CHAPTER 8:

ENVIRONMENTAL MANAGEMENT PLAN

FINAL REPORT

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CHAPTER 8. ENVIRONMENTAL MANAGEMENT PLAN

8.1 INTRODUCTION

This Environmental Management Plan (EMP) has been established to ensure that the project complies with the Namibian Environmental Management Act (No. 7 of 2007); and to provide a control framework for implementing the management actions described in the Environmental Impact Assessment (EIA), during dredging. The EMP is to be submitted to the Namibian Ministry of Environment and Tourism (MET) as part of the application to receive an Environmental Contract for the proposed project – The Recovery of Marine Phosphates from Mining Licence 170 (ML170).

This framework EMP is supported by detailed verification and monitoring programmes (Section 8.9).

The EMP addresses dredging activities within ML170 and relevant activities of the dredging vessel during non-dredging operations.

8.2 THE ENVIRONMENTAL MANAGEMENT PROGRAMME.

Namibian Marine Phosphate (NMP) is committed to the implementation of responsible environmental management of their dredging operation, this commitment applies equally to all contractors retained by the Company.

8.2.1 Environmental Management Programme: Objectives

The implementation of the EMP serves to reduce the negative effects and optimize the positive effects of the marine operations.

The objectives of the EMP are:

- ***Processes:*** To achieve all requirements outlined in the EMP, including maintaining communication with all Interested and Affected Parties (I&APs) and compilation of Performance Assessments;
- ***Management systems:*** To establish an integrated safety, health, environment and quality (SHEQ) management system to facilitate the implementation of the EMP;
- ***Monitoring Surveys:*** To undertake the described monitoring programme;
- ***Vessels at sea:*** To ensure that the operations at sea are undertaken in accordance with accepted safe and responsible vessel management practices, and
- ***Emergencies:*** To have appropriate systems of response in place.

The matrices presented herein provide detail of the *activities, aspects,* and *impacts* of the project and the m*anagement actions* required to address these impacts arising from the dredging operation and associated activities.

The commitments described here (the EMP) form part of the authorisation agreement between NMP and the Government of the Republic of Namibia, as represented by the Ministry of Environment and Tourism (MET), the Ministry of Mines and Energy (MME), and other Line Ministries as advised. Non-compliance with these commitments may result in approval being withdrawn.

8.2.2 Monitoring and ongoing assessment of impacts

The monitoring of activities with significant impacts is detailed in Sections 8.5 and 8.9.

8.2.3 Performance Assessment

An Environmental Performance Assessment Report will be submitted annually to the Mining Commissioner of the Ministry of Mines and Energy, the Permanent Secretary of the Ministry of Environment and Tourism and other Line Ministries as detailed in the Environmental Contract.

8.2.4 Financial Provision

The project holds at all times Protection and Indemnity (P&I) insurance cover at a suitable level, up to a maximum of US$ 1 billion[1].

8.2.5 Responsibilities

The responsibility for the implementation of the EMP lies with the NMP appointed Environmental Manager, who in turn will appoint line managers who are responsible for the elements of this management plan.

[1] Proof of insurance coverage. Appendix 2h

8.3 COMPANY STANDARDS

Activity	Aspect	Impact	Management Requirements	Duration
Internal communication: The Company environmental policy.	Policy	Improved awareness	• All personnel (including contractors) are to be made aware of the contents of the Company Environmental Policy Statements	Life of mine
Implementation of the EMP	Policy	Improved awareness	• Define the roles, responsibilities and authorities of employees responsible for implementing this EMP. • Address training needs of staff required to implement specialised aspects of the EMP. • Maintain records of plans, decisions, data collected, communications made, emergency responses, etc., which document the implementation of the EMP.	Life of mine
Instructions to all employees, including contractors	Policy	Improved awareness	• Provide instructions and training to all staff about aspects of the EMP that to relate their work. • Present environmental awareness training. • Subcontracting companies are to have specific environmental compliance requirements written into their contracts.	Life of mine
Environmental Performance Assessment	Policy	Improved awareness	• Annually undertake performance assessments to verify that the requirements of the EMP have been met. • Where compliance has not been achieved, present details of non-compliance and corrective actions. • Submit the Environmental Performance Reports to MET and MME.	Annually – throughout life of mine
Amending the EMP	Policy	Improved awareness	• Assess all actions required through the EMP, identify any changes and or new environmental issues arising. • Communicate and consult with authorities and key I&APs informing them of proposed changes to the EMPR.	Annually – throughout life of mine
I&APs communications	Policy	Improved awareness	• Consult / inform I&APs as may be relevant. • Retain a register of all communication. • Participate in relevant community and industry forums	Life of mine

Activity	Aspect	Impact	Management Requirements	Duration
Environmental budget	Policy	Improved awareness	• Allocate an operational budget that is adequate to cover all requirements as detailed in the EMP	Life of mine
Environmental Insurance	Policy	Improved awareness	• Maintain Protection and Indemnity (P&I) Insurance Cover (initially indicated at US$ 1 billion) • Review the cover amount annually. • Review the scope of the cover is appropriate to the operational activities	Annually – throughout life of mine
Compilation of Information	Communication	Improved awareness	• Ensure that the outcome of specialist studies and the results of monitoring programmes as initiated are incorporated into the company integrated environmental (GIS) information database.	Life of mine

8.4 VESSEL: STANDARD OPERATIONS

Commencement of operations (includes all general ship activities, sailing, bunkering, and discharging of hopper contents, but excludes recovery of sediments).

Performance Objectives	
The management objectives are to: • Ensure for the safe operation of the vessel. • Minimise disruption to all other users of the sea by respecting the right of passage. • Optimally manage (reduce and recycle) all wastes generated and discharged to sea, air, and land. • Maintaining open communications with other marine users. • Ensure emergency contingency plans are in place.	
Standards of compliance	
• Minerals (Prospecting and Mining) Act (33 of 1992). • MARPOL[2]. • Merchant Shipping Act 57 of 1951. • London Convention 1972/1996. • Wreck and Salvage Act (2004). • United Nation Convention on Law of the Sea. • Territorial Sea and Exclusive Economic Zone of Namibia Act, No. 3 of 1990. • Marine Resources Act 27 of 2000. • Namibian Ports Authority Act 2 of 1994. • Marine Traffic Act, No. 2 of 1981 as amended by the Marine Traffic Amendment Act 15 of 1991. • Prevention and Combating of Pollution of the Sea by Oil Act No 6 of 1981 (as amended by Act 24 of 1991). • Dumping at Sea Control Act 73 of 1980.	• Comply with international recommendations regarding the use of CFCs • Dredging contractor: approved vessel safety certification[3] • Dredging contractor: approved International Standard for the safe management and operation of ships and for pollution prevention (ISM) approved waste management plan. • Dredging contractor: approved ISM approved emergency response plan. • Dredging contractor: approved ISM approved safe bunkering plan. • Dredging contractor: approved ISM approved project environmental management plan. • Dredging contractor: approved ISM approved ballast water management plan. • Dredging contractor: approved ISM approved SOPEP plan. • Dredging contractor: approved ISM system. • Environmental Policy – Namibian Marine Phosphate. • Safety, Health, Environmental & Quality Policy – Dredging Contractor

[2] The relevant sections of MARPOL are reproduced in the appendix 2h
[3] Dredging contractor certifications reproduced in appendix 2h

Activity	Aspect	Impact	Management Requirements	Duration
Commencement of operations	Interaction with all marine users	Initiation of operations - exclusivity of use	14 days in advance of commencement of a continuous dredging campaign, notify: • The Permanent Secretary: MME in writing providing particulars regarding the location, nature and extent of the operations. • The Permanent Secretary: MFMR in writing providing particulars regarding the location, nature and extent of the operations. • Other potential user groups (maritime authorities, fishing industry) in the area in writing, providing detail of the location and extent of the operations. • Other potential users of zones of exclusive use around the dredging project area for the particular dredging period. • Walvis Bay Radio of intended vessel activities. • On termination of dredge activities of more than one month duration, inform Walvis Bay Radio.	Before each dredging campaign during project production ramp up (yrs 1, 2 & 3)
			• Record observations of, and interactions with, other vessels.	Life of mine during dredging campaigns
	Safety of passage	Exclusivity of use	• Display signals to indicate right of passage when dredging. • De activate right of passage signals when not dredging. • Maintain visual watch at all times.	Life of mine during dredging campaigns
	Exclusion zone extent	Exclusivity of use	• An exclusive dredging zone is declared over the active dredging block area. • The exclusive zone of 23 x 9 km (SP-1, SP-2) is declared as a 'no fishing zone,' - around the active target recovery area. • Vessels may transit through this zone, with due consideration to rights of passage and navigational warning lights.	Life of mine block
		Research, survey and fisheries assessment vessels	• Vessels undertaking fisheries stock assessment and or related scientific surveys are to be given navigational rights of passage within the declared zones of exclusion. The company / organisation intending to undertake these surveys is required to notify the company 14 days in advance, so that appropriate arrangements can be made.	Life of mine block - duration of survey
	Noise /	Disturbance of	• Initiate the Marine Sightings Programme (birds, mammals, and jellyfish).	Life of mine during

Activity	Aspect	Impact	Management Requirements	Duration
	vibration	marine mammals and seabirds	• Record the numbers and species sighted during all activities associated with the dredging operation. • Avoid disturbances to whales whilst underway.	dredging campaigns
Refuelling	Pollution	Potential impact on the ocean and fauna and flora	• Obtain permission from the Department of Maritime Affairs before refuelling outside of harbour limits and within the Namibian Economic Exclusive Zone. • Confirm the bunkering procedure of the delivery vessel. • Ensure that both delivery and receiving vessel are familiar with each party's procedures and operational requirements for transfer of bunkers at sea. • Bunkering in areas under the jurisdiction of the port's authority is to be carried out under the requirements as prescribed by NamPort.	Prior to refuelling at sea
Grounding - sinking – collision of vessel(s)	Marine Pollution	Potential impact on the ocean and fauna and flora	• Reduce the probabilities of accidental grounding - sinking – collision through enforcement of safe operational vessel systems.	Life of mine
			• Maintain all emergency procedures and insurances as legally required. • Ensure that emergency procedures are current and in accordance with established standards of practice.	Life of mine
			• In the event that an emergency occurs (grounding, sinking, collision & fire) follow the standards: 1. Shipboard Emergency Response Manual 2. Shipboard Oil Pollution Emergency Plan (SOPEP). 3. Shipboard Hazardous Spill Manual.	In the event of an emergency
			In the appropriate manner notify: • MWTC (Department of Maritime Affairs) and as is required, coordinate with them on the activation of the National Oils Spill Response Plan. • MET and, as required, coordinate with them on the activation of the National Oil Spill Response Plan. • MFMR and, as required, coordinate with them on the activation of the National Oil Spill Response Plan. • MME and, as required, coordinate with them on the activation of the National Oil Spill Response Plan. • Walvis Bay Harbour Master and, as required, coordinate with them on the	In the event of an emergency

Activity	Aspect	Impact	Management Requirements	Duration
			activation of the National Oil Spill Response Plan. • Advise other parties as may be relevant to minimize damage to their activities.	
			Provide the following information when reporting a spill: 1. The volume of oil spilled (so MWTC can determine whether or not it is significant). 2. The type and circumstances of incident, ship type, port of registry, nearest agent representing the ship's company. 3. Geographic location of the incident, distance off-shore and extent of oil spill. 4. Prevailing weather conditions and sea state in affected area (wind direction and speed, weather and swell) 5. Persons and authorities already informed of the spill. 6. Estimates of the numbers of different species of mammals and seabirds in the vicinity, and of the numbers of each species oiled.	In the event of an emergency
			• If feasible, rescue and stabilise oiled seabirds. • If feasible, transfer oiled seabirds to MFMR Lüderitz for further rehabilitation.	In the event of an emergency
Small oil or cleaning solvent spills onboard the vessel	Marine pollution	Pollution of the water column	• Use low toxicity biodegradable detergents to clean up spills. • Avoid spilling toxic chemicals but if spillages occur then clean up spilled chemicals immediately and place adsorbent material (rags) used for this purpose in sealed waste containers for safe disposal ashore. • Keep records of spillages and estimate amounts not retrieved by clean up actions.	Life of mine,
Disposal of wastes (solid, oily and sewage - including bilge discharges to the sea	Waste	Pollution of the environment	• The oil content of any discharge is required to be less than 15 parts per million (MARPOL). • Galley wastes discharged overboard only after maceration through a 25 mm screen (MARPOL). • Sewage processed in approved treatment plants (MARPOL). • Do not discharge any treated or untreated sewage from a vessel within 4 nautical miles (nm) of land, but comminuted and disinfected sewage may be discharged beyond 4 nautical miles. • Only incinerated wastes may be discharged overboard and then only when the	Life of mine

Activity	Aspect	Impact	Management Requirements	Duration
			vessel is more than 25 nautical miles from shore. • With the exception of macerated galley and incinerated wastes do not dump or throw solid waste of any kind into the sea. • Do not discharge any hydrocarbon products into the sea. • Retain a register of all wastes discharged to sea. • Contain all oils, grease or hydraulic fluids spilled on the vessel for disposal at a recognised land-based disposal site.	
Waste disposal within harbour limits	Waste & materials	Pollution of the environment	• Do not dump or throw any solid waste of any kind into harbours. • Do not discharge any sewage into harbours. • Do not discharge any oily or waxy effluents into a harbour. • Do not discharge effluent or water from any tank contaminated with greater than 15 parts per million of oil into a harbour. • Separate wastes into recyclable and "other" materials. Incinerate combustible materials on board. Store the balance in leak-proof skips for safe transfer to a registered waste site on land, or contain all in leak-proof containers onboard and dispose at a recognised disposal site on a regular basis.	Life of mine,
Waste management record keeping	Waste & materials	Pollution of the environment	• Maintain a garbage record book of all discharged/ incinerated food and domestic and operational waste (excluding oil, sewage or noxious liquids listed in other annexes to MARPOL) • Record garbage in the record book under the categories of: i) Plastics, ii) Floating dunnage, lining or packaging material, iii) Ground-down paper products, rags, glass, metal, bottles, crockery, etc., iv) Paper products, rags, glass, metal, bottles, crockery, etc., v) Food waste, vi) Incinerator ash. • As per the prescribed form, record estimated amounts (m^3) of each category whenever garbage is discharged to sea, or to reception facility ashore or to other ships, or incinerated, or in accidental or other exceptional discharge. Also record date/time of discharge/ occurrence, position of ship, and nature of discharge (incineration/ port/ facility/ name of ship) or circumstances and reasons for accidental or other exceptional discharge. • The officer in charge is to sign for each record on the date of incineration or	

