ENVIRONMENTAL ASSESSMENT OF PRODUCTION CHEMISTRY ASSET - 2002 REVIEW AND UPDATE

PETROLEUM DEVELOPMENT OMAN

SULTANATE OF OMAN

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EXECUTIVE SUMMARY

Introduction

This report updates the environmental assessment of Production Chemistry asset, which is one of the eight service assets within PDO's concession area in the Sultanate of Oman. The first environmental assessment for Production chemistry asset was carried out in September 1999. Since then, several changes with respect to the facilities, processes and procedures have taken place in the asset. In order to review the impacts on the environment due to these changes, the environmental hazards and effects associated with the activities in the asset are reassessed in this study. This study is conducted, on behalf of PDO by HMR Environmental Consultants during the period of June-December 2002.

Overview of Asset Activities and Facilities

PDO operates over 113,550 km^2 of concession area consisting of about a hundred fields, 2,454 oil producing wells and 72 gas producing wells. Currently, PDO produces 843,490 barrels/day of crude and 44 million Sm^3 of gas on average per day.

Production chemistry asset is one of the eight service providers in PDO. The areas of operation of the asset cover the entire interior concession area in south and central Oman as well as Mina Al Fahal (MAF) on the coast.

The production chemistry asset consists of Drilling support chemistry (TTKW) and Process & treatment chemistry (TTKC). The main responsibility of the TTKW section is to provide technical support to the well engineering team on matters related to the chemistry of drilling fluids, well cementing, well completion fluids and well stimulation. It also provides technical support to chemicals procurement, research and development. While the TTKC section consists of a consultancy group and a laboratory services group. The consultancy group provides expert advice on all chemical and physical processes related to the production, treatment and transport of crude oil and gas. It also provides expert advice on water treatment for re-injection and disposal, corrosion and safe use of chemicals. The laboratory services group operates analytical laboratory facilities within PDO for the chemical and physical analysis of a range of materials including oil, gas, produced water, groundwater, wastewater, drilling fluids, well cements, process chemicals etc. It also provides technical advice on handling and disposal of wastes containing naturally occurring radioactive materials (NORM).

Description of Environment

The topographical features from the southernmost part of the concession area (Marmul) to the northern coast (MAF) show three distinct zones as below:

- Desert plains with very low population within most of the concession area
- Low to medium altitude hills over the southernmost and northernmost parts
- A small coastal plain surrounded with urban population

The natural vegetation is composed of desert plants and grasses, and is restricted to the wadi plains only. Among all the assets, Nimr and Marmul assets have relatively denser vegetation.

Most of the concession area falls under central and south-central Oman and is characterised by flat gravel desert plains with occasional rocky outcrops interspersed with a few wadi channels. The altitude in the plains is mostly in the range of 100-150m above the mean sea level. The desert plains are very thinly populated.

Hills of low to medium altitude are encountered over the southernmost and northernmost parts of the concession area.

The MAF terminal area is located within the MAF industrial area on the shore of MAF bay and surrounded by hills, rising to 214 m altitude above the sea level on the eastern boundary. There are large urban settlements adjacent to MAF area to northwest.

The geology of most of the PDO's concession area comprises of mainly limestone with shale, dolomite and sandstone. The central plains mostly consist of flat limestones of oligocene and miocene ages to mid-tertiary. UeR aquifer is the main prolific aquifer in the area.

The mineral content in UeR water increases as it travels from south to north. Within the entire PDO concession area, only Marmul asset has groundwater that is potable without any pre-treatment. In all other assets the UeR water is very saline.

The mean monthly temperatures range from around 20^{o}C in December/ January to about 35^{o}C in July. The maximum absolute temperature will be as high as 50^{o}C and the minimum absolute temperature will be as low as 5^{o}C.

Rainfall in this region is scanty and is highly variable in time and space with an average of 36 mm per annum. Although the annual average rainfall is very low, flash floods are known to have occurred in the area. Wind speeds vary considerably from calm to strong gusts. The dominant wind direction is from the south with an average wind speed of 8 knots.

