

Annex C

Baseline Methodologies

CONTENTS

C1	INTRODUCTION	C1
C1.1	OVERVIEW	C1
C2	AIR QUALITY	C2
C2.1	OVERVIEW	C2
C2.2	ASSESSMENT CRITERIA FOR THE PROTECTION OF HUMAN HEALTH	C2
C2.3	ASSESSMENT CRITERIA FOR THE PROTECTION OF ECOLOGICAL HABITATS	C3
C2.4	SIGNIFICANCE CRITERIA	C3
C2.5	RECEPTORS	C5
C2.6	POINT SOURCE DISPERSION MODELLING INPUTS AND METHODOLOGY	C6
C2.6.1	<i>Overview</i>	C6
C2.6.2	<i>Dispersion Model</i>	C8
C2.6.3	<i>Operating Scenarios</i>	C8
C2.6.4	<i>Model Inputs for LNG Trains</i>	C8
C2.6.5	<i>Model Inputs for the Flares</i>	C12
C2.6.6	<i>Meteorological Data Selection</i>	C12
C2.6.7	<i>Consideration of Terrain Effects</i>	C13
C2.6.8	<i>Consideration of Building Downwash</i>	C14
C2.6.9	<i>Conversion of NO_x to NO₂</i>	C14
C2.6.10	<i>Non-Routine Events</i>	C15
C3	CLIMATE CHANGE	C16
C3.1	INTRODUCTION	C16
C3.2	CARBON FOOTPRINT CALCULATION	C16
C3.2.1	<i>Methodology</i>	C16
C3.2.2	<i>Emissions Boundary Definition</i>	C17
C3.3	IMPACT ASSESSMENT METHODOLOGY	C18
C3.4	SCOPE OF THE CARBON FOOTPRINT	C19
C3.4.1	<i>Introduction</i>	C19
C3.4.2	<i>Organisational and Operational Boundary</i>	C19
C3.4.3	<i>Timeframe</i>	C20
C3.4.4	<i>Overview of Project Emission Causing Activities</i>	C20
C3.5	ASSUMPTIONS MADE IN ESTIMATING OPERATIONAL ACTIVITY DATA	C21
C4	NOISE	C22
C4.1	APPROACH AND METHODOLOGY	C22
C4.1.1	<i>Overview</i>	C22
C4.1.2	<i>Noise Sensitive Receptors</i>	C22
C4.2	IMPACT PREDICTION	C24
C4.2.1	<i>Noise Prediction Methodology - LNG Plant</i>	C24
C4.2.2	<i>Modelling Scenarios</i>	C26
C4.2.3	<i>Noise Prediction Methodology - Airstrip</i>	C31
C4.3	EVALUATING SIGNIFICANCE	C33

C4.3.1	<i>Overview</i>	C33
C4.3.2	<i>Impact Threshold Noise Levels</i>	C33
C4.3.3	<i>Evaluating Significance of Noise Impacts</i>	C34
C4.3.4	<i>Noise Criteria – LNG Plant</i>	C35
C4.3.5	<i>Noise Assessment Criteria – Airport</i>	C36
C4.4	BASELINE DATA COLLECTION	C37
C4.4.1	<i>Overview</i>	C37
C4.5	DATA COLLECTION METHODOLOGY	C37
C4.5.1	<i>Long Term Measurements</i>	C37
C4.5.2	<i>Short Term Attended Measurements</i>	C38
C5	SOILS	C40
C5.1	METHODOLOGY	C40
C5.2	INVESTIGATION OF AREA 1	C40
C5.2.1	<i>Data Collection</i>	C41
C5.2.2	<i>Sampling Program</i>	C43
C5.3	INVESTIGATION APPROACH FOR AREA 2	C43
C6	HYDROLOGY	C44
C6.1	METHODOLOGY	C44
C6.1.1	<i>Introduction</i>	C44
C6.1.2	<i>Delineation of Water Courses and Catchment Boundaries</i>	C44
C6.1.3	<i>Determination of the Peak Rainfall Estimates</i>	C44
C6.1.4	<i>Determination of Floodlines</i>	C45
C7	GROUNDWATER	C47
C7.1	APPROACH	C47
C7.2	INITIAL BASELINE INVESTIGATION	C47
C7.2.1	<i>Literature Review</i>	C47
C7.2.2	<i>Hydrocensus</i>	C47
C7.2.3	<i>Geotechnical Boreholes</i>	C50
C7.2.4	<i>Geochemical Assessment</i>	C51
C7.3	FURTHER BASELINE INVESTIGATION	C51
C7.3.1	<i>Borehole Drilling</i>	C51
C7.3.2	<i>Aquifer Testing</i>	C52
C7.3.3	<i>Water Sampling</i>	C52
C7.3.4	<i>Quality Assurance/Quality Control – QA/QC</i>	C54
C7.3.5	<i>Topographic Survey</i>	C54
C7.4	GROUNDWATER MODELLING METHODOLOGY	C55
C7.4.1	<i>Conceptual Site Model Development</i>	C55
C7.4.2	<i>Modelling Approach</i>	C56
C7.4.3	<i>Model Calibration</i>	C56
C7.4.4	<i>Software Selection</i>	C57
C7.4.5	<i>Model Limitations</i>	C58
C7.5	NUMERICAL GROUNDWATER MODELLING	C58
C7.5.1	<i>Model Setup</i>	C58
C7.5.2	<i>Model Parameters</i>	C63
C7.5.3	<i>Steady State Calibration</i>	C64

C7.5.4	<i>Transient Calibration</i>	C69
C7.6	GROUNDWATER MODELLING SCENARIOS	C74
C7.6.1	<i>Model Setup</i>	C75
C7.6.2	<i>Drawdown Correction</i>	C78
C8	SURFACE WATER ECOLOGY	C79
C8.1	OVERVIEW	C79
C8.2	SAMPLING SITES	C79
C8.3	FRESHWATER ASSESSMENT	C82
C8.3.1	<i>Water Quality</i>	C82
C8.3.2	<i>Diatoms</i>	C83
C8.3.3	<i>Habitat Integrity (IHI)</i>	C84
C8.3.4	<i>Macro-Invertebrates</i>	C86
C8.3.5	<i>Fish</i>	C88
C8.3.6	<i>Ecological Integrity / Present Ecological Status</i>	C88
C8.4	ESTUARINE ASSESSMENT	C90
C8.4.1	<i>Sediment</i>	C90
C8.4.2	<i>Water Quality</i>	C95
C8.4.3	<i>Microalgae and Diatoms</i>	C95
C8.4.4	<i>Invertebrates</i>	C96
C8.4.5	<i>Fish</i>	C97
C8.4.6	<i>Bird Counts</i>	C98
C8.4.7	<i>Vegetation</i>	C98
C8.5	WETLAND ASSESSMENT	C98
C8.5.1	<i>Wetland Classification</i>	C99
C8.5.2	<i>Criteria for Determining Wetland Extent</i>	C102
C8.5.3	<i>Riparian Present Ecological State (VEGRAI)</i>	C103
C8.5.4	<i>Ecosystem Services Assessment</i>	C104
C8.5.5	<i>Wetland Sensitivity</i>	C106
C8.5.6	<i>Buffer Requirements</i>	C108
C8.6	STUDY LIMITATIONS	C109
C9	VEGETATION	C111
C9.1	LITERATURE REVIEW AND DESKTOP STUDY	C111
C9.2	FIELD SURVEYS	C111
C9.3	RED DATA FLORA ASSESSMENT	C112
C10	HERPETOFAUNA	C113
C10.1	LITERATURE REVIEW AND DESKTOP STUDY	C113
C10.2	FIELD SURVEYS	C113
C10.2.1	<i>Herpetofauna Traps</i>	C114
C10.2.2	<i>Climate Monitoring</i>	C115
C10.2.3	<i>Active Searching</i>	C116
C10.2.4	<i>Opportunistic Sampling</i>	C117
C10.2.5	<i>Interviews with Local Inhabitants</i>	C117
C10.3	LIMITATIONS AND ASSUMPTIONS	C118
C11	MAMMALS	C120

C11.1	LITERATURE REVIEW AND DESKTOP STUDY	C120
C11.2	FIELD SURVEYS	C120
C11.2.1	<i>Timing</i>	C121
C11.2.2	<i>Data Collection Methodology</i>	C121
C11.3	LIMITATIONS	C124
C12	AVIFAUNA	C125
C12.1	LITERATURE REVIEW AND DESKTOP STUDY	C125
C12.2	FIELD SURVEYS AND DATA ANALYSIS	C125
C12.3	LIMITATIONS AND ASSUMPTIONS	C127
C13	MARINE MODELLING AND ECOLOGY	C128
C13.1	OVERVIEW	C128
C13.2	ASSUMPTIONS, LIMITATIONS AND UNCERTAINTIES	C129
C13.3	DATA COLLECTION -OFFSHORE AREA	C129
C13.3.1	<i>Oceanography</i>	C129
C13.3.2	<i>Plankton</i>	C130
C13.3.3	<i>Sediment</i>	C130
C13.3.4	<i>Benthos</i>	C131
C13.3.5	<i>Reef Structures</i>	C132
C13.4	DATA COLLECTION -PALMA BAY AND AFUNGI PENINSULA	C133
C13.4.1	<i>Palma Bay Water Column Properties</i>	C135
C13.4.2	<i>Sediment Properties and Seabed Features</i>	C135
C13.4.3	<i>Intertidal Sand Beaches</i>	C135
C13.4.4	<i>Seagrass Distribution</i>	C137
C13.4.5	<i>Shallow Coral Reefs and Outcrops</i>	C138
C13.4.6	<i>Fringing Coral Reef</i>	C138
C13.4.7	<i>Fish</i>	C139
C13.5	ADJUSTED IMPACT ASSESSMENT METHODOLOGY	C139
C13.5.1	<i>Nearshore/ Palma Bay Environment</i>	C140
C13.5.2	<i>Offshore Environment</i>	C142
C14	LANDSCAPE AND VISUAL	C143
C14.1	ASSESSMENT METHODOLOGY	C143
C14.2	STUDY AREA	C144
C14.3	METHODOLOGY - KEY STEPS	C144
C14.3.1	<i>Sensitivity of Landscape and Seascape</i>	C145
C14.3.2	<i>Sensitivity of Viewers at Viewpoint Locations.</i>	C146
C14.3.3	<i>Magnitude of Change</i>	C146
C14.3.4	<i>Significance of Impacts</i>	C147
C15	WASTE	C148
C15.1	STUDY APPROACH	C148
C16	SOCIO-ECONOMICS	C149
C16.1	OVERVIEW	C149

C16.2	SITE SELECTION- PRELIMINARY SITE VISITS AND MAPPING	C149
C16.3	DESK BASED PREPARATION FOR THE SOCIO-ECONOMIC SURVEYS	C149
C16.4	FIELD VISITS, INTERVIEWS AND SURVEYS	C149
C16.4.1	<i>Phase 1 of the Socio-economic Study - November, 2011</i>	C149
C16.4.2	<i>Phase 2 of the Socio-economic Study - January, 2012</i>	C150
C16.5	PREPARATION OF THE SOCIAL BASELINE AND IMPACT ASSESSMENT	C152
C16.6	DATA GATHERING TOOLS	C152
C16.6.1	<i>Household (HH) Questionnaire</i>	C152
C16.6.2	<i>Focus Groups Discussions (FGD)</i>	C152
C16.6.3	<i>Semi-structured Key Informant Interviews</i>	C152
C16.7	SAMPLING DESIGN	C153
C17	HEALTH IMPACT ASSESSMENT METHODOLOGY	C154
C17.1	HIA METHODOLOGY	C154
C17.1.1	<i>Form and Nature of Health Impact Assessment</i>	C154
C17.1.2	<i>Environmental Health Areas</i>	C156
C17.1.3	<i>Community Profiling</i>	C157
C17.1.4	<i>Risk Assessment and Impact Categorization</i>	C158
C17.1.5	<i>Direct Versus Indirect Impacts</i>	C158
C17.1.6	<i>Cumulative Impacts</i>	C159
C17.1.7	<i>Management and Mitigation</i>	C159
C17.1.8	<i>Stakeholder Consultation</i>	C160
C18	ARCHAEOLOGY	C162
C18.1	OVERVIEW	C162
C18.1.1	<i>Desktop Study</i>	C162
C18.1.2	<i>Field Investigations</i>	C162

C1 INTRODUCTION

C1.1 OVERVIEW

This annex provides the methodologies developed and used by the various environmental and socio-economic specialists to collect, interpret and present baseline findings for their respective specialist studies. In the cases where modelling was undertaken (eg air quality and noise), the methodology for that modelling and any assumptions made are provided in the relevant sections. This annex is set out as follows:

- *Section C2* Air Quality
- *Section C3* Climate Change
- *Section C4* Noise
- *Section C5* Soils
- *Section C6* Hydrology
- *Section C7* Groundwater
- *Section C8* Surface Water Ecology
- *Section C9* Vegetation
- *Section C10* Herpetology
- *Section C11* Mammals
- *Section C12* Avifauna
- *Section C13* Marine Ecology
- *Section C14* Landscape and Visual
- *Section C15* Waste
- *Section C16* Socio-Economics
- *Section C17* Health
- *Section C18* Archaeology

The Impact Assessment (IA) methodology used by the specialists is based on the methodology developed and distributed by ERM and Impacto which is described in *Chapter 3* of the EIA. Any deviations to the IA methodology are included in this annex under the respective studies. Those sections that present different IA approaches are the Air Quality and Landscape and Visual studies). They are different because the general impact assessment methodology did not lend itself to the specifics of the subject matter. Therefore more appropriate methodologies are described herein for these.

C2.1 OVERVIEW

This section sets out the methodology used for the air quality baseline description and the assessment of potential impacts that may arise from the operation of the facility. Site visits were undertaken to take air quality baseline measurements. The impact assessment used differs from the methodology provided in *Chapter 3* of the EIA Report and is more appropriate for specifically air quality assessments.

C2.2 ASSESSMENT CRITERIA FOR THE PROTECTION OF HUMAN HEALTH

Air emissions for the purposes of this guideline are framed within the Regulations on the Emission of Effluents and Environmental Quality Standards (Decree, 18/2004 dated June 2) and Decree No. 67/2010, dated December 31 (amendments to Appendix I and inclusion of Appendices 1A and 1B to Decree No. 18/2004). The IFC General Environmental Guidelines and the IFC EHS LNG Facility Guidelines defer to the WHO Air Quality Guidelines Global Update, 2005 as set out in *Table 2.1*. Both Mozambique national air quality standards and WHO standards have been used in the assessment. This approach was adopted to ensure that the results are robust, and because the Mozambique standards do not cover impacts associated with PM₁₀ and PM_{2.5}.

Table 2.1 Air Quality Standards and Guidelines

Pollutant	Averaging Period	Guideline Value ($\mu\text{g}/\text{m}^3$)	
		WHO	Mozambique Decree no. 67/2010
SO ₂	1-year mean		40
	24-hour maximum	125 (Interim target-1) 50 (Interim target-2) 20 (guideline)	100
	1-hour maximum		800
	10-minute maximum	500 (guideline)	500
NO ₂ *	1-year mean	40 (guideline)	10
	24-hour maximum		-
	1-hour maximum	200 (guideline)	190
TSP	1-year mean		60
	24-hour maximum		150
PM ₁₀	1-year mean	70 (Interim target-1) 50 (Interim target-2) 30 (Interim target-3) 20 (guideline)	-
	24-hour assessed as the third highest 24 hour period (99 th percentile)	150 (Interim target-1) 100 (Interim target-2) 75 (Interim target-3) 50 (guideline)	-

Pollutant	Averaging Period	Guideline Value ($\mu\text{g}/\text{m}^3$)	
		WHO	Mozambique Decree no. 67/2010
PM _{2.5}	1-year mean	35 (Interim target-1)	-
		25 (Interim target-2)	
		15 (Interim target-3)	
		10 (guideline)	
	24-hour maximum	75 (Interim target-1)	
		50 (Interim target-2)	
		37.5 (Interim target-3)	
		25 (guideline)	

*MICOA has authorised the Project to use the WHO NO₂ standard instead of the Mozambican NO₂ standard.

C2.3 ASSESSMENT CRITERIA FOR THE PROTECTION OF ECOLOGICAL HABITATS

Impacts relating directly to air quality (ie NO_x, SO₂) are not habitat or species specific and are the same for all sites. NO_x and SO₂ are especially relevant in this context as they both play a role in the acidification of water and soil and NO_x also contributes to eutrophication. These criteria used in this assessment are derived from European Directives, and are set out in *Table 2.2*.

Table 2.2 Air Quality Critical Levels used for the Assessment of Impacts on Sensitive Ecological Receptors

Pollutant	Averaging Period and Statistic	Assessment Criterion ($\mu\text{g}/\text{m}^3$)	Source
NO _x	Annual mean	30	AQS ⁽¹⁾
SO ₂	Annual mean	20	AQS ⁵

C2.4 SIGNIFICANCE CRITERIA

The magnitude of impacts was quantified using predictive techniques based on detailed dispersion modelling. The magnitude of the impact is the 'Process Contribution (PC)'; this is the impact arising solely from project related emissions. In order to consider the significance of those impacts, consideration is required of the existing baseline. The PC added to the existing baseline is described as the Predicted Environmental Concentration (PEC). Baseline data is available from 24th February till 27th June, but only for NO₂ and NO_x. Therefore not all PECs can be derived for this assessment. Based on initial baseline results we will assume that the local airshed is considered undegraded.

When considering the significance of impacts in the context of air quality, all receptors are considered equally sensitive. This arises from the fact that all receptors will experience similar health effects when exposed to increases in

(1) Air Quality Standard - these are derived from CAFÉ.

airborne pollution. Therefore, the significance of impact is dependent on the magnitude of impact, with due regard to the existing baseline (as stated above the airshed is defined as undegraded based on initial baseline data). The significance criteria used in this study for the assessment of human health follow the IFC guidelines, but are expanded upon to provide an indication of the importance of impacts.

When considering sensitive ecological receptors, generally all receptors are considered to be equally sensitive to the main pollutants of interest (NO_x and SO₂).

The significance of the predicted impacts was ascertained by means of comparison to air quality standards and guidelines as set out in Section C2.2 and *Table 2.1* above. The significance of impacts is primarily based upon whether or not the impacts result in air quality standards being exceeded or contribute a substantial proportion of airborne pollutants in the local airshed.

IFC make differentiation in the significance of impacts, based upon the existing baseline air quality in the vicinity of a proposed development. Essentially, this is based upon whether there is a significant risk of the existing baseline air pollution to result in air quality guidelines being exceeded; this is described in more detail below.

The IFC General EHS Guidelines state:

“Projects with significant sources of air emissions, and potential for significant impacts to ambient air quality, should prevent or minimize impacts by ensuring that:

- *Emissions do not result in pollutant concentrations that reach or exceed relevant ambient quality guidelines and standards by applying national legislated standards, or in their absence, the current WHO Air Quality Guidelines, or other internationally recognized sources.*
- *Emissions do not contribute a significant portion to the attainment of relevant ambient air quality guidelines or standards. As a general rule, this Guideline suggests 25 percent of the applicable air quality standards to allow additional, future sustainable development in the same airshed [ie in an undegraded airshed]”.*

And:

“An airshed should be considered as having poor air quality [degraded] if nationally legislated air quality standards or WHO Air Quality Guidelines are exceeded significantly”.

The IFC guidelines further state:

“Facilities or projects located within poor quality airsheds, and within or next to areas established as ecologically sensitive (eg national parks), should ensure that any increase in pollution levels is as small as feasible, and amounts to a fraction of the applicable short-term and annual average air quality guidelines or standards as established in the project-specific environmental assessment.”

On the basis of the IFC guidance, a degraded airshed is therefore defined in this assessment as locations where the baseline air quality is already in excess of the air quality standards.

The significance of impacts is therefore defined in terms of the magnitude of impacts (*ie* the Process Contribution or PC), and whether the baseline pollution concentrations are above or below the air quality standards. Using this approach, the significance criteria for air quality have been defined. These are set out in *Table 2.3*. As stated above complete baseline data is not available yet (monitoring started in February 2012). Based on initial baseline results we will assume that the local airshed is considered undegraded.

Table 2.3 *Significance Criteria for Assessment of Airborne Pollutants¹*

Significance of impact	Magnitude of impact	
	Undegraded airshed	Degraded airshed
Not Significant	<i>Negligible:</i> PC <25% of AQS	<i>Negligible:</i> PC <10% of AQS
Minor Adverse	<i>Small:</i> PC between 25% and 50% of AQS and PEC <100% of AQS	<i>Small:</i> PC between 10% and 30% of AQS and PEC >100% of AQS
Moderate Adverse	<i>Medium:</i> PC between 50% and 75% of AQS, and PEC <100% AQS; or <i>Medium:</i> PC between 25% and 50% of AQS, and PEC >100% of AQS	<i>Medium:</i> PC between 30% and 50% of AQS, and PEC >100% of AQS; or
Major Adverse	<i>Large:</i> PC between 75% and 100% of AQS, and PEC <100% AQS; or <i>Large:</i> PC between 50% and 75% of AQS, and PEC >100% of AQS	<i>Large:</i> PC between 50% and 100% of AQS, and PEC >100% of AQS; or
Critical Adverse	<i>Very Large:</i> PC>100% of AQS; or <i>Very Large:</i> PC between 75% and 100% of AQS and PEC >100% of AQS	<i>Very Large:</i> PC>100% of AQS
PC: Process Contribution		AQS: Air Quality Standard
PEC: Predicted Environmental Concentration		

C2.5

RECEPTORS

The air quality standards and guidelines apply at all off-site locations (see *Table 2.1* and *Figure 2.1*).

In order to capture the maximum off-site impacts the model utilises four grids of receptors with following characteristics:

- grid 1:
 - resolution = 50 m;
 - extent around plant fenceline = 1 – 2.9 km;
- grid 2:
 - resolution = 100 m;

(1) ¹ the significance for humans and ecology are treated as the same in light of no alternative information.

- extent around plant fenceline = 3.6 – 6.7 km;
- grid 3:
 - resolution = 500 m;
 - extent around grid 2 = 5 km;
- grid 4:
 - resolution = 1000 m;
 - extent = proposed Rovuma National Reserve.

The maximum air impacts have been assessed for all off-site locations within the receptor grid.

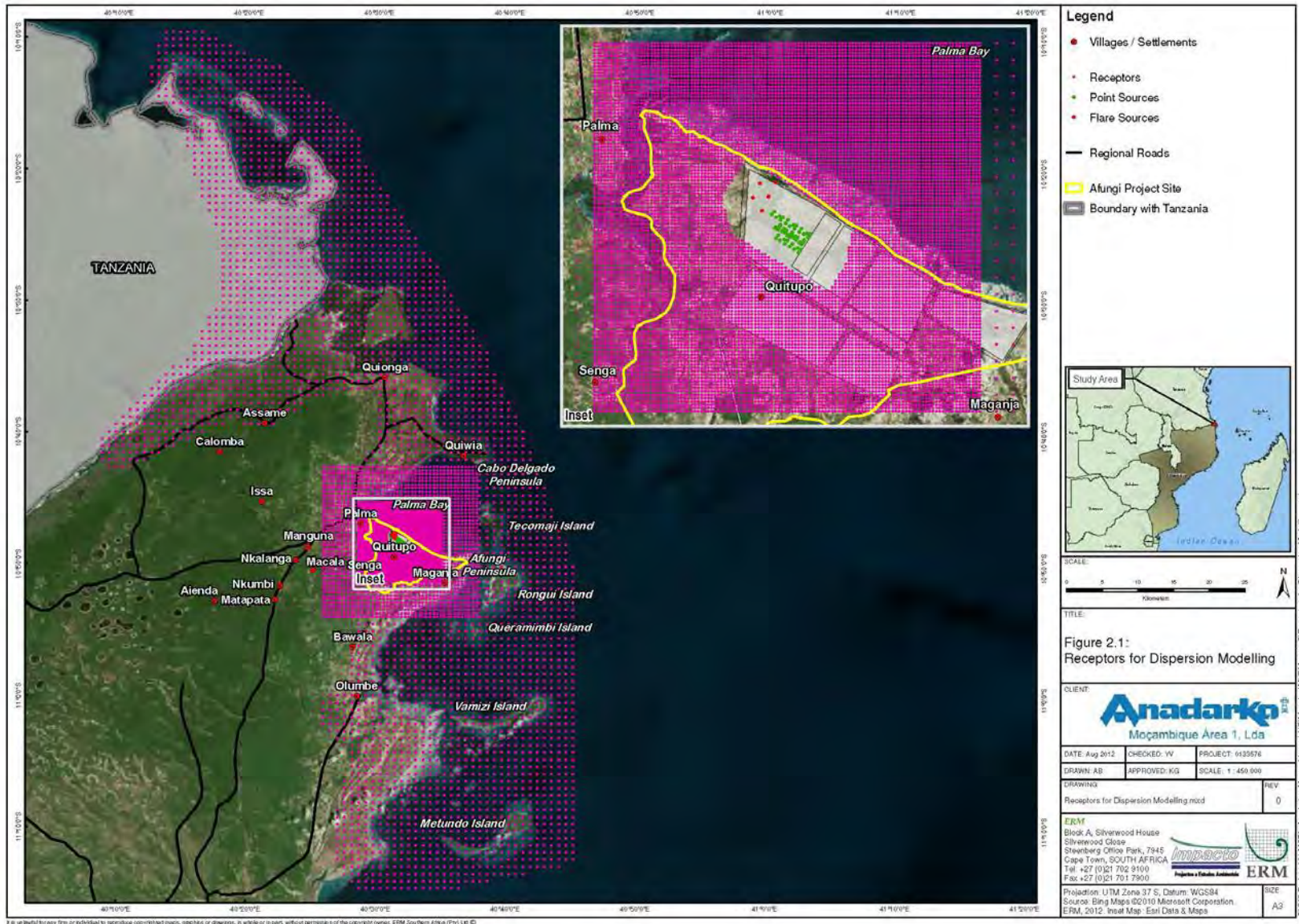
C2.6 *POINT SOURCE DISPERSION MODELLING INPUTS AND METHODOLOGY*

C2.6.1 *Overview*

The potential for impacts to air quality due to emissions arising from the project are assessed by comparing the predicted impacts against standards and guidelines for the protection of human health, and critical levels for the protection of sensitive ecology as described above. The assessment uses dispersion modelling to predict the ground level increases in pollution concentrations attributable to the plant emissions to establish whether there is the potential for significant impacts to occur.

The detailed dispersion modelling is used to predict concentrations of pollutants at ground level locations outside the plant boundary, at sensitive receptors. Five years of hourly sequential meteorological data are used, so that inter annual variability is incorporated in the model. The results of the assessment are based upon the worst case result for any of the five meteorological years used.

Figure 2.1 Receptors for Dispersion Modelling



It is unlawful for any firm or individual to reproduce copyrighted maps, graphics or drawings, in whole or in part, without permission of the copyright owner, ERM Southern Africa (Pty) Ltd. ©

T:\GIS\Project0133576_Anadarko_Mozambique_LNG\Mapping\000\Jurnal_C\Receptors for Dispersion Modelling.mxd

C2.6.2 *Dispersion Model*

The model used in the assessment is the United States Environmental Protection Agency's AERMOD dispersion model.

AERMOD is considered to be appropriate for this type of assessment as the model is well recognised within the air quality and impact assessment practice by numerous organisations including IFC.

C2.6.3 *Operating Scenarios*

The air quality assessment has evaluated impacts from 4 operating scenarios. These scenarios are as follows:

Scenario 1 (normal phase 1 operation):

- Train 1 and 2 operating normally; and
- No flaring.

Scenario 2 (short term assessment only, normal phase 1 operation with maximum flaring event):

- Train 1 and 2 operating normally; and
- 60 minutes emergency flaring event on 1 flare.

Scenario 3 (normal phase 2 operation):

- Train 1, 2, 3, 4, 5 and 6 operating normally; and
- No flaring.

Scenario 4 (short term assessment only, normal phase 2 operation with maximum flaring event):

- Train 1, 2, 3, 4, 5 and 6 operating normally; and
- 60 minutes emergency flaring event on 2 flares.

C2.6.4 *Model Inputs for LNG Trains*

Each LNG Train comprises following relevant emission sources:

- 1 MR Compressor Turbine (47 MWth);
- 1 PR Compressor Turbine (47 MWth);
- 1 Hot Oil Heater (15 MWth);
- 4 Power Generator Turbines (total of 116 MWth) for Train 1;
- 3 Power Generator Turbines (total of 99 MWth) for Trains 2 - 6;
- 1 Acid Gas Incinerator (3.5 MWth) per 2 trains.

The stack parameters for the emission sources for 1 LNG Train are set out in *Table 2.4*.

The pollutant emissions data for these sources that has been used in the assessment are set out in *Table 2.5*. As much of the design of the plant is still

unknown, no accurate emission data is available, therefore the client has provided emission data based on emission factors from literature¹ (except for SO₂ which was calculated based on material balance and sulphur content).

The PCs are based upon modelling of emissions at design limits.

(2) AP-42 Compilation of Air Pollutant Emission Factors <http://www.epa.gov/ttnchie1/ap42/>

Table 2.4 Summary of Stack Parameters for LNG Trains

Installations		MR Turbine	PR Turbine	Power Generator Turbines		Hot Oil Heater	Acid Gas Incinerator
Parameter	Units	1 x 47 MWth per train	1 x 47 MWth per train	train 1: 4 x 29 MWth	train 2- 6: 3 x 33 MWth per train	1 x 15 MWth per train	1 x 3.5 MWth per 2 trains
Number of installations per stack		1	1	1	1	1	1
Stack height actual	m	40	40	40	40	25	40
Flue diameter	m	3.85 ¹	3.85 ¹	3.23 ¹	3.44 ¹	0.677 ¹	0.769 ¹
Stack Area	m ²	11.6 ¹	11.6 ¹	8.18 ¹	9.31 ¹	0.36 ¹	0.464 ¹
Gas-fired							
Emission velocity	Am/s	15.0 ²	15.0 ²	15.0 ²	15.0 ²	10.0 ²	10.0 ²
Volume flow rate gas fired (normalised, dry)	Nm ³ /s	61.78 ³	61.7 ³	43.4 ³	49.3 ³	2.08 ³	1.64 ³
Volume flow rate gas fired (actual)	Am ³ /s	175	175	123	140	3.60	4.64
Emission temperature gas fired (actual)	Celsius	500 ⁴	500 ⁴	500 ⁴	500 ⁴	200 ⁵	500 ⁴
Oxygen (normalised)	%v/v	15.0	15.0	15.0	15.0	3.00	3.00
Oxygen gas fired (actual)	%v/v	15.0 ⁶	15.0 ⁶	15.0 ⁶	15.0 ⁶	3.00 ⁶	3.00 ⁶
¹ calculated based upon ASSUMED emission velocities and calculated/ ASSUMED volumetric flow rates			SENSITIVITY: decreasing stack diameter/area will increase emission velocity and therefore increase dispersion, resulting in lower impacts.				
² ASSUMPTION: based upon relevant project experience							
³ calculated based on provided estimations of NOx mass flow and NOx concentration of:			SENSITIVITY: higher concentrations, without increase in mass flow will result in lower volumetric flow rates and therefore decreased dispersion and higher impacts.				
<ul style="list-style-type: none"> o 51 mg/Nm³ for turbines (per WB/IFC standards); o 100 mg/Nm³ for acid gas incinerator and hot oil heater (ASSUMPTION). 							
⁴ ASSUMPTIONS based upon relevant project experience			SENSITIVITY: lower temperature will reduce dispersion and increase impact				
⁵ ASSUMPTION based upon relevant project experience							
⁶ ASSUMPTION: actual oxygen content in flue gases is usually around the normalised oxygen content			SENSITIVITY: Actual oxygen level in flue gases are indicative of the amount of air used for combustion and establishing exhaust flow through the stack. Higher actual oxygen level means more air is used, diluting in effect the flue gases with higher volume flow rates and lower actual emission concentrations as a result.				

Table 2.5 **Pollutant Emissions Data**

Pollutant	Units	Emissions					Basis of emission rate used in modelling	
		MR Turbine	PR Turbine	Power Generator Train 1	Turbines Train 2 - 6	Hot Oil Heater	Acid Gas Incinerator	
NO _x	g/s	3.15 per train	3.15 per train	4 x 2.21	3 x 2.52 per train	0.208 per train	0.164 per 2 trains	estimated data provided by client and based on: - AP-42 for acid gas incinerator and hot oil heater; and - WB/IFC for gas turbines provided by client and based on material balance with 100% conversion of vent/fuel gas sulphur to SO ₂
SO ₂	g/s	-	-	-	-	-	4.31 per 2 trains	estimated data provided by client and based on: AP-42
TSP	g/s	0.294 per train	0.294 per train	4 x 0.182	3 x 0.207 per train	0.0308 per train	0.0250 per 2 trains	estimated data provided by client and based on: AP-42
PM ₁₀	g/s	0.294 per train	0.294 per train	4 x 0.182	3 x 0.207 per train	0.00770 per train	0.00560 per 2 trains	estimated data provided by client and based on: AP-42

C2.6.5 Model Inputs for the Flares

The stack parameters and emission rates for the LNG worst case flaring are set out in Table 2.6.

Table 2.6 Summary of Stack and Emission Parameters for the Flare

Parameter	Units	Combined HP / LP
Continuous flaring?		No
Description of flaring event		worst case emergency
Duration of flaring event	min	60 ¹
Amount of gas flared in emergency blowdown event	kg	~350 000 ²
Composition of typical flared gas		C1-C6 > 94% (rest = N2)
Number of stacks		1
Stack height actual	m	140 ³
Emission velocity	m/s	100 ⁴
Volume flow rate (actual)	Am ³ /s	126 ⁵
Heat Release Rate	cal /s	1 436 000 000
Emission temperature (actual)	Celsius	1 000 ⁶
NO _x Emission Rate	g/s	87.8 (AP-42)
PM ₁₀ /PM _{2.5} Emission Rate	g/s	negligible
SO ₂ Emission Rate	g/s	negligible
¹ ASSUMPTION based upon relevant project experience	SENSITIVITY: longer events will cause larger impacts given that other parameters stay the same	
² ASSUMPTION based upon relevant project experience and design capacity	SENSITIVITY: higher mass flow will result in higher impacts	
³ conservative ASSUMPTION based upon relevant project experience	SENSITIVITY: increasing stack height will result in lower impact.	
⁴ ASSUMPTION based upon relevant project experience	SENSITIVITY: since a flare is an external combustion process, mass flow and volumetric flow are directly related to each other. The mass of gas that needs to be flared will define the volume flow through the flare pipe and the emission velocity, and more importantly the mass of emitted pollutants. The combustion of this mass of gas and the resulting flame height and temperature are the main factors that will define dispersion of these pollutants.	
⁵ ASSUMPTION based upon calculations, relevant project experience and design capacity		
⁶ ASSUMPTION based upon relevant project experience	SENSITIVITY: lower temperature will reduce dispersion and increase impact.	

C2.6.6 Meteorological Data Selection

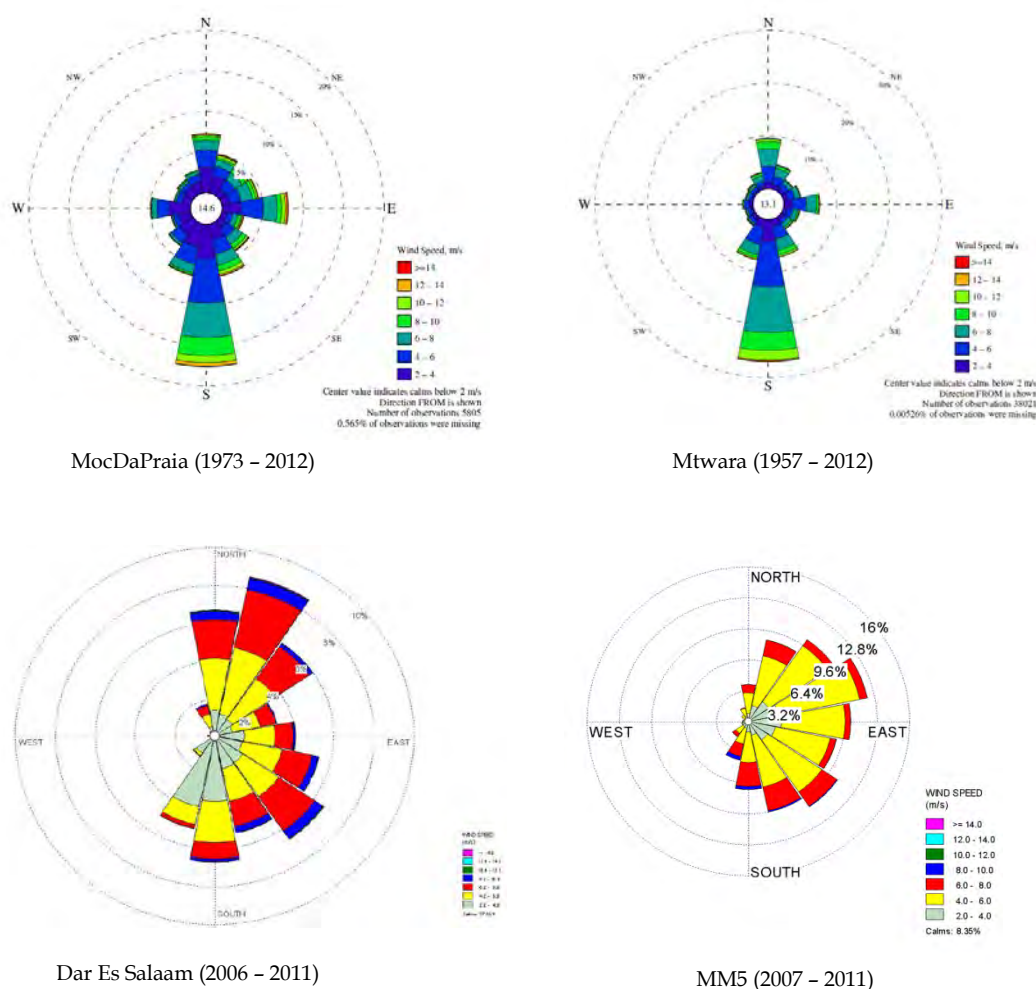
The meteorological data used in the model must be reflective of the local conditions. Unfortunately there are only a very limited number of meteorological stations in Africa which measure all of the parameters required by the model. The station at Dar Es Salaam Airport is the closest station to the LNG plant which measures all of the parameters and is also located at a shoreline, but is approximately 450 km north northwest of the site.

The most critical parameters determining local dispersion are wind speed and wind direction. During the assessment process, data on these parameters was sought from a more local source of monitoring (Mocimboa Da Praia (approx.

70 km south of LNG plant) and Mtwara (~70 km north of LNG plant)). This provided some understanding of the uncertainty in the modelling and proved that the data from Dar Es Salaam Airport is somewhat unrepresentative of the conditions at the development site as shown in *Figure 2.2*. It is clear that Dar Es Salaam has less frequent southern and western winds, and more eastern winds.

Therefore, five years of MM5 modelled meteorological data for 2007-2011 was sourced from Lakes Environmental, as this is somewhat more representative of local conditions. However, as illustrated by the locally sourced data, uncertainties in the local meteorological conditions remain. For the modelling the MM5 data was used. Wind roses based on the MM5 data are also shown in *Figure 2.2*. According to this figure easterly winds dominate, just as in Dar Es Salaam, but with lower wind speeds.

Figure 2.2 Comparison of meteorological data for Dar Es Salaam and project region



C2.6.7 Consideration of Terrain Effects

Changes in terrain elevations (ie hills or mountains) can have a significant impact on dispersion of emissions, in terms of funnelling of plumes and changing local wind flows. Terrain effects are typically considered important

where there are sustained gradients of 1:10 or greater which is not the case here. For this assessment terrain was therefore not included in the model.

C2.6.8 *Consideration of Building Downwash*

When air flow passes over buildings, a phenomenon known as building downwash occurs where the air is entrained in the lee of the building and drawn down to ground level. This effect can bring the plume from the stack down to ground level more quickly than would otherwise be the case, and therefore increase the ground level concentration relative to a case where there are no buildings. Based on currently available data, only the LNG Train buildings with the coolers on top have been included in the model. At this point, detailed height information is available, but only basic plant footprint is available.

Within the model, buildings are conceptually considered as a block shape, as the model cannot take into account downwash effects around a complex building shape. The dimensions of the buildings are presented in *Table 2.7*.

Table 2.7 *Dimensions of Buildings, as Modelled*

Buildings	Shape	Height (m)	Length/Diameter (m)	Width(m)
LNG Train building	rectangular	20	221	36
Power generator buildings	rectangular	6	18	6
Storage tanks	circular	45	80	-

C2.6.9 *Conversion of NO_x to NO₂*

The combustion process generates oxides of nitrogen (NO_x). In the exhaust gases from the stack, these are in the ratio of approximately 95% nitric oxide (NO) to 5% nitrogen dioxide (NO₂). With regard to the assessment of impact on human health NO₂ is the pollutant of interest as NO is largely inert in the human body. Within the atmosphere various processes oxidise NO to create NO₂ but this process will not occur quickly or completely before the plume reaches ground level. Therefore it is overly pessimistic to assume 100% conversion from NO to NO₂, and it is necessary to use a factor to estimate ground level concentrations of NO₂ based upon total NO_x emitted.

A number of international agencies have developed guidelines for including in assessments the conversion of NO to NO₂. A summary of the main guidelines are set out below in *Table 2.8*. The ratios set out in *Table 2.8* indicate that a wide range of ratios to convert NO to NO₂ are recommended by a variety of country agencies as set out in *Table 2.8* These conversion factors have been applied in the results interpretation.

Table 2.8 *Recommended NO to NO₂ conversion ratio*

Country	Averaging period	Recommended NO to NO ₂ conversion ratio
United States	24 hour	75%
	Annual	75%
Germany	24 hour	60%
	Annual	60%
United Kingdom	Short term (1 hour)	35%
	Annual	70%
Hong Kong	24 hour	20%
	Annual	20%
Ontario, Canada	24 hour	52%
	Annual	68%

Adopting a pragmatic approach a conversion factor of 35% for the short term and 70% for long term was adopted.

This applies only to the assessment of impacts on sensitive human receptors, as when assessing impacts on sensitive ecological receptors total NO_x is assessed and therefore no conversion is required.

C2.6.10 *Non-Routine Events*

A technically complex process, such as a LNG plant, is highly unlikely to operate for a protracted period of time without some non-routine events occurring. These events are typically short term but have the potential to result in short term elevated emissions. In the case of this facility, the key consideration is the safe disposal of gas when the plant is experiencing a non-routine event. This is achieved by diversion of gas to flares where it can be burned off until the plant operations are restored to normal.

Flares will be installed to combust gas from non-routine events related to maintenance and emergencies. Typical flaring events will occur for less than 60 minutes. The flaring event selected for modelling represents the worst case volume of gas reasonable expected to be flared from anticipated non-routine events. Note that an assessment of gas composition for identified flaring events revealed that no sour gas flaring is expected, so SO₂ emissions should remain negligible for all flaring.

C3 CLIMATE CHANGE

C3.1 INTRODUCTION

This study has been undertaken in accordance with international best practice emissions estimation techniques and the impact assessment methodology outlined in *Chapter 3* of the EIA. This section provides an overview of the methodology for calculating the carbon footprint and provides comment on how the impact assessment has been approached.

