- Source based performance indicators for the storage piles and ash dump would include vegetation cover density to be 80% on the entire slope up to 1 m from crest, and dustfall immediately downwind to be <1 200 mg/m^2/day.
- For unpaved haul roads on the plant site it is recommended that dustfall in the immediate vicinity of the road perimeter be less than 1,200 mg/m^2/day.
- The absence of visible dust plume at all material transfer points would be the best indicator of effective control equipment in place. In addition the dustfall in the immediate vicinity of various sources should be less than 1,200 mg/m^2/day.

8.3.2 Receptor Based Performance Indicators

Site-specific meteorological data are invaluable for air quality management purposes, most specifically being used for:

- Emission estimation, providing the climatic data needed for the application of predictive emission factor equations;
- Simulation of the atmospheric dispersion and removal of pollutants;
- Interpretation of trends in ambient air concentration and deposition level measured;
- Examining causes of peaks in pollution levels, and assisting in the investigation of complaints received; and
- Designing and reviewing the efficiency of watering control programmes.

It is recommended that the existing ambient monitoring station be continued throughout the life of the project. It is recommended that this ambient station is calibrated at least once every six months to ensure accurate and continuous data capturing. This would also prove invaluable information on the effectiveness of the mitigation measures and control equipment and should future expansions be planned.

The pollutants identified to be monitored and the monitoring equipment is aimed at monitor impacts on human health. Nuisance impacts were also taken into consideration with dust fallout buckets providing an effective and economical way of measuring dust fallout levels.

Based on the increase in particulate emissions due to the proposed operations (an even thought the PM10 concentrations were within compliance) it is recommended that a dust fallout network be designed for the site. Dust fallout buckets should be placed at the following locations:

- 1 directional dust fallout bucket next to the unpaved road from the plant to the ash dump;
- 5 directional dust fallout buckets around the existing and proposed ash dumps;
- 1 directional dust fallout bucket near each of the main materials transfer points; and,
- 1 directional dust fallout bucket down wind (i.e. to the southwest) of the coal and lime storage piles.

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APPENDIX A: TECHNICAL DESCRIPTION OF EMISSIONS QUANTIFICATION

A.1 Fugitive Dust Emissions

Emissions from materials handling operations associated with mining will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature (moisture content) and volume of the material handled. Fine particulates are most readily disaggregated and released to the atmosphere during the material transfer process, as a result of exposure to strong winds. Increases in the moisture content of the material being transferred would decrease the potential for dust emission, since moisture promotes the aggregation and cementation of fines to the surfaces of larger particles.

The four main sources of fugitive particulate emissions associated with most mining operations are: (i) materials handling operations (e.g. loading to trucks/conveyors, stockpiling and reclamation of material); (ii) entrainment of roadway dust by on-site vehicles; (iii) wind erosion of stockpiles and open areas; and (iv) drilling and blasting operations.

A.1.1 Fugitive Dust Emissions from Tipping Operations

The following predictive equation was used to estimate emissions from anticipated material tipping operations are as follows:

$$E_{TSP} = 0.0016\frac{(U/2.2)^{1.3}}{(M/2)^{1.4}} \quad (1)$$

where,

ETSP	=	Total Suspended Particulate emission factor (kg dust / t transferred)
U	=	mean wind speed (m/s)
M	=	material moisture content (%)
k	=	particle size multiplier (dimensionless)

The particle size multiplier varies with aerodynamic particle sizes and is given as a fraction of TSP. For PM30 the fraction is 74%, with 35% of TSP given to be equal to PM10, and the PM2.5 fraction is 11% of TSP (EPA, 1998a). Hourly emission factors, varying according to the prevailing wind speed, were used as input in the dispersion simulations. Moisture content for the different types of material were not available and use was made of the typical moisture contents given by US-EPA in the section pertaining aggregate handling and storage piles (EPA, 1998a).

A.1.2 Wind Erosion from Exposed Areas

Significant emissions arise due to the mechanical disturbance of granular material from open areas and storage piles. Parameters which have the potential to impact on the rate of emission of fugitive dust include the extent of surface compaction, moisture content, ground cover, the shape of the storage pile, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture contents, whether due to precipitation or deliberate wetting, promote the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. Surface compaction and ground cover similarly reduces the potential for dust generation. The shape of a storage pile or disposal dump influences the potential for dust emissions through the alteration of the airflow field. The particle size distribution of the material on the disposal site is important since it determines the rate of entrainment of material from the surface, the nature of dispersion of the dust plume, and the rate of deposition, which may be anticipated (Burger, 1994; Burger et al., 1995).

An hourly emissions file was created for each of these source groups. The calculation of an emission rate for every hour of the simulation period was carried out using the ADDAS model. This model is based on the dust emission model proposed by Marticorena and Bergametti (1995). The model attempts to account for the variability in source erodibility through the parameterisation of the erosion threshold (based on the particle size distribution of the source) and the roughness length of the surface.

In the quantification of wind erosion emissions, the model incorporates the calculation of two important parameters, viz. the threshold friction velocity of each particle size, and the vertically integrated horizontal dust flux, in the quantification of the vertical dust flux (i.e. the emission rate). The equations used are as follows:

$$E(i) = G(i)10^{(0.134(\%clay)-6)} \tag{2}$$

for

$$G(i) = 0.261\left[\frac{P_a}{g}\right]u^{*3}(1+R)(1-R^2)$$

and

$$R = \frac{u_*^t}{u^*}$$

where,

$E_{(i)}$	=	emission rate (g/m²/s) for particle size class i
P_a	=	air density (g/cm³)
g	=	gravitational acceleration (cm/s³)
u_*^t	=	threshold friction velocity (m/s) for particle size i
u^*	=	friction velocity (m/s)

Dust mobilisation occurs only for wind velocities higher than a threshold value, and is not linearly dependent on the wind friction and velocity. The threshold friction velocity, defined as the minimum friction velocity required to initiate particle motion, is dependent on the size of the erodible particles and the effect of the wind shear stress on the surface. The threshold friction velocity decreases with a decrease in the particle diameter, for particles with diameters >60 µm. Particles with a diameter <60 µm result in increasingly high threshold friction velocities, due to the increasingly strong cohesion forces linking such particles to each other (Marticorena and Bergametti, 1995). The relationship between particle sizes ranging between 1 µm and 500 µm and threshold friction velocities (0.24 m/s to 3.5 m/s), estimated based on the equations proposed by Marticorena and Bergametti (1995), is illustrated in Figure A-1.

The logarithmic wind speed profile may be used to estimate friction velocities from wind speed data recorded at a reference anemometer height of 10 m (EPA, 1998c):

$$U^* = 0.053U_{10}^+ \quad (3)$$

(This equation assumes a typical roughness height of 0.5 cm for open terrain, and is restricted to large relatively flat piles or exposed areas with little penetration into the surface layer.)

The wind speed variation over the dump is based on the work of Cowherd et al. (1988). With the aid of physical modelling, the US-EPA has shown that the frontal face of an elevated pile (i.e. windward side) is exposed to wind speeds of the same order as the approach wind speed at the top of the pile. The ratios of surface wind speed (us) to approach wind speed (ur), derived from wind tunnel studies for two representative pile shapes, are indicated in Figure A-2 (viz. a conical pile, and an oval pile with a flat top and 37° side slope). The contours of normalised surface wind speeds are indicated for the oval, flat top pile for various pile orientations to the prevailing direction of airflow. (The higher the ratio, the greater the wind exposure potential.)

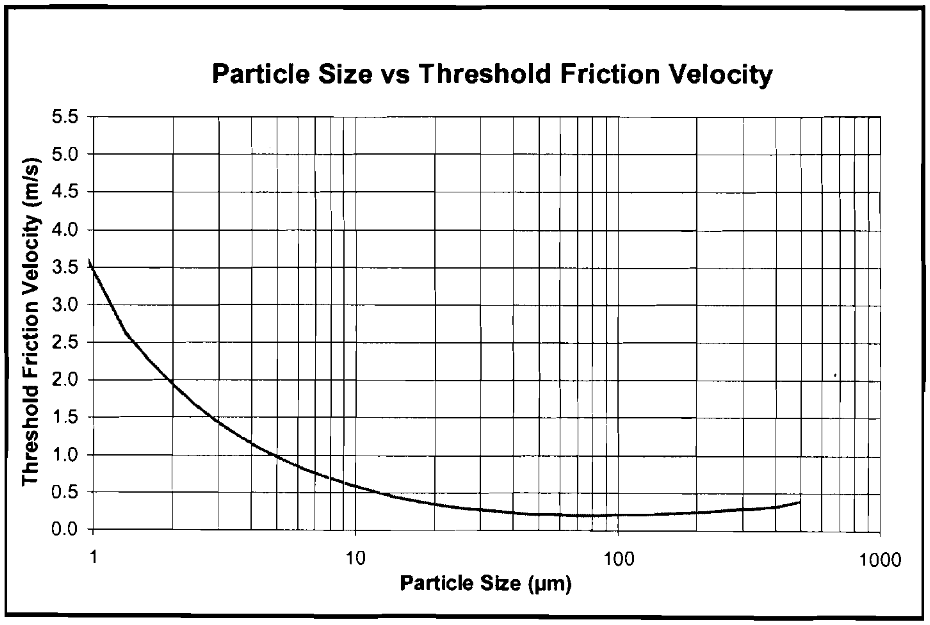


Figure A- 1: Relationship between particle sizes and threshold friction velocities using the calculation method proposed by Marticorena and Bergametti (1995).

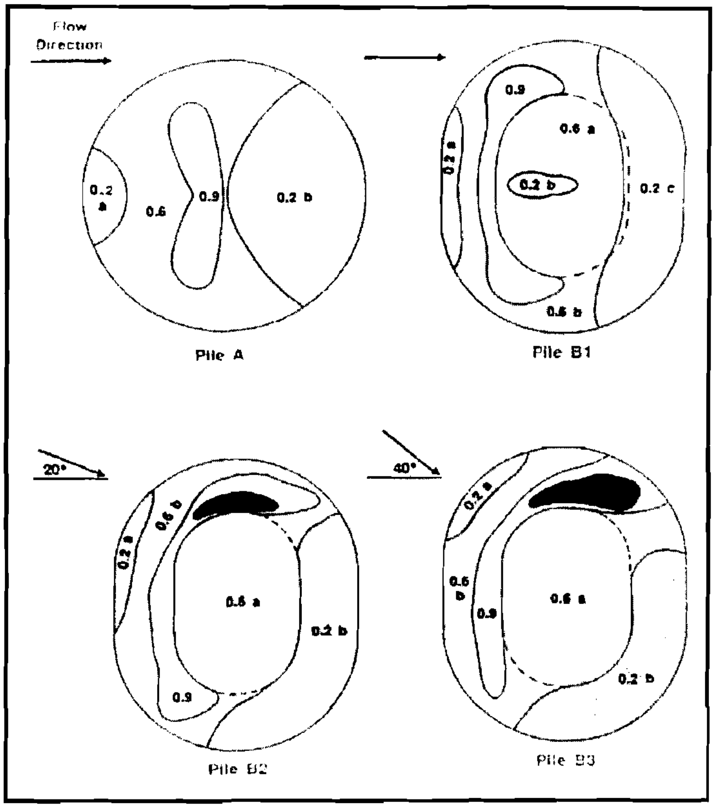


Figure A- 2: Contours of normalised surface wind speeds (i.e. surface wind speed / approach wind speed) (after EPA, 1998c).

A.1.3 Vehicle-Entrained Emissions from Unpaved Roads

The force of the wheels of vehicles travelling on unpaved roadways causes pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to affect the road surface once the vehicle has passed. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic. In addition to traffic volumes, emissions also depend on a number of parameters which characterise the condition of a particular road and the associated vehicle traffic, including average vehicle speed, mean vehicle weight, average number of wheels per vehicle, road surface texture, and road surface moisture (EPA, 1998b).

The unpaved road size-specific emission factor equation of the US-EPA was revised in their 1998 AP42 document on Unpaved Roads and was used in the quantification of emissions for the current study. It is given as follows:

$$E = k\left(\frac{s}{12}\right)^a \left(\frac{W}{3}\right)^b \qquad (4)$$

where,

E = emissions in kg of particulates per vehicle kilometer traveled (lb/VMT)
K,a,b and c = empirical constants (Table E-1)
s = surface material silt content (%)
W = mean vehicle weight (tonnes)

The metric conversion from lb/VMT to grams (g) per vehicle kilometre travelled (VKT) is as follows:

1 lb/VMT = 281.9 g/VKT

Table A- 1: Constants for unpaved road equation (US.EPA, 1998).

[illegible]	PM2.5	PM10	[illegible]
K (lb/VMT)	0.38	2.6	10
a	0.8	0.8	0.8
b	0.4	0.4	0.5
c	0.3	0.3	0.4

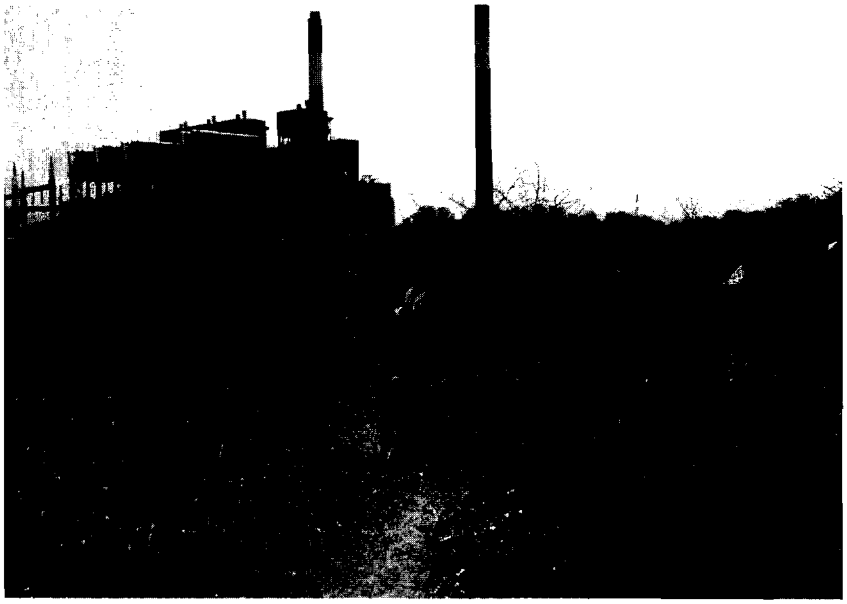
Notes: (1) PM-30 may be used as a substitute for TSP.

Appendix 4.4

Archaeological impact assessment report

AN ARCHAEOLOGICAL IMPACT ASSESMENT REPORT

FOR THE PROPOSED MORUPULE B POWER STATION



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OCTOBER 2007

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1.0 Introduction

This Archaeological Impact Assessment (AIA) report presents the findings of a field survey study that was carried out at the proposed site for the Morupule B Power Station near Palapye, Central District of Botswana. The purpose of the survey was to determine as to whether there are any archaeological remains within or along the proposed power station development site. Since some of the project activities will involve excavating or disturbing the landscape, it was therefore necessary to carry out the survey to determine how the development activities would impact the archaeology in the study area.

1.1 The Monuments and Relics Act 1972 (As amended 2001)

Archaeological sites are the main source of information about Botswana's past and the only tangible evidence of that past. The protection of such sites is therefore essential to safeguard the national heritage which includes a written history beginning from around the 1850's. Such sites are protected through the Monuments and Relics Act 2001. This Act, which is implemented, monitored and enforced by the National Museum, protects all archaeological sites (ancient monuments) and artifacts (man-made objects or 'relics') dating before 1902, whether or not they are known and registered with the National Museum, as well as any historic structures and objects since 1902 that have been proclaimed a recent historic monument, historic landscape or recent artifact, as well as natural features that have been proclaimed a natural monument.

This AIA involves the physical survey of the project area so that an inventory of sites within the impact zone can be provided. These sites are evaluated for their importance on the basis of research value, preservation and potential as public sites; importance can be graded from 1= of national importance to 5=not important.

The impact of the proposed development on the site has been assessed. Based on this assessment, recommendations have been made as to whether or not a site may be destroyed, or whether mitigation, such as mapping, excavation dating, etc will be required.

This AIA is therefore in compliance with the requirements of the Monuments and Relics Act of 2001, under which it is illegal for any unauthorized person to alter, destroy or damage ancient sites or monuments, or to remove archaeological materials from their sites of discovery. The Act provides for an AIA to be carried before any form of construction or development takes place in any given area in Botswana.

Under Section 18(1) such places and objects may be destroyed only if an Impact Permit is issued. Such a permit needs to be applied for from the Botswana National Museum, and that permit is normally issued only when the Botswana National Museum is satisfied that the Monument or relic is not of national importance and that enough information is rescued about the monument or relic as a mitigation measure. It is only after the impact assessment has been carried out and the results made available to the Botswana National Museum, that the developer may be given permission to impact on the land based on the recommendations of the report.

2.0 Environmental Background

The proposed power station development site is within the existing Morupule Power Station site located in Palapye, in the central district of Botswana. The site under investigation trends to the east and south-east and it is south of the existing Morupule Power Station. It is approximately 7 km west of Palapye along the Palapye-Serowe road. The area is generally flat and largely undeveloped except for the existing nine-hole golf course, clubhouse building, railway line trending east-west in the southern side of the site, overhead high capacity power lines across the southern fraction of the site, a school and some residential developments in the south-western portion of the site.

2.1. Brief Geological Background

Geological maps indicate that the project area may straddle a geological boundary amidst the Lotsane Formation of the Palapye Group, comprising micaceous varicoloured siltstone, and possibly the Ecca Group, which comprises interbedded carbonaceous sedimentary rocks (siltstone, mudstone or sandstone) and probably coal. There are also transported aeolian (windblown) soils covering the site.

The underlying geological material comprises of cemented aeolian sands, pedocrete (ferricrete and calcrete overlying varicoloured siltstone, possibly of the Lotsane Formation. However, there are no rock outcrops in the project area.

3.0 Archaeological Background

Morupule Coal Mine is located near Palapye in the East Central part of Botswana. Surveys of the eastern parts of Botswana have identified sites ranging from the early Stone Age through to the Late Stone Age, to the Iron Age and the historic period. In other words, there are signs of human activity in the eastern parts of Botswana from as early as two million years ago until historic times.

Stone Age research in this area has been very limited and this is evident from the National Museum site register whereby very few sites have been recorded. The Stone Age in terms of early human activity has been divided into three phases, these being; Early Stone Age [ESA], Middle Stone Age [MSA], and Late Stone Age [LSA]. The divisions were based on distinctive stone tool industries which fall within these different time scales in comparison with other sites elsewhere in Southern and Eastern Africa [Volman 1984].

The Early Stone Age dates from around two million, to about 120,000 years ago. Sites, which fall within this time frame, are very rare in this area, and according to the National Museum site register-listing records, two sites belonging to this period have been recorded within the Morupule neighborhood. This lithic industry is mainly characterized by crude and large stone tools, which include choppers, and axes, hammer stones and cleavers. The period after the Early Stone Age (ESA) is known as the Middle Stone Age (MSA). This period has been placed between 150 000 years ago to around 30 000 years ago. The MSA industry is characterized by a predominantly smaller lithic industry than the ESA. The stone tools are flake-like and they are more varied and they appear to have been made for specific duties. The tools include: blades, denticulate, scrapers, etc. These tools have been associated with *Homo sapiens.*

The Late Stone Age (LSA) is dated from around 20 000 years ago until quiet recently. Much smaller stone tools, commonly called microliths, characterize this period. The stone tools from this period are not only much smaller, but are also more specialized. Recently more LSA sites were discovered in the Letsibogo area [Campbell *et al* 1995].

The Stone Age period precedes by the Iron Age, which represents some of Botswana's most researched phenomena, especially in Eastern Botswana. This period is far better known in comparison to the Stone Age. The major contribution to the study of archaeology of this area has been the work of Denbow [1979, 1982, and 1983]. Denbow identified more than 400 archaeological sites in Eastern Botswana. The vast majority of these sites were defined or classified as being part of the Toutswe Tradition, which were identified from aerial photographs. It was found that these sites with dense concentrations of dung sponsored a distinct kind of vegetation [*Cenchrus Ciliaries*-grass], which enabled sites to be recognized with comparative ease on the aerial photographs [Denbow, 1979]. The grass turns white in winter and thus it appears as white patches on aerial photographs, which are easily recognizable. It has since become clear that *Cenchrus Ciliaries* is dominant in most of the Toutswe type-sites. This is because the grass coexists with other grass species and when a site is abandoned it gradually replaces the other species. This is attributed to the high phosphate content of the soil, to which *Cenchrus Ciliaries* easily adapts, when compared to other species [Segobye 1994].

Archaeological excavations at several sites confirm that the Toutswe Tradition was a coherent archaeological entity, which flourished in Eastern Botswana between around A.D. 700 and 1400. In particular there seems to have been an increase in settlement between A.D. 900 and 1200 [Reid 1996].

The 400 Toutswe sites that Denbow identified were further divided into three different classes of sites based on the size of the middens that could be recognized on their surface. He defined this tripartite settlement distribution pattern as Class 1, 2 and 3. Class 1 being small and located in low-lying areas or on hilltops.

Class 2 sites were significantly larger and were always on hilltops and finally Class 3 were found on hilltops and had very large middens. The settlement sizes and their distribution were interpreted in terms of a settlement hierarchy, with power within the society being focused on Class 3 sites, and this included Toutswemogala Hill. [Denbow 1984a].

It is evident from the national Site register that many Toutswe type-sites have been identified in and around the mining lease area, including other Iron Age cultures, which are not classified as Toutswe.

3.1. Brief historical background

Difaqane wars in the 18th century had some positive and negative aftermaths among the people of Southern Africa. These wars also had implications among the Batswana in different places including areas around the project area. The Ngwato settled on the area near Shoshong hills for defense from the Amandebele (Lye. W and Murray C 1980). In 1889 Khama III decided he would leave Shoshong for Palaptswe as Shoshong had become a 'Desert City' in the 1880s almost waterless and very dirty (Parsons N 1998). Phalaptswe was a place of historical interest to Khama; it was a temporary capital for Amandebele in 1836-37 and for the cattle raiders in 1863 also. Phalaptswe then became a token of Khama's alliance with the British forward movement against the Amandebele. Phalatswe was situated in the north side of Tswapong hills, therefore was appropriate for defense from the BaSeleka in 1886 and the Boers in 1887 (Parsons N, 1998).

According to Parsons, Phalatswe became depleted in September 1889, the soil was contaminated and there was malaria fever outbreak. Khama's wife, Sekgoma's mother died and in 1893 the fever hit again and Khama's other wife died. Drought and crop failure were next in 1894-97. Khama then decided to move his capital to Serowe in September 1898 as his people were complaining of water scarcity, but changed his mind again in November of the same year. The Bangwato Started moving to Serowe in sections in 1901, but Khama still refused to move.

In June 1902 there was a major population movement of the population to Serowe together with Khama and in August 1902, he sent a regiment to burn down the old capital (Parsons N, 1998).

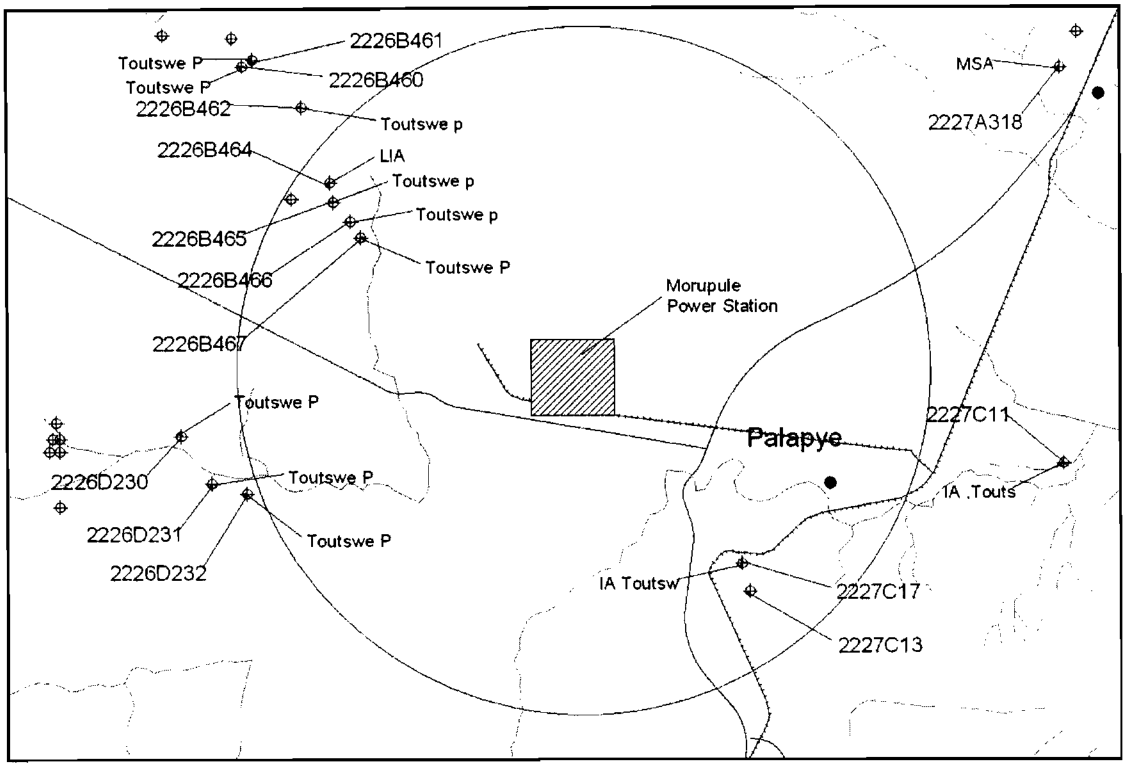
4.0 Survey Method

Before the survey was conducted, archival material kept at Botswana National Museum was consulted. Around Morupule's vicinity about 17 sites were recorded and indicated in the 27-C1-map sheet. These were mostly sites of Stone Age, Iron Age and historic period with the Toutswe culture mostly represented in the Iron Age [**see Table 1**]. Previous investigations done in and around Morupule area were also consulted for reference purposes. A handheld GPS was used to record and mark any important features encountered in the survey.

Table 1 List of reported sites as listed by the Botswana National Museum

Site No.	Type	Location	Name
27-C1-1	Toutswe	194 E 070 N	Naboom Hill
27-C1-2	Toutswe	245 E 056 N	N\A
27-C1-3	Toutswe	103 E 030 N	N\A
27-C1-4	Stone Age\ Toutswe	185 E 926 N	Ikotwe Hill
27-C1-5	Middle Stone Age	020 E 709 N	Ramherwane Hill
27-C1-6	Middle Stone Age	016 E 509 N	N\A
27-C1-7	Iron Age\ Toutswe	101 E 539 N	Khurumela Hill
27-C1-8	Historic	Palapye	Postal tree
27-C1-9	Toutswe	019 E 879 N	Ramherwane Hill
27-C1-10	19^{th} Century	2233 83.4S\2708 83.6E	Malekakopu Hill
27-C1-11	19^{th} Century	224323.9S\270115.9E	N\A
27-C1-12	Iron Age	749 2700E\524600N	East of Lecheng
27-C1-13	Iron Age	0525300E\7493300N	Lecheng South East
27-C1-14	Iron Age	0525500E\7493400N	N\A
27-C1-15	Iron Age	052400E\7493100N	West of Lecheng
27-C1-16	Early Stone Age	0508937E\7505076N	Palapye
27-C1-17	Early Stone Age	0511051E\7506125N	Palapye

Figure 1: The location of sites in or adjacent to the study area (Source: CDILUP, FFM, 2000)



A team of four, including the author surveyed the proposed Morupule B Power Plant site and this was done on foot with the aid of maps, aerial photographs and a GPS to mark and record anything that could bear archaeological significance. Surface surveying was done in transects covering a total width of 150 meters and this was achievable as the whole site was sparsely vegetated with short shrubs which made it easily accessible. For additional information, interviews from the previous research conducted in the same area by the author are annotated in **Appendix 1**.