Activity	Aspect	Impact	Management Requirements	Duration
			discharge, and the Master of the ship is to sign each completed page of the Garbage Record Book.	
Management of hydrocarbons	Waste & materials	Pollution of the environment	• Keep records (vessel logbooks) of quantities and types of all hazardous materials and oils taken onboard vessels, and of their method of storage, use and disposal.	Life of mine, duration of dredging operations
Discharge of ballast water	Pollution: Introduction of alien species	Possible invasive species dominance	• Ballast discharges are controlled through the ISM approved Shipboard Ballast Management Plan (IMO guidelines on ballast water management).	Life of mine
Discharges to the atmosphere	Pollution	Pollution of the environment	• NO_x, SO_x and VOCs are to be compliant with the requirements of MARPOL. • Only MARPOL approved incinerators may be used and incineration may only take place according to MARPOL. • Use environmentally friendly substitutes for CFCs where feasible.	Life of mine, operation duration of vessel
Vessel engine cooling seawater intake	Seawater intake in jellyfish infested waters	Possible block ages of sea water intakes	• As part of the Marine Sightings Programme when large concentrations of jellyfish are observed, advise the Chief Engineer to maintain watch on seawater intakes to ensure that surface aggregating jellyfish do not block them.	During dredging when high densities of jellyfish are observed
Equipment loss at sea	Pollution	Pollution of the environment navigation hazard	• Establish hazards database, detailing: item, location, date, and recovery date. • Depending on the size of the loss, advise MWTC (Department of Maritime Affairs) if it may present a navigation hazard.	Life of mine
Vessels in distress	Safety at sea	Prevention of pollution. Saving lives	• Adhere to conventional maritime obligations regarding vessels in distress.	Life of mine, during vessel campaigns
Exclusion zone around discharge pipeline	Interaction with co-users	Conflict of use	• Provide the authorities with information indicating the location of the pipeline and connection buoy. • Provide the fishing industry with information indicating the location of the pipeline and connection buoy.	Before start of operations

Activity	Aspect	Impact	Management Requirements	Duration
			• Indicate the extent of the exclusion zones. • Clearly mark the exclusion zone using buoys. • Ensure the hazard location is listed on navigational charts.	
	Exclusion zone extent	Safety at sea	• A zone of 500 m radius from the marker buoy is declared as an exclusion zone: 'no vessel zone.' • Along the pipeline (approximately one kilometre in length) a zone of 100 m wide is declared as a 'no fishing zone'.	For the life of mine
Vessel to shore slurry transfer	Approaching the connection area	Conflict of use	• Ensure that the approach to the connection point and exclusion zone is clear of marine traffic • Ensure that the exclusion zone area is free of marine traffic. • Verify that sea conditions are acceptable for ship to shore slurry transfer. • Ensure that the support vessel is on station. • Notify all relevant parties of intended slurry transfer.	For each transfer
	Connecting to the pipeline	Prevention of pollution.	• Deploy anchor. • Receive connection cable from the support vessel, support vessel stand clear. • Activate the connection process, and verify seal.	For each transfer
	Pipeline slurry transfer	Prevention of pollution.	• Pump seawater to flush the line of any residual sediment. • Initiate slurry transfer. • Pump seawater at the end of the transfer to flush the line of any residual slurry (residual slurry is captured in the holding pond ashore)	For each transfer
	Pipeline disconnection	Prevention of pollution.	• De-couple the vessel from the pipeline. • Verify that the pipeline returns to the seabed. • Engage engines and recover the anchor. • Advise the support vessel to return to port.	For each transfer
	Pipeline integrity	Prevention of pollution.	• Verify the integrity of the pipeline – pipeline inspection programme	Regular intervals according to inspection programme

Activity	Aspect	Impact	Management Requirements	Duration
Damage to, or disturbance of shipwrecks	Archaeological and historic sites	Loss of heritage information	• Stop dredging. • Advise the project manager. • Reinitiate dredging 1000 m from the suspected (identified) wreck location and or as advised by the project manager. • The project manager is to advise the National Monuments Council as relevant to the discovery. • Continue operations in that area only under the instruction of the National Monuments Council. • Retain all correspondence.	When a shipwreck is suspected

8.5 VESSEL: DREDGING OPERATIONS:

Commencement of dredging operations (includes recovery of sediments, fine tailings return, water column and marine fauna, but excludes all general ship activities, steaming, bunkering, and discharging of hopper contents) – Refer to Section 8.9 for detailed verification and monitoring survey programmes.

<table>
<tr><th colspan="2">Performance Objectives</th></tr>
<tr><td colspan="2">The management objectives are:
• Through mitigation and monitoring, minimise direct effects of the operation on the marine environment.
• Manage dredging related impacts on the marine environment to avoid compromising future exploitation of renewable marine resources.
• Establish and maintain an information base that will assist in evaluating cumulative impacts.
• Establish recovery rates of marine habitats impacted during the dredging.
• Through communication minimise potential conflict with other marine users.
• Promote information exchange with scientific institutions and I&APs.
• Protect heritage sites (shipwrecks) if encountered.
• Ensure for safety of the operation, by applying all relevant safe vessel operations</td></tr>
<tr><th colspan="2">Standards of compliance</th></tr>
<tr><td>• Minerals (Prospecting and Mining) Act (33 of 1992).
• Environmental Management Act (Act 7 of 2007).
• Marine Resources Act 27 of 2000
• MARPOL.
• Petroleum products and energy amendment Act (2000).
• Draft Pollution Control and Waste Management Bill.
• Merchant Shipping Act 57 of 1951.
• Wreck and Salvage Act (2004).
• United Nation Convention on Law of the Sea.</td><td>• The London Convention.
• Convention of Biological Diversity.
• Territorial Sea and Exclusive Economic Zone of Namibia Act, No. 3 of 1990.
• Namibian Ports Authority Act 2 of 1994.
• Marine Traffic Act, No. 2 of 1981 as amended by the Marine traffic Amendment Act 15 of 1991.
• Prevention and Combating of Pollution of the Sea by Oil Act No 6 of 1981 (as amended by Act 24 of 1991).
• Dumping at Sea Control Act 73 of 1980.
• Environmental Statement Policy</td></tr>
</table>

Activity	Aspect	Impact	Management Requirement	Duration
Dredging of the deposit	Biodiversity	Destruction of Sediment profile	For each target area, conduct geophysical survey prior to dredging and post dredging, to determine / provide information on: • Area and volume (thickness) of sediment removed versus predicted; • Residual volume (thickness) of sediment covering the footwall; • Morphological character of the seafloor; • Seabed areas within the dredged target area that are undisturbed by the dredging process; • Readjust frequency and scope of further post dredging geophysical surveys if required as a function of interpreted information against the primary objectives of the survey; • Integrate output information into adjustments for the next period of dredging; and • Retain data and interpretations to a GIS system.	Before the start of dredging & 3-5 yrs after dredging is completed & thereafter at redefined intervals
			• Through geophysical techniques record the morphological characteristics of a completed dredge zone; • Integrate output information into subsequent recovery surveys; and • Retain data and interpretations to an environmental GIS system.	During dredging
		Removal of sediments, destruction of benthos and disturbance to the environment	For each of the target areas prior to dredging being undertaken the following initial sample / data collection and or verification assessments are required: • Collection of representative macro faunal assemblages • Collection of meiofaunal samples • Collection of sediment for the evaluation of grain size, organics, dissolved nutrients & H_2S. (surficial and internal samples) • Distribution of bacterial mats • Integrate output information into adjustments of the planned recovery surveys; • Revise EIA assumptions in context accordingly, and • Retain data and interpretations to an environmental GIS system • Fisheries swept area type survey • Fisheries acoustic survey • Marine mammal, seabird & other marine fauna observations	Pre dredging verification assessment:

Activity	Aspect	Impact	Management Requirement	Duration
Dredging of the deposit		Recovery of benthos and environment	Dependent on the verification assessment, conduct for the target dredge areas: • Collection of representative macro faunal assemblage • Collection of meiofaunal samples • Sediment collection for grain size, organics, dissolved nutrients, trace metals & H_2S. (surficial and internal samples) • Disturbance, distribution, recovery of bacterial mats • Identify areas of actual and potential high sedimentation (inhibiting benthos recovery via smothering or particulate organic matter build up and possible anoxia) • Determine benthos recovery / re-colonisation rates • Revise future recovery monitoring programmes in context of the EIA accordingly, and • Retain data and interpretations to an environmental GIS system	Post dredging, in year 3, 5 and thereafter at redefined intervals
			• Fisheries swept area type survey • Fisheries acoustic survey • Marine mammal, seabird & other marine fauna observations	Annual survey to year 5 and thereafter by reassessment
	Discharge of 'lean' water overboard: Turbidity plumes	Water column quality	For each of the target areas prior to dredging being undertaken the following initial sample / data collection and or verification assessments are required: • Collection of seabed sediment for the evaluation of grain size, organics, dissolved nutrients, trace metals & H_2S. (surficial and internal samples) • Integrate the biogeochemical output information into the assumptions and determination of the EIA; • Integrate the biogeochemical output information into adjustments of the planned in-plume verification surveys; • Revise EIA assumptions in context accordingly, and • Retain data and interpretations to an environmental GIS system	Pre dredging verification assessments:

Activity	Aspect	Impact	Management Requirement	Duration
			For each target area undertake in-plume verification surveys designed to: • Verify plume behaviour, distribution and impacts determined from EIA, (as revised from site specific collected information); • Integrate in-plume survey output information and determine the need for further / frequency of in-plume evaluation assessments; • Based on output recommend the plan for the next in-plume survey(s); and • Revise EIA assumptions in context accordingly, and • Retain data and interpretations to an environmental GIS system	During target area dredging: Year 1 & 2. Pre dredging verification assessments:
Dredging of the deposit			If in-plume verification surveys indicate that plume impacts are more severe than predicted from the EIA, then real time controls on e.g. exceedances of turbidity, dissolved oxygen, H_2S thresholds etc., should be established to manage the dredging phase. • Revise EIA and management criteria; • Conduct appropriate in-plume monitoring; • Based on output recommend the plan for the next in-plume survey(s); and • Revise EIA assumptions in context accordingly, and • Retain data and interpretations to an environmental GIS system	As may be required, during dredging in following years

8.6 SUPPORT VESSEL

Includes all support activities to the dredging vessel (operations alongside), and matters related to the coupling of the sinker line to the dredger (operations in the pipe coupling area) and operations in the port control area, but excludes all general ship activities, as these are described in section 8.4 above.

Performance Objectives	
The management objectives are to: • Ensure for the safe operation of the support vessel. • Minimise disruption to all other users of the sea by respecting the right of passage. • Maintaining open communications with other marine users. • Ensure emergency contingency plans are in place.	
Standards of compliance	
• Minerals (Prospecting and Mining) Act (33 of 1992). • MARPOL[4]. • Merchant Shipping Act 57 of 1951. • Wreck and Salvage Act (2004). • Territorial Sea and Exclusive Economic Zone of Namibia Act, No. 3 of 1990. • Marine Resources Act 27 of 2000. • Namibian Ports Authority Act 2 of 1994. • Marine Traffic Act, No. 2 of 1981 as amended by the Marine traffic Amendment Act 15 of 1991. • Prevention and Combating of Pollution of the Sea by Oil Act No 6 of 1981 (as amended by Act 24 of 1991).	• Contractor approved waste management plan. • Contractor approved emergency response plan. • Contractor approved bunkering plan • Contractor approved project environmental management plan. • Contractor approved SOPEP plan. • Dredging contractor vessel safety management system. • Environmental Policy – Namibian Marine Phosphate. • Safety, Health, Environmental & Quality Policy – Contractor

[4] The relevant sections of MARPOL are reproduced in the appendix 2h

Activity	Aspect	Impact	Management Requirement	Duration
General operations alongside the dredger, e.g. victualling, crew transfers, etc.	Approaching the dredger	Safety of operation – incident / pollution prevention	• Ensure that the approach to the dredger is clear of marine traffic. • Verify that sea conditions are acceptable for ship-to-ship goods (including personnel) transfer. • Ensure open communications are established with the dredging vessel.	Life of mine – per transfer.
	Transfer of materials		• Secure all materials before transfer and confirm all is safe. • Deck duty officers to mutually approve materials transfers, initiate transfer. • Ensure open communications are established with the dredging vessel.	Life of mine – per transfer.
	Transfer of personnel		• Verify that the man transfer mechanism is fully functional and approved. • Initiate final briefing of parties to be transferred. • Deck duty officers to mutually approve personnel transfer, initiate transfer. • Ensure open communications are established with the dredging vessel. • Ensure that all personnel are equipped with appropriate personal protective gear.	Life of mine – per transfer.
Operations at the pipeline coupling area	Approaching the connection area	Safety of operation – incident / pollution prevention	• Verify that sea conditions are acceptable for ship to shore slurry transfer. • Ensure that the approach to the connection point and exclusion zone is clear of marine traffic • Ensure that the exclusion zone area is free of marine traffic. • Ensure open communications are established with the dredging vessel.	For each transfer
	Retrieving the sinker line leader cable		• Approach the sinker line marker buoy. • Deploy mechanism to retrieve the sinker line leader cable. • Retrieve sinker line leader cable. • Transfer the sinker line leader cable to the dredger. • Stand clear. • Ensure open communications are established with the dredging vessel.	For each transfer
	Monitor slurry transfer		• Observe sea surface for sediment plumes that may indicated pipeline leaks or failure. • Advise dredging Master of any questionable observations. • Monitor the transfer zone and surrounding area for other vessel activity. • Ensure open communications are established with the dredging vessel.	For each transfer
	Pipeline		• Assist as is necessary in the decoupling of the sinker line from the dredger.	For each