The study has involved a desktop assessment of international and national climate change literature; review of relevant documentation and discussion with the Project and specialist consultants. No field work was undertaken.

C3.2 CARBON FOOTPRINT CALCULATION

C3.2.1 Methodology

A carbon footprint is a measure of the estimated greenhouse gas emissions caused directly and indirectly by an individual, organisation, event or product. The calculation of a carbon footprint generally involves the following equation:

Carbon footprint emissions = activity data x emissions factor x global warming potential

- *Activity data* relates to the emission causing activity eg the combustion of a quantity of diesel or the use of a quantity of refrigerant gases;
- *Emission factors* convert the activity data collected and consolidated into tonnes of the relevant greenhouse gas; and
- *Global warming potentials* are applied to non-CO₂GHG to convert the result to carbon dioxide equivalent (tCO₂e).

The Projects carbon footprint has been estimated in accordance with the *GHG Protocol: Corporate Accounting & Reporting Standard* developed by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI). The *GHG Protocol* provides comprehensive guidance on accounting and reporting corporate GHG emissions. It is the most widely used standard for mandatory and voluntary GHG programmes and makes use of the Intergovernmental Panel on Climate Change (IPCC) GHG Inventory guidelines for specific heating values, carbon content, densities and emission factors. Where applicable, ERM has referred to specific data provided by the Engineering Team and the following sources for country and process specific factors:

- IPIECA Petroleum industry guidelines for reporting greenhouse gas emissions; and
- American Petroleum Institute's 2009 Compendium of Greenhouse Gas Emissions.

The calculation using these standards ensures that the Project's Carbon Footprint is aligned with international standards.

C3.2.2 Emissions Boundary Definition

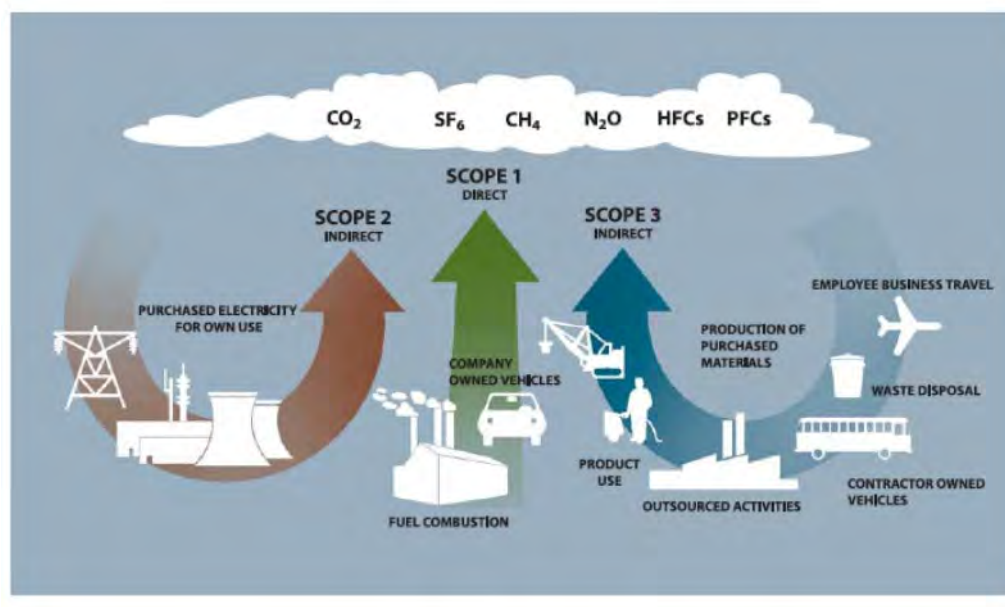
The scope of the carbon footprint depends on definition of two boundaries relating to the organisational and operational aspects of the project as outlined below. The boundaries drawn for the purposes of this project are discussed below.

Organisational boundaries determine whether reporting is done according to the "equity share approach" (different economic interest is reflected by companies being wholly owned, incorporated or non incorporated joint ventures or subsidiaries) or the "control approach" (emissions accounted for from operations under the direct operational control of the parent company).

Operating boundaries determine which emission causing activities will be included in the carbon footprint. The GHG Protocol divides emissions into three categories as described below and illustrated in *Figure 3.1*.

- *Scope 1 – direct emissions* from sources owned or under the operational control of the company;
- *Scope 2 – indirect emissions* from the consumption of purchased electricity; and
- *Scope 3 – indirect emissions* an optional reporting category allowing for other indirect emissions associated but not controlled by the company to be included such as contractor activities.

Figure 3.1 GHG Protocol Emission Scopes



C3.3 IMPACT ASSESSMENT METHODOLOGY

A traditional impact assessment is conducted by determining how the proposed activities will affect the state of the environment prior to development of a project (as outlined in *Chapter 3 of the EIA Report*). In the case of GHG emissions, this process is complicated by the fact that the impact of GHG emissions on the environment cannot be quantified within a defined space and time.

The greenhouse effect occurs on a global basis and the point source of emissions is irrelevant when considering the future impact on the climate. It is not possible to link emissions from a single source such as the LNG facility to particular impacts in the broader study area.

Subsequently, this specialist study does not consider the physical impacts of climate change resulting from increasing GHG emissions, but rather the impact of the project on Mozambique's National GHG Inventory and the implications of this.

The impact of the estimated Project's operational emissions has been compared with a national emissions trajectory from Mozambique from 1994 to 2028 which has been determined based on historic and projected economic growth and development pathways.

C3.4 SCOPE OF THE CARBON FOOTPRINT

C3.4.1 Introduction

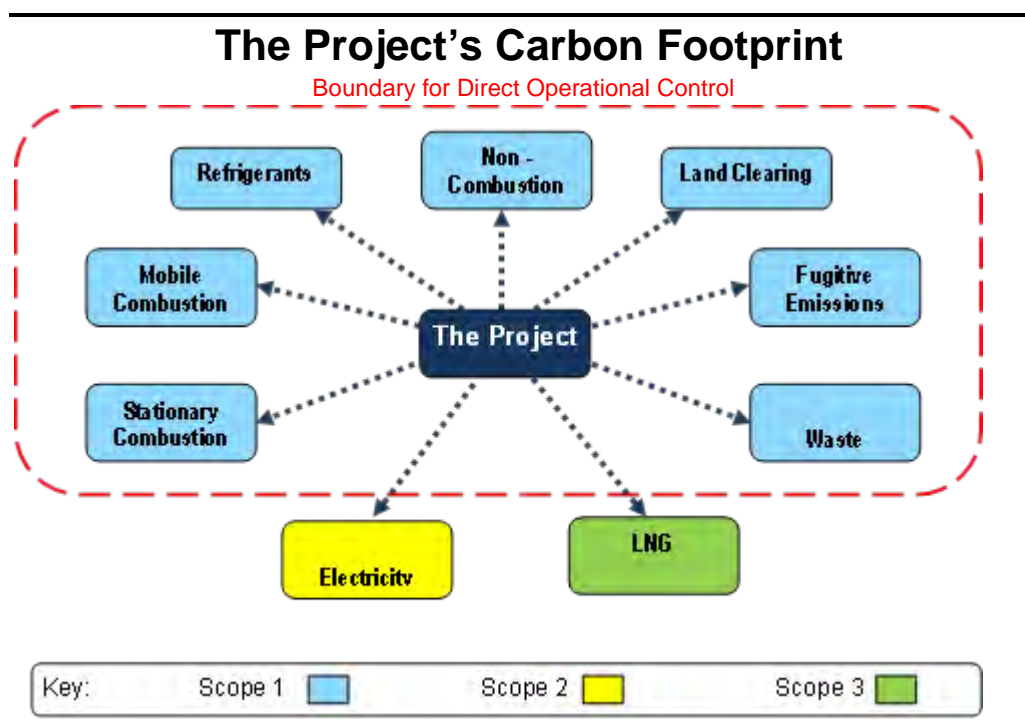
This section defines the scope of the Project’s carbon footprint in terms of emission boundaries, timing of emission causing activities coming online, and an overview of emission causing activities.

C3.4.2 Organisational and Operational Boundary

The organisational boundary has been defined according to the control approach where emissions from sources under the direct operational control of the Project will be included in the carbon footprint as illustrated in Figure 2.3.

Scope 3 (indirect) emissions would typically be from outsourced activities, such as contractor activity and employee business travel. These emissions have been excluded for the purposes of this study due to the fact that there is considerable uncertainty with respect to estimating contractor activity and employee business travel.

Figure 2.3 The Project’s Carbon Footprint Boundary



It is assumed that the Project will pay for the fuel used by contractors on site and therefore the emissions associated with their activities have been included under Scope 1. All electricity is generated on site (Scope 1) and therefore there are no Scope 2 emissions from purchased electricity. Scope 3 emissions associated with export of LNG have been estimated but not included in the overall carbon footprint as discussed in Section 5.

C3.4.3 *Timeframe*

Construction is due to begin in 2014 with operations beginning as the first LNG 'train' comes online during Quarter 4 of 2018. The production capacity of each LNG train is 5 million tonnes of LNG per year. Construction will continue until 2021 when six trains will be in operation bringing the total production of the facility to 30 million tonnes of LNG per year. The life of the facility is anticipated to be approximately 30 to 40 years indicating closure in 2058. *Table 3.1* shows the timing of trains coming online and how the three phases of activity are expected to impact the number of people working on site.

Table 3.1 *Timeframe from Construction to Full Operations of the Project*

Phase	Timing of trains	Approx number of people on site
Construction 2014 - 2018	N/A	8,000
Combined Construction and Operations 2018 - 2021	Train 1 - 2018 Q4 Train 2 - 2019 Q2 Train 3 - 2020 Q1 Train 4 - 2020 Q3 Train 5 - 2021 Q1 Train 6 - 2021 Q3	10,000
Operations only Phase 2021 - 2058	N/A	700

C3.4.4 *Overview of Project Emission Causing Activities*

The proposed LNG and support facilities are expected to cover an area of some 36km² within a larger site area of approximately 80km². The associated offshore gas fields are located approximately 50 kilometres east of the onshore facilities. The Project Description in *Chapter 4* of the *EIA Report* provides a detailed account of the activities associated with the proposed project.

There are four major components to the project which include:

- Offshore - gas fields and associated infrastructure;
- Onshore
 - LNG industrial complex;
 - a residential camp accommodating up to 10,000 people; and
 - services including port, roads, power, water and sewage etc.

Table 3.2 summarises the key emission sources occurring on site and indicates those which are included in the carbon footprint.

Table 3.2 *Summary of Key Emission Sources (all Scope 1)*

Emission Scope	Emission Source
Mobile combustion	Fuel used in marine vehicles including tug, utility and chase boats, freight carriers and Project LNG carriers Fuel used in terrestrial vehicles including cars, utility vehicles, buses etc Fuel used in airplanes contracted for exclusive use by the Project
Stationary combustion	Diesel used for power generation Gas used for power generation Diesel use by contractors during construction Flaring Incineration of acid and fuel gas Oil heating
Waste emissions	Methane emissions from waste water (sewage) treatment
Refrigerants	Leakage/use of refrigerant gases in air conditioning units in vehicles and offices/accommodation
Fugitives	Natural gas leaks from pipelines
Lubricants	Use of lubricant oils and greases in machinery
Land clearance	Clearance of vegetated land (at the start of the project)

C3.5 *ASSUMPTIONS MADE IN ESTIMATING OPERATIONAL ACTIVITY DATA*

Good practice for calculating a carbon footprint dictates that actual activity data (eg litres of diesel consumed) for a financial year is used. Given that this project involves an estimation of a future carbon footprint for activities yet to begin, a series of assumptions have been made in order to obtain the activity data required to undertake this calculation.

Data was obtained from the ESIA Aspects Register, the Specialist Study Workshop held on 25 – 26 January 2012 and through discussion with the Engineering Team to clarify and confirm assumptions. The carbon footprint has been estimated in accordance with current design options and these may well change following completion of the ESIA and Front End Engineering and Design (FEED) studies. A number of assumptions have been made in relation to each aspect of the carbon footprint calculation (these are not detailed here).

The carbon footprint includes estimated direct emissions from activities associated with the construction and operation of the facilities. Embedded emissions associated with the materials used are regarded as Scope 3 and not included as they are outside the scope of this project. The emissions from the consumption of LNG sold by the Project are not included as this is outside the control of the company and the demand for LNG would have been met by an alternative supplier, meaning that it does not add additional emissions into the atmosphere.

C4 **NOISE**

C4.1 **APPROACH AND METHODOLOGY**

C4.1.1 **Overview**

The broad objectives are to implement a project that in an environmentally, economically and socially sustainable manner consistent with the requirements of the IFC/ WB Noise Guidelines and Performance Standards.

C4.1.2 **Noise Sensitive Receptors**

The LNG Plant will be located on the eastern coastal area approximately 5km from the town of Palma. There are several villages and settlements located in the vicinity of the proposed LNG Plant and airstrip. There are sizeable settlements of more than 20 dwellings and smaller hamlets lie scattered throughout the area. The surrounding land is largely used for agriculture, particularly rice fields.

Several villages and communities are currently situated within the Afungi Project Site. It is envisaged that these receptors will be resettled as part of the Resettlement Plan, and hence, have not been assessed as Noise Sensitive Receptors (NSR). NSRs outside the Afungi Project Site are considered in the impact assessment.

Existing ambient and background noise levels within the Project Area and surrounds were also measured to inform the impacts assessment. The methodology in determining representative existing noise levels is described in the section below.

An overview of the Project area highlighting the location of the LNG facility, airstrip, baseline noise measurement locations and noise assessment locations are shown in *Figure 4.1* and are listed in *Table 4.1*

Figure 4.1 LNG Plant and Assessment Locations

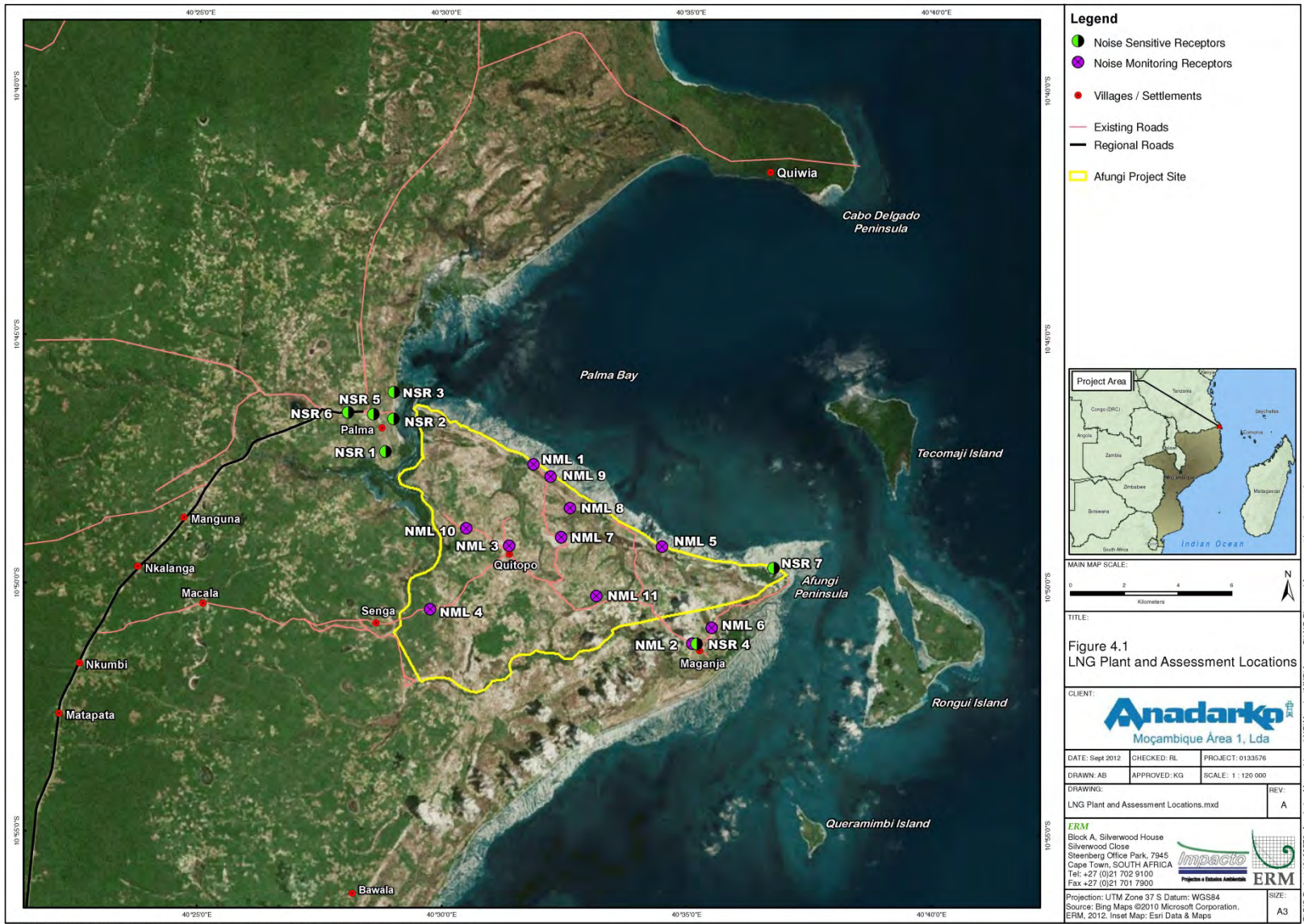


Table 4.1 *Assessment Locations and Characteristics*

NSR ID	District	Village	Population	Easting ⁽¹⁾ (m)	Northing ⁽¹⁾ (m)	Distance to LNG plant (m)	Nearest Noise Survey Location (distance)
1				661826	8806977	3000	Road closest to airstrip (4.1km)
2				662120	8808185	3200	Road closest to airstrip (5km) Maganja village (5.5km)
3				662137	8809181	3600	Maganja village (5.8km)
4				673400	8799835	3000	Near village 5,6,7 (0.1km)
5				661374	8808355	3900	Road closest to airstrip (5.4km)
6				660428	8808433	4800	Road closest to airstrip (6.1km)
7				676257	8802645	1700	Heli Pad (3.2km) Quitopo village (4.3km)

Note 1: Coordinate System: WGS84 – UTM 37S

C4.2 *IMPACT PREDICTION*

C4.2.1 *Noise Prediction Methodology – LNG Plant*

During the construction phase, impacts are related to machinery noise emissions that have the potential to affect the area adjacent to the project site. Construction noise sources are generally intermittent and impacts depend on the number and types of machinery used for each activity. An increase in the noise level in the area adjacent to the Afungi Project Site is also expected during the operational phase.

Noise level predictions must take into account all significant noise sources associated with the proposed operations. One method of determining the impact of numerous noise sources at a receiver is to develop a computer model of the proposed operations using a commercially available software package. An acoustic model has been developed using the environmental noise modelling program “SoundPLAN”, version 7.0, developed by Braunstein + Berndt GmbH. The model has been used to generate expected noise contours for the area surrounding the LNG plant and also to predict noise levels at the nearest noise sensitive receptors, identified in *Figure 4.1* for the following scenarios:

- LNG Plant construction;
- Airstrip construction; and
- Normal LNG plant operation.

The model has been used to implement the methods identified within ISO9613 Part 2 for the propagation of noise. SoundPLAN uses the following information to predict noise levels attributable to the LNG plant at nearby receivers:

- three-dimensional digital terrain map of site and surrounding area;
- frequency-based sound power level noise source data for plant and equipment operating at the site;
- intervening ground cover;
- shielding by barriers, intervening buildings or topography; and
- atmospheric conditions.

Meteorology

The model has been used to predict noise levels and produce noise contours considering (as per ISO 9613-2) the following environmental conditions:

- Air Pressure 101,325 Pa
- Air Temperature 299.15 K (26 °C)
- Humidity 83%

The noise propagation is carried out under down wind conditions (from source to receptor). Downwind propagation conditions for the method specified in ISO 9613 are:

- wind direction within an angle of $\pm 45^\circ$ of the direction connecting the centre of the dominant sound source and the centre of the specified receiver region, with the wind blowing from source to receiver; and
- wind speed between 1 m/s and 5 m/s, measured at a height of between 3 m to 11 m above the ground.

The meteorological parameters have been set up for the whole calculation domain, to represent as the probable atmospheric conditions of the Project area.

Topography and Land Cover

Topographical information for the acoustic model was extracted from 1m ground contours available in electronic format for the area surrounding the LNG Plant. A 3-D representation of the terrain's surface has been calculated through the generation of a digital ground model (DGM) in SoundPlan. The screening effects of buildings and barriers at the site have been excluded from the acoustic model to represent a conservative calculation methodology.

The attenuation due to the ground between the noise sources and the receptors has been included in the noise model. An absorption coefficient value of 0.2 dB has been applied for surfaces covered by vegetation and fields; and an absorption value of 0.0 dB has been applied for the plant site and the sea.

Construction Phase

Noise associated with construction of the LNG plant will be variable in nature and will depend on the particular activities being undertaken as well as the equipment in operation. The construction phase is expected to be approximately 51 months and is anticipated to begin in early 2014.

Noise will be potentially generated at the LNG Facilities site, both onshore and offshore, by:

- **Site preparation and earthmoving.**
This scenario includes significant noise-producing activities such as vegetation clearance, topsoil removal, earthworks, construction of the earth causeway and the Materials Offloading Facility. These activities will require heavy construction vehicles and equipment such as bulldozers, scrapers, graders, rollers, dump trucks and water carts.

- **Civil works and Plant Fabrication.**
This scenario includes significant noise-producing activities such as installation of concrete and asphalt batch plants, installation of foundation structures and paved areas within the LNG Facilities, upgrade of the existing local road and installation of on-site roads. These activities will require equipment such as piling, heavy rollers, concrete trucks, generator sets and steel reinforcement fabrication hand tools such as grinders.

- **Construction of the Plant Utilities.**
This scenario will include activities such as receiving and transporting large plant items from the Materials Offloading Facility to the LNG Facilities site, which will typically require equipment such as offloading crawler cranes and heavy transport equipment. Onsite steel fabrication, pipe erection and assembly of plant items will typically require tower cranes, grinders, welders, generator sets, air compressors and forklifts.

The overall noise produced during the construction phase comes from several types of equipment and from specific activities. Therefore, the noise impact related to this phase can be variable and it is difficult, to accurately predict construction noise emissions throughout the entire construction period. Hence, to facilitate the noise assessment, three 'worst case' scenarios have been developed:

- a site preparation scenario;
- a civil works scenario; and
- a construction plant utilities scenario.

Considering that construction activities will extend throughout the project site, each scenario has been simulated several times, varying the location of the equipment to represent a 'typical' maximum activity with all equipment operating in the area closest to noise sensitive receptors.

The predicted noise levels from the model are based on the assumption that all equipment is operating simultaneously and at full load. The equipment simulated and their acoustic performances for each scenario are shown in Table 4.2 to Table 4.4.

Table 4.2 Site Preparation Equipment List

Equipment	Num.	Octave Band (Hz) Sound Power Level, dBA								Lw(dBA)	Location Area	
		63	125	250	500	1K	2K	4K	8K			
Chainsaws	1	81	91	98	104	107	108	108	106	114	Onshore facilities area	
Bulldozer	2	101	105	108	111	109	104	99	-	116		
Scraper	1	76	85	91	96	98	97	90	81	113		
Grader	1	83	92	98	103	105	104	97	88	110		
Loader	2	89	93	97	100	103	101	96	91	108		
Roller	1	89	68.5	73	74	71	69	64	56	106		
Dump truck	3	96	100	104	107	110	108	103	98	115		
Water cart	1	81	85	89	92	95	93	88	83	100		
4WD vehicle	3	43	56	66	73	76	73	70	64	80		
Dump truck	2	96	100	104	107	110	108	103	98	115		
Excavator large	2	91	95	99	102	105	103	98	93	110		
Bulldozer small	1	99	103	106	109	107	102	97	-	114		Offshore facilities area
Roller	1	89	68.5	73	74	71	69	64	56	112		
Sheet pile driver	1	80	110	115	110	119	110	104	97	122		
4WD vehicle	2	43	56	66	73	76	73	70	64	80		

Table 4.3 Civil Works Equipment List

Equipment	Num.	Octave Band (Hz) Sound Power Level, dBA								Lw(dBA)	Location Area
		63	125	250	500	1K	2K	4K	8K		
Pile driver	1	80	110	115	110	119	110	104	97	122	Onshore facilities area
Roller	2	89	68.5	73	74	71	69	64	56	106	
Concrete and asphalt batch plant	1	92	96	100	103	106	104	99	94	111	
Concrete mixer truck	3	91	95	99	102	105	103	98	93	110	
Concrete pump	2	106	106	98	98	102	97	92	92	112	
Grinder	3	-	91	97	100	102	97	92	88	111	
Generator	3	99	98	96	92	91	90	78	81	105	
4WD vehicles	5	43	56	66	73	76	73	70	64	80	

Table 4.4 Plant Utilities Equipment List

Equipment	Num.	Octave Band (Hz) Sound Power Level, dBA								Lw (dB A)	Location Area
		63	125	250	500	1K	2K	4K	8K		
Tower crane	1	-	-	-	110	-	-	-	-	110	Onshore facilities area
Welder and generator	3	99	98	96	92	91	90	78	81	105	
Grinder	3	-	91	97	100	102	97	92	88	110	
Air compressor	3	91	90	93	96	96	94	91	-	106	
Forklift	2	62	72	79	85	88	89	89	87	95	
Flat bed truck	2	79	95	96	100	104	103	98	92	114	
4WD vehicle	5	43	56	66	73	76	73	70	64	80	
Crawler crane	1	-	-	-	111	-	-	-	-	111	Offshore facilities area
Heavy transport	1	70	86	87	91	95	94	89	83	105	
Piling from barge	1	76	106	111	106	115	106	100	93	118	
Crawler crane from barge	1	-	-	-	113	-	-	-	-	113	

Operation Phase

LNG Facilities operations comprise a large number of processes, activities and equipment that generate noise. It is anticipated that the operational life of the facility will be approximately 30 years and the LNG Plant will run 24 hours a day, 7 days a week and the main noise sources will be located within:

- the LNG Plant and utilities areas, characterised by up to 6 LNG trains, different operational areas (feed gas reception, water and effluent treatment, air compression and fractionation area, MEG unit, refrigeration storage) and common facilities;
- the flare area, due to the necessity during normal LNG plant operations to occasionally and intermittently burn unwanted gas from the flare tower. The flare will be 140 meters above ground level; and
- the LNG Jetty and harbour area, where LNG loading will require tankers, tugs and equipment such as pumps and tanker auxiliary power generators.

To predict noise emissions from LNG processing operations, a typical worst case activity case has been assumed based on the simultaneous occurrence of the following typical scenarios:

- LNG Processing scenario;
- Flare scenario; and
- Shipping scenario.

The predicted noise levels in the model are based on the assumption that equipment is operating simultaneously and at full load. The equipment simulated and their acoustic performances for each scenario are shown in *Table 4.5 to Table 4.7*.

Table 4.5 LNG Processing and Utilities Scenario Equipment List

Equipment	Octave Band (Hz) Sound Power Level, dBA									Overall (dBA)
	31.5	63	125	250	500	1K	2K	4K	8K	
<i>Power generation and refrigeration storage</i>										
LNG Train	58	70	90	108	105	120	116	102	77	125
Air coolers (number =189)	67	69	71	76	82	86	88	88	93	96
Exhaust chimney	103	99	98	93	86	83	79	76	67	90
Generator	98	98	97	95	91	90	89	77	80	104
Ethane/Propane pumps	89	89	89	87	87	85	80	75	75	96
<i>Feed gas reception area</i>										
Gas reception unit	87	91	85	81	79	91	95	72	57	101
<i>Water treatment area</i>										
Fresh water pump	85	85	85	83	83	81	76	71	71	92
Potable water pump	84	84	84	82	82	80	75	70	70	91
Demin water pump	84	84	84	82	82	80	75	70	70	91
Fresh water fire pump	93	110	99	97	95	97	92	79	66	111
Jockey pump	84	84	87	88	86	86	86	86	80	95
Fresh water diesel fire pump	93	110	99	97	95	97	92	79	66	111
<i>Air compression and nitrogen area</i>										
Air compression	-	91	90	93	96	96	94	91	-	102
<i>Emergency and laboratory</i>										
Labs sanitary pump	84	84	84	82	82	80	75	70	70	91
<i>Effluent treatment</i>										
Contaminated water recycle pump	82	82	82	80	80	78	78	68	68	89
Irrigation water pump	82	82	82	80	80	78	78	68	68	89

Effluent discharge pump	82	82	82	80	80	78	78	68	68	89
<i>Fractionation</i>										
Fractionation column	89	96	95	97	100	100	94	82	110	112
Pumps	89	89	89	87	87	85	80	75	75	96
<i>MEG Unit</i>										
Meg flash separator recycle heater	101	102	97	95	89	88	89	85	77	106
Pumps	89	89	89	87	87	85	80	75	75	96
Lean MEG booster pump	87	87	87	85	85	83	78	73	73	94

Table 4.6 *Elevated Flare Equipment List*

Equipment	Height (m)	Octave Band (Hz) Sound Power Level, dBA								Overall (dBA)
		63	125	250	500	1K	2K	4K	8K	
Flare	140	119	118	115	110	109	109	111	112	124

Table 4.7 *Shipping Equipment List*

Equipment	Number	Sound Power Level (dBA) (ref 10 ⁻¹¹ Watts)
LNG tanker	1	111
Tugs	4	111
Condensate tanker	1	101
Condensate pumping	1	105

C4.2.3 *Noise Prediction Methodology - Airstrip*

The Integrated Noise Model (INM) version 7.0b was used to compute flight profiles and noise contours based on the following data:

- Runway geometry.
- Aircraft types.
- Aircraft performance data.
- Aircraft numbers for the peak period, during the construction phase.
- Flight tracks (or routes).
- Meteorological data.

The Integrated Noise Model was developed in the USA, and is maintained with an up to date database of aircraft performance and noise data. Version 7.0b has such data for 138 types of commercial aircraft, 115 military aircraft and 19 helicopters. The model is not solely a noise model. As well as predicting noise levels, the INM computes 3-dimensional flight paths, based on the 2 dimensional flight 'track' and the vertical flight profile that it computes from individual aircraft thrust and flap settings, aircraft air speed, and headwind data specific to each aircraft operation that the user defines. Hence, a great deal of information is required to construct a reliable airport noise model.

Most of the necessary aircraft performance data was available in the INM databases. Where particular aircraft types were not available in the INM, suitable substitutions were made based on aircraft function, weight and performance.

In this case three types of aircraft are expected to use the airstrip, as follows:

- Antonov 124 (INM standard substitution Boeing 747 20B);
- Cessna 208 Caravan (INM standard substitution General Aviation single turboprop GASEPF); and
- Sikorsky S76 Sprint helicopter.

Flight numbers will be highest during construction, and are assumed as follows:

- Antonov 124 1 every 2 days
- Cessna 208 1 every 2 days
- Sikorsky S76 1 per day

It is assumed that all flights will operate during daytime hours.

Given the low total number of daily flights (2 arrivals and 2 departures on average) a relatively simple noise model has been created to predict peak noise levels (L_{Amax}) and assess impacts on the local area.

Key Data and Assumptions

It has been assumed that all flights will land and take off heading to the south due to the predominance of winds from the South and South East. However, given the low numbers of flights each day it may be possible to operate the runway in both directions to allow, say, arrivals from the south and departures to the South. Indeed, in this case, the direction of operation is a noise mitigation measure that could be explored if necessary.

It is assumed that all aircraft approach on a standard 3 degree glide slope and approach and depart using standard aircraft operating procedures. The Sikorsky S76 helicopters are assumed to operate from a helipad at the

northern end of the airstrip and to follow the same routes straight in and out of runway for the area of interest to this study, departing and arriving on Visual Flight Rules to/from a height of 1000ft.

KBR meteorological data (CV-60-G20-0001, 16 January 2012) has been used to generate appropriate headwinds for runway operations, temperature and pressure, which influence aircraft climb rates and hence noise levels on the ground. An average temperature of 25 degrees Celsius was used. Although there is a predominance of winds from the South, headwinds were taken to be neutral, to model a likely worst case. Annual mean pressure was taken to be 101,400 Pa.

C4.3 *EVALUATING SIGNIFICANCE*

C4.3.1 *Overview*

The environmental values to be protected are the qualities of the acoustic environment that are conducive to:

- the wellbeing of the community or a part of the community; and
- the wellbeing of an individual, including the individual's opportunity to have sleep, relaxation and conversation without unreasonable interference from intrusive noise.

C4.3.2 *Impact Threshold Noise Levels*

Review of the IFC guidelines and the WHO guidance, indicates that where possible, the overall noise level at a receptor should not exceed identified threshold values (*Table 4.8*). Hence, the noise emissions from the Project (the Specific Noise Level) should be designed to ensure that compliance with these noise levels is achieved.

Table 4.8 IFC/World Bank Noise Level Guidelines

Receptor	Maximum Allowable Ambient Noise Levels, LAeq,1hr, dBA Free field	
	Daytime 07:00 – 22:00	Night-time 22:00 – 07:00
Residential, institutional, educational	55	45
Industrial, commercial	70	70

C4.3.3 *Evaluating Significance of Noise Impacts*

Four key factors are considered when determining the significance of noise effects – receptor sensitivity, magnitude of impact, duration and likelihood of occurrence. Of these factors, three are generally the same for the operation:

- the sensitivity of the receptor – generally all humans hear noise and react to noise similarly and the difference between daytime and night time is addressed by adopting different thresholds;
- likelihood – we know the noise will occur from predictive modelling; and
- duration – the noise is relatively continuous and would be considered to be of a long term duration (except for construction).

For construction the noise duration is a more variable factor which is accounted for in the impact assessment matrix by a reduction in the acceptable noise thresholds adopted for the Project.

For both construction and operational noise, impacts are considered to be *Direct* in their nature and of a *Local* extent, whereas *Intensity* is not considered when determining impacts from noise.

Therefore, the deciding factor in determining the significance of an impact is the magnitude of the noise level, expressed as an exceedance of the criterion (*Table 4.9* and *Table 4.10*). The significance assessment matrix is presented in Tables below and sets out the level of significance based on noise levels during the construction and operation phases. The definition of the significance ratings are explained below:

- **Negligible/ Not Significant** – no need to consider in decision making, no mitigation required;
- **Minor** – an impact that is significant, to be considered by decision makers, but small enough that noise management practices would ensure noise levels are below significance criteria;
- **Moderate** – an impact that is significant and mitigation should be considered. Mitigation is likely to affect design and cost;
- **Major** – an impact that is significant and mitigation must be considered. Mitigation will alter project design and cost. Impacts are undesirable if not addressed; and
- **Critical** – Creating adverse direct and immediate potential health and human comfort effects and should stop the project proceeding in this form and significant mitigation will be required to alter design.

C4.3.4

Noise Criteria - LNG Plant

Construction Phase

There is no relevant national guidance for construction noise and it is not addressed directly by IFC EHS guidance. In consideration of the construction period, being a period of over 4 years, it is considered that the IFC and WHO threshold levels of 55 dB(A) for the daytime and 45 dB(A) for the night time would be appropriate for this project. Additionally, a L_{AMax} of 85 dBA is a well-accepted action limit for occupational noise management as it is the threshold at which the potential for hearing damage starts to occur. This level has been adopted as the threshold for critical impacts.

The significance of construction noise is evaluated by establishing a threshold noise level at which significant impacts start to occur and higher levels for *moderate* and *major* impacts. Using these standards and guidelines for reference, usually it is appropriate to set significance thresholds for day and night time according to the duration of the noise, on the basis that temporary construction (<1 month) will have lesser impact than short term (1-6 months) or long term (> 6 months).

Table 4.9 presents the impact assessment matrix relating to the contributed noise level from the construction phase. Given the duration of construction for this project, a conservative approach has been taken, adopting the most stringent (> 6 months duration) long term criteria.

Table 4.9 Noise Impact Significance NSR - Construction Phase

Operating Period	Daytime Noise Level, dBA				Night time Noise Level, dBA				All Periods	
	Impact Rating	Not Significant	Minor	Moderate	Major	Not Significant	Minor	Moderate		Major
Construction LAeq,1hr										
Temporary exposure < 1 month	<70	70-75	>75-80	>80	<55	55-60	>60-65	>65	>85	
Short term exposure 1 to 6 months	<65	65-70	>70-75	>75	<45	45-55	>55-60	>60	>85	
Long term exposure >6 months	<55	55-60	>60-65	>65	<45	45-50	50-55	>55	>85	

Operation Phase

There is no relevant national guidance for noise and therefore IFC EHS guidelines will be adopted for the project.

Table 4.10 presents the impact assessment matrix relating to the contributed noise level from the Project operational phase.

Table 4.10 Noise Impact Significance for Residential Receptors. Operational Phase

Operating Period	Daytime Noise Level, dBA				Night time Noise Level, dBA				All Periods
	Not Significant	Minor	Moderate	Major	Not Significant	Minor	Moderate	Major	
Plant Operation LAeq,1hr	<55	55-60	>60-65	>65	<45	45-50	>50-55	>55	> 85
Δ LA90	<3	3 -8	>8 - 15	>15	<3	3 -8	>8 - 15	>15	> 85

For the operational phase, the noise generated by plant activities at NRSs will be compared with the background noise level monitored during the field survey, taking into account the LA90 value that describes the A-weighted sound pressure level exceeded for 90% of the measurement time ¹. Where background level is not available, due to the significant distance between monitoring sites and noise sensitive receptors, a value of 30 dB(A) as LA90 will be considered. This assumption is acceptable due to the particular nature of the area surrounding the plant site, largely used for agricultural activities, with no significant noise sources.

C4.3.5 Noise Assessment Criteria – Airport

There are no aircraft noise guidelines in Mozambique.

There are numerous metrics used around the world to describe aircraft noise. Most are either peak or averages of some type. For example:

- LAeq 12 hr dB: The A-weighted equivalent noise level, log averaged over a 12 hour period (0700-1900 hours) gives a form average noise exposure taken over an average day.
- LAmax dB: The A-weighted maximum noise level during any aircraft noise event (ie the peak).

In Europe the Day Evening Night Noise Level (Lden) is the noise metric now used most widely for assessing aircraft noise impacts. The metric is based on LAeq but sums all aircraft noise events over a 24 hour period, giving the different logarithmic summation weightings according to time of day. Other metrics are based on LAeq all of which sum noise over a period and logarithmically average. In this case, there will be on average up to about four aircraft movements each day, and an averaging approach is not considered appropriate.

LAmax(peak) noise levels are sometimes used to assess sleep disturbance or to compare peak noise levels during an aircraft fly-over against ambient noise

(4)ETSU-R-97 Guidelines for Wind Farm Noise Assessment advises using the LA90 noise index for background noise; the LA90 level noise is typically 2 dBA less than the equivalent LAeq,t value.

levels. An aircraft noise level of L_{Amax} of 80dB (with ground effect) is commonly taken as the level above which significant community sleep disturbance can arise, assuming a degree of habituation over time.

C4.4 ***BASELINE DATA COLLECTION***

C4.4.1 ***Overview***

An important part of the noise assessment is the quantification and understanding of the existing acoustic environment including the identification baseline noise levels at potentially affected NSRs. The baseline environment can be defined as the conditions that would prevail in the absence of this Project. This information sets the scene for the assessment of the potential for noise impacts at the NSRs created by the LNG Facility.

C4.5 ***DATA COLLECTION METHODOLOGY***

Representative measurement locations were chosen in on the outskirts of each village to capture the baseline noise level without being affected by village noise sources, such as people, vehicles or the movement of animals.

Ambient (background) noise levels for the Project Area were measured by undertaking long-term measurements during the day and night and a series of attended short-term measurements during the day over the period between 20th February to 27st February 2012 at the measurement locations shown in *Figure 4.2* to capture the existing day and night time noise baseline.

A Rion NL-52 Type 1 Sound Level Meter (SLM) was used to conduct unattended long term and attended short-term measurements. The instruments were calibrated before and after measurements and no significant calibration drift was detected. Meteorological conditions during the measurement period were observed as predominantly sunny; however, light rain did occur over the period of measurement. An anemometer recorded the average wind speed to be under 5.2 km/h during the short-term measurements and recorded an average temperature of 34 °C.

C4.5.1 ***Long Term Measurements***

At each long term location, a minimum of 24 hours continuous noise monitoring was conducted to provide a description of the noise levels and to understand the variation between the daytime and night time periods. The microphone of the long term monitor was set on a tripod to a height of 1.5m and greater than 3.5m from any reflective surface (except ground) so that it was a free-field measurement. The monitor automatically logged environmental noise measurement parameters including L_{Aeq} , L_{A90} , L_{A10} , L_{Amax} and L_{Amin} parameters.

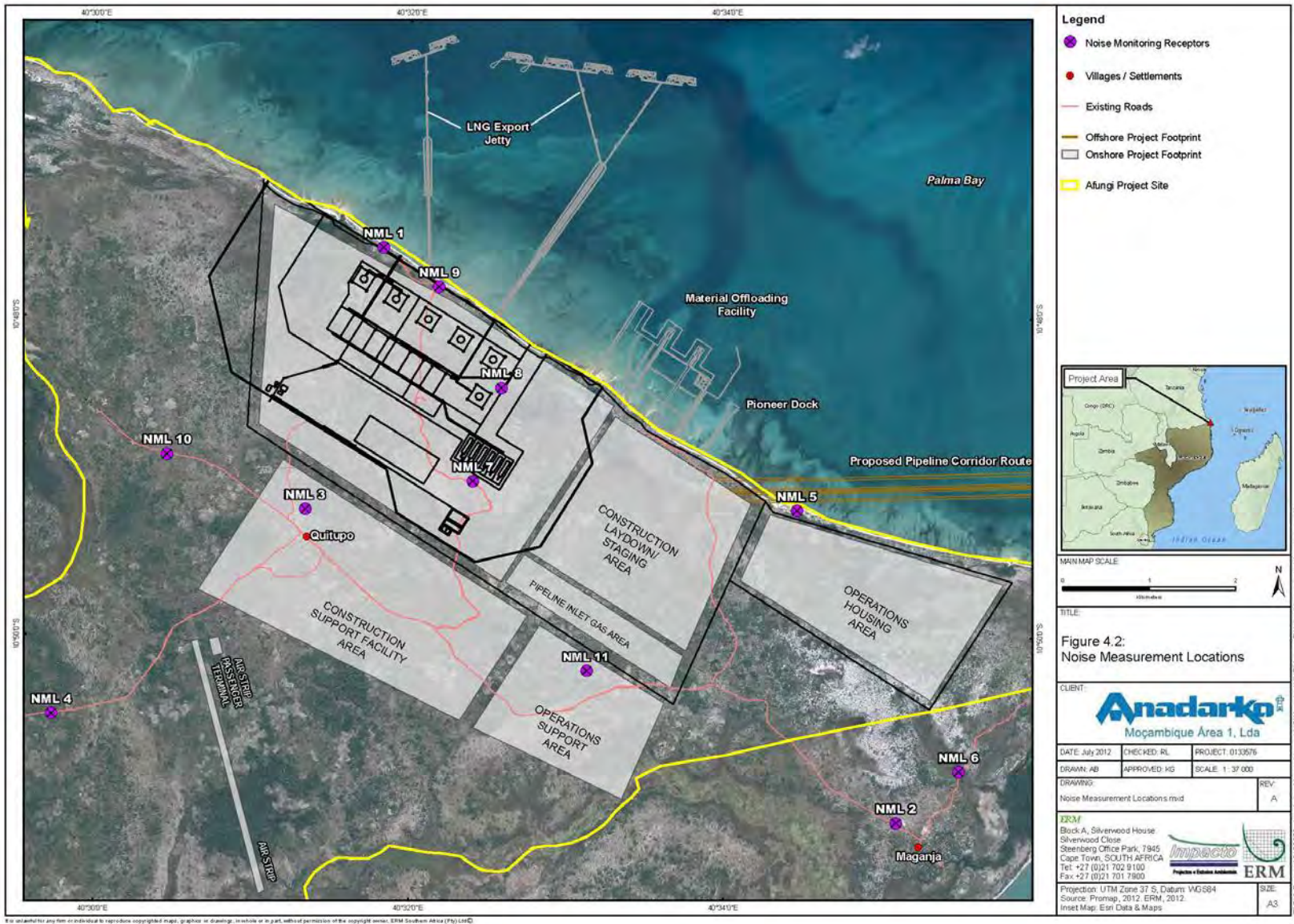
Long term measurements were collected at a total of four locations (see *Figure 4.2*). Location D (NML1) is situated along the coast line north east of the

project site, Maganja (NML2) to the south east, Quitopo (NML3) to the west, and final location (NML4) being the road closest to the air strip, south west of the project site. These four locations were deemed representative of the acoustic environment for the typical rural villages, located in and around the Project site.