5.0 Results of Survey

The focus of the investigation was carried out in the primary area where the main plant is proposed. The surrounding area around the primary area was also included in the investigation (**see Appendix 2**). The possible extension area was also covered (**see Appendix 2 for area marked B**). This area was however mostly covered by rubble dumps. Generally, the survey revealed nothing of archaeological significance in the total area walked. However, given that the project area is in the fringes of the Kalahari Desert, some archaeological materials may be buried or covered by the sand. Additionally, the rubble in the dumping area (**Figure 2**) to the east of the main entrance to the existing power station may have some imported cultural materials which are now covered by the dumps. Other human traces encountered in the area are the recent kraals (**Figure 3**) and modern house structures (**Figure 4**) which do not bear any archaeological significance. Other relevant features found in the area is a heap of Calcrete (**Figure 5**) exposed during construction of the golf clubhouse and abandoned mound of coal (**Figure 6**).

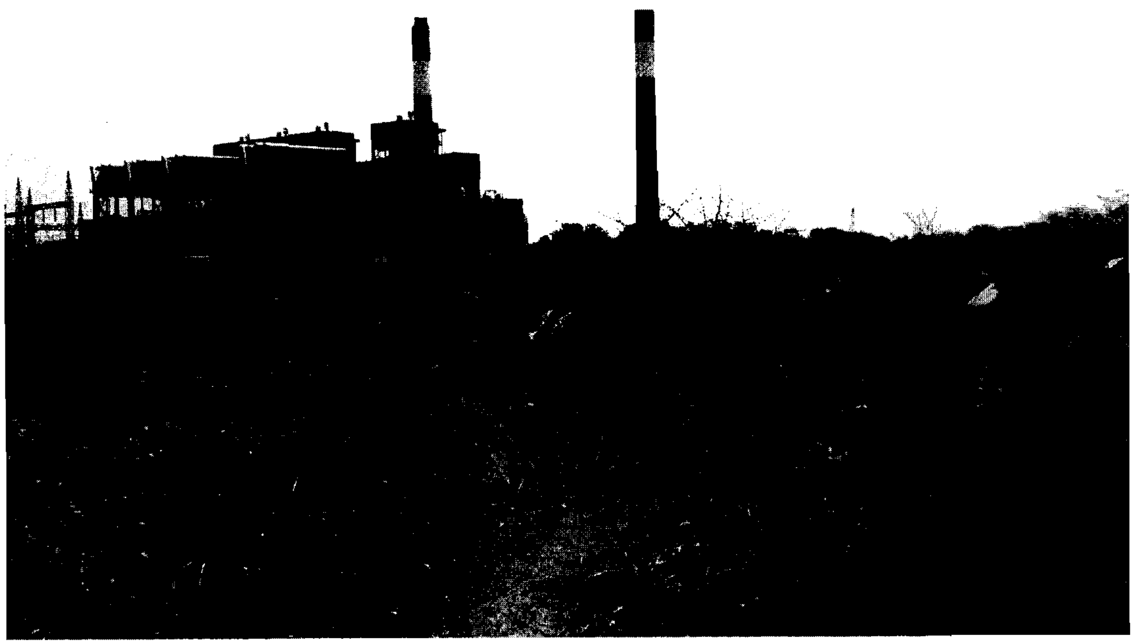


Figure 2: Rubble behind the existing power station

Figure 3: Abandoned kraal

Figure 4: Abandoned modern house structure

Figure 5: Heap of Calcrete

Figure 6: Abandoned coal heap in area B

6.0 Summary and Recommendations.

This report has presented the findings of a survey done on the site for the proposed Morupule "B" Power Station. Nothing of archaeological importance was identified during the survey within the development area. However, the developer should be cautioned that the absence of archaeological material on the surface of the area does not rule-out the probability of encountering any during the course of project activities as the sands may cover some artifacts. Additionally, the developer should be encouraged to immediately inform the Botswana National Museum should they encounter anything of archaeological significance. If the proposed project site will be extended to the area marked B (Appendix 2), it is recommended that close archaeological monitoring be adhered to during site clearance as this area has not been surveyed due to the rubble dumps. With all this in mind, it is recommended that the proposed development can proceed.

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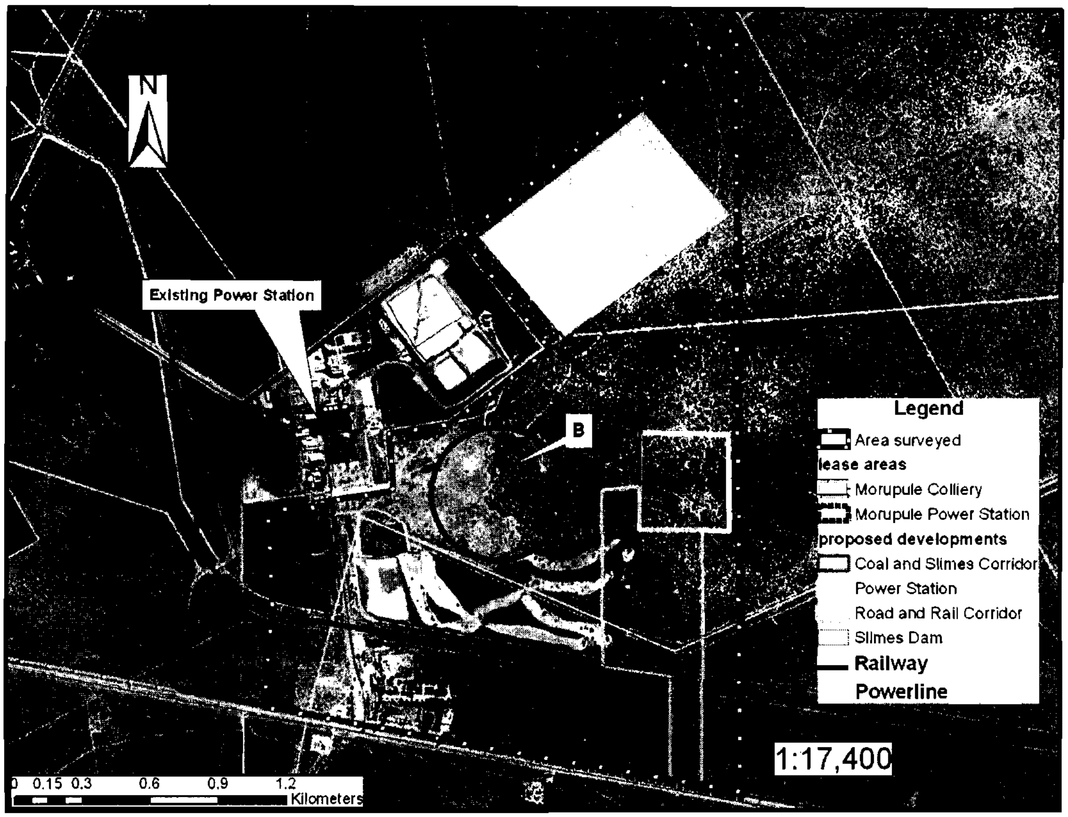
8.0 Appendix 1: Interviews conducted during a previous study by the same author in the Morupule mine project area

No	Name	Birth Year	Local area	Occupation	Comments
1	Abram Kedikilwe	1943	Morupule Lands	Farmer	Reported the presence of pottery along the Morupule river
2	Gaboratwe Lesole	1923	Morupule lands	Farmer	Has not seen or heard anything
3	Bashi Moyonda	1962	Molapowadipitse	Sherpard	New in the area and so has not seen anything yet
4	Gaoduelwe Lesole	1970	Molapowadipitse	Sherpard	Has not seen or heard anything
5	Marea Kobe	1952	Molapowadipitse	Farmer	Has not seen or heard anything
6	Motshabiwa Tshwantsho	1930	Molapowadipitse	Farmer	Has not seen or heard anything
7	Mosarwa Molete	1922	Molapowadipitse	Farmer	Has not seen or heard anything
8	Lorato Tumelo	N\A	Mine Village	Mine Environmentalist	Has not seen or heard anything

9.0 Appendix 2: Map of study area



Appendix 4.5

Social impact assessment report

SOCIAL IMPACT ASSESSMENT

DRAFT REPORT

MORUPULE B POWER STATION PROJECT
BOTSWANA

October 2007

Prepared for

Ecosurv Environmental Consultants

by

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SECTION 1: INTRODUCTION

1.1 BACKGROUND TO STUDY

The Botswana Power Corporation (BPC) has experienced an unprecedented increase in demand for electricity averaging 10% per annum. In terms of current generation capacity the existing Morupule Power Station generates 132 MW per annum. This is equivalent to approximately 30 % of Botswana's current demand for electricity. The remaining 70 % is imported from other countries, with South Africa being the main supplier. The shortage of surplus power generation capacity in Southern African is affecting Botswana's power imports. As a result Botswana must either find an alternative source or be exposed to higher energy prices for imported power.

In response to this situation a feasibility study carried out in 2004 concluded that the most suitable option for the rapidly developing Botswana economy is to expand the existing power station at Morupule. Based on these findings BPC has taken the decision to expand the Morupule Power Station. Phase 1 of the expansion option includes the construction and operation of Morupule B Power Station which will be a coal-fired, steam turbine driven thermal plant with a capacity of 600 MW (4 units of 150 MW each) together with necessary associated infrastructure. It is understood that an additional 600 MW will be installed in Phase 2, after an add-on feasibility study has been completed, bringing the aggregate to 1200 MW. Phase 2 does not form part of this study.

The site for the new power station is located within the current lease area for the BPC Morupule power station, east of the existing station (Figure 1.1). The project will thus benefit from the proximity of the existing coal supplies and transport infrastructure. Approximately 2.6 million tonnes of coal per annum will be supplied to the plant through a conveyor belt from the adjacent Morupule Colliery. A wellfield approximately 80 km north-west of the existing plant is currently under development to augment the water supply to the existing station and meet the needs of the proposed Morupule B Power Station. The water supply (well field and supply pipeline), the expansion of the Morupule Colliery and the transmission line for the electrical grid connection are understood to be undergoing separate Studies and as such, these aspects of the Phase 1 development are not covered by this study.

The construction phase of the Morupule B Power Station is expected to be undertaken over 3 years with the new plant being commissioned between January and October 2010. In terms of employment opportunities the construction phase is expected to employ between 1000 and 1500 people. The operational phase will create approximately 240 permanent jobs.

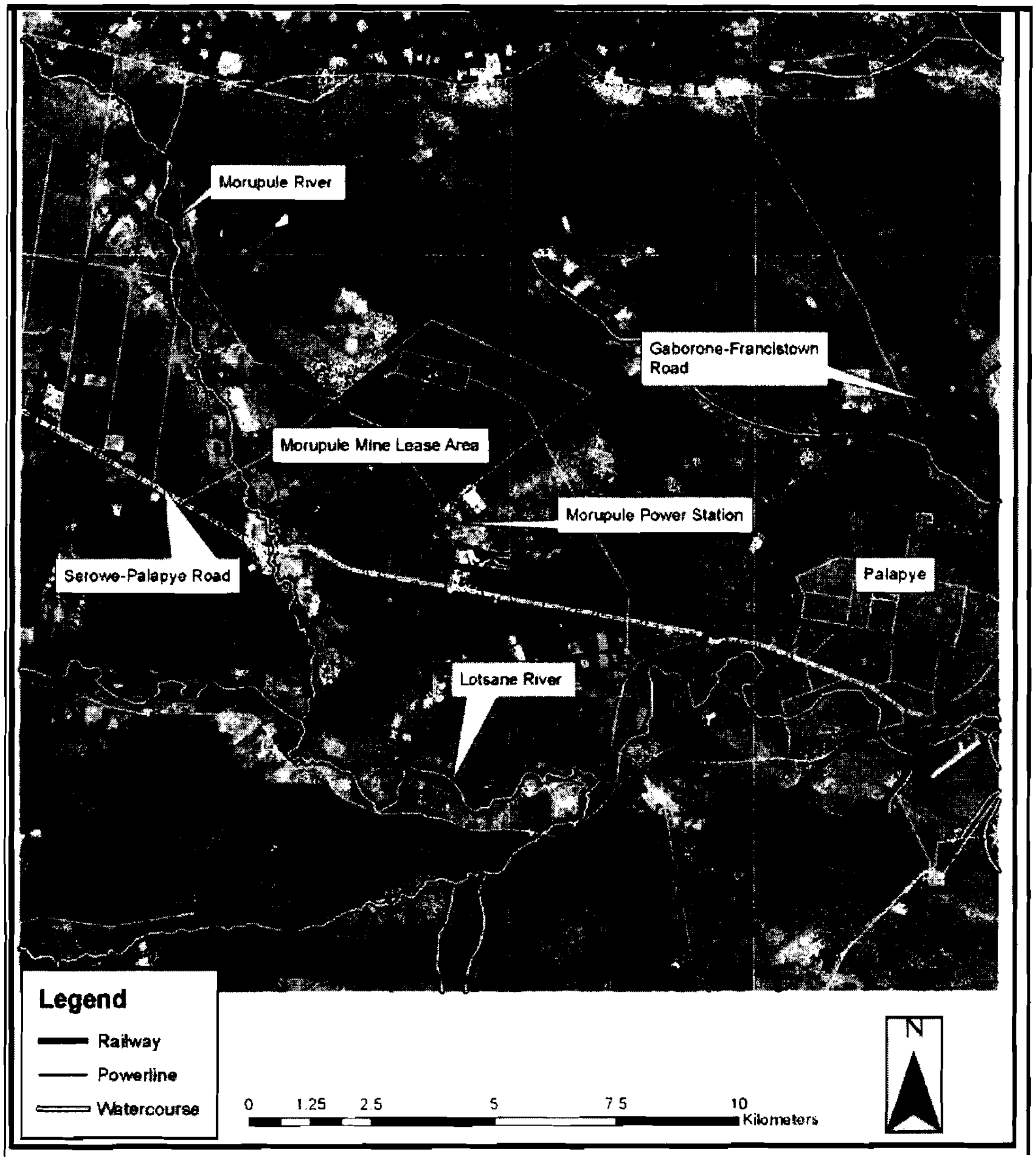


Figure 1.1: Locality Map

1.2 TERMS OF REFENCE

The terms of reference for the study are to identify and assess the potential social impacts associated with the proposed development of Phase 1 the Morupule B Power Station which. This will include a coal-fired, steam turbine driven thermal plant with a capacity of 600 MW (4 units of 150 MW each) together with necessary associated infrastructure. Approximately 2.6 million tonnes of coal per annum will be supplied to the plant through a conveyor belt from the adjacent Morupule Colliery.

1.3 APPROACH

The approach to the study is based on internationally accepted guidelines for Social Impact Assessment. Specific activities included:

- Interaction with the ESIA consultants to discuss study;
- Review of existing project information;
- Collection and review of relevant reports and baseline socio-economic data on the area;
- Site visit and interviews with key stakeholders in the area including local authorities, farmers and local business;
- Identification and assessment of the key social issues and opportunities;
- Preparation of Draft Social Impact Assessment (SIA) Report.

1.4 ASSUMPTIONS AND LIMITATIONS

1.4.1 Assumptions

Alternatives: No Go Option
The strategic importance of the project for Botswana's future energy security is acknowledged. As such the "No Go Option" is not regarded as a feasible option and, as such, has not been assessed.

Alternatives: Site options
In order to take advantage of the existing infrastructure the proposed new power station is located next to the existing Morupule Power Station and the Morupule Colliery. While the exact location of the new power station on the land currently leased by BPC has not been determined, no alternative sites beyond the existing power station lease area have been assessed.

Project related data
It is assumed that the project information provided by the proponent is accurate.

1.4.2 Limitations

Due to time constraints the lead author was only able to spend one day on site. However, subsequent follow up work on site was undertaken by Tshepo Phuthego. This included focus group meetings with local authorities, farmers and businesses. The information from these meetings was forwarded to the lead author for consideration. In this regard the lead author is confident that the information contained in this report is adequate to make an informed decision.

1.5 REPORT STRUCTURE

The report consists of four sections, namely:

- Section 1: Introduction;
- Section 2: Description of the study area;
- Section 3: Assessment of key social issues;
- Section 4: Key findings and recommendations.

SECTION 2: DESCRIPTION OF THE STUDY AREA

2.1 INTRODUCTION

Section 2 provides a description of the study area and surrounding land uses. The information contained in this section is drawn from Section 5, Baseline, of the Environmental and Social Impact Assessment.

2.2 SOCIO-ECONOMIC ENVIRONMENT

Data on the socio – economic environment was sourced from the Central District Development Plan 6, Central District Council Land use Plan, Palapye Planning area Development Plan 1995 – 2015 (currently under review), Botswana National settlement Policy, Central Statistics Office Documents, and the internet.

2.2.1 National context

Botswana is a land locked country located in Southern Africa with a population of approximately 1.7 million persons and an annual growth rate of 3.6% (2001 Population census). The country has enjoyed a stable democracy since independence in 1966. Botswana is also one of the fastest growing economies in Africa. This growth has been boosted by natural resources such as diamonds and soda ash and beef processing. Tourism is also an important economic sector, contributing in the region of 12% to the GDP in 2003 – 2004 period (www.state.gov/r/pa/ei/bgn/1830). In terms of administration, the country is divided into four planning regionsn namely the Eastern, South Eastern, Western, and Northern regions. In addition the country is divided into nine district and five town councils.

Land use in Botswana has been divided into four categories namely settlement, agriculture and wildlife and forest reserves. On the other hand, land tenure has been divided into three categories which are tribal, state and freehold. Tribal land accounts for about 71% of the land whiles state land and freehold are 23% and 6% respectively.

Transport and communications infrastructure in Botswana is well developed and most parts of the country are connected by well maintained tarred roads. Telephone communications are also available in most parts with services rendered by Botswana Telecommunications Corporation as well as two cellular phone providers. These factors, combined with the country's political stability, have contributed to Botswana's economic development and growth.

In terms of basic services the government of Botswana provides basic health and education services to all citizens. Primary school education is provided for free. As a result the adult literacy rate for the Republic of Botswana currently stands at 81%.

However, there is a small cost recovery fee charged for provision of other services such as refuse collection, and tertiary education.

2.2.2 Regional and local context

The proposed project site falls within the Palapye Planning Area which in turn is located within the Central District. The site itself falls within the existing Botswana Power Corporation (BPC) Lease area which is located approximately 4 km west of the developments of Palapye village and 1 km east of the existing power station. In terms of location, Palapye is strategically located at the junction of major roads linking Gaborone and Francistown to the south and north respectively and Serowe to the west. This gives the village an advantage as a social, administrative and commercial centre.

In terms of the settlement hierarchy Palapye is classified as a Primary III centre in the Central District and falls within the eastern planning region. Planning regions were done in order to harmonise the planning, provision and maintenance of infrastructure and services. The Central district is divided in traditional settlement patterns of village, lands and cattle posts. In Palapye, the older residential areas are mostly of a nucleated pattern while the newer areas have a linear pattern. Most businesses are located along the A1 trunk road and also along the tarred roads within the village. In terms of land tenure most of the land within Central district is tribal with just two areas of state owned land. The Palapye planning area is located on tribal land which has to cater for different uses including residential, commercial, agriculture and industrial. There is also freehold land around the Palapye Planning area.

2.2.2.1 Population

Central District has a population of about 501 381. The majority of the population (153 035) are concentrated in the Serowe – Palapye sub district. The sub district covers an an area of 30 925km^2 with a population density of 5 persons/km^2. Palapye is the third largest town in the Central district and had estimated population of 26,293 in 2001 (2001 Population Census). Palapye has experienced phenomenal population growth over the years (20.4% between 1991 and 2001) partly due to a number of factors which include the designation of the village as the Serowe – Palapye Sub District headquarters, and the opening of the Morupule Coal Mine. (Source: CSO 2001). According to the 1991-2021 Population Projections, Palapye population is set to grow by an estimated 2% between 2006 and 2011. Females have consistently accounted for a greater proportion of the total population. Table 2.1 provides information on the population of Palapye.

Table 2.1: Population figures for Palapye (1981 – 2001)

Population and Housing Census Year	Total population	Males	Females
1981	9,593	Data not available	
1991	17,362	8,098	9,264
2001	26,293	12,087	14,206

2.2.2.2 Employment

Employment opportunities in the area are linked to variety of economic activities, which include agriculture (arable and pastoral), mining, industrial and commercial, manufacturing, and construction. The location of the Morupule coal mine and the BPC Power Station has boosted employment opportunities in the Palapye area. Unemployment rates are high as indicated in (Table 1).

Table 1: Employment statistics: Population 12 years and older by type of economic activity in the Serowe-Palapye sub-district 2004 (Source CSO, Page 69 of the Botswana AIDS Impact Survey 11)

Sector	Number of People	% of Sub-District
Paid employee	33670	50.05 %
Self employed	6245	9.28 %
Working family business	421	0.63 %
Working in lands/cattlepost (unpaid)	13146	19.54 %
Other economically active	213	0.32 %
Actively seeking employment	13582	20.19 %
Unemployment rate		20.20 %

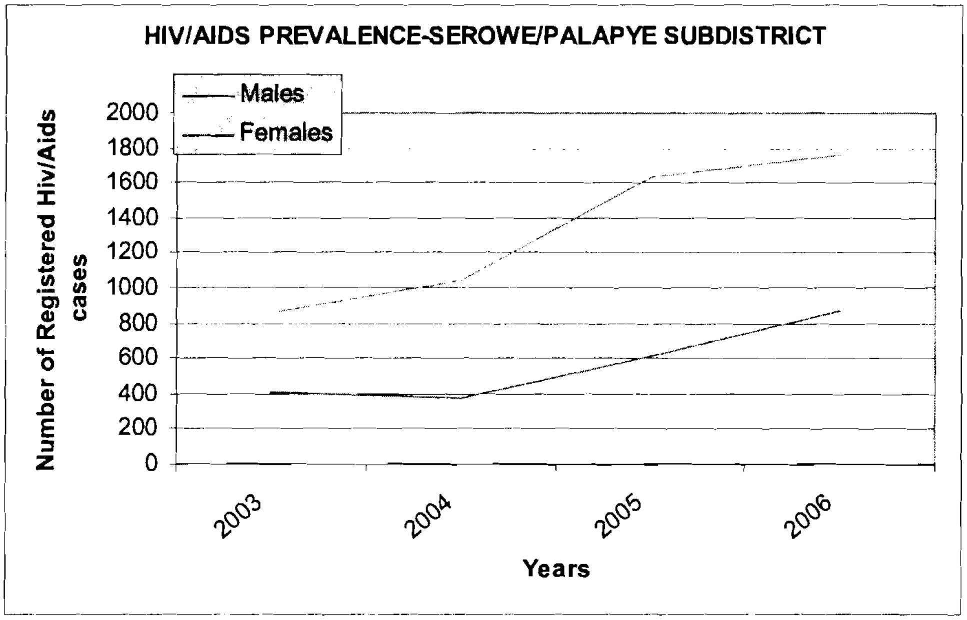
It is clear from the statistics that unemployment is high and that self-employed initiatives are few.

Tourism in the Central District is still largely wildlife based, with most of the operations located outside the village of Palapye. However, there are a number of hotels and lodges in Palapye, which offer employment opportunities for local residents.

2.2.2.3 Health

Health data (HIV/AIDS and Sexually Transmitted Infections prevalence in Palapye is high and at present increasing.

Figure 1: Total HIV/AIDS infections in Serowe-Palapye Sub-District 2003-2006 (Source: Council Health – Palapye)



2.2.2.4 Services

Education

The literacy rate for Central District was in the region of 62% during the 2001 census. There are nine government-owned primary schools and one privately owned school in Palapye. Preschools are also available throughout the village. There are three junior secondary and one senior secondary school in the village. There is also a vocational training centre, and non formal education centre.

Health

The delivery of health services in Palapye is provided through a primary hospital and four clinics. The primary hospital falls under the Ministry of Health while clinics are coordinated by the Ministry of Local Government. There are also specialised centres such as anti-retroviral drugs distribution centres to address the high HIV/AIDS rate in Botswana. There are also a number of private medical practitioners in the village.

Housing

Housing structures in Palapye as well as most villages in Central District are predominantly modern structures with tin roofing. However, there are still traditional housing structures made from mud and grass thatch scattered throughout the village.

Social amenities

Palapye is serviced by one police station and there are plans to build a bigger one due to the rapid growth of the village. Water supply is from the national supply, community standpipes and private connections. There are three cemeteries, but only one of these is in use.

Transport and communication
The A1 trunk road (Francistown – Gaborone) links the south and the north parts of the country. There is also the B14 road, which links Central and Ngamiland Districts. The village is also serviced by an airstrip for small aircraft. Telecommunications in the area are served by Botswana Telecommunications Corporation (BTC) and cellular phone service providers. Botswana Post provides postal services.

Electricity supply
Palapye benefits from the location being close to Morupule Power Station. The village is connected to the national supply grid through one substation. However, there is another under construction as residents have been complaining about frequent power surges and outages. Main consumers of electricity are the commercial industrial establishments.

2.3 SITE LOCATION AND SURROUNDING LAND USES

The site is situated approximately 6km from Palapye. Various cattle posts are located in the vicinity of the site and a small "squatter" settlement is situated to the north east of the site on the BPC lease area. Adjacent to the site, on BPC lease area, near junction with the main road lies a school and small community including workshops and some housing. The housing is to be removed due to presence of asbestos in the wall and roof materials. Directly north of the site lies the Colliery village and east, northeast is the colliery.

Within the surrounding area there are a number of land uses practices. These include:
- Arable agriculture;
- Livestock production;
- Urban development (mainly housing);
- Land developed for mining and power production.

Table 2.3: Area and percentages of various land use activities within 10 km of the proposed development

L.U. Type	Areas (ha)	% of Radius	% of Developed	Comment
Total Area within 10 km (ha)	31,416	100	26	26% of the area within 10 km is developed
Total Developed Land	8,160			
Cultivated (%)	2,661	8.5	32.6	Includes active, recent fallow and fallow lands areas
Disturbed (%)	96	0.3	1.2	Areas cleared e.g. borrow pits
Urban (%)	2,860	9.1	35.1	Palapye urban area falling within 10 km of power station
Mine & Power (%)	106	0.4	1.5	Modified areas within leases including slimes
Morupule Al Camp (%)	2,424	7.7	29.7	Fenced rangeland
Wildlife (Morupule) (%)	1,689	5.4	Not applicable	Fenced game management area
Communal Grazing (%)	21,579	68.6	Not applicable	Undeveloped rangeland

2.3.1 Agricultural land

Most of the lands areas are on the fluvial soils of the three main drainages, the Lotsane, the Morupule and the Kametaka as indicated in Figure 10. Dry land farming is seen to be a common land use practice in the area with this practice accounting for approximately 11% of the total area within the district (Central District Planning Study – 1992). Soil fertility and water resources are the determining factors with regards to the distribution of this land use practice. The majority of the lands areas are situated in close proximity to the Morupule River. Some lands areas exist on the southern side of the road towards Palapye.

Fields are near the national upper average size, being just larger than 6ha. The total number of lands areas identified from the aerial photography analysis was 435 (Table 2.4). Distribution of the lands areas along drainages and near to Palapye can be seen in Figure 2.1.

The main crops grown in the Palapye area are sorghum. Maize, cowpeas, millet, and melons. Average yields for these crops are low as indicated in Table 2.5.