Activity	Aspect	Impact	Management Requirement	Duration
	disconnection		• Verify that the pipeline returns to the seabed. • Ensure that the sinker line marker buoy is secure and in working order. • Await instructions from the dredge vessel, return to port.	transfer
	Pipeline integrity	Pollution prevention	• Verify the integrity of the pipeline – pipeline inspection programme	Regular intervals according to inspection programme
Operations in the port control area	Taking bunkers	Pollution prevention	• Compliance with the NamPort requirements for the taking of bunkers. • Compliance with the requirements of MWTC for the taking of bunkers. • Initiate bunker transfer in compliance with 'standards of transfer.' • Standby of emergency protocol.	For each transfer
	Victualling		• Use of local resources and service providers. • Verification of safe staking area on quayside. • Immediately transfer goods from the quayside to the vessel.	For each transfer
	Waste management		• Compliance to the NamPort requirements for quayside waste transfers. • Ensure at all times that wastes are contained and do not spill, leak or blow away. • Retain waste transfer / disposal log	For each transfer
Vessel at standby status	Emergency assistance	Safety of operation – incident / pollution prevention	• At all times the support vessel is to be on standby to provide whatever assistance may be required.	Life of mine – 24 / 7.

8.7 SOCIO-ECONOMICS

Performance Objectives
• Establish a balance between economic, social and environmental responsibilities. • Provide training and development opportunities. • Provide services supply opportunities for local business. • Consult with the business community.
Standard of compliance
• Minerals (Prospecting and Mining) Act (33 of 1992). • Minerals Agreement (1995). • Labour Act (1992)

Activity	Aspect	Impact	Management Requirement	Duration
Communication	Managing perceptions	Conflict	• Develop I&AP relationships by maintaining communication on relevant issues. • Retain records of all I&APs communications.	Life of mine
			• Participate with relevant established community stakeholder forums. • Ensure regular feedback to the Company Steering Committee on environmental performance.	Life of mine
			• Publicise and make available information on the environmental monitoring programmes and environmental performance.	Life of mine
			• Participate in the development of the marine SEA. • Supply data and reports to the information custodians of the SEA	Life of mine
Dredging	Economy	Namibian economy	• Pay all applicable taxes and royalties to the Government as required.	Life of mine
Services		Local economy	• Use local suppliers of goods and services where economically practicable. • Invite local service providers to the tendering process.	Life of mine
Harbours		Financial contribution	• Pay all relevant harbour fees. • Use Walvis Bay harbour infrastructure and services where possible.	Life of mine
Recruitment	Social wellbeing	Erongo region	• Prioritise employment options to suitably qualified and skilled local citizens.	Life of mine
Skills Transfer	Knowledge transfer	Training	• Provide employees with development and skills training. • Provide environmental awareness programmes.	Life of mine
Research, education and community projects	Cooperative participation	Improved knowledge and awareness	• Where relevant, assist research and education to contribute to the general and specific understanding of environmental issues and management practices related to phosphate mining. • Where relevant supply monitoring data to the marine science and fisheries communities	Life of mine

8.8 MONITORING PLAN

Activity	Criteria	Frequency
Dredging Operations		
Fish – Mammals – Seabirds	• Fisheries swept area type survey • Fisheries acoustic survey • Marine mammal, seabird & other marine fauna observations	Pre dredging verification survey Annual monitoring survey
Fish (Monk fishery)	• Monitor the effectiveness of implementation of cooperation agreement.	Per event / annually
Discharge of 'lean' water overboard: Turbidity plumes	• Sampling of overspill water for particulates. • Photographs of the plume. • Monitoring organics, dissolved nutrients, trace metals & H_2S. • Record wind speed, direction, general ocean / climatic conditions	Once off verification survey for target dredging area.
Excavation of dredged seabed / Destruction benthic fauna	• Conduct a pre-dredging geophysical and benthic macrofaunal (include meiofaunal collection) survey to record seabed topography and types of marine life present. • Monitor the affected area using geophysical and/or benthic sampling techniques to assess recovery / re colonisation and residual sediment distribution	Pre dredging verification survey. Post-dredging, year 3 - 5. Re-evaluate the survey frequency thereafter
Marine fauna sightings	• Record the number of mammals, species of birds and jellyfish aggregations and sighted.	Daily.
Shipwrecks	• Record the date, time and location. • Advise the authorities.	Per event
Hydrogen sulphide	• On-board air quality monitoring.	During dredging
Transport and transfer of dredge sediments		
Other vessels in the area	• Record sightings / interactions with other vessels. • Maintain a communications register.	Per event
Discharge of dredged sediments	• Retain records of the volumes of sediments discharged to shore.	Per event

Activity	Criteria	Frequency
Waste Management		
Wastes	• Retain Garbage Record Book for all discharges of wastes and incinerations.	Per event
Hazardous substances	• Retain records of quantities used and disposed.	Monthly
Leaks and spills	• Retain records of all spills and remedial actions	Per event
Hydrocarbon consumption	• Retain records of oil and fuel consumption.	Monthly
Water consumption	• Retain records of quantities of fresh water used and the sources of supply.	Monthly
Lost equipment	• Record the item, location, date time, and recovery status	Per event

8.9 VERIFICATION AND MONITORING.

8.9.1 Verification: Sediment Properties in Main Areas.

MARINE ENVIRONMENTAL MONITORING SURVEY

SEDIMENT PROPERTIES IN MINE AREAS

Prepared by : Dr. R Carter of Lwandle Technologies (Pty) Ltd

8.9.1.1 Need for monitoring surveys

The conclusions and predictions of the environmental effects of dredging marine pelletal phosphate resources on the Namibian continental shelf are primarily based on the sediment properties in the dredging areas. We consider that the information on this is robust as it is drawn from the seminal work conducted by Bremner (1978), direct surveys of sediment properties across one of the mine areas by Rogers (2008) and because it is consistent with adduced distributions of turbulent energy across the shelf which control sediment texture distributions. All of this indicates that the sediments in the dredging areas are predominantly muddy sand. Hydrogen sulphide, methane and other chemical flux rate measurements conducted by, inter alia, Namibian and South African marine scientists indicate that these are low as sedimenting pelagically produced particulate organic matter (POM) does not accumulate on these sediments. Further, the phosphate deposit is considered to be derived from estuarine deposition in the Miocene (5-20 million years ago) so any organic material incorporated in the ore body would be extremely refractory. This implies that the only sources of sulphur would be pyrites which have low dissolution rates.

On the basis of the above the water quality and associated environmental risks associated with the dredging process, dredging, were considered to be predominantly physical as opposed to biogeochemical. Consequently the conclusions on sediment textures in the mine area are of pivotal importance in the environmental assessment.

It is clear from comments received from interested parties in Namibia especially that this is a contentious issue as, although no data or analyses (peer reviewed or not) are presented in support of alternative views, there is a persistent concern that sulphidic sediments will be exposed during dredging with important consequences for water quality.

In our view the only practical response to this is to conduct a sediment property verification survey, which should cover the identified dredging areas, prior to the commencement of any dredging operations.

8.9.1.2 Proposed Verification Survey

8.9.1.2.1 Purpose

The purpose of the survey is to gather primary data on sediment properties and characteristics in the mine areas. These data are to be used as verification of the sediment texture, associated hydrogen sulphide fluxes and trace metal distributions that underpin water quality risk assessments in the EIA. Clearly if the proposed survey contradicts the conclusions on sediment properties in the water quality assessment then the inferred associated impacts will require re-assessment.

8.9.1.2.2 Survey area

The survey area is defined as the three specified dredge areas (SP-1, SP-2 and SP-3). A grid of sampling sites is to be placed across each of the mine areas such that the broad distributions of sediment properties in each of them can be determined. Figure 8.1 (a - c) shows the provisional sampling station layout.

Figure 8.1/…

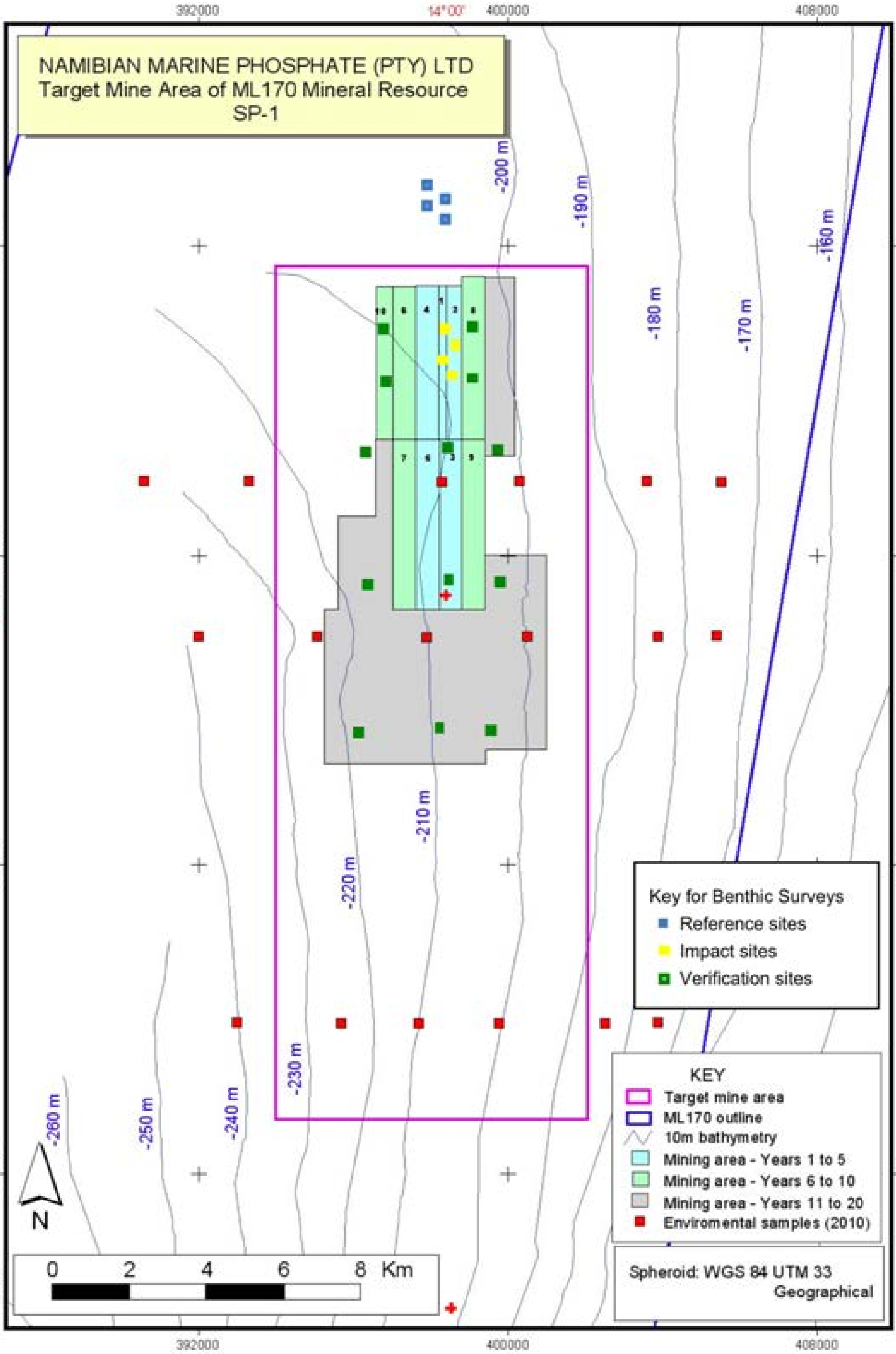

Figure 8.1 (a): Provisional verification sampling sites in Mine Area SP-1. Note that the sites are coloured green; additional sampling sites for the companion benthos monitoring programme are shown in yellow (impact) and blue (reference).