The natural flora in most of the concession area is composed of desert plants and grasses, and trees are rarely seen. Several fauna groups including mammals, birds and reptiles are seen. Large mammalian species known to inhabit the area include the Arabian Gazelle (*Gazelle gazelle*), the Rhim Gazelle (*Gazella subgutturosa marica*), the Nubian Ibex (*Capra nubiana*). These animals are currently listed on the IUCN World Red List and the Regional Red List threat categories. The Arabian Oryx is seen in Mukhaizna field in Bahja asset.

The beaches along the coastline are composed primarily of fine sand derived from the neighbouring land with shallow areas extending up to 2 km offshore. The seawater temperature at MAF ranges from 25°C in winter (February and March) up to 39°C in summer (June and July). The salinity ranges from 35 to 40 parts per thousand.

The human population density within PDO's concession area (interior areas) is extremely low and is to the order of 26 persons per 100 km^2. Within the total concession area of 114,000 km^2, the total current population is of the order of 30,000. The majority are the PDO and contractor staff living in the various accommodation camps located in the assets, and they number about 20,000 currently.

There are no forts, ruins or other archeological declared sites in PDO's concession area. However, abundant marine fossils are present in Jabal Fahud and Natih areas (Fahud asset).

Significant Environmental Effects

Based on the existing activities and the current status of the environment in the asset, the environmental hazards and potential effects are identified. The potential environmental effects are assessed based on the HEMP methodology outlined in PDO's document GU-195 "Environmental Assessment Guideline". The effects with a risk rating level of medium or higher are short-listed and the necessary additional mitigation measures are recommended. The following table summarizes the recommended additional mitigation measures against each of the environmental specifications of PDO, *viz.*, SP-1005 to SP-1012 and SP-1170.

Specification	Areas of Non-compliance or Concern	Recommended Additional Mitigation Measures
SP-1005: Specification for Emissions to Atmosphere	▪ Vent air or ambient air is never monitored to check whether toxic gases or vapour are present in significant concentrations.	▪ Evidence shall be provided through monitoring or theoretical predictions that air dilution rate is sufficient and that toxic gases or vapour are not present in significant concentrations in the vent air.
SP-1006: Specification for Aqueous Effluents	▪ Non-oily effluents are discharged into the sewers for treatment and disposal along with the sewage generated in the production asset.	▪ Evidence shall be provided through monitoring or theoretical predictions that toxic substances are not present in significant concentrations in the raw or treated sewage. ▪ A better alternative is to provide dedicated packaged effluent treatment plants based on solar evaporation for non-oily laboratory effluents.
SP-1007: Specification for Accidental Releases to Land and Water	▪ Accidental leaks and overflows from oily effluent holding tanks in the production chemistry laboratories are likely.	▪ Carry out periodic integrity checks on the holding tanks.
SP-1008: Specification for Use of Energy, Materials and Resources	▪ None	▪ None
SP-1009: Specification for Waste Management	▪ None	▪ None
SP-1010: Specification for Environmental Noise and Vibration	▪ None	▪ None
SP-1011: Specification for Flora and Fauna	▪ None	▪ None
SP-1012: Specification for Land Management	▪ None	▪ None
SP-1170: Specification for Management of Naturally Occurring Radioactive	▪ None	▪ None

Conclusion

Based on the present study, it is concluded that no change in PDO's existing HSE management system is required. However, it is necessary to modify the HSE plans and programmes in the asset by incorporating the additional mitigation measures recommended above. This will ensure that the potential environmental risks are minimized, non-compliances are eliminated and the overall environmental performance in the asset is significantly improved.