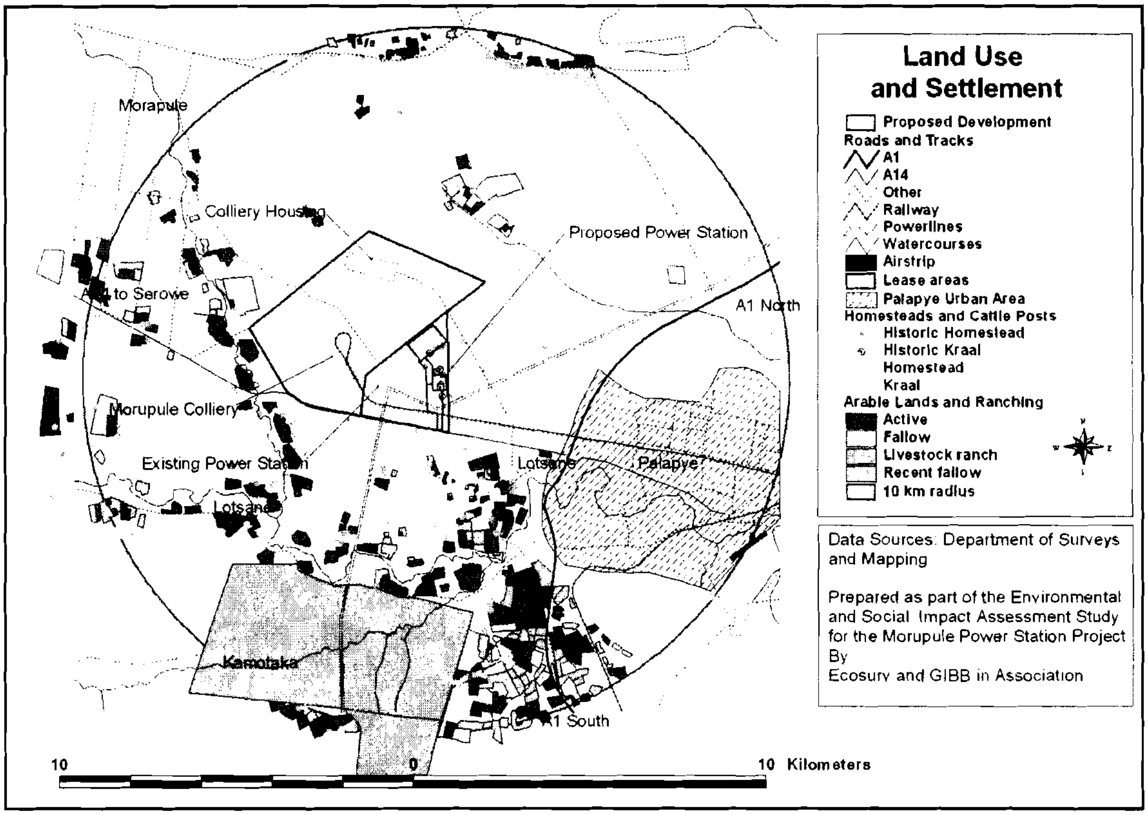
Table 2.4: Yields of common crops (Source: National Master Plan for Agricultural Development, MoA, 2000)

Crop	Yield in kg/ha & Estimated average Yields for Palapye
Sorghum	Max yield sandy soils 4,000, maximum yield on fine medium soils 4,600 kg/ha. Average yield on sandy soils 2,060 kg/ha
Maize	4,400 to 5,500 kg/ha. Average yield on sandy soils 1,550 kg/ha
Cowpeas	1,000 to 1,200 kg/ha. Average yield on sandy soils 470 kg/ha
Pearl millet	1,500 to 1,730 kg/ha. Average yield on sandy soils 610 kg/ha
Watermelon	30,000 – 40,000 kg/ha. Average yield on sandy soils 15,100 kg/ha

Table 2.5: Average size of lands areas and number identified within 10 km of the development

Status	Size	Count	National Average
Active	6.12	244	4 to 6 ha
Recent fallow	6.06	91	
Fallow		100	
Total lands areas within 10 km of the development		435	

Figure 2.1: Distribution of arable agriculture in the area surrounding the proposed development



2.3.2 Urban and residential

There are three main types of residential area within the secondary impact zone, these are:

- Homesteads linked to lands areas and cattle post (approximately 163 homesteads);
- Formal housing for Morupule Colliery staff;
- Urban Palapye which has both traditional and modern housing (2,860 ha of urban area fall within the 10 km radius).

2.3.3 Mining

Morupule Colliery is owned and operated by Debswana, a partnership between the government of Botswana and De Beers. Founded in 1973 to supply the nearby Bamangwato Concessions, Ltd copper and nickel mine, operations have expanded considerably since then to supply a number of regional power plants and industries, especially the nearby Morupule Power Station.

The coalfield is composed of four main seams, only one of which, the No. 1 Seam, is currently being mined subsurface using slope mining. The No. 1 Seam has an average height of 8.5 meters (28 ft), and is located at an average depth of 80 meters (260 ft) below surface. Production over a recent 7-year stretch averaged 877,000 tons per year. I (http://en.wikipedia.org/wiki/Morupule_Colliery).

The coalfield is immense and contains good quality coal, with overall reserves of over 9 billion tons. Production has increased steadily over the years from 145 000 tons per annum in 1973. A total of 984 838 tons of coal were mined and 964 555 tons were sold during the year 2005.

A number of key industries in Botswana depend on coal supply from Morupule. More than half of the mine's current annual production is supplied directly by overland conveyor to the adjacent Morupule Power Station, while the BCL Mine at Selebi Phikwe and the Botswana Ash plant at Sua Pan remain major customers. Coal is also supplied to the Botswana Meat Commission, Botswana Breweries, Foods Botswana, Makoro Bricks and two coal distributors. The Colliery has also been able to penetrate the SADC market and is currently supplying graded coal to Zimbabwe, Zambia and the DRC.

The Colliery has over 250 employees, over 97 % of whom are citizens of Botswana (http://www.debswana.com/Debswana.Web/About+Debswana/Investments/Morupule+Colliery/).

2.3.4 Livestock

Communal grazing livestock farming is the largest practiced land use in the area as well as within the district with over 65% of the district being under this land use practice (Central District Planning Study – 1992). Cattle, goats and sheep are common to the area, which is situated in a communal grazing area. Little management occurs with regards to farming practices and overgrazing.

Within the 10 km radius of the proposed development about 68% of the land is available for traditional livestock production with an additional 8% fenced for commercial livestock production (there is a partially disused AI camp belonging to MOA, called Leupane, in the southern part of the 10 km radius). Immediately west of the 10 km radius is another AI camp called Morupule which is still operated by MOA.

Livestock carrying capacities are presently 7ha/LSU and the number of livestock within the 10 km radius are estimated as indicated in Table 2.6 (MoA Livestock Crush Figures).

Table 2.6: Crush figures for the area falling within the 10 km radius (Source MoA, DAHP, Veterinary Officer Serowe)

Crush	Cattle	Sheep	Goats	Horses	Donkeys	Dogs and Cats
Bollantoko	78	7	26	1	0	4
Botepetepe	352	80	197	4	70	26
Lewele	1194	146	522	0	175	50
Masama	840	29	388	0	22	42
Totals	2464	262	1133	5	267	122

Based on the aerial photography assessment there are at least 163 homesteads within the area all of which will have livestock as an important component of their livelihoods. The Morupule Colliery also keep game within a fenced area in its lease area and is in the process of developing the wildlife population through protection and stocking.

In terms of the farmers in the immediate vicinity of the site, all of the farmers interviewed during the study, specifically arable one's, have been farming in the area for on average 30 years or more Most of them have developed houses near their fields (mostly traditional, round mud thatched huts). The average size of the fields is in the region of 6 ha. Farming is undertaken as a full time activity though the farmers tend to practice a three-site system (live in town/village, cattlepost and lands). In this way they concentrate on pastoral farming during the dry season and undertake mixed farming during the wet season. To this end, farming (at subsistence level) is a very important component of local people's livelihoods. They keep a reasonable number of cattle, goats, sheep and donkey and grow crops that include maize, sorghum, beans, millet and watermelons. Maize and sorghum constitute staple food. Some families (parents) augment their income through remittances from their working relatives (children) and rent from houses in Palapye. The commercial farmers practise mixed farming. Most of them keep dairy cows and cultivate vegetables and the produce is sold in Palapye to the general public at open stalls.

SECTION 3: ASSESSMENT OF KEY SOCIAL IMPACTS

3.1 INTRODUCTION

Section 3 provides an assessment of the potential key social impacts (negative and positive) associated with Phase 1 of the Morupule Power Station. The identification of key social issues and impacts was based on:

- Review of project information;
- Review of relevant socio-economic baseline for the area;
- Focus group meetings and discussions with representatives from local authorities, farmers and business in the area;
- Experience with similar projects.

The findings of the focus group meetings are summarized in Section 3.2. Based on these findings and the experience with similar project the key impact will be associated with the construction and operational phase of the project. The impacts associated with these phases include:

Construction phase
- Employment and business opportunities;
- Influx of job seekers;
- Noise, dust and safety impacts;
- Stock theft;
- Increased risk of veld fires.

Operational phase
- Employment and business opportunities.
- Influx of job seekers.

These impacts are discussed in more detail in Section 3.3 and 3.4 below

3.2 ISSUES RAISED DURING FOCUS GROUP MEETINGS

3.2.1 Government Departments

All the government departments consulted noted that the short and long term employment opportunities associated with the project represented a major opportunity for the town. It should also be noted that Palapye will be undergoing major infrastructural development in the future as the government has recently taken a decision to build the country's second university in the town. Land has already been acquired from the Ngwato Land Board (main landboard for the Central District). The university is expected to start operating in 2009 with an initial intake of 2 500 pupils, growing to 10 000 in 2016. Other proposed developments in the area will include a modern fire station (between the proposed power plant site and the existing bus terminus) and an airport between Serowe village and Palapye. The proposed university and associated developments also represent major opportunities for the town and area.

Table 3.1 summarises the key challenges identified by the different government departments interviewed during the study.

Table 3.1: Key challenges identified by government departments

Department / Unit	Major challenges
Animal Health and production-Palapye	None – facilities and resources adequate
Physical planning	Shortage of manpower for monitoring Less powers and long procedures in enforcement or bye laws and issuing of enforcement notices.
Economic Planning	None
Environmental health	Uncontrolled dumping at a designated solid waste disposal site in Palapye Inadequate equipment for waste management
District Health Team	inadequate resources i.e. staffing and other resources such as equipment and vehicles

Identification of existing potential issues, concerns and opportunities
In terms of existing issues and concerns, none of the government departments interviewed have experienced any problems with either the power station or the coal mine. To this end, a cordial relationship exists between the local council/central government departments and the mine/power station. Both the coal mine and the power station play a significant role in the local economy as all power station workers and most of the mine workers stay in the town. They inject a good portion of their income into the local economy through various business transactions and multiplier effects such as further employment creation. The development of a new power station will enhance these benefits.

Identification of potential future issues, concerns and opportunities
The local council is fully aware of the plans to expand the Morupule Power Station and have been kept informed via the official fora such as Full Council Meetings (official and scheduled council meetings). They also acknowledged that they have been kept informed about the progress of the new station e.g. the Physical Planning department has been involved throughout since the scoping phase.

The all felt that the proposed development was beneficial as it would ensure reliable and secure power supply to the country. On the negative side all the government departments indicated that they were concerned about the impact during construction phase as increased population in the area and the pressure that this may have on existing amenities and services. The District Health Team, for instance, felt that the expansion might necessitate upgrading of the Palapye Primary Hospital. The Environmental Health Department indicated that they were concerned about the proximity of the proposed site to the town's existing solid waste disposal site (dumpsite) which is about 3 km away (north east of the proposed site).

Potential mitigation and enhancement measures
All the government officers consulted recommend that close liaison should be maintained with local authorities during the construction phase. Further the DHT advised that the contractor should provide on site health facilities if possible to ease pressure on existing facilities.

3.2.2 Local farmers

Interviews were undertaken with farmers in an area located within a 10km radius of the proposed power station. Table 3.2 lists the land and land uses that fall within the 10km radius.

Table 3.2: Land and land uses within 10km radius of power station

Lands area	App. Distance from proposed power station (km)	Direction relative to proposed station	Type of farming	Legal Status
Morupule	2.5	W to SW	Mixed farming (Arable and pastoral)	Legal settlement
Mantshadidi	8	SW	Arable and pastoral	Legal settlement
Molapowadipitse	4	S	Arable and pastoral	Legal settlement
Mmalenakana	1	N	Pastoral	Illegal settlement that sprawls into the BPC lease area
Dikabeana	9.5	N	Arable and pastoral	Legal settlement

The initial intention was to consult with local structures such as Farmers Associations, however, most of the members were not available at time of consultation. Consequently the consultations team conducted household to household discussions with a maximum of 5 households per village except in one of the lands area where some members of the local farmers association were available. Further consultations were also conducted with the commercial farmers whose farms are located along the Serowe-Palapye road.

All of the people interviewed agreed with the scoping results – no new issues brought up during consultations. They further indicated that generally they had a good relationship with both the power station and mine personnel. To this end, they have never had any serious concerns about the operations of the two facilities. Most people in the land areas that were interviewed were not aware of the proposed expansion nor that a scoping exercise had been carried out in 2004.

Identification of existing potential issues, concerns and opportunities
The farmers on the Molapowadipitse lands indicated that they are sometimes exposed to noise from the existing power station and the noise is more intense at night during still conditions. The residents, however, have never raised their concerns with BPC. The rest of the settlement did not register any concerns. However the Mmalenakana residents were not receptive to the consultations team probably due to their legal status. The farmers indicated that they benefit from the existing power station and mine. This could be attributed to the closure of a watering point that BPC used to operate near the station to supply water to livestock and people residing near the power station to offset effects of drought in the area. Morupule Power Station Engineer Planning Engineer, B. Dinonyane) indicated that the pipeline was closed in 2001 after it was realised that the drought situation had improved and local people could seek alternative water sources elsewhere. The decision probably has had an effect on the farmers' attitude toward BPC.

Identification of potential future issues, concerns and opportunities
All the subsistence farmers indicated that they were not aware of the proposed expansion. However, they indicated that they saw the project as a benefit to the area in that it would create jobs for the local people. No major negative impacts were identified. However, they did indicate that they were concerned that there was a tendency by contractors working on local projects to employ people originating outside their area for non-skilled jobs.

Potential mitigation and enhancement measures
Residents recommend that preference should be given to local people for non-skilled and semi-skilled jobs.

3.2.3 Local businesses

A number of the business operations in Palapye are located along the A1 trunk road that links Gaborone to the south and Francistown to the north. The rest are located along the secondary, internal roads that provide access to the other parts of the town. Discussions were held with businesses involved in furniture, food retailing, hospitality and fuel sales. Each of the business interviewed have operated in the town for more than 10 years and employ an average of more than 10 people with the hospitality industry employing the highest number. All the employees reside in Palapye. Most of the businesses operations in Palapye do not have satellite or other business types in the town.

The majority of representatives from the business community in Palapye who were interviewed indicated that they do not have direct business links with either the mine or power station. With specific reference to the existing power station, only the largest hotel in Palapye has direct links and offers BPC credit facilities. Where business links do exist, these are largely associated with the mine and not the power station. They did note that the expanded power station would benefit local businesses through a local service provider preference system and that these benefits would trickle down to the local community.

Identification of existing potential issues, concerns and opportunities
No problems have been experienced by the local businesses save for intermittent power cuts. However they do not view the power cuts as a localized problem but rather it is a national one.

Identification of potential future issues, concerns and opportunities
All the business operators in Palapye interviewed were aware of the proposed expansion of the Morupule power station. Many had been informed via the media. The proposed project was seen as a positive undertaking in that it would ensure a reliable power supply for their businesses. In addition the construction phase will generate significant business opportunities for the town. They also felt that the towns' facilities/amenities would be able to cope with the increased pressures created by the project. Business operators strongly believe that Palapye has good and efficient business base to support the proposed expansion.

Potential mitigation and enhancement measures
The contractor/s appointed for the construction phase should use local facilities for services and BPC should ensure that this is taken on board during the tendering stage.

3.3 CONSTRUCTION PHASE

The findings of the study indicate that the impacts associated with the construction phase include:

- Employment and business opportunities;
- Influx of job seekers;
- Noise, dust and safety impacts;
- Stock theft;
- Increased risk of veld fires.

These impacts are discussed in more detail below

3.3.1 Creation of local employment opportunities

Description of the effect

The construction phase is expected to last approximately 3 years and employ in the region of 1 000-1 500 personnel. The estimated capital expenditure associated with the construction phase is in the region of XX million Pula. This represents a large investment in the area and will create significant business and employment opportunities in the local and regional economy.

Given the nature of large construction projects, a large number of the employment opportunities are likely to be for semi-skilled workers. A number of these jobs can be taken up by members of the local community. The majority of these jobs are likely to be filled by men. Depending on the level of local employment, a percentage of the wage bill associated with the construction phase will be earned by local residents. Given the relatively low income levels in the area this represents a significant opportunity for both the community and the local economy.

Assessment of the impact

The employment opportunities associated with the proposed development are likely to represent a significant positive socio-economic opportunity for the local economy. Workers employed and trained during the construction phase would also be in a position to apply for work during the operational phase and or other projects in the area and Botswana.

However, the potential employment opportunities for locals may be somewhat reduced by the shortage of appropriate skills levels in the area. The issue of available and appropriate skills will, therefore, need to be addressed in order to maximise the employment opportunities for the local community during the construction phase.

Table 3.1: Assessment of employment creation opportunities during the construction phase

	No Mitigation	Mitigation*
Extent	Local and regional	Local and regional
Duration	Temporary	Temporary
Probability	High	High
Status	Positive	Highly Positive
Confidence	High	High
Significance	High*	High*

* Any opportunity to create additional employment, even if it is temporary employment, is regarded as a significant positive impact. This was confirmed by the feedback from all of the interest groups interviewed (local government departments, farmers and businesses).

Recommended enhancement measures

In order to enhance local employment opportunities associated with the construction phase of the Project the following measures should be implemented:

- Where possible BPC should implement a 'local's first' policy for jobs. This should also apply to contracting firms. However, due to the low skills levels in the area, the majority of skilled posts are likely to be taken by people from outside the area;
- An employment office should be set up in Palapye prior to the commencement of the construction phase in order to identify locals who can be employed on the project. A skills audit should also be undertaken to assess the ability to maximise the opportunities for local residents;
- The local authorities, community organizations and leaders should be informed of the project and the potential job opportunities for locals;
- Where necessary a training and skills development programmes should be initiated prior to the initiation of the construction phase;

- The employment selection process should seek to promote gender equality and the employment of women wherever possible;

3.3.2 Creation of local business opportunities: Construction Phase

Description of the effect

As indicated above, the capital expenditure associated with the development phase of the Project is significant. This expenditure will create significant business opportunities in the national, regional and local economy. In addition, a proportion of the total wage bill from the 1 000 -1 500 workers employed over the 3 year construction period will be spent in the local economy. This will also create additional opportunities for local businesses in Palapye.

The local hospitality industry is also likely to benefit during the construction phase. These benefits are associated with accommodation and meals for professionals (engineers, quantity surveyors etc) involved on the Project. The local economy will therefore benefit from the injection of capital associated with construction phase of the Project.

Assessment of the impact

Table 3.2: Assessment of opportunities for local businesses

	No Mitigation	Mitigation
Extent	Local and regional	Local and regional
Duration	Temporary	Temporary
Probability	High	High
Status	Positive	Highly Positive
Confidence	High	High
Significance	High	High

Recommended enhancement measures

In order to enhance the opportunities for local businesses the following measures should be implemented:

- BPC should develop a database of local firms that qualify as potential service providers (construction companies, catering companies, waste collection companies etc) prior to the commencement of the tender process. These companies should be notified of the tender process and invited to bid for project related work;
- Where necessary, BPC should assist firms to enable them to fill in and submit the required tender forms, compete for work and fulfil contracts;
- Local businesses should ensure that they identify and cater for the needs of the construction workers (to maximise spending of wages within the local economy);
- The local chamber of business and hospitality industry should identify strategies aimed at maximizing the potential benefits associated with the Project.

3.3.3 Influx of construction workers

Description of the effect

The concern is that there will be an influx of construction workers from outside the area associated with the construction phase. The majority of construction workers on large construction projects are single males. The influx of predominantly single males during the construction phase of the project can create a number of negative social impacts in the host community. These impacts include:

- Transmission of sexually transmitted diseases, including HIV/AIDS;
- Increase in prostitution;
- Increase in alcohol and drug related incidents;
- Increase in crime;
- Creation of tension and conflict within the local community;
- Pressure on existing services and amenities.

The influx of workers will also result in additional spending in the local economy. The influx of workers will, therefore, also have a positive socio-economic benefit.

Large construction projects also frequently result in the influx of job seekers. The influx of job seekers to the area will place pressure on local services and facilities, such as housing, clinics and schools. The influx of job seekers can also lead to tension and conflict over available jobs and resources within the local community.

Assessment of the impact

Approximately 1 000 - 1 500 construction workers will be employed for a period of 3 years during the construction phase. These workers will be housed on the site in a construction workers camp. Every effort should be made to employ local residents during the construction phase where the available skill levels permit. The measures aimed at enhancing the opportunities for local residents are outlined above. If these measures are effectively implemented the potential impacts associated with the influx of construction workers from outside the area can be mitigated.

The representatives from the government departments interviewed also expressed concern that the influx of workers and job seekers to the area will place pressure on existing services and amenities.

The proposed development will also attract additional job seekers to the area. It is unlikely that it will be possible to stop these people from coming to the area in search of a job. As such no mitigation measures are recommended. However, as indicated above, BPC should ensure that the employment criteria favour local residents in the area. The influx of workers will also result in additional spending in the local economy.

The proportion of the monthly wage during the construction phase will also be spent in the local economy. The influx of workers will, therefore, also have a positive socio-economic benefit.

Table 3.3: Assessment of influx of construction workers

	No Mitigation	Mitigation
Extent	Local and regional	Local and regional
Duration	Temporary-Permanent (some job seekers may settle in the area)	Temporary- Permanent (some job seekers may settle in the area)
Probability	Medium	Medium
Status	Negative (Impact on community structures and networks) Positive (Increase spending in local economy)	Negative-Neutral Positive (Steps are taken to meet needs of workers)
Confidence	Moderate	Moderate
Significance	Moderate	Moderate-Low

The construction workers from outside the area will be housed in the surrounding villages or the contractors may, via a request to the local chiefs set up a Construction Camp during the construction phase of the Project.

Recommended mitigation measures
The mitigation measures that can be considered to address the typical social impacts associated with construction workers who are housed in the community or a construction camp include:

- BPC should liaise with the local authorities and local community leaders to identify the available accommodation in Morupule and the best location for the establishment of a construction camp on the site for the construction phase;
- BPC should liaise with the local authorities to assess the potential impact on existing services and amenities and look at ways of addressing these issues in a co-operative and constructive manner;
- BPC should draft a code of good conduct for construction workers to be signed between BPC, the Local Authorities and adjacent and neighbouring landowners. The agreement should outline what types of behaviour and activities by construction workers are not permitted. Construction workers who breach the code of good conduct should be dismissed by BPC;
- BPC should establish a liaison committee consisting of contractors and the local authorities and adjacent landowners to devise a code of conduct for workers and to address conflicts that may arise;
- BPC should ensure that internal and external complaints are dealt with speedily and in an open and transparent manner;
- BPC should consider implementing curfews when construction workers must return to the camp;
- BPC should provide appropriate and adequate entertainment for the construction workers at the camp, including soccer pitch, pool tables, TVs and videos, radio etc;
- BPC should implement a HIV/AIDS awareness programme for construction workers.

3.3.4 Impact of heavy vehicles

Description of the effect

The movement of heavy vehicles along the road between the Morupule Power station site and Palapye will create noise, dust and safety impacts for other road users and adjacent landowners.

Assessment of the impact

The existing road between the site and Palapye is not surfaced and dust generated by the movement of heavy construction vehicles during the construction phase will impact on other road users and adjacent landowners. Other activities that will be negatively affected include the Palapye Bus and Taxi rank located on the northern side of the road at the intersection with the Francis Town-Gaborone Main road that passes through Palapye. The Bus and Taxi rank also has an outdoor market area which will also be affected by dust and noise generated by heavy vehicles during the construction phase.

The Gaborone Veterinary Clinic Palapye Branch located to the south of the road opposite the Bus and Taxi rank will also be negatively affected by noise and dust generated by heavy vehicles during the construction phase.

Table 3.4: Assessment of the impacts along the Serowe–Morupule Road associated with heavy vehicles

	No Mitigation	Mitigation
Extent	Local	Local
Duration	Temporary (Limited to the duration of the construction phase)	Temporary (Limited to the duration of the construction phase)
Probability	Moderate - High	Moderate – Low
Status	Negative	Negative – Neutral
Confidence	Moderate	Moderate
Significance	Moderate	Moderate – Low

The Kgaswe Primary School located at the entrance to the Morupule Power Station will also be negatively affected by the noise and dust generated by heavy vehicles during the construction phase. The noise and dust generated from the activities on the construction site which is located approximately 200-300m north of the Kgaswe Primary School will also impact negatively on the school. These impacts will need to be carefully monitored during the construction phase.

Table 3.5: Assessment of the impacts on the Kgaswe Primary School associated with heavy vehicles

	No Mitigation	Mitigation
Extent	Local	Local
Duration	Temporary (Limited to the duration of the construction phase)	Temporary (Limited to the duration of the construction phase)
Probability	Moderate - High	Moderate – High
Status	Negative	Negative – Neutral I
Confidence	Moderate	Moderate
Significance	High	Moderate

Recommended mitigation measures

The potential impacts associated with heavy vehicles and dust can be effectively mitigated. The detailed mitigation measures should be outlined in the Environmental Management Plan (EMP) for the Construction and Operation Phase. The aspects that should be covered include:

- Implementing operating hours for heavy vehicles ;
- Implementing dust suppression measures for heavy vehicles such as wetting roads on a regular basis and ensuring that vehicles used to transport sand and building materials are fitted with tarpaulins and covers;
- Enforcing operating hours for heavy vehicles so as to avoid times of day when pedestrian use of the roads is high. For example in the early mornings and late afternoons when school children walk to and from school and farmers are going to their farmlands and returning home. Operations should also take into consideration important days when there is likely to be more traffic on the roads, such as market days and local festivals;
- Ensuring that all vehicles are road worthy, drivers are qualified and are made aware of the potential safety issues.

3.3.5 Stock theft and losses

Description of the effect

The construction workers living in the construction camp on the site may resort to stock theft and, in the process, also damage farm infrastructure, such as fences, gates and kraals. Stock losses may also result from gates being left open or fences being damaged.

Although this issue was not raised by the local farmers it is regarded as a potential threat based on experience with other large construction projects and an understanding of the local conditions.

Assessment of the impact

The presence of a large number of construction workers on the site does pose a threat to the livestock of farmers in the area. In the process farm infrastructure may be damaged or destroyed. The damage to fences and gates that are left open may also result in further stock loses.

Table 3.6: Assessment of stock theft and damage to farm infrastructure

	No Mitigation	Mitigation
Extent	Local and regional	Local and regional
Duration	Temporary (limited to the construction phase)	Temporary (limited to the construction phase)
Probability	Medium	Medium
Status	Negative	Negative-Neutral
Confidence	Moderate	Moderate
Significance	High	Moderate

Recommended mitigation measures

The detailed mitigation measures should be outlined in the Environmental Management Plan (EMP) for the Construction and Operation Phase. The mitigation measures that can be considered to address the potential impact on livestock and farm infrastructure include:

- BPC should liaise with the local farmers to identify the best location for the establishment of a construction camp on the site for the construction phase;
- BPC should set up a liaison committee between contractors and the local authorities and adjacent landowners to devise a code of conduct for workers and to address conflicts that may arise;
- BPC should compensate farms in full for any stock losses and or damage to farm infrastructure that can be positively linked to construction workers. This should be contained in an agreement of good conduct to be signed between BPC and all adjacent and neighbouring landowners;
- BPC should ensure that all construction workers are informed of the consequences of stock theft and trespassing on adjacent farms at the outset of the construction phase;
- BPC should ensure that construction workers who are found guilty of stealing livestock and or damaging farm infrastructure are dismissed and charged.