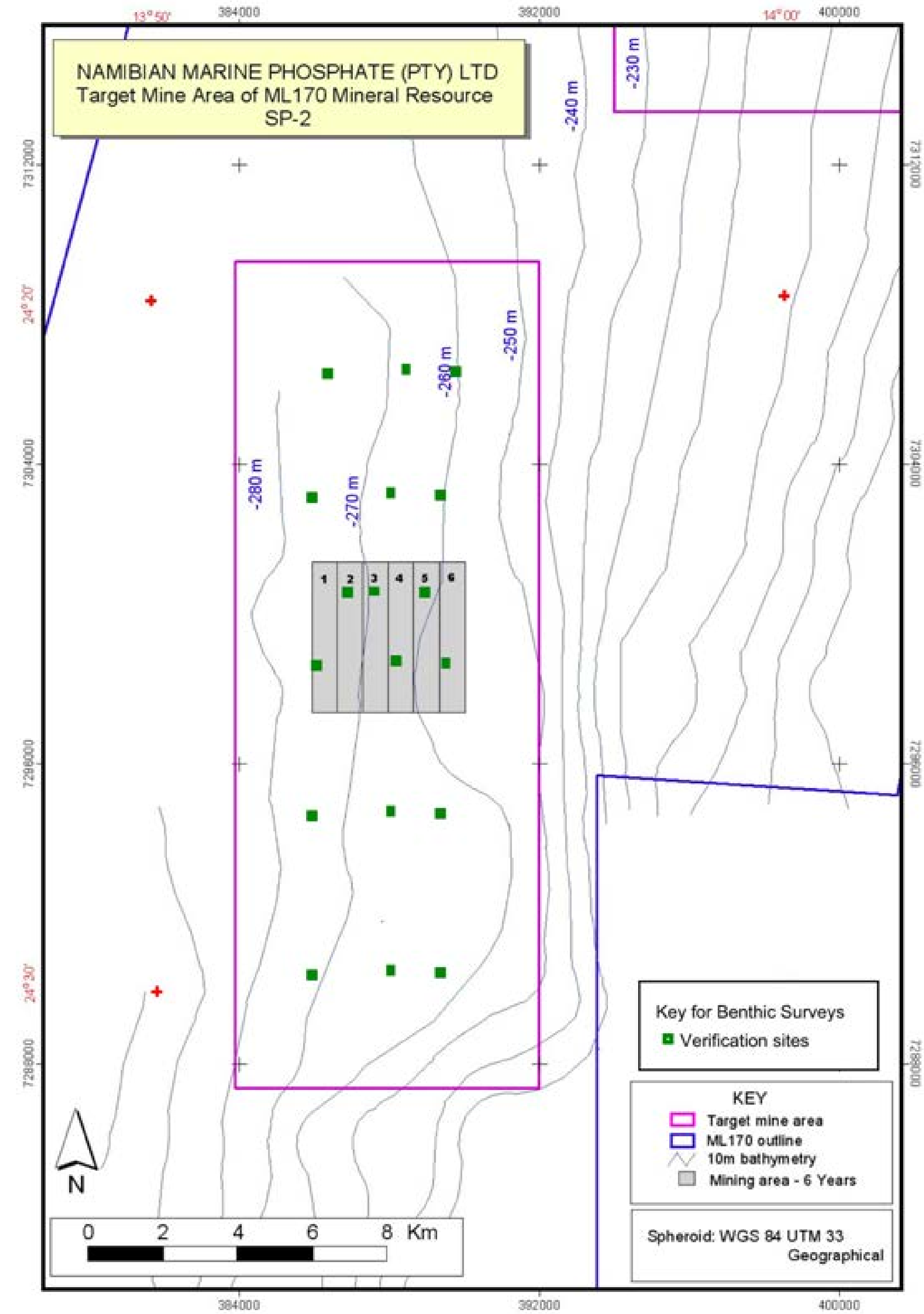

Figure 8.1 (b): ***Provisional verification sampling sites in Mine Area SP-2. Note that the sites are coloured green.***

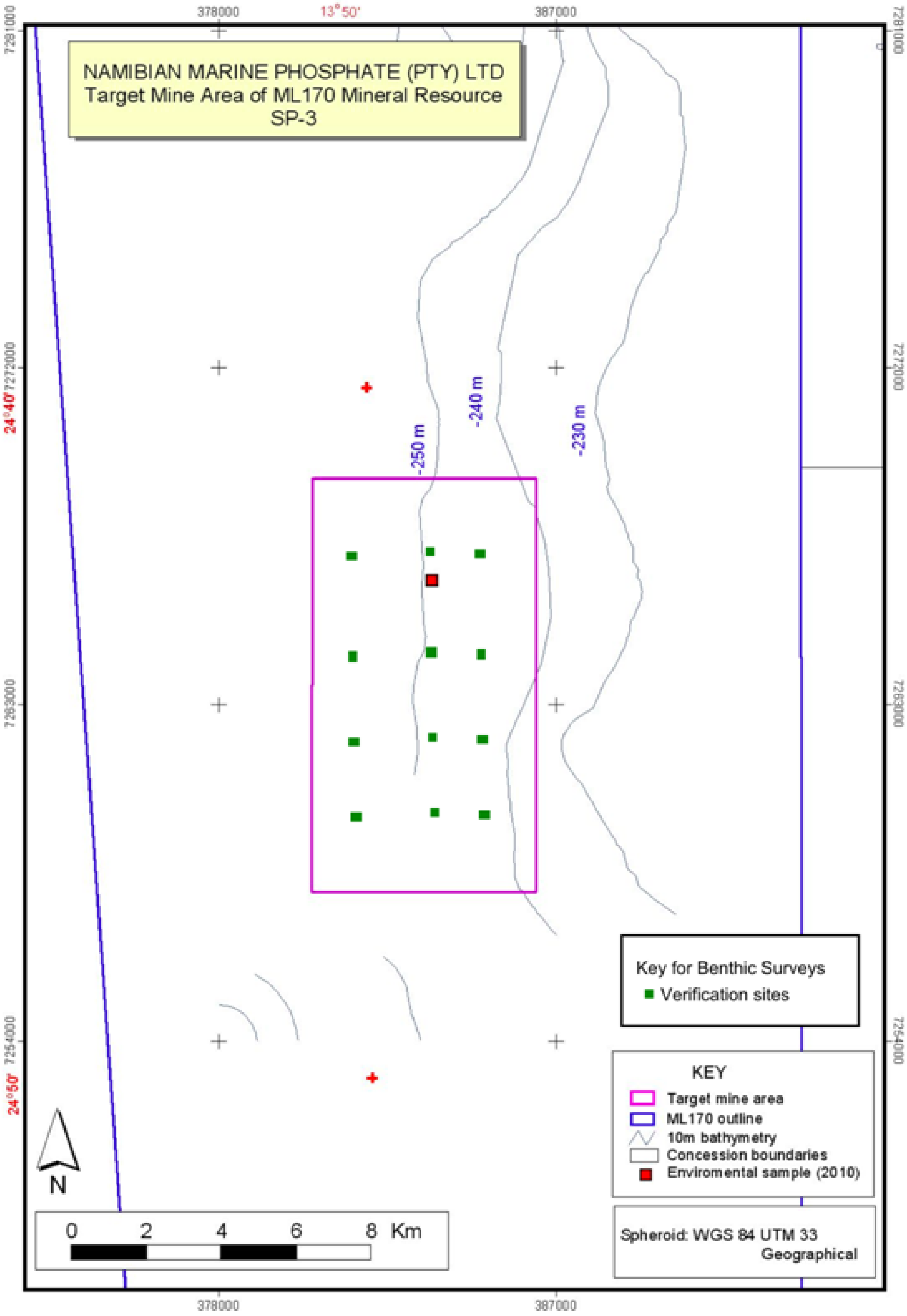

Figure 8.1 (c): Provisional verification sampling sites in Mine Area SP-3. Note that the sites are coloured green.

8.9.1.2.3 SURVEY METHODS

Survey vessel and equipment

The survey will need to be undertaken from a vessel that allows safe deployment, recovery and working on surficial sediment grab samples (0.25 m2 Day Grab) and gravity cores. In addition it should have winch and laboratory space for operating multi-parameter CTD equipment as well as non-food refrigeration and freezer space. The standard safe navigation, communication and associated equipment is mandatory as is crew experienced in winch and crane/davit/A frame operation.

Sediment sampling and analyses

At each sampling site shown in Figure 8.1 (a - c) a Day Grab sample will be recovered. At approximately 12 of the sites sediment cores will be recovered with the gravity corer. The following sampling and analyses will be conducted:

- *Day Grab*
    - ~500 ml surficial sediment for sediment particle size and texture analyses (Geoscience Laboratory, Cape Town). This will include > and <63 µm fraction.
    - ~250 ml surficial sediment for particulate organic carbon and (total) nitrogen analyses ((CSIR Analytical Laboratory, Stellenbosch).
    - ~250 ml surficial sediment for trace metal analyses (CSIR Analytical Laboratory, Stellenbosch). Samples will be taken at all sites but a subset of these will be processed (~15); and
    - Core samples for benthos macrofauna analyses (see companion benthos verification survey).

- *Gravity Core*
    - Sub-sections of the core down the length of the sampled sediment for sediment texture, particle size and organic carbon and nitrogen analyses as above, and
    - Direct determinations of (hydrogen) sulphide concentrations and redox potential down the length of the sampled sediment (in situ probe measurements.

Water Column

Water column profiling will be undertaken with a multi-parameter CTD operating in internal logging mode. Water column features are temporally and spatially variable in the mine area and the intention of the profiling is to obtain representative data rather than firm statistical descriptions of the measured variables. The variables to be measured will include:

- Conductivity/temperature
- Dissolved oxygen (Ringco fluorescence sensor)
- pH
- Turbidity (OBS), and
- Chlorophyll fluorescence.

8.9.2 Verification: Dredge Sediment Plume Behaviour and Water Quality Effects

MARINE ENVIRONMENTAL MONITORING SURVEYS

DREDGE SEDIMENT PLUME BEHAVIOUR & WATER QUALITY EFFECTS

Conceptual Design

Prepared by : Dr. R Carter of Lwandle Technologies (Pty) Ltd

8.9.2.1 Need for monitoring surveys

By definition dredging disturbs the seabed and resuspends sediments, the latter at the dredge head and through overspill of from dredger hopper. Both plumes modify seawater quality through increased total suspended sediment (TSS) concentrations but also through possible reductions in dissolved oxygen concentrations, diminished pH levels, elevated dissolved trace metal concentrations etc. The impacts associated with these were evaluated in the EIA specialist study on water quality where it was concluded that the respective impact significance levels would be low. This is predicated on information on seabed sediment properties (texture, particle size, probable organic loads) and dredging rates and dredger behaviour. The former is to be verified in a pre-dredging survey into sediment properties (surficial and through the upper metres of the deposit), the latter can only be constrained when dredging commences. Therefore the predicted impact levels can only be confirmed at this project phase.

Dredger plume behaviour and plume intensity (TSS and dissolved oxygen etc. concentrations) are contentious issues in dredging in general and are particularly so in the context of dredging middle continental shelf sediments off Namibia due to the biogeochemistry of the seafloor sediments and possible conflicts with other ecosystem services. Consequently measurements of actual plume properties in the early stages of dredging are advisable both in confirming predictions made in the EIA phase and/or for instituting real time or other controls on dredging such that the environmental risks are constrained. Examples of the latter can be surveys of, e.g., TSS distributions against water quality thresholds, monitoring TSS or oxygen concentrations at fixed points in the dredging area in real time and instituting controls when thresholds are compromised etc.

8.9.2.2 Conceptual Monitoring Design

8.9.2.2.1 Monitoring Objective

The monitoring objective is to determine the extent of, primarily, turbidity plumes generated by dredging of phosphate deposits, the concentration gradients of suspended sediments, dissolved oxygen and pH in the plumes in comparison with adjacent unaffected seawater, together with plume decay rates over space and time. These data are to be used to refine the impact predictions made in the EIA and to determine the requirement for real time dredger plume monitoring and control.

8.9.2.2.2 Monitoring survey approach

The monitoring should combine short term fixed moorings comprising upward looking ADCPs (acoustic doppler current profiler) (currents and ADCP beam intensity as proxy for TSS concentrations through the water column), moored optical backscatter (OBS) and dissolved oxygen (Rinko) sensors for continuous recording of turbidity and dissolved oxygen at specific depths within the water column, water column profiling with a multi parameter CTD (CTD+DO+pH+Chla+OBS) and water sampling for dissolved trace metals and calibration samples for DO, pH and OBS (and ADCP) probes. The instrumentation moorings should be located immediately adjacent (within ~1 km) of the 4 km long dredge panel being mined during the period of the survey, one mooring to the S, one N and one E. CTD profiling should be conducted intensely across the dredger track with multiple transects across a fixed point at ~30 minute intervals to determine the temporal decay rates of dredger plumes. In addition the entire dredge panel should be surveyed on a grid of stations to determine the spatial dynamics of the plumes. The two CTD surveys patterns are to be conducted sequentially. Finally, far field profiling and water sampling will need to be conducted to define the reference conditions for each survey day.

8.9.2.2.3 Survey area (schematic)

The survey area is defined as the dredge panel being mined at the time of the survey. This will be in the SP-1 target mine area. According to details in the EIA the spatial extent of the dredging in year one will be 4 km long by 200 m wide, in year two, 400 m wide and in year three and thereafter 600 m wide. This gives rise to the provisional mooring and measurement grids shown in Figure 8.2. Note that these are 'generic' and can be applied to whichever dredge panel is the focus of dredging at the time of survey. The main constraint is that dredging should not shift between panels during surveys as this would interrupt the time series measurements being made at the moored instrumentation sites.

8.9.2.2.4 Survey periods

Survey periods should be 5 days of measurements indicating overall cruise periods of 8-10 days to allow for instrumentation deployments and recoveries.

8.9.2.2.5 Survey platform

The survey ship should be sufficiently equipped for the safe deployment and recovery of sophisticated oceanographic instrumentation yet be sufficiently manoeuvrable to operate closely behind an operating dredger. It will need to be equipped with light winches for handling CTD deployments and have laboratory working space for water sample processing (filtration, titrations, etc.)