C4.5.2 *Short Term Attended Measurements*

A series of attended short-term (day time) measurements were undertaken to identify the nature, character and dominant noise sources surrounding and within the Project site. Short-term measurements were also undertaken at each long-term location before in order to verify the long-term measurements. Short-term measurements were recorded at total of 11 locations.

Figure 4.2 Noise Measurement Locations



C5.1 METHODOLOGY

Baseline data for the soil section was collected during a site visit from 9 to 22 December 2011. Baseline information provides a description of the current soil environment against which the impacts can be assessed and future changes monitored.

A soil survey was planned with the objective of identifying and classifying the area in terms of:

- soil types associated with the area to be disturbed;
- physical and chemical properties of the identified soil types;
- depth of the soil;
- erodibility of the soils;
- nutrient status of the soil; and
- pre-construction soil utilisation potential (land capability)

The Study Area comprised the boundary of the larger area (Areas 1 and 2) as shown in *Figure 5.1*. Area 1 shows the demarcation originally identified for investigation, while the larger enclosure was added at a later stage (Area 2) to incorporate a larger project footprint. Access to Area 1 was limited by the absence of roads during the time of study, while access to Area 2, as indicated above, was prohibited. Consequently two methods of deriving the products data were employed. Delineations on Area 2 were conducted based on the field observations, namely landscape positions of sandy well drained soil and waterlogged wetland soil, found in Area 1 including additional satellite image interpretation. Reconnaissance soil survey accuracy can be expected using this approach.

C5.2 INVESTIGATION OF AREA 1

The method applied is summarised below. Details of specific steps are addressed in Appendix D.

- GIS software was used to generate a grid system (350 m spacing) to cover the area under discussion;
- The grid system allows for geo-referenced points at the gridline intersections;
- The points were numbered and transferred to a Global Positioning System (Garmin GPS instrument) using WGS84 datum;
- The geo-referenced coverage provided was used as a basis for the selection of points for investigation;

- Based on in-field interpretation of topography, anticipated pattern and characteristics of the soil and outlay of roads and foot pathways, a selection of grid points was chosen to investigate and represent the area of study;
- Existing pits encountered during the fieldwork sessions were included for investigation; and
- By application of the above, 127 observation points (including 5 pits) were established and visited for investigation.

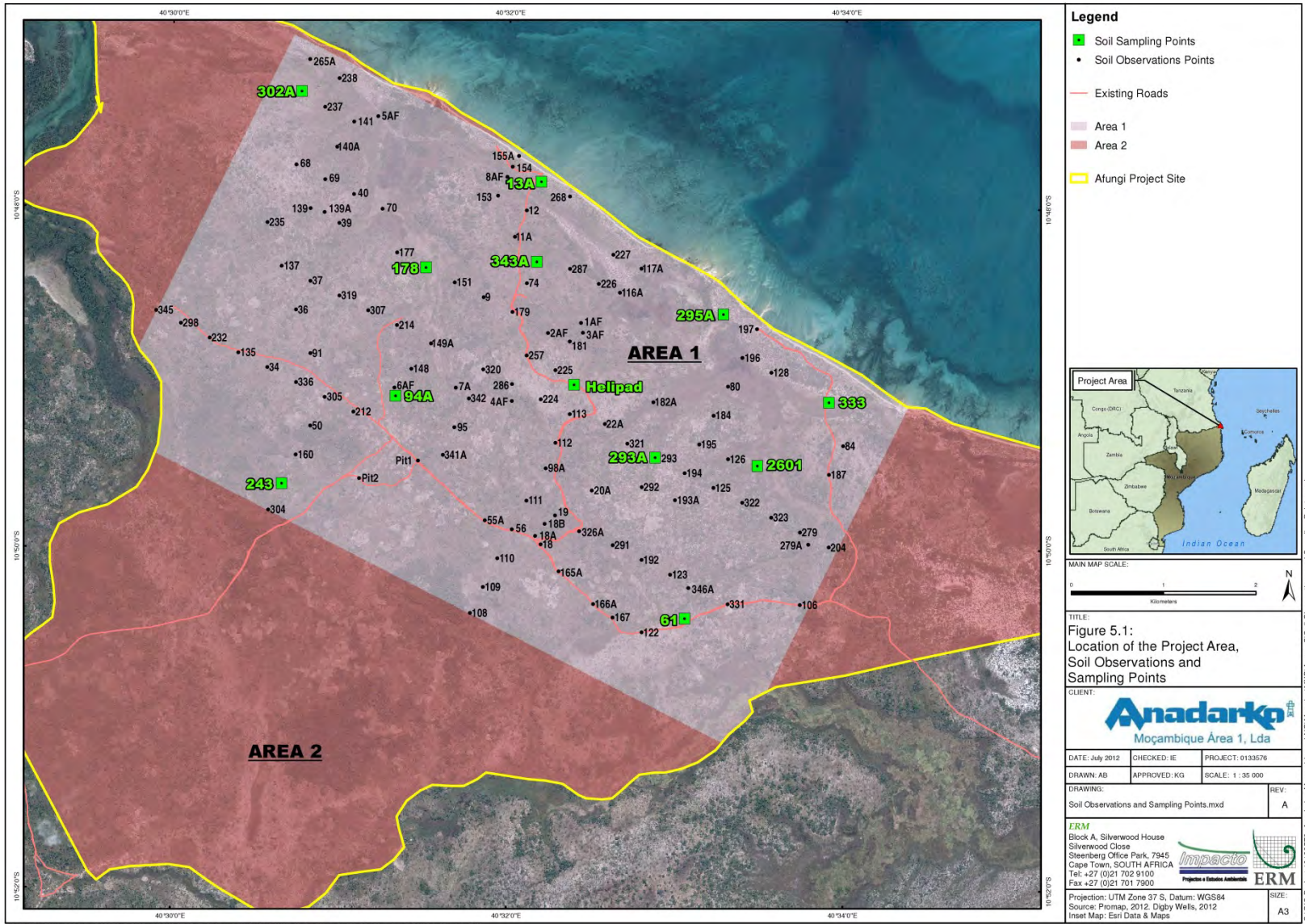
C5.2.1 *Data Collection*

The data collection phase consisted of collecting soil information for evaluation of physical properties as presented in the section below. For soil chemical and particle size evaluation samples were collected at selected points as depicted in *Figure 5.1*. At each observation point the following tasks were executed in order to collect baseline information of the soil cover:

- At each observation point the soil was excavated using a hand operated auger to a depth of 1,500 mm or until refusal was obtained.
- The auger holes (and pits) allowed for an in-situ examination of the soil profile from which an identification and classification (and descriptions) of the soil type (soil form) was made.
- The Taxonomic Soil Classification System for SA ⁽¹⁾ was applied to derive a soil form for each observation point.

(1) Soil Classification Working Group, 1991. Soil classification. A taxonomic system for South Africa. Memoirs on the Agricultural natural resources of South Africa No. 15. Institute for Soil, Climate and Water, Pretoria.

Figure 5.1 Location of the Project Area, Soil Observations and Sampling Points.



C5.2.2 *Sampling Program*

Sampling was conducted on selected sites with the following purposes in mind:

- to obtain adequate representation of the soils in each of the identified units;
- to compare laboratory analysis with field findings; and
- to obtain a baseline for the current chemical status.

Twelve sampling sites were selected from which a total of 27 samples were collected, see *Figure 5.1*. The samples were submitted to Geolab analytical laboratory for analysis. The soil samples were analysed for physical and chemical properties as follows:

- Extractable cations namely Na, K, Ca and Mg using an ammonium acetate as extractant.
- Cation Exchange Capacity of the topsoil.
- Carbon content of the topsoil.
- Phosphorus (Bray1) of the topsoil.
- Soil texture namely sand, silt and clay were also determined.

No sampling and analysis was conducted with a baseline contaminated status in mind as it was very unlikely that extreme levels of any elements will occur. Apart from low impact cultivation practices (minor or no use of artificial fertilizers) no known events with the potential to have given rise to such disturbances were known.

C5.3 *INVESTIGATION APPROACH FOR AREA 2*

Based on an existing broad scale land inventory map (FAO, 1982), aerial image interpretation and results of the Area 1 fieldwork, it was inferred that the non-wetland areas in outside Area 1 will comprise of deep (>1.5 m) deposited sand as was found for Area 1.

C6 *HYDROLOGY*

C6.1 *METHODOLOGY*

C6.1.1 *Introduction*

The methodology utilized in this study entailed a review of available data sets and reports from the public domain, a site visit, and computer modelling.

C6.1.2 *Delineation of Water Courses and Catchment Boundaries*

The modeled drainage network and catchments were developed by applying Watershed Modeling System (WMS) software and NASA' Aster Global Digital Elevation Model (GDEM). WMS was developed by Aquaveo (2004) and provides typical hydrologic and hydraulic modeling using models such as HEC-HMS and HEC-RAS. River/stream/drainage networks and catchment basins were mapped using Digital Elevation Model data.

C6.1.3 *Determination of the Peak Rainfall Estimates*

The determination of peak rainfall events for the respective return periods and peak flow rates for the identified rivers within the catchments was undertaken by the rational and SCS Methods.

The peak flow and volume generated were determined using the Rational Method. This is a simplistic method of peak flow estimation, which includes a composite estimation of the runoff coefficient, and allows for the influence of slope, soil permeability, vegetation and land cover (eg area of natural forests compared to areas which have been cleared of vegetation) to be considered. A time of concentration (Tc) was calculated (defined as the time it would take for water travelling from the furthest point in the catchment to reach the point of consideration) that enabled a more realistic estimation of the peak rainfall intensity.

The calculated rainfall intensities (mm/hr), which is defined as the amount of rainfall over a time period, and through the inclusion of a catchments specific runoff coefficient, and catchment area (km²) enabled the application of the Rational Method through the formula:

$$Q = 0.36CIA$$

Where:

- Q = peak flow (m³/s)
- C = runoff coefficient (dimensionless)
- I = average rainfall intensity over the catchment (mm/hr)
- A = effective area of the catchment (km²)
- 3.6 = conversion factor

The SCS method was also used for computing the peak flows and runoff-volumes. The United States Department of Agriculture's (USDA) Soil Conservation Service developed a method to calculate run-off from small catchments with different soil groups, vegetation covers and land uses by examining measured precipitation and run-off amounts, and named it as 'SCS Curve Number Method'. The SCS-CN method arose out of the empirical analysis of run-off from small catchments and hill slope plots monitored by USDA.

The SCS method defines stormflow as the direct runoff response to a given rainfall event, and consists of both surface runoff and subsurface flows, but excludes baseflow (ie the delayed subsurface response). A detailed description of the SCS method and its applications in South Africa is given by Schulze and Arnold (1979).

The general equation for the SCS method is as follows:

$$Q = (P - I_a)^2 / (P - I_a) + S \quad \text{for } P > I_a$$

Where:

Q = stormflow depth (mm)

P = daily rainfall depth (mm)

S = potential maximum retention (mm), index of wetness of the catchments soil prior to a rainfall event

I_a = initial abstraction prior to the commencement of stormflow, comprising of depression storage ,interception and initial infiltration (mm)

$$I_a = 0.1S$$

Stormflow depth represents a uniform depth over the catchment and may be converted to volume by introducing the catchment area. The SCS method accounts for potential maximum soil water retention through the application of:

- hydrological soil properties;
- land cover and land management conditions;
- takes into account the time distribution and duration of rainfall
- catchment antecedent soil moisture status prior to the rainfall event (through application of a dimensionless response index termed the catchments Curve Number (CN)). The CN and S are related by the following equation:

$$S = (24500 / CN) - 245$$

C6.1.4 *Determination of Floodlines*

The HEC-RAS model is designed to perform one-dimensional hydraulic calculations for natural and constructed channel networks and was used to assess all major surface water systems within the study area that could be impacted by the project.

The floodlines were calculated with the HECRAS Model by performing a steady state analysis. Calculations for steady state analysis require the relevant information presented in the Floodline Analysis – *Chapter 8 of the EIA Report*. A Manning’s Roughness Coefficient of 0.04 was considered for the wide river channels. User defined cross sections are created in the model.

C7 GROUNDWATER

C7.1 APPROACH

The following sections outline the approaches used to undertake an initial groundwater baseline investigation (*Section C7.2*), a further baseline investigation (*Section C7.3*) and modelling (*Section C7.4 to C7.5*).

C7.2 INITIAL BASELINE INVESTIGATION

The key steps involved in the initial baseline investigation included:

- a literature review;
- a field investigation involving a hydrocensus and sampling for geotechnical boreholes; and
- geochemical analysis.

These are detailed below.

C7.2.1 Literature Review

The following technical reports were reviewed in the compilation of this baseline assessment:

- Pre-feasibility and scope definition report and terms of reference, Impacto, November 2011.
- Afungi Site Improvement – Final report on a geotechnical investigation, WorleyParsons, May 2012.
- Onshore reconnaissance geotechnical investigation – Factual field interim report, AMA1, IntecSea WorleyParsons Group, February 2012.
- AMEC hydrogeological conditions desk top study, LNG siting in northern coastal Mozambique, IntecSea WorleyParsons Group, November 2011.
- Soil specialist assessment as part of an environmental impact assessment for the development of a LNG plant on the Afungi peninsula near Palma, north Mozambique, Digby Wells, April 2012.

C7.2.2 Hydrocensus

The aim of a hydrocensus survey was:

- To determine groundwater level information for the study area;
- To identify groundwater users in the study area and establish baseline groundwater use (volume); and
- To recover groundwater samples from selected wells and boreholes for selected laboratory analyses to establish the baseline groundwater quality.

Two field visits were conducted with the first being in February 2012 (dry season) and the second during May 2012 (wet season). The groundwater quality data for both of these sampling runs is presented in this report.

A total of 20 water abstraction points were visited, including:

- four community supply boreholes equipped with handpumps;
- seven monitoring boreholes installed by AMA1;
- seven natural spring-fed hand-dug wells for community use;
- one borehole at the Pemba site camp; and
- one dambo (wetland area).

A summary of data pertaining to the hydrocensus points is summarized in *Table 7.1* and *Table 7.2*. The locations of the hydrocensus points indicated in *Figure 7.1*.

Table 7.1 Rest Water Level Measurements in selected Hydrocensus Points

Source Ref	Description	February 2012 (m bgl)	April 2012 (m bgl)	Comment
HC1	Borehole	0.230		Working handpump in the middle of the village
HC4	Well	0.320		Hand dug well next to stream
HC5	Well	0.290		Hand dug well next to stream
HC6	Well	0.480	0.400	Hand dug well next to stream Hand dug well next to stream close to beach
HC7	Well	0.210		
AF06	Borehole	2.810	1.500	Piezometer installed in bore
AF14	Borehole	4.200	2.850	Piezometer installed in bore Additional sample AF17c taken as control
AF17	Borehole	0.005		
AF18	Borehole	1.695	0.150	Piezometer installed in bore No sample due to obstruction in piezometer
AF20	Borehole	2.290		
AF21	Borehole	5.030		Piezometer installed in bore No access due to obstruction in well
HC1	Borehole	5.030		

Table 7.2 *Location and Description of Hydrocensus Points*

Source ref	Source Description	Latitude (dd.dddd)	Longitude (dd.dddd)	Altitude (GPS) mamsl	Topographical Setting	Comment
HC1	Handpump	10.82264	40.52168	30	Flat surface	Working handpump in the middle of the village
HC2	Handpump	10.82222	40.52192	31	Flat surface	Non-working handpump in the middle of the village
HC3	Handpump	10.82161	40.52272	29	Flat surface	Working handpump in the middle of the village
HC4	Well	10.81800	40.52734	14	Along stream	Hand dug well next to stream
HC5	Well	10.82238	40.53188	13	Along stream	Hand dug well next to stream
HC6	Well	10.82039	40.56497	11	Along stream	Hand dug well next to stream
HC7	Well	10.81828	40.56903	8	Along stream	Hand dug well next to stream close to beach
HC8	Well	10.81344	40.54964	9	Next to mangrove	Hand dug well next to stream/mangrove
HC9	Well	10.81087	40.50038	19	Along stream	Hand dug well next to stream
HC10	Handpump	10.84521	40.47839	51	On hill	Working handpump in the middle of the village
HC11	Well	10.84782	40.47372	31	Along stream	Hand dug well next to stream
AF06	Borehole	10.81806	40.54095	15	Flat surface	Piezometer installed in well
AF14	Borehole	10.80762	40.53704	14	Flat surface	Piezometer installed in well
AF17	Borehole	10.80532	40.54504	10	Close to ocean	Piezometer installed in well
AF18	Borehole	10.80769	40.54285	12	Flat surface	Piezometer installed in well
AF19	Borehole	10.81248	40.54038	15	Flat surface	No sample due to obstruction in well
AF20	Borehole	10.83976	40.50328	36	Flat surface	Piezometer installed in well
AF21	Borehole	10.80037	40.51055	26	Flat surface	No sample due to obstruction in well
Camp	Borehole	10.76145	40.47345	24	On hill	Borehole supplying the base camp
Dambo	Wetland	10.84061	40.46881	38	On hill	Natural wetland structure known as Dambo

AMA1 advanced eighteen geotechnical boreholes in the project area as part of the preliminary investigation. Details pertaining to borehole depths are described in Table 4.4 and the positions of these boreholes are indicated in Figure 7.1. However, as these boreholes were drilled for geotechnical purposes, only seven bores remain suitable for groundwater monitoring.

Figure 7.1 AMA1 Geotechnical Borehole Localities

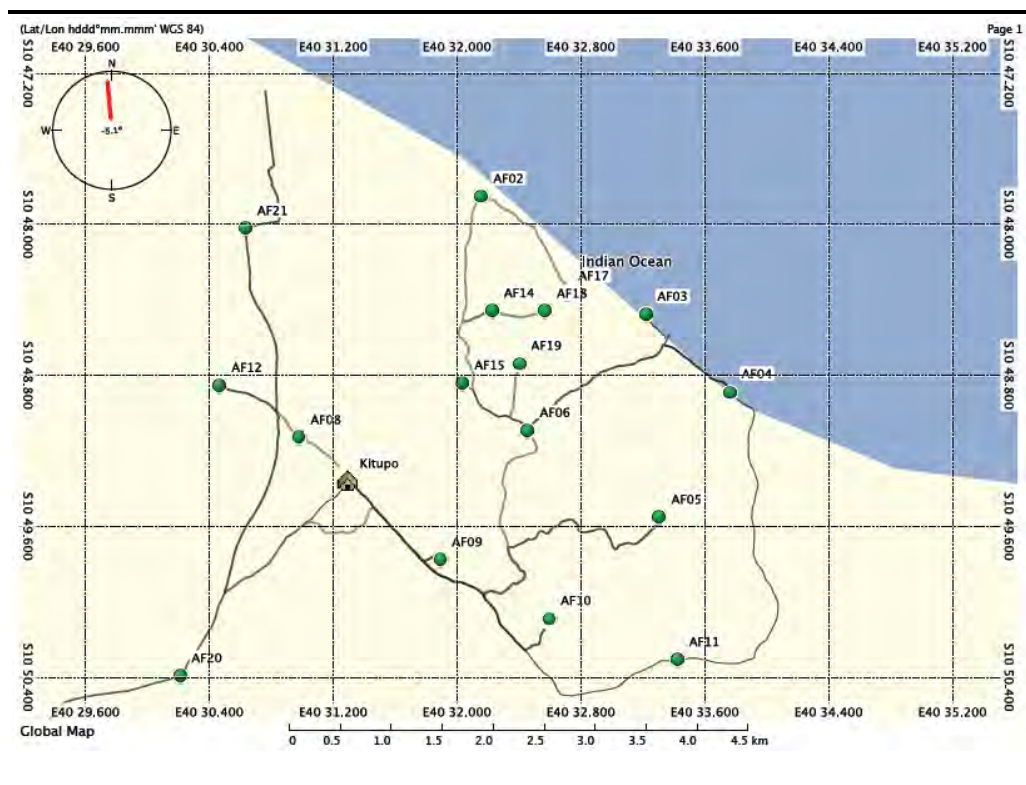


Table 7.3 Geotechnical Borehole Co-ordinates and Depth

Borehole No.	Coordinates (Latitude and Longitude)	Depth (m)	Contractor
AF02	S10 47.96173 E40 32.32831	100	SUGEC
AF03	S10 48.72300 E40 33.16371	100	SUGEC
AF03A	S10 48.74700 E40 33.00000	10	Geopractica
AF04	S10 48.88994 E40 33.76639	100	SUGEC
AF05	S10 49.55189 E40 33.31169	40	Geopractica
AF06	S10 49.07131 E40 32.45870	40	SUGEC
AF08	S10 49.13026 E40 30.98171	40	Geopractica
AF09	S10 49.62764 E40 31.90172	40	Geopractica
AF10	S10 49.90847 E40 32.70051	40	Geopractica
AF11	S10 50.30834 E40 33.42825	40	Geopractica
AF12	S10 48.85974 E40 30.48525	40	Geopractica
AF14	S10 48.45792 E40 32.23012	40	Geopractica
AF15	S10 48.84042 E40 32.04009	40	SUGEC
AF17	S10 48.36700 E40 32.71097	100	SUGEC
AF18	S10 48.46040 E40 32.57116	40	SUGEC
AF19	S10 48.73714 E40 32.40541	40	SUGEC
AF20	S10 50.39182 E40 30.21299	40	SUGEC
AF21	S10 48.02202 E40 30.63715	40	Geopractica

C7.2.4 *Geochemical Assessment*

The groundwater quality was determined both in the field and by laboratory analyses. Parameters included:

- Field measured parameters – pH, electrical conductivity (EC);
- Dissolved anions - fluoride, sulphate, chloride, nitrate as NO₃, ortho phosphate as PO₄, total alkalinity;
- Dissolved cations – magnesium, potassium, sodium, calcium, ammonia.
- Dissolved trace elements - aluminium, antimony, arsenic, barium, bismuth, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum nickel, niobium, phosphorus, selenium, silver, strontium, thallium, tungsten, vanadium, zinc, zirconium.
- Organic compounds including benzene, toluene, ethylbenzene, xylene, naphthalene, tert-amyl-methyl-ether (TAME) and extractable petroleum hydrocarbons (EPH).

The geochemical assessment of the groundwater was undertaken:

- To establish the baseline groundwater quality in the study area; and
- To undertake a geochemical assessment of the water quality.

C7.3 *FURTHER BASELINE INVESTIGATION*

C7.3.1 *Borehole Drilling*

Based on the findings of the baseline study (as described above), a drilling programme was designed and executed between August and September 2012. The programme included drilling of groundwater exploration boreholes for Project water supply, community water supply boreholes and environmental monitoring boreholes.

G. M. Todd Irrigation LDA undertook the drilling and well installations. Based on the ground conditions on site, the mud-rotary drilling method was selected to achieve the drilling objectives. In the mud rotary drilling method, the drill bit is attached to the drill rod and the borehole advanced while mud is pumped down the hole as a formation stabiliser. The drilling mud is circulated into a mud pit where the cuttings from the borehole drop out and the mud is reused.

Due to the selected drilling method and available equipment on site, the collection of geological and hydrogeological data was limited. The geology was logged by an experienced field hydrogeologist and final blow yield

recorded after the successful completion of each boreholes (note blow yields should be regarded only as indications of the yield potential of a borehole, and should not be considered a sustainable yield). Electrical conductivity (EC) was measured in the recovered drill mud on a regular basis and used as an indicator of groundwater inflow into the bore and to guide the placement of the screened casing.

C7.3.2 *Aquifer Testing*

Each of the drilled boreholes was subjected to an aquifer test to define the hydraulic parameters and response of the groundwater occurrence on site. Aquifer testing was undertaken by *G. M. Todd Irrigation LDA*.

As the pumping rate was limited due to the diameter of the installed casing and the available test pumps, only constant discharge tests (CDT) and recovery tests (RT) were undertaken.

During the CDT each individual borehole was pumped for 1440 minutes (24 hours) at a constant rate, with the exception of borehole LNG-W009 which returned a yield that was too low to sustain a 24 hour test.

Prior to each test, water levels were measured in both the pumped and observation boreholes from a fixed reference point. In the abstraction boreholes an electronic contact gauge was employed to record water level changes, and in the observation boreholes automatic water level loggers were used to record water levels. Drawdown over time in the abstraction boreholes was monitored at gradually increasing time periods, since drawdown as a result of pumping normally varies logarithmically with time.

During the CDT the temporal water level drawdown was recorded in both the pumping and the available observation boreholes. Discharge measurements were taken at predetermined intervals to ensure that the constant discharge rate was maintained throughout the test period. Any changes in discharge were recorded and reported.

The RT water level recordings commenced directly after pump shut down at the end of the CDT. The water level recovery was measured in both the pumped and the observation boreholes for a period of 24 hours, or until at least 90% water level recovery had been achieved.

The time-drawdown data gathered during the aquifer tests was analysed using *Aquifer Test Pro v2011.1* (Schlumberger Water Services). *Aquifer Test Pro* includes a range of analytical methods to obtain representative hydraulic properties of the aquifers.

C7.3.3 *Water Sampling*

The exploration, environmental monitoring and camp supply boreholes (open boreholes) were sampled by a submersible pump. The community and camp

water supply boreholes were equipped with hand pumps and powered pumps respectively.

The sampling methodology for both open boreholes and boreholes equipped with hand pumps is based on *USGS National Field Manual for the Collection of Water-Quality Data* (USGS, 2006).

The open boreholes were purged according to the volumetric purging method. This involved the removal of three times the volume of standing water in the well and pore space of the filter pack prior to sample collection. The rationale is to ensure that all the stagnant water in the casing and filter pack is removed and replaced with fresh formation water.

Prior to any purging/sampling activities, the depth to groundwater was measured using a dip meter and recorded on the sampling fieldsheet. The pump was lowered to beneath the water level and the borehole purged at a rate of approximately 2.6 l/s. Field parameters (pH, temperature and electrical conductivity (EC)) were monitored on a regular basis.

The boreholes were until at least three times the well volume was removed and until stabilisation of field parameters was achieved.

Samples were collected directly from the pump with the groundwater being discharged directly into the appropriate sample container.

Due to the community water supply boreholes and the camp supply boreholes having existing pumps, access was restricted and therefore static water levels were not measured. The boreholes were purged using the existing pumps until stabilisation of field parameters was achieved.

Samples were collected directly from the pump with the groundwater being discharged directly into the appropriate sample container.

At each sample point, samples were collected in separate sample bottles for:

- General chemical parameters and major ions to establish the groundwater baseline quality and to allow fingerprinting of groundwater, including:
 - Total hardness (dissolved as CaCO₃)
 - Cations - sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), ammonium (NH₄⁺);
 - Anions - fluoride (F), chloride (Cl), sulphate (SO₄²⁻), alkalinity, nitrate (NO₃⁻), nitrite (NO₂⁻) phosphate (PO₄³⁻); and
 - Total phosphorus and total nitrogen.
- Trace elements (filtered and acidified to pH <2) to establish the baseline groundwater quality, including aluminium (Al), antimony (Sb), bismuth (Bi), arsenic (As), barium (Ba), beryllium (Be), boron (B), cadmium (Cd), chromium total (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), lithium

(Li), manganese (Mn), mercury (Hg), molybdenum (Mo), nickel (Ni), niobium (Nb), selenium (Se), silver (Ag), strontium (Sr), thallium (Tl), tin (Sn), titanium (Ti), tungsten (W), vanadium (V), zinc (Zn) and zirconium (Zr).

- Organic compounds to establish the baseline groundwater quality, including:
 - Extractable petroleum hydrocarbons (EPH) (C8-C40);
 - Benzene, toluene, ethylbenzene and xylenes (BTEX); and
 - Naphthalene.
- Stable isotope analysis to allow groundwater fingerprinting, namely deuterium and oxygen-18.

All samples were placed in a cooled container directly after sampling and transported (at 4°C) to Jones Environmental Laboratory (an accredited analytical facility) in the UK.

C7.3.4 *Quality Assurance/Quality Control – QA/QC*

As part of ERM's Quality Assurance and Quality Control protocol (QA/QC) standard operation procedures for sample collection were followed. Defensible quality control for sampling and decontamination procedures were followed to allow for the collection of representative samples and to minimise the potential for cross-contamination between samples. The samples were collected in laboratory-supplied sample bottles, filtered on site using a 0.45µm nylon membrane filter (laboratory supplied) where required. Two blind duplicate samples were collected.

During sampling and decontamination activities, disposable nitrile gloves were worn to minimise transfer of contaminants. Any disposable equipment, such as gloves, was dedicated to each sampling location and disposed of after use.

Samples were handled, stored and transported to the laboratory in accordance with established protocols using Chain of Custody documentation, which was used to track samples and to ensure that the correct analyses were performed.

C7.3.5 *Topographic Survey*

The sub-contractor *Nikotcholaka Engenharia & Construção, EI* undertook the required topographical survey in December 2012 to allow for accurate coordinates and elevation data of boreholes and selected surface water points.

Three Benchmark Co-ordinates were provided to the sub-contractor to support the survey (*Table 7.4*).

Table 7.4 **Benchmark Coordinates**

Benchmark	X (m) - Easting	Y (m) - Northing	Z (mamsl) - Elevation
BEACH	670854.740	8804079.260	5.850
KUMBI	651171.380	8800246.840	86.950
TOWER	667947.460	8803967.700	17.320

The Benchmark coordinates are in WGS84 Datum projected in UTM Zone 37 South Zone, corresponding to the Cabo Delgado Province.

For the field observations 2 Topcon Hiper Pro model GPS + GNSS Receivers (L1 + L2) were used, resorting to the RTK and Static Occupation Survey modes.

For the detailed methodology please refer to the complete report of the topographic survey, which is appended in *Annex D*.

C7.4 **GROUNDWATER MODELLING METHODOLOGY**

C7.4.1 **Conceptual Site Model Development**

Information collected during the field investigation, combined with information sourced from literature and historical reports, was interpreted to develop a catchment scale hydrogeological conceptual site model (CSM) for the proposed Project area.

In detail, the CSM describes the dynamics of groundwater and contaminant transport movement, considering groundwater recharge, boundaries to groundwater flow, hydraulic characteristics of the aquifers in the area and potential contaminant source areas, as well as the groundwater - surface water interaction.

The CSM can be described as a simplified representation of the hydrogeological conditions, describing the source-pathway-receptor interaction which is described in more detail below:

Source areas are assessed in the context of the groundwater hydrochemical environment. From this assessment the contaminants of concern (CoC) that could potentially pose a risk to human health and the environment through exposure via the different exposure pathways, are determined.

Groundwater *pathways* link sources with receptors, and only in the case where a source and receptor are linked, can environmental and human health risks arise. The main groundwater pathways, including aquifers and preferential flow paths (ie geological structures), are identified.

Typical *receptors* include water supply boreholes, base flow to rivers, springs or wetlands. The understanding of linkages between the source, pathway and

receptor are essential to determine the potential exposure risk for each identified CoC.

The CSM allows for the effective determination and characterisation of the identified contamination source areas and activities, as well as the preferred migration pathways to reach identified receptors, or points of exit along the boundaries of the Project area.

Using the CSM, a numerical groundwater model representing the current catchment scale hydrogeology was developed simulating the current groundwater conditions. The flexibility of the model allowed for the effect of potential Project impacts to be simulated allowing for predictive outputs to be generated, allowing for the impacts to be evaluated and enabling management scenarios to be evaluated.

C7.4.2 *Modelling Approach*

The steady-state groundwater flow model was calibrated based on groundwater elevations measured in the field. In steady-state, the hydraulic head does not change with time, and the calibrated steady state solution represents the baseline groundwater elevations and flow direction. Steady state simulations are used to calibrate time independent model parameters such as the hydraulic conductivity.

The hydraulic head distribution of the calibrated steady state solution is then used as the initial head distribution for the transient (time-dependent) model. The transient model is calibrated using available time-dependent data such as time-drawdown data from aquifer tests. Transient calibration is then performed to define additional parameters required for transient models, eg. specific storage, and also for verification purposes of the steady state solution.

The calibrated transient model is then used to quantify potential impacts caused by the proposed Project and assess the effectiveness of various mitigation options.

C7.4.3 *Model Calibration*

Model calibration is the process of varying model input data within realistic ranges of values until a satisfactory match between simulated and observed data can be reproduced. The large number of parameters and complex nature of the natural system, combined with the simplification assumptions made in the CSM, means that the calibration solution is non-unique. Reducing the non-uniqueness of the parameter combinations that can lead to a seemingly calibrated model can, for example, be achieved by reducing the number of degrees of freedom (i.e. the number of unknown input parameters) by choosing a distinct calibration strategy and by constraining spatially distributed input data via remote-sensing techniques (Brunner *et al.*, 2007).

In order to avoid an over-fitting of the model, the number of unknown input parameters (i.e. the degrees of freedom) must be limited. The more the

degrees of freedom used for model calibration, the better the measured water levels, called “piezometer heads” can be reproduced by the model. However, with an over-fitted or over-parameterised model a good fit between the observed and simulated piezometric heads can always be obtained even if the model does not reflect the structure and the behaviour of the real aquifer.

An objective criterion is used (MSE: mean square error or variance) to compare different calibrations:

$$MSE = \frac{1}{n} \sum_{i=1}^n (h_i^m - h_i^c)^2 \quad \text{with } h_m \text{ measured head and } h_c \text{ calculated head}$$

The model has reached a good or acceptable model calibration, when the root mean square error (RMSE) is $\sqrt{MSE} \leq 10\%$ of the head difference between upstream and downstream measured groundwater heads.

Models should ideally be used in prediction in a manner that is consistent with their calibration. For example, a model that is calibrated in steady state only will likely produce transient predictions of low confidence. Conversely, when a transient calibration is undertaken, the model may be expected to have a high level of confidence when the time frame of the predictive model is of less or similar to that of the calibrated model.

Furthermore, when a predictive model includes stresses (i.e. groundwater abstraction) that are well outside the range of stresses included in the calibration, the reliability of the predictions will be low and the model confidence level also (Barnett *et al.*, 2012).

C7.4.4 *Software Selection*

Processing Modflow Pro (PMWIN version 8.0.31) was used for the groundwater flow simulation. PMWIN is a proven finite-difference modelling software package for 3-D groundwater flow and contaminant transport problems, utilising MODFLOW, MT3DMS, PEST and other analytical packages and algorithms.

MODFLOW is a 3-D finite-difference groundwater flow model that was developed by the U. S. Geological Survey for groundwater flow simulation.

MT3DMS is a modular three-dimensional transport model that can simulate advection, dispersion, and chemical reactions of dissolved constituents included in PMWIN, which was used to provide numerical solutions for the contaminant transport simulations.

PEST (Doherty *et al.*, 2004) is an inverse code, used for the automated estimation of parameters and sensitivity analysis of parameters including for example transmissivity, hydraulic conductivity and recharge etc.

C7.4.5 *Model Limitations*

Numerical models have become a popular tool to solve problems. However, groundwater systems are complicated beyond our capability to practically evaluate them in detail. A model, no matter how sophisticated, will never describe the investigated groundwater system without deviation of model simulations from the actual physical processes that occur in the study area (Spitz, 1996).

All numerical modelling simulations require assumptions to be made during the translation of the CSM into a numerical model. These assumptions, which reflect data gaps in the conceptual model regarding the aquifer distribution and the aquifer parameters, can result in uncertainty in the model output and predictions.

Sensitivity analysis gives an indication of which assumptions regarding the model input parameters are most likely to affect the model output most. Based on the sensitivity analysis results, areas of concern and parameters that should be studied in more detail were identified and included in the recommendations.

C7.5 *NUMERICAL GROUNDWATER MODELLING*

C7.5.1 *Model Setup*

Model Domain

The model domain was selected based on the CSM to achieve the modelling objectives. The model domain includes the Project area and extends from the Rio Mipama in the north to the ocean (Palma Bay) along the shoreline of the Afungi Peninsula in the east and south-east.

In the south, the model boundary follows the surface water/wetlands catchment boundary. The western boundary was chosen approximately 8km west of the planned Pioneer Camp, located sufficiently far away from planned groundwater extraction activities.

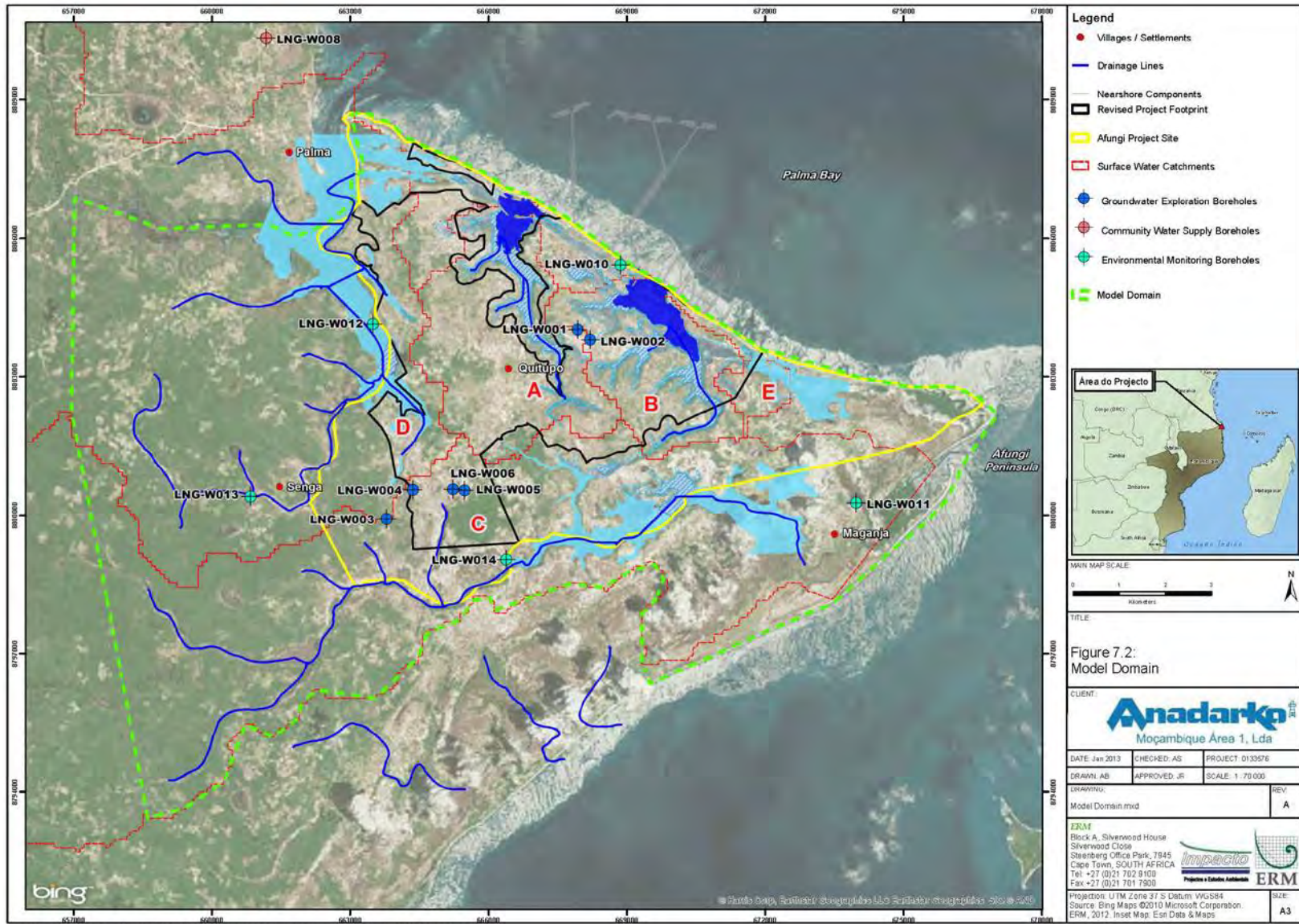
The model domain covers a total area of just over 160km² and is presented in *Figure 7.2*.

Model Geometry

Topography data was available at an accuracy of 1m for 95% of the model domain. For the remaining 5%, the accuracy was 90m. The data was combined and interpolated to the model grid using *Surfer* (version 9.x). The topography elevation ranges roughly from 0 to 60mamsl in the north-west (*Figure 7.3*).

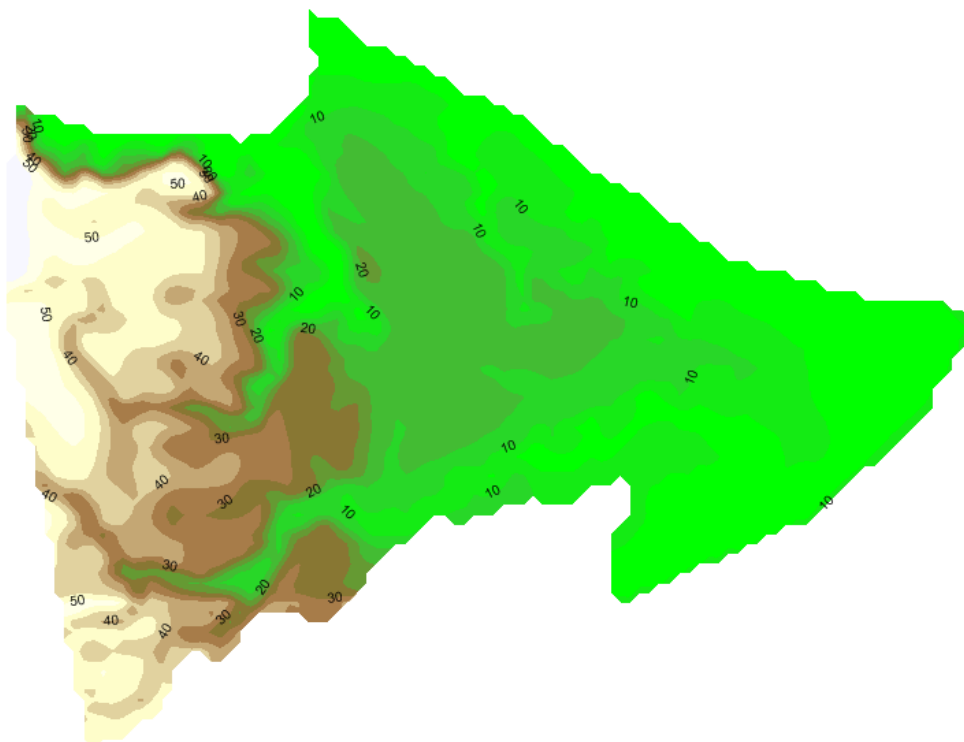
As no boreholes were drilled to intersect the base of the aquifer, a constant model aquifer thickness of 200m was applied to avoid boundary effects.