3.3.6 Increased risk of veld fires

Description of the effect

The construction related activities and workers living in the construction camp on the site pose an increased risk of veld fires in the area.

Although this issue was not raised by the local farmers it is regarded as a potential threat based on experience with other large construction projects and an understanding of the local conditions.

Assessment of the impact

The presence of a large number of construction workers on the site does pose an increased risk of veld fires that in turn pose a threat to the livestock of farmers in the area. In the process farm infrastructure may be damaged or destroyed.

Table 3.7: Assessment of increased risk of veld fires

	No Mitigation	Mitigation
Extent	Local	Local and
Duration	Temporary (limited to the construction phase)	Temporary (limited to the construction phase)
Probability	Medium	Medium
Status	Negative	Negative-Neutral
Confidence	Moderate	Moderate
Significance	High	Moderate

Recommended mitigation measures

The potential increased risk of veld can be effectively mitigated. The detailed mitigation measures should be outlined in the Environmental Management Plan (EMP) for the Construction and Operation Phase. The aspects that should be covered include:

- Ensure that open fires on the site for cooking or heating are not allowed;
- Provide fire fighting equipment for fighting veld fires and other fires on site;
- Provide fire fighting training to selected construction staff.

3.4 OPERATIONAL PHASE

The key social issues during the operational phase are linked to employment and business opportunities, and the influx of workers. These impacts are discussed in more detail below.

3.4.1 Creation of employment opportunities

Description of the effect

The operational phase is expected to create an approximately 240 additional permanent jobs. In addition to the creation of jobs the project is also likely to create opportunities for training and skills development for members from the local community.

Assessment of the impact

The direct employment opportunities created by the proposed development represent a significant positive socio-economic opportunity for the local economy. In this regard the current annual wage bill for the existing power station is in the region of 40 million Pula. The annual wage bill for the new power station is likely to be in the region of 20-25 million Pula. The lower wage bill is due to the fact that the existing power station employs 435 people as opposed to 240 for the new power station.

However, the potential local employment opportunities associated with the proposed development may be somewhat reduced by the shortage of appropriate skills levels in the area. The issue of available and appropriate skills will, therefore, need to be addressed in order to maximise the employment opportunities for the local community during the operational phase.

Table 3.8: Assessment of employment creation opportunities

	No Mitigation	Mitigation
Extent	Local and regional	Local and regional
Duration	Temporary	Temporary
Probability	High	High
Status	Positive	Highly Positive
Confidence	High	High
Significance	High*	High*

* Any opportunity to create additional employment, even if it is temporary employment, is regarded as a significant positive impact. This was confirmed by the feedback from all of the interest groups interviewed (local government departments, farmers and businesses).

Recommended mitigation measures

In order to enhance local employment opportunities associated with the operational phase of the Project the following measures should be implemented:

- Where possible BPC company should implement a 'local's first' policy for jobs, to apply to contracting firms as well as the company itself.
- BPC should establish an employment office in Palapye prior to the commencement of the Project in order to identify and employ suitably qualified individuals. A skills audit should be also undertaken to assess the ability to maximise the opportunities for local residents. However, due to the low education and skills levels in the area, the majority of skilled posts are likely to be taken by people from outside the area.
- Where local skills and expertise are not available BPC should, where possible, look to employ Botswana's as opposed to expatriates;
- BPC should inform local authorities and community leaders of the project and the potential job opportunities for locals;
- Where necessary BPC should implement a training and skills development programmes prior to the initiation of the construction phase;

- The employment selection process should seek to promote gender equality and the employment of women wherever possible.

3.4.2 Creation of business opportunities

Description of the effect

The operational phase of the mine will create opportunities for local business in Palapye. The majority of these opportunities are likely to be linked to the retail and service industry, such as cleaning, security, catering etc.

Assessment of the impact

A percentage of the total wage bill will be spent in the local economy and this will create additional opportunities for local businesses. As indicated above, the annual wage bill for the new power station is likely to be in the region of 20-25 million Pula. The annual expenditure in maintenance for the current power station is 13.6 million Pula. A similar amount is likely to be spent on the new power station.

In addition a number of services such as security, cleaning, catering etc are likely to be outsourced and this will create potential opportunities for local businesses in Palapye. The local hospitality industry is also likely to benefit during the operational phase. These benefits are associated with accommodation and meals for professionals (engineers, geologists, quantity surveyors etc) involved on the Project who do not live in the area. The local economy will therefore benefit from the injection of capital associated with construction phase of the Project.

Table 3.9: Assessment of opportunities for local businesses

	No Mitigation	Mitigation
Extent	Local and regional	Local and regional
Duration	Temporary	Temporary
Probability	High	High
Status	Positive	Highly Positive
Confidence	High	High
Significance	High	High

Recommended enhancement measures

In order to enhance the opportunities for local businesses the following measures should be implemented:

- A database of local firms that qualify as potential service providers (construction companies, catering companies, waste collection companies etc) should be developed prior to the commencement of the tender process. These companies should be notified of the tender process and invited to bid for project related work;
- BPC should include a clause in its procurement policy that favours local businesses;
- Where necessary, firms should be assisted and or capacitated to enable them to fill in and submit the required tender forms and fulfill contracts;

- The local chamber of business and hospitality industry should identify strategies aimed at maximizing the potential benefits associated with the Project.
-

3.4.3 Influx of workers and job seekers

Description of the effect

The project is likely to result in an influx of workers (estimated 1000-1500 during construction) and job seekers to the area during both the construction and operational phase. The majority of workers are likely to be males and this can create a number of negative social impacts in the host community. These impacts include:

- Transmission of sexually transmitted diseases, including HIV/AIDS;
- Increase in prostitution;
- Increase in alcohol and drug related incidents;
- Increase in crime;
- Pressure on local services, such as housing, clinics, schools, water supplies etc;
- Increase in local prices and the cost of living;
- Tension and conflict within the community and impact on family networks and relationships;
- Competition for available jobs and resources.

The influx of workers and job seekers will also result in additional spending in the local economy. The influx of workers will, therefore, also have a positive socio-economic benefit.

Assessment of the impact

Every effort should be made to employ local residents during the operational phase of the Project. The measures aimed at enhancing the opportunities for local residents are outlined above. If these measures are effectively implemented the potential impacts associated with the influx of construction workers from outside the area can be mitigated to some extent. However, this will not stop the in-migration of job seekers to the area.

Table 3.10: Assessment of impact of influx of job seekers

	No Mitigation	**Mitigation**
Extent	Local and regional	Local and regional
Duration	Temporary-Permanent (Some job seekers may settle in the area)	Temporary- Permanent (some job seekers may settle in the area)
Probability	High	High
Status	Negative Positive (The influx of job seekers will result in additional income being	Negative-Neutral Positive (The influx of job seekers will result in additional income being

	spent in the local economy)	spent in the local economy)
Confidence	High	High
Significance	Moderate-High	Moderate-High

Recommended mitigation measures

- Where possible BPC should implement a 'locals first' policy for jobs;
- Where local skills and expertise are not available BPC should, where possible, employ Botswana nationals as opposed to expatriates.

SECTION 4: KEY FINDINGS AND RECOMMENDATIONS

4.1 INTRODUCTION

Section 4 lists the key findings and recommendations of the Social Impact Assessment. These key findings are based on:

- Review of project information;
- Review of relevant socio-economic baseline for the area;
- Focus group meetings and discussions with representatives from local authorities, farmers and business in the area;
- Experience with similar projects.

4.2 KEY FINDINGS

All of the key interest groups interviewed, namely the local authorities, farmers and businesses all indicated that they did not experience any major problems with the operations of the existing power station and mine. In addition they all indicated that the proposed power station would benefit both Botswana and the town of Palapye. The benefits to Botswana were linked to improved power generation reliability and energy security. The benefits to the town of Palapye were linked to the creation of local employment and business opportunities during both the construction and operational phase.

The potential benefits associated with the creation of employment and business opportunities during the construction and operational phase can be enhanced by implementing the mitigation measures listed in Section 3.3.1, 3.3.2, 3.4.1 and 3.4.2.

Concerns were raised by the representatives from local government regarding the potential pressure that the increased number of employees and job seekers would have on existing services, such as housing and medical facilities. However, it was felt that these issues could be effectively managed. The mitigation measures to address these concerns for the construction and operation phase are listed in Section 3.3.3 and 3.4.3 respectively.

Based on the experience with similar projects and an understanding of the local conditions a number of potential impacts during the construction phase were also identified, specifically the impact of heavy vehicles (noise, dust and safety impacts), stock theft and increased risk of veld fires. However, each of these issues can be effectively mitigated by the implementation of an Environmental Management Plan during the construction phase. The mitigation measures to address these issues are listed in Section 3.3.4, 3.3.5 and 3.3.6.

4.3 RECOMMENDATIONS

Based on the findings of the Social Impact Assessment it is recommended that Phase 1 of the Morupule Power Station proceed. In order to enhance the local employment and business opportunities the mitigation measures listed in the report should be implemented.

The mitigation measure listed in the report to address the potential negative impacts during the construction phase, specifically the impact of heavy vehicles (noise, dust and safety impacts), stock theft and increased risk of veld fires, should also be implemented.

Appendix 4.6

Noise impact report

NOISE IMPACT ASSESSMENT OF THE PLANNED MORUPULE B POWER STATION

FINAL REPORT

(October 2007)

Report Prepared by Jongens Keet Associates

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EXECUTIVE SUMMARY

Botswana Power Corporation (BPC) is planning a new power station (Morupule B Power Station). The Project site is located in the Central District of Botswana, approximately 280 kilometres north of Gaborone and just to the west of the village of Palapye. Palapye is classified as a secondary centre and is located on the main Gaborone-Francistown road (Road A1) and railway. The new Power Station site is to be sited approximately 4500 metres to the west of the village of Palapye and 1200 metres north of the main road between Serowe and Palapye (Road A14) near to the existing power station (Morupule Power Station).

As the noise from the planned power station is considered to be a potential problem, a noise impact investigation was undertaken by Jongens Keet Associates. The general procedure used to determine the noise impact was guided by the requirements of the South African National Standard (SANS) 10328:2003: *Methods for Environmental Noise Impact Assessments*. The level of investigation was the equivalent of an EIA. The noise impact criteria used specifically take into account those as specified in the South African National Standard SANS 10103:2004, *The Measurement and Rating of Environmental Noise with Respect to Land Use, Health, Annoyance and Speech Communication* as well as those in relevant Noise Control Regulations. The investigation comprised the following:

i) Determination of the existing situation (prior to the construction of the planned power station).

ii) Determination of the situation during construction and after commissioning of the planned power station.

iii) Assessment of the change in noise climate and impact.

iv) Identification of mitigating measures.

The existing noise climate of the proposed Morupule B Power Station study area was established from a noise survey. The findings were as follows:

i) The main sources of noise in the area are from:
- Traffic on Road A1 North, Road A1 South and Road A14.
- Morupule A Power Station.
- Morupule Colliery.
- The colliery trains.

ii) The main noise sensitive areas/sites/receivers in the study area are:

- Palapye Village.
- Morupule Colliery Village (residential).
- Settlement ("Molapu Wapitsi") just north of the Lotsane River. This is the only isolated settlement in the study area.
- Contractor village adjacent to the Kgaswe Primary School.
- Kgaswe Primary School

iii) Noise levels in Palapye Village are high and are typical of an urban complex. The existing *noise climate* alongside the main roads in Palapye is degraded with regard to acceptable urban residential living standards (SANS 10103 noise impact criteria), that is noise exceeds acceptable levels particularly at night. Residences in some areas are negatively impacted from traffic noise (night-time standard) for up to 220 metres from the main roads. In general the daytime conditions are acceptable (SANS 10103).

iv) The areas outside Palapye and remote from the main roads and the power station/colliery are very quiet and reflect a rural character.

v) The existing *noise climate* alongside Road A14 outside Palapye Village is degraded with regard to acceptable rural residential living standards (SANS 10103 noise impact criteria). Any residences within 2000 metres of the road are negatively impacted from traffic noise (particularly at night).

vi) The impact of the power station on noise sensitive sites in the surrounding area is minor. Noise levels from the power station exceed 35dBA (the maximum allowable night-time level for rural residential use) up to a distance of about 2500 metres from the facility. The Colliery Village and the settlement ("Molapu Wapitsi") lie outside this zone and are thus not impacted by the power station noise. These residential areas are also not adversely impacted by traffic noise from Road A14. The "contractors" housing adjacent to the Kgaswe Primary School lies within this zone but noise levels at this site are more severely affected by the Road A14 traffic noise. The power station will be heard late at night when traffic volumes are low.

vii) Noise levels from traffic on Road A14 at the Kgaswe Primary School are slightly higher than desirable for an educational environment. The outdoor ambient noise level should not exceed 50dBA. Noise from vehicles passing over the rumble strips on the power station access road just to the west of the school is a significant noise nuisance factor.

viii) Noise from the power station does not have a significant impact on the activities at the Kgaswe Primary School.

ix) The overall impact of the noise from the coal trains on noise sensitive sites in the area is not significant. There is a minor nuisance effect at the school from the warning horn sounding when the train approaches the level crossing with the power station access road.

There will be a potential for noise impacts during the construction phase. The level and character of the construction noise from the proposed power station site will be highly variable as different activities with different plant/equipment take place at different times, over different periods, in different combinations, in different sequences and on different parts of the construction site. It should be noted that for residential land uses, higher ambient noise levels than recommended as maxima in SANS 10103 are normally accepted as being reasonable during the construction period, provided that the very noisy construction activities are limited to the daytime and during the week, and that the contractor takes reasonable measures to limit noise from the work site. Note that it has been assumed that construction will generally take place from 07h00 to 18h00 with no activities (or at least no noisy construction activities) at night. Note also that the nature of the contract is such that construction activity at any one site will be of short duration. The volumes of construction generated traffic will be small and are unlikely to be a problem. From the details presently available, it appears that the construction noise impact is unlikely to be too severe at noise sensitive sites in the study area.

Once the proposed power station becomes operational, the situation is predicted to be as follows:

i) Noise levels near to the main roads will remain high and will continue to increase as traffic volumes increase.

ii) Although the operation of the Morupule B Power Station will introduce a very loud new source of noise into the study area, its location is such that its noise impact will be minor.

iii) Noise sensitive areas/sites with a residential character that lie within the offset distances of the proposed power station shown below could experience ambient noise levels higher than considered acceptable. The night-time period condition will be the control. Specifically the noise climate at night will be higher than the recommended maximum standard at any *urban residential* homes within 1500 metres, *suburban residential* homes within 2350 metres and *rural residential* homes within 3400 metres. The situation in the study area is however a positive one, that is:

    a) The residences on the western edge of Palapye (*urban residential*) lie well outside the power station's 45dBA+ impact zone and thus will not be negatively affected.

    b) The Colliery Village (*suburban residential*) lies well outside the power station's 40dBA+ zone and thus will not be negatively affected.

c) The "Molapu Wapitsi" settlement (*rural residential*) lies well outside the power station's 35dBA+ zone and thus will not be negatively affected. No other settlements are potentially affected.

d) Night-time noise levels in the "contractor's" village are already degraded from road traffic noise and the anticipated increase from the planned power station will be minor.

iii) The noise from the power station will not significantly worsen the noise climate at the Kgaswe Primary School.

iv) Noise impact from ancillary works and equipment (such as the conveyor belts) will in general be low and localised. The drive houses for the conveyor belt system, however, will be sites of high noise levels.

v) The volume of traffic generated by the operations at the proposed power station will only marginally increase the ambient noise levels along the road corridor between the power stations and Palapye.

The foregoing noise impact description is summarised in the Table overleaf. The predicted cumulative effects of the existing power station, the proposed Morupule B Power Station and the road traffic on the various noise sensitive sites in the study area are given in the Table. These predicted (calculated) noise levels are compared to the existing measured noise levels and the maximum acceptable standards as prescribed by the WHO, World Bank and SANS 10103. The specific noise impact of the Morupule B Power Station on the study area is also identified.

TABLE: PREDICTED CUMULATIVE NOISE EFFECTS IN STUDY AREA AND THE SPECIFIC NOISE IMPACT OF THE PROPOSED NEW MORUPULE B POWER STATION

Noise Sensitive Site	Period	Maximum Allowable Noise Level (dBA)		Measured Noise Level (Year 2007) (dBA)	Calculated Noise Level from Noise Source Component Indicated (Year 2012) (dBA)			Cumulative Noise Level (Σ) with and without New Power Station (NPS) (dBA)		Increase in Noise Level (Δ) due to New Power Station (dBA)
		WHO & WB	SANS 10103		Existing Power Station (a)	Road Traffic Noise (b)	New Power Station (c)	Without NPS (Σ_1) (Σ_1 = a+b)	With NPS (Σ_2) (Σ_2 = a+b+c)	($\Delta = \Sigma_2 - \Sigma_1$)
Site 1: Colliery Village (Suburban Residential)	Day	55	50	47.5	33.2	39.6	35.0	40.5	41.6	+1.1
	Night	45	40	39.2	33.2	33.5	35.0	36.4	38.7	+2.3
Site 2: Colliery Village (Suburban Residential)	Day	55	50	39.8	33.4	39.8	35.0	40.7	41.7	+1.0
	Night	45	40	28.8	33.4	33.8	35.0	36.6	38.9	+2.3
Site 3: Kgaswe School (Educational)	Day	55	50	57.9	44.5	55.6	46.7	55.9	56.4	+0.5
	Night	na	na	49.3	44.5	49.6	46.7	50.8	52.2	+1.4
Site 4: Settlement (Rural Residential)	Day	55	45	45.5	26.0	40.3	30.5	40.5	40.9	+0.4
	Night	45	35	30.8	26.0	34.2	30.5	34.8	36.2	+1.4
Site 5: Palapye (Urban Residential)	Day	55	55	62.4	24.1	61.6	32.8	61..6	61.6	0
	Night	45	45	46.2	24.1	55.5	32.8	55.5	55.5	0
Site 6: Palapye (Urban Residential)	Day	55	55	56.8	23.0	54.2	31.1	54.2	54.2	0
	Night	45	45	51.0	23.0	48.2	31.1	48.2	48.3	+0.1

Note: The Cumulative Noise Level (Σ) is obtained by summing the relevant component noise levels logarithmically.

The following conclusions have been drawn from the study:

i) Although not all of the final baseline noise design data was available for the analysis, the assumptions made are considered adequate to give a meaningful analysis of the noise impact situation, taking into account the fact that the proposed power station was modelled on the data from an existing similar technology type power station and that a conservative (worst case scenario) approach was used.

ii) Road traffic noise will continue to have a major negative impact in the areas immediately adjacent to the main roads.

iii) Although the existing general noise climate of much of the study area is still fairly representative of a quiet rural/farming district, ambient noise levels in the corridor between Palapye and Morupule A Power Station are already severely degraded near to the power station as well as at the colliery and near to the main roads. The positioning of the new power station very close to and to the east of the existing facility can therefore be supported.

iv) Although the operation of the Morupule B Power Station will introduce a very loud new source of noise into the study area, the power station's location is such that its noise impact will be minor. The area of potentially serious noise impact around the new power station will be fairly small (contained within a radius of about 3400 metres). There are only a few noise sensitive sites within this area of influence, and it has been shown that even under worst case scenario conditions these are not adversely affected.

v) Noise mitigating measures intended for the proposed power station will further reduce its area of potential negative impact.

There are noise control management measures (mitigating measures) that should be applied during the construction and the operational phases. For the construction phase, the restricting of construction activities to the day (07h00 to 18h00) would be the main issue. For the operational phase, the latest technology incorporating maximum noise mitigating measures for all plant and equipment should be designed into the system.

From the details presently available, it may be concluded that noise impact from the proposed Morupule B Power Station will not be significant.

NOISE IMPACT ASSESSMENT OF THE PLANNED MORUPULE B POWER STATION

1. INTRODUCTION

1.1. Background and Locality

Botswana Power Corporation (BPC) is planning a new power station (Morupule B Power Station). The Project site is located in the Central District of Botswana, approximately 280 kilometres north of Gaborone and just to the west of the village of Palapye. Refer to Figure 1. Palapye is classified as a secondary centre and is located on the main Gaborone-Francistown road (Road A1) and railway.

The new Power Station site is to be sited approximately 4500 metres to the west of the village of Palapye and 1200 metres north of the main road between Serowe and Palapye (Road A14) near to the existing power station (Morupule Power Station). It is situated on property, which BPC leases from the Bamangwato Tribal Authority.

Ecosurv and GIBB Botswana Pty (Ltd). are undertaking the environmental and social impact assessment study of the project while Jongens Keet Associates has undertaken the investigation of the potential noise impact of the new power station. This report documents the approach, findings and recommendations for the noise impact investigation.

1.2. Terms of Reference

The terms of reference (TOR) were as follows:

i) A sufficiently detailed quantitative (by measurement) and qualitative assessment was to be undertaken within the area of influence of the planned Morupule B Power Station, in order to enable a full appreciation of the nature, magnitude, extent and implications of the potential noise impact of all aspects of the project.

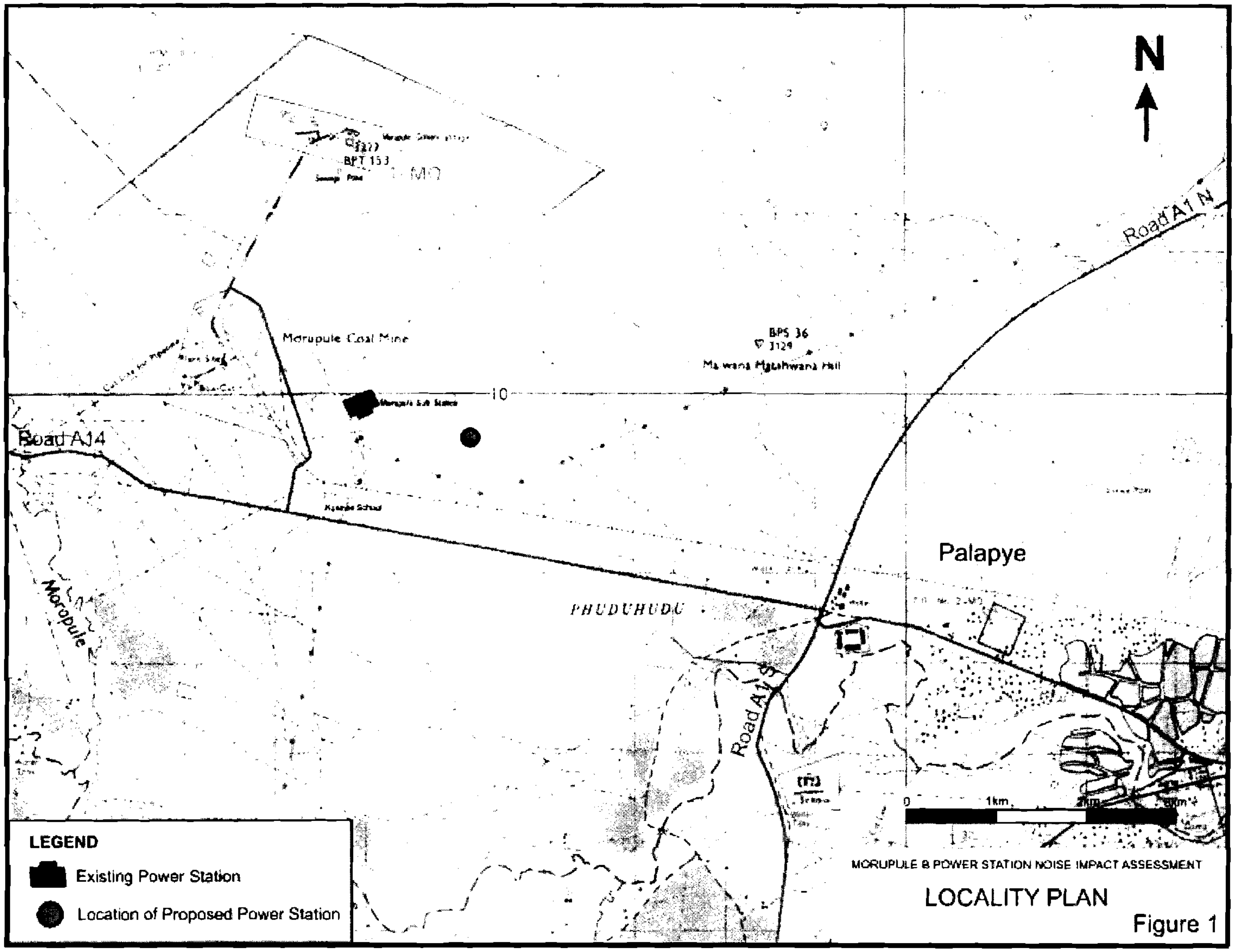
ii) The level of investigation was to be that of an EIA.

iii) All aspects of the investigation were to conform to the requirements of relevant environmental legislation and noise standards.

iv) The potential impacts at the pre-construction, construction and operational phases of the project were to be assessed.

v) Where relevant, appropriate noise mitigating measures were to be identified. These needed only to be conceptual at this stage.

vi) No public involvement meetings were to be attended by JKA.


N
Road A1 N
Morupule Coal Mine
BPT 153
BPS 36
10
Road A14
Palapye
PHUDUHUDU
Road A1 S
Morupule
0
1km
LEGEND
Existing Power Station
Location of Proposed Power Station
MORUPULE B POWER STATION NOISE IMPACT ASSESSMENT
LOCALITY PLAN
Figure 1

1.3. Study Area

The study area is that within the area of influence of the noise generated by the operations of and traffic generated by the planned Morupule B Power Station.

1.4. Details of the Morupule B Power Station Project

The proposed power station is to be developed approximately 1400 metres south-east of the existing power station (Morupule Power Station). Phase 1 of the proposed expansion includes the construction and operation of the Morupule B Power Station which will be a coal-fired, steam turbine driven thermal plant with a generating capacity of 600 Mega-Watts (MW) from 4 generator units of 150MW each, together with the necessary associated infrastructure. The likely position and orientation of the proposed power station buildings, ancillary works and ash dump have been provided by BPC.

Morupule B Power Station will source its coal supply from the existing Morupule Colliery which lies just to the north-west of the existing Morupule Power Station. Approximately 2,6 million tonnes of coal per annum will be supplied to the plant through a conveyor belt system from the adjacent Morupule Colliery. A wellfield approximately 80 kilometres north-west of the existing plant is currently under development to augment water supply to the existing power station and to supply the proposed Morupule B Power Station.

Construction of the Morupule B Power Station is expected to take approximately 4 years starting in Year 2008 and with commissioning in Year 2012.

2.0. DETAILS OF THE STUDY AREA

Only the aspects, which have an influence on the potential noise impact are dealt with in this Section.

2.1. Topography

The proposed new power station site is at an elevation of approximately 950 metres above mean sea-level (mamsl). The land to the northwest of the site (e.g. the rocky country around Serowe) rises to an elevation of 1100 mamsl. In general there is a gentle gradient falling away to the southeast. There are a few topographical features in the area that attain elevations of approximately 100 metres above the surrounding countryside. These features include the Tswapong hills, which lie about 10 kilometres to the southeast and the two small "koppies", to the north of the site. The rocky outcrops fall on the Colliery Property.

The Project site lies within the Lotsane River Catchment. This is a major ephemeral river in the area. This catchment is slightly hilly, but predominantly undulating. The area is drained by a series of seasonal rivers that form the Lotsane River. The regional drainage direction is to the east and southeast (Colquhoun, O'Donnell & Partners, 1979). The Lotsane River flows in a west to east direction through the southern sector of the study area approximately 5000 metres south of the existing power station. The Morupule River drains the area in a north to south direction and has its confluence with the Lotsane River approximately 4000 metres west of the existing power station.