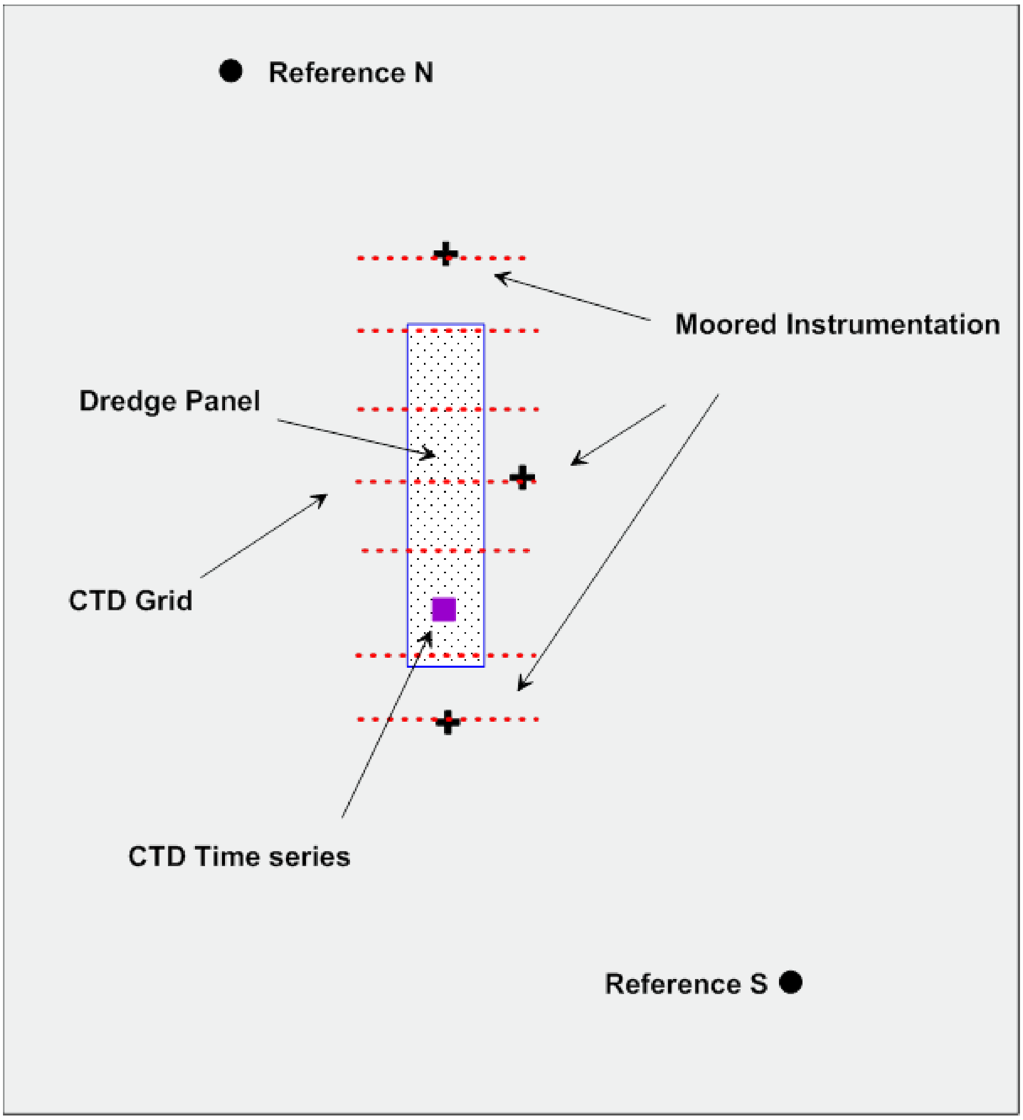

Figure 8.2: ***Schematic showing the provisional plume monitoring measurement sites for a dredge panel in Mine Area SP-1. It is expected that dredger tracks will be north/south. If sea conditions dictate otherwise the measurement locations will be relocated as needed***

8.9.3 Verification Survey and Baseline for Benthic Macrofauna

BASELINE VERIFICATION SURVEY AND A LONG-TERM BENTHIC MACROFAUNA MONITORING SURVEY FOR A PROPOSED DEVELOPMENT OF PHOSPHATE DEPOSITS IN THE PHOSPHATE LICENCE AREA ML170

Prepared by: Dr. Nina Steffani
Steffani Marine Environmental Consultant

Proposal for a Baseline Verification Survey and a Long-term Benthic Macrofauna Monitoring Survey for a Proposed Development of Phosphate Deposits in the Phosphate Licence Area ML170 off the Coast of Central Namibia

8.9.3.1 Introduction and Scope

Namibian Marine Phosphate (Pty) Ltd (NMP) has been awarded a 20-year mining licence (ML170), which is located on the Namibian continental shelf offshore Conception Bay in water depths ranging from 180 to 300 m covering a total area of 2233 km^2. Within the mineralized resource zones of the licence area, also named Sandpiper licence area, three target areas have been identified, i.e. Sandpiper-1 (SP-1), 2 (SP-2), and 3 (SP-3). SP-1 is in the north of ML170 in water depth from 190-235 m, SP-2 is in the centre in depth 245-285 m and SP-3 is in the south at 235-270 m depth. Both SP-1 and SP-2 target areas are 22 km long x 8 km wide, while SP-3 is 11 km long x 6 km wide. NMP is proposing to dredge the uppermost 1-2.5 m (possibly up to 3 m) of the seafloor in these target areas to recover phosphate rich material for use as fertilizer.

With respect to this proposed project, it is necessary to conduct an Environmental Impact Assessment (EIA) and compile an Environmental Management Plan (EMP). An earlier scoping process had identified key environmental issues, which were addressed in a series of Marine Specialist Studies including a report on benthic fauna. First drafts of the EIA and the Specialist Studies were published for comments in January 2012, due to be finalised by end of March 2012.

With the exception of a benthic macrofauna and sediment property survey derived from 20 stations in SP-1, information on the physical and biological environment specific to the ML170 is very sparse. Most of the impact assessments discussed in the Benthic Specialist Study are thus based on assumptions that are arrived from publicly available data from areas outside the Sandpiper licence area. The assumptions drawn from these data are deemed robust, but nonetheless it is recommended that an initial 'verification' survey to confirm these. An important aspect of this verification survey is the sampling of the macrofauna communities in all three dredging target areas. Continuing from this initial verification survey, the severity of the removal and destruction of benthic communities by the dredging process and the subsequent recovery (functional recovery) process need to be ascertained. A post-dredging benthic monitoring programme thus needs to be established.

NMP has requested Steffani Marine Environmental Consultant to prepare a proposal pertaining to a macrofauna verification survey and a subsequent monitoring survey, both of which are outlined in this proposal. This proposal is part of a series of verification surveys that are described in separate proposals. These surveys have to be seen in a combined context as they complement each other and will be undertaken at the same time.

8.9.3.2 Benthic Habitat

Dredging for offshore marine phosphate deposits is destructive by nature and thus inevitably affects the benthic communities of the receiving environment. The sea bed disturbed by the dredging activity is home to many communities, living on (epifauna) or in (infauna) the superficial sediments of the sea floor, with the greatest abundance to a depth of ~20 cm. The fauna is typically divided by size into megafauna (>10 cm), macrofauna (large enough to be retained on a 1-mm sieve, while some researchers also use a 500-micron sieve), meiofauna (0.1-1 mm) and microfauna (<0.1 mm). The macrofauna usually constitute the dominant biomass or organisms within marine sediments and typical taxa include polychaete annelids, smaller crustaceans (e.g. amphipods, isopods, shrimps, crabs), and molluscs (gastropods and bivalves) besides many other phyla. Megafauna include large crustaceans, molluscs, and echinoderms, and are often associated with the surface of the sea floor. The meiofauna is dominated by the large and diverse groups of nematodes and harpacticoid copepods, while microfauna include bacteria and protists. Macrofauna and other benthic fauna are a major food source for fish and other benthic predators, and play important roles in ecosystem processes such as nutrient cycling, pollutant metabolism, and dispersion and burial of organic matter.

The northern and central Benguela regions are characterised by the occurrence of natural shelf hypoxia, which is referred to as Oxygen Minimum Zone (OMZ) (Monteiro *et al.* 2011). OMZs have dissolved oxygen concentrations of ≤0.5ml/ℓ and typically impinge upon the continental margins of upwelling regions. Off Namibia, this layer extends between at least 18°S and 28°S and up to 60 km from the shore. The hypoxic conditions depict seasonal variation, locally shifting to anoxic conditions in late summer-autumn (Monteiro *et al.* 2008). A further significant feature of the central Namibian middle shelf is an extensive mud belt comprising organically rich diatomaceous oozes originating from planktonic detritus from the high productivity in the upwelled waters. The diatomaceous mud belt with a thickness of up to 14 m extends over 700 km in an N-S direction and 100 km in an E-W direction. Depending on the local bathymetry and dynamic current intensity, the landward flank of the mud belt is found at 15-104 m water depth, and the seaward flank from 45-151 m (Bremner 1983). The mud belt is characterised by often anoxic bottom water conditions and high H_2S fluxes, occasionally resulting in H_2S eruptions with devastating effects on the local fauna . These natural events can spread over 20 000 km^2 (Weeks *et al.* 2004).

The Sandpiper Mining Licence Area lies offshore from the mud belt at the fringe of the central Namibian OMZ and is thus affected by variable dissolved oxygen conditions with bottom-water oxygen concentrations probably below 0.5 ml/ℓ, but it is likely to be less affected by high H_2S concentrations in the surficial sediments or near-bottom waters, or severe anoxic conditions.

Despite oxygen depletion, benthic assemblages can thrive in OMZs as many organisms have developed highly efficient ways to extract oxygen from oxygen-depleted water (e.g. small bodies, enhanced respiratory surface area, blood pigments, and specialised enzymes) (Levin 2003). Within OMZs, foraminiferans, meiofauna, and macrofauna typically exhibit high dominance and relatively low species richness (Levin 2003). In contrast to meiofauna, macrofauna and megafauna often have depressed densities and low diversity in the cores of OMZs, where the oxygen concentration is lowest, but they can form dense aggregations at the OMZ edges (Levin 2003, Levin *et al.* 2009).

Very little is known about the Namibian OMZ benthic infauna (see Arntz *et al.* 2006, Zettler *et al.* 2009). In May 2010, a macrofauna baseline survey was conducted by NMP in SP-1 as this is the initial priority area for proposed dredging operations (Steffani 2010a). Overall species richness of the benthic macrofauna assemblages was relatively low and strongly dominated by polychaetes (64% of species), followed by crustaceans, and molluscs. Most species found in the study area have a larger geographical distribution and/or have been recorded elsewhere from the Namibian and/or South African west coast (e.g. Savage *et al.* 2001, Steffani 2007, 2009, 2010b, Steffani & Pulfrich 2004, 2007, Zettler *et al.* 2009). The most abundant species was the polychaete *Paraprionospio pinnata* (44% of overall abundance), which is a low-oxygen indicator species prevalent in OMZs worldwide. Generally, the benthic community composition in terms of species diversity and phyla dominance is in agreement with studies from other OMZs around the world (e.g. Gutierrez *et al.* 2000, Levin *et al.* 2000, Gallardo *et al.* 2004, Gooday *et al.* 2009, Levin *et al.* 2009).

In contrast to the core of OMZs where macrofauna density is often reduced, macrofauna has been found to increase at the edges of OMZs dominating the benthic fauna (e.g. Mullins *et al.* 1985, Gooday *et al.* 2009, Levin *et al.* 2009). Levin *et al.* (2009), for example, reported dramatic changes in macrofaunal dominance from the core of the OMZ at the Pakistan margin to the lower boundary and documented the existence of dissolved oxygen thresholds for macrofauna between 0.1 and 0.2 ml/ℓ. Below such thresholds, most taxa are excluded through physiological intolerance to hypoxia, while above them selected taxa are able to take advantage of an abundant food supply. The availability of both oxygen and organic carbon seem to determine the richness of macrofaunal species in OMZs until the oxygen content rises to about 0.45 ml/ℓ; above that level oxygen is much less important (Levin & Gage 1998). It has been further hypothesized that under conditions of permanent hypoxia, small-bodied animals, with greater surface area for O_2 adsorption, should be more prevalent than large-bodied taxa (Levin 2003). However, body sizes were found not to be smaller within the lower OMZs of the Oman (Levin *et al.* 2000) and Pakistan margins (Levin *et al.* 2009), and it was suggested that the abundant food supply in the lower or edge OMZs promotes larger macrofaunal body size. Zettler and co-workers (2009), who studied the macrofauna community in the OMZ off northern Namibia (offshore the Kunene River mouth, which is at the northern fringe of the OMZ), reported a far lower species diversity in the hypoxic zone than compared to oxygenated nearshore areas, but the high dominance of molluscs (not typically found in core OMZs) led them to suggest that the community is probably rather representative of the fringes of the upwelling cells of the northern Benguela than of the centre where severe anoxia and high hydrogen sulphide concentrations occur. Molluscs also contributed a relatively significant proportion to the fauna in the SP-1 target area and as the Sandpiper licence area is situated at the southern fringe of the OMZ, a similar scenario is likely to apply, suggesting that the macrofauna is playing a significant role in the benthos of the target areas. Similarly, in an early study by Sanders (1968) of the benthos in the Namibian OMZ, a reduction in macrofauna species diversity has been observed in the core, whereas higher abundances and biomasses have been recorded from the edge of the OMZ.

8.9.3.3 Objectives and Key Questions

As part of their Environmental Management Programme for the Sandpiper licence area, NMP has committed to undertaking a benthic macrofauna verification survey to collect information on general macrofauna distribution patterns in the three target areas. This will also aid in verifying some of the assumptions on which the assessment of impacts was based. This initial survey will be followed by a macrofauna monitoring programme, whose principal objective is to study the rate of recovery of disturbed macrofaunal communities once the dredging activity has ceased in a particular dredge block. Recovery has been shown to be both spatially and temporally variable, and to confidently measure the ecological recovery rate of mined areas, it is therefore necessary to develop a benthic monitoring plan that is not only appropriate in the medium-term (~5 years), but has the flexibility and potential to be extended into the long-term.

The key objectives for the *verification survey* are:

- Establish a data set on general macrofauna distribution patterns in all three target areas;
- Relate the distribution patterns to environmental factors such as water depth, sediment texture, near-bottom oxygen concentrations, organic carbon content, and H2S concentrations; and
- Investigate the relative importance of the smaller macrofauna size fractions.