Figure 7.2 Model Domain



© 2010 Microsoft for any use or reproduction to reproduce copyrighted maps, graphics or drawings, in whole or in part, without permission of the copyright owner, ERM Southern Africa (Pty) Ltd.

Figure 7.3 Surface Topography in Model Domain (mamsl)



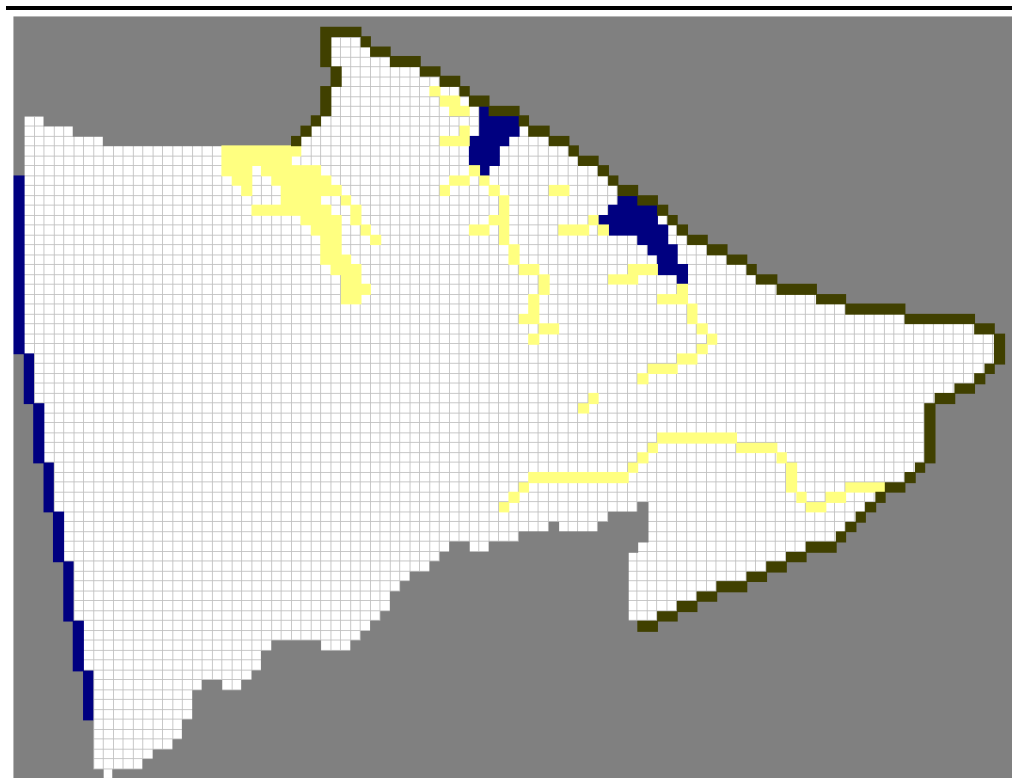
Discretisation

The numerical simulation of groundwater flow by a block-centred finite difference method as used in MODFLOW requires a spatial discretisation of the aquifer parameters across a rectangular grid that can be orientated to correspond to the general flow direction.

The cell size in the steady state numerical groundwater flow model grid is 200m in both horizontal directions (north/south and west/east). The rectangular grid has side lengths of 20.2km corresponding to 101 cells (west/east) and 15.4km corresponding to 77 cells (north/south). The model grid is presented in *Figure 7.4*.

The model grid was subsequently refined horizontally and vertically for transient model calibration and scenario modelling, to allow for accurate groundwater drawdown calculation induced by groundwater abstraction.

Figure 7.4 Model Grid and Boundary Conditions



Notes: White cells are active cells and grey cells are inactive
Blue cells represent Constant Head Boundary cells (estuaries and regional groundwater inflow)
Yellow cells represent Drain Cells (wetlands and streams)
Brown cells represent General Head Boundary cells (Palma Bay)

Boundary Conditions

The model boundaries were chosen in order to centralise the area of interest (Project area) and follow real hydrogeological and hydrological boundaries as far as possible. The Palma Bay coast was followed along the Afungi Peninsula as well as the Rio Mipama in the north and the surface water catchment boundary in the south. The western boundary was chosen approximately 8km to the west of the planned Pioneer Camp, located sufficiently far away from planned groundwater extraction activities.

The following boundary conditions were selected for the model domain:

- *General head boundary* condition (3rd order or Cauchy Boundary) along the Palma Bay coastline north-east to south-east;
- *General head boundary* condition (3rd order or Cauchy Boundary) along the lower reaches of Rio Mipama in the north, where it meets Palma Bay;
- *No flow boundary* condition (2nd order or Neumann Boundary) along the rest of Rio Mipama;
- *Constant head boundary* condition (1st order) along the western boundary representing regional groundwater inflow. This boundary was converted into an inflow boundary (2nd order or Neumann Boundary) using the *Well Package* after model calibration;

- *No flow boundary* condition (2nd order or Neumann Boundary) along the surface water catchment boundary in the south simulating a water shed;
- *Drain boundary* condition (3rd order or Cauchy Boundary) along the rivers, streams and wetlands within the model domain;
- *Recharge boundary* condition (2nd order or Neumann Boundary) on the model top; and
- *No flow boundary* condition (2nd order or Neumann Boundary) at the model bottom.

C7.5.2 *Model Parameters*

Hydraulic Conductivity

Data pertaining to hydraulic conductivity (K) was available from 11 aquifer tests (refer *Section C7.3.2*). K values derived from aquifer tests were mostly within one order of magnitude for each of the tested boreholes.

No distinct areas of different K values were identified and therefore, an average K value of 7m/d was assigned to the entire model domain.

Groundwater Recharge

Groundwater recharge represents infiltration of rainwater through the overlying geology into the modelled aquifer. Recharge is one of the most uncertain model parameters because the collection of direct field measurements is difficult and no specific recharge assessment was carried out. Limited information about groundwater recharge was available from literature. Recharge was therefore calibrated during steady state calibration.

Surface Water Features

Wetlands and Streams

Numerous non-perennial streams and drainage channels are located within the model domain, however, no detailed mapping of the streams was available. Therefore a watershed analysis was performed using *Global Mapper* (version 12) in order to identify surface water drainage lines based on topography data.

In topographically lower areas of the model domain, these surface drainage lines are closely related to the numerous wetlands present in the study area as documented by NSS (2012). A detailed study of wetlands was only performed within the Afungi Project area, which identified estuaries, perennial and seasonal wetlands. A number of unidentified wetlands are also mentioned outside of the Project area.

Drainage lines identified in the western part of the model domain were found mostly dry during the various field visits and were therefore not included in the model representing seasonal features.

Within the Project area, perennial wetlands were represented in the model using the *Drain Package* and outside some unidentified wetlands were also included based on model calibration.

The surface elevation (topography) was set for the drain elevation and a drain conductance of $50\text{m}^2/\text{d}$ was applied reflecting sandy riverbeds.

Estuaries

Two prominent estuaries were identified by NSS (2012) in the model domain. These are thought to be in direct contact with the ocean at Palma Bay and also with groundwater. Therefore they were implemented in the model using *Constant Head Cells*. The elevation of these cells (water level) was set to between 3.5 and 4mamsl following model calibration and based on available survey data.

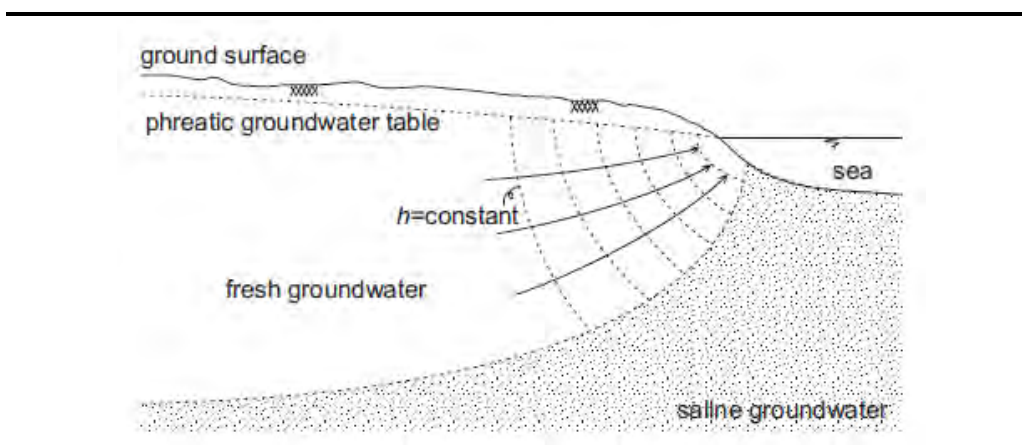
Ocean - Palma Bay

The Palma Bay coastline is thought to be a major groundwater discharge area in the model domain. Currently the saline water in the bay is expected to be in equilibrium with the fresh groundwater, which is replenished by groundwater recharge representing a natural equilibrium.

As illustrated in *Figure 7.5* (Oude Essink, 2001), groundwater outflow into the ocean is limited by saline groundwater which is present. Therefore the groundwater boundary at Palma Bay (ocean) was modelled using the *General Head Boundary* (GHB) package enabling to simulate a decreased outflow area with regards to the total model thickness.

GHB conductance was calibrated at $70\text{m}^2/\text{d}$, resulting in an outflow zone of 10m thickness and the elevation was set to mean sea level (0mamsl). Since the model time scale is yearly, daily tidal influence was not modelled.

Figure 7.5 **Groundwater Outflow Zone**



C7.5.3 **Steady State Calibration**

During steady state calibration groundwater recharge was optimized in order to best fit groundwater elevations observed in the model domain. Other

optimised parameters included drain conductance, GHB conductance, water elevation in estuaries and regional groundwater inflow.

Calibration was performed using both manual and automated methods. PMWIN includes a number of automated parameter estimation methods of which PEST (Doherty *et al.* 2004) was used.

Observation Boreholes

The eleven deeper boreholes (*viz.* LNG-W001 to LNG-W006 and LNG-W010 to LNG-W014) were used as observations for steady state model calibration of the numerical groundwater flow model. The observation boreholes and water levels used in the model calibration are detailed in *Table 7.5*. As the piezometers that were installed for geotechnical purposes (MSJ, 2012) only intersect the shallow perched groundwater, this data was not used for calibration purposes.

Table 7.5 *Observation Boreholes*

BHID	X	Y	SWL (mamsl)
LNG-W001	667930	8804020	5.08
LNG-W002	668207	8803800	6.47
LNG-W003	663784	8799918	13.41
LNG-W004	664354	8800548	12.44
LNG-W005	665478	8800537	11.53
LNG-W006	665234	8800562	11.69
LNG-W010	668864	8805421	3.95
LNG-W011	673967	8800273	4.17
LNG-W012	663490	8804139	6.51
LNG-W013	660836	8800409	16.70
LNG-W014	666381	8799042	10.73

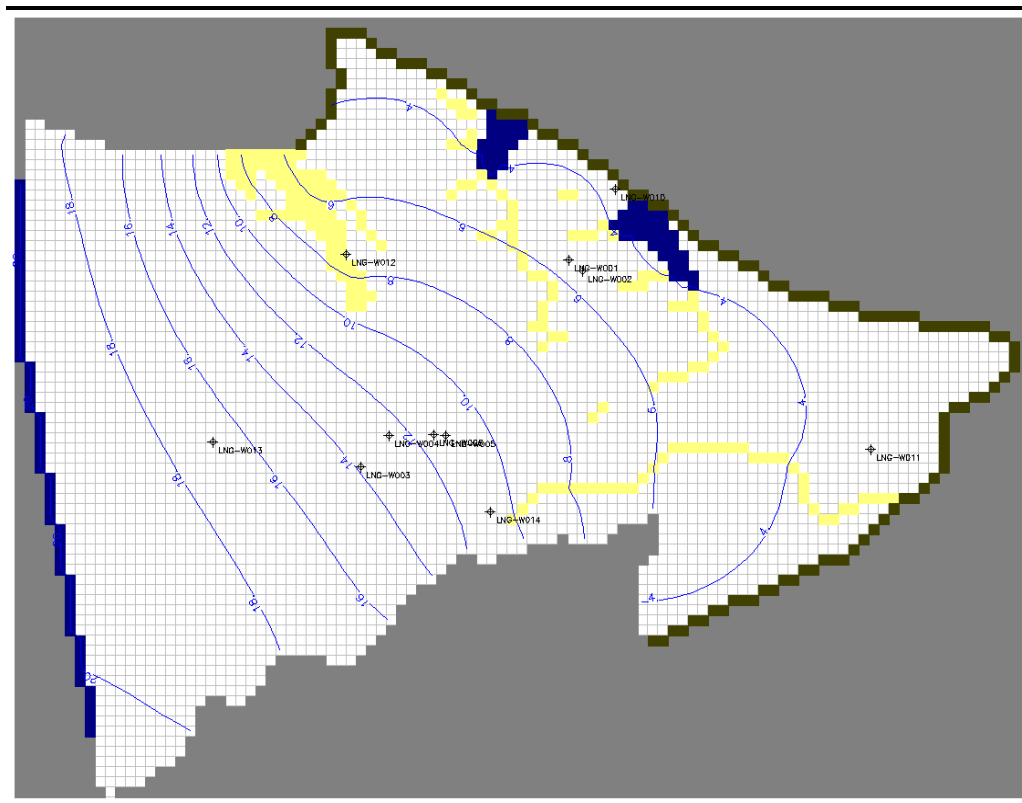
Notes: Surveyed Coordinates and Elevations: Datum: WGS84, Projection: UTM37S
SWL Static Water Level

Steady State Calibration Results

Groundwater Levels and Flow Direction

Piezometric heads for the calibrated steady state models range from 1,306 to 1,812mamsl for the low recharge scenario and from 1.6mamsl in the east to 20mamsl (*Figure 7.6*) in the west. The groundwater flow direction is to the north-east and east towards Palma Bay.

Figure 7.6 Steady State Piezometric Head Distribution



Scatter Diagram

Calculated piezometric heads were compared to observed heads in Figure 7.7. The residuals (difference between observed and calculated heads) are mostly below 0.5m except for LNG-W002, LNG-W011 and LNG-W0012 with residuals of 1m, and 0.8m respectively. The root mean square error of the model calibration is 0.3m, which is considered to be sufficiently small, given the model area, limited data and given that the maximum head difference over the model area is approximately 25m.

Figure 7.7 Scatter Diagram of Calculated vs. Observed Heads

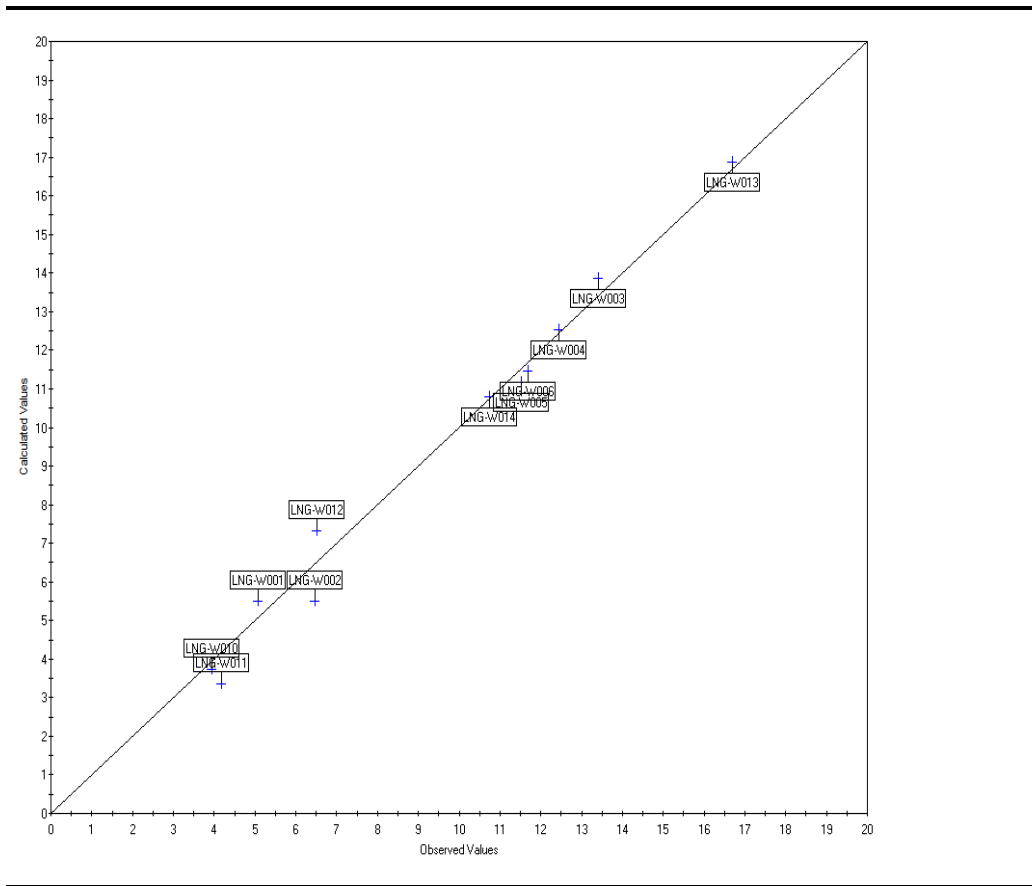
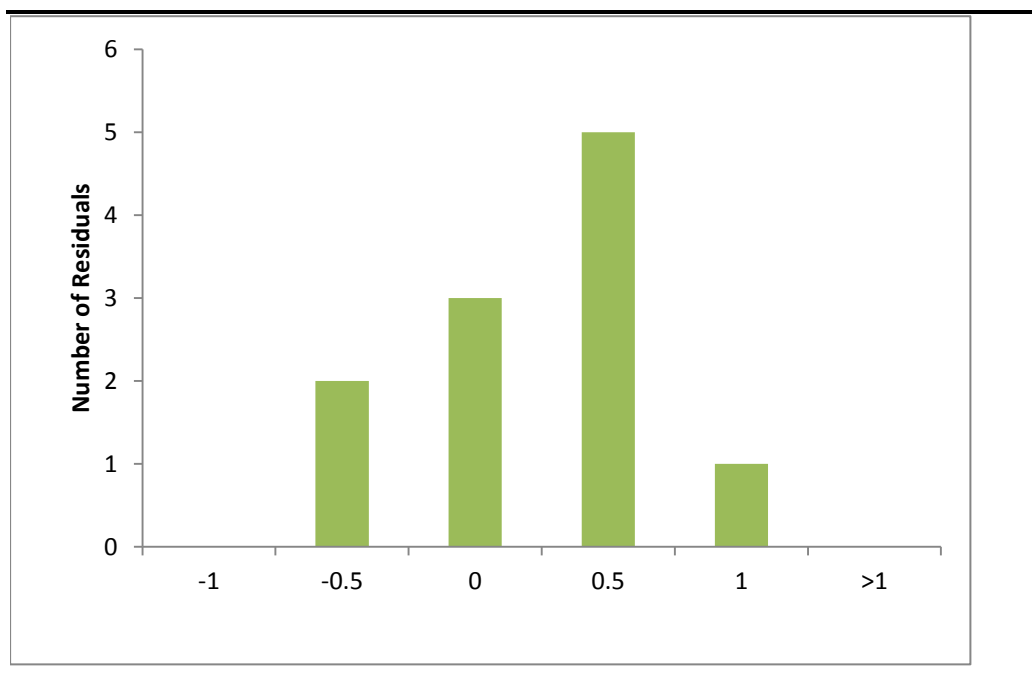


Figure 7.8 Histogram of Residuals (Observed Minus Calculated Heads)



In Figure 7.8 the histogram of the differences between observed and calculated head values (residuals) is plotted for both recharge scenarios. Class “0”, for example indicates how many residuals were between -0.5 and 0.

73% of all residuals are between -0.5m and 0.5m. In conclusion, the histogram shows that the model very slightly over-predicts, rather than under-predicts water levels.

Calibrated Parameters

The model recharge value was optimised during steady state calibration and an optimal value of 3.2×10^{-4} m/d was calculated. This represents 10% of the mean annual precipitation (MAP) in Palma, compared to the literature values of between 9%-26% MAP.

Considering the CSM where it was postulated that not all the groundwater recharge actually reaches the modelled aquifer but rather remains perched on localised clay/silt lenses and discharges directly into surface drainage features, the 10% recharge rate adopted for modelling is considered representative.

Drain conductance was optimised to 50m²/d representing sandy streambeds and wetland bottoms. GHB conductance was optimised to 70m²/d representing the model hydraulic conductivity of 7m/d and a groundwater outflow zone thickness of 10m. The water elevation in estuaries was calibrated to between 3.5 and 4mamsl and regional groundwater inflow amounts to 9 300m³/d, distributed to a total inflow length of 11km.

Groundwater Balance

The steady state water budget of the whole model domain is shown in *Table 8.2*. In flux represents water flowing into the groundwater system (aquifer/model) and out flux represents water leaving the system (groundwater discharge).

Water flows into the model domain mainly via recharge and regional groundwater flow across the western model boundary and leaves the model to Palma Bay, rivers, streams and wetlands in the model domain (drains) and the Estuaries.

As expected, there is limited water exchange from, and to, the estuaries. Furthermore, 0.4% of the total in-flux is leaving the model across the western boundary, which is related to local hydraulic head distribution in proximity of the edges of the inflow boundary. This flux is, however, negligible compared to the total groundwater fluxes.

In a steady state system total inflow and total outflow fluxes are equal. Total flux into and leaving the model domain equals 61 700m³/d. In-flux across the western boundary represents 15% of the total inflow and direct recharge from rainfall 82%. Water exchange at the estuaries accounts for 3% of the total in-flux.

Most groundwater is discharged from the model via drains (wetlands and streams) and via Palma Bay (ocean). Groundwater discharge into wetlands

and streams accounts for 49% and into the ocean for 36% of the total out-flux. Water exchange at the estuaries accounts for 15% of the total out-flux.

Table 7.6 *Groundwater Budget Steady-State Calibration*

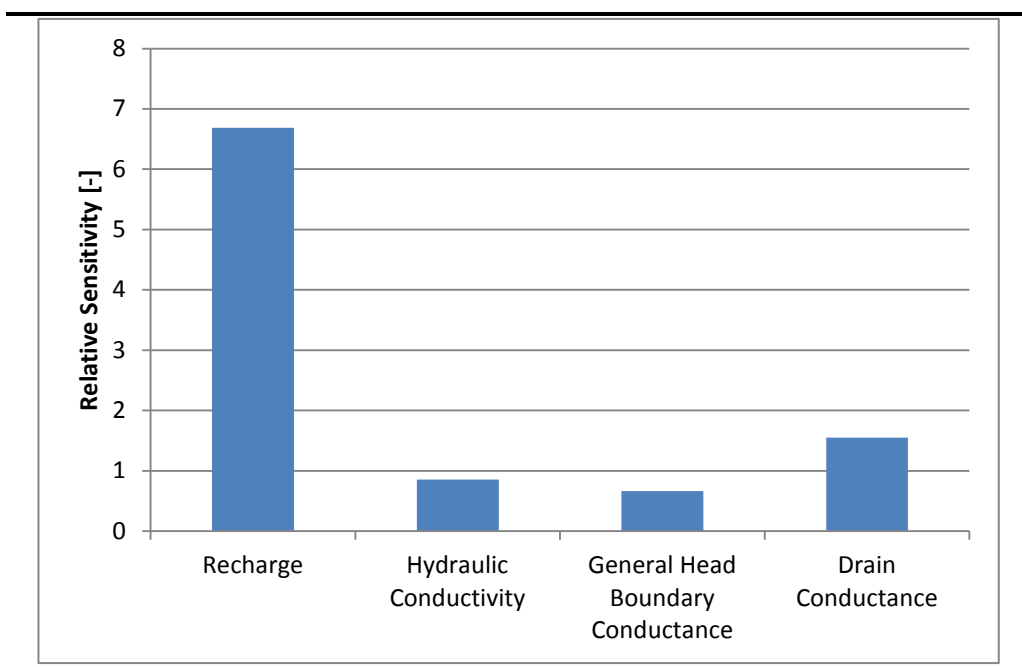
Boundary	In-Flux (m ³ /d)	Out-Flux (m ³ /d)
Palma Bay (Ocean)	0	22 000
Western Boundary	9 500	200
Estuaries	1 700	9 400
Recharge	50 500	0
Drains	0	30 100
Sums	61 700	61 700

Sensitivity Analysis

Sensitivity analysis was carried out using PEST for recharge, hydraulic conductivity, GHB conductance and drain conductance. *Figure 7.9* presents the relative sensitivities for the respective parameters. Relative sensitivity of a parameter is a measure of the changes in model outputs that are incurred by a change in the value of the parameter (Doherty et al., 2004).

The most sensitive parameter is recharge followed by the drain conductance. Changes in these parameters will have a greater impact on the model output than other less sensitive parameters.

Figure 7.9 *Sensitivity Analysis Results*



C7.5.4 *Transient Calibration*

Transient simulations require additional parameters, specific storage and specific yield. Specific storage is the amount of water per unit volume of a

saturated formation that is stored or expelled from storage owing to compressibility of the mineral skeleton and the pore water per unit change in head and is relevant in confined layers.

Specific yield is relevant for unconfined layers and represents the unit volume of water that is drained from the formation per unit decrease in head. No field measurements were available for these parameters (refer *Section C7.3.2*).

The model was calibrated using time-drawdown data of the aquifer tests carried out by ERM (*Section C7.3.2*). Borehole pumping was simulated and the models were calibrated to fit the measured time-drawdown data. This model *stress* is similar to the planned groundwater exploration but on a much shorter time scale.

Model Setup

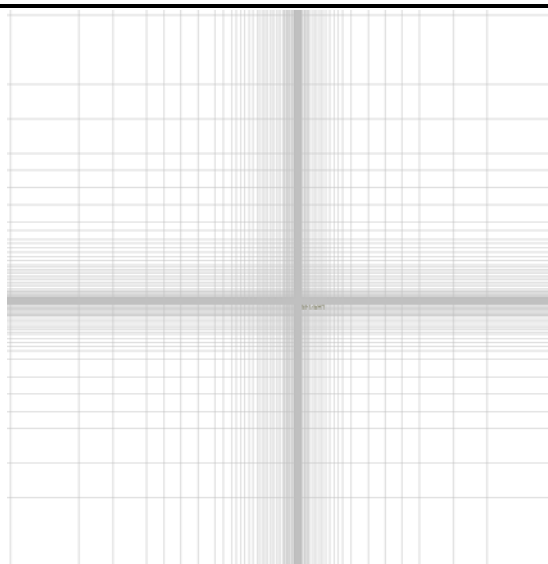
During the setup of the transient model, the steady state groundwater flow model is converted into a transient (“time-dependent”) groundwater flow model in order to run time-dependent simulations and predictive model scenarios.

The geometry of the model domain, model boundaries, top and bottom of the model, discretization and layer type were taken from the steady state model as well as the time-independent parameters like hydraulic conductivity, recharge, drain conductance and elevation etc. The solution of the calibrated steady state model was used as initial hydraulic head distribution.

Grid Refinement

A different model was created for each of the boreholes. In a first step, the model grid needs to be gradually refined around the tested borehole. The cell size within which the tested well is located should ideally represent the borehole diameter (114 - 165mm). However, due to model restrictions, the grid could only be refined to a cell size of 195mm, which is considered sufficiently accurate. As an example, *Figure 7.10* details the grid refinement around LNG-W001, where the biggest cells (in the corners) are 200m by 200m in size.

Figure 7.10 Grid Refinement LNG-W001



Furthermore, the grid was refined in vertical direction in order to accurately represent the tested interval. Based on the individual borehole constructions, three layers with variable thickness were modelled and the layer thickness of layer 2, where the aquifer was pumped, was also optimised (see below).

Boundaries and Model Parameters

Steady state model boundary conditions were used for each of the three layers except for the surface water features including estuaries, wetlands and streams, that were only implemented in the first layer. Vertical hydraulic conductivity (K_v) was assigned at 10% of the horizontal hydraulic conductivity (K_h) following a common approach. Other model parameters were taken as is from the calibrated steady state model.

Stress Periods and Time Steps

Time unit (minutes), stress periods and time steps were chosen in order to accurately represent the aquifer tests performed for the respective boreholes. 24 hour aquifer tests were conducted with increasing time intervals. This was followed by recovery tests of variable length where, after pump shut down, groundwater levels in the boreholes were measured until at least 90% recovery was achieved.

Observation Boreholes

As no water level fluctuations were recorded in any of the observation boreholes during abstraction from the pumped borehole, only the water levels measured in the pumped boreholes could be used as observations for the calibration process. Observation data is detailed in *Annex B*.

Aquifer Test - Groundwater Abstraction

Pump rates varied for each borehole. Pumping was implemented in the model using the *Well Package*. The tested interval was based on the borehole

construction and also optimised during calibration. Pumping was simulated from layer two in the middle.

Optimised Parameters

Optimised parameters include *Specific Storage* and *Layer Thickness*, which is directly related to the *Transmissivity (T)* of the tested formation:

$$T = \text{Layer Thickness} \times K$$

The model uses T to calculate groundwater flow and head distribution in the model domain.

Transient Calibration Results

Specific storage and layer thickness was calibrated using the aquifer test data of a total of 11 boreholes (constant discharge tests). Calibration results figures are presented in *Annex F*.

Due to a restriction in Processing Modflow Pro with regards to number of digits and the fine discretisation at the pumping well, the observation point could not be located exactly in the middle of the pumping well cell. Hydraulic gradients close to the pumping well are very steep and therefore there is a discrepancy between the maximum modelled drawdown in the model and in the figures (observation point). Therefore the modelled maximum drawdown in the pumping well cell is also mentioned in the figure titles.

Calibrated specific storage values vary mostly within less than one order of magnitude (*Table 7.7*). Considering only boreholes with acceptable drawdown data an optimised specific storage value of $9 \cdot 10^{-4}$ (geomean) was retained for scenario modelling.

The results for layer thickness indicate that the layer thickness and indirectly the transmissivity (T), which is used for the flow calculations, have a significant impact on the magnitude of drawdown in the borehole. For most boreholes calibrated layer thickness was smaller than the length of the well screen.

Table 7.7 *Transient Calibration Results*

BHID	Q (l/s)	Aquifer Tests			Numerical Model			SS Cal (-)	Notes
		Screen Length (m)	T (m ² /d)	K (m/d)	Layer Thickness (m)	T (m ² /d)	K (m/d)		
LNG-W001	1.5	21	5E+01	2E+00	10	7E+01	7E+00	1E-03	-
LNG-W002	4.7	9	5E+01	6E+00	4	3E+01	7E+00	3E-03	-
LNG-W003	1.5	9	2E+02	2E+01	5	4E+01	7E+00	1E-04	DD data not acceptable
LNG-W004	3.8	9	2E+00	2E-01	2	1E+01	7E+00	1E-03	DD data not acceptable
LNG-W005	1.7	9	6E+00	7E-01	0.8	6E+00	7E+00	2E-03	Based on Recovery
LNG-W006	4.6	9	6E+01	7E+00	5	4E+01	7E+00	1E-03	-
LNG-W010	2.9	12	7E+01	5E+00	8	6E+01	7E+00	1E-03	DD data not acceptable
LNG-W011	1.7	17	6E+00	4E-01	1	7E+00	7E+00	6E-03	-
LNG-W012	0.8	14	4E+01	3E+00	5	4E+01	7E+00	1E-04	Based on Recovery
LNG-W013	1.8	11	1E+02	1E+01	8.7	6E+01	7E+00	1E-03	-
LNG-W014	0.8	12	9E+01	7E+00	12	8E+01	7E+00	1E-04	-

The main potential groundwater impacts of the proposed Project are related to following activities:

- Over-abstraction of water supply wells;
- Surface sealing in the LNG Processing Area; and
- Filling in of estuaries, wetlands and streams in the LNG Processing Area.

Groundwater modelling scenarios were run to quantify potential impacts of the planned groundwater abstraction and other Project activities on the groundwater environment, groundwater users and groundwater-dependent ecosystems. Furthermore, the aquifer capacity to deliver the total Project water demand for domestic use was investigated and recommended pumping rates calculated for each production borehole.

Pumping rates per borehole can be limited by a number of factors including the following:

- Borehole and aquifer capacity;
- Borehole depth;
- Available drawdown;
- Saline intrusion; and
- Casing diameter.

The borehole capacity to sustain a given pumping rate was determined by scenario modelling using the calibrated model, where a maximum pumping rate is limited by the aquifer capacity and/or the borehole becoming dry (i.e. the dynamic water level ⁽¹⁾ falling below the bottom of the borehole).

The concept of *available drawdown* was applied per individual borehole to determine a maximum pumping rate to avoid saline intrusion. A safety buffer was applied to keep the dynamic water levels in the different boreholes above 3mamsl at all times, which is deemed sufficient to avoid saline intrusion (given that the maximum pumping rates are below the ones calculated).

Another limiting factor to maximum pumping rates is the casing diameter, which determines what kind of commonly used submersible pumps can be accommodated. Submersible pumps that fit in a 4½" OD borehole can generally deliver approximately 1.5L/s (5.4m³/hour) whereas pumps that fit in larger diameter boreholes with 5-6½" OD casing can deliver up to 4L/s (14.4m³/hour) and more depending on the available groundwater head (i.e. the pumping rate would decrease with decreasing head). However, higher pumping rates can be achieved by using alternative pumping-systems (i.e. mono-pumps etc.).

¹ *Dynamic water level* describes the groundwater level in the borehole during pumping

Five scenarios were run in steady-state and four in transient (time-dependent) state. The different scenarios are presented in *Table 7.8*.

Table 7.8 *Groundwater Modelling Scenarios*

Scenario Number	Model Type	Description	Aim
Scenario 1	Steady-State	Determine maximum recommended pumping rate for each borehole, based on borehole/aquifer capacity, in order to avoid saline intrusion	Respect the maximum available drawdown to avoid saline intrusion: Dynamic water level > 3mamsl
Scenario 2	Transient	Meet Project borehole water demand (peak of 600m ³ /d) using the least number of boreholes required (3 boreholes for peak demand and 2 backup)	Only pump inland (Pioneer Camp) using maximum recommended pumping rates determined in Scenario 1; no restrictions in pumping rates with regards to borehole diameter
Scenario 3	Transient	Meet Project borehole water demand (peak of 600m ³ /d) using the least number of boreholes required but restricted to feasible pumping rates using submersible pumps (5 boreholes for peak demand and 1 backup)	Only feasible pumping rates in terms of maximum recommended pumping rates determined in Scenario 1 and borehole diameter, i.e. 5.4m ³ /hour (1.5L/s) in 4½" boreholes and 14.4m ³ /hour (4L/s) in 5 - 6½" boreholes
Scenario 4	Transient	Model the maximum impact by pumping the total water demand (peak of 3 000m ³ /d) from one borehole (LNG-W006)	Determine whether the aquifer can sustain the total Project water demand (domestic)
Scenario 5	Transient	Maximum impact after mitigation (pump each of the existing boreholes at the maximum allowable pumprate (Scenario 1) and additional 3-11 boreholes at 120 - 220m ³ /d to meet the peak demand)	To keep the dynamic water level above 3mamsl by adding more extraction boreholes to deliver the total demand
Scenario 6	Steady-State	Surface Sealing resulting in reduced recharge based on an inferred LNG Processing Area (6km ²)	Investigate impact of reduced recharge
Scenario 7	Steady-State	Surface Sealing resulting in reduced recharge and filling of estuaries, wetlands and streams; based on the inferred LNG Processing Area (6km ²)	Investigate impact of reduced recharge combined with filling of estuaries, wetlands and streams
Scenario 8	Steady-State	Surface Sealing resulting in reduced recharge based on the total Revised Project Footprint area (14km ²)	Investigate impact of reduced recharge (largest potentially sealed area)
Scenario 9	Steady-State	Surface Sealing resulting in reduced recharge and filling of estuaries, wetlands and streams; based on the total Revised Project Footprint area (14km ²)	Investigate impact of reduced recharge combined with filling of estuaries, wetlands and streams (largest potentially sealed area)

C7.6.1 *Model Setup*

Grid Refinement

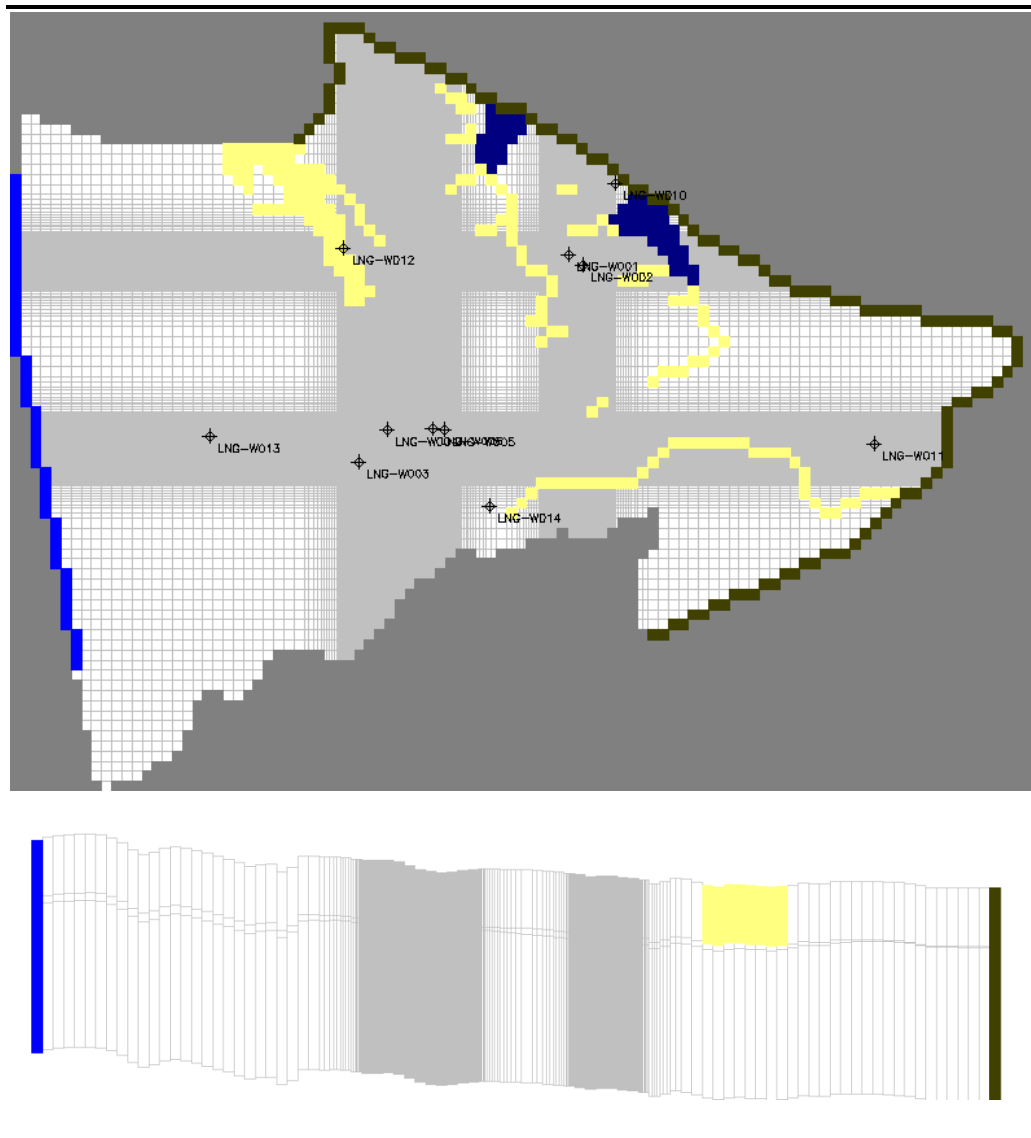
To accommodate the likely steep hydraulic gradient in the vicinity of extraction boreholes, the model grid was gradually refined horizontally in the

areas where groundwater abstraction is to take place to a 10m cell size: (i) Pioneer Camp and (ii) LNG Processing Area. In vertical direction the grid was refined to three layers as follows: (i) overburden, (ii) pumping horizon and (iii) base layer based on the transient state model calibration.

The borehole construction and the calibrated layer thickness per borehole were used to interpolate the top and bottom of the second layer.

The refined model is presented in *Figure 7.11* in both plan-view and cross-section view (west-east).

Figure 7.11 Refined Model



Boundary Conditions

The constant-head boundary in the west was converted to an inflow boundary simulated using the well package. The inflows were distributed to the three layers relative to the area of through-flow of each individual cell.

The ocean at Palma-Bay was implemented the same way as in the steady-state model but across all three layers. The surface water features (estuaries, streams and wetlands) were implemented in the first layer (top) only representing shallow surface features.

Aquifer Type

The uppermost layer was modelled as an unconfined layer and the two layers at the bottom as confined/unconfined layers.

Hydraulic Parameters

Vertical hydraulic conductivity (K_v) was assigned at 10% of the steady-state horizontal hydraulic conductivity (K_h) following a common approach. The calibrated specific storage (SS) of $9 \cdot 10^{-4}$ was assigned for all layers.

Other model parameters were taken as is from the calibrated steady state model including recharge, horizontal hydraulic conductivity, drain conductance and general-head-boundary conductance.

Stress Periods and Time Steps

For the transient (time-dependent) simulations, time unit (days), stress periods and time steps were selected to enable accurate simulation of the time-dependent groundwater abstraction as per Project water demand.

Stress periods are detailed in *Table 7.9* relative to the different Project phases. Stress periods were further divided into monthly time steps to facilitate numerical model stability except for the 10 year post-closure phase that was sub-divided into ten yearly time steps.

A one-year *dry-run* was modelled at the beginning of the transient models. This is a common approach used in transient modelling to assure the correct initial parameters are implemented. In order to calculate the initial parameters (initial head distribution), the refined model was first run in steady-state mode.

Table 7.9 *Stress Periods and Time Steps*

Stress Period Number	Stress Period Length (days)	Stress Period		Project Phase
		Length (months)	Number of Time Steps	
1	360	12	12	Dry run
2	180	6	6	Construction
3	180	6	6	Construction
4	360	12	12	Construction
5	720	24	24	Construction
6	720	24	24	Construction and Operation
7	10140	338	338	Operation
8	3600	120	10	Post-closure

The model cells (10m by 10m) are much larger than the boreholes, which results in calculate drawdowns that are smaller than in reality. Therefore, the calculated drawdowns have to be corrected in order to get effective drawdowns in a production borehole (*real drawdown*).