2.2. Roads

The main roads influencing the study area are:

i) Road A1: The main road from Gaborone to Palapye to Francistown. It is aligned in a south to north direction through the centre of Palapye. For convenience in the report this road has been divided into two sections:
   a) Road A1 North is the section of the A1 north of Road A14 (from Palapye to Francistown).
   b) Road A1 South is the section of the A1 south of Road A14 (from Palapye to Gaborone).

ii) Road A14: The main road from Palapye to Serowe. It is aligned in an east to west direction through the central sector of the study area. It intersects with Road A1 in the centre of Palapye.

2.3. Railway Lines

There are two railway lines in the study area:

i) The mainline from Gaborone to Francistown is aligned in a south to north direction on the eastern side of Palapye.

ii) The spur-line from the Morupule Colliery to Palapye is aligned in a west to east direction just south of the Morupule Power Station. It links to the Gaborone-Francistown mainline in Palapye.

2.4. Land Use

2.4.1. ***Existing Situation***

The Power Station is situated on property, which BPC leases from Bamangwato Tribal Authority. Subsistence agriculture as well as the Morupule Colliery and the Palapye Village dominate the land that is immediately adjacent to the property.

The existing land uses in the area are:

i) Residential:

a) Village of Palapye. The nearest section of the town to the study area lies approximately 5500 metres to the east of the existing Morupule Power Station.

b) The Morupule Colliery Village is situated approximately 2850 metres north-west of the existing power station.

c) Settlement ("Molapu Wapitsi") just north of the Lotsane River. This is the only isolated settlement in the study area.

d) The "Contractor" village is located approximately 1200 metres south of the power station, just to the north of Road A14 and adjacent to the Kgaswe Primary School.

ii) Educational: The Kgaswe Primary School is located approximately 1200 metres south of the power station and just to the north of Road A14.

iii) Industrial: Morupule Power Station.

iv) Mining. The Morupule Colliery is located just to the west of the new power station site. It provides the existing power station with coal and will provide the Morupule B Power Station with fuel.

v) Agriculture. The main land use in the study area and its environs is crop growing (sorghum, maize, millet and beans) and livestock (cattle, goats and sheep).

It is the existing residential areas and the school in the study area that may defined as noise sensitive land uses.

2.4.2. ***Planned Land Use***

There are presently no known developments in the study area that could be adversely affected by the planned power station.

2.5. Aspects of Acoustical Significance

The terrain across the study area is flat falling gently to the south-east towards the Lotsane River. There are no natural features that will assist in the attenuation of noise.

The main meteorological aspect that will affect the transmission (propagation) of the noise is the wind. The wind can result in periodic enhancement downwind or reduction upwind of noise levels. Analysis of the wind records for the area indicates that overall (day and night average) the main prevailing winds blow from a north and a north-easterly direction, but the area does experience winds from the southeast, a condition which is associated with thunderstorms in summer months and cold fronts during winter months.

3. METHODOLOGY

3.1. General

Botswana in general applies the World Health Organisation (WHO) and World Bank (WB) environmental standards and procedures. There are South African National Standards (SANS) codes of practice and procedures which have been developed based on the requirements of the WHO and WB as well as those of the International Standards Organisation (ISO). As the South African documents are more detailed, more prescriptive and often apply more stringent standards it is recommended that the South African as well as the international standards be applied on this project. The general procedure used to determine the noise impact was guided by the requirements of the Code of Practice SANS 10328:2003: *Methods for Environmental Noise Impact Assessments*. The level of investigation was the equivalent of an EIA. A comprehensive assessment of all noise impact descriptors (standards) has been undertaken. The noise impact criteria used specifically take into account those as specified in the South African National Standard SANS 10103:2004, *The Measurement and Rating of Environmental Noise with Respect to Land Use, Health, Annoyance and Speech Communication* as well as those in relevant Noise Control Regulations.

The investigation comprised the following:

i) Determination of the existing situation (prior to the construction of the planned power station).

ii) Determination of the situation during construction and after commissioning of the planned power station.

iii) Assessment of the change in noise climate and impact.

iv) Identification of mitigating measures.

3.2. Determination of the Existing Conditions

This phase comprised the following:

i) The relevant technical details of the existing and the planned power stations, the existing traffic patterns and the existing and planned land use in the study area were reviewed in order to establish a comprehensive understanding of all aspects of the project that influence the existing noise climate and will influence the future noise climate in the study area.

ii) Using these data, the limits of the study area of the development site were determined and the potential noise sensitive areas, other major noise sources and potential problems in these areas were identified.

iii) Applicable noise standards and codes of practice were established. In the absence of local noise standards and codes of practice, the World Health Organisation Standards, the South African National Noise Control Regulations, and the SANS 10103:2004 standards were applied. These standards and codes of practice are consistent with the World Bank Group guidelines for thermal power plants.

iv) The existing *noise climate* of the Study Area was determined by means of a field inspection and a noise measurement survey. The measurement survey appropriately covered the whole of the study area, focussing specifically on the identified noise sensitive/problem areas. Measurements were taken at 13 monitoring sites in the study area. Both the daytime and night-time conditions were measured. The sound pressure level (SPL) (noise) measurements were taken in accordance with the requirements of the Code of Practice SANS 10103:2003, *The Measurement and Rating of Environmental Noise with Respect to Land Use, Health, Annoyance and to Speech Communication*. Type 1 Integrating Sound Level meters were used for the noise measurements. All measurements were taken under dry weather and normal traffic (that is mid-week/school term) conditions. Refer to Appendix B.

v) On the general field inspection and at the same time as each individual measurement was being taken, the qualitative nature of the *noise climate* in the area of the measurement site was assessed and recorded. This comprised an appraisal of the general prevailing acoustic conditions based on the subjective response to the sounds as perceived by the listener (i.e. *auditory observation* by the surveyor), as well as identifying those noise incidents, which influenced the noise meter readings during that measurement period. This procedure is essential in order to ensure that that there is a *human* correlation between the noise as perceived by the human ear and that, which is measured by the meter, as well as to establish any anomalies in the general ambient noise conditions.

vi) The noise profile of the existing Morupule Power Station was determined from measurement and calculation. The parameters for the calculation were determined from a baseline noise measurement of the various plant and equipment at the power station. These in turn were used as input to an appropriate noise propagation calculation model.

vii) The existing noise climates along the main roads as related to the current traffic volumes and patterns were established. These traffic noise levels were calculated using the South African National Standard SANS 10210 (SABS 0210) *Calculating and Predicting Road Traffic Noise*. The Year 2007 traffic was used as the baseline reference. The calculated 24-hour period noise indicators, as well as those for the daytime period and night-time period provided the main data for the impact assessment.. The measured data provided a field check of the acoustic conditions.

3.3. Assessment of the Construction Phase Impacts

Aspects of the construction activities that potentially will have a noise impact were identified and, where appropriate, mitigating measures have been recommended.

3.4 Assessment of Operational Phase Impacts

The main focus of the operational phase assessment was to establish the nature, magnitude and extent of the potential change in *noise climate* in the study area directly related to and within the area of influence of the planned power station site. This was done as follows:

i) The noise profile of the planned power station was calculated. The noise impact of the planned power station with its ancillary operations was established, and then its cumulative effects with Morupule Power Station were calculated. It should be noted that the design engineers (Fichtner) of the planned power station were not able at this stage to provide all the necessary details of the power station that are required for the noise generation calculation, or the detailed sound power level ratings for the various plant and equipment for the new facility, other than to specify the maximum sound pressure level that were not to be exceeded at a 1 metre offset from these various plant and equipment that will be installed. The required baseline data for the planned power station was thus based on typical acoustical characteristics measured and calculated at other similar types of power stations. Refer to Appendix C.

ii) Based on the findings, appropriate noise mitigating measures (site scale) have been investigated and recommendations made. These are conceptual and not detailed to final design level.

4. FINDINGS AND ASSESSMENT OF IMPACT

The following conditions were observed in the study area and the following aspects were determined from the surveys, calculations of noise indicators and the predictive modelling undertaken for the assessment of the noise impact of the planned power station.

4.1. General Details

General aspects of note were as follows:

i) The main sources of noise in the area are from:
   a) Traffic on Road A1 North, Road A1 South and Road A14.
   b) Morupule Power Station.
   c) Morupule Colliery.
   d) The colliery trains.

ii) The main noise sensitive areas/sites/receivers in the study area are:
   a) Palapye Village.

b) Morupule Colliery Village (residential).

c) Settlement ("Molapu Wapitsi") just north of the Lotsane River. This is the only isolated settlement in the study area.

d) Contractor village adjacent to the Kgaswe Primary School.

e) Kgaswe Primary School

4.2. The Existing Ambient Noise Climate

Measurements and *auditory observations* were taken at nine monitoring sites during the noise impact investigation in order to establish the ambient noise conditions of the study area. These were taken at appropriate sites at varying distances from the power station site. For a description of all of the measurement sites and for more technical details of the measurement survey, refer to Appendix B. Briefly the main sites are:

i) Site 1: In Morupule Mine Village in Mokowe Crescent.

ii) Site 2: At entrance gate to Morupule Mine Village on eastern side of access road.

iii) Site 3: On the western boundary of Kgaswe Primary School.

iv) Site 4: At remote settlement ("Molapu Wapitsi") just north of the Lotsane River.

v) Site 4a: On road to settlement (Site 4) at approximately 1000m south of Road A14.

vi) Site 5: On the south side of the road to Serowe (Road A14) just west of Palapye.

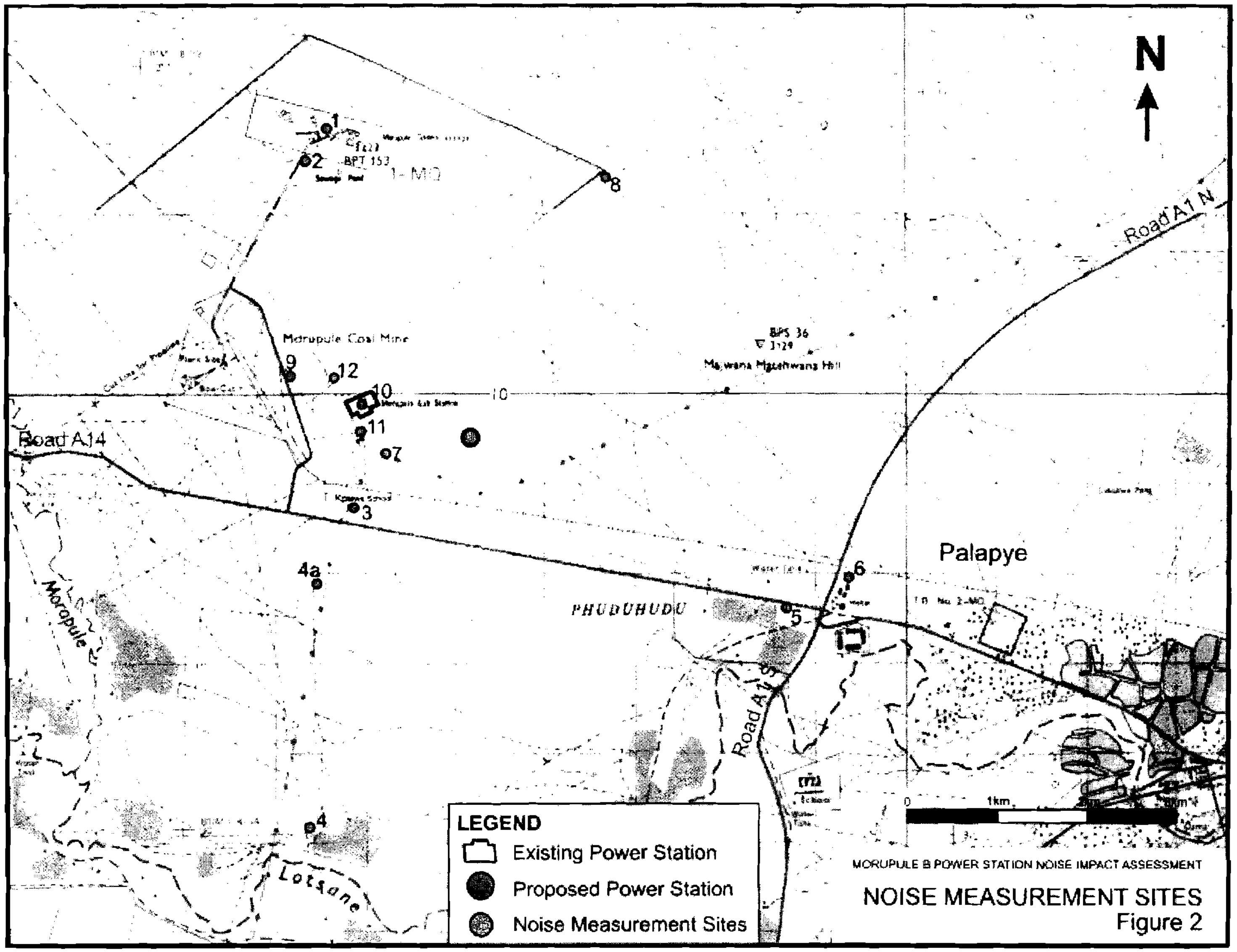
vii) Site 6: In residential area of Palapye to the east of Road A1 and just north of the Desert Sands Motel.

viii) Site 7: At the entrance gate to the Morupule Golf Course.

ix) Site 8: At the southeast corner of the Morupule Colliery Game Park.

Refer to Figure 2.

Conditions for the daytime and evening periods were ascertained. The summary of all the noise measurements taken at the main sites is given in Table 1. The equivalent sound pressure (noise) level (L_{Aeq}), the maximum sound pressure level (L_{Amax}) and the minimum sound pressure level (L_{Amin}) are indicated. Note that the equivalent sound pressure (noise) level may, in layman's terms, be taken to be the average noise level over the given period. This "average" is also referred to as the residual noise level (excluding the impacting noise under investigation) or the ambient noise level (if the impacting noise under investigation is included). The definitions/details of the noise descriptors for the measurements are given in Appendix A and Appendix B.


N
Road A1 N
Road A14
Road A1 S
Morupule Coal Mine
Palapye
PHUDUHUDU
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1
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12
0
1km
LEGEND
Existing Power Station
Proposed Power Station
Noise Measurement Sites
MORUPULE B POWER STATION NOISE IMPACT ASSESSMENT
NOISE MEASUREMENT SITES
Figure 2

TABLE 1: MEASURED CURRENT NOISE LEVELS IN THE MORUPULE POWER STATION STUDY AREA (YEAR 2007)

Measurement Site	Measured Sound Pressure Level (Noise) (dBA)					
	Daytime Period			Evening Period		
	L_{Aeq}	L_{max}	L_{min}	L_{Aeq}	L_{max}	L_{min}
Site 1	47.5	68.0	32.3	39.2	52.0	23.0
Site 2	39.8	52.8	27.1	28.8	45.1	21.1
Site 3	57.9	76.6	38.8	49.8	54.6	44.8
Site 4	45.4	58.3	29.5	30.8	38.5	28.2
Site 4a	43.5	57.6	33.0	n	n	n
Site 5	62.4	79.0	43.6	46.2	52.0	41.3
Site 6	56.8	76.0	43.9	51.0	58.7	39.6
Site 7	46.6	54.4	39.9	n	n	n
Site 8	35.2	50.1	30.5	n	n	n
Note: n indicates that no noise measurements were taken.						

The details of the sites where measurements were taken to isolate the Morupule Power Station noise are given in Appendix B. It was determined that the noise profile from the existing power station is as follows:

Offset Distance From Power Station	Sound Pressure Level (noise) (dBA)
1000m	46.7
1500m	41.9
2000m	38.2
2500m	35.2
3000m	32.6

In order to complement the short-term noise measurements in the study area, the existing 24-hour residual noise levels related to the average daily traffic (ADT) flows on Road A1 and Road A14 were also calculated. These data provide an accurate base for the SANS 10103 descriptors. The noise levels generated from the traffic on these roads were calculated using the South African National Standard SANS 10210 (SABS 0210), *Calculating and Predicting Road Traffic Noise*. Typical situations for the roads in the area, namely the cross sections are at grade, were used for the calculation sites. The Year 2007 traffic was used as the baseline for the calculations. The traffic data were obtained from the Botswana Department of Transport.

The noise levels at various offsets from the centreline of these main roads are summarised in Table B2 in Appendix B. The noise levels given are the unmitigated values. A conservative approach has been taken in that a hard intervening ground condition has been modelled to simulate winter conditions (burnt veld). The thick vegetation in the area will generally result in greater attenuation with distance than shown. There will also be greater attenuation with distance than shown where there are houses, other buildings and terrain restraints in the intervening ground between the source and the receiver point.

The number of coal trains on the line from the Morupule Colliery to Palapye varies and generally does not exceed more than one train per day. The noise from the passing of a freight train (drawn by a diesel locomotive) travelling at 45km/h peaks in the vicinity of 92dBA at a 30 metre offset from the track. There are level crossings at the Colliery access road, the power station access road and Road A1 N where it is mandatory that the trains sound a warning horn. Noise from these horn soundings can be as loud as 105dBA at 30 metres and 84dBA at 350 metres from the train.

In overview, the existing situation with respect to the *noise climates* in the study area was found to be as follows:

i) Noise levels in Palapye Village are high and are typical of an urban complex. The existing *noise climate* alongside the main roads in Palapye is degraded with regard to acceptable urban residential living standards (SANS 10103 noise impact criteria), that is noise exceeds acceptable levels particularly at night. Residences in some areas are negatively impacted from traffic noise (night-time standard) for up to 220 metres from the main roads. In general the daytime conditions are acceptable (SANS 10103).

ii) The areas outside Palapye and remote from the main roads and the power station/colliery are very quiet and reflect a rural character.

iii) The existing *noise climate* alongside Road A14 outside Palapye Village is degraded with regard to acceptable rural residential living standards (SANS 10103 noise impact criteria). Any residences within 2000 metres of the road are negatively impacted from traffic noise (particularly at night).

iv) The impact of the power station on noise sensitive sites in the surrounding area is minor. Noise levels from the power station exceed 35dBA (the maximum allowable night-time level for rural residential use) up to a distance of about 2500 metres from the facility. The Colliery Village and the settlement ("Molapu Wapitsi") lie outside this zone and are thus not impacted by the power station noise. These residential areas are also not adversely impacted by traffic noise from Road A14. The "contractors" housing adjacent to the Kgaswe Primary School lies within this zone but noise levels at this site are more severely affected by the Road A14 traffic noise. The power station will be heard late at night when traffic volumes are low.

v) Noise levels from traffic on Road A14 at the Kgaswe Primary School are slightly higher than desirable for an educational environment. The outdoor ambient noise level should not exceed 50dBA. Noise from vehicles passing over the rumble strips on the power station access road just to the west of the school is a significant noise nuisance factor.

vi) Noise from the power station does not have a significant impact on the activities at the Kgaswe Primary School.

vii) The overall impact of the noise from the coal trains on noise sensitive sites in the area is not significant. There is a minor nuisance effect at the school from the warning horn sounding when the train approaches the level crossing with the power station access road.

Refer to Appendix B for more details.

4.3. Noise Standards/Impact Criteria

From these findings it was considered appropriate to determine the noise impact in Palapye on the basis of urban residential standards, namely the daytime period ambient noise level should not exceed 55dBA and that for the night-time period should not exceed 45dBA. The noise impact criteria for the Morupule Colliery Village and "Contractor's Village" at Kgaswe Primary School should be based on suburban residential standards, namely the daytime period ambient noise level should not exceed 50dBA and that for the night-time period should not exceed 40dBA. The noise impact criteria for any rural settlements should be based on rural residential standards, namely the daytime period ambient noise level should not exceed 45dBA and that for the night-time period should not exceed 35dBA. Noise levels at schools should not exceed 50dBA (outdoor condition).

4.4. Assessment of the Construction Phase

4.4.1. ***General***

The potential noise climate was established in general for the construction of the new power station complex, inclusive of appurtenant works such as the internal road and access road system, the coal conveyor and the ash dump. A large construction camp will be established near to the construction site.

Although not all of the details of the proposed power station and its infrastructure have been finalised, general concepts have been used in the noise impact evaluation and these are adequate to provide a sound basis for the analysis of typical noise conditions and impacts that are likely to prevail due to the project. Data related to construction have been sourced from various consultants and the experience that JKA has had working on similar sites.

4.4.2. ***Construction Noise Conditions***

Construction will likely be carried out during the daytime only (07h00 to 18h00 or 20h00). It should however be noted that certain activities may occasionally extend into the late evening period, while others such as de-watering operations may need to take place over a 24-hour period. Some of the activities such as the construction of the chimney stacks could take place continuously (24-hours a day) over a number of weeks if a continuous sliding shutter concreting operation is used. It is estimated that the development of the project will take place over a period of 3 to 4 years.

4.4.2.1. *Sources of Noise*

The following are likely to be the main construction related sources of noise for the proposed power station and the related infrastructure:

i) Construction camp establishment. This will be for the site offices, workshops and the accommodation camp for the workers on site.

ii) Activities related to the relocation of services.

iii) Excavation of service trenches. Blasting may be required in places but in general pneumatic breakers will be used where rock is encountered.

iv) Piling operations.

v) Erection of shuttering for concrete works.

vi) Fixing of steel reinforcing.

vii) Placing and vibration of concrete. Poker vibrators will be used.

viii) Stripping of shuttering after concrete pour.

ix) Erection of structural steelwork.

x) Installation of plant and equipment.

xi) Finishing operations on buildings. Cladding, services installation, etc.

xii) General movement of heavy vehicles such as concrete delivery vehicles, mobile cranes, mechanical dumpers and water trucks (dust suppression) around the site.

xiii) De-watering pumps for storm-water and ground water in the excavations. A 24-hour operation may sometimes be necessary.

xiv) Road construction equipment. Scrapers, dozers, compactors, etc. (Construction of the internal road system, and access roads).

xv) Construction site fabrication workshops and plant maintenance workshops.

xvi) Construction material and equipment delivery vehicles.

xvii) Concrete batching plant and asphalt batching plant on site.

The level and character of the construction noise from the proposed power plant will be highly variable as different activities with different plant/equipment take place at different times, over different periods, in different combinations, in different sequences and on different parts of the construction site. Typical noise levels generated by various types of construction equipment are given in Table 2. These noise levels assume that the equipment is maintained in good order. Conservative attenuation conditions (related to intervening ground conditions and screening) have been applied. Using baseline data from typical construction sites, the ambient noise conditions at various offsets from the construction activities are likely to be as indicated in Table 3.

TABLE 2: TYPICAL NOISE LEVELS GENERATED BY CONSTRUCTION EQUIPMENT

Plant/Equipment	Typical Operational Noise Level at Given Offset (dBA)							
	5m	10m	25m	50m	100m	250m	500m	1000m
Air compressor	91	85	77	71	65	57	51	46
Compactor	92	86	78	72	66	58	52	46
Concrete mixer	95	89	81	75	69	61	55	49
Concrete vibrator	86	80	72	66	60	52	46	40
Conveyor belt (mobile)	77	71	63	57	51	43	37	32
Crusher (aggregate)	90	84	76	70	64	56	50	44
Crane (mobile)	93	87	79	73	67	59	53	47
Dozer	95	89	81	75	69	61	55	49
Loader	95	89	81	75	69	61	55	49
Mechanical shovel	98	92	84	78	72	64	58	52
Pile driver	110	104	97	91	85	77	71	65
Pump	86	80	72	66	60	52	46	40
Pneumatic breaker	98	92	84	78	72	64	58	52
Rock drill	108	102	94	88	82	74	68	62
Roller	84	78	70	64	58	50	44	38
Trucks	-	81	73	67	64	60	57	54

TABLE 3: TYPICAL CONSTRUCTION NOISE LEVELS FOR THE POWER STATION SITE

Equipment	Sound pressure level at given offset (dBA)										
	200 m	400 m	500 m	600 m	700 M	800 m	1000 m	1200 m	1500 m	2000 m	2500 m
Total construction operation	53.5	46.4	43.9	41.9	40.1	38.5	35.7	33.4	30.4	26.3	22.9

4.4.2.2. *Noise Impact*

The nature of the noise impact from the construction sites is likely to be as follows:

i) Source noise levels from many of the construction activities will be high. Noise levels from all work areas will vary constantly and in many instances significantly over short periods during any day working period.

ii) Exact daytime period and night-time period continuous equivalent sound pressure levels are not possible to calculate with certainty at this stage as the final construction site layout, work programme for the various components, work *modus operandi* and type of equipment have not been finalised. Working on a worst case scenario basis, it is estimated that the ambient noise level from general construction should not exceed 35dBA at the nearest noise sensitive receptor (namely the Kgaswe Primary School that is offset by about 1350 metres from the construction). Refer to Table 3. This is an acceptable level for this land use. The Morupule Colliery Village, the "Molapu Wapitsi" Settlement and the residential areas of Palapye will not be negatively affected by the construction site noise.

iii) No Traffic Impact Assessment was undertaken for the project. It has been estimated that the construction activities at the site will on average generate no more than about 250 vehicle trips (two way trips) daily. The main percentage of the trips will be concentrated in the morning and evening peak periods. As the daily volume of construction generated traffic will be relatively small in comparison with the existing daily traffic on the external main road system, the noise impact from this additional traffic on the surrounding areas will be insignificant. Ambient traffic noise levels on Road A14 due to the construction traffic will increase only marginally.

iv) For all construction work, the construction workers working with or in close proximity to equipment will be exposed to high levels of noise as can be seen from Table 2 (refer to the 5 metre offset noise levels).

It should be noted that for residential areas, higher ambient noise levels than recommended in SANS 10103 and WHO Guidelines for Community Noise are normally accepted as being reasonable during the construction period, provided that the very noisy construction activities are limited to the daytime and during the week, and that the contractor takes reasonable measures to limit noise from the work site. Note that it has been assumed that surface facility construction will generally take place from 07h00 to 18h00 with no activities (or at least no noisy construction activities) at night. From the details presently available, it appears that the construction noise impact is not likely to be a problem in the area.

4.5. Assessment of the Operational Phase

The following predicted conditions in the study area and the following aspects were determined from the surveys, calculations of noise indicators and the predictive modelling undertaken for the assessment of the noise impact of the planned Morupule B Power Station. This Section summarises the more detailed technical analysis, which is documented in Appendix C. The altered noise climate situation was evaluated on the basis of the noise impact from Morupule B Power Station, the cumulative noise impact effects of both power stations, the noise impact from ancillary works (such as the coal supply conveyor system), and the noise impact from traffic generated by the new power station.

4.5.1. *Noise Sources*

The main sources of noise in the area will be from:

i) Traffic on Road A1 North, Road A1 South and Road A14.

ii) Morupule Power Station.

iii) Morupule B Power Station.

iv) Morupule Colliery.

v) The colliery trains.