The key questions for the *monitoring programme* are the following:

- What is the rate of recovery of the physical environment e.g. in-filling of mined-out areas with unconsolidated sediments?
- What is the process of the recovery of the benthic macrofauna?
- How long after the disturbance does it take for the benthic community to recover to at least an ecologically functional community?
- How does the physical environment (e.g. sediment particle size, organic matter, dissolved oxygen) influence the recovery rate?

8.9.3.4 Survey Method and Design

8.9.3.4.1 General Sampling Procedure

Sampling for macrofauna will involve the use of a Day grab or box corer. Both sampling tools are capable of retrieving a sediment sample with an undisturbed surface. The Day grab has the advantage that it can be handled from a smaller surveying vessel. Once retrieved, macrofauna samples will be taken from the larger grab with subcorers with an inside diameter of 9.6 cm x 30 cm length (72.4 cm^2). It is proposed to take one to two subcorers per grab. The sample volume collected with this method is in agreement with other studies conducted in OMZs (e.g. Gallardo *et al.* 2004, Gooday *et al.* 2009, Levin *et al.* 2000, but see Zettler *et al.* 2009). From the same grab, sediment particle size and total organic carbon (TOC) will be determined. In addition, near-bottom dissolved oxygen concentrations will be measured with a CTD and H_2S concentrations in the pore water analysed for a selected number of grabs, and in addition in a number of gravity cores down to depth. These measurements are described in the proposal for the sediment properties verification survey (Lwandle 2012).

The original macrofauna baseline survey in SP-1 used a 1-mm sieve to separate the macrofauna from the sediment as this is the traditional standard mesh size used in macrofauna surveys (Rumohr 2009). Studies on macrofaunal abundance in OMZs, however, often use smaller sieve sizes in anticipation that many macrofauna species will be generally smaller (e.g. Gallardo *et al.* 2004, Gooday *et al.* 2009, Levin *et al.* 2009). Sieve sizes used in OMZ studies vary between 0.3 mm (e.g. Gallardo *et al.* 2004, Gooday *et al.* 2009, Levin *et al.* 2000, 2009), 0.5 mm (e.g. Sahling *et al.* 2002, Gutiérrez *et al.* 2000, Palma *et al.* 2005), and 1 mm (e.g. Rosenberg *et al.* 1983, Zettler *et al.* 2009, see also Levin & Gage 1997 for references on studies using sieve sizes ranging from 0.3 to 1.0 mm). For example, the only recently published study on the Namibian OMZ macrofauna (northern Namibia), has used a 0.1m^2 van Veen grab and a sieve size of 1 mm (Zettler *et al.* 2009), similar to the Sandpiper benthic baseline study. To determine the relative importance of the various size fractions, it is proposed to sieve the samples on-board through a 0.3-mm sieve. In the laboratory sorting procedure, the 0.3 - 0.5 mm, 0.5 - <1 mm, and the >1 mm size fractions will be separated for a number of samples with a nested sieve design and analysed separately to indicate the right mesh size for the long-term monitoring study and also permit comparison to the baseline study. Sieving of the samples will be conducted with an automated Wilson autosiever that gently keeps the material in the sieve in motion by flotation with water from below instead of spraying with water from above. This will reduce damage to fragile organisms. As found during the benthic baseline survey and substantiated by the extensive geological mapping by NMP, it can be expected that the surficial sediment layers (top >30 cm) will contain significant amounts of large broken shell pieces. This not only will drastically increase the amount of material retained on the 0.3 mm screen and thus the sieving time, but may also damage the organisms. It is thus proposed to use a 3 mm or 5 mm screen to separate this shelly layer from the actual macrofauna sample. Careful visual inspection of the material retained on the larger screen will ensure that any larger organisms retained are transferred to the macrofauna sample. The sieved sample will be stored in 10% buffered formalin.

In the laboratory, macrofauna samples will be re-sieved through a 0.3-mm sieve and sorted under a stereo binocular microscope at 10-25 x magnification. If needed, the sample may be stained with Rose Bengal to aid in the sorting. Specimens will be identified to the lowest taxon possible and counted. Wet biomass will be 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 0.3 mm screen that traditionally are considered to be meiofauna (e.g. nematodes, copepods, ostracods and foraminifera) will not be included in counts, biomass measurements or subsequent analyses. This is in line with other studies on OMZ macrofauna (e.g. Levin *et al.* 2000, Gallardo *et al.* 2004). At first, a minimum of ten samples will be sorted with a nested sieve design separating the three size fractions. After analysis of the absence/presence and relative importance of macrofauna in the various fractions, a final sieve size will be determined.

8.9.3.4.2 LAYOUT OF VERIFICATION SURVEY

For the verification survey, an increased spatial coverage has been opted for at the expense of replication per site. This will provide a better resolution of macrofaunal distribution patterns across the three target areas. Small scale patchiness, however, cannot be investigated with this design but increased replication per site in the monitoring survey will provide data on small-scale variability (see Monitoring Programme below). Sampling stations will be spread across the target areas in a grid pattern with increased spatial coverage in the mine blocks proposed for dredging within SP-1 and SP-2. Proposed numbers of sample stations are 16 in SP-1 (plus 4 monitoring sites, see below), 18 in SP-2, and 12 in the smaller SP-3; this amounts to a total of 46 samples (plus the four impact and four reference sites for the monitoring survey, see below). Figures 8.3 (a - c) illustrate the proposed layouts of the sampling stations in the three target areas SP-1, SP-2, and SP-3.

8.9.3.4.3 MONITORING PROGRAMME

Continuing from the initial assessment survey, the severity of the removal and destruction of benthic communities by the dredging process and the subsequent recovery (functional recovery) process need to be ascertained. A post-dredging benthic monitoring programme thus needs to be established.

Worldwide, the study of benthic assemblages has been used to investigate the impacts on the seafloor of human activities. There is continuous debate whether such monitoring programmes should focus on macrofauna or meiofauna, or on both (e.g. Somerfield *et al.* 1995, Coull & Chandler 1998, Kennedy & Jacoby 1999, Schratzberger *et al.* 2001). Typically macrofauna is the preferred option as sample collection and species identification is comparatively easier (Kennedy & Jacoby 1999). Macrobenthos is commonly used as biological indicator because as a group they are relatively sedentary and reflect the quality of their immediate environment, many benthic species have relatively long life spans and their responses integrate water and sediment quality changes over time, and they include diverse species with a variety of life history characteristics and tolerances to stress and can usually be classified into different functional groups. Examples of the use of macrofaunal monitoring surveys include studies on the effects of oil pollution (e.g. Dauvin *et al.* 2003), organic enrichment (Pearson & Rosenberg 1978, Macleod *et al.* 2004), offshore drilling operations (Daan *et al.* 1995, 1996), submarine tailings disposal (Ellis 1982, Burd 2002), and particularly of marine aggregate dredging operations (e.g. Newell *et al.* 1998, Herrmann *et al.* 1999, Newell *et al.* 2004).

In low-oxygen environments such as OMZs, body size seems to be very important as small organisms are best able to cover their metabolic demands in the OMZ, and besides adaptation to low oxygen often have a capability to conduct anaerobic metabolism. Meiofauna may thus increase in dominance in relation to macro- and megafauna (Levin 2003). However, the Sandpiper licence area and specifically the target areas are at the edge of the OMZ, and several studies have shown that macrofauna has been found to increase at the edges of OMZ dominating the benthic fauna (see above). The difficulty in conducting meiofauna monitoring surveys in comparison to macrofauna studies thus favours the use of macrofauna for long-term studies, and the extensive use of macrofauna surveys for a wide variety of anthropogenic disturbances suggests that data on macrofauna composition and abundance should be able to shed light on it. Macrofauna is also routinely and often solely collected in studies on OMZ benthos (e.g. Levin &

Gage 1998, Levin *et al.* 2000, 2009, Ueda *et al.* 2000, Gallardo *et al.* 2004, Arntz *et al.* 2006, Gooday *et al.* 2009, Zettler *et al.* 2009).

In identifying and assessing the impacts of phosphate dredging on the macrobenthic communities, it is important to recognize that the marine environment can be very variable both in space and time. An impact should not therefore be characterized as being the difference in some measure at a particular site before and after a disturbance, but should be distinguished as being the relative difference between changes at a disturbed/impact site compared with changes that have occurred in a similar undisturbed reference site (Underwood 1992, 1993, 1994). In other words there must be some change from before to after a disturbance and such change must be significantly different from what occurred in undisturbed reference areas. Community parameters, however, vary both spatially as well as with time, fluctuating in response to natural variations in the environment (these may be monthly, seasonal or annual variations). Without adequate indices of natural variability, it will be inherently difficult to place dredging-related impacts in context. It is therefore important to have a number of impact sites in association with a number of reference sites that are in a similar environment (e.g. depth and sediment texture) but will remain undisturbed over the period of the monitoring programme. Here it is important to note that it would be prudent to select sites that will also not be affected by other anthropogenic activities such as trawling. If possible, the sites should either be located in areas not utilised by the trawling industry or trawling should be excluded from the immediate area for the duration of the monitoring programme. This is important as effects of trawling may have traditionally affected parts of the mining licence area beyond the 200-m isobath but since trawling will not occur in the target areas once phosphate dredging operations commence (due to safety issues), this impact should also be avoided for the reference sites. The envisaged position of the reference sites are, however, such that conflict is expected to be low as trawling usually occurs in deeper waters.

The proposed position of the sampling stations is illustrated in Figure 8.3 (a - c). For operations in SP-1, four impact stations and four associated reference sites are proposed. At each site, five replicate samples will be taken. Included in the sampling procedure should be at least the sampling for sediment properties (i.e. grain size analysis) as well as near-bottom dissolved oxygen concentrations and organic matter content. Sites have been selected according to the currently proposed mine schedule to fall into the mine blocks that will be mined in Year 1 and Year 2 of the schedule. This ensures that any information on recovery processes can be collected as early as possible to inform the Environmental Management Programme. Prior to operations being initiated in SP-2, a second monitoring programme needs to be established and similarly for activities in SP-3.

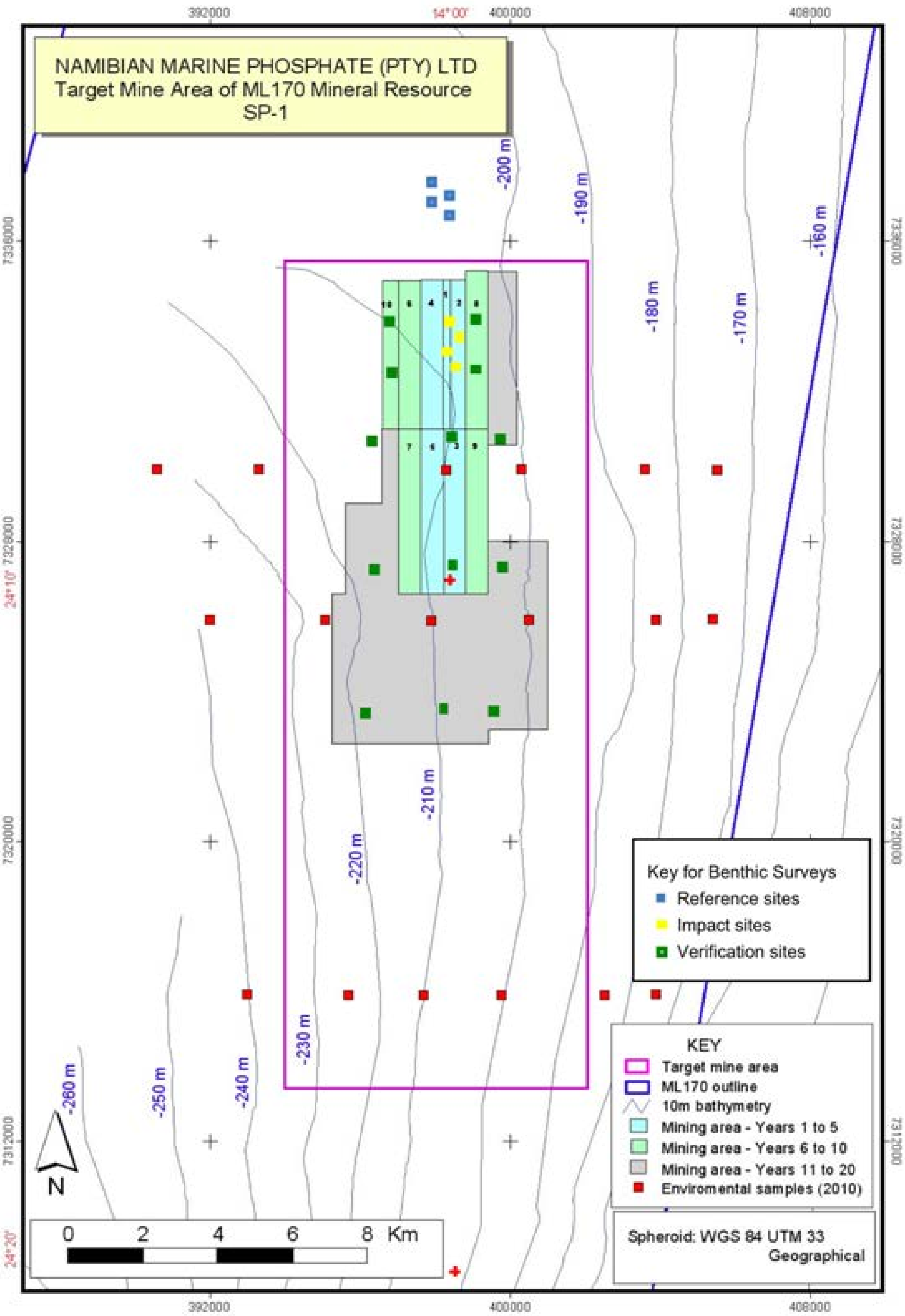

Figure 8.3 (a): Proposed layout of macrofauna sampling stations for the verification and monitoring survey in SP-1.