To obtain the effective drawdown (Δd_{eff}) of a borehole with the radius r_{BH} , the drawdown calculated (Δd_{calc}) in a model cell with a certain grid size a is corrected by a corrective term Δd_{corr} as follows (Prickett and Lonquist, 1971):

$$\Delta d_{\text{eff}} = \Delta d_{\text{calc}} + \Delta d_{\text{corr}}$$

$$\Delta d_{\text{corr}} = 0.3665 \left(\frac{q}{T} \right) \log \left(\frac{a}{4.81 r_{BH}} \right)$$

Where:

- q Abstraction rate of well [m³/d];
- T Transmissivity [m²/d];
- a Grid cell size [m]; and
- r_{BH} Radius of the well [m].

C8.1 OVERVIEW

This study was undertaken by Natural Scientific Services CC. The methodologies utilised for the aquatic and wetland assessment are detailed below. Since no known protocols have been developed for Mozambique, these methodologies have been largely based on South African methodologies, which have been designed for southern African environments and are therefore considered suitable for this study.

C8.2 SAMPLING SITES

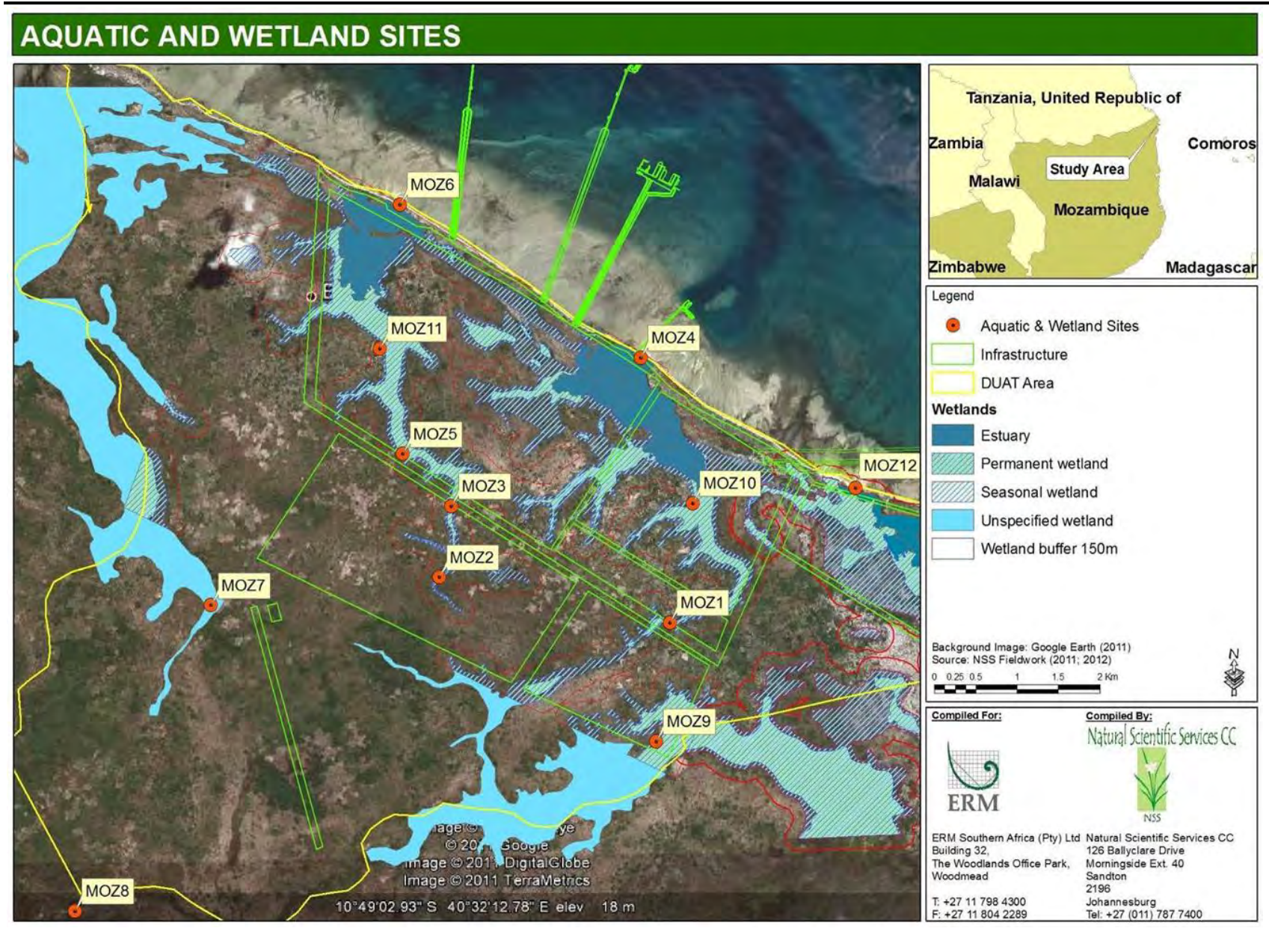
The initial objective of the study was to set a baseline status for the area by assessing the aquatic and wetland systems in the vicinity of the Afungi Project Site, specifically the Onshore Project Footprint Area, prior to the construction of the onshore LNG facilities, and the impacts that will follow due to these developments. The sampling sites were, therefore, positioned based on the proposed location of the Project infrastructure. The accessibility of areas also played a role in final site selection. The sites selected are summarised in *Table 8.1* and illustrated in *Figure 8.1*.

Table 8.1 Selected Sampling Sites

Site Position (in relation to proposed LNG Facility)	Site Name	Site Description	Co-ordinates	
In the proposed pipeline gas inlet area	MOZ 1	Wetland	S 10°50'07.58"	E 40°33'21.57"
In the proposed construction support facility area	MOZ 2	Wetland	S 10°49'50.94"	E 40°31'50.89"
On the proposed main access road	MOZ 3	Wetland	S 10°49'21.89"	E 40°31'55.34"
In the proposed operation dock zone	MOZ 4	Estuary	S 10°48'23.53"	E 40°33'09.69"
Upstream from proposed utilities area	MOZ 5	Wetland	S 10°49'00.74"	E 40°31'36.83"
In the proposed process utilities area	MOZ 6	Estuary	S 10°47'23.84"	E 40°31'35.83"
Upstream from the proposed airstrip	MOZ 7	Wetland	S 10°50'00.73"	E 40°30'20.72"
Upstream from the proposed airstrip	MOZ 8	Wetland	S 10°52'01.51"	E 40°29'27.94"
Upstream from operations support area	MOZ 9	Wetland	S 10°50'54.77"	E 40°33'16.08"
Downstream from construction staging area	MOZ 10	Wetland	S 10°49'21.31	E 40°33'30.34"
Downstream from process utilities area	MOZ 11	Wetland	S 10°40'20.53"	E 40°31'27.52"
In the operations housing area	MOZ 12	Estuary	S 10°49'15.53"	E 40°34'34.29"

All of the twelve sites selected were wetlands, nine of which were freshwater sites namely MOZ 1, 2, 3, 5, 7, 8, 9, 10 and 11. Three of the sites were estuarine sites ie MOZ 4, 6 and 12.

Figure 8.1 Aquatic and Wetland Monitoring Sites



C8.3 FRESHWATER ASSESSMENT

The freshwater sites were assessed by determining the present ecological status (PES) of each site during low flow 2011 and high flow 2012. Four of the sites, MOZ 8, 9, 10 and 11 were added during high flow 2012. The low flow assessment of these sites was done during low flow 2012 (21-26 June 2012).

C8.3.1 Water Quality

Water quality is a measure of the physical attributes (turbidity, suspensoids, temperature) and chemical constituents (non-toxic: pH, TDS, salinity, conductivity, individual ions, nutrients, organic enrichment and dissolved oxygen including toxicants such as: trace metals and endocrine disrupting chemicals) of a sample of water, of which most can have an effect on the aquatic ecosystem characteristics.

Physical Water Quality Parameters

The physico-chemical constituents measured *in situ* included five standard physical WQ variables, namely, Dissolved Oxygen (DO) (mg/l and %), temperature (°C), Electrical Conductivity (EC) (mS/m), Total Dissolved Solids (TDS) (mg/l) and pH. This was done by using a pre-calibrated HI 9828 Multiparameter with pH/ORP/EC/TDS/DO multisensor probe (Hanna Instruments).

Chemical Water Quality Parameters

The anthropogenic activities (agriculture and informal settlements) taking place in the Afungi Project Site were identified. The pollutants commonly associated with these activities were tested to determine the chemical constituents (nutrients and trace metals) through collection of water samples in polyethylene bottles. The analysis was done by Cleanstream (Pty) Ltd (ISO accredited laboratory) based in Pretoria, South Africa. The variables evaluated in low flow 2011 were: total alkalinity, chloride (Cl), fluoride (F), sulphate (SO₄), nitrate (NO₃), ammonium (NH₄), orthophosphate (PO₄), total hardness, including the metals aluminium (Al), beryllium (Be), bismuth (Bi), boron (B), cadmium (Cd), calcium (Ca), cobalt (Co), copper (Cu), gallium (Ga), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), potassium (K), rubidium (Rb), silicon (Si), sodium (Na), strontium (Sr), silver (Ag), tellurium (Te), thallium (Tl), total chromium (Cr), vanadium (V) and zinc (Zn). Some of the constituents, identified in low concentration (undetectable) during low flow 2011, were excluded from the high flow 2012 and low flow 2012 analysis, ie beryllium, bismuth, gallium, rubidium, tellurium, thallium and vanadium. Various constituents, namely mercury (Hg), nitrite (NO₂), chemical oxygen demand (COD), suspended solids (SS), turbidity (NTU) and soap, grease and oil (SOG), were added for WQ analysis of high flow 2012 and low flow 2012.

The physical and chemical water quality results were compared against the Target Water Quality Range (TWQR), which is a management objective

developed by DWAF (1996) for South African aquatic ecosystems and used to specify the desired or ideal concentration range and/or water quality requirements for a particular constituent. Although there are some water quality standards in place in Mozambique, none are specifically related to the standards required for optimal ecosystem functioning (Mozambique Environmental quality regulations, 2004). Consequently, the South African guidelines were utilised to give an indication of ecosystem deterioration in this study. Unfortunately no historical data was available at the time of this report write up due to limited commercial activity in the area. This project will thus form the baseline water quality monitoring for the area.

C8.3.2

Diatoms

Diatoms are a group of unicellular algae with characteristic siliceous cell walls, unique photosynthetic pigments and specific storage products (oil and chrysolaminarin). They are important components in algal communities and form the base of aquatic ecosystems (Taylor *et al.* 2007). The assessment of diatoms involves a biological monitoring technique that has been introduced as part of routine monitoring programmes because of certain shortcomings in standard physical and chemical methods. Although they do not currently form part of the array of bioindicators used in the National Aquatic Ecosystem Biomonitoring Programme (NAEBP), there is strong motivation to include diatoms as alternatives to macro-invertebrate assessments when low habitat diversity occurs (Dr Taylor, Annual Champions Symposium, 2006). The main advantage of this biological approach is that it examines organisms whose exposure to water and any pollutants there-in is continuous, and reflects the actual impacts (both long and short-term) of pollutants on the ecosystem. Therefore, diatoms are considered useful organisms to include in the suite of biomonitoring tools used in this study, both to establish current water quality and historical conditions (Taylor *et al.* 2005) in the wetland sites analysed. These wetland habitats have limited habitat availabilities, which has a large influence on other biotic assemblages within the system. Macro-invertebrates are particularly influenced by the lack of diverse habitats including cobbles, fast flowing waters and other biotopes and as such diatoms are particularly useful as an alternative to determine water quality influences in these habitats.

Diatoms were collected at the sampling sites according to the methodology described by Taylor *et al.* (2005) as well as Fore and Grafe (2002). Five objects submerged in water (plants, roots, reeds etc) were chosen from each site. The diatoms were collected by scrubbing the upper surfaces of these objects with a toothbrush and then rinsed into a tray. These were mixed with a small amount of water (obtained from the aquatic ecosystem) and poured in polyethylene bottles. Thereafter, the samples were fixed with 20% ethanol (final concentration by volume) to preserve and store the samples. The laboratory techniques, namely cleaning, preparation, enumeration, notation of deformed cells and identification of the diatoms, were done according to Taylor *et al.* (2005). All slides and material have been archived in the Diatom Collection of the North-West University, South Africa, should any material be required for independent verification. Index scores were calculated using OMNIDIA version 5.3 (Lecointe *et al.* 1993; database updated March 2009). The index

scores used in the interpretation of the data included the Specific Pollution sensitivity Index (SPI), Biological Diatom Index (BDI) and Percentage Pollution Tolerant Valves (%PTV). These index scores, ranging from deteriorated to high quality as defined by Eloranta and Soininem (2002), for each site was classed and presented in *Table 8.2*

Table 8.2 *Index score and class used for interpretation of diatom assessment (Taylor 2011)*

Interpretation of index scores		
SPI and BDI	%PTV	Class
>17	-	high quality
13 to 17	-	good quality
9 to 13	10-15	moderate quality
5 to 9	<20	poor quality
<5	<20	bad quality
- Not available		

C8.3.3 *Habitat Integrity (IHI)*

The Index of Habitat Integrity (IHI) assessment protocol, described by Kleynhans (1996), was used to assess the impacts on the aquatic and surrounding habitats of each site. Respectively the instream (IH) and riparian (RH) habitats are analysed based on a set of 12 weighted disturbances in the index. These disturbances represent some of the important and easily quantifiable anthropogenically induced impacts, including bank erosion, bed-, channel- and flow modification; exotic aquatic fauna, -macrophytes and -vegetation encroachment; indigenous vegetation removal; inundation; solid waste disposal and water abstraction. The respective level of impacts for the IH and RH habitats were calculated. Each disturbance was assigned an impact rating (*Table 8.3*) and a confidence score. These values were used to calculate an impact score using the formula: $(\text{impact rating}/25) \times (\text{the weight of that impact defined in Table 8.4})$. The estimated impacts of all criteria was summed, expressed as a percentage and subtracted from 100 to obtain a habitat integrity value for the instream and riparian components, respectively in accordance with Kleynhans (1996).

However, in cases where riparian zone criteria and the water abstraction, flow, bed and channel modification, water quality and inundation criteria of the instream component exceeded ratings of large, serious or critical, an additional negative weight was applied. The aim of this is to accommodate the possible cumulative effect (and integrated) negative effects of such impacts (Kemper, 1999). The following rules were applied in this respect:

- Large Impact = Lower the integrity status by 33% of the weight for each criterion with such a rating.
- Serious Impact = Lower the integrity status by 67% of the weight for each criterion with such a rating.

- Critical Impact = Lower the integrity status by 100% of the weight for each criterion with such a rating.

The final IHI estimate was then calculated by adding the negative weights for the instream and riparian habitat values and subtracting this total from the provisionally determined intermediate habitat integrity. This final IHI is then characterized into one of the six categories defined by Kleynhans and Louw (2008) and indicated in *Table 8.3*

Table 8.3 *The IHI scoring of each criterion to describe the extent of each impact (from Kleynhans 1996)*

Impact Class	Description	Score
None	No discernible impact or the modification is located in such a way that it has no impact on habitat quality, diversity, size and variability	0
Small	The modification is limited to very few localities and the impact on habitat quality, diversity, size and variability is limited.	1-5
Moderate	The modifications are present at a small number of localities and the impact on habitat quality, diversity, size and variability are fairly limited.	6-10
Large	The modification is generally present with a clearly detrimental impact on habitat quality, diversity, size and variability. Large areas are, however, not affected	11-15
Serious	The modification is frequently present and the habitat quality, diversity, size and variability in almost the whole of the defined area are affected. Only small areas are not influenced.	16-20
Critical	The modification is present overall with a high intensity. The habitat quality, diversity, size and variability in almost the whole of the defined section are influenced detrimentally.	21-25

Table 8.4 *Criteria and weightings used for the assessment of Instream and Riparian Habitat*

Instream Criteria	Weight	Riparian Criteria	Weight
Water abstraction	14	Vegetation removal	13
Water quality	13	Exotic vegetation	12
Flow modification	13	Bank erosion	14
Bed modification	13	Channel modification	12
Channel modification	14	Water abstraction	13
Inundation	10	Inundation	11
Exotic macrophytes	9	Flow modification	12
Exotic fauna	8	Water quality	13
Rubbish dumping	6		

Fish Habitat Availability

A fish habitat assessment was undertaken to provide a measure of the fish refuge potential associated with each of the sampling sites. This assessment characterises the fish habitats into four velocity-depth classes (including slow-deep, slow-shallow, fast-deep and fast-shallow habitat class, where fast is greater than 0.3 m/s, slow is less than 0.3 m/s, deep is greater than 0.3 m and shallow is less than 0.3 m) and associated cover present at each of the habitats (Dallas 2005). All of these were quantified on a scale from 0 to 5, being absent (0), rare (1), sparse (2), common (3), abundant (4) or entire (5) (Dallas 2005). Measuring these various habitat types are an essential component in the interpretation of the fish integrity because it can influence (by creating or restricting) the fish populations and communities present within each sampling site.

Macro-Invertebrate Habitat Availability

Macro-invertebrate communities, like most aquatic fauna, are largely influenced by the habitat diversity within an aquatic ecosystem. Therefore, different biotope diversities were evaluated where available ie instream vegetation, marginal vegetation and GSM (gravel, sand and mud)¹. Each of the biotopes were scored, rated on a scale from 0 to 5 according to presence of biotopes, namely absent (0), rare (1), sparse (2), common (3), abundant (4) or entire (5) (Dallas, 2005). The invertebrate habitat assessment system (IHAS) index was not incorporated into the present study as it still requires validation, according to Dallas (2005). NSS however does utilise the index as a guide to identify impacts in the habitat eg algal enrichment etc. Some of the categories from the IHAS were therefore identified in this study, including algal presence, biotopes and dominant vegetation types.

C8.3.4 *Macro-Invertebrates*

The assessment of macro-invertebrate communities in a river system is a recognised means of determining river “health” (Dickens and Graham 2002). Macro-invertebrates are good indicators because they are visible, easy to identify and have rapid life cycles. The macro-invertebrates were collected and identified to family level using the standardised SASS5 (South African Scoring System, version 5) sampling method described by Dickens and Graham (2002). SASS5 is a rapid assessment method of macro-invertebrate status of a flowing instream system. Macro-invertebrates were collected using a standard SASS net in available habitat types within specified time frames. Fifteen minutes were taken to identify the presence and approximate abundances of macro-invertebrate families in each of the habitats. The results for each site was then analysed using the following metrics:

(1) ¹ Unfortunately, stones in fast and slow flowing habitats were not present at any of the sampling sites. Such habitats are generally more favourable for macro-invertebrates and therefore their absence will reduce the macro-invertebrate index scores utilised in this study.

- Occurrence of macro-invertebrates: The number and abundances of families sampled were used to determine the overall family richness. These two measures are simple and were used as an indicator of contaminant stress on macro-invertebrate communities.
- EPT richness: This evaluates the total number of families occurring in the order Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) (Marshall et al., 2001) ie $EPT = \# \text{Ephemeroptera families} + \# \text{Plecoptera families} + \# \text{Trichoptera families}$. It is based on the sensitivity of these families and as such a decrease in the number of these orders would indicate an increase in water quality perturbations.
- Biotic indices: Such indices are usually based on the assignment of various macro-invertebrate taxa. Their utility in countries other than those for which they are originally designed may be limited as tolerances may not be reliably transferred to different areas where there are different families, climates and ecoregions. The biotic indices included SASS5, Average Score Per Taxon (ASPT) and Macro-invertebrate response index (MIRAI).

SASS5

The SASS5 score was calculated by the sum of the sensitivity scores of the present families. The average score per taxon (ASPT) was calculated by dividing the total SASS score by the total number of taxon. The results were interpreted based on the SASS5 score defined in *Table 8.5*. However, the use of SASS5 and ASPT, was included in this study as a **guide** to identify impacts as family tolerances have been shown to have similar trends throughout the world. It was only used as guide as these are wetland systems and are therefore not flowing rivers and no eco-region data is available for comparison.

MIRAI

The MIRAI was used in this study, as an alternative to the SASS5, to determine the Present Ecological Status (PES) of the macro-invertebrate community assemblage. The index integrates the ecological requirements of the invertebrate taxa in a community or assemblage and their response to modified habitat conditions, whilst comparing the present assemblage with a reference list (Thirion, 2008). No historical data was available for the macro invertebrates that occur in these aquatic systems. Therefore, the reference list for this study was compiled based on the macro-invertebrate preference to the biotopes found at the sampling sites. These included macro-invertebrates which occur in no and/or slow flowing water which also favour vegetation and/or GSM habitats. This excluded all species with a preference to fast flowing water and stone (in and out of current) biotope. In addition, the functional feeding groups and riverine continuum were considered when compiling the reference list. Due to the fact that the sites are connected, it was assumed that the species that occurred at one site should hypothetically also occur at the other sites. This method made it possible to compare each individual site to the predetermined reference conditions.

The MIRAI model makes a comparison between the expected macro-invertebrate families with the present assemblages obtained using SASS5 sampling protocol (Thirion, 2007). The habitat preferences for each of the macro-invertebrates were incorporated in terms of flow, habitat and water quality. Each component was rated within a metric in terms of how much the macro-invertebrate presence and abundances changed from reference, and were done for each of the metrics. After all of the metrics were scored, the model generated a MIRAI score for each site and was characterised into an EC as defined in *Table 8.5*.

C8.3.5 *Fish*

At each site, the fish were sampled according to standardised fish sampling methods (Kleynhans, 2008) which included seine-, cast- and fyke nets. The small seine net was used in shallower areas with overhanging vegetation by running the net out to the banks of the wetland. A minimum of five casts was done at the sites which had sufficient water depth. The small fyke net was positioned in the water for a minimum of two hours at each site. The sampled fish were identified to species level using Skelton (2001) and safely returned to the aquatic system before they were documented into the separate segments and habitat types. In the cases where fish could not be identified with certainty, specimens were sent to the Fishery Research Institute in Maputo, Mozambique. Photos of the species were taken and sent to the South African Institute for Aquatic Biodiversity (SAIAB) for positive identification (Bills 2011, personal communication).

Multivariate statistical techniques have been widely used to assess biological community structures and patterns in various ecosystems, including fresh water fish community assemblages and other biological data sets. A principle component analysis (PCA) approach, by means of Canoco Version 4.5 was used to determine if there were any spatial or temporal differences between the various freshwater sites by overlaying the WQ on the fish species sampled during low and high flow. A Redundancy Analysis (RDA) was undertaken to determine the differences between the freshwater sampling sites to determine which environmental variables are possibly responsible for the differences.

C8.3.6 *Ecological Integrity / Present Ecological Status*

The present ecological status (PES) of the freshwater systems was determined by assessing the water quality, diatoms, habitat, macro-invertebrates and fish community integrity. Ecological categories (EC) were used to assist in the interpretation of this data because they define the ecological condition of a river or freshwater system in terms of the deviation of biophysical components from the natural reference condition (Kleynhans and Louw, 2008). These categories range over a continuum of levels of disturbance from the natural state of the ecosystem, from no disturbance or natural (Category A) to critically modified (Category F) and were represented by characteristic colours defined by Kleynhans and Louw (2008) in *Table 8.5*.

Table 8.5 *Present Ecological Status Codes and Descriptions with Standardised Colour Coding*

Category	IHI (%), MIRAI (%), SASS5, VEGRAI	Short Description	Long Descriptions
A	90 - 100	Natural	Unmodified state with no impacts, conditions natural (Scores between 87.4 and 92 = A/B)
B	80 - 89	Largely natural	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged (Scores between 77.4 and 82 = B/C)
C	60 - 79	Moderately modified	Moderately modified - loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged (Scores between 57.4 and 62 = C/D)
D	40 - 59	Largely modified	Largely modified - a large loss of natural habitat, biota and basic ecosystem functions has occurred (Scores between 37.4 and 42 = D/E)
E	20 - 39	Seriously modified	Seriously modified - the loss of natural habitat, biota and basic ecosystem functions are extensive (Scores between 17.4 and 22 = E/F)
F	< 20	Critically modified	Critically/Extremely modified - modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible

Source: Modified from Kleynhans and Louw (2008); Kleynhans (1996; 1999) and in Kleynhans *et al.* (2007))

In some cases, there is an uncertainty as to which category a particular waterbody belongs. This situation falls within the concept of a “fuzzy” boundary, where a particular entity may potentially have membership of both classes and for practical purposes these situations are referred to as boundary categories and are denoted as for example B/C as depicted in *Figure 8.2*.

Figure 8.2 *Illustration of the distribution of categories on a continuum as shown in Kleynhans and Louw (2008)*



In the current study, the results obtained from the index scores of the IHI measuring habitat and MIRAI scores (see *Section C8.3.1*) measuring macro-invertebrate integrity were assigned to the ECs outlined in *Table 8.5*. The SASS5 and ASPT scores could not be calculated by the method defined by Dallas (2007) where assigned ECs were used by calculated percentiles based on South African eco-regions. None of these ecoregions were present in this study and as such could not be utilised to predict the current status of the macro-invertebrate community structures. Eco-regions generally have similar ecological characteristics and are usually used to predict what the biotic structures would be composed of under natural circumstances and thus used to determine and interpret EC. Since these limitations were particularly problematic with the SASS5 and ASPT scores derived by Dallas (2007), a more general SASS scoring system by Thirion *et al.* (1995) was utilised ⁽¹⁾. In terms of the WQ, measured variables were not assigned into an EC, as there are no recognised scores for water variables and they can therefore not be characterised into an index score.

C8.4 *ESTUARINE ASSESSMENT*

The three estuarine sites were assessed using the guideline for estuaries RDM Methods (version 3) with the procedures discussed in detail below and described in DWA (2010). Two of the sites (MOZ 4 and MOZ 6) were assessed at three points within each estuary (mouth, middle and upper reaches) (*Figure 8.3* and *Figure 8.4*). The third estuary (MOZ 12) was a small shallow system and samples were collected mainly at the estuarine mouth. In assessing the PES of the three estuaries the sediment, water quality, invertebrates, fish, microalgae and diatoms were assessed. Bird counts were also undertaken at two of the estuaries (MOZ 4 and MOZ 6) by Enviro-Insight, the data of which feeds into this report. The estuary site MOZ 4 and MOZ 6 were assessed in both high and low flow, with the third estuary (MOZ 12) only being assessed in June 2012, during the low flow assessment.

C8.4.1 *Sediment*

The techniques used to analyse the physical characteristics of the sediment of the two estuary sites are standard methods as defined by the United States Environmental Protection Agency (2001) and have been used successfully in Southern Africa (Cyrus *et al.* 2000). Two sediment samples (a – close to estuary mouth and b – close to middle reaches) were collected at each site in a polyethylene jar, and transported to the laboratory at the University of Johannesburg, South Africa, for analysis. The physical characteristics of the sediment analysed included moisture content, organic content and the grain size. The moisture content was determined by taking a known amount of sediment from each samples and drying it in an oven for four days at 60°C. The organic content was determined by taking a known amount of dry sediment (accurate to 0.00001g) and incinerating the sample for six hours at

(1) Note that SASS5 and ASPT scores and their associated ecological categories were only used as a guide in this study (see *Section C8.3.4*)

600°C. The samples were then reweighed to determine the percentage organic content in the sample.

Figure 8.3 Estuarine Sampling Site MOZ4

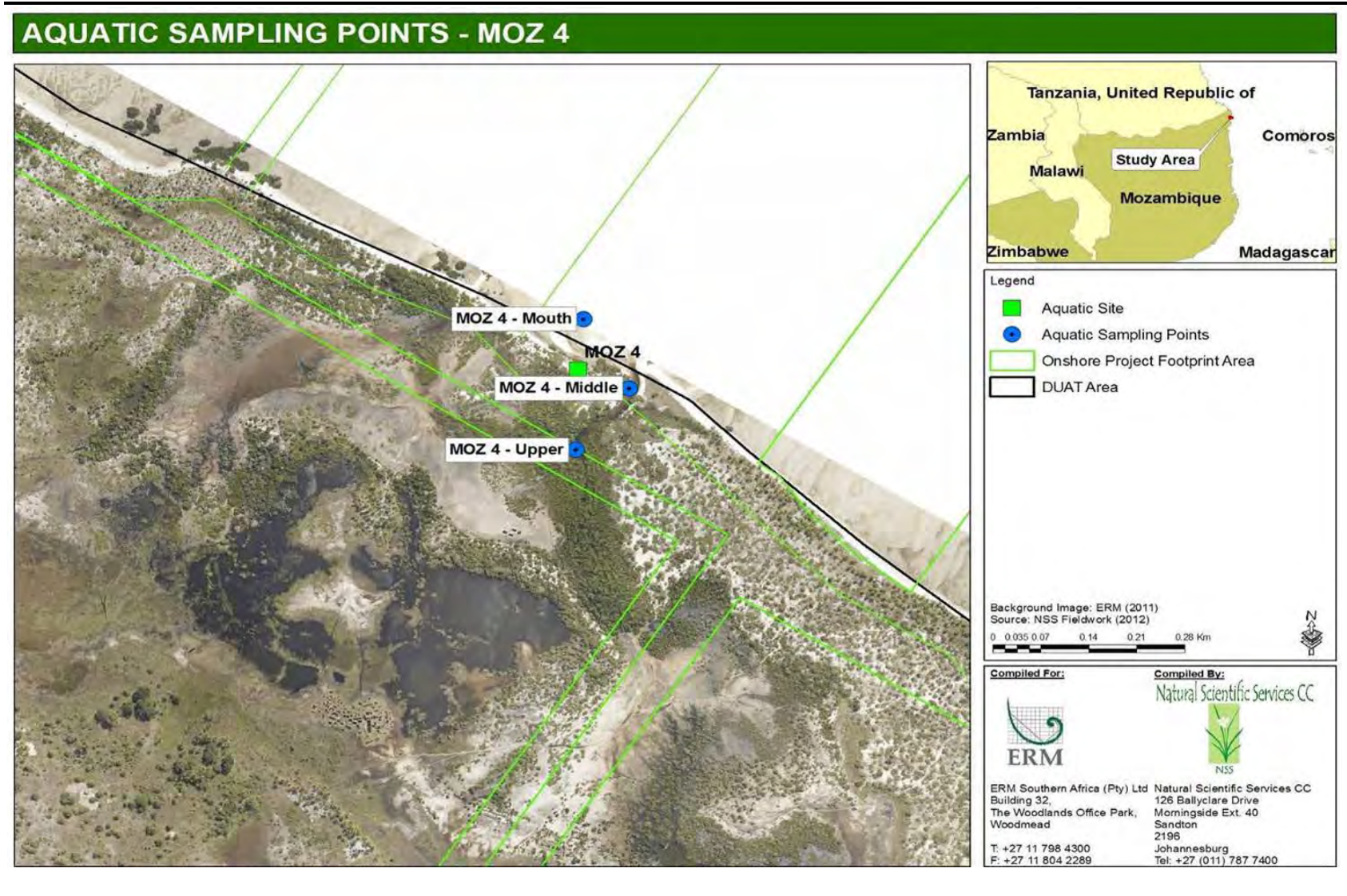
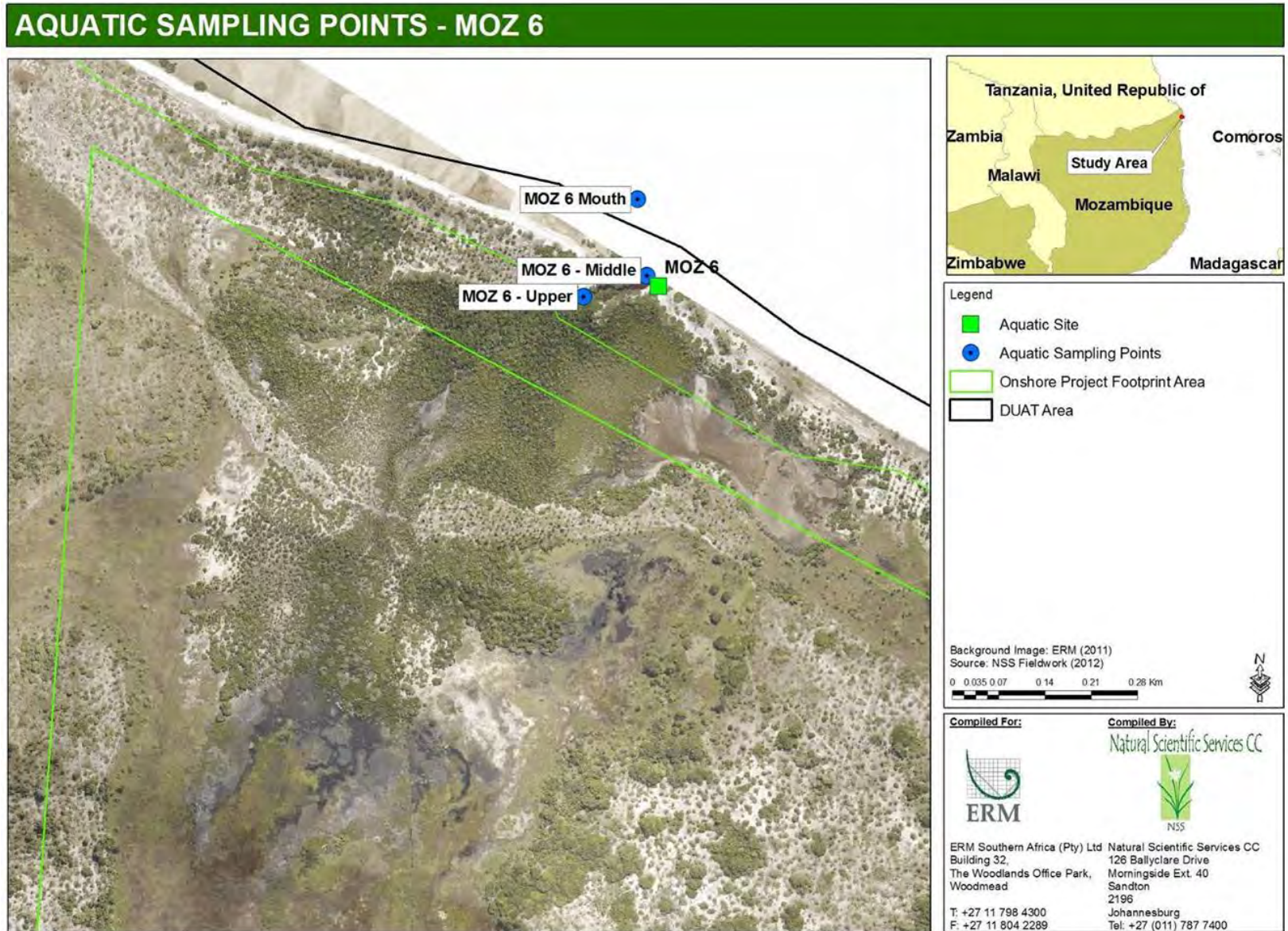


Figure 8.4 Estuarine Sampling Site MOZ6



The United States Environmental Protection Agency (2001) classifies the percentage organic content as follows:

Very low	=	< 0.05%
Low	=	0.05 - 1%
Moderately low	=	1 - 2%
Medium	=	2 - 4%
High	=	> 4%

The remaining dried sediment was used to determine the grain size of each sample by using an Endecott sieve system with various sieves ranging from > 4000 µm to 53 µm. The grain size categories that were used with their descriptions are summarized in *Table 8.6* (Cyrus *et al.*, 2000).

Table 8.6 *Various Grain Size Categories and Average Phi Values used to assess the Grain Size Distribution of the Estuarine Sediment*

Grain Size Categories (µm)	Average Phi (Φ) value	Description
Larger than 4 000	-2	Gravel
4 000 - 2 000	-1.58	Very Coarse Sand
2 000 - 500	-0.32	Coarse Sand
500 - 212	1.49	Medium Sand
212 - 53	2.92	Very Fine Sand
Less than 53	4.24	Mud

In estuarine sediment assessments, sediment grain-size data is given in phi (Ø) intervals rather than in microns, millimetres, or inches. Phi diameter is computed by taking the negative log of the diameter in millimetres. The phi values were obtained by calculating the negative logarithm to the base 2 of the particle diameter ie $\Phi = -\log_2 D$. Statistical computations and graphic presentations are much simpler when phi diameters are used. For the purposes of this assessment, the sediment grain size analysis was done by calculating the average phi values as well as the sorting coefficients for each site. By means of a cumulative curve, constructed by plotting substratum grain size percentage distributions of each site against the average phi values, the phi size for each of the following phi values at 5, 16, 25, 50, 75, 84 and 95 % respectively were determined (the % refers to the cumulative percent).

Consequently the sorting coefficients were calculated by using the following formula:

$$\sigma_1 = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$$

The results were then plotted on a graph to determine how well the sediment was sorted. The various categories for how well the sediment is sorted were given below (Lewis and McConchie, 1994a):

< 0.25	Φ	very well sorted
0.35 – 0.5	Φ	well sorted
0.5 – 0.7	Φ	moderately well sorted
0.71 – 1.0	Φ	moderately sorted
1.0 – 2.0	Φ	poorly sorted
2.0 – 4.0	Φ	very poorly sorted

C8.4.2 *Water Quality*

The same constituents tested for freshwater were also tested in the estuaries. See *Section C8.3.1*.

C8.4.3 *Microalgae and Diatoms*

Microalgae biomass / abundance provide information on eutrophication ⁽¹⁾ while changes in the dominant groups can indicate changes in the community due to water quality and quantity. Microalgae are important for the invertebrate and fish communities, particularly in large permanently open estuaries where benthic microalgae or phytoplankton are important primary producers. Ideally measurements should be taken under different flow conditions to establish natural variations. In shallow estuaries, situated close to the sea, or in the permanent open estuaries with large intertidal areas, the benthic microalgae are important primary producers. The characteristics of the microalgae community are important as they provide a better understanding of the invertebrate community (Gibson *et al.* 2000; WA, 2010). It is advantageous to analyse and characterise microalgae in baseline and impact monitoring as they have short life cycles which makes it easy to identify short term impacts and any influence in nutrient balance which affects their community. The use of microalgae as an indicator also carries some disadvantages: rapid distribution by wind and tides can mean they are not exposed to short term impacts, identification is difficult and time consuming, increased grazing by zooplankton can counteract higher microalgae biomass caused by nutrient enrichment, and indeterminate blooms by microalgae making characterization difficult (Gibson *et al.*, 2000).

Microalgae were sampled at three different areas within site MOZ 4 and MOZ 6 (*Figure 8.3* and *Figure 8.4*) and at the estuarine mouth at MOZ 12. A water sample was taken to collect microalgae specimens. The sample was allowed to settle and a sub sample was taken for analysis under a light microscope (at 400x magnification). The different microalgae groups ie green algae, flagellates, dinoflagellates, diatoms and blue-green algae were identified and counted. Benthic microalgae were also collected at three areas within each estuarine site. The benthic microalgae layer on top of the sediment was collected using a small diameter pipe at approximately six different areas

(1) The process by which a body of water acquires a high concentration of nutrients, especially phosphates and nitrates.

within a site. As was the case with the water microalgae, the benthic microalgae were identified and counted under a light microscope at the University of Johannesburg, South Africa.

The diatom community present at each of the estuarine sites was also sampled separately according to the protocol in *Section C8.3.2*.

C8.4.4 *Invertebrates*

Zooplankton

The zooplankton community is important in estuary systems as they are often closely related to the microalgal community function as well as any potential effects on the microalgal community. The zooplankton community has similar advantages for inclusion in an estuarine assessment as that of the microalgae, they have a rapid lifecycle that can provide fast responses to water quality changes or impacts, sampling equipment is inexpensive and easy to use and identification and sorting is easier than microalgae. Disadvantages include the lack of any substantial baseline or reference data for estuaries in Southern Africa, especially in northern Mozambique as well as the rapid lifecycles making cause and effect relationships difficult (Gibson *et al.*, 2000).

The zooplanktonic community at each site was sampled using a 100µm mesh size plankton net (50 x 50cm 25 µm). The net was dragged through the water for approximately 15m at each of the three areas within site MOZ 4 and MOZ 6 and at the estuary mouth at site MOZ 12. The debris and plankton caught within the net was transferred to a polyethylene jar, fixed with ethanol and stained using a vital dye, Rose Bengal. The zooplankton was identified to the lowest possible taxonomic level at the laboratories of the University of Johannesburg, South Africa.

In addition, a light trap was set over night at sites MOZ 4 and MOZ 6 to sample zooplankton and micro-invertebrates (some zooplankton species only feed at night). The light trap is comprised of a plastic jar, a funnel and a light stick. The invertebrates are attracted to the light source during the night and enter the funnel at the jar's opening from which it cannot escape. In the morning the trap was removed and the invertebrates were transferred into a polyethylene jar, stained with Rose Bengal and fixed with ethanol. The invertebrates caught with this method were identified to the lowest possible taxonomic level at the University of Johannesburg.

Benthic Invertebrates

Benthic invertebrates were sampled by taking five random grab samples at the three areas within Site MOZ 4 and MOZ 6 using a grab sampler, and within the estuarine mouth at MOZ 12. The contents of each grab were emptied into separate buckets and a small amount of 10% formalin added to force invertebrates present to release their hold on any particulate matter. Each bucket was filled with water and the mixture thoroughly stirred. The suspended matter was then decanted through a 0.5mm mesh (conical net),

and the process repeated 5 times. The remainder of the sample was then transferred into a polyethylene jar. The fauna and debris retained were preserved in 10% formalin, and a biological stain (vital dye, rose bengal) was added to aid in sorting and counting the invertebrates in the laboratory at the University of Johannesburg, South Africa.

C8.4.5

Fish

The fish sampling at the two estuary sites was carried out using selected seine netting techniques. A medium seine net (35m length, 1.6m depth and a 16mm mesh size with a 2m deep bag) and a small seine net (5m length, 1.6m depth, with two 20mm x 1.8m wood poles attached at each end) were mainly used to sample the fish community in different parts of the estuary. Within the estuary, the medium seine net was pulled with the tide employing a “quarter sweep” method where one end of the seine is held on shore while the other end is fully extended perpendicular to the shore, and then pulled back into shore forming a semi-circle (USEPA, 2000). Precautions were taken upon approaching the site in order to avoid disturbance of the sampling area (USEPA, 2000). The small seine net was used to sample shallower areas and areas covered with overhanging vegetation by means of running the net out from the estuary. Additionally, a small fyke net was also used in each estuary as a passive sampling technique. The fyke net was deployed for a minimum of three hours at a time during the day. Fish species collected in the field were identified (*in situ* and confirmed in the laboratories of the Fisheries Research Institute in Maputo, Mozambique and at the University of Johannesburg in South Africa) using the following guides:

- Freshwater Fishes of Southern Africa (Skelton, 2001);
- Coastal Fishes of Southern Africa (Heemstra and Heemstra, 2004);

The conservation status of most estuarine fish species observed in the study could not be established as most of the captured species are not well documented in scientific literature or (data deficient), or have not been evaluated by the IUCN (2011). Therefore, the conservation status of fish was not used as a weighing factor in the assessment of the estuarine sites, and an alternative method was used (Elliot *et al.*, 2007).

The fish community data can be structured in various functional guilds according to Elliot *et al.* (2007). The guild approach compares the fish community according to their community function rather than at a taxonomic level. A fish guild is defined as a group of species that exploits the same class of environmental resource in a similar way (Elliot *et al.* 2007). These categories of guilds provide information on the functioning, hierarchical structure and connectivity of an estuary. This classification can also be used to simplify the very complex estuarine ecosystem. The three guilds that are identified by Elliot *et al.* (2007) are:

- Estuarine Use (EUFG): the overall ecological use of an estuary by a given species – migratory and physiological tolerances.