4.5.2. *Noise Sensitive Areas*

The main noise sensitive areas/sites/receivers in the study area are:

i) Palapye Village.

ii) Morupule Colliery Village (residential).

iii) Settlement ("Molapu Wapitsi") just north of the Lotsane River. This is the only isolated settlement in the study area.

iv) "Contractor" village adjacent to the Kgaswe Primary School.

v) Kgaswe Primary School

4.5.3. ***Predicted Noise Generated by the Morupule B Power Station***

Analysis of the existing Morupule Power Station and similar types of power stations elsewhere to the proposed power station indicated that, although there would be a large number of noise sources at the power station, the predominant noise source would be the cooling fans. The noise profile of the proposed power station is predicted to be:

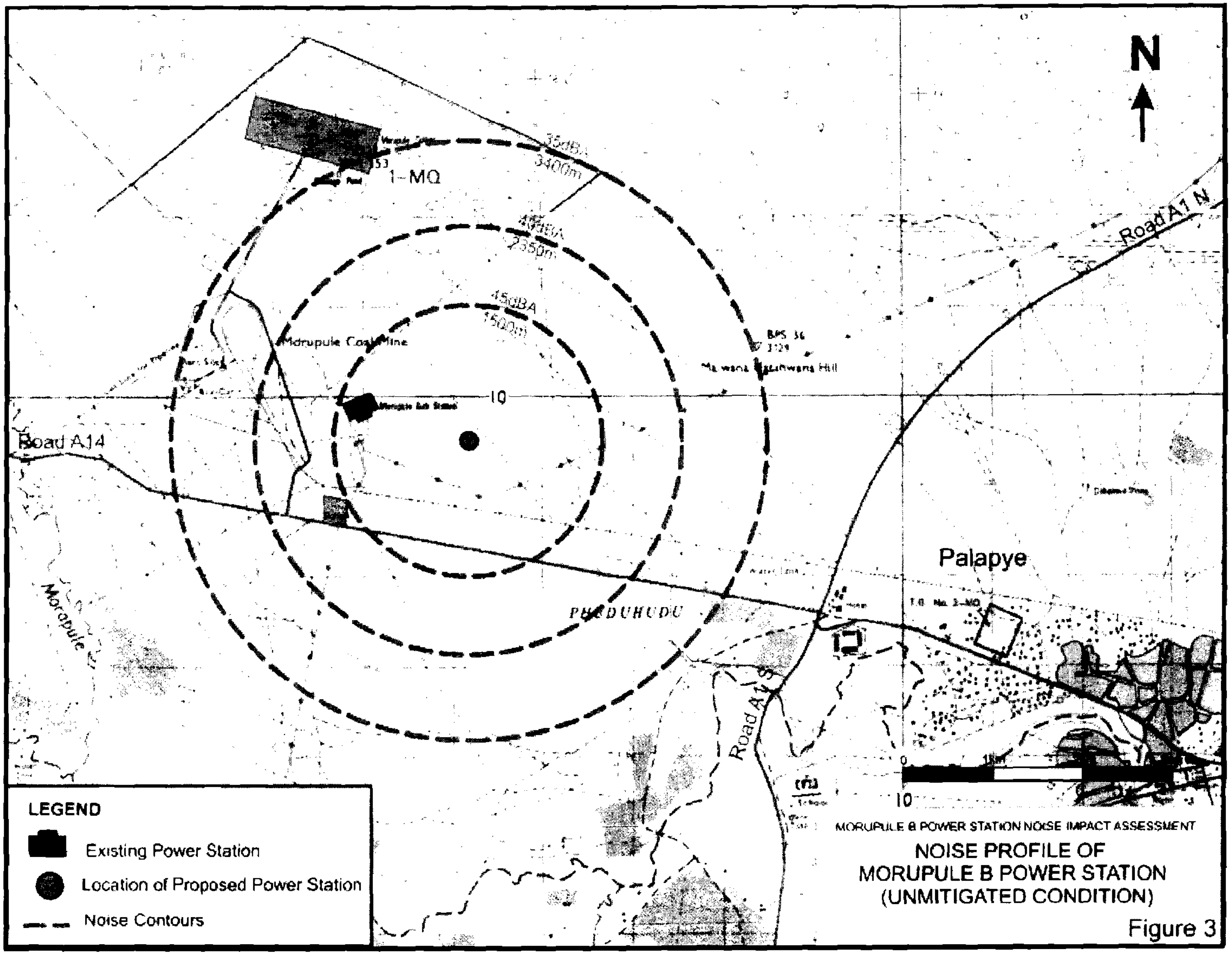
Offset Distance From Power Station	Sound Pressure Level (noise) (dBA)
400m	60.0
500m	57.3
1000m	50.0
1500m	45.0
2000m	41.9
2350m	40.0
2500m	39.1
3000m	36.7
3400m	35.0
4000m	32.8

Refer to Figure 3

The noise levels given are the unmitigated values. A conservative approach has been taken in the estimate of the number of cooling fans and the rated sound power level of these fans. A conservative approach has also been taken for the propagation of the sound in that a hard intervening ground condition has been modelled. The thick vegetation in the area will however generally result in greater attenuation with distance than shown. There will also be greater attenuation than shown with distance where there are houses, other buildings and terrain restraints in the intervening ground between the source and the receiver point.

4.5.4. ***Cumulative Effect of the Two Power Stations***

The proposed power station will be constructed approximately 1500 metres to the south-east of the existing power station. There will thus be cumulative effects, that is, the noise from the individual power stations at any point within the area of influence of both power stations will be enhanced to some extent. The maximum increase will be 3dBA. This noise enhancement will be experienced mainly in the area between the power stations. Morupule B Power Station will be the louder of the two, if unmitigated, and thus there will also be some enhancement to the west of the existing power station.


N
35dBA
3400m
40dBA
2350m
45dBA
1500m
1-MQ
Morupule Coal Mine
Road A14
10
Road A1 N
Road A1 S
Palapye
PHUDUHUDU
Morapule
LEGEND
Existing Power Station
Location of Proposed Power Station
Noise Contours
MORUPULE B POWER STATION NOISE IMPACT ASSESSMENT
NOISE PROFILE OF
MORUPULE B POWER STATION
(UNMITIGATED CONDITION)
Figure 3

4.5.5. ***Ancillary Works***

4.5.5.1. Conveyor Belt Systems

Coal will be delivered to the proposed Power Station by means of a conveyor belt. Noise will be generated by the conveyor belt drive houses and by the belt sections of the conveyor system. The predicted noise profile ("footprint") around a drive house is as follows:

Offset Distance from Drive House	Sound Pressure Level (noise) (dBA)
250m	57.3
500m	50.3
1000m	42.6
2000m	33.8
3000m	28.2

The predicted noise profile ("footprint") at the indicated offsets from the belt sections is as follows.

Offset Distance from Conveyor	Sound Pressure Level (noise) (dBA)
100m	48.2
250m	39.6
500m	32.7
1000m	25.0

The details and the position of the conveyor system has not been finalised, but it can be assumed that it will be on the most direct route between the colliery and the proposed power station. It is therefore unlikely that the noise from the conveyor system will cause significant impact at any of the noise sensitive sites near to the proposed power station.

4.5.5.2. Ash Dump Operations

The residue ash from the power station will be pumped as slurry to the ash dump which will be located to the north of the proposed Morupule B Power Station. The noise from the pumps will be a minor component in comparison to other noise sources.

4.5.5.3. Sewage/Waste Water Works Operation

The details and the position of the sewage/waste water works have not been finalised. The noise from such a plant is unlikely to be a major factor in the overall noise from the power station installation. For a typical plant, the ambient noise level is unlikely to exceed 40dBA at a 300 metres offset when the aeration rotors are working.

4.5.5. ***Traffic Noise***

The predicted noise levels related to the average daily traffic (ADT) flows on Road A1 South, Road A1 North and Road A14 (Palapye to Serowe) were calculated for Year 2012 (anticipated year of commissioning of the proposed power station). No Traffic Impact Assessment report was prepared for the EIA and thus the natural traffic growth on the main roads was estimated at 3% per annum and the Year 2007 traffic volumes were extrapolated on this basis. The Year 2007 traffic noise is predicted to increase by approximately 0.7dBA by the year 2012 and will still have a significant influence on the noise climate.

There are no predictions of the additional traffic which will be generated by the proposed power station once operational as no Traffic Impact Assessment was undertaken. Based on the situation at other similar sites, the estimated additional traffic that will be generated by normal operations at the power station once it is commissioned could be in the order of 400 trips to 500 trips (two way) daily. This increase in traffic will only marginally increase the ambient noise condition along Road A14, that is, an increase of 0,6dBA on the background traffic noise levels shown in Table C1 is predicted.

4.5.6. ***Assessment of Impact***

It was established that:

i) Noise levels near to the main roads will remain high and will continue to increase as traffic volumes increase.

ii) Although the operation of the Morupule B Power Station will introduce a very loud new source of noise into the study area, its location is such that its noise impact will be minor. Refer to Figure 3, Table C2 in Appendix C and the following discussion.

iii) Noise sensitive areas/sites with a residential character that lie within the offset distances of the proposed power station shown below could experience ambient noise levels higher than considered acceptable. The night-time period condition will be the control. Specifically the noise climate at night will be higher than the recommended maximum standard at any *urban residential* homes within 1500 metres, *suburban residential* homes within 2350 metres and *rural residential* homes within 3400 metres. The situation in the study area is however a positive one, that is:

   a) The residences on the western edge of Palapye (*urban residential*) lie well outside the power station's 45dBA+ impact zone and thus will not be negatively affected.

   b) The Colliery Village (*suburban residential*) lies well outside the power station's 40dBA+ zone and thus will not be negatively affected.

   c) The "Molapu Wapitsi" settlement (*rural residential*) lies well outside the power station's 35dBA+ zone and thus will not be negatively affected. No other settlements are potentially affected.

d) Night-time noise levels in the "contractor's" village are already degraded from road traffic noise and the anticipated increase from the planned power station will be minor.

iii) The noise from the power station will not significantly worsen the noise climate at the Kgaswe Primary School.

iv) Noise impact from ancillary works and equipment (such as the conveyor belts) will in general be low and localised. The drive houses for the conveyor belt system, however, will be sites of high noise levels.

v) The volume of traffic generated by the operations at the proposed power station will only marginally increase the ambient noise levels along the road corridor between the power stations and Palapye.

4.5.7. *Significance Rating of Impact*

The following procedure for the *rating of impact* was provided by GIBB Botswana. It relates to the operational phase of the project.

Classification of Impact

Impact	*Nature*	*Intensity*	*Extent*	*Duration*	*Probability*	*Confidence*
Noise	-	Low	Local	Long-term	Probable	High
With Mitigation	-	Low	Local	Long-Term	Probable	High

Consequence Rating

Impact	*Nature*	*Consequence*	*Probability*	*Confidence*
Noise	-	Low	Probable	High
With Mitigation	-	Low	Probable	High

Significance Rating

Impact	*Consequence*	*Probability*	*Significance*	*Confidence*
Noise	Low	Probable	LOW	High
With Mitigation	Low	Probable	LOW	High

5. MITIGATING MEASURES

Potential noise mitigating measures for the project were assessed.

5.1. Construction Phase

The noise mitigating measures to be considered during the construction phase are as follows:

i) Construction site yards, concrete batching plants, asphalt batching plants, construction worker camps (accommodation) and other noisy fixed facilities should be located well away from noise sensitive areas adjacent to the development site.

ii) All construction vehicles and equipment are to be kept in good repair.

iii) Construction activities, and particularly the noisy ones, are to be contained to reasonable hours during the day and early evening.

iv) With regard to unavoidable very noisy construction activities in the vicinity of noise sensitive areas, the contractor should liaise with local residents on how best to minimise impact.

v) In general operations should meet the noise standard requirements of the relevant occupational health and safety legislation.

vi) Construction staff working in areas where the 8-hour ambient noise levels exceed 75dBA should wear ear protection equipment.

5.2. Operational Phase

The following noise mitigating measures, which will need to be considered where appropriate, are preliminary indicators that may assist further in the design of the Morupule B Power Station:

i) The design of the proposed power station is to incorporate all the necessary acoustic design aspects required in order that the overall generated noise level from the new installation does not exceed a maximum equivalent continuous day/night rating level (L_{Rdn}), namely a noise level of 70dBA (just inside the *property projection plane*, namely the property boundary of the power station) as specified for industrial districts in SANS 10103. Refer to Appendix A. Notwithstanding this provision, the design is also to take into account the maximum allowable equivalent continuous day/night rating level of the potentially impacted noise sensitive sites outside the new power station property. Where the L_{Rdn} for the external site is presently lower than the maximum allowed, the maximum shall not be exceeded. Where the L_{Rdn} for the external site is presently at or exceeds the maximum level allowed, the existing level shall not be increased by more than indicated as acceptable in SANS 10103 (refer to Table A3 in Appendix A).

ii) The latest technology incorporating maximum noise mitigating measures for the power station components should be designed into the system. (The contract specifications for the proposed power station indicate that the contractor shall achieve a sound pressure level of 85dBA at a 1 metre offset from all plant and equipment.)

iii) The design process is to consider, *inter alia*, the following aspects:

a) The position and orientation of buildings on the site.

b) The design of the buildings is to minimise the transmission of noise from the inside to the outdoors.

c) The insulation of particularly noisy new plant and equipment. (The contract specifications for the proposed power station indicate that the contractor shall achieve a sound pressure level of 85dBA at a 1 metre offset from all plant and equipment.).

d) The alignment of the coal conveyor system and in particular the positioning of the drive houses.

iv) The access road to the Morupule B Power Station from Road A14 should be built in line with the new power station (approximately 1000 metres east of the access road to the existing power station past the school) in order to limit the traffic to and from the new facility from passing the school. The one negative noise related aspect to this new road is that an additional level crossing of the railway line will need to be constructed, and will be an additional point where approaching trains will need to sound a warning horn.

It should be noted that any measures taken at the development site will limit the impacts in the specific areas designed for, and will not necessarily contribute to improving the degraded noise climates in adjacent areas where there is already a problem. One existing area which was observed to have a significant noise nuisance problem is along the existing access road to the power station and just west of the school where traffic speed calming measures have been installed. Many vehicles do not reduce speed sufficiently when crossing the two speed humps (steel hemispheres), with a resultant noisy transition over the hump. More speed restriction signs should be installed on the approaches to the speed humps or, if the safety of the school children is not jeopardized, the speed humps should be removed.

6. CONCLUSIONS

The following conclusions may be drawn from the foregoing analysis:

i) Although not all of the final baseline noise design data was available for the analysis, the assumptions made are considered adequate to give a meaningful analysis of the noise impact situation, taking into account the fact that the proposed power station was modelled on the data from an existing similar technology type power station and that a conservative (worst case scenario) approach was used.

ii) Road traffic noise will continue to have a major negative impact in the areas immediately adjacent to the main roads.

iii) Although the existing general noise climate of much of the study area is still fairly representative of a quiet rural/farming district, ambient noise levels in the corridor between Palapye and Morupule Power Station are already severely degraded near to the power station as well as at the colliery and near to the main roads. The positioning of the new power station very close to and to the east of the existing facility can therefore be supported from the noise impact perspective.

iv) Although the operation of the Morupule B Power Station will introduce a very loud new source of noise into the study area, the power station's location is such that its noise impact will be minor. The area of potentially serious noise impact around the new power station will be fairly small (contained within a radius of about 3400 metres). There are only a few noise sensitive sites within this area of influence, and it has been shown that even under worst case scenario conditions these are not adversely affected.

v) Noise mitigating measures intended for the proposed power station will further reduce its area of potential negative impact.

7. RECOMMENDATIONS

The following are recommended:

i) The WHO Guidelines for Community Noise, the South African National Noise Control Regulations, and SANS 10103 should be used as the main guidelines for addressing the potential noise impact on this project. These guidelines are as stringent as the World Bank Group guidelines for thermal power plants but provide additional guidance to that provided by the World Bank Group.

ii) Once the final design details of the planned power station are known, the parameters which directly affect the calculations made in this noise impact study are to be checked and validated. If necessary, the calculations are to be redone and the noise impact checked.

iii) Various measures to reduce the potential noise impact from the planned power station are possible, and the mitigating measures indicated in Section 5, *inter alia*, need to be considered.

iv) The noise mitigating measures will need to be designed and/or checked by an acoustical engineer in order to optimise the design parameters and ensure that the cost/benefit of the measure is optimised.

v) At commissioning, the noise footprint of the planned power station should be established by measurement in accordance with the relevant standards, namely SANS ISO 8297:1994 and SANS 10103. The character of the noise (qualitative aspect) should also be checked to ascertain whether there is any nuisance factor associated with the operation.

8. REFERENCES

1. World Health Organization (WHO) (1999). *Guidelines for Community Noise*. Birgitta Berglund, Thomas Lindvall & Dietrich H Schwela (Eds.)
2. South African National Standard SANS 10103:2004, *The Measurement and Rating of Environmental Noise with Respect to Land Use, Health, Annoyance and to Speech Communication*.
3. South African National Standard SANS 10210 (SABS 0210), *Calculating and Predicting Road Traffic Noise*.
4. South African Bureau of Standards Code of Practice SANS 10328 (SABS 0328), *Methods for Environmental Noise Impact Assessments.*
5. South African National Standard SANS 10357 (SABS 0357), *The Calculation of Sound Propagation by the Concawe Method*.
6. South African National Noise Control Regulations.

APPENDIX A

GLOSSARY OF TERMS
AND
NOISE IMPACT CRITERIA

APPENDIX A: GLOSSARY OF TERMS AND NOISE IMPACT CRITERIA

A1. GLOSSARY OF TERMS

In order to ensure that there is a clear interpretation of this report the following meanings should be applied to the acoustic terminology:

- **Ambient sound level** or **ambient noise** means the totally encompassing sound in a given situation at a given time, and usually composed of sound from many sources, both near and far. Note that ambient noise includes the noise from the noise source under investigation. The use of the word *ambient* should however always be clearly defined (compare with *residual noise*).
- **A-weighted sound pressure, in Pascals**: The root-mean-square sound pressure determined by use of frequency-weighting network A.
- **A-weighted sound pressure level (SPL) (noise level) (L_{pA}), in decibels**: The sound pressure level of A-weighted sound pressure is given by the equation:

  $L_{pA} = 10 \log (p_A/p_o)^2$ where:

  p_A is the A-weighted sound pressure, in Pascals; and

  p_o is the reference sound pressure ($p_o = 20$ micro Pascals (μPa))

  Note: The internationally accepted symbol for sound pressure level, dB(A), is used.
- **Controlled areas** as specified by the SA National Noise Control Regulations are areas where certain noise criteria are exceeded and actions to mitigate the noise are required to be taken. Controlled areas as related to roads, airports and factory areas are defined. These Regulations presently exclude the creation of *controlled areas* in relation to railway noise.
- **dB(A)** means the value of the sound pressure level in decibels, determined using a frequency weighting network A. (The "A"-weighted noise levels/ranges of noise levels that can be expected in some typical environments are given in Table A2 at the end of this appendix).
- **Disturbing noise** means a noise level that exceeds the outdoor equivalent continuous rating level for the time period and neighbourhood as given in Table 2 of SANS 10103:2004. For convenience, the latter table is reproduced in this appendix as Table A1.
- **Equivalent continuous A-weighted sound pressure level ($L_{Aeq,T}$)** means the value of the A-weighted sound pressure level of a continuous, steady sound that, within a specified time interval, has the same mean-square sound pressure as a sound under consideration whose level varies with time.

- **Equivalent continuous rating level ($L_{Req,T}$)** means the equivalent continuous A-weighted sound pressure level during a specified time interval, plus specified adjustments for tonal character and impulsiveness of the sound and the time of day.
- **Equivalent continuous day/night rating level ($L_{R,dn}$)** means the equivalent continuous A-weighted sound pressure level during a reference time interval of 24-hours, plus specified adjustments for tonal character and impulsiveness of the sound and the time of day. (An adjustment of +10dB is added to the night-time rating level).
- **Integrating sound level meter** means a device that integrates a function of the root mean square value of sound pressure over a period of time and indicates the result in dBA.
- **Noise** means any acoustic phenomenon producing any aural sensation perceived as disagreeable or disturbing by an individual or group. Noise may therefore be defined as any *unwanted* sound or sound that is *loud, unpleasant or unexpected.*
- **Noise climate** is a term used to describe the general character of the environment with regard to sound. As well as the ambient noise level (quantitative aspect), it includes the qualitative aspect and the character of the fluctuating noise component.
- **Noise Control Regulations** means the regulations as promulgated by the SA National Department of Environmental Affairs and the World Health Organisation.
- **Noise impact criteria** means the standards applied for assessing noise impact.
- **Noise level** means the reading on an integrating impulse sound level meter taken at a measuring point in the presence of any alleged disturbing noise at the end of a total period of at least 10 minutes after such meter was put into operation, and, if the alleged disturbing noise has a discernible pitch, for example, a whistle, buzz, drone or music, to which 5dBA has been added. (The "A"-weighted noise levels/ranges of noise levels that can be expected in some typical environments are given in Table A2 at the end of this appendix).
- **Noise nuisance** means any sound which disturbs or impairs or may disturb or impair the convenience or peace of any reasonable person considering the location and time of day. This applies to a disturbance which is not quantitatively measurable such as barking dogs, etc. (compared with disturbing noise which is measurable).
- **Residual sound level** means the ambient noise that remains at a position in a given situation when one or more specific noises are suppressed (compare with *ambient noise*).
- **Sound exposure level or SEL** means the level of sound accumulated over a given time interval or event. Technically the sound exposure level is the level of the time-integrated mean square A-weighted sound for stated time or event, with a reference time of one second.
- **Sound (pressure) level** means the reading on a sound level meter taken at a measuring point.

- **SANS 10103** means the latest edition of the South African National Standard SANS 10103 titled *The Measurement and Rating of Environmental Noise with Respect to Land Use, Health, Annoyance and to Speech Communication.*
- **SANS 10210** means the latest edition of the South African National Standard SANS 10210 titled *Calculating and Predicting Road Traffic Noise.*
- **SANS 10328** means the latest edition of the South African National Standard SANS 10328 titled *Methods for Environmental Noise Impact Assessments.*
- **SANS 10357** means the latest edition of the South African National Standard SANS 10357 titled *The Calculation of Sound Propagation by the Concawe Method.*

- Refer also to the various South African National Standards referenced above, the World Health Organisation Guidelines for Community Noise and the SA National Noise Control Regulations for additional and, in some instances, more detailed definitions.

TABLE A1: TYPICAL NOISE RATING LEVELS FOR AMBIENT NOISE IN DISTRICTS (NOISE ZONES) SANS 10103

Type of District	Equivalent Continuous Rating Level for Noise ($L_{Req,T}$) (dBA)					
	Outdoors			Indoors with open windows		
	Day-night ($L_{R,dn}$)	Daytime ($L_{Req,d}$)	Night-time ($L_{Req,n}$)	Day-night ($L_{R,dn}$)	Daytime ($L_{Req,d}$)	Night-time ($L_{Req,n}$)
RESIDENTIAL DISTRICTS						
a) Rural districts	45	45	35	35	35	25
b) Suburban districts (little road traffic)	50	50	40	40	40	30
c) Urban districts	55	55	45	45	45	35
NON RESIDENTIAL DISTRICTS						
d) Urban districts (some workshops, business premises and main roads)	60	60	50	50	50	40
e) Central business districts	65	65	55	55	55	45
f) Industrial districts	70	70	60	60	60	50

TABLE A2: NOISE LEVELS/RANGES OF NOISE LEVELS THAT MAY BE EXPECTED IN SOME TYPICAL ENVIRONMENTS

Noise Level dB(A)	Typical Environment	Subjective Description
140	30m from jet aircraft during take-off	
130	Pneumatic chipping and riveting (operator's position)	Unbearable
>120	Hearing damage possible even for short exposure	
120	Large diesel power generator	
105-120	Low level military aircraft flight	
110-120	100 m from jet aircraft during take-off	
110	Metal workshop (grinding work), circular saw	
105-110	High speed train at 300 km/h (peak pass-by level at 7,5m)	
90-100	Printing press room	Very noisy
95-100	Passenger train at 200km/h (peak pass-by level at 7,5m).	Very noisy
95-100	Freight train at 100 km/h (peak pass-by level at 7,5 m)	Very noisy
90-100	Discotheque (indoors)	
75-100	7,5 m from passing motorcycle (50 km/h)	
75-80	10 m from edge of busy freeway (traffic travelling at 120 km/h)	
80-95	7,5 m from passing truck (50 km/h)	
80	Kerbside of busy street	
70	Blaring radio	Noisy
70	3 m from vacuum cleaner	Noisy
60-80	7,5 m from passing passenger car (50 km/h)	
65	Normal conversation	
65	Large busy office	
60	Supermarket/small office	
50	Average suburban home (day conditions)	Quiet
40	Library	
40-45	Average suburban home (night-time)	
30-35	Average rural home (night-time)	
25-30	Slight rustling of leaves	
20	Background in professional recording studio	Very quite
20	Forest (no wind)	
0-20	Experienced as complete quietness	
0	Threshold of hearing at 1000 Hz	

A2. NOISE IMPACT CRITERIA

The international tendency is to express noise exposure guidelines in terms of absolute noise levels. These guidelines imply that in order to ascertain an acceptable living environment, ambient noise in a given type of environment should not exceed a specified absolute level. This is the approach provided by the environmental guidelines of the World Health Organisation and the World Bank, which specify 55dBA during the day (06:00 to 22:00) and 45dBA during the night (22:00 to 06:00) for residential purposes, determined over any hour.

TABLE A3: WORLD HEALTH ORGANISATION (WHO) GUIDELINES FOR AMBIENT SOUND LEVELS

Environments	Ambient Sound Level L_{Aeq} dB			
	Daytime		Night-time	
	Indoor Space	Outdoor Space	Indoor Space	Outdoor Space
Dwellings	50	55	-	-
Bedrooms	-	-	30	45
Schools	35	55	-	-
Hospitals				
- general	35	-	35	45
- ward rooms	30	-	30	40

TABLE A4: WORLD BANK GUIDELINES FOR AMBIENT SOUND LEVELS

Receptor	Maximum Allowable Ambient Noise Levels 1-hour L_{eq} (dBA)	
	Daytime 07:00 – 22:00	Night-time 22:00 – 07:00
Residential, institutional, educational	55	45
Industrial, commercial	70	70
Note: No interior L_{Aeq} values nor values for rural areas are stipulated.		

SANS 10103 conforms to the described international tendency but makes recommendations for urban, suburban and rural districts. The recommended standards to be applied are summarised in Table A1.

A3. COMMUNITY RESPONSE TO NOISE

Communities generally respond to a change in the ambient noise levels in their environment, and the guidelines set out in SANS 10103 provide a good indication for estimating their response to given increases in noise. The suggested severity criteria for the noise impacts are summarised in terms of the above guidelines in Table A5.

TABLE A5: CATEGORIES OF COMMUNITY/GROUP RESPONSE (CRITERIA FOR THE ASSESSMENT OF THE SEVERITY OF NOISE IMPACT)

Increase in Ambient Noise Level (dBA)	Estimated Community/Group Response	
	Category	Description
0 – 10	Little	Sporadic complaints
5 – 15	Medium	Widespread complaints
10 - 20	Strong	Threats of community/group action
Greater than 15dBA	Very strong	Vigorous community/group action

Changes in noise level are perceived as follows:

- *3dBA:* For a person with average hearing acuity, an increase in the general ambient noise level of 3dBA will be just detectable.
- *5dBA:* For a person with average hearing acuity an increase of 5dBA in the general ambient noise level will be significant, that is he or she will be able to identify the source of the intruding noise. According to SANS 10103 the community response for an increase of less than 5dBA will be 'little' with 'sporadic complaints'. For an increase of equal or more than 5dBA the response changes to 'medium' with 'widespread complaints'.
- *10dBA:* A person with average hearing will subjectively judge an increase of 10dBA as a doubling in the loudness of the noise. According to SANS 10103 the estimated community reaction will change from 'medium' with 'widespread complaints' to 'strong' with 'threats of community action'.

APPENDIX B:

DETAILS OF THE NOISE MEASUREMENT SURVEY AND EXISTING NOISE CLIMATE CONDITION ASSESSMENT

APPENDIX B: DETAILS OF THE NOISE MEASUREMENT SURVEY AND EXISTING NOISE CLIMATE CONDITION ASSESSMENT

B1. GENERAL

The technical details of the noise measurement survey and general *noise climate* investigation related to the potential noise impact of the proposed Morupule B Power Station which is to be constructed in the area to the west of Palapye in Botswana are dealt with in this Appendix.