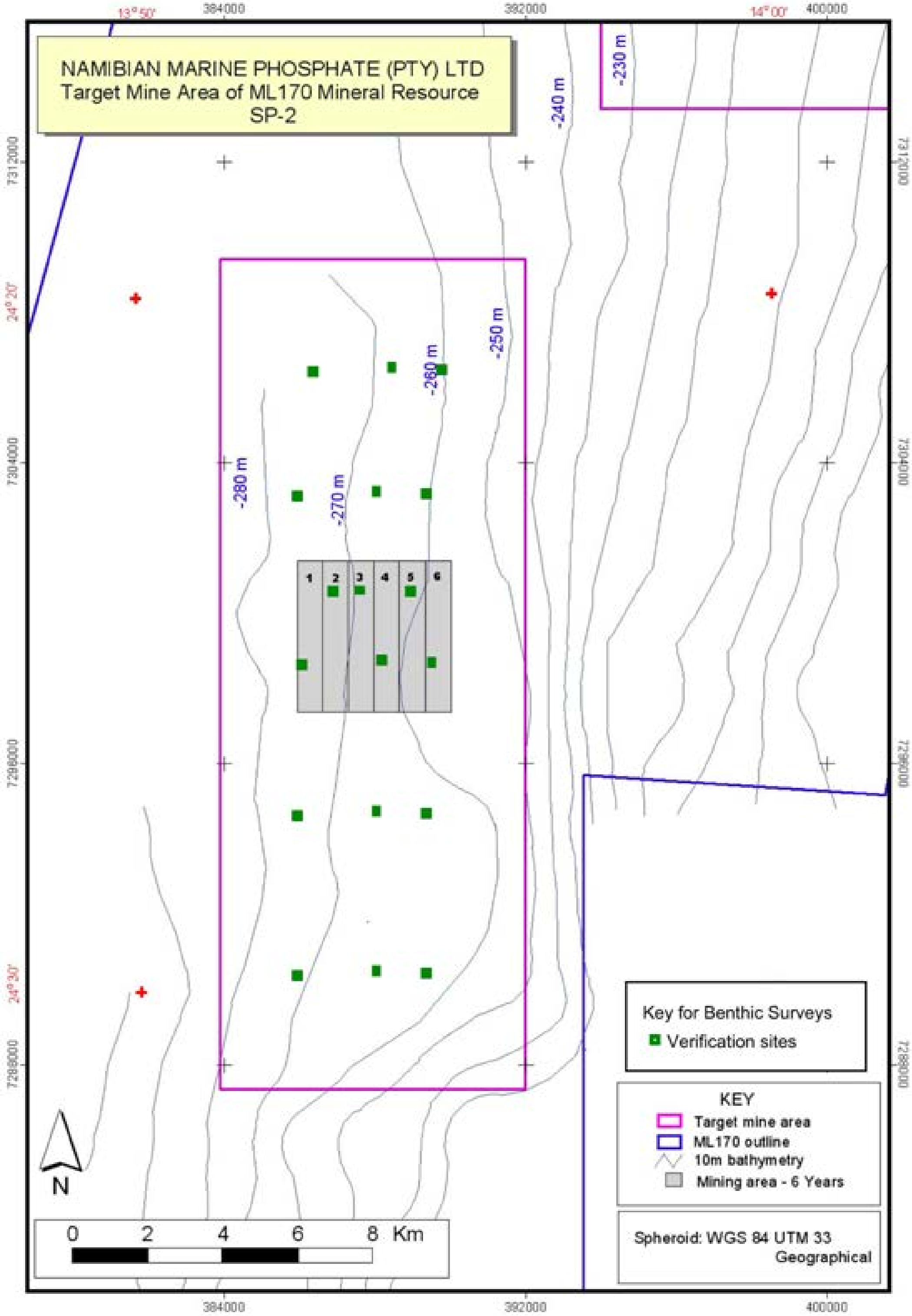

Figure 8.3 (b): Proposed layout of macrofauna sampling stations for the verification survey in SP-2.

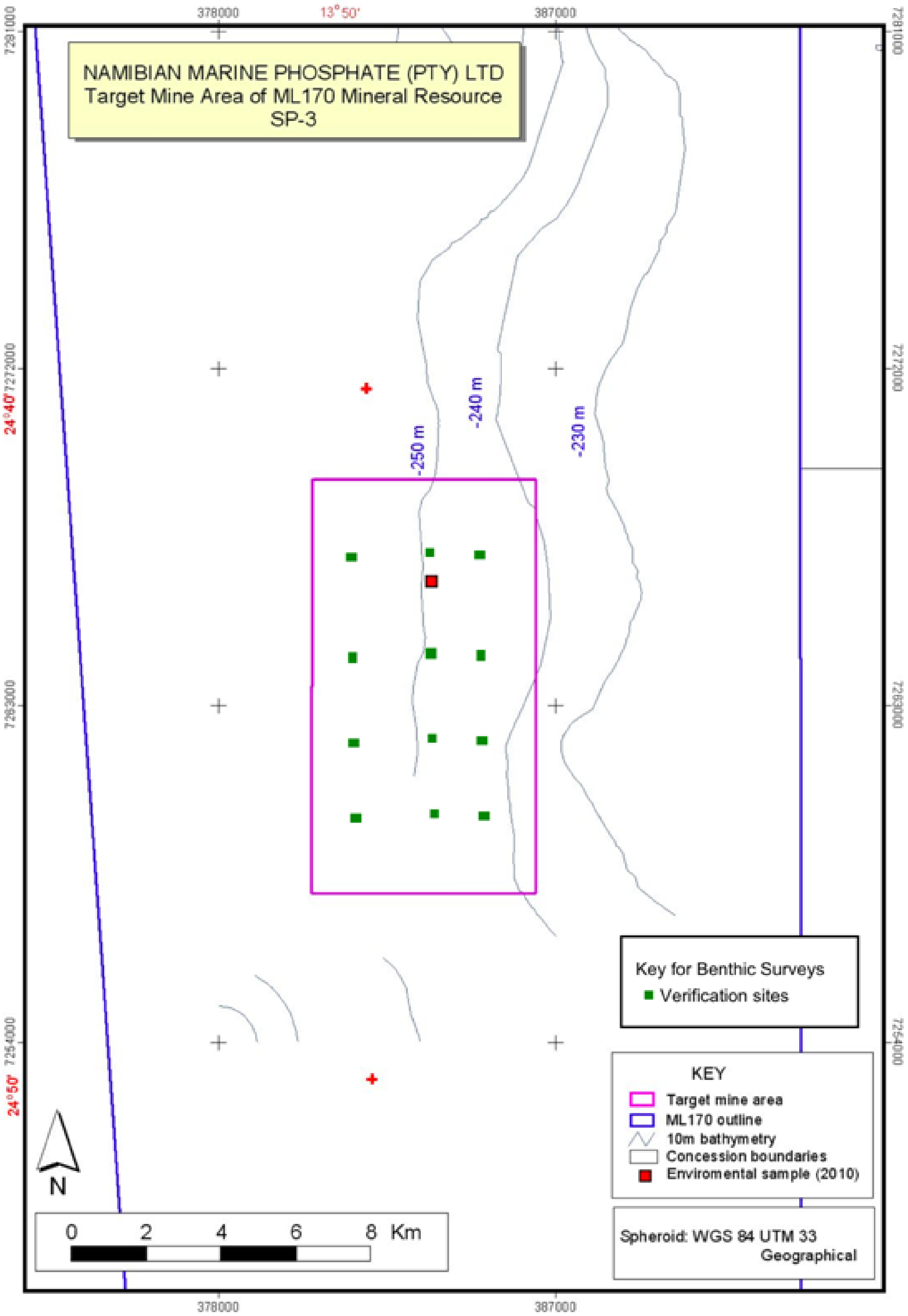

Figure 8.3 (c):Proposed layout of macrofauna sampling stations for the verification survey in SP-3.

Sampling in SP-1 should be undertaken both before the start of operations, as well as at regular intervals after completion of dredging to determine the (functional) recovery rates of the benthic communities. One of the basic assumptions of developing a benthic monitoring programme is that recovery of disturbed macrofaunal communities does in fact occur. The process and rate of recovery is, however, strongly dependent on the rate of the in-filling of sediment in the mined-out areas, and the type of sediment. A wide range of recorded recovery rates highlight the inherent difficulties in the application of general impact/recovery predictions to sites with varying environmental characteristics (Robinson *et al.* 2005). From existing information on the natural rehabilitation of mined-out areas in the deep-water diamond mining licence area in southern Namibia, it is known that despite the reduced wave and current action at the depths at which mining is currently being conducted (100-150 m), significant smoothing and in-filling of mined areas is visible in sidescan sonar surveys 1 - 2 years after mining (Penney & Pulfrich 2004). However, such information cannot be simply extrapolated to the central Namibian shelf, where the sedimentation and near-bottom current regime is likely to be very different. It is recommended that high resolution geophysical surveys (e.g. side scan sonar) are conducted immediately after dredging, and 2-3 years post-dredging (and potentially at later years depending on the results) to determine the depth of the dredged trenches and the sediment infilling-rates. Depending on the geophysical survey results, it is assumed that the first post-dredging survey can be conducted 2-3 years after cessation of dredging (three years for Target Block 1 and two years for Target Block 2 of the SP-1 resource). The subsequent sampling interval can best be determined after the first post-dredging sampling campaign, but an appropriate interval may be every 2-3 years. Periodically reviewing the monitoring plan as new data are collected and analysed will ensure that the monitoring plan and associated sampling schedule remains a dynamic process.

Traditionally, the ecological recovery of the disturbed seafloor has been defined as the establishment of a successional community of species, which progresses towards a community that is similar in species composition, population density and biomass to that previously present. Measures used to assess recovery typically include biodiversity analysis such as the numbers of species and/or individuals in an assemblage. However, this approach presents a number of challenges, especially when the physical characteristics of the sediment have been altered to such an extent that it can no longer accommodate its original assemblage. Recovery in the sense of the above definition may thus not be achieved (only when the sediment properties revert to their original state). For this reason, it may be more sensible to consider the functional capacity (or health) of the ecosystem rather than simply the range and proportion of species present. Some ecosystem functions can be undertaken by a variety of different organisms, leading to the notion of possible functional redundancy, whereby the loss of a particular species may not affect the basic functioning of an ecosystem as long as the function performed by that species is taken up by another species from the same functional group. To address this issue, many studies have recently focussed on functional diversity to assess faunal recovery following anthropogenic perturbations by incorporating biological differences among species showing that function- or trait-based diversity metrics may represent appropriate additional methods for assessing changes in ecosystem function (e.g. Borja *et al.* 2003, 2010, Bremner *et al.* 2006, Josefson *et al.* 2009, Cooper *et al.* 2008, Hussin *et al.* 2012). In terms of dredging impact on functional diversity, communities of organisms inhabiting an area of dredged seabed may possibly differ in composition or diversity from the pre-dredged state, but may develop similar functional capacity through the recovery process (functional recovery). Therefore, system recovery may not require similar biomass, biodiversity or community composition. It is thus proposed to utilise a variety of analyses including biodiversity measures, multivariate approaches as well as functional traits analyses to describe the macrofaunal colonization process after the dredging impact.

8.9.4 Verification: Fish, Mammals and Seabirds

VERIFICATION AND BASELINE MONITORING SURVEY FOR THE FISH, MAMMALS AND SEABIRDS IN THE PROPOSED MARINE PHOSPHATE MINE AREA (SP-1) IN NAMIBIA

Prepared by : D Japp

Capricorn Fisheries Monitoring cc

8.9.4.1 **Introduction**

The Environmental Impact Assessment (EIA) for the proposed phosphate dredging in ML-170 specialist report Appendix 1a on fish resources, fisheries, marine mammals and birds identified five primary impacts *viz.*

1) the likely impact of dredging on commercial fisheries;
2) the likely impact of dredging on the main commercial fish species;
3) the likely impact of dredging on the recruitment of commercially important species;
4) the likely impact of dredging on fish biodiversity and
5) the likely impact of dredging on seabirds and marine mammals.

These impacts and the associated estimates of environmental risk were in part based on marine survey data provided by NatMIRC as well as historical information on fisheries and the Benguela Ecosystem as a whole. The report acknowledges that information/data in the specific sites proposed to dredge phosphate (SP1; SP2 and SP3) is lacking. The risk assessment has therefore had to use information from surveys etc. in the proximity of the MLA and made assumptions on impacts such as fish recruitment and biodiversity, by extrapolating data from the nearest sampling points from which relevant data were available, which is a standard practice.

These data have therefore provided a baseline which informed the risk assessment, based on the best available information.

In order to address this uncertainty it is proposed that a baseline and verification survey be undertaken prior to dredging taking place (without assuming that project will be approved once the EIA is submitted and finalised).

8.9.4.2 **Survey Proposal**

Verification surveys (to verify the findings of the Specialist assessment - Appendix 1a) and subsequent annual monitoring surveys typically incorporate:

a) Fisheries swept area type surveys;
b) Fisheries Acoustic survey (integrated with swept area surveys); and
c) Marine mammal, seabird and other marine fauna observations.

These integrated surveys can be undertaken prior to dredging and can be done using a suitable vessel from the region. Preferably one of the current vessels used in Namibian waters for swept area surveys would be appropriate. This will allow for the collection of data comparable with similar surveys undertaken in the proximity of the MLA in recent years. If a Namibian research vessel is not available, an alternative would be a research vessel from the region or a commercial vessel (assuming a satisfactory sampling platform can be arranged).