- Feeding Mode (FMFG): the primary method of feeding used by a given species – feeding behaviour and body structure.
- Reproductive Mode (RMFG): indicates how and, in some cases, where an estuarine species reproduces

A statistical approach was taken to assess the two estuarine sites associated with the proposed development. No reference fish community data is available for this part of Mozambique making a PES calculation difficult. The statistical programme used to analyse the fish community data was Canoco 4.5 software for multivariate data analysis. A Redundancy Analysis (RDA) was completed to determine the differences between the two estuary sites as well as to determine which environmental variables are possibly responsible for the differences. RDA is derivative of PCA, where the values entered into the analysis are not the original data but the best-fit values estimated from a multiple linear regression between each variable in turn and a second matrix of environmental data. Interpretation of RDA is undertaken through biplots (Shaw, 2003), which is a *map* of the samples being analysed on a two dimensional basis, where the placements of the samples reflect the (dis)similarities between the samples; in this case the sampling sites.

C8.4.6 *Bird Counts*

Enviro-Insight undertook bird counts at sites MOZ 4 and MOZ 6 during the high flow assessment, to feed into the estuarine assessment. The bird counts were undertaken at the same three points, along each of the estuaries, as sampled in the aquatic assessment. The bird counts were undertaken for approximately 10 minutes at each site, with all birds seen within a 50m radius recorded. Wader species within the intertidal zone were also noted at each of the estuary sites.

C8.4.7 *Vegetation*

Using Turpie (2010) as a guideline, habitats along the estuary profiles were identified based on vegetation identified. These habitats were assessed for species richness, rareness and diversity.

C8.5 *WETLAND ASSESSMENT*

A detailed wetland assessment was undertaken as part of the high flow aquatic assessment carried out in 2012. The low flow assessment focused on the wetlands directly associated with the aquatic sampling points. The methodology for the overall wetland assessment (low and high flow) is described below.

Prior to any field investigations being undertaken, the area was surveyed at a desktop level which involved the analysis of aerial imagery and contour data to determine the layout and extent of potential wetlands in the Onshore

Project Footprint Area. An interim classification of the wetlands was then carried out, as described below, and later verified in the field.

C8.5.1 *Wetland Classification*






The first level of classification of wetlands in the Onshore Project Footprint Area was based the following descriptions by Van Ginkel *et al.* (2011) for the basic terminology relating to wetland types:

- Palustrine wetland systems. Wetland systems with a high ground water content but which tend to be dry during the dry season. Water accumulates during the wet season and obligate wetland plants are adapted to grow in these habitats.
- Lacustrine wetland systems. Wetlands with permanent wet conditions and may include water bodies and shallow pans. The systems typically have plants growing in the water although riparian zones or floodplain areas can become dryer during the dry season.
- Riverine systems. River systems that have perennial running water or are seasonally dry. The habitats include the seasonal floodplains along the river reaches.
- Estuarine systems. Systems with water varying from fresh to brackish to very saline, and often close to coastal areas.

A popular wetland classification method for Southern Africa found in the WET-EcoServices manual (Kotze *et al.* 2007) was subsequently used for classifying the freshwater wetlands in the Onshore Project Footprint Area. This method classifies wetlands into hydro-geomorphic units based on characteristics of the geomorphology; patterns of water movement and the landscape / topographic setting. Six hydro-geomorphic categories are recognized as illustrated and described in *Table 8.7*. Artificial wetlands are excluded from the classification.

Table 8.7

Characteristic Wetland Hydro-Geomorphic Types Supporting Inland Wetlands in Southern Africa

HYDRO-GEOMORPHIC WETLAND TYPES		SOURCE MAINTAINING WETLAND	
		Surface	Sub-surface
Floodplain	 <p>Valley bottom areas with a well-defined stream channel, gently sloped and characterised by floodplain features such as oxbow depressions and natural levees and the alluvial (by water) transport and deposition of sediment, usually leading to a net accumulation of sediment. Water inputs occur from the main channel (when the channel banks overspill) and from adjacent slopes.</p>	***	*
Valley bottom with a channel	 <p>Valley bottom areas with a well-defined stream channel but lacking the characteristic floodplain features. May be gently sloped characterised by the net accumulation of alluvial deposits, or may have steeper slopes and be characterised by the net loss of sediment. Water inputs occur from the main channel (when channel banks overspill) and from adjacent slopes.</p>	***	*/***
Valley bottom without a channel	 <p>Valley bottom areas with no clearly defined stream channel, usually gently sloped and characterised by alluvial sediment deposition, generally leading to a net accumulation of sediment. Water inputs occur mainly from the channel entering the wetland and also from adjacent slopes.</p>	***	*/***
Hillslope seepage linked to a stream channel	 <p>Slopes of hillsides which are characterised by colluvial (transport by gravity) movement of materials. Water inputs are mainly from sub-surface flow and outflow is usually via a well-defined stream channel connecting the area directly to a stream channel.</p>	*	***
Isolated hillslope seepage	 <p>Slopes of hillsides which are characterised by the colluvial (transported by gravity) movement of materials. Water inputs mainly from sub-surface flow and outflow either very limited or through a diffuse sub-surface and/or surface flow, but no direct surface water flow connection to a stream channel.</p>	*	***
Depression (includes pans)		*/***	*/***



A basin-shaped area with a closed elevation contour that allows for the accumulation of surface water (ie it is inward draining). It may also receive sub-surface water. An outlet is usually absent, and therefore this type is usually isolated from the stream channel network.

Key: * = Contribution usually small; *** = Contribution usually important;
*/*** Contribution may be small or important depending on circumstances

Source: Kotze *et al.* (2007)

The wetland delineation methods used in the field were based on the DWA field procedure for identification and delineation of wetlands and riparian areas (DWAF, 2005). The following four indicators described by DWAF (2005) were used to determine wetland extent:

- **Terrain Unit Indicator:** The topography of the area was used to determine where in the landscape wetlands were likely to occur, and determine their outer limits. Detailed digital contour data with a 1 meter interval was provided by AMA1 for the Afungi Peninsula and surrounding areas. This data indicated even relatively minor topographical changes that have been useful for determining wetland extent.
- **Soil Form Indicator:** Some soil forms such as Champagne, Katspruit, Willowbrooke and Rensburg soils (based on McVicar, 1991) display distinctive soil wetness characteristics and can be used as indicators of wetland conditions. Some soil forms may occur in seasonal and temporary wetland zones, such as Kroonstad, Longlands, Wasbank, Lamotte, Estcourt, Klapmuts, Vilafontes, Kinkelbos, Cartref, Fernwood, Westleigh, Dresden, Avalon, Glencoe, Pinedene, Bainsvlei, Bloemdal, Witfontein, Sepane, Tukulu, Montagu, Inhoek, Tsitsikamma, Houwhoek, Molopo, Kimberley, Jonkersberg, Groenkop, Etosha, Addo, Brandvlei, Glenrosa, Dundee (DWAF, 2005). Such soil forms require further investigation into evidence of soil wetness and/or vegetation indicators for determining wetland extent.
- **Soil Wetness Indicator:** The soil wetness and duration of wetness are indicated by the colour of the soil. A grey soil matrix such as a G-horizon is an indication of wetness for prolonged periods of time and mottles(1) indicate a fluctuating water table. These mottles are normally most prominent just below the A-horizon. In terms of the DWA guidelines (DWAF, 2005), signs of soil wetness must be found within the top 50 cm of the soil surface to classify as a wetland. It must be noted that mottles may occur in non-wetland soils that have a high chroma matrix, and the colour of the matrix must therefore always be considered in conjunction with the presence of mottles.
- **Vegetation Indicator:** Vegetation is also a key component of a wetland definition, and a useful indicator of wetness extent. The presence or absence of hydrophytes provides a useful additional criterion in determining the boundaries of wetlands.
- **Riparian vegetation:** Wetlands may be delineated based on the extent of riparian vegetation. Mackenzie & Rountree (2007) describe an approach for delineating the riparian vegetation for sites that support

(1) High Chroma mottles develop in a soil profile under conditions of fluctuating saturation levels. Conditions fluctuating between aerobic and anaerobic states cause iron in the soil to oxidize. These particles accumulate and form mottles that are consider

predominantly indigenous and naturally occurring vegetation. The procedure involves identifying species that show evidence of being obligatory riparian species. Determine the outer edges of these species. With an overview of soil wetness indicators as described above and geomorphology (shape of the channel and riverbanks), the selected locations based on riparian indicator species should be at or close to an inflection point (change of slope) between the riparian area and the upland (terrestrial) slopes. This site can be considered as the edge of the riparian zone.

C8.5.3 *Riparian Present Ecological State (VEGRAI)*

The Riparian Vegetation Response Assessment Index (VEGRAI) model was applied to assess the riparian vegetation at selected sites in the Survey Area. The VEGRAI model, developed by Kleynhans *et al.* (2007), is used for qualitative assessment of the response of riparian vegetation to impacts in a way that qualitative ratings translate into quantitative and defensible results. Being impact-based, the VEGRAI system provides an indication of the causes for riparian vegetation degradation.

The VEGRAI model separates the vegetation of a site into the Marginal, Lower and Upper zones. The three zones are distinguished based on changes in lateral elevation, geomorphic structure and plant species composition. *Table 8.8* provides an overview of criteria for separation of zones.

Table 8.8 *Description of Riparian Vegetation Zones*

Extent	Zone		
	Marginal Zone	LowerZone	Upper Zone
Extends from	Water level at low flow	Marginal zone	Lower zone
Extends to	Geomorphic features / substrates that are hydrologically activated (inundated or moistened) for the greater part of the year.	Usually a marked increase in lateral elevation.	Usually a marked decrease in lateral elevation
Characterized by	Moist substrates next to water's edge; water loving- species usually vigorous due to near-permanent access to soil moisture	Geomorphic features that are hydrologically activated (inundated or moistened) on a seasonal basis. May have different species than marginal zone	Geomorphic features that are hydrologically activated (inundated or moistened) on an ephemeral basis. Presence of riparian and terrestrial species with increased stature

The zones are individually assessed but their scores are integrated to provide an overall index value for a site. Several vegetation characteristics such as Abundance, Cover, Alien infestation and Species Composition are used to describe and rate the status of the riparian vegetation. Each characteristic is assessed (where appropriate) for both a woody and non-woody vegetation component. A six-point rating system is followed, where metrics are scored in terms of the degree to which they have changed compared to the natural or close-to-natural reference:

- 0 - No discernible change from reference/close to reference
- 1 - Small modification from reference
- 2 - Moderate modification from reference
- 3 - Large modification from reference
- 4 - Serious modification from reference
- 5 - Extreme modification from reference

The vegetation zones are weighted using a similar approach. These weights are summed and a proportional weight determined for each metric group to provide an integrated value that relates to the Ecological Category for the riparian vegetation from A to F (*Table 8.5* and *Figure 8.2*).

C8.5.4 *Ecosystem Services Assessment*

The wetlands identified will be assessed in terms of their ecosystem services. The WET - EcoServices tool is a technique for rapidly assessing ecosystem services supplied by wetlands (Kotze *et al.*, 2007). This tool has been designed for inland palustrine wetlands, ie marshes, floodplains, vleis and seeps and has been developed to help assess the goods and services that individual wetlands provide to support planning and decision-making.

No systems are available for assessment of wetlands in Mozambique, the WET-EcoServices model developed for South African conditions is applicable to conditions in the Survey Area, and has thus been used. The wetland benefits included in the WET-EcoServices model were selected based on their importance, and how readily these can be assessed. Some benefits, for example groundwater recharge / discharge and biomass export may be important but are difficult to characterise at a rapid assessment level, and have thus been excluded. *Figure 8.5* identifies and describes the ecosystem services assessed during the rapid field assessment. Results are presented for each site using the standard spider charts produced by an Excel spreadsheet supplied with the model. Important ecosystem services are then briefly discussed.

Figure 8.5 Ecosystem Services Assessed using the WET-EcoServices Model (Kotze et al. 2007)

Ecosystem Services supplied by Wetlands		Indirect Benefits			
		Regulating & supporting benefits			
Direct Benefits	Regulating & supporting benefits	Flood attenuation		The spreading out and slowing down of floodwaters in the wetland, thereby reducing the severity of floods downstream	
		Streamflow regulation		Sustaining streamflow during low flow periods	
		Water quality enhancements	Sediment trapping		The trapping and retention in the wetland of sediment carried by runoff waters
			Phosphate assimilation		Removal by the wetland of phosphates carried by runoff waters
			Nitrate assimilation		Removal by the wetland of nitrates carried by runoff waters
			Toxicant assimilation		Removal by the wetland of toxicants (e.g. metals, biocides and salts) carried by runoff water
	Erosion control		Controlling of erosion at the wetland site, principally through the protection provided by vegetation		
	Carbon storage		The trapping of carbon by the wetland, principally as soil organic matter		
	Biodiversity maintenance		Through the provision of habitat and maintenance of natural process by the wetland, a contribution is made to maintaining biodiversity		
	<i>Biodiversity maintenance is not an ecosystem service as such, but encompasses attributes widely acknowledged as having potentially high value to society</i>				
	Provisioning benefits		Provision of water for human use		The provision of water extracted directly from the wetland for domestic, agriculture or other purposes
	Provisioning benefits		Provision of harvestable resources		The provision of natural resources from the wetland, including livestock grazing, craft plants, fish, etc.
Provisioning benefits		Provision of cultivated foods		The provision of areas in the wetland favourable for the cultivation of foods	
Cultural benefits		Cultural heritage		Places of special cultural significance in the wetland, e.g., for baptisms or gathering of culturally significant plants	
Cultural benefits		Tourism and recreation		Sites of value for tourism and recreation in the wetland, often associated with scenic beauty and abundant birdlife	
Cultural benefits		Education and research		Sites of value in the wetland for education or research	

An addition to the above wetland ecosystem services, DWA has published a list of goods and services provided by estuarine systems (DWA, 2008). These goods and services have been listed in *Table 8.9* and have been taken into account in the current study as sample sites MOZ 4, MOZ 6 and MOZ 12 are all estuarine sites.

Table 8.9 *Goods and Services Provided by Estuaries (DWA, 2008)*

Goods and services	Examples
Biological Control Refugia/Migratory Corridors	Maintaining the balance/diversity of plants/ animals Fish and crustacean nurseries and roosts for residential and migratory bird species
Sediment supply	Outputs of sediments which contribute to beaches, sand bars and sand banks
Erosion control	Soil retention by estuary vegetation, and by capturing soil in reed beds and mangroves
Soil formation	Accumulation of sediment and organic material on floodplains and in mangroves, beach replenishment
Nutrient supply and cycling	Nutrient supply, nitrogen fixation and nutrient cycling through food chains
Genetic Resources	Genes for mariculture, ornamental and fibre-producing species
Disturbance regulation	Flood control, drought recovery and refuges from natural and human induced catastrophic events (eg oil spills)
Living resources for food (or resale)	Line fishing, harvesting of inter-tidal invertebrates, beach and seine netting
Raw material for subsistence use (eg building material)	Harvesting of craftwork and house-building materials
Nature appreciation	Providing access to estuaries and associated wildlife for viewing and walking
Scenic views	Resort, residential houses, housing complexes and offices with scenic views, increasing value of properties with seaviews
Culture	Aesthetic, educational, research, spiritual, intrinsic and scientific values of estuary ecosystems
Sports fishing	Estuary fly-fishing, estuary and inshore conventional fishing
Water sports	Water sports: swimming, sailing, canoeing, skiing and kayaking
Waste treatment	Breaking down of waste and detoxifying pollution
Water supply and regulation	Fresh water supply to marine environment and water for mariculture
Mariculture (eg oysters, bait, etc.)	Production (natural and cultivated) of fish, crustaceans and worms
Commercial food production	Fishing
Raw material for commercial use	Diamond and titanium mining, sand winning and salt production
Transport services	Ports, harbours, marinas and ski boat launching sites

C8.5.5 *Wetland Sensitivity*

The sensitivity ⁽¹⁾ of wetlands was compared utilising frogs as key indicator species.

(1) Significance assessed based on sensitivity, presence of Conservation Important species and current level of disturbance.

A variety of factors make frogs particularly sensitive to environmental deterioration (Du Preez and Carruthers, 2009). These factors include:

- Absorbent skin surface – the permeable skins of frogs readily absorb water and any solvents that it may contain;
- Accessibility – frogs are a convenient group to monitor, being visually and acoustically conspicuous and widely distributed in most environments. Various field guides have been published with distribution data to facilitate field identification.
- Food contaminants – many tadpole species feed at the bottom of a water body where they are susceptible to ingesting chlorinated compounds and heavy metals if present. Most adult frogs are terrestrial and partly fossorial, and may also swallow contaminated soil and plant material;
- Fragmented distributions – many amphibians have specific habitat requirements resulting in patchy distributions for many species. Loss of habitat may isolate surviving populations, placing them under increased risk of local extinction in certain areas;
- Sequestered tissue contaminants – exposure to foreign hormones (or hormone-mimicking compounds) can disrupt the hormone-driven process of metamorphosis and the healthy development of tadpoles. The susceptibility of *Xenopus* (platanna frogs) to hormones was for many years exploited as a means of pregnancy testing.
- Temperature – frogs are small and unable to regulate their body temperature and are thus sensitive to extreme environmental temperatures which can adversely affect their biology;
- Amphibious lifestyle – frogs are dependent on both terrestrial and aquatic environments to maintain their life cycle. Deterioration in either of these habitats will result in a decline in the abundance and/or diversity of frogs.
- Trophic level – frogs are both voracious predators of invertebrate life and are themselves an important food source for a wide diversity of predators, particularly birds and reptiles. In either capacity, frogs are thus able to influence a wide ecological spectrum.

A species list for Mozambique was compiled prior to the site visit using a combination of sources (Channing 2001, Channing & Howell 2006, IUCN 2012). The probability of finding a particular species on site was estimated using a combination of distribution records and habitat preferences, in order to prioritize sampling strategy and active searching efforts towards detecting potential conservation important species during the site visit.

Frog species richness was assessed both diurnally and nocturnally through active searching and acoustic recording. Species were identified using field guides compiled by Du Preez and Carruthers (2009), Channing (2001) and Channing & Howell 2006.

Although frogs are sensitive to environmental change and meet the requirements for good indicator species further research is required to determine key indicator species based on measured responses to a wide range of anthropogenic stresses in order to develop a frog sensitivity response index.

Despite the limitations, a subjective method of describing wetland sensitivity based on the presence of frogs is explored here. Species were assigned a conservation importance rating (CI) based on the sum of the following variables:

- Population trend (PT)
- Number of records (NR)
- Distribution of records (DR)
- Habitat specificity (HS)
- IUCN Global Status (GS)

The wetland association (WA) of each frog species was assessed. This is defined as the degree to which the frogs are restricted to wet habitats throughout their adult lives. Spatial habitat use varies depending on the species as a general example *Xenopus sp.* are restricted to permanently aquatic habitats whereas various toads are able to make use of both terrestrial and aquatic habitats and move freely between such habitats.

A species sensitivity index (SI) was calculated by multiplying the CI rating with the wetland association (WA). The diversity of frogs was recorded for a wetland, and an Amphibian Wetland Significance (AWS) determined from the sum of the SI scores.

The Amphibian Wetland Significance can be summarised using the following formula:

$$AWS = \Sigma (WA \times (PT + NR + DR + HS + GS))$$

All wetlands are considered sensitive due to their ecological importance, however sites were allocated to one of three classes, namely Sensitive, Moderately Sensitive or Highly Sensitive based on a subjective assessment of the above criteria. In addition, discussions were held with the vegetation and herpetofauna specialists to agree on the wetland sensitivity classification.

C8.5.6

Buffer Requirements

A buffer is a strip of land surrounding a sensitive area in which activities are controlled or restricted to reduce the impact of adjacent land uses on the sensitive site. South African legal requirements (National Water Act of 1998), and similarly for many other countries, state that wetlands are to be

designated as sensitive and that buffers are necessary to protect wetlands against the harmful impacts of development but there is a lack of clarity on their specific extent. The basis for the determination of buffers used in this document is therefore guided by the following guidelines:

- Recently published wetland delineation guidelines (INR, 2011) stipulate that the determination of a wetland buffer should follow a holistic approach that incorporates the ecological state of aquatic systems, the level and sensitivity of biodiversity that is present and promote the continuity of ecological corridors. These attributes are to be determined at the discretion of appropriately qualified specialists that have conducted on-site assessments in these respective disciplines.
- Ezemvelo KZN Wildlife guidelines (2010) for buffer determination around wetland systems state the extent of a buffer is to be determined at the discretion of an appropriately qualified specialist, and increased under the following circumstances:
 - Steep slopes justify wider buffers;
 - Wider buffers are required around high impact developments;
 - Wider buffers are required where there is a greater pollution potential;
 - Wetlands of high conservation value deserve wider buffers.

This study does not include an in-depth assessment of terrestrial biodiversity ⁽¹⁾, however the determination of buffer extent requires insights into the Present Ecological State (PES), the levels of biodiversity and the sensitivity of wetlands. Such assessments (described below) have been conducted at a variety of sites with emphasis on riparian vegetation, frogs and general sensitivity as a result of red data species and anthropogenic impacts as per methods described below. Results of these assessments have been combined with input from Enviro-Insight to develop a holistic perspective on determination of buffer extent.

C8.6

STUDY LIMITATIONS

Limitations and uncertainties often exist within the various techniques adopted to assess the condition of natural ecosystems. The following limitations apply to the techniques and methodologies utilised to undertake the aquatic and wetland assessment:

- Mozambique experienced a civil war and there remains a threat of landmines in the DUAT Area. Demining of various areas of the DUAT Area has taken place, however a restriction of movement outside of cleared areas hindered the field procedures for accessing certain wetland portions. As the wetland delineation was largely desktop based this limitation is not significant.

(1) An assessment of the terrestrial biodiversity of the Afungi Project Site has been undertaken in a separate study by Enviro-Insight.

- No historical data (except aerial maps) was available for the aquatic and wetland systems assessed, the results of this investigation therefore serve as the baseline for the area.
- The watercourses mostly consisted of wetland systems, which lead to difficulty in interpreting the aquatic ecological status utilising standard riverine indices. The naturally lower numbers of sensitive taxa result in lower index scores, however, indices were incorporated into this study and utilised as a guide for future monitoring and impact identification.
- As no long term monitoring data is available for the Palma estuaries, a reference condition cannot be compared to the present ecological state of the system. For these reasons, assumptions have to be made based on a hypothetical natural state.
- At the time of this study there was insufficient record of historical rainfall history and estuary mouth conditions (regarding breaching of the open/closed system) for the Palma estuaries. The implications are that the influence of cyclical weather patterns on the estuarine vegetation could not be determined and the baseline hydrological status of the estuaries is unknown.
- The methodology used is largely intended for South African systems. It is possible that any components of the Palma estuaries that differ from the South African reference system may not be accounted for in this study.
- The degree of confidence, for a number of impacts, was assessed as Low due to limited information available. The results of a number of investigations were outstanding at the time of report compilation. The results of these studies will assist in finalising the impact assessment, for example the hydrology report.

C9.1 LITERATURE REVIEW AND DESKTOP STUDY

Prior to the start of site surveys planned for December 2011, a preliminary classification of the vegetation of the Study Area was made. This preliminary classification relied upon vegetation descriptions and maps presented in the report by Timberlake *et al.* (2010). This preliminary classification was updated based on the data gathered during the surveys conducted in December 2011 and March/ April 2012.

For an initial and broad scale differentiation of vegetation units of the area, vegetation communities are identified using vegetation classification criteria. The Study Area boundaries are delineated from satellite imagery, from which homogenous topographic-physiognomic areas are identified and delineated. The differing patterns, variations or shades on the satellite images are used to define the homogenous unit boundaries. To refine these, further environmental factors are taken into account. Geological formations and land types are obtained from geological and land type maps. Geographic factors (such as terrain form, topography and drainage lines) as well as man-made factors (such as roads and villages) are obtained from topocadastral and hydrological maps. Superimposing the different layers on the satellite imagery shows a more detailed partitioning of homogenous vegetation communities and highlights potential driving forces in plant community development.

C9.2 FIELD SURVEYS

After homogenous plant communities have been identified from maps and satellite imagery, potential survey plots are chosen using a stratified random sampling method ⁽¹⁾. Attempts were made to verify these potential survey plots in the field however, modification was required to avoid health and safety risks associated with the possible presence of UXOs. Survey plots were therefore restricted to areas accessible by use of existing roads and pathways.

Vegetation surveys were conducted during December 2011 and March/ April 2012. An assessment of the dominant plant species and habitat features, were made at each 25m x 25m survey plot. All plant species within the survey plots were identified and a percentage canopy cover value allocated, which is required for the classification and description of the plant communities. Representative percentage estimates of the vegetation canopy cover were made of each structural layer (lower, intermediate and upper canopy covers).

During the December 2011 survey period 45 survey plots were surveyed. During the follow-up visit in March/ April 2012 these plots were re-sampled to verify the presence or likely absence of Red Data plant species. Also during

(1) A randomly stratified sampling method distributes sampling plots evenly throughout the area to be surveyed.

this follow-up period, an additional 9 sample plots were surveyed, bringing the total to 54 survey plots.

A classification of the vegetation data was done with the TURBOVEG and MEGATAB computer programs (Hennekens & Schaminee 2001). Vegetation structure was analysed by calculating mean values (with standard deviation).

To visualise the relationship between the communities the floristic data were arranged using principal co-ordinates analysis (PCoA) (McCune & Grace 2002) in the SYN-TAX computer program (Podani 2001). Cover-abundance values were converted to percentages and the percentage values standardised using a natural logarithmic (loge) standardisation. The Bray-Curtis distance measure was applied for the ordination. An incremental sum of squares cluster analysis was also run in SYN-TAX using the log-transformed values and the Bray-Curtis distance measure (Podani 2001). The cluster analysis of the floristic data of all 54 survey plots clearly indicated the separation between the different plant communities.

C9.3

RED DATA FLORA ASSESSMENT

Because many countries in southern Africa do not have a list of endangered plant species one must attempt to gain this information elsewhere. It was assumed that if a species is on the red data list in a neighbouring country it is most likely also going to be rare in Mozambique. Therefore, baseline data from the National Herbarium Pretoria Computerised Information System PRECIS and data from the Red Data List of South African Plant Species were used to facilitate the identification of protected plant species. Verification of the presence or likely absence of these plant species was achieved by actively searching for these plant species. Proper identification of some species of Red Data plant relies on the identification of subtle differences in flower structure; when these species are not in bloom positive identification cannot be confirmed. In such instances emphasis was placed on the identification of potentially suitable habitat. This was done by comparing the habitat characteristics to known habitat types occupied by Red Data plant species.

During the December 2011 survey period 45 survey plots were surveyed for the occurrence of Red Data plant species. During the follow-up visit in March/April 2012 these plots were resampled to verify the presence or likely absence of Red Data plant species. Also during this follow-up period, an additional 9 sample plots were surveyed, bringing the total survey sites to 54.

C10.1 LITERATURE REVIEW AND DESKTOP STUDY

All available books providing information on distribution ranges and/or conservation status of Southern and Eastern African herpetofauna were utilized to make predictions of occurrence (see reference list). Limited herpetofauna reference material exists for northeast Mozambique; data related to geographic distribution ranges of herpetofauna show either Southern Africa (South of the Zambezi River, Mozambique) or Eastern Africa (North of the Rovuma river, Tanzania) distributions.

Consequently, there are no published geographic distribution ranges of herpetofauna for the portion of Mozambique on which the Survey Area is located. Extrapolation from existing geographic distributions was therefore performed in conjunction with habitat information obtained on-site to develop a list of herpetofauna predicted to occur within the Study Area. The precautionary principle was applied by including a species in the predictive list if the likelihood of occurrence was above an estimated 50% chance.

Reptile species nomenclature follows a field guide to the reptiles of East Africa (Spawls *et al.* 2004). A complete guide to frogs of Southern Africa (Du Preez & Carruthers 2009) and Amphibians of East Africa (Channing & Howell 2006) were used as the primary identification guides for amphibians and amphibian species nomenclature following the latter reference as well as that of AmphibiaWeb (www.amphibiaweb.org). It is important to note that the species nomenclature followed in the available references (Spawls *et al.* 2004; Channing & Howell 2006; AmphibiaWeb 2012) is outdated. Major taxonomic revisions have taken place and many new genus/species names now exist for some of these animals that are found in southern Africa (see SARCA 2012). For example, the genus *Bufo* no longer exists for African toad species (Du Preez & Carruthers 2009; IUCN 2012) but both Channing & Howell (2006) and AmphibiaWeb (2012) have retained this genus name. The outdated nomenclature is still preferable for the purposes of this report due to the lack of available literature on the updated nomenclature. However, in order to avoid confusion, the updated nomenclature is also provided where possible (eg verification by IUCN). The IUCN website (www.iucnredlist.org) was utilized to provide the most current account of the global conservation status of reptiles and amphibians. The Mozambique Forestry and Wildlife Law Regulation (Decree No. 12/2002) lists protected fauna in Mozambique and was consulted.

C10.2 FIELD SURVEYS

Data collection occurred over three distinct survey periods:

1. October 2011 – Scoping survey (no trapping) where herpetofauna were observed.
2. December 2011 – Main field survey with trapping.
3. March/April 2012 – Additional field survey with trapping.

The herpetofauna Study Area was restricted to the terrestrial environment and therefore no marine species or marine habitats were evaluated. The surveys were focused within the Afungi Project Site and concentrated in areas demarcated for infrastructure development. While observations were made outside of the Afungi Project Site, especially during driving to and from the site, it was not necessary to evaluate the herpetofauna in the regional context as their dispersal abilities are poor compared to birds and large mammals.

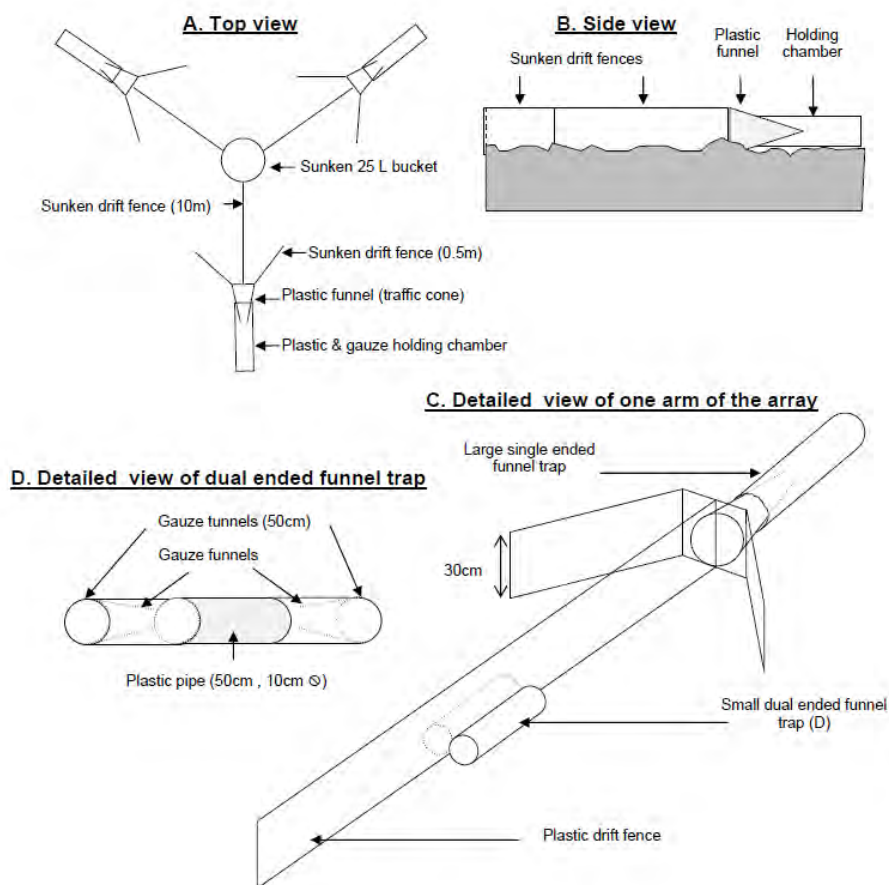
C10.2.1 *Herpetofauna Traps*

Trapping herpetofauna methods include the intercept drift fence principle where moving herpetofauna are diverted from their intended directional path along an impassable fence and into either a pitfall bucket or a specially designed funnel trap system. During the two field surveys (8-22 December 2011 and 28 March – 5 April 2012), a total of ten funnel trap drift fence arrays were placed in areas where herpetofauna diversity was expected to be greatest within a particular habitat. Trap array placement was also based on prevailing physical conditions, such as soil conditions and slope.

Each of the eight trap arrays deployed during the December survey were operational for 4 full nights, providing a total of 32 trap nights. The two traps deployed during the March/April survey were deployed for 7 and 6 nights each respectively, providing a total of 13 trap nights. The combined trapping effort was therefore executed over 45 trap nights. Traps were set at a particular location and then left active for a minimum of 4 trap nights before being re-deployed elsewhere. Each trap array was therefore active for 24 hours per day for a minimum of 4 nights. Traps were inspected each morning between 06:00-08:00 and all captured specimens were photographed and released away from the traps.

The general pitfall trap design is very effective in trapping herpetofauna, particularly lizards, small snakes and amphibians (Corn & Bury 1990; Branch 1998; Crosswhite *et al.*, 1999). However trap efficacy was increased by replacing the terminal 25 litre pitfall buckets with specialized terminal funnels (designed by L. Verburgt) and by the addition of funnel traps along the drift fences (eg Masterson *et al.*, 2009) as shown in *Figure 10.1*. This design of the funnel trap/ drift fence arrays retained the center 25 litre bucket (for trapping fossorial herpetofauna) and the combination of the pitfall and funnel traps provides enhanced trapping success.

Figure 10.1 *Funnel Trap Drift Fence Array used for the Capture of Herpetofauna*



Source: Enviro-Insight 2012

C10.2.2 *Climate Monitoring*

Because all herpetofauna are ectothermic and their behavior is heavily influenced by the presence of humidity and rain it is necessary to present reptile survey data in the context of the prevailing climatic conditions. A DS1923 HygrochroniButton® was placed at each funnel trap drift fence array to log the temperature and the relative humidity at 30 min intervals. Each iButton was placed inside an inverted ventilated polystyrene cup (Figure 10.2) to protect it against the effects of rain and direct solar radiation, and then fixed under a leafy tree at head-height in order to provide shade for the device over the duration of the day.

Figure 10.2 Climate Data Logger (Hygrochron Button)



Source: Enviro-Insight 2012.

C10.2.3 Active Searching

Reptiles were searched for on foot within the Survey Area during the day. Active sampling was focused on representative sites within each of the structural habitat types defined. Active searching for reptiles involved:

- photographing reptiles from a distance with a telephoto lens;
- searching under debris or rocks; which were returned to their original positions;
- removing exfoliating bark from trees;
- excavation of burrows that appeared to be in use;
- scanning for any signs of reptiles such as shed skins (the positive identification of which were taken as an observation of that species); and
- catching by hand where required.

Nocturnal reptiles were searched for by driving very slowly on the roads at night and shining with a spotlight on the road and surrounding vegetation. Nocturnal amphibians (frogs and toads) were searched for by torchlight at night along dam/pond edges and in wetland areas. Positive identification of amphibian acoustic signals (males call to attract females) was also used as a means of identifying amphibians. Where possible, acoustic signals were recorded with high-precision recording equipment and identification confirmed with existing recordings (Du Preez & Carruthers 2009). Furthermore, on several occasions acoustic signals were recorded at a location for the entire night by placing an automatically activated remote sound

recorded near the edge of a pond/wetland which was then retrieved the following day for data analysis.

C10.2.4 *Opportunistic Sampling*

Reptiles, especially snakes are very elusive and are consequently difficult to observe. Therefore, all possible opportunities to observe reptiles were taken in order to augment the standard sampling procedures described above. This was done to enhance the understanding of the herpetofauna species diversity within the broader Study Area. Methods employed include the following:

- During driving between the camp and Survey Area (minimum of 3 hours per day) the road was constantly scanned for active and killed (road collisions) reptiles. Driving speed was slower than normal to increase the chance of a successful observation. Once a reptile was observed the vehicle was brought to a halt and the observed reptiles would be photographed.
- People residing at the camp (AMA1 staff or other specialists) would on occasion take photographs of reptiles observed within the Afungi Project Site. These images were reviewed and, upon proper identification, added to the list of random observations.

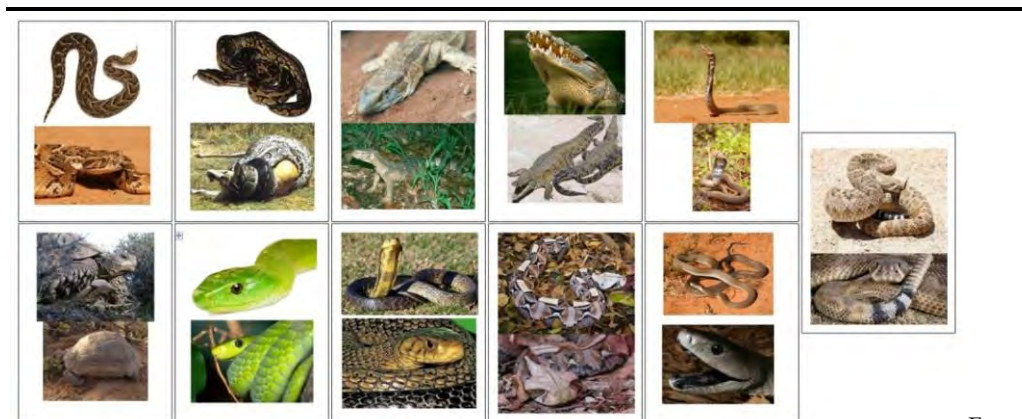
C10.2.5 *Interviews with Local Inhabitants*

Interviews were conducted with three villages/ communities (Maganja, Quitupo and Senga) during the March/ April survey. During these interviews, the village elders were asked (with the aid of an interpreter) to identify images of reptiles presented to them on a flash card (*Figure 10.3*) and answer several questions about these species. Flash cards were presented to interviewees in random order at each village. For each reptile species interviewees were asked the following questions:

- Do they kill the animal?
- Do they eat the animal?
- Is the skin used of this animal?
- Is any part of the animal used for traditional medicinal purposes?
- Has this animal bitten or spat at anyone?
- Has this animal killed anyone from this particular village?

All of the reptiles pictured on the flash cards are expected to occur in the Survey Area except for the Rattle Snake (North America) which served as a control to gauge whether the interviewees were being honest and were indeed capable of identifying a particular species correctly.

Figure 10.3 *Photographic Flash Cards Presented to Local Inhabitants during Interviews on Herpetofauna*



From

left to right, top to bottom: Puff adder, African rock python, Rock monitor lizard, Nile crocodile, Mozambique spitting cobra, Leopard tortoise, Green Mamba, Forest Cobra, Gaboon Adder, Black mamba, Rattle Snake

Source: Enviro-Insight 2012

C10.3 *LIMITATIONS AND ASSUMPTIONS*

The complete lack of published geographic distribution information for herpetofauna in North-Eastern Mozambique is a limitation of great importance. Almost no sampling for herpetofauna by scientists has taken place in this region which makes the prediction of species likely to occur on the Study Area problematic. Nevertheless, great care has been taken to use all of the available information and carefully extrapolate probable geographic distribution ranges for herpetofauna based on the proximity to known distributions (eg southern Tanzania) and the availability and continuity of important habitat types.

Site access was a highly significant logistical hurdle to overcome during the surveys for two main reasons:

1. The distance (~45 km) and poor condition of the only access road between the staff camp and the Survey Area meant that a minimum of 3 hours was spent driving per day (1.5hr one-way). This combined with health and safety restrictions on night time driving placed limitations of the time available for fieldwork. However, this transport time was used to maximum efficiency by actively searching for herpetofauna in the road and along the road edges (see *Section C10.2.4* above).
2. Access on foot was restricted to areas that had been cleared of unexploded ordinances and existing roads, which are limited in the area. This presented many constraints because it was not possible to access all of the areas preselected for sampling or general visitation. Furthermore, the ecological integrity of the demined areas was compromised by the disturbance associated with the demining activity (ie the removal of

vegetation and undergrowth to allow for the sweeping of their metal detectors. These areas are therefore significantly disturbed.

3. Upon raising these issues with the Project Team, it was suggested that access can be gained on foot if walking was restricted to the clearly used paths of the local inhabitants and/or livestock. While this compromise provided much better access, it influenced the surveys due to the disturbance expected to be associated with well-trodden paths (eg noise, vibration, erosion, vegetation clearing and wood cutting etc.).

The results of these field surveys provide a snapshot of the herpetofauna community and are intended to be used as a guideline to understand the composition of this community and its interaction with the different available habitat types.

C11.1 LITERATURE REVIEW AND DESKTOP STUDY

Prior to the site visit, a desktop review of publically available data was conducted. The following reference sources were consulted to gain an understanding of the expected mammals of the region:

- Red-data mammal lists (global and for Mozambique) were obtained from the IUCN Red List of threatened species (IUCN, 2012).
- Lists of nationally protected species were obtained from article 43(5) of the Regulations of Law No. 10/99, of 7 July.
- Stuart and Stuart (1998) and Skinner and Chimimba (2007) were consulted in order to aid with the identification of small mammals.
- Liebenberg (2005) and Stuart (1998) were consulted to aid with identification of tracks and signs.
- Geographic distribution and general data were acquired from Skinner and Chimimba (2007) and The Mozambique Ministry for the Coordination of Environmental Affairs (2009) to provide a predictive focal point for the survey.

The Project Team provided a large amount of site-specific information prior to the field surveys. This information was used in the selection of the trapping and sampling sites and this provided some degree of focus for the field study. Information used included:

- Aerial imagery provided by Promap.
- Remote sensing imagery obtained from Google Earth (Google Corporation).
- Site shapefiles provided by the Project Team.
- Basic site infrastructure plan provided by the Project Team.

C11.2 FIELD SURVEYS

Three baseline studies were carried out between October 2011 and April 2012. As mammals are endothermic, temperatures in a perennially warm area such as the Cabo Delgado province will not represent a limiting factor in movements, activity or behaviour. Seasonal differences in mammalian activity and breeding may be influenced primarily by water availability. Water not only provides basic moisture resources, but directly influences

habitat structure (refugia) and forage (food) availability; annual grasses provide both these functions and are the most seasonably variable vegetation type. A two-season approach has become standard practice for baseline data collection; this is aligned with best-practice models used for other projects in similar environments. Although the Project footprint did increase significantly during the study, it was an assumption that the data gathered during the two wet-seasons site visits as well as the initial dry-season baseline study would be sufficient to extrapolate the dry season data based on habitat similarities.

C11.2.1 *Timing*

The initial winter-dry season sampling period took place between the 11th and 20th of October 2011.

The first summer-wet season sampling period took place between the 8th and 21st of December 2011.

The second summer-wet season sampling period took place between the 27th of March and the 5th of April 2012.

C11.2.2 *Data Collection Methodology*

Data collection to characterize the mammalian baseline of the Survey Area was accomplished by using four methods; these comprise small mammal trapping, camera trapping, nocturnal surveys, and spoor tracking. These methods are described in detail below:

Small Mammal Trapping

Site selection for trapping focused on the representative habitats within the Survey Area. General trapping locations were selected on the basis of GIS mapping and aerial imagery; the selection of the actual trap site was confirmed through ground truthing. Habitat types sampled included primary woodlands, drainage lines and wetlands as well as disturbed and semi-disturbed zones (cultivation, tree felling and livestock).