Botswana in general applies the World Health Organisation (WHO) and World Bank (WB) environmental standards and procedures. There are South African National Standards (SANS) codes of practice and procedures which have been developed based on the requirements of the WHO and WB as well as those of the International Standards Organisation (ISO). As the South African documents are more detailed, more prescriptive and often apply more stringent standards it is recommended that the South African as well as the international standards be applied on this project. The noise impact assessment was undertaken in accordance with the requirements of the South African National Standard SANS 10328 (SABS 0328) *Methods for Environmental Noise Impact Assessments*. Daytime and evening period noise measurements were taken at nine main monitoring sites at appropriate locations in the study area in order to establish the residual (existing) *noise climate*.

B2. STANDARDS AND MEASUREMENT EQUIPMENT

The sound pressure level (SPL) (noise) measurements were taken in accordance with the requirements of the South African National Standard SANS 10103:2004, *The Measurement and Rating of Environmental Noise with Respect to Land Use, Health, Annoyance and Speech Communication*. Two Type 1 Integrating Sound Level Meters, a Bruël and Kjaer Model 2230 meter and a Larson Davis 824 were used for the noise measurements. Both meters were calibrated at an accredited acoustical laboratory within the last 12 months. The calibration status of the meters was also checked before and after completion of the total measurement period of the day. A calibrated signal with a sound pressure level of 94,0dB at 1 kHz and 114,0dB at 1 kHz were applied to the Bruël and Kjaer meter and the Larson Davis meter respectively. A Larson Davis Model CAL200 was used.

For all measurements taken to establish the ambient noise levels, the equivalent noise level (L_{Aeq}), the maximum sound pressure level (L_{Amax}) and the minimum sound pressure level (L_{Amin}) during that measurement period were recorded. The frequency weighting setting was set on "A" and the time weighting setting of the meters were set on *Impulse* (I). Measurement periods of a minimum of 10 minutes were used. In addition, the variation in instantaneous sound pressure level (SPL) over a short period was also measured at some of the Sites. For these latter measurements the time weighting setting of the meter was also set on *Impulse* (I). At all the measurement sites, the meters were set up with the microphone height at 1,3 metres above ground level and well clear of any reflecting surfaces (a minimum of 3 metres clearance). For all measurements, a standard windshield cover (as supplied by the manufacturers) was placed on the microphone of each meter.

At the same time as each individual measurement was being taken, the qualitative nature of the *noise climate* in the area of the measurement site was assessed and recorded. This comprised an appraisal of the general prevailing acoustic conditions based on the subjective response to the sounds as perceived by the listener (i.e. *auditory observation* by the surveyor), as well as identifying those noise incidents, which influenced the noise meter readings during that measurement period. This procedure is essential in order to ensure that that there is a *human* correlation between the noise as perceived by the human ear and the noise, which is measured by the meter, as well as to establish any anomalies in the general ambient noise conditions.

B3. MEASUREMENT SITES

B3.1. Sites to Establish the Residual Noise Climate

Noise measurements to establish the residual (current ambient) noise conditions were taken at nine (9) main sites in the study area. Refer to Figure 2. These are:

Site No	Location Description	GPS Co-ordinates
1	In Morupule Mine Village in Mokowe Crescent (Assembly Point 4).	S22°29.564' E27°02.088'
2	At entrance gate to Morupule Mine Village on eastern side of access road.	S22°29.684' E27°01.910'
3	On the western boundary of Kgaswe Primary School, at approximately 30m from centre line of access road to the Morupule Power Station.	S22°31.841' E27°02.312'
4	At remote settlement ("Molapu Wapitsi") just north of the Lotsane River. (Approximately 3500m south of Road A14).	S22°33.777' E27°01.927'
4a	On road to settlement (Site 4) at approximately 750m south of Road A14.	S22°32.310' E27°01.990'
5	On the south side of the road to Serowe (Road A14) just west of Palapye. The site is at the north-west boundary of the Palapye Development Trust houses. The site is approximately 30m from the centre line of Road A14.	S22°32.427' E27°05.067'
6	In residential area of Palapye to the east of Road A1. The site is just to the north of the Desert Sands Motel and is approximately 100m east of the centre line of Road A1.	S22°32.282' E27°05.432'
7	At the entrance gate to the Morupule Golf Course to the southeast of the Morupule Power Station.	S22°31.485' E27°02.409'
8	At the southeast corner of the game fence of the Morupule Colliery Game Park, approximately 3750m north east of the Morupule Power Station.	S22°29.809' E27°03.660'

B3.2. Measurement Sites to Isolate the Existing Power Station Noise

Some of the sites already indicated, namely Site 2, Site 3, and Site 7 as well as the following four sites were used to determine the propagation characteristics of the noise generated by the existing power station:

Site No	Location Description	GPS Co-ordinates
9	At the coal conveyor crossing of the Colliery access road	S22°31.134' E27°01.835'
10	At the centre of the cooling fan banks (dominant noise source)	S22°31.190' E27°02.254'
11	At the southern fence-line of the power station.	S22°31.363' E27°02.304'
12	At the northern fence-line of the power station.	S22°31.091' E27°02.069'

Refer to Figure 2.

B4. MEASUREMENT DATES/TIMES

General observation of the noise conditions in the study area as well as the site specific sound pressure level (noise) measurements and observations were taken on Thursday 20 September 2007 during the daytime from 09h00 to 18h00 and in the evening/night from 19h30 to 23h00. The more specific measurements of plant and equipment at the power station were taken on the morning of Friday 21 September 2007.

B5. NOISE MEASUREMENT DETAILS

B5.1. Residual Sound Pressure Level Measurements

The results of the residual noise condition measurement survey are summarised in Table B1. The equivalent sound pressure (noise) level (L_{Aeq}), the maximum sound pressure level (L_{Amax}) and the minimum sound pressure level (L_{Amin}) are indicated. Note that the equivalent sound pressure (noise) level may, in layman's terms, be taken to be the average noise level over the given period. This "average" is also referred to as the residual noise level (excluding the impacting noise under investigation) or the ambient noise level (if the impacting noise under investigation is included).

TABLE B1: MEASURED CURRENT NOISE LEVELS IN THE MORUPULE POWER STATION STUDY AREA (YEAR 2007)

Measurement Site	Measured Sound Pressure Level (Noise) (dBA)					
	Daytime Period			Evening Period		
	L_{Aeq}	L_{max}	L_{min}	L_{Aeq}	L_{max}	L_{min}
Site 1	47.5	68.0	32.3	39.2	52.0	23.0
Site 2	39.8	52.8	27.1	28.8	45.1	21.1
Site 3	57.9	76.6	38.8	49.8	54.6	44.8
Site 4	45.4	58.3	29.5	30.8	38.5	28.2
Site 4a	43.5	57.6	33.0	n	n	n
Site 5	62.4	79.0	43.6	46.2	52.0	41.3
Site 6	56.8	76.0	43.9	51.0	58.7	39.6
Site 7	46.6	54.4	39.9	n	n	n
Site 8	35.2	50.1	30.5	n	n	n
Note: n indicates that no night-time measurements were taken at the site						

The weather conditions on the two survey days were such that the measurements to establish the ambient noise levels were not adversely affected and no specific corrective adjustments needed to be made.

B5.2. Noise Climate Generated by the Existing Power Station

Noise measurements were taken at six sites where the level of noise from the Morupule Power Station could be clearly heard and could be isolated from other background noise sources. These measured noise levels were then checked by calculation based on the baseline sound power level of the power station (cooling fans predominant noise). The noise profile of the power station as related to these six monitoring sites is summarized in Table B2.

TABLE B2: MORUPULE POWER STATION NOISE PROFILE

Site	Distance from Power Station	Noise Level (dBA)	
		Measured	Calculated
Site 11: South fence line of power station	330m	60.8	58.3
Site 12: North fence line of power station	336m	60.2	58.2
Site 7: At Golf Club entrance	606m	50.0	52.2
Site 9: Conveyor crossing of access road	726m	50.6	50.2
Site 3: At school	1205m	46.0	44.5
Site 2: At Colliery Village entrance	2841m	32.0	33.4

B5.3. Noise Climate Related to the 24 hour Road Traffic

In order to complement the short-term noise measurements, the existing 24-hour residual noise levels related to the average daily traffic (ADT) flows on Road A1 South (south of Palapye), Road A1 North (north of Palapye) and Road A14 (Palapye to Serowe) were also calculated. These data provide an accurate base for the SANS 10103 descriptors. The noise levels generated from the traffic on these roads were calculated using the South African National Standard SANS 10210 (SABS 0210), *Calculating and Predicting Road Traffic Noise*. Typical situations were used for the calculation site. The Year 2007 traffic data were used as the baseline for the calculations. The traffic data were obtained from the Botswana Department of Transport.

The noise levels at various offsets from the relevant road centrelines were established and are summarised in Table B3. The noise descriptors used are those prescribed in SANS 10103:2004, namely:

i) Daytime equivalent continuous rating (noise) level ($L_{Req,d}$) (L_d used in Table), namely for the period from 06h00 to 22h00).

ii) Night-time equivalent continuous rating (noise) level ($L_{Req,n}$) (L_n used in Table), namely for the period from 22h00 to 06h00).

iii) Day-night equivalent continuous rating (noise) level ($L_{R,dn}$) (L_{dn} used in Table), namely for the 24 hour period from 06h00 to 06h00).

The noise levels given are for generalised and the unmitigated conditions. There will be greater attenuation than shown with distance where there are houses, other buildings and terrain restraints in the intervening ground between the source and the receiver point.

It should be noted that the noise contours calculated for Road A1 are those within the urban area of Palapye where traffic speed is 60km/h. Outside the urban area where traffic speeds increase to between 110km/h and 120 km/h, the noise level values shown in Table B3 for Road A1 North and Road A1 South will increase by approximately 3dBA.

TABLE B3: EXISTING NOISE CLIMATE ADJACENT TO THE MAIN ROADS IN THE MORUPULE POWER STATION STUDY AREA (YEAR 2007 TRAFFIC)

Road	Noise Climate Alongside the Main Roads at Given Offset from Centreline (SANS 10103 Indicator) (dBA)																	
	25m Offset			50m Offset			100m Offset			250m Offset			500m Offset			1000m Offset		
	L_d	L_n	L_{dn}	L_d	L_n	L_{dn}	L_d	L_n	L_{dn}	L_d	L_n	L_{dn}	L_d	L_n	L_{dn}	L_d	L_n	L_{dn}
Road A1 N	60.2	54.2	62.0	57.2	51.2	59.0	54.2	48.2	56.0	50.2	44.2	52.0	47.2	41.2	49.0	44.2	38.2	46.0
Road A1 S	60.7	54.7	62.5	57.7	51.7	59.5	54.7	48.7	56.5	50.7	44.7	52.5	47.7	41.7	49.5	44.7	38.7	46.5
Road A14	60.3	54.2	62.0	57.3	51.2	59.0	54.3	48.2	56.0	50.3	44.2	52.0	47.3	41.2	49.0	44.3	38.2	46.0

B5.4. Noise Climate Related to the Coal Train Traffic

The number of coal trains on the line from the Morupule Colliery to Palapye varies and generally does not exceed more than one train per day. The noise from the passing of a freight train (drawn by a diesel locomotive) travelling at 45km/h peaks in the vicinity of 92dBA at a 30 metre offset from the track. There are level crossings at the Colliery access road, the power station access road and Road A1 N where it is mandatory that the trains sound a warning horn. Noise from these horn soundings can be as loud as 105dBA at 30 metres and 84dBA at 350 metres from the train.

B5.5. Existing Noise Climate

In overview, the existing situation with respect to the existing *noise climate* in the study area was found to be as follows:

i) The main sources of noise in the area are from:
   a) Traffic on Road A1 North, Road A1 South and Road A14.
   b) Morupule Power Station.
   c) Morupule Colliery.
   d) Colliery railway line.

ii) The main noise sensitive areas/sites/receivers in the study area are:
   a) Palapye Village.
   b) Morupule Colliery Village (residential).
   c) Settlement ("Molapu Wapitsi") just north of the Lotsane River. This is the only isolated settlement in the study area.
   d) Contractor village adjacent to the Kgaswe Primary School.
   e) Kgaswe Primary School

iii) Noise levels in Palapye Village are high and are typical of an urban complex. The existing *noise climate* alongside the main roads in Palapye is degraded with regard to acceptable urban residential living standards (SANS 10103 noise impact criteria), that is noise exceeds acceptable levels particularly at night. Residences in some areas are negatively impacted from traffic noise (night-time standard) for up to 220 metres from the main roads. In general the daytime conditions are acceptable (SANS 10103).

iv) The areas outside Palapye and remote from the main roads and the power station/colliery are very quiet and reflect a rural character.

v) The existing *noise climate* alongside Road A14 outside Palapye Village is degraded with regard to acceptable rural residential living standards (SANS 10103 noise impact criteria). Any residences within 2000 metres of the road are negatively impacted from traffic noise (particularly at night).

vi) The impact of the power station on noise sensitive sites in the surrounding area is minor. Noise levels from the power station exceed 35dBA (the maximum allowable night-time level for rural residential use) up to a distance of about 2500 metres from the facility. The Colliery Village and the settlement ("Molapu Wapitsi") lie outside this zone and are thus not impacted by the power station noise. These residential areas are also not adversely impacted by traffic noise from Road A14. The "contractors" housing adjacent to the Kgaswe Primary School lies within this zone but noise levels at this site are more severely affected by the Road A14 traffic noise. The power station noise will be heard late at night when traffic volumes are low.

vii) Noise levels from traffic on Road A14 at the Kgaswe Primary School are slightly higher than desirable for an educational environment. The outdoor ambient noise level should not exceed 50dBA. Noise from vehicles passing over the rumble strips on the power station access road just to the west of the school is a significant noise nuisance factor.

viii) Noise from the power station does not have a significant impact on the activities at the Kgaswe Primary School.

ix) The overall impact of the noise from the coal trains on noise sensitive sites in the area is not significant. There is a minor nuisance effect at the school from the warning horn sounding when the train approaches the level crossing with the power station access road.

APPENDIX C

ASSESSMENT OF NOISE IMPACT

APPENDIX C: ASSESSMENT OF NOISE IMPACT

C1. GENERAL

Botswana Power Corporation (BPC) is planning a new power station (Morupule B Power Station), which is to be constructed at a site 4,5 kilometres west of Palapye Village. The proposed power station is to be located just to the east of the existing Morupule Power Station.

The assessment of the noise impact was guided by the requirements of the South African National Standard SANS 10328 (SABS 0328) titled *Methods for Environmental Noise Impact Assessments*, the World Health Organisation (WHO) Noise Standards and relevant Noise Control Regulations and Guidelines including those of the World Bank Group for thermal power plants. A comprehensive assessment using the appropriate noise impact descriptors (standards) has been undertaken. The noise impact criteria used in this investigation specifically take into account those as specified in the South African National Standard SANS 10103:2004, *The Measurement and Rating of Environmental Noise with Respect to Land Use, Health, Annoyance and Speech Communication,* as well as those in the National Noise Control Regulations. Relevant aspects of these Regulations and SANS 10103:2004 are provided in Appendix A.

All of the noise sensitive sites in the area that are potentially affected by operations at the new power station were provided by the team undertaking the social impact assessment. These were confirmed during the site inspection by the acoustician. The following 1:50 000 topographical cadastral maps were also used in the analysis of the area:

- REPUBLIC OF BOTSWANA 1:50 000, Sheet 2226 B4, Edition 3-DSL 1983.
- REPUBLIC OF BOTSWANA 1:50 000, Sheet 2226 D2, Edition 3-DSL 1983.
- REPUBLIC OF BOTSWANA 1:50 000, Sheet 2227 A3, Edition 3-DSL 1983.
- REPUBLIC OF BOTSWANA 1:50 000, Sheet 2227 C1, Edition 3-DSL 1983.

C2. ASSESSMENT OF THE OPERATIONAL PHASE

C2.1. General

The proposed Morupule B Power Station was evaluated on the following basis:

i) Noise impact from Morupule B Power Station.
ii) Cumulative noise impact effects of both power stations.
iii) Noise impact from ancillary works.
iv) Noise impact from traffic generated by the new Power Station.
v) Features of acoustical significance.

C2.2. General Noise Conditions Related to the Existing and the Planned Power Stations

C2.2.1. Existing Morupule Power Station

The noise profile of the existing Morupule Power Station was determined from measurement and calculation. The parameters for the calculation were determined from a baseline noise measurement of the various plant and equipment at the power station and these in turn were used as input to an appropriate noise propagation calculation model, namely SANS 10357:2000, *The Calculation of Sound Propagation by the Concawe Method*. The dominant source of noise from the power station in the far field (exceeding 300 metres) was found to be that from the cooling fans. The noise profile of the power station was found to be:

Offset Distance from Power Station	Sound Pressure Level (noise) (dBA)
1000m	46.7
1500m	41.9
2000m	38.2
2500m	35.2
3000m	32.6

C2.2.2. Morupule B Power Station

The proposed Morupule B Power Station is to have a total generating capacity of 600 Mega-Watts (MW). It has also been specified that there should be 4 generating units each with a generating capability of 150 MW. It should however be noted that the design engineers of the planned Power Station (Fichtner) were not able at this stage to provide all the necessary details of the facility that are required for the noise generation calculation. This is because of the detailed design not being complete as yet. In particular, an estimate of the number of cooling fans that would be necessary for each generating unit could not be provided. These data are critical as the noise from the cooling fans will be the main component of the overall noise from the power station. The detailed sound power level ratings for the various plant and equipment for the new facility could also not be provided, other than the maximum sound pressure levels that were not to be exceeded at a 1 metre offset from these various plant and equipment that are to be installed. The required baseline data for the planned power station was thus based on typical acoustical characteristics measured and calculated at other similar types of power stations.

The baseline noise data was sourced from the existing Eskom Matimba Power Station in South Africa that has a generating capacity of about 3 900 Mega-watts (MW) from six generator units. There are a total of 288 cooling fans, namely 48 fans per generating unit. The planned Eskom Matimba B Power Station is likely to have 72 cooling fans per generating unit. The intended installed generating capacity of the new Morupule B Power Station is 600 MW from four generator units. On the basis of proportioning the number of fans to the generating units' MW rating, a generating unit at the Morupule B Power Station is calculated to require between 11 and 14 cooling fans. Conservatively sixteen (16) cooling fans (with the same sound power level as those at Matimba Power Station) per generating unit (64 total) have been used to calculate the noise profile of the Morupule B Power Station. It should be noted that from a noise sensitivity perspective, a doubling of the number of fans from 64 to 128 would result in an increase in noise level of 3dBA from the power station. With a further doubling to 256 fans, the noise level would increase by another 3dBA. Similarly it should be noted that from a noise sensitivity perspective, a halving of the number of fans from 64 to 32 would result in a decrease in noise level of 3dBA from the power station. The condenser fan platform at fan level is likely to be 35 metres above ground level. This configuration of fans is likely to result in approximately the following ambient noise conditions around the Morupule B Power Station (from power station source only):

Offset Distance from Power Station	Sound Pressure Level (noise) (dBA)
400m	60.0
500m	57.3
1000m	50.0
1500m	45.0
2000m	41.9
2350m	40.0
2500m	39.1
3000m	36.7
3400m	35.0
4000m	32.8

Noise levels on the far side of the power station building to the fans will be slightly quieter due to shielding from the building.

The noise levels given are the unmitigated values. A conservative approach has been taken in that a hard intervening ground condition has been modelled. The thick vegetation in the area will however generally result in greater attenuation with distance than shown. There will also be greater attenuation than shown with distance where there are houses, other buildings and terrain restraints in the intervening ground between the source and the receiver point.

C2.3. General Noise Conditions Related to Ancillary Works

C2.3.1. ***Conveyor Belt Systems***

Coal will be delivered to the proposed Power Station by means of a conveyor belt. Noise will be generated by the conveyor belt drive houses and by the belt sections of the conveyor system. The predicted noise profile ("footprint") around a drive house is as follows:

Offset Distance from Drive House	Sound Pressure Level (noise) (dBA)
250m	57.3
500m	50.3
1000m	42.6
2000m	33.8
3000m	28.2

The predicted noise profile ("footprint") at the indicated offsets from the belt sections is as follows.

Offset Distance from Conveyor	Sound Pressure Level (noise) (dBA)
100m	48.2
250m	39.6
500m	32.7
1000m	25.0

The final details and the position of the conveyor system has not been finalised, but it can be assumed that it will be on the most direct route between the colliery and the proposed power station. It is therefore unlikely that the noise from the conveyor system will cause significant impact at any of the noise sensitive sites near to the proposed power station.

C2.3.2. ***Ash Dump Operations***

The residue ash from the power station will be pumped as slurry to the ash dump which will be located to the north of the proposed Morupule B Power Station. The noise from the pumps will be a minor component of the noise sources.

C2.3.3. ***Sewage/Waste Water Works Operation***

The details and the position of the sewage/waste water works have not been finalised. The noise from such a plant is unlikely to be a major factor in the overall noise from the power station installation. For a typical plant, the ambient noise level will be 40dBA at a 300 metres offset when the aeration rotors are working.

C2.4. Traffic Operational Conditions

The predicted noise levels related to the average daily traffic (ADT) flows on Road A1 South (south of Palapye), Road A1 North (north of Palapye) and Road A14 (Palapye to Serowe) for

Year 2012 (anticipated year of commissioning of the proposed power station) were calculated. No Traffic Impact Assessment report was prepared for the EIA and thus traffic growth on the main roads was estimated at 3% per annum and the Year 2007 traffic volumes were extrapolated on this basis. The noise levels generated from the traffic on these roads were calculated using the South African National Standard SANS 10210 (SABS 0210), *Calculating and Predicting Road Traffic Noise*. Typical situations for the roads in the area, namely the cross sections are at grade, were used for the calculation sites.

The noise levels at various offsets from the relevant road centrelines were established and are summarised in Table C1. The noise descriptors used are those prescribed in SANS 10103:2004, namely:

i) Daytime equivalent continuous rating (noise) level ($L_{Req,d}$) (L_d used in Table), namely for the period from 06h00 to 22h00).

ii) Night-time equivalent continuous rating (noise) level ($L_{Req,n}$) (L_n used in Table), namely for the period from 22h00 to 06h00).

iii) Day-night equivalent continuous rating (noise) level ($L_{R,dn}$) (L_{dn} used in Table), namely for the 24 hour period from 06h00 to 06h00).

The noise levels given are for generalised and the unmitigated conditions. There will be greater attenuation than shown with distance where there are houses, other buildings and terrain restraints in the intervening ground between the source and the receiver point.

It should be noted that the noise contours calculated for Road A1 N and Road A1 S are those within the urban area of Palapye where traffic speed is 60km/h. Outside the urban area where traffic speeds increase to between 110km/h and 120 km/h, the noise level values shown in Table C1 for Road A1 North and Road A1 South will increase by approximately 3dBA.

No Traffic Impact Assessment report was prepared for the EIA and thus there are no predictions of the additional traffic which will be generated by the proposed power station. Based on estimates at other similar sites, the estimated additional traffic that will be generated by normal operations at the power station once it is commissioned could be in the order of 400 trips (two way) daily. This increase in traffic will only marginally increase the noise along Road A14, that is, an increase of 0,6dBA on the levels shown in Table C1 is predicted.

TABLE C1: EXISTING NOISE CLIMATE ADJACENT TO THE MAIN ROADS IN THE MORUPULE POWER STATION STUDY AREA (YEAR 2012 TRAFFIC)

Road	Noise Climate Alongside the Main Roads at Given Offset from Centreline (SANS 10103 Indicator) (dBA)																	
	25m Offset			50m Offset			100m Offset			250m Offset			500m Offset			1000m Offset		
	L_d	L_n	L_{dn}	L_d	L_n	L_{dn}	L_d	L_n	L_{dn}	L_d	L_n	L_{dn}	L_d	L_n	L_{dn}	L_d	L_n	L_{dn}
Road A1 N	61.0	55.0	62.7	58.0	52.0	59.7	55.0	49.0	56.7	51.0	45.0	52.7	48.0	42.0	49.7	45.0	39.0	46.7
Road A1 S	61.5	55.4	63.2	58.5	52.4	60.2	55.5	49.4	57.2	51.5	45.4	53.2	48.5	42.4	50.2	45.5	39.4	47.2
Road A14	61.0	55.0	62.7	58.0	52.0	59.7	55.0	49.0	56.7	51.0	45.0	52.7	48.0	42.0	49.7	45.0	39.0	46.7

C2.5. Features of Acoustical Significance

C2.5.1. ***Wind***

Analysis of the wind records for the area indicates that overall (day and night average) the main prevailing winds blow from a north and a north-easterly direction. Under windy conditions there will thus be a sight enhancement of noise levels to the south-west of the proposed power station, namely in the area of the Kgaswe Primary School.

C2.5.2. ***Topography***

The terrain in the study area is relatively flat with a gentle fall to the south-east. There are no real features in the area that will influence the propagation and attenuation of sound.

C2.5.3. ***Vegetation***

The vegetation in the area is thick bush and trees that will result in some attenuation of the power station noise with increasing distance from the source.

C3. ANALYSIS OF THE CUMULATIVE NOISE IMPACT EFFECTS

The predicted cumulative effects of the existing power station, the proposed Morupule B Power Station and the road traffic on the various noise sensitive sites are given in Table C2. These predicted (calculated) noise levels are compared to the existing measured noise levels and the maximum acceptable standards as prescribed by the WHO and SANS 10103. The specific noise impact of the Morupule B Power Station on the study area is identified in the Table.

TABLE C2: PREDICTED CUMULATIVE NOISE EFFECTS IN STUDY AREA AND THE SPECIFIC NOISE IMPACT OF THE MORUPULE B POWER STATION

Noise Sensitive Site	Period	Maximum Allowable Noise Level (dBA)		Measured Noise Level (Year 2007) (dBA)	Calculated Noise Level from Noise Source Component Indicated (Year 2012) (dBA)			Cumulative Noise Level (Σ) with and without New Power Station (NPS) (dBA)		Increase in Noise Level (Δ) due to New Power Station (dBA)
		WHO & WB	SANS 10103		Existing Power Station (a)	Road Traffic Noise (b)	New Power Station (c)	Without NPS (Σ_1) (Σ_1 = a+b)	With NPS (Σ_2) (Σ_2 = a+b+c)	($\Delta = \Sigma_2 - \Sigma_1$)
Site 1: Colliery Village (Suburban Residential)	Day	55	50	47.5	33.2	39.6	35.0	40.5	41.6	+1.1
	Night	45	40	39.2	33.2	33.5	35.0	36.4	38.7	+2.3
Site 2: Colliery Village (Suburban Residential)	Day	55	50	39.8	33.4	39.8	35.0	40.7	41.7	+1.0
	Night	45	40	28.8	33.4	33.8	35.0	36.6	38.9	+2.3
Site 3: Kgaswe School (Educational)	Day	55	50	57.9	44.5	55.6	46.7	55.9	56.4	+0.5
	Night	na	na	49.3	44.5	49.6	46.7	50.8	52.2	+1.4
Site 4: Settlement (Rural Residential)	Day	55	45	45.5	26.0	40.3	30.5	40.5	40.9	+0.4
	Night	45	35	30.8	26.0	34.2	30.5	34.8	36.2	+1.4
Site 5: Palapye (Urban Residential)	Day	55	55	62.4	24.1	61.6	32.8	61..6	61.6	0
	Night	45	45	46.2	24.1	55.5	32.8	55.5	55.5	0
Site 6: Palapye (Urban Residential)	Day	55	55	56.8	23.0	54.2	31.1	54.2	54.2	0
	Night	45	45	51.0	23.0	48.2	31.1	48.2	48.3	+0.1

Note: The Cumulative Noise Level (Σ) is obtained by summing the relevant component noise levels logarithmically.