Ideally the survey proposed here could "piggy back" on one of the routine fisheries surveys – this would minimize costs and optimize personnel available.

8.9.4.3 **Survey Design**

A simple transect design using swept areas, and if considered necessary, simultaneously the collection of acoustic data, is proposed. Schematically the survey design with sampling stations is shown in Figure 8.4. *Note* : This is not intended to be prescriptive and will need refinement and discussion with marine scientists at NatMIRC.

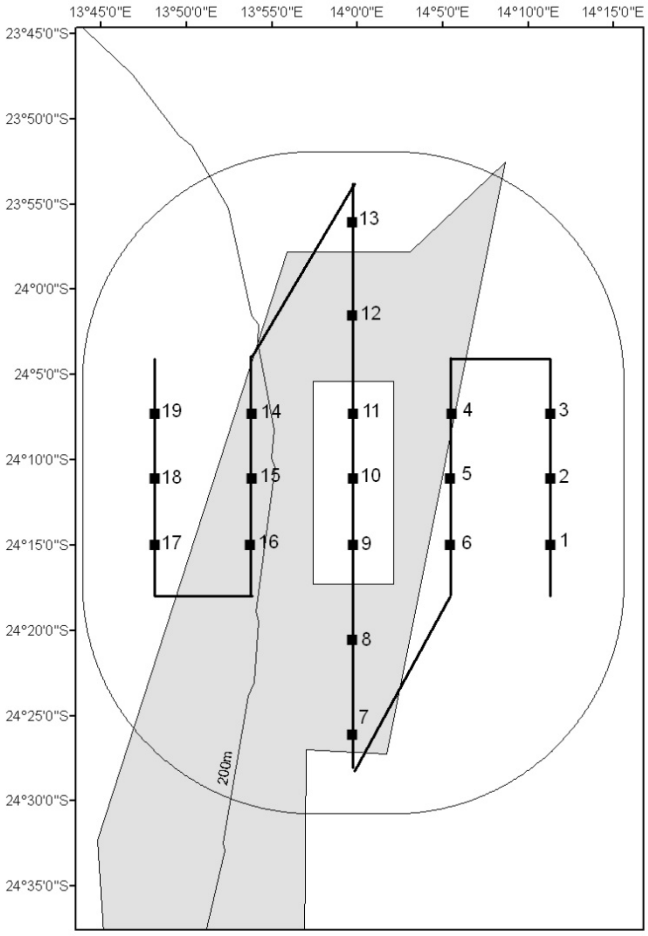

Figure 8.4: Location of survey stations in SP –1

Key elements of the survey are :

a) Trawls are undertaken north to south following the bathymetry;
b) Typically trawls will be for 20-30 minutes each (max. 1.5 nm);
c) Stations to be positioned within the area to be mined (SP-1 initially) and thereafter at suitable intervals in a perimeter around the mined area;
d) Standardisation of trawl gear (similar to that used in biomass surveys);
e) It is essential that stations cover the mined area prior to any dredging that may take place as well as stations within the MLA and then some distance (to be agreed) outside the MLA and within the 25 km zone used in the fisheries EIA report (Appendix 1a). A total of no more than 20 stations are proposed taking approximately 3-6 days of survey time.
f) Acoustics can also be run along transects and between lines (primarily to determine small pelagic targets) – this is not a high priority but the need can be determined in discussion with the Namibian marine scientific community.

8.9.4.4 **Expected Outputs**

I. A comparative relative abundance estimate of the main commercial species in the dredged area and adjacent grounds (biomass). This can potentially show any changes in relative abundance due to dredging (such as species displacement to areas adjacent to the dredged area);
II. Verification of relative species abundance in the area with the on-going and historical abundance estimates of the main commercial species;
III. Species counts and classification of all flora and fauna (including fish and epifauna) captured in the trawls. This can be compared with stations from adjacent historical surveys;
IV. Provision for a marine mammal and seabird specialists or suitable marine observers to record mammals, seabirds, turtles and other interactions while in the survey area;
V. Length frequency measurements of the main species and sex ratios;
VI. Basic biological data collection on main commercial species including gonad staging for comparative spawning and recruitment indices;
VII. Use of digital photography to record species;
VIII. Deployment of CTDs (if an appropriate vessel is used) to determine essential water conditions (conductivity, temperature, depth).

8.9.4.5 **Time Frames**

A survey prior to the commencement of dredging should be undertaken. Preferably this should be coordinated with other swept area surveys in the area (most likely monk or hake surveys) using the same vessel. The survey can be repeated annually (for the first 5 years as reviewed) at the same time for the duration of the dredging activity. Transects can subsequently be included in the other proposed dredging areas (SP-2 and SP-3), but due to the initiation of the project in SP-1, it is recommended that priority should be given to a focused survey around this target area.

8.9.4.6 **Conclusions**

Correctly designed and undertaken with professional staff and a suitable sampling platform, the survey can provide a baseline from which the changes in fish availability, abundance, recruitment, biodiversity (as best can be determined from swept area trawls), marine mammals, seabirds and other flora and fauna can be estimated.

This baseline can be compared with historical data in the proximity of the MLA. Changes of the many parameters measured can be tracked over the lifetime of the exploitation and can be used to determine the effects (environmental impacts) of the proposed project over time. The data would be subjected to scientific and statistical scrutiny for accurate interpretation.

8.10 REFERENCES

Arntz WE, Gallardo VA, Gutierrez D, Isla E, Levin LA, Mendo J, Neira C, Rowe GT, Tarazona J and Wolff M (2006). El Niño and similar perturbation effects on the benthos of the Humboldt, California, and Benguela Current upwelling ecosystems. *Advances in Geosciences* **6**:243-265

Bremner JM (1983). Sediments on the continental margin off south west Africa between the latitudes 171 and 251S. Ph.D. Thesis University of Cape Town, South Africa, pp.233

Coull BC and Chandler GT (1992). Pollution and meiofauna: field, laboratory, and mesocosm studies. *Oceanogr Mar Biol Annu Rev* **30**:191-271

Gallardo VA, Palma M, Carrasco FD, Gutiérrez D, Levin LA and Cañete JI (2004). Macrobenthic zonation caused by the oxygen minimum zone on the shelf and slope off central Chile. *Deep-Sea Research* II **51**:2475-2490

Gooday AJ, Levin LA, Silva AAd, Bett BJ, Cowie GL, Dissard D, Gage JD, Hughes DJ, Jeffreys R, Lamont PA, Larkin KE, Murty SJ, Schumacher S, Whitcraft C and Woulds C (2009). Faunal responses to oxygen gradients on the Pakistan margin: A comparison of foraminiferans, macrofauna and megafauna. *Deep-Sea Research* II **56**:488-502

Gutiérrez D, Gallardo VA, Mayor S, Neira C, Vásquez C, Sellanes J, Rivas M, Soto A, Carrasco F and Baltazar M (2000). Effects of dissolved oxygen and fresh organic matter on the bioturbation potential of macrofauna in sublittoral sediments off Central Chile during the 1997/1998 El Niño. *Mar Ecol Prog Ser* **202**:81-99

Gutiérrez D, Gallardo VA, Mayor S, Neira C, Vásquez C, Sellanes J, Rivas M, Soto A, Carrasco F and Baltazar M (2000). Effects of dissolved oxygen and fresh organic matter on the bioturbation potential of macrofauna in sublittoral sediments off Central Chile during the 1997/1998 El Niño. *Mar Ecol Prog Ser* **202**:81-99

Kennedy AD and Jacoby CA (1999). Biological indicators of marine environmental health: meiofauna-a neglected benthic component? *Environmental Monitoring and Assessment* **54**:47-68

Levin L and Gage JD (1998). Relationships between oxygen, organic matter and the diversity of bathyal macrofauna. *Deep-Sea Research* II **45**:129-163

Levin LA (2003). Oxygen minimum zone benthos: adaptation and community response to hypoxia. Oceanography and Marine Biology: an Annual Review **41**:1-45

Levin LA, Gage JD, Martin C and Lamont PA (2000). Macrobenthic community structure within and beneath the oxygen minimum zone, NW Arabian Sea. *Deep-Sea Research II* **47**:189-226

Levin LA, Whitcraft CR, Mendoza GF, Gonzalez JP and Cowie G (2009). Oxygen and organic matter thresholds for benthic faunal activity on the Pakistan margin oxygen minimum zone (700 - 1100 m). *Deep-Sea Reserach II* **56**:449-471

Monteiro PMS, Dewitte B, Scranton MI, Paulmier A and van der Plas AK (2011). The role of open ocean boundary forcing on seasonal to decadal-scale variability and long-term change of natural shelf hypoxia. *Environ Res Lett* **6** doi:10.1088/1748-9326/6/2/025002

Monteiro PMS, van der Plas AK, Melice J-L and Florenchie P (2008). Interannual hypoxia variability in a coastal upwelling system: Ocean shelf exchange, climate and ecosystem-state implications. *Deep-Sea Research I* **55**:435-450

Mullins H, Thompson JB, McDougall K and Vercoutere TL (1985). Oxygen-minimum zone edge effects: Evidence from the central California coastal upwelling system. *Geology* 13: 491-494.

Palma M, Quiroga E, Gallardo VA, Arntz W, Gerdes D, Schneider W and Hebbeln D (2005). Macrobenthic animal assemblages of the continental margin of Chile (228 to 428S*). J Mar Biol Ass UK* **85**:233-245

Penney AJ and A Pulfrich (2004). Recovery and Rehabilitation of Deepwater Marine Diamond Mining Operations off the Southern African West Coast. Report to De Beers Marine, South Africa, May 2004. 92pp. (confidential)

Robinson JE, Newell RC, Seiderer LJ and Simpson NM (2005). Impacts of aggregate dredging on sediment composition and associated benthic fauna at an offshore dredge site in the southern North Sea. *Marine Environmental Research*, **60**:51-68.

Rosenberg R, Arntz WE, Flores ECd, Flores LA, Carbajal G, Finger I and Tarazona J (1983). Benthos biomass and oxygen deficiency in the upwelling system off Peru. *Journal of Marine Research* **41**:263-279

Rumohr H (2009). Soft-bottom macrofauna: collection, treatment, and quality assurance of samples. *ICES Techniques in Marine Environmental Sciences* **43**:20 pp

Sahling H, Rickert D, Lee RW, Linke P and Suess E (2002). Macrofaunal community structure and sulfide flux at gas hydrate deposits from the Cascadia convergent margin, NE Pacific. *Mar Ecol Prog Ser* **231**:121-138

Sanders HL (1968). Marine benthic diversity: A comparative study. *The American Naturalist* **102**:243-282

Savage C, Field JG and Warwick RM (2001). Comparative meta-analysis of the impact of offshore marine mining on macrobenthic communities versus organic pollution studies. *Mar Ecol Prog Ser* **221**:265-275

Schratzberger M, Boyd S, Rees H and Wall C (2001). Assessment of meiofaunal communities, Centre for Environment, Fisheries & Aquaculutre Sciences (CEFAS), Burnham on Crouch (UK). 117 pp.

Somerfield P, Rees HL and Warwick RM (1995) Interrelationships in community structure between shallow-water marine meiofauna and macrofauna in relation to dredgings disposal. *Mar Ecol Prog Ser* **127**:103-112

Steffani N (2007). Biological Monitoring Survey of the Macrofaunal Communities in the Atlantic 1 Mining Licence Area and the Inshore Area between Kerbe Huk and Bogenfels-2005 Survey. Report prepared for De Beers Marine Namibia. pp. 51 + Appendices (confidential)

Steffani N (2009). Biological monitoring surveys of the benthic macrofaunal communities in the Atlantic 1 Mining Licence Area and the inshore area 2006/2007, Prepared for De Beers Marine Namibia (Pty) Lt d by Steffani Marine Environmental Consultant, pp. 81 + Appendix (confidential)

Steffani N (2010a). Biological Baseline Survey of the Benthic Macrofauna Communities in the Phosphate Licence Blocks EPL 3415 and EPL 3233 in the Sandpiper/Meob JV Project Area. Prepared for Namibian Marine Phosphate. May 2010. pp 28 + Appendices (confidential)

Steffani N (2010c). Biological Monitoring Surveys of the Benthic Macrofaunal Communities in the Atlantic 1 Mining Licence Area - 2008. Prepared for De Beers Marine Namibia, pp. 40 + Appendices (confidential).

Steffani N and Pulfrich A (2004). Environmental Baseline Survey of the Macrofaunal Benthic Communities in the De Beers ML3/2003 Mining Licence Area, Pisces Report (confidential)

Steffani N and Pulfrich A (2007). Biological survey of the macrofaunal communities in the Atlantic 1 Mining Licence Area and the inshore area between Kerbehuk and Lüderitz. 2001-2004 surveys. Prepared for De Beers Marine Namibia (Pty) Ltd. pp 89 (confidential)

Ueda N, Tsutsumi H, Yamadi M, Hanamoto K and Montani S (2000). Impacts of oxygen-deficient water on the macrobenthic fauna of Dokai Bay and on adjacent intertidal flats, in Kitakyushu, Japan. *Marine Pollution Bulletin* **40**:906-913

Underwood AJ (1992). Beyond BACI: the detection of environmental impact on populations in the real but variable world. *Journal of Experimental Marine Biology and Ecology*, **161**: 145-178.

Underwood AJ (1993). The mechanics of spatially replicated sampling programmes to detect environmental impacts in a variable world. *Australian Journal of Ecology*, **18**: 99 - 116.

Underwood AJ (1994). On beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecological Applications, **4**: 3-15.

Zettler ML, Borchert R and Pollehne F (2009). Macrozoobenthos diversity in an oxygen minimum zone off northern Namibia. *Marine Biology* **156**:1949-1961