For all three sample periods, the traps were deployed in pre-selected areas as described above. Each trap line consisted of 15 large Sherman traps baited with a combination of peanut butter, oats, sardines and oil; *Figure 11.1* shows an example of the traps used. In order to adequately cover the entire Survey Area, not all of the trap locations were repeated over the sample periods. Non-productive traps were relocated to increase the effectiveness of the trapping effort.

Each trap line was deployed and left active for five nights. They were then checked and re-baited each morning between 06:00-08:00. Traps were therefore active for 24 hours per day for a minimum of five nights. Captured animals were removed from the traps into clear plastic bags, identified, photographed and then released. The small mammal data collected was

limited to species trap successes and diversity in order to get a basic understanding of the small mammal assemblages in the area.

Figure 11.1 Sherman Trap



Source: Enviro-Insight 2012

Camera Trapping

Two infra-red camera traps were deployed in the Study Area for a period of 7 days, giving a total of 28 trap nights (4 traps x 7). *Figure 11.2* shows the typical trap set up for the camera stations. Traps were baited with dead goats in order to maximise the chances of any species in the area moving into the field of view to investigate.

Figure 11.2 Camera Trap



Source: Enviro-Insight 2012

Nocturnal Surveys

Eight night drive surveys took place during the three survey periods. Night drives were conducted after sunset to maximise the chances of encountering both crepuscular and fully nocturnal species. The routes taken were designed to encompass a representation of all the main habitat types. A one million candle power spotlight and smaller spotlights and torches were used to illuminate animals. The duration of these night surveys was between 2 and 3 hours each. Twice per season, a predator call-up was carried out in order to lure in large and medium sized carnivore species. A high powered amplifier was used and various sounds (dying animals, predator activity) were played for a period of three hours. In addition, baits were deployed in close proximity to the call-up site in order to maximise the chances of luring large predators to the area.

Spoor Tracking

Spoor tracking is considered to be the world's oldest science (Liebenberg 2005), enabling detailed sampling of mammalian species without the need for trapping or direct observation. All spoor, including footprints, scats, den sites, burrows, hairs, scrapings and diggings were documented through geo-referenced photography. The spoor tracking itself was focused on optimal tracking substrates, especially roads (in the early morning), drainage lines and wetland banks (where animal movements are focused). Liebenberg (2005) and Stuart and Stuart (1998) were the primary reference guides used for spoor tracking.

Interviews with Local Inhabitants

Throughout Mozambique, the acquisition of local knowledge has proved to be a highly useful method for obtaining data. A questionnaire was used in the interviews of the local communities. The information gathered from the questionnaire was used to provide focus on a number of issues concerning the mammalian fauna within both the Survey Area and the surrounding communities.

Sixteen sets of interviews were conducted during the three survey periods. Interviews were conducted both in Palma and in the villages of Quitupo, Maganja and Senga; additionally several random interviews of hunters and farmers were conducted. Rather than being randomly selected, the selection of villages surveyed was designed to be spatially representative in order to apply local knowledge to the specific areas within the habitats. The interviews were designed to provide information on:

- The extent of the current impacts on the mammalian fauna within the Survey Area (including poaching, human/wildlife conflict and use).
- The attitudes of the local communities towards the mammalian fauna.
- The mammalian assemblages, including density, diversity, preferred habitats and seasonality of various mammals.
- Occurrence of red-data species on the site (including the community awareness towards legislative protection of the protected species).

C11.3

LIMITATIONS

The objective of the field studies is to characterize the current mammalian baseline of the proposed Project Area. Sites were selected to represent habitat diversity as well as spatial representation. However, due to the potential for equipment theft (eg motion activated cameras) and restricted access due to the risk of unexploded ordinances, sample points were often positioned in sub-optimal zones. However, despite these limitations, it is deemed adequate coverage was achieved to characterize the mammalian baseline of the Survey Area.

C12.1 LITERATURE REVIEW AND DESKTOP STUDY

The following literature and published papers were consulted prior to the site visit:

- del Hoyo *et al.* (1992-2011) and Hockey *et al.* (2005) were consulted for general information on the life history attributes of relevant bird species.
- Distributional data (apart from those obtained during the surveys) was sourced from del Hoyo *et al.* (1992-2011) and Sinclair and Ryan (2010).
- Nomenclature, taxonomy, common names and the species order were used according to the IOC World Bird Names unless otherwise specified (see www.worldbirdnames.org; Gill & Donster, 2012).
- The conservation status of bird species was categorised according to the IUCN Red List of threatened species (IUCN, 2010), while their biogeographic affinities were obtained from Parker (2001).

C12.2 FIELD SURVEYS AND DATA ANALYSIS

As with other terrestrial baseline surveys, the avian baseline surveys encompasses two seasons. The dry season field studies were conducted 11-18 October 2011, while a wet season survey was performed during the periods of 8-20 December 2011 and 29 March - 5 April 2012.

During the surveys, bird species and their respective habitat types were identified, and where necessary, verified using Sinclair and Ryan (2010). The occurrence of certain bird species was also recorded by means of their calls and other signs such as nests, discarded egg shells (Tarboton, 2001), feathers and road kills. Particular attention was paid to suitable roosting, foraging and nesting habitat for threatened, near-threatened and endemic species.

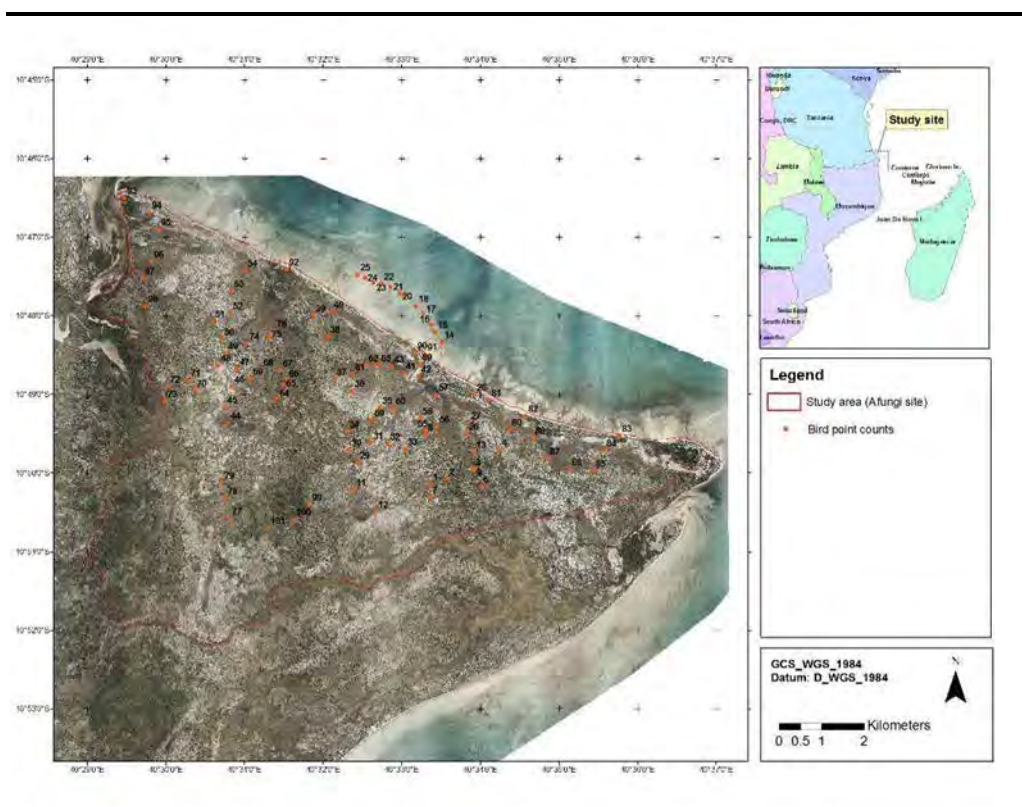
In addition, the expected occurrence of cryptic or elusive species was verified by the playback of their respective calls (eg African Broadbill (*Smithornis capensis*), Red-throated Twinspot (*Hypargos niveoguttatus*) and nocturnal/crepuscular taxa such as owls and nightjars).

Bird species were also recorded by means of random transect walks and during nocturnal road surveys. Inshore and pelagic seabird species was observed by means of a powered boat. Areas that were surveyed include the main bay area, the Cabo Delgado peninsula and the waters surrounding the two islands of Tecomaji and Rongui. These methods provide a continuous process of documenting bird species while moving between the different habitat types. These are effective methods to obtain a more complete list of

species but are not used to obtain data on abundances or dominance; point counts, described below, provide this data. However, point counts on their own will not provide a complete inventory due to the mobility birds and differences in habitat heterogeneity.

In order to obtain a statistically significant amount of information regarding the dominant/typical species, as well as the differences in community composition, an assessment was conducted whereby 101 point counts (see Buckland *et al.* 1993) were chosen. These point count locations represent the different habitat types on the Survey Area (eg closed and open woodland, dambos, mangrove forest and the inter-tidal littoral zone along the coastline) (Figure 12.1). Due to the smaller size of the intertidal area fewer locations were required to obtain a statistically significant data set. Therefore twelve point count locations were also dedicated to shorebird counts to evaluate the densities of wader species in the intertidal area.

Figure 12.1 Location of Bird Point Counts



During each point count, the number of bird species seen within a 50m radius (or 100m during shorebird counts) was recorded, as well as their respective abundances. Each point count lasted approximately 10-15 minutes and was at least 200m apart to ensure the independence of observations. The data generated from the point counts was analysed according to Clarke & Warwick (1994) and was based on the percentage contribution of each species to a particular habitat type including the consistency (calculated as the similarity coefficient \div standard deviation) of its contribution on the Survey Area.

Hierarchical Agglomerative Clustering - a cluster analysis based on group-average linkages (Clarke & Warwick, 1994) - was performed on calculated Bray-Curtis coefficients derived from the point counts. The bird count data was also subjected to fourth square-root transformation to allow for common as well as rare species to participate in the overall similarity analysis. A cluster analysis is used to assign associations between samples with the aim to objectively delineate groups or communities. Therefore, sampling entities that group together (being more similar) are believed to have similar compositions.

The use of point counts is advantageous since it suits areas of dense habitat (eg forest) and is preferred for cryptic or elusive species. In addition, it is the preferred method to line transects where access is problematic, or when the terrain appears complex. It is a good method to use, and very efficient for gathering a large amount of data in a short space of time (Sutherland, 2006).

Bird species richness was measured on each habitat type by means of rarefaction and selective diversity indices. Rarefaction adjusts the number of species expected from each sample if all were reduced to a standard size.

C12.3

LIMITATIONS AND ASSUMPTIONS

In order to obtain a comprehensive understanding of the dynamics of terrestrial communities, as well as the status of endemic, rare or threatened species in any area, assessments should always consider investigations at different time scales (across seasons/years) and through replication. Therefore, the current document only provides a “snapshot” of the avifaunal composition and structure.

The analysis of the community structure and composition was primarily based on data collected during the two independent sampling surveys (although a preliminary survey was also initiated during October 2011). Therefore, the avifaunal richness on the Survey Area should be interpreted within these limitations. Certain species (eg Palaearctic and Intra-African migrants) may have been absent during part of the survey period.

The risk posed by unexploded ordnances prevented the field survey team from accessing certain locations within the Survey Area.

C13.1 OVERVIEW

The Marine Modelling study has been undertaken using a combination of numerical models including:

- Spectral wave refraction modelling.
- 2D Hydrodynamic modelling.
- 3D Hydrodynamic modelling and cohesive sediment transport models.
- Lagrangian particle tracking modelling for offshore drill cuttings.

Baseline conditions have been ascertained from available bathymetry, aerial photographs and hindcast wind and wave data. Based on this available hydrographic wind and wave data (~13 years) representative conditions have been used to force the models in order to determine the impacts on the physical environment caused by the construction and operation of the near shore infrastructure

The approach followed in the marine ecology assessment included:

- Field investigations and measurements in Palma Bay and the Golfinho and Prosperidade Gas Fields.
- Interrogation of the available peer and non-peer reviewed scientific literature.
- Based on the provided project details (*Chapter 4* of the EIA), an evaluation of the risks that the proposed LNG development project presents to marine ecology in the region.

The assessment was aided by companion surveys of bathymetry and seabed features in Palma Bay conducted by UWS, metocean measurements made by MSI and the detailed EIAs for earlier phases of the project (Impacto 2008, CSA 2007, 2008).

The marine modelling studies were used in the assessment of the potential impacts on the marine ecology. These include the fate and dispersion of fines released during the dredging operations associated with the construction of the facility, the dispersion of expected marine discharges including desalination brine concentrates and process water, the dispersion of drilling cuttings, etc.

The impact assessment is guided by the methodology outlined in *Chapter 3* of the EIA however some deviations and specificities have been made and these are detailed in *Section C13.5* below.

Predictions made in this assessment are constrained by the facts that:

- The simulation modelling results used are theoretical until monitoring has been done to test them.
- Cumulative marine effects cannot be predicted with confidence as it is unclear how the offshore and onshore hydrocarbon industry, and associated developments, in the central east African region will be co-ordinated.
- As it is proposed, with the current development being built by various construction and installation contractors using equipment and methodologies yet to be identified, details cannot be assessed at this stage.

Accordingly, in addition to using the results of fieldwork done on site by Lwandle, this assessment draws on specialist opinion and experience with environmental work in the oil and gas industry.

The host environment of the proposed development is described below in two overlapping parts; the offshore gas field and the nearshore development site in Palma Bay. The descriptions are drawn from previous environmental assessments for the exploration phases (eg Impacto Lda 2008), contributions by Mozambican specialists on ecology and fisheries, observations made during site visits to Palma Bay in June and November 2011 and March 2012, and an oceanographic survey of the offshore Prosperidade and Golfinho gas fields in June 2012.

C13.3

DATA COLLECTION –OFFSHORE AREA

Data for the Offshore Project Area was drawn from available secondary information including previous environmental assessments for the exploration phases of the Project (eg Impacto Lda 2008), contributions by Mozambican specialists on ecology and fisheries, and an oceanographic, plankton and sediment survey of the offshore Prosperidade and Golfinho Gas Fields undertaken by Lwandle in June 2012 on the Rylan-T cruise commissioned by AMA1. The surveys undertaken in the offshore are detailed further below.

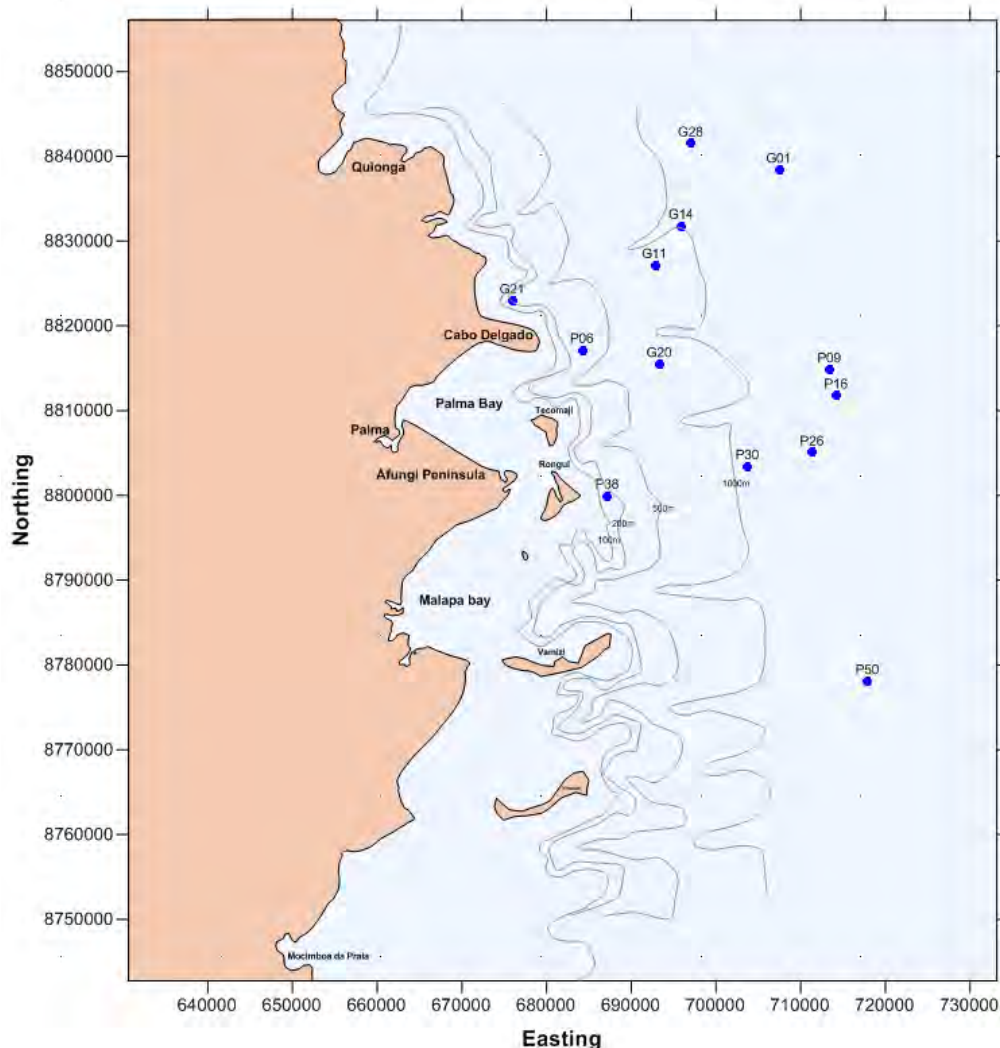
C13.3.1

Oceanography

To gain information on the oceanography of the offshore gas field development area, upper water column profiles of temperature, conductivity (= salinity), dissolved oxygen concentrations, turbidity, chlorophyll fluorescence (= chlorophyll a) and UV fluorescence were measured in June 2012 on the Rylan-T cruise with Lwandle marine specialists present.

The measurement locations are shown in *Figure 13.1*. The main features of the acquired data are presented below.

Figure 13.1 Conductivity-Temperature-Depth (CTD) Survey Sampling Locations in the Offshore Study Area, June 2012



Source: Lwandle, 2012. Data collected during June 2012 survey.

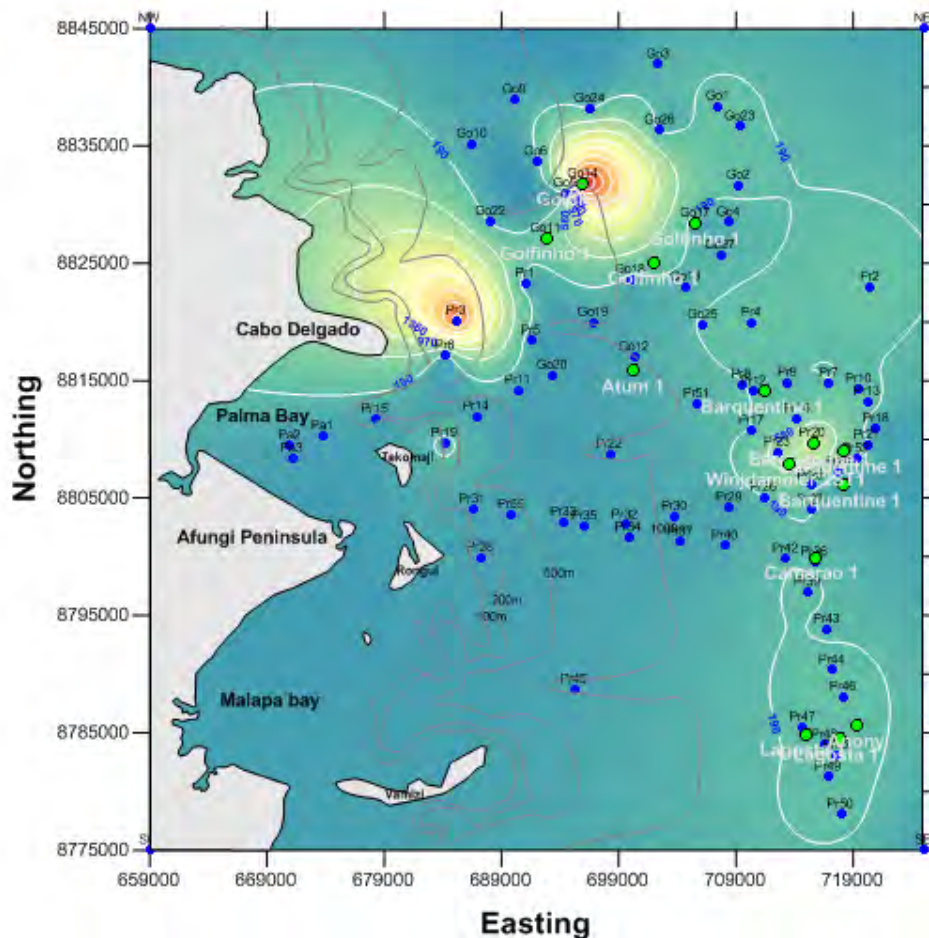
C13.3.2 *Plankton*

Water samples collected from the offshore CTD sampling stations in June 2012 (see Section C13.3.1) were analysed for chlorophyll fluorescence and composite profiles.

C13.3.3 *Sediment*

Surficial sediment sampling in the offshore gas fields and pipeline corridors was conducted by box core (deep water sites) and Day grab (shallow water sites) on the Rylan-T cruise in June 2012 to determine sediment properties. The locations of sediment sampling stations are shown in Figure 13.2. Sediments from 75 samples were analysed for particle size distributions and texture, and heavy metal concentrations.

Figure 13.2 Sediment Survey Sampling Locations in the Offshore Study Area, June 2012



Key: Blue dots: locations of sediment sampling locations. Green dots: known locations of drilled wells. White Line: distribution of the barium concentrations in mg/kg.
 Source: Lwandle 2012. Data collected during June 2012 survey.

C13.3.4 *Benthos*

Benthos samples were taken by box core at the locations shown in the figure above. For each station approximately 12 litres of sediment was filtered through a 0.5 mm aperture mesh sieve on a Wilson’s autosiever. The retained benthos was preserved in 4% formalin neutralised with sodium borate and delivered to a laboratory for processing.

In the laboratory, benthos specimens were identified to the lowest taxonomic level possible and counted. Wet biomass was estimated by blot-drying the specimens on absorbent tissue for a standard period of time and weights recorded per species per sample using an analytical balance. Taxa retained on the 0.5 mm screen that traditionally are considered to be meiofauna (eg nematodes, copepods, ostracods and foraminifera) were not included in counts, biomass measurements or subsequent analyses. This is in line with other studies on deep sea macrofauna (eg Levin et al. 2000, Gallardo et al. 2004).

Diversity indices (eg number of species, abundance, biomass per 0.1m², richness, evenness, and Shannon-Wiener diversity) were computed for all samples (PRIMER v6, Clarke & Warwick 2001). The Shannon-Wiener diversity index is a measurement of biodiversity taking into account the number of species and the evenness of the species (evenness expresses how evenly the individuals are distributed among the different species, in other words whether a community is dominated by individuals of one or few species (low evenness) or whether all species contribute evenly to the abundance (high evenness)). The unit-less index is increased either by having additional unique species, or by having a greater species-evenness.

The computer package PRIMER 6 & PERMANOVA+ was used to analyse the benthic data following the multivariate analysis procedures described by Clarke & Warwick (2001), Clarke & Gorley (2006), and Anderson et al. (2008, and other references therein). All data were 4th-root transformed, and a Bray-Curtis resemblance matrix computed. This was followed by hierarchical cluster analysis and multi-dimensional scaling (MDS). The latter is an ordination 'map' in two dimensions, where the distances between the samples represent their dissimilarity; i.e. the closer the samples are depicted in the MDS, the more similar they are. The stress value gives a measure of how well the two-dimensional picture may represent the sample relationship, a stress value >0.25 indicates that a higher dimensional projection may be more appropriate and that patterns discerned in the two dimensional plot should be treated circumspectly.

C13.3.5 Reef Structures

CSA as part of their gas field exploration and simulation modeling for drill cuttings and mud discharges, analysed ROV seabed video surveys around five sites in the Golfinho gas field in 2012. Lwandle augmented the findings of this study with Remotely Operated Vehicle (ROV) video records from five current meter deployment sites off Palma Bay. The locations of these and the water depths for each and types of transects deployed are listed in *Table 13.1*.

Table 13.1 Seabed ROV Video Surveys in the Gas Fields Offshore of Palma Bay

Site	Approximate Location (WGS 1984 UTM Zone 37S)		Water Depth (m)	No. of transects	Transect lengths and layout
	X	Y			
Golfinho 1	694835	8835250	1010	17	400 m, grid
Golfinho G	692805	8827130	845	8	400 m, radial
Golfinho M	705570	8828395	1290	8	400 m, radial
Golfinho N	694820	8841230	1075	8	400 m, radial
Golfinho O	686515	8835175	730	8	400 m, radial
CM8	693024	8812646	655	4	~500 m, orthogonal
CM9	685690	8805685	390	4	~500 m, orthogonal
CM10	692767	8798344	515	4	~500 m, orthogonal
CM11	709885	8820012	1459	4	~500 m, orthogonal
CM13	716142	8806133	1510	4	~500 m, orthogonal

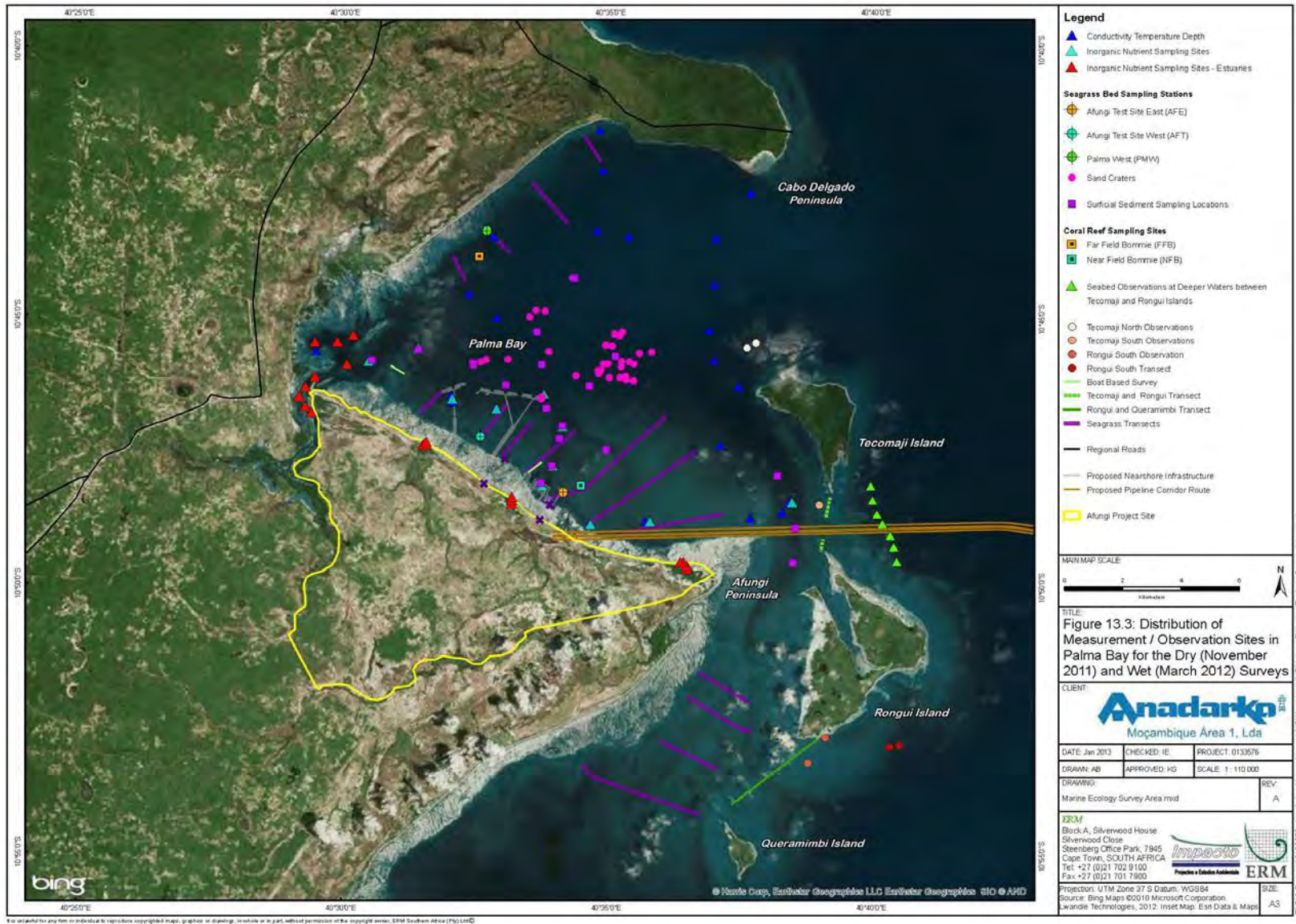
Source: Lwandle 2012. Data from CSA (2012) and MSI (2012 in litt.).

Location specific information and data for Palma Bay are sparse. Therefore as part of the LNG Facility site selection process, and subsequent environmental baseline data gathering and design data procurement, intensive investigations of the area have been carried out. These include bathymetric and sub-bottom profiling (UWS), metocean measurements within the bay and offshore (MSI) and dry (November 2011) and wet season (March 2012) marine ecology surveys (Lwandle). The results of these surveys are discussed in *Chapter 7* of the EIA Report with the main focus being on marine ecology surveys which are augmented by contributions on the marine ecology of the region (Adriano Macia) and fish and fisheries (Emídio André and Atanasio Brito).

The marine ecology surveys undertaken in Palma Bay by Lwandle comprised water column measurements of temperature, salinity, dissolved oxygen, turbidity and pH, water sampling for dissolved inorganic nutrients concentrations, distributions, and surveys on seagrass, coral and sandy beach ecology. The survey and analysis methods used are detailed in Sections C13.4.1 to C13.4.7 below.

Figure 13.3 provides a schematic view of the distribution of measurement stations and observation sites surveyed in Palma Bay in relation to the marine facilities planned for the LNG Facility.

Figure 13.3 Distribution of Measurement / Observation Sites in Palma Bay for the Dry (November 2011) and Wet (March 2012) Surveys



C13.4.1 *Palma Bay Water Column Properties*

Various physical parameters were measured within Palma Bay including:

- temperature and salinity;
- dissolved oxygen;
- turbidity;
- pH;
- organic nutrients;
- inorganic nutrients; and
- chlorophyll.

The location of the sampling sites are shown in *Figure 13.3*. Each of these parameters were measured in the dry (November) and wet (March) seasons in Palma Bay with the exception of inorganic nutrients which were only observed during the wet season.

C13.4.2 *Sediment Properties and Seabed Features*

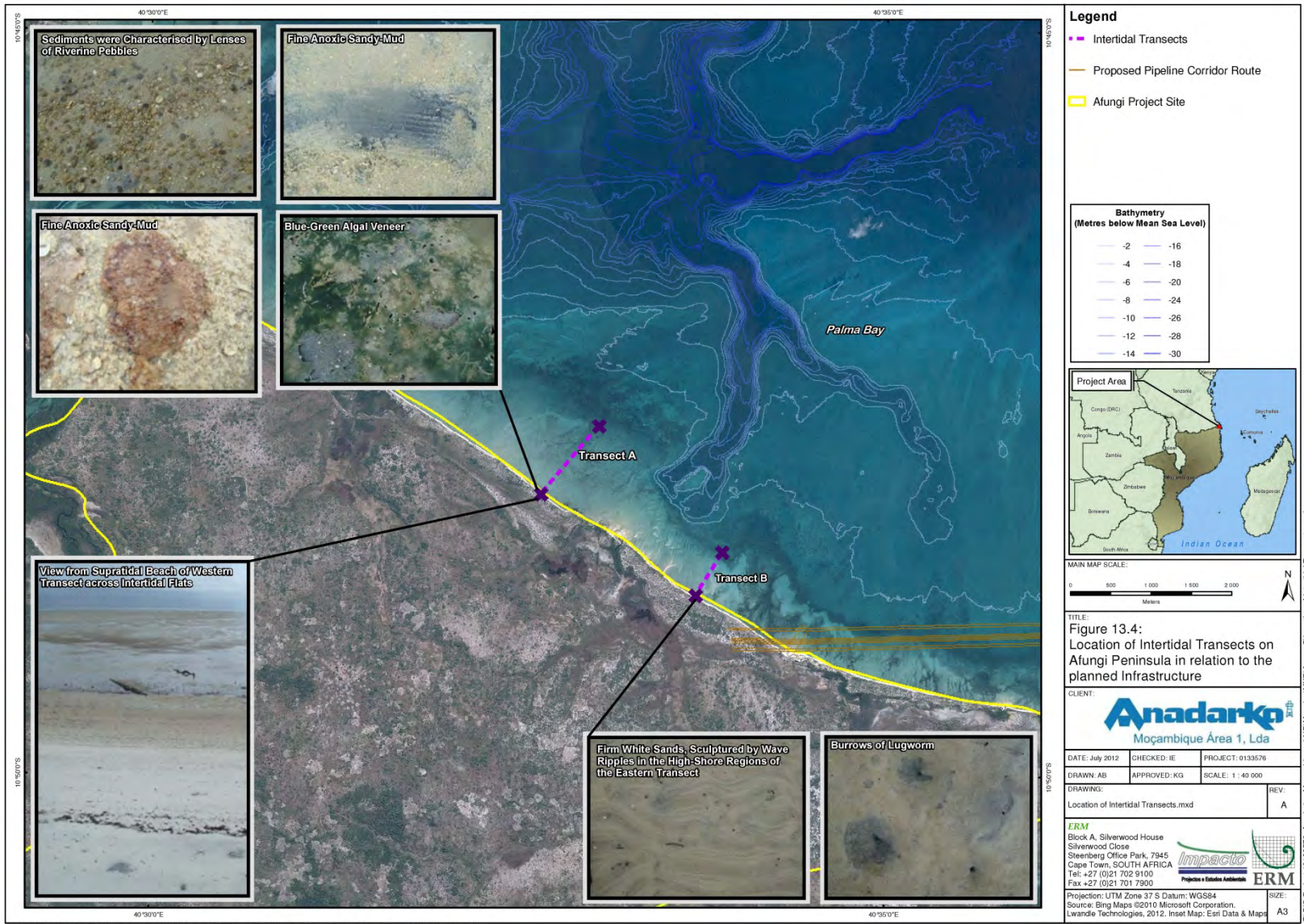
Surficial sediment samples were taken from various locations within the bay (see *Figure 13.3*) during the wet season survey.

C13.4.3 *Intertidal Sand Beaches*

The extensive sandy beach area on the northern shore of the Afungi Peninsula was inspected during the wet season survey in March 2012. Qualitative assessments of beach type and the major biological features were made on two transects extending from the primary dune to the bottom of the intertidal zone (*Figure 13.4*).

The inspection involved collecting both video footage and photographs along the transects. Samples of seagrass and dead shells were collected in limited quantities for subsequent identification.

Figure 13.4 Location of Intertidal Transects on Afungi Peninsula in relation to the planned Infrastructure



C13.4.4 *Seagrass Distribution*

Three sampling sites were selected for the quantitative seagrass bed survey; two 'test' or 'impact' sites in the extensive Afungi seagrass bed bordering the proposed development area and one 'reference' site on the western shore of Palma Bay (*Figure 13.3*).

Sites Afungi Test Site West (AFT) and Afungi Test Site East (AFE) are directly west and east of the area that will be dredged for the construction of the jetty and to deepen the entrance channel for vessels, and may thus be potentially affected by the dredging activity. The reference site Palma West (PMW) is located in the seagrass bed on the western shore of Palma Bay, >8 km away from the proposed development site on Afungi peninsula.

At each of the three sites, five 40 m long transects (A-E) were placed parallel to the shore at distance intervals of approximately 100 m. Positioning of the transect lines was random, but care was taken that all transects were in comparable water depths (1-1.50 m), both within a site as well as among sites. The GPS positions of the starting points were recorded.

Starting at 0 m, a 50 x 50 cm quadrat (0.25 m²) was placed every 5 m along the transect line, resulting in 8 quadrats per transect line. In principle, the survey method followed the seagrass bed survey manual developed by Short et al. (2004), and included the following observations and measurements for each quadrat:

- A photo of the sea bottom in the quadrat;
- Per cent cover of all seagrass plants in the quadrat, and cover of each species separately. Cover in this study was defined as the fraction of the total quadrat area that is obscured by a particular species (or the sum of all plants) when viewed directly from above;
- Shoot density of all seagrass species counted in a smaller 25 x 25cm (0.0625 m²) quadrat that was positioned in the right hand corner of the larger quadrat towards the transect line;
- Canopy height of the dominant species. For large species, this was done by selecting a clump of seagrass blades from within the quadrat, extending the leaves to their maximum height, and measuring from the substrate to the leaf end, but ignoring the tallest 20% of leaves. For small species that were widely distributed, the length of five individual shoots was measured and the average height calculated; and
- A biomass core (10-cm diameter or 0.00785 m²) from an area outside the quadrat that was representative to the species assemblage inside the quadrat. If not all species present could be covered with one biomass core, a second core targeting the desired species was taken. The sediments were washed from the core sample, shoot density per species counted and the

plant material separated into leaves, sheath/stem and root-plus-rhizome. Due to logistical limitations, plant material could not be dried to constant weight for determination of dry weight, and thus only wet-weight biomass could be estimated. Each plant section was blot-dried on absorbent paper towels and weighed to the nearest 0.1 g.

For each transect, the average (n = 8 quadrats) total %cover, %cover per species (per 0.25m²), shoot density per species (no/0.0625 m²), and canopy height of dominant seagrass species (per 0.25 m²) was calculated. Per species biomass was calculated by dividing the biomass per species by the number of shoots per species collected in each core sample. Species biomass was then calculated by multiplying species specific per-shoot-biomass by the number of shoots counted in the 0.0625 m² quadrat. Biomass was divided into total above-ground (leaves-plus-sheaths/stems) and below-ground biomass (roots-plus-rhizome) and expressed per 0.0625 m².

C13.4.5 *Shallow Coral Reefs and Outcrops*

Count, visual and photographic observations of coral reef features were undertaken at two locations within Palma Bay, a nearfield site, which is situated sufficiently close to the proposed marine facilities area to be exposed to potential dredging effects, and a far-field site in the same depth range but at a distance unlikely to be impacted by the dredging (*Figure 13.3*).

C13.4.6 *Fringing Coral Reef*

The fringing coral reef areas around and between the three islands in and immediately south of Palma Bay were surveyed to provide comparative information to be used in the selection of a gas import pipeline corridor. The surveys comprised surface and diver based inspections of the shallower areas (<15m depth) and ROV video coverage of the outer reef area between Tecomaji and Rongui Islands to ~50m depth. The sites/transects surveyed are shown in *Figure 13.3*.

Inter-Island Transects

- Rongui – Queramimbi Islands: Fifty individual observations of coral reef and associated or isolated coral bommies were made along the 3.8 km long transect between these two islands.
- Tecomaji – Rongui Islands: This transect was relatively short at 2.04 km and 19 observations of seabed types were made across the transect.

Island Transects

- Rongui South Transects: Three 100 m length transects were surveyed. Underwater still photography was used to aid the interpretation of the video records per transect.

- Tecomaji South Transects: Three 100 m length transects were surveyed. Underwater still photography was used to aid the interpretation of the video records per transect.
- Tecomaji North Observations: Visual and photographic observations of coral reef features were undertaken towards the seaward drop-off at two locations to the north of Tecomaji Island (Tecomaji North Deep: ~7 m and Tecomaji North Shallow: ~5 m). No video transects were conducted at these sites.
- Rongui South Observations: Visual and photographic observations of coral reef features were similarly undertaken at two locations offshore the Rongui south video transects and west of the southern point of Rongui Island (Rongui South Deep: ~6 m and Rongui South Shallow: ~4 m). Again, no video transects were conducted at these sites.

Coral and Seabed Features in Deeper Water between Tecomaji and Rongui Islands

During the wet season survey (March 2012) ROV video footage was obtained between the approximated depths of 5m and 70m at seven locations between Tecomaji and Rongui Islands. This area was selected for inspection as the Project Engineers had determined that it was the most suitable area for the gas import pipeline corridor.

The video record was examined and the seafloor broadly classified according to whether it comprised well developed reef, patchy sand and reef, or sand in 5m depth bands (depth record taken from ROV pressure sensor). The criterion used was whether the seafloor in the depth band could be readily classified into one of the three categories.

C13.4.7 *Fish*

There are no survey data available for fish within Palma Bay. However, being part of the Quirimbas Archipelago it is probable that the fish species recorded for coral reef and seagrass biotopes to the south of Palma Bay will occur in the bay. The larger pelagic species listed in Section 4.3.1 of the Marine Ecology Assessment (2012) are wide ranging and will certainly occur in the area, even if confined to deeper waters at the entrance to Palma Bay.

Data related to fish associated with coral reefs and seagrass beds are based mainly on data derived from the Darwin/Frontier Mozambique Quirimbas Archipelago Marine Research Programme (April 1996 to December 1997).

C13.5 *ADJUSTED IMPACT ASSESSMENT METHODOLOGY*

The impact assessment criteria used are as specified in *Chapter 3* of the EIA Report. Where feasible, specific standards or guidelines are used to determine the acceptability of impacts, and any key gaps in knowledge are mentioned. For the purpose of assessing the potential impacts, natural components of the

nearshore marine and Palma Bay environment are assessed separately from impacts on natural components of the offshore/ deep-water environment. The dividing line used to separate these environments for impact assessment purposes is illustrated in *Figure 13.5*; this line approximately follows Mozambique's Maritime Baseline designating its internal waters (Law of the Sea, 4 of 1996).

Figure 13.5 Maritime Baseline (white dotted line) between Off/On-Shore Areas of Impact Assessment, (set at ~1.5 km east of the islands)



Source: Lwandle, 2012.

C13.5.1 Nearshore/ Palma Bay Environment

For the Palma Bay/ nearshore assessment the “scale/extent” criterion used is as illustrated in *Figure 13.6* below.

Figure 13.6 Indicative Divider (white dotted lines) Between areas of Impact Assessed for the Inshore Marine Environment



Source: Lwandle, 2012.

On-site means impacts are restricted to inside a block drawn around the marine facility construction area (approximately 1 km east of the gas import line shore crossing point).

Local means impacts are restricted to within the Internal Waters of Palma Bay inside the Maritime Baseline approximately 1.5 km east of the Islands, between Cabo Delgado Peninsula and a line through Queramimbi Island.

Regional means impacts are restricted to within the Internal Waters of Cabo Delgado Province, ie to a line approximately 1.5 km east of the easternmost islands (Figure 13.6).

National means impacts are restricted to within Mozambique's EEZ which in this area possibly means about ~30 km to the north (Tanzania EEZ) and ~70 km to east (Comoros potential EEZ)⁽¹⁾.

International means impacts extend into adjacent States' Maritime Zones (ie Comoros and Tanzania), or affects internationally valued resources.

Furthermore, Lwandle have added a "**medium term**" of 7 years to the duration criteria to provide for a reasonable marine recovery period after construction and commissioning.