Appendix 5.1

Scoping background information document

ENVIRONMENTAL SCOPING STUDY OF THE PROPOSED EXPANSION OF THE BPC POWER STATION AT MORUPULE

ENVIRONMENTAL SCOPING STUDY

BACKGROUND INFORMATION DOCUMENT

(Discussion Document)

December 2003

SUMMARY

The Botswana Power Corporation (BPC) wishes to carry out a study of the proposed expansion of the Morupule Power Station. The aim of the study will be to; evaluate the expansion of the station versus the alternative of increasing the power imported from Eskom in South Africa.

The overall objectives of the entire feasibility study are to:

- Review the information from all previous studies;
- Determine the technical, and economic feasibility of this generation expansion whilst taking into account the availability of both the water and coal supplies;
- Evaluate the ability of BPC to implement the proposed expansion;
- Perform an analysis of the future power demand, expected growth as well as potential tariff structures; and
- Estimate the capital costs and the financing of such an expansion.

GIBB Botswana has been appointed to undertake Environmental Scoping Study and to investigate the potential environmental impacts of the proposed expansion of the Morupule Power Station on the environment. GIBB Botswana has in turn appointed Botsalano Coyne to conduct the Public Participation Process/Facilitation.

If you wish to participate in the study and receive further information, please contact Botsalano Coyne. Contact details are provided at the end of this document.

INTRODUCTION

Botswana Power Corporation (BPC) wishes to carry out a feasibility study of the proposed expansion of the Morupule Power Station. This environmental assessment of the impacts is one component of the feasibility study.

In terms of the NCSA Guidelines, the Botswanan Government requires that all environmental issues be evaluated. As a result GIBB Botswana and the Public Participation Consultant will investigate environmental and other impacts of proposed scheme. The methodology to be used, to identify these potential impacts, is a Scoping Study with some specialist input. This strategy has been adopted, to obtain as much information at an early stage, as is possible, to enable the environmental team to identify any potential "red flag" issues that could prevent the expansion of the Power Station.

The end result of this process will be a Scoping Report handed in to the relevant department (in this case the National Conservation Strategy Co-ordinating Agency - NCSA).

APPROACH TO THE ENVIRONMENTAL SCOPING STUDY

The specific objectives would to be:

- To consult and inform all relevant stakeholders about the proposed project and inform them of the EIA process to be followed;
- To provide an opportunity for the exchange of information as well as the raising of issues, ideas and concerns;
- Identify any "red flag" issues that could prevent the proposed expansion;
- Focus the remaining phases of the EIA (viz. the Impact Assessment Phase) on the viable project alternatives and the relevant issues; and
- Identify all the significant issues that will need to be addressed in the Impact Assessment Phase.

YOUR OPPORTUNITY TO GET INVOLVED

The purpose of our meetings and this Background Information Document will be to share information and discuss issues and solicit your comments/issues concerns/ideas. <u>All verbal comments made will be incorporated into the process.</u>

To obtain further information on the proposed developments, please contact:

Ms Botsalano Coyne Private Bag 0045, Gaborone, Botswana.
(Tel) 09267 395 7203, (Fax) 9267 395 1258, (E-Mail) coyne@info.bw

We would like to hear from you as a stakeholder and value your comments/concerns/issues/background information. Please submit these comments at our face-to-face interviews or at your soonest convenience thereafter.. Failure to do so will mean your written comments will not be incorporated into this environmental scoping process.

Initials & Surname:

____

Please indicate the area you stay in, and note any issues / concerns / ideas with regards to the above-mentioned proposed expansion.

Area: ____

Current problems/issues/concerns

General issues / concerns / ideas.

Appendix 5.2

Scoping comments and responses

1 I&APS ISSUES, CONCERNS, QUERIES, RED FLAGS AND SUGGESTIONS

Table 6.1 below outlines the issues, concerns and queries raised by stakeholders to date as well as the comments the stakeholders had upon reviewing the Draft Scoping Report.

The organisation or individual who raised the issue and place where the issue was raised has been noted. The table also provides a response to the queries where information is readily available.

PLEASE NOTE THE FOLLOWING:

- The issues, concerns, queries and suggestions raised by stakeholders are not quoted verbatim and have been summarised.
- The answers provided in Table 6.1 below are based on currently available information. As the Scoping Study progresses, more information will become available that may modify or qualify these answers. This fact should be taken into account when reading through the responses given below.
- All amendments to the Issues Trail and to the Drafts Scoping Report that is now termed the Final Scoping Report will be made in ***bold italic writing***.

Table 6.1: Issues, concerns, queries and suggestions raised by I&APs

ISSUES, STATEMENTS, QUERIES AND CONCERNS	COMMENTATOR	SOURCE	RESPONSE
Some wildlife exists in the area – for example: diphuduhudu (steenboks), ditholo (kudus) and others. Morupule Colliery has indicated interest in stocking some wildlife species on their premises. The DWNP representative said that they have not been informed about any negative impact on the wildlife in the Morupule area. The physical planning unit raised a concern that the district officers do not seem to have access to any environmental assessment documents to give them some clue about the impact or the environment friendliness of the Coal Thermal Power Station on the adjacent areas. Along the Palapye-Serowe main road, the proposed land use zones are industrial in the northern side, surrounding both the Colliery and the Power Station. The southern zone is proposed for commercial farming including poultry, piggery, horticulture, and dairying. The power station lies in the catchment of the Lotsane River, a very important water source, and this raises a concern since the environmental condition is not known. There was a consensus that the district officials need to have access to the environmental scoping report after its complete. The Agricultural Land Use Officer pointed out that Palapye village is rather close to the Power Station and a thorough environmental impact assessment covering the village is necessary if the option of expanding the operations of the Power Station is taken.	Mr. Bitsang, Land Use Officer – Chairman Ms Motlopi, District Officer (Lands) - Secretary Mr. Siviya, Physical Planner Baletetse, Tourism Modisi, Land Board Legwaila, Dairy Officer Sinombe, Land Use Officer Motshegwa, Agricultural Resources Board Bantsi, Wildlife and National Parks Mr. Oageng, District Officer (Lands	***Serowe/Palapye Sub-DLUPU***	The baseline information relating to Fauna and Flora is contained in **Section 5.5** of this report. A response relating to these biophysical issues is given in ***Chapter 5 Part 5.5***. The Environmental Impact Assessmnet (EIA) Report that was issued during the development of the original Morupule Power Station could not be located. This report is referenced at the Geological Survey Library in Lobatse as being located in the Government Library in Francistown. This report cannot be located in this library. This Draft Scoping Report (DSR) ***was*** distributed to BPC in Gaborone, BPC at Morupule, and two copies ***were*** located in the Administartive Offices in Palapye and Serowe as well as a copy in the main libraries in Palapye and Serowe. Stakeholders ***were notified that these documents were available at the time and the stakeholders had over*** 2 weeks in which to respond with comments. These comments ***are*** recorded ***in this, the*** Final Scoping Report. ***The FSR*** will be submitted to the National Conservation Strategy Co-ordinating Agency (NCSA) for their consideration. The Air Pollution Study indicates that the concentrations of sulphur dioxide and oxides of nitrogen exceed the acceptable levels as provided by the World Bank (**Appendix *5K***) and the European Community and in some cases exceed the Botswanan Guidelines. This Specialist report is available in ***Appendix 5B***. The physical planning units from Serowe and Palapye will have the opportunity to view the zone of influence of the current and the proposed expansion to the Project site e.g. soil, air, water. These authorities will be able to plan the land use accordingly. The issue of the EIA is noted and has been explained in ***Section 5.6***.

ISSUES, STATEMENTS, QUERIES AND CONCERNS	COMMENTATOR	SOURCE	RESPONSE
District Officials: Are you aware of any emission from the Morupule Power Station? Are you carrying out any monitoring of these emissions? We need such information to find out how the physical environment and the people around the Morupule are affected by the present plant We believe that the communities residing in the vicinity of the Power Station should be the first to make noise about the ills that they might suffer from the Power Plant. As far as we know, the district officials have not heard any complaints related to the operations of the Morupule power station. ***2.5.2 BPC Project Team*** Air Pollution monitoring is done by BPC and the findings are sent to the National Air Pollution Laboratory in Gaborone. The Department has an air pollution sampling station south west of the Morupule, downwind from the plant. The data from both BPC and the department of Air Pollution is used to compile an annual report. The consultants reminded the meetings that the environmental assessment will cover geotechnical air quality, archaeological and ecological issues. Following this, a draft scoping report will be compiled. ***2.5.3 District Officials:*** We recognize that, electricity is quite an important resource. When we hear about expansion, we are worried that we have no information on the impact of the present power plant on the environment. We need to see the environmental scoping report. We think this will serve as an environment audit of the existing plant. After presenting such a report to the district a lot of issues might arise. So we expect the Consultants to circulate the report and present it to the district officials.	Mr. M. Phiri, Land Board Secretary (Chairman) Mr. Oageng, District Officer (Lands) – Secretary Mr. Bantsi, Wildlife Department Mr. Ellard, Regional Forestry Officer Mr. Feng, Land Surveyor, Ngwato Land Board Mr. Gabanamotse, Physical Planning Mr. Kebiditse, Physical Planning Mr. Kenosi. District Officer (Lands) Mr. Kgangmotse, Economic Planner Mr. Lesenyegile, Physical Planner Ms. Mangoye, District Officer (Development) Mr. Moesi, Economic Planners Mr. Mogomela, Economic Planning Mr. Mokotedi, Economic Planning Mr. Mosimane, District Officer (Lands) Mr. Motlogelwa, Physical Planning Mr. Mudongo, Economic Planning Mr. Radisebo. Physical Planning Ms. Raditladi, Land Board Mr. Rampate, Physical Planning Mr. Sebodje, Town and Regional Planning, Francistown Mr. Tladi, Physical Planning Mr. Tiro, Physical Planning Ms. Raditladi, Land Board. Mr. Mudongo, Economic Planning Mr. Radisebo. Physical Planning Ms. Raditladi, Land Board Mr. Rampate, Physical Planning Mr. Sebodje, Town and Regional Planning, Francistown Mr. Tladi, Physical Planning Mr. Tiro, Physical Planning Ms. Raditladi, Land Board.	***Main DLUPU Meeting***	Stack emissions are measured by both BPC and Air Pollution Control whoare based in Gaborone. The sulphur dioxide, oxides of nitrogen and particulates are the emissions that are measured 3 hourly. The specialist report contained in **Appendix *5B*** provides detailed information on the air pollution and emissions data at Morupule. This specialist report also gives the reader an indication of the health impacts which can result due to exposure to certain concentrations of these emissions. The Public participation Process (PPP) specalist has consulted a number of stakeholders and these include the immediate neighbours to the Morupule Power Station. A detailed description of this consultation process is contained in **Section *5.4.4*** of this report. A number of stakeholders completed questionnaires; copies of which are presented in ***Appendices 5G & 5H*** of this report. The issues raised during these consultations have been included in this Issues Trail (**Table 6.1**). Where possible answers have been provided to the queries and issues discussed in *Chapter 5.6.* As a matter of good practice BPC should keep an official complaints register. These complaints can be forwarded to senior management and then actioned. BPC and Air Pollution Control must harmonise their emmisions measurement criteria. This DSR ***was*** available for the stakeholders to comment on. Comments ***are*** recorded and indicated in ***this*** Final Scoping Report (FSR). If the expansion is feasible the issues raised during the scoping phase will be carried forward into the Impact Assessment Phase. During the impact assessment phase the issues will be quantified and mitigatory measures suggested. This plant has been in existence since 1987, with the previous EIA report not being available, the DSR serves as the baseline information for the site.

ISSUES, STATEMENTS, QUERIES AND CONCERNS	COMMENTATOR	SOURCE	RESPONSE
Land south of Morupule Power Station and the Palapye-Serowe road has been proposed for commercial agriculture. It is feared that the area might not be suitable since it is downwind from the plant, and emissions are likely to pollute it. Buffer zones might become necessary. Squatting might re-emerge at Mmalonaka when people speculate about new jobs. Expansion of the Power station will surely cause the expansion of the Morupule operations, hence the need for more land. This could have an impact on the land use zones proposed for industrial all around the Colliery and the Power Plant. Workers from both the Colliery and the BPC have established cattleposts nearby, thereby putting more pressure on the grazing resources as a result of overstocking. The farming community nearby has observed poor growth of crops, stunted vegetation, veldt products (e.g. *moretlwa* plants/*Greiwa Flava*) covered in black dust, vegetation shoots late and wilts early. ??? The farming community raised the point that the boreholes, which used to serve the area, dried up as a result of the coal mining operations of the Morupule Colliery. The Power Plant lies within the catchment of the Lotsane River, which serves several villages in the Sub-district. This poses a threat to the water quality of this river as all the emissions – particulate matter - are washed into the river by the rains. The nearby farming community has noticed a strong smell of sulphur dioxide especially when the North Easterly winds are blowing strongly towards their area. The BPC sewage ponds and storm water reservoir are reported to be attracting mosquitoes. The farming community has observed smoke lingering especially during stable weather conditions, and this bothers their breathing/respiration.	Minister B. Sebetlela's Farm Manager Mma-Maitumelo Rra-Maitumelo	*Morupule Farming Community*	

ISSUES, STATEMENTS, QUERIES AND CONCERNS	COMMENTATOR	SOURCE	RESPONSE
Your clients Botswana Power Corporation are allowed to go ahead with plans to extend the mine to the surveyed area. They should however engage an archaeologist to monitor their work during the first stages of the project – striping off the topsoil and to investigate trenches where possible. This is because the Palapye-Serowe areas are rich in archaeological deposits, some of which may be in the subsurface.	N.M Ndobochani	***Botswana National Museum***	
• ***Generally all concerns and suggestions have been captured.*** • ***On Executive Summary Part 4 (Planning Context), the main planning instrument, which predetermines the General Land uses is the Central District Integrated Land Use Plan. However this plan does not detail the zoning of buildings and roads. Instead these are more detailed within the Palapye Development Plan. As for the need to consult the Town and Country Planning Board, please look at the Town and Country Planning Act (General Development) Order Group VII. Liaise with DTRP on the interpretation of the same esp (b) concerning the planning stage at which the Minister is responsible for planning.***	***Ms B. Siviya***	***Physical Planner, Central District Council: SerowePalapye Sub District***	***The point is noted and the planning aspect should be taken further by BPC into the EIA Phase. See 5.12.2 (b) in Appendix 5M of this chapter.***
The specialist study on groundwater in Appendix 5D was not inserted correctly into the DSR.	***Ms M. Kelesitse***	***Station Chemist, BPC Palapye***	***The environmental consultant has ensured that this document is in the FSR in Appendix 5D.***
My concern is on the Potential Social Impact – especially because the PPP indicates that the farmers around the Colliery and BPC seem not to pleased with the co-operation (BPC) concerning water resources. I checked the recommendations but I could not find anywhere that indicates how this issue will be addressed more so if the expansions will be carried out. – Otherwise I think most issues were covered satisfactory.	***Ms F. Kgobe***	***Department of District Administartion Palapye***	***In Appendix 5M in sections 5.12.2 a & c, this is where this issue would be attended to. Section a would require that the farmers are continually engaged in the EIA phase and section c investigate the socio-economic effects that the lack of water is having on the surrounding farmers.***

ISSUES, STATEMENTS, QUERIES AND CONCERNS	COMMENTATOR	SOURCE	RESPONSE
Executive Summary Section 1.1 • *Executive summary should read SADC-Southern African and not South African.*	Mr M. Moffat	*National Environmental Laboratory, Gaborone*	• *Point noted and correcte.*
• *3.1.3 of the Executive summary does not link up with section 1.1 of the same document.*			• *BPC currently imports 410 mw of power from South Africa to address the baseline needs of the country. At present this 410MW represents approximately a 70% dependency. If left unattended the power demand will increase to a point where BPC could be up to 80% dependent on Eskom for power.*
Section 6.1.4 • *Emissions from the burning of materials at landfills should not be allowed at all.*			• *This is not a BPC phenomenon as there is a culture of burning landfill waste I rural areas of Botswana and South Africa. This can be reduced through education and recycling.*
• *Particle size distribution reaches the power station*			• *It is acknowledged that dust particles from the colliery impact the BPC. The size and distribution of these particles is unknown at this stage.*
• *PM 10 and SO_2 emission standards are stipulated in the APRC*			• *This point is noted and must be investigated in the EIA phase as is stipulated in Appendix M Section 5.12.2(d).*
• *Ground level concentrations exceeds the hourly EU guidelines, why not refer to the Botswanan standard?*			• *Sulphur dioxide could not be compared to a Botswanan guideline. The specialists indicated that where there were no Botswanan guidelines to compare against.*
• *No excedences of annual Botswana or SA guidelines? proof*			• *The air specialist modeling indicated that there are likely, no excedences of annual Botswanan or South African guidelines were noted from current and future operations. The stricter EC guideline was exceeded fro a distance of 2 km for current operations and 4.7 km for future operations.*

ISSUES, STATEMENTS, QUERIES AND CONCERNS	COMMENTATOR	SOURCE	RESPONSE
Section 6.1.5 Water	Mr M. Moffat	***National Environmental Laboratory, Gaborone***	
• *Pollution monitoring boreholes, seem to indicate that there is pollution, then what action is being taken.*			• ***BPC are currently modeling the pollution plume and its spread. Once this is fully understood BPC should investigate mitigatory interventions such as those recommended in Appendix 5; before the extent of the pollution becomes so great that it becomes excessively costly.***
• *APCD is a not a department within the NCSA but rather the Ministry of Environment, Wildlife and Tourism.*			• ***Point noted and correction made.***
• *In terms of the Air pollution study methodology, it appears that the stack height was varied between 100-300 m. It appears that 100 m has been chosen. What does the dispersal simulation indicate?*			• ***The model that was used varied the height of the stacks between 100-300 m. 100 m was not chosen, it was simply tabulated as an example. The results indicate Appendix 5B that as the height of the stack increases, so the ground level concentration excedences reduce (i.e. there is a greater dilution effect) in distance away from the Morupule Station.***
• *If you retain the existing 4 boilers as Background pollution, what is the combined effect of the six boilers?*			• ***As indicated in section 4.1 of Appendix 5 B there will be excedences due to the existing boiler emissions.***
• *Incinerator stack emissions should be treated as the open burning of waste since it is being operated more like an open burn than an incineration process. This type of incinerator should not continue to operate.*			• ***This confirms what the specialists report in Appendix 5B.***
• *Note that the Botswana SO_2 emission standard is site and equipment specific. Therefore may not be applicable to the proposed expansion.*			• ***Point noted.***
• *Meteorological data was used from South Africa and why not Selebi-Phikwe. The wind profile was completed at 10 m were any attempts made at 30 m.*			• ***Te required data set from a Botswanan source was not available. The specialists did try to source this from a number of sources. Point noted.***
• *In terms of key findings and recommendations, where the specialist indicates that the station adjacent to the Morupule Power Station was set up by the Danish organisation NILU. This is incorrect as it was set upby the Air Pollution Control Division in Botswana in collaboration with the Norwegian Institute for Air Research (NILU)*			• ***Point noted.***

Appendix 5.3

Newspaper advertisements

BOTSWANA POWER CORPORATION

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT (ESIA) STUDY FOR THE MORUPULE B POWER STATION (MORUPULE POWER STATION EXPANSION PROJECT)

Public Consultations

Project Background
Botswana Power Corporation (BPC) has experienced an unprecedented increase in demand for electricity averaging 10% per annum. The current capacity of the existing power station is 132MW and the demand for electricity within Botswana currently exceeds available capacity at Morupule. Morupule Power Station contributes about 30% of the electricity requirements of the country. The balance of about 70% is met through imports from other countries, mainly South Africa (Eskom). The looming shortage in surplus generation capacity in Southern African will affect imports of power (electricity) by Botswana. Consequently, Botswana must either find an alternative source or pay more for imported power.

A feasibility study carried out in 2004 concluded that the most suitable option for the rapidly developing Botswana economy is to expand the existing power station at Morupule. BPC has since made a decision to implement the expansion option.

The expansion option includes the construction and operation of Morupule B Power Station which will be a coal-fired power plant with a capacity of 600 MW (4x150 MW) together with necessary associated infrastructure, as Phase 1. An additional 600MW will be installed, after an add-on feasibility study has been completed, bringing the aggregate to 1200MW.

The development will be undertaken within the current lease area for the BPC Morupule power station, east of the existing station. The project will thus benefit from the proximity of the existing coal supplies and transport infrastructure.

In pursuance of the EIA Act of 2005, the Botswana Power Corporation has commissioned Ecosurv Environmental Consultants, in association with GIBB

Botswana, to undertake an Environmental and Social Impact Assessment which shall form the basis for environmental permission and approval of the project.

Predicted impacts of the project
It is anticipated that the following impacts will be brought about by the project during construction and operational phases:

Benefits
- Increased and secure power supply to Botswana and the region
- Employment opportunities during construction

Adverse impacts
- Increased air emissions into thc atmosphere
- Increased noise emission to the immediate surrounding area

Public Hearings/Consultations
In accordance with the Section 7 of the EIA Act (2005), the Consultant will address a public meeting on the **4th September 2007** at 0900hrs at the Palapye Main Kgotla. The purpose of the meeting is to inform the community about the technical project components and final scope of work. The meeting will also be used to update residents on project information gathered during the ESIA Scoping exercise conducted in 2004.

Registration of stakeholders and comments registration
Interested and affected parties may request an electronic Project Background Information Document (BID) and comment sheet, seek clarity on proposal background information or register their names with the consultations team before the meetings at the following numbers: Tel: 3161533 Fax: 3161878: E-mail: phuthcgo@ccosurv.com. Hard copies of comment sheets and BID will be available at the Palapye Main Kgotla from **13th August 2007 to 7th September 2007**.

Appendix 5.4

ESIA Background Information Document (BID)

BOTSWANA POWER CORPORATION

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT (ESIA) STUDY FOR THE MORUPULE B POWER STATION (MORUPULE POWER STATION EXPANSION PROJECT)

PROJECT BACKGROUND INFORMATION DOCUMENT

Project rationale
Botswana Power Corporation (BPC) has experienced an unprecedented increase in demand for electricity averaging 10% per annum. The current capacity of the existing power station is 132MW and the demand for electricity within Botswana currently exceeds available capacity at Morupule. Morupule Power Station contributes about 30% of the electricity requirements of the country. The balance of about 70% is met through imports from other countries, mainly South Africa (Eskom). The shortage of surplus power generation capacity in Southern African is affecting Botswana's power imports. Consequently, Botswana must either find an alternative source or pay more for imported power.

A feasibility study carried out in 2004 concluded that the most suitable option for the rapidly developing Botswana economy is to expand the existing power station at Morupule. BPC has since made a decision to implement the expansion option.

Proposed power plant
The expansion option includes the construction and operation of Morupule B Power Station which will be a coal-fired, steam turbine driven thermal plant with a capacity of 600 MW (4 units of150 MW each) together with necessary associated infrastructure.

This environmental & social impact assessment is considering the foreseen 600 MW option, which will be a turnkey project undertaken within the current lease area for the BPC Morupule power station, east of the existing station. The project will thus benefit from the proximity of the existing coal supplies and transport infrastructure. Approximately 2.6 million tonnes of coal per annum will be supplied to the plant through a conveyor belt from the adjacent Morupule Colliery. A wellfield approximately 80 km northwest of the existing plant is currently under development to supply the proposed one.

The water supply as well as the expansion of the Morupule Colliery and the transmission line for the electrical grid connection will be the subject of separate and unrelated studies.

Construction is expected to be undertaken over 3 years with the new plant being commissioned between January and October 2010.

Environmental and Social Impact Assessment (ESIA)

In pursuance of the EIA Act of 2005, the Botswana Power Corporation has commissioned Ecosurv Environmental Consultants, in association with GIBB Botswana, to undertake the necessary Environmental and Social Impact Assessment.

The objective of the ESIA is to determine how the proposed project could impact on the environment and the livelihoods of people. The ESIA findings are expected to inform the final design and form the basis for environmental permission and approval of the project. The ESIA process will be undertaken within the ambit of the World Bank Operational Manual on Environmental Assessment (OP 4.01). Further, it will comply with the Environmental Impact Assessment Act, 2005 (Act 6 of 2005) that prescribes the following approach:

Scoping Phase: This involves the identification of the main concerns, issues and impacts of the project and defining the scope of detail to be considered. This phase was completed in 2004 and involved a mandatory public consultation process. At the end of this phase, a Scoping Report was submitted to the Department of Environmental Affairs (DEA) for review and approval. The related Terms of reference were developed February/March 2007 and were as well subject of approval by DEA. Subsequently DEA concurred with the Scoping report's recommendation for detailed ESIA and identified the following key areas of concern or issues:

- Water pollution

  Expansion of the site is more likely to increase current groundwater pollution levels.

- Air pollution

  The expansion of the emission stacks, the ash dams, coal stockpiles and evaporation ponds are likely to increase the wind and waterborne pollutants.

- Noise emissions

  During construction and operation of the expanded station higher levels of noise is likely to occur.

- Institutional capacity

  There is need by BPC to train more staff to carry out environmental monitoring (e.g. stack emissions, water quality from boreholes and evaporation ponds).

- Socio-economic impacts

  Archaeological/cultural and historic sites may be found during construction and will have to be investigated further.

Detailed Environmental Impact Assessment Phase: This entails identification and assessment of possible negative and positive impacts (environmental and social) of the proposed activity, recommendation for mitigation measures and the preparation of an Environmental Management Plan. An Environmental Impact Statement (EIS) will be submitted to the Department of Environmental Affairs (DEA) at the end of this Phase. Progression to this phase was contingent upon acceptance by DEA of the earlier Scoping Report and associated Terms of Reference. The approved Terms of Reference forms the basis of this ESIA.

Invitation to participate

Anyone who is interested or affected by the proposed project has a right to participate. Please make use of the following opportunities:

- Study the information made available in this Background Information Document.
- Attend the public stakeholder meetings to obtain further project information, interact on a one-on-one basis with the Project Team, and/or raise issues and concerns. A public meeting will be held at **Palapye Main Kgotla on the 4th September 2007 at 0900 hrs.** The purpose of the meeting is to inform the community about the technical project components and final scope of work. The meeting will also be used to update residents on project information gathered during the ESIA Scoping exercise conducted in 2004.
- Contact the Consultations Team to obtain further project information, and/or raise issues and concerns.
- Register as an Interested and Affected Party in order to receive future project information and/or formally record issues and concerns.
- Complete the comment sheet (attached) and return by hand, mail, fax or e-mail. Hard copies of comment sheets and BID will be available at the **Palapye Main Kgotla from 13th August 2007 to 7th September 2007.**

Your participation in the ESIA process

Your issues and comments will demonstrate your participation in the proposed development. It will also help to focus the ESIA process and enhance the quality of the decision taken by the authorities.

Appendix 5.5

Comments Sheet

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT (ESIA) STUDY FOR THE MORUPULE B POWER STATION (MORUPULE POWER STATION EXPANSION PROJECT)

COMMENT SHEET

Please complete and return by no later than 7th September 2007 to:

Tshepo Phuthego

Postal address	Tel: 3161533
P. O. Box 201306	Fax: 3161878
Gaborone	E-mail: phuthego@ecosurv.com

TITLE		*NAME*	
ORGANISATION			
ADDRESS			
TEL NO		**FAX NO**	
CELL NO		**E-MAIL**	

I would like to participate in the EIA Process — **YES** ☐ **NO** ☐

Please delete my name from your mailing list — **YES** ☐ **NO** ☐

COMMENTS (*Please use additional sheets if you wish)*

1. The following issues should be addressed as part of the EIA:
   ....
   ....
   ....
2. Any other comments:
   ....
   ....
   ....
   ....
   ....
2. Please add the following neighbours/interested or affected parties to your mailing list (please provide contact details)
   ....
   ....
   ....

We thank you for your participation