C13.5.2 *Offshore Environment*

The criteria used to assess the significance of potential impacts in the offshore area are the same as those used for the inshore area under *Section C13.5.1* above except that, because the gas fields are in the open ocean, '**extent**' is defined in km² around the source of the impact as follows:

On-site = <5 km²

Local = 5-50 km² (~7x7 km)

Regional = 50-500 km² (~22x22 km)

National = ~30 km to the north (Tanzania EEZ) and ~70 km to east (Comoros potential EEZ).

International = beyond Mozambique's EEZ.

(1) Because of an agreement with Tanzania and potential claims by Comoros (refer Section 5.4.1: International Maritime Boundaries)

C14.1 ASSESSMENT METHODOLOGY

The following references were used to inform the methodology and assessment process:

- The Landscape Institute and Institute of Environmental Management and Assessment (2002) Guidelines for Landscape and Visual Impact Assessment: Second Edition.
- United Kingdom Department of Trade and Industry (DTI) (2005) Guidance on the Assessment of the Impact of Offshore Wind Farms: Seascape and Visual Impact Report, DTI, London.
- CCW (2001) Guide to best practice in seascape assessment. CCW, Brady Shipman Martin and University College Dublin.

Key definitions of relevance to this study are presented below as follows:

- Seascape is defined in the above referenced guidance by DTI as the coastal landscape and adjoining areas of open water, including views from land to sea, from sea to land and along the coastline. Every seascape has three components. These include an area of sea (the seaward component), a length of coastline (the coastline component) and an area of land (the landward component).
- Landscape is the land based element only. It starts at the coastline and extends inland.
- Landscape character is the distinct and recognisable pattern of elements that occurs consistently in a particular type of landscape, and how this is perceived by people.

There are no standardised seascape assessments covering the coastline of Mozambique. Guidance on this topic is currently in use in the United Kingdom, specifically the above referenced DTI (2005) Guidance. This defines National Seascape Units as 'an extensive section of the coast with an overriding defining characteristic such as coastal orientation or landform, defined by major headlands of national significance'. The same methodology for defining seascape is used in this assessment, applied to the local landscape of the study area.

Similarly there is no available landscape character data covering the landscape of the site at Mozambique. The baseline addresses also the landscape character of the study area with reference to the above mentioned guidance.

C14.2

STUDY AREA

A study area for the assessment was defined based on the main large scale elements of the proposal which include the LNG Storage Tanks (45m height), Flare Stack (140m height), Airport Control Tower (6m height), and the Near Shore Project components (two LNG export jetties (hereafter referred to as the 'LNG Export Jetty'), Pioneer Dock and MOF). The study area for the elements of the proposal includes an area with a 30km radius measured from the centre of the site as shown in *Chapter 6*. The study area has been defined in the absence of specific guidance in relation to this type of development and has been selected based on professional judgement in the belief that all significant landscape, seascape and visual effects would be captured within this 30 km radius range.

C14.3

METHODOLOGY – KEY STEPS

The key steps in the methodology were:

- Zones of Theoretical Visibility (ZTVs) were defined for the main potentially visible elements of the scheme. These include the LNG Storage Tanks (45m height), Flare Stack (140m height), Airport Control Tower (6m height), and the Near Shore Project components (LNG Export Jetty, future jetty, Pioneer Dock and MOF). The ZTVs show the theoretical visibility of the scheme covering the landscape and seascape of the study area. The visibility is measured as theoretical. It is based on bare earth reflecting existing topography only and excludes screening provided by vegetation and buildings. The ZTVs are illustrated in *Chapter 12* of the EIA Report.
- The landscapes and seascapes of the study area were defined and characterised as part of the baseline study. A written account of the characteristics of each landscape and seascape is presented in the baseline derived from studies undertaken by the project ecologist and the findings of site visits. The sensitivity of each area to development of the type and scale proposed was determined.
- Viewpoints across the ZTVs were selected as representative of the range of views and types of viewer likely to be affected by the Scheme and the sensitivity of each viewpoint was determined.
- Photomontage images of the scheme from five viewpoint locations were prepared. These are illustrated in *Chapter 12* of the EIA Report.
- The sensitivity of each landscape, seascape and visual receptor was assessed.

- The magnitude of change in each landscape and seascape character area was determined. Similarly the magnitude of change at each viewpoint was predicted.
- the level of significance of impact on each landscape and seascape character area and each viewpoint was evaluated as negligible, minor, moderate and major. Significance is determined based on the sensitivity of the impact and the magnitude of change as described below.

The landscape, seascape and visual impact assessment was informed by data gathered from the following sources:

- ordnance Survey maps made available from AMA1;
- field surveys undertaken in January 2012;
- aerial photography and satellite imagery;
- computer generated ZTVs;
- computer modelled photomontages; and
- consultations with statutory bodies undertaken as part of the social impact assessment baseline specifically in regard to tourism and landscape quality of the study area.

C14.3.1 *Sensitivity of Landscape and Seascape*

The sensitivity of a landscape or seascape is judged based on the extent to which it can accept change of a particular type and scale without adverse effects on its character. Sensitivity varies according to the type of development proposed and the nature of the landscape or seascape: its individual elements, key characteristics (land use, pattern and scale of landscape, enclosure/openness), inherent quality, condition, presence of detracting elements (eg pylons), value and capacity to accommodate change, and any specific values such as designations that apply. A landscape or seascape which is highly sensitive to change is one which is at greater risk of having their key characteristics fundamentally altered as a result of the LNG Facility, leading to a different landscape or seascape character.

Landscape or seascape sensitivity is also informed by other criteria such as *value* and *quality*. Value is concerned with the relative value or importance attached to a landscape (often as a basis for designation or recognition), which expresses national or local consensus, because of its quality, special features including perceptual aspects such as scenic beauty, tranquillity or wildness, cultural associations or other conservation issues.

Quality is based upon judgements about the physical state of the landscape, its condition and its intactness from visual, functional, and ecological

perspectives. It also reflects the state of repair of individual features and elements which make up the character in any one place.

C14.3.2 *Sensitivity of Viewers at Viewpoint Locations.*

The purpose of the visual impact assessment is to determine the visibility of the proposed development and to assess the visual impact of the proposals from a range of representative viewpoints within the study area.

A wide variety of viewer types (visual receptors) will be potentially affected by the proposed LNG Facility. These receptors will vary considerably depending on the intricacies of the coastline and will include local residents, those travelling through the area and those visiting the area for recreational and amenity purposes. Most of these will be onshore receptors, but there is potential for offshore receptors such as those travelling or working on boats. It is acknowledged that one person can fall into more than one category of receptor.

Each viewpoint was selected to represent a typical view from the immediate area which it represents. Viewpoint sensitivity depends on a number of factors including the context of the viewpoint, the current occupation (residents, recreational visitors, passers by, workers) and viewing opportunity of the groups of people being considered, and the number of people affected. The sensitivity of a viewpoint also depends upon the extent to which the viewers it represents are affected by changes in their view together with the quality of the existing view.

Viewer sensitivity is defined as Low, Medium or High.

C14.3.3 *Magnitude of Change*

The magnitude of change affecting landscape, seascape or visual receptors depends on the nature, scale and duration of the particular change that is envisaged in the landscape or seascape and the overall effect on a particular view. In a landscape or seascape, this will require consideration of the loss of or change in any important characteristic or feature, the proportion of the landscape or seascape that is affected, and any change in the backdrop to, or outlook from, the landscape or seascape affected.

The magnitude of change in views will depend on the scale of the development and the distance from the viewpoint, the angle of view occupied by the development, the extent of shielding by intervening features, the degree of obstruction of existing features, the degree of contrast with the existing view and the frequency or duration of visibility.

Magnitude of Change of an impact on a receptor is regarded as: Negligible, Low, Medium or High.

C14.3.4 *Significance of Impacts*

No established, measurable technical thresholds of significance exist for landscape, seascape and visual impacts, as is the case for some other EIA disciplines such as air quality or noise. Significance is therefore determined by considering the sensitivity of the landscape or visual receptor and the magnitude of change expected as a result of the development. Professional judgement and experience are applied on a case by case basis in order to identify broad levels of significance for each receptor. Each case is assessed on its own merits as factors unique to each circumstance need to be considered.

There are, however, general principles which can be used as a guide to this process and these are set out in *Sections C14.3.1, C14.3.2 and C14.3.3*. Following these the level of significance of impact is described as being *Negligible, Minor, Moderate, or Major*. This is however recognised as a continuum and, where impacts lie on the borderline, impacts may be described as *minor to moderate* for example.

Impacts which are graded as being *major* are those which ought to be given greatest weight in decision making. They usually concern immediate landscapes or seascapes around the site and close views from sensitive visual receptors. *Moderate* levels of impact are also considered significant, but they are of progressively reducing importance. Impacts graded as *minor* still constitute effects which warrant being brought to the attention of the decision-maker, but the team considers these should carry little if any weight in the decision. Impacts that are less than *minor* are considered to be *not significant*, the assessment team considers these impacts should carry no weight in the decision making process.

C15.1

STUDY APPROACH

A waste management review was undertaken which entailed essentially a desk study and used information about the Project provided by the Engineering Team during the pre-FEED design. Where data/information about waste generation from Project activities was not available, estimates have been made based on similar projects (developed in similar environments) to determine the likely types and quantities of waste that may be generated.

The final detailed design information for the Project is not available yet as it will be developed as part of the FEED stage. Hence, in many cases, specific waste treatment/disposal methods/routes are not yet known. In these cases assumptions have been made based on AMA1's stated policies and recommendations have been included as to how the Project should manage particular waste streams in compliance with applicable Mozambican regulations and IFC guidance.

The following steps were undertaken to inform the impact assessment process.

- Review of the Mozambique Regulatory Requirements and required International Standards as they impact management of the Project's wastes.
- Review of the types and quantities of waste that are anticipated will be generated during the construction, operational and decommissioning phases of the Project including available estimates of non-hazardous and hazardous wastes generated by different aspects of the Project (offshore, onshore, nearshore).
- Assessment and evaluation of the current plans for the management of Project wastes.
- Development of recommendations for how wastes generated by the different Project activities should be managed in order to minimise the potential environmental and social impacts.

C16 SOCIO-ECONOMICS

C16.1 OVERVIEW

The socio-economic study was conducted in five key phases using a number of research methods and tools in order to obtain a broad understanding of the socio-economics characteristics of the Study Area. These phases are outlined below in *Section C16.4*.

C16.2 SITE SELECTION- PRELIMINARY SITE VISITS AND MAPPING

Two preliminary site visits were undertaken during the site selection process (between May and August, 2011). During the visits, general information was gathered about the Afungi Peninsula and more specifically about the Afungi Project Site. Exploratory interviews were conducted with households in Quitupo village, the agricultural production zones and various fishing centres located along the coast. The field visit allowed the consulting team to draft maps of the villages and surrounding settlements as well as fishing centres within the 3,400 ha area.

C16.3 DESK BASED PREPARATION FOR THE SOCIO-ECONOMIC SURVEYS

Desk-based research was undertaken in preparation for the study (field documents and logistics). Activities undertaken are outlined below.

- Preparation of study protocol: drafting of the questionnaires for the household survey, focus group discussions with local leaders, men and women as well as a checklist for interviews with local government officials and NGOs.
- Identification of field workers to undertake the household surveys: the field workers were recruited from the Cabo Delgado Province specifically Pemba City.
- Preparation for the primary logistical aspects of the study.

C16.4 FIELD VISITS, INTERVIEWS AND SURVEYS

The socio-economic team visited Palma District during two field trips. Activities undertaken are detailed below.

C16.4.1 Phase 1 of the Socio-economic Study – November, 2011

In November 2011, the team visited the Palma District and the Afungi Project Site. The main results achieved during this phase include:

- hiring of field workers to conduct the household surveys, field work training and testing of questionnaires in the Quiwia village;
- completion of the mapping work of the amended Afungi Project Site, following on from mapping undertaken during the site selection;
- administration of 140 household questionnaires;
- seven focus group discussions conducted with local leaders, men and women in Quitupo, Maganja, Nsenga villages and the Milamba Fishing Zone/Centre; and
- key informant interviews with the Administration of Palma District, District services and village leaders.

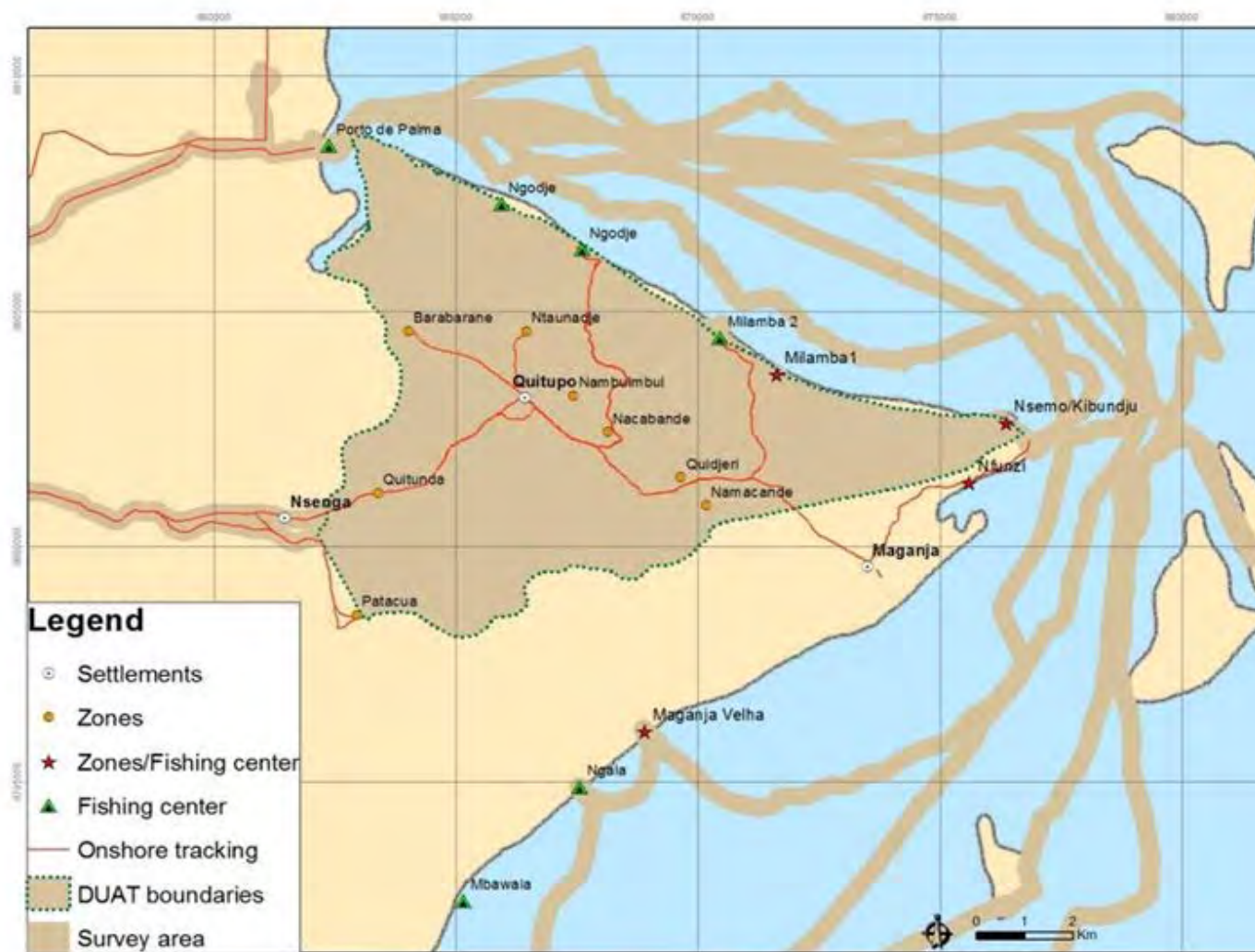
C16.4.2 *Phase 2 of the Socio-economic Study – January, 2012*

This phase of the study was conducted in Pemba City and in Palma District in January 2012. The main results achieved during this phase included:

- key informant interviews in Pemba and Palma with NGOs working in Palma District;
- additional key informant interviews with the Administration of Palma District and District services;
- interviews with fishermen in the main fishing centres within the Afungi Project Site and other sites in the Locality of Mute;
- mapping of the main villages in Mute Locality; and
- mapping of the main fishing areas on the coastline near Palma, the Afungi Project Site and the fishing centres in the Locality of Mute, as reported by the fishermen.

Figure 16.1 shows the tracks of the survey team, onshore and offshore, in November 2011 and January 2012.

Figure 16.1 Socio-economic Survey Team Tracks, November 2011 and January 2012



C16.5 ***PREPARATION OF THE SOCIAL BASELINE AND IMPACT ASSESSMENT***

During this phase of the socio-economic study, the main activities undertaken included the following:

- preparation of a questionnaire database;
- questionnaire data cleaning and analysis;
- analysis of focus group discussion reports;
- analysis of statistical reports and data from the main sectors (tourism, fishing, agriculture) of the Province of Cabo Delgado and Palma District; and
- write-up of findings.

C16.6 ***DATA GATHERING TOOLS***

Several data gathering tools were designed for use in the field and the objectives of each of these are discussed below.

C16.6.1 ***Household (HH) Questionnaire***

The survey was administered in 140 households in three villages and two settlement zones. The objective of the survey was to collect information regarding the composition of the households, their social and demographic characteristics, household infrastructure, use of natural resources, primary strategies for their survival and development, as well as their perceptions and expectations about the Project.

C16.6.2 ***Focus Groups Discussions (FGD)***

FGDs were conducted with men, women and local leaders in order to obtain a more detailed and qualitative understanding of socioeconomic receptors and community issues such as access to land, use of natural resources, household survival strategies, local cultural practices and traditions, local history, as well as expectations related to the Project.

C16.6.3 ***Semi-structured Key Informant Interviews***

Interviews were conducted with members of the local government such as the Administrator, Permanent Secretary, Heads of District Services, Local Village Leaders, and Fishermen. This was done to gather data about the administration and the Study Area.

Sample Selection

There was a lack of reliable population data for the area as the National Institute of Statistics (INE) and the District Administration was unable to provide data at a village level. To select the locations of villages in which to conduct interviews, cluster sampling was undertaken based on knowledge of the area and the various sub-groupings. The clusters selected are outlined below.

- *Village of Quitupo*: the main settlement in the Afungi Project Site.
- *Areas Surrounding Quitupo*: scattered settlements located in the 'production zones' which have a mixture of permanent and seasonal residents.
- *Coastal Zone*: settlements located along the coast of the Afungi Project Site (ie Ngodje, Milamba 1 and 2 and N'semo/Quibundju).
- *Village of Senga*: a village located on the boundary of the Afungi Project Site; whose residents use agricultural and coastal areas inside the Afungi Project Site.
- *Village of Maganja*: an important village located near the boundary of the Afungi Project Site; its population may use the agricultural and coastal areas in the Afungi Project Site.

Selection of households within each sampled village was done using a systematic sampling method. Based on the density of the houses in each sampling/cluster location ⁽¹⁾, an appropriate sampling interval was calculated. The field workers applied this interval when selecting households.

Sample Size

The sample size consisted of 140 households (approximately 14 percent) of all households residing in the area. The numbers of the households interviewed in each of the locations is shown in *Table 16.1*

Table 16.1 *Number of Questionnaires Administered in the Locations Selected for Sampling*

Location where the survey was conducted	No. of questionnaires
Village of Quitupo	52
Areas Surrounding Quitupo	16
Coastal Zone	22
Senga	20
Maganja	30
Total	140

(1) Upon arriving at a village or settlement, the Consultant and the enumerators mapped the village in conjunction with local leaders, selecting the addresses to follow and using a systematic selection interval based on the density of the houses.

C17.1 HIA METHODOLOGY

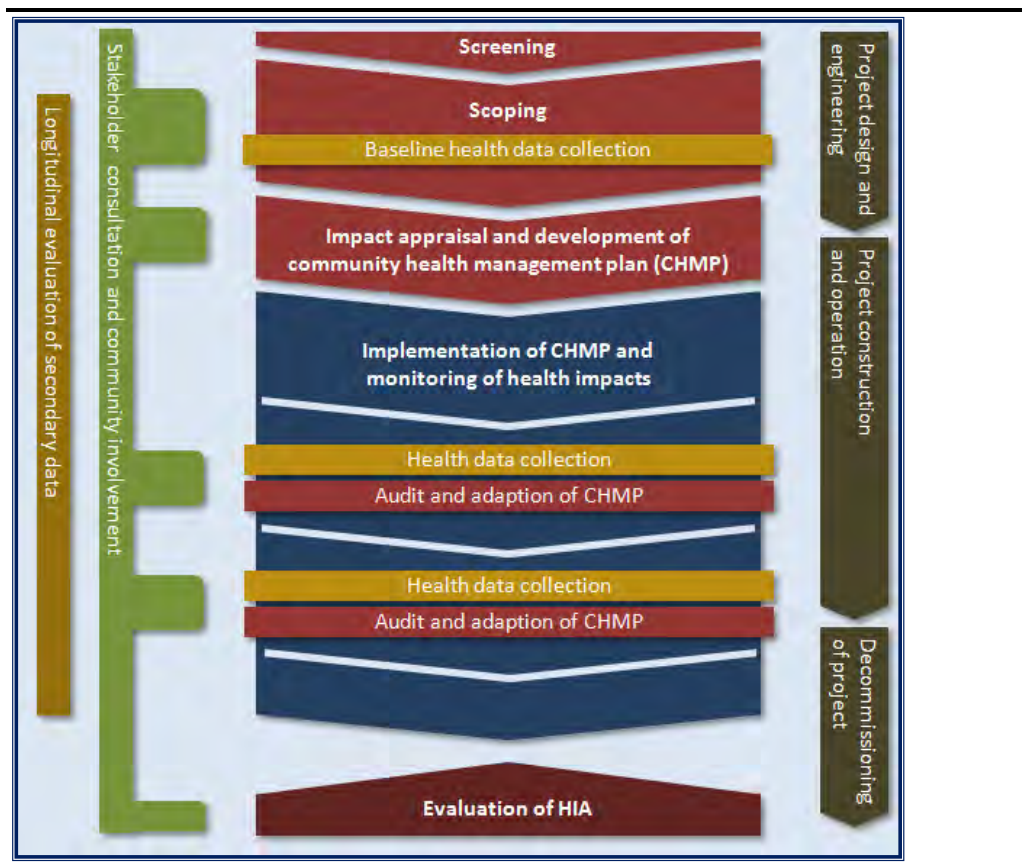
To ensure compliance with the IFC performance standards the methodology outlined in the GPN for HIA from the IFC was followed. The main elements of the GPN are discussed briefly, so the context and methodology of the HIA process is understood.

It is important that a distinction is made between HIA and Health Risk Assessment (HRA). HRA is concerned with the identification of hazards and risks to the workforce which relate to occupational health and safety and engineering design. Generally, HRA is “within the fence” while HIA is “outside the fence” but there are distinct overlaps with HIA often taking a central position as workplace activities can effect community health and existing community health needs or disease burdens can effect workplace health. It is thus important that these assessments should not be placed into individual elements but integrated to support an overall strategic plan for the Project.

C17.1.1 *Form and Nature of Health Impact Assessment*

Figure 17.1 presents the framework that is commonly used for HIA and which follows a 6-step process, which is based on a similar approach as adopted in environmental and social impact assessments (ESIA). This approach has been used to support effective integration of the health component in the environmental, social and health impact assessments ESHIA process and the development of the SEMP for the Project.

Figure 17.1 HIA Flow Chart



HIAs are generally divided into three main levels as described in *Table 17.1*. These levels generally consider the following; (i) the range and magnitude of potential health impacts; (ii) the social sensitivity of the potentially affected communities; and (iii) the definition of the Project and its areas of influence (project footprint) which can include direct and indirect impacts. The different phases of the Project also need to be considered in the consideration of impacts.

Table 17.1 Levels of HIA

Level of HIA	Characteristics
Desktop/Scoping HIA	<ul style="list-style-type: none"> Provides a broad overview of possible health impacts. Analysis of existing and accessible data. No new project specific survey data collection.
Rapid Appraisal HIA	<ul style="list-style-type: none"> Analysis of existing data. Stakeholder and key informant analysis. No new project specific survey data collection.
Comprehensive HIA	<ul style="list-style-type: none"> Provides a comprehensive assessment of potential health impacts. Robust definition of impacts. New project specific survey data collection. Participatory approaches involving stakeholders and key informants.

A rapid appraisal HIA was chosen as the preferred methodology to support the Project, as by definition no new primary quantitative data was collected.

The IFC methodology uses 12 environmental health areas (EHAs) to support the systematic analysis of health considerations. These are summarized in *Table 17.2*. The set of EHAs provides a linkage between Project-related activities and potential positive or negative community-level impacts and incorporate a variety of biomedical and key social determinants of health (reductionist approach). In this integrated analysis, cross-cutting environmental and social conditions that contain significant health components are identified instead of an HIA focusing primarily on disease-specific considerations. While every EHA may not be relevant to a given project, it is still important to systematically analyse the potential for project-related impacts (positive, negative or neutral) across the various EHAs.

Table 17.2 *Environmental Health Areas*

Environmental Health Areas	
1	Communicable diseases linked to poor environmental and socio-economic conditions, housing design and occupancy – Transmission of communicable diseases (eg acute respiratory infections, pneumonia, tuberculosis, meningitis, plague, leprosy, etc.) that can be linked to inadequate housing design, overcrowding and housing inflation. It also considers indoor air pollution related to use of biomass fuels.
2	Vector-related diseases – Mosquito, fly, tick and lice-related diseases (eg malaria, dengue, yellow fever, lymphatic filariasis, rift valley fever, human African trypanosomiasis, onchocerciasis, etc.).
3	Soil-, water- and waste-related diseases – Diseases that are transmitted directly or indirectly through contaminated water, soil or non-hazardous waste (eg diarrheal diseases, schistosomiasis, hepatitis A and E, poliomyelitis, soil-transmitted helminthiasis, etc.).
4	Sexually-transmitted infections, including HIV/AIDS – Sexually-transmitted infections such as syphilis, gonorrhoea, chlamydia, hepatitis B and, most importantly, HIV/AIDS. Linkages of TB will be discussed where relevant under HIV, but often linked to EHA1.
5	Food- and nutrition-related issues – Adverse health effects such as malnutrition, anemia or micronutrient deficiencies due to eg changes in agricultural and subsistence practices, or food inflation; gastroenteritis, food-borne trematodiasis, etc. This will also consider feeding behaviors and practices. Access to land plays a major role in developing subsistence farming contexts
6	Non-communicable diseases – Cardiovascular diseases, cancer, diabetes, obesity, etc.
7	Accidents/injuries – Road traffic or work-related accidents and injuries (home and project related); drowning.
8	Veterinary medicine and zoonotic diseases – Diseases affecting animals (eg bovine tuberculosis, swinepox, avian influenza) or that can be transmitted from animal to human (eg rabies, brucellosis, Rift Valley fever, Lassa fever, leptospirosis, etc.).
9	Exposure to potentially hazardous materials, noise and malodors – This considers the environmental health determinants linked to the project and related activities. Noise, water and air pollution (indoor and outdoor) as well as visual impacts will be considered in this biophysical category. It can also include exposure to heavy metals and hazardous chemical substances and other compounds, solvents or spills and releases from road traffic and exposure to mal-odors. There is a significant overlap in the environmental impact assessment in this section.
10	Social determinants of health – Including psychosocial stress (due to eg resettlement, overcrowding, political or economic crisis), mental health, depression, gender issues, gender based domestic violence, suicide, ethnic conflicts, security concerns, substance misuse (drug, alcohol, smoking), family planning, health seeking behaviors, etc. There is a significant overlap in the social impact assessment in this section.

Environmental Health Areas

- 11 Cultural health practices – Role of traditional medical providers, indigenous medicines, and unique cultural health practices.
 - 12 Health services and systems infrastructure and capacity – Physical health infrastructure (eg capacity, equipment, staffing levels and competencies, future development plans) and institutional capacity within health service.
 - 13 Program management delivery systems - coordination and alignment of the project to existing national and provincial level health programs, (eg, TB, HIV/AIDS, malaria), and future development plans.
-

C17.1.3 *Community Profiling*

To identify and quantify potential health impacts an accurate population profile is required and it is important to distinguish between differences in exposure and susceptibility. Thus, besides a demographic profile of the at-risk population and the identification of the most vulnerable groups, it is crucial to understand how the development, construction and operational activities are likely to impact at an individual, household and community level.

The key aspects when considering the potential influence of the Project to the potentially affected communities (PACs) is the exposure pathway of the potential health determinant, which consider the following key elements:

- is there a hazard;
- who or what may be exposed to this hazard;
- the mode (air, water, food, vector, social determinants etc.) and route (inhalation, ingestion, vector borne, sexually transmitted etc.) of exposure;
- what is the risk of exposure based on a likelihood and consequence analysis (magnitude, duration and length)- the impact assessment and modelling phase; and
- how sensitive or vulnerable is the receptor to the potential hazard or impact.

As part of the analysis, the relevant overall population is stratified into PACs. A PAC is a defined community within a clear geographical boundary where Project-related health impacts may reasonably be expected to occur. PACs are inherently prospective and simply represent best professional judgments, with the potential that these may change over time. Findings of social and economic assessments, resettlement plans and influx management plans need to be carefully updated as this allows linkage between the PACs and key demographic determinants such as age structure and population numbers.

Mitigation strategies may also require specific considerations for the different PACs. On the one hand, not all the EHAs may be of concern for mitigation for the individual PACs. On the other hand a separate risk analysis for a PAC may be indicated due to a particular susceptibility to a specific health impact.

C17.1.4 *Risk Assessment and Impact Categorization*

This process analyses, models and ranks the potential impacts associated with the Project and their potential influence on PACs through the different life cycle stages of the Project. It includes the analysis of potential negative impacts and their management measures, but also the discussion of potential positive impacts and measures to enhance these. This is based on the evidence presented in the baseline health description, the project activities and information obtained from the ESHIA process and other specialist reports/studies which were available.

A standardized risk assessment model was followed for the modelling of impacts and includes:

- identification of health related issues where Project activities may impact on a variety of receptors;
- a prediction of what may happen to the PACs and environment as a result of the direct and indirect activities of the Project- the impact definition/assessment. The precautionary principle was adopted in analysing and modelling the impact definition ;
- the impact evaluation which considers the significance of the health impacts based on a consequence and likelihood modelling. This initial inherent ranking considers the risks at baseline (no-go situation/ present health status of communities, or the existing health needs) and the Project related impacts without mitigation; and the residual risks consider the significance of risks after the successful implementation of mitigation measures.

The evaluation of the significance of the impacts will also consider the confidence/uncertainty of the assessment. This will occur for both inherent and residual risks with the following considerations:

- the uncertainty analysis for the assessment of inherent risks will present the confidence of the assessor in determining the potential of the impacts to occur based on the evidence to hand; and
- the uncertainty analysis for the assessment of residual risks will present the confidence of the assessor in determining how likely the mitigation measures are to succeed if properly implemented, as well as the ease and practicality of the proposed mitigation measures and the potential for them to be effectively sustained.

C17.1.5 *Direct Versus Indirect Impacts*

There are two general categorizations of impact effects, namely (i) direct and (ii) indirect. A direct (primary) effect demonstrates a specific cause-and-effect relationship. An indirect effect is a secondary by-product of an interaction among multiple variables and may be a consequence of a direct effect.

Indirect effects are often of equal or greater significance than the more obviously observable direct impacts. The HIA analyses both potential direct and indirect effects.

Theoretically, there are virtually a limitless number of indirect effects that could be hypothesized, and in order to manage this situation the following approach is considered:

- a set of most likely indirect effects will be constructed on the basis of past relevant experiences at similar projects; and
- a sufficiently robust monitoring and evaluation system will be developed in a CHMP such that early detection of significant indirect effects is possible.

C17.1.6 *Cumulative Impacts*

In this HIA, cumulative impacts will be considered, but only in a qualitative fashion, as there is no formal agreed definition for cumulative impacts from an HIA perspective. For the purpose of this HIA, cumulative impacts are considered to be generated by multiple causes and pathways and may arise on a human receptor at any scale.

C17.1.7 *Management and Mitigation*

Impact Evaluation and Mitigation

As part of the impact categorization and evaluation a range of mitigation/management measures are generally proposed. Mitigation refers to measures which avoid, minimize, or eliminate an adverse effect, or maximize a potential benefit. Although mitigation is presented as the final phase of the HIA, it should be viewed as an on-going process, beginning as the Project is being conceptualized and designed, and ending only when impacts from the Project operations and final decommissioning have concluded.

Recommendations for mitigation/management will focus on identification of measures that can be taken to reduce potential impacts to as low as reasonably practicable (ALARP) both from a technical and financial perspective. These are generally presented based on a hierarchy of controls with avoidance as the priority where possible, as presented in the following (in order of importance) list:

- avoid at source – remove the source of the impact;
- abate at source – reduce the source of the impact;
- attenuate – reduce the impact between the source and the receptor;
- abate at the receptor – reduce the impact at the receptor;
- remedy – repair the damage after it has occurred; and

- compensate – replace a lost or damaged resource with a similar or a different resource of equal value.

The measures described above promote pre-execution advice to the Project which can be incorporated in the design phase and support the use of HIA as a decision making tool. This can include a range of alternatives for example location of specific project infrastructure and selection of equipment, social development priorities etc. It is easier to propose changes at the front end rather than promoting challenging and expensive retrofits.

For the purposes of the project, mitigation measures have been divided into three categories based on the focus of the intervention, namely:

- **Project impact mitigation:** Interventions required in order to mitigate the future health impacts of the project on the communities. These are required by the project and are not voluntary contributions. The precautionary principle will apply when analysing these. These are also generally regulatory requirements.
- **Occupational health and safety:** Interventions aimed at ensuring a healthy, safe and productive workforce. In addition, it considers aspects that can be controlled in the workforce to prevent community health impacts.
- **Strategic community investments:** Interventions suggested that will improve the existing health status of the communities. These can be in the form of negotiated commitments made by the project proponents as well as extended benefits which should bring about health benefits and improve social license to operate in the receptive communities. It should also promote project sustainability if developed based on sustainability principles.

The current HIA will have limited focus on these strategic community investments as it is anticipated that these will be developed as part of a community development management framework, which sits out of the scope of the current HIA. It is however noted that there is often an overlap between required mitigation measures and extended benefits which are generally based on negotiated commitments to maximize potential health benefits in the affected communities.

The management and mitigation measures proposed in the impact assessment will form part of the framework ESMP.

C17.1.8 Stakeholder Consultation

Stakeholder engagement and consultation is a crucial element of the HIA process. Stakeholder consultation in an impact assessment improves the quality and relevance of the findings by providing insights into the likely positive and negative health impacts both from stakeholder experience of the locality, as well as their experiences of other projects. Stakeholders can inform

the Project about what they value, as well as recommending, and hopefully partnering in the implementation of the most acceptable ways of mitigating, enhancing and monitoring the potential health and well-being impacts of a project.

C18.1 OVERVIEW

The study was based on both desktop studies and fieldwork investigation undertaken in October 2011, as discussed below.

C18.1.1 Desktop Study

A desktop study was conducted to collect, analyse, and collate existing secondary data and information to establish an understanding of the archaeological and cultural heritage of the wider area. The desk based study also included discussions with local informants and research into the following for the Study Area:

- The list of declared monuments protected by the National Board of Cultural Heritage (NBCH).
- The list of sites of cultural heritage identified by the NBCH or Department of Archaeology and Anthropology of Eduardo Mondlane University (EMU).
- Publications on local historical, architectural, anthropological, archaeological and other cultural studies.
- Any other unpublished archaeological investigation and excavation reports kept by the NBCH.
- Cartographic and aerial photographic records from National Directorate of Geography and Cadastre (DINAGECA).
- Existing Geotechnical information.

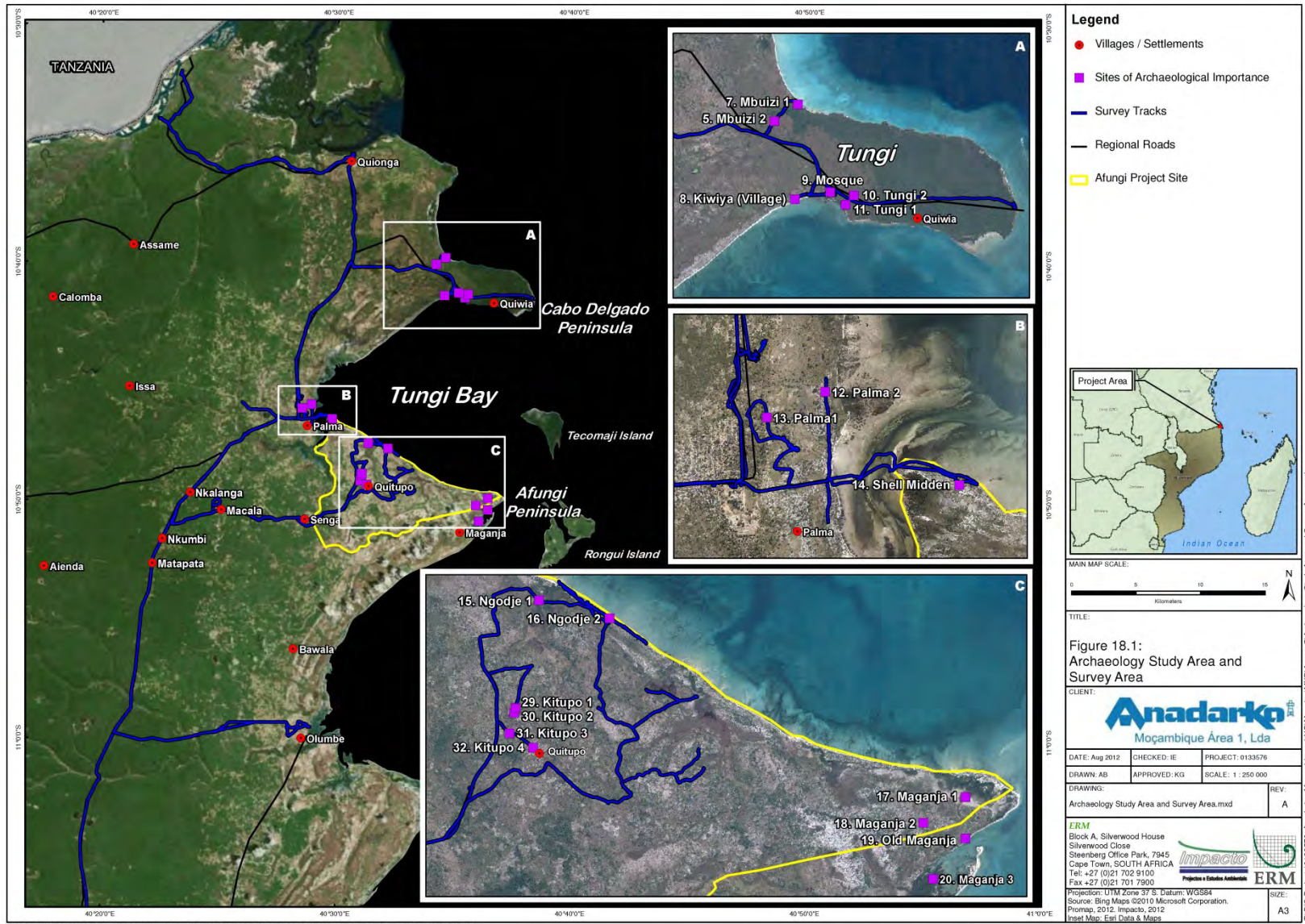
Discussions with local informants were undertaken.

C18.1.2 Field Investigations

A systematic field survey of the Study Area was conducted by the archaeologist Prof. Leonardo Adamowicz and a field assistant (Ercídio J. J. Nhatule) between 20 and 30 October 2011.

A field survey was conducted which was focused in the Afungi Peninsula, around Palma Town and within the Cabo Delgado Peninsula as shown in *Figure 18.1* these areas may be potentially directly or indirectly affected by the Project. In addition, areas from Quionga to the Rovuma River, and to Olumbi in the south were included in the investigation in order to determine the significance of the archaeological and historical heritage in these areas.

Figure 18.1 Archaeology Study Area and Survey Area



It is unlawful for any firm or individual to reproduce copyrighted maps, graphics or drawings, in whole or in part, without permission of the copyright owner: ERM Southern Africa (Pty) Ltd ©

T:\GIS Project\0133576_Anadarko_Mozambique_LNGI Mapping\MXD\Anex. C\Archaeology Study Area and Survey Area.mxd

It should be noted, that some sites, particularly those in the Maganja area of Afungi Peninsula, were surveyed in detail and recorded during a previous study in 2008 ⁽¹⁾.

During the field investigation undertaken for the LNG Project, the following tasks were undertaken:

- Identification of archaeological and cultural heritage sites.
- Location, mapping and classification of the archaeological and historical heritage sites in the area.
- Detailed description of the archaeological and historical environment.
- The identification of structures and artefacts of archaeological and historical value with georeferenced locations ⁽²⁾.

All collected information and material were documented and recorded (eg potsherds and shell midden) on site specific inventory sheets. On these sheets the following were recorded:

- Description of each site and its immediate environment; and technical drawing of boundaries and configuration of the site, photographic, cartographic and GPS geo-referencing (also registering the brand and model of the device, and the margin of error).
- Organization of the photographic records according to the occurrence to which they belong and their surroundings.

Archaeological remains from each collection unit were separated and packed according to the type of raw material for analysis.

A controlled-exclusive surface survey was carried out, where sufficient information exists on an area to make solid and defensible assumptions and judgments about where (heritage resource) sites may and may not be and these included an inspection of the ground floor, wherever the floor was visible, with no substantial attempt to clear brush, deadfall, leaves or other material that may cover the surface and with no attempt to look beneath the surface beyond the inspection of rodent burrows, cut banks and other exposed areas that are observed.

No excavations or extensive sampling were undertaken, since a permit from the National Board of Culture Heritage is required to disturb a heritage

(1) Undertaken in conjunction with the League of Scouts of Mozambique (LEMO), in collaboration with United Nations Educational, Scientific and Cultural Organization (UNESCO) and ICOMOS (International Council on Monuments and Sites).

(2) Some sites, particularly those in Maganja area were recorded in previous visit of author in frame of ICOMOS/UNESCO/LEMO project in 2008. Survey was done by author leading Circle of Interest of Cultural Heritage of the League of Scouts of Mozambique shortly before sponsored by UNESCO camp at Ibo Island in 2008. Other sites were recorded during trip from Palma to Pemba. Most of recorded site were sacred places.

resource. The value and significance of heritage resources was assessed as per definitions in the 10/88 Heritage Protection Law and the criteria described below. Cultural heritage was assessed according to rules established by the Department of Archaeology and Anthropology of Eduardo Mondlane University (UEM) and included:

- a comprehensive inventory of the archaeological sites, historic buildings and structures within the proposed project area, which include:
 - all sites of archaeological interest;
 - all pre-1950 buildings and structures;
 - selected post-1950 buildings and structures of high architectural and historical significance and interest; and
 - landscape features, including sites of historical events or providing a significant historical record or a setting for buildings or monuments of architectural or archaeological importance, historic field patterns, tracks and fish ponds and cultural elements such as sacred places and graves.

- Identification of the direct and indirect impacts on the site of cultural heritage at the planning stage in order to prevent any negative effects.

Various provincial databases were consulted, including historical, archaeological and geological sources and a limited literature review was undertaken.