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ABBREVIATIONS

AP	atmospheric pressure (<0.5 kPa gauge pressure)
API	American Petroleum Institute
bar(g)	unit of gauge pressure (equal to 101.3 kPa gauge)
bbl	barrel (equal to about 159 liters)
bpd	barrels per day
Bq	Bequerel, unit for measurement of radioactivity (One nuclear disintegration/second)
^oC	degree centigrade
^oK	degree Kelvin
$CaCO_3$	calcium carbonate
CFC	chloro-fluoro-carbon
d	day
DGEA	Directorate General of Environmental Affairs
DLN	dry low NO_x
DWD	deep water disposal
ESP	electrical submersible pump
E&P	exploration & production
EPC	engineering, procurement and construction
EU	European Union
h	hour
ha	hectare
HCFC	hydro-chloro-fluoro-carbon
HFC	hydro-fluoro-carbon
HEMP	hazards and effects management process
HMR Consultants	HMR Environmental Engineering Consultants
HP	high pressure (>150 kPa gauge pressure)
kg	kilogram
km	kilometer
km^2	square kilometer
kPa	kilo Pascal, unit of pressure (1 atm = 101.13 kPa)
LP	low pressure (0.5 – 150 kPa gauge pressure)
LIMS	lab information management system
m^3	cubic meter
mg	milligram
ml	milliliter
MLPS	main line pumping station
MOL	main oil line
MPN	most probable number
mPa.s	milli-Pascal-second (a unit of viscosity equivalent to 1 centipoise or cp)
MD	ministerial decision
MJ	mega-Joule
NOCS plant	North Oman crude stabilization plant
MW	megawatt
MWh	megawatt-hour
MRME&WR	Ministry of Regional Municipalities, Environment and Water Resources
MSDS	material safety data sheet
NAAQ	national ambient air quality
Nm^3	normal cubic meter (at 1atm and 0^oC)
NO	nitric dioxide
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
NORM	naturally occurring radioactive materials

PDO	Petroleum Development Oman LLC
ppm	parts per million
ppmv	parts per million, volume based
PM_{10}	particulate matter of <10 µm size
$PM_{2.5}$	particulate matter of <2.5 µm size
RD	royal decree
RMS	remote manifold station
RO	reverse osmosis
SHOC	safe handling of chemicals
Sm^3	standard cubic meter (at 1atm and 20^oC)
t	metric tonne (equal to 1000 kg)
TDS	total dissolved solids
tpa	tonnes per annum (year)
tpd	tonnes per day
tph	tonnes per hour
TSP	total suspended particulates
UeR	Umm er Radhuma
UNEP	United Nations Environmental Program
UNESCO	United Nations Scientific and Cultural Organisation
USEPA	United States Environmental Protection Agency
WHO	World Health Organisation
µg	micro-gram
µm	micro-meter (also known as micron)
µS/cm	micro-Siemens per centimeter (unit of electrical conductivity)

1 INTRODUCTION

1.1 Petroleum Development Oman

Petroleum Development Oman (PDO) is the largest petroleum exploration and production (E&P) company in the Sultanate of Oman, with over 113,550 km^2 of concession area, covering most of the central and southern parts of the Sultanate. The geographical map of PDO's concession area is shown in Figure 1.1. Presently, PDO's concession area is divided into two main administrative assets viz., North Oman and South Oman. The production assets within North Oman include Fahud, Lekhwair, Yibal and Qarn Alam, and those within South Oman include Bahja, Nimr (including Rima) and Marmul. The crude oil export facilities and the administrative head quarters are located on the coast in Mina Al Fahal.

Currently PDO operates from about a hundred fields and has 2,454 oil producing wells and 72 gas producing wells. The total production of crude oil currently is about 843,490 barrels per day, and that of associated gas is 44 million Sm^3 per day. A network of 9,300 km of pipelines, 28 gathering stations and 18 production stations feed the produced crude oil into the main storage facility located at Mina Al Fahal near Muscat (at Muscat coastal area), from where the oil is loaded into tankers moored offshore. The produced gas is partly utilised within the assets and the rest processed in three gas stabilisation stations (located in Yibal, Saih Rawl and Saih Nihayda) and then exported. The asset-wise break-up for land area, crude oil production, gas production and production water is presented in Table 1.1 below for the current year (2002).

Table 1.1: Description of Production Assets in PDO

Production Asset	Land Area (km^2)	Crude Oil Production (m^3/d average)	Gas Production (10^3 x Sm^3/d average)	Produced Water (m^3/d average)
Fahud	11,580	14,670	5,007	11,239
Lekhwair Asset	3,560	14,601	1,550	21,977
Yibal Asset (Including Gas Asset)	5,830	31,134	31,995	154,970
Qarn Alam Asset	18,900	14,462	3,084	67,255
Bahja Asset	30,560	12,347	550	27,050
Nimr Asset (Including Rima and Al Noor)	16,160	35,669	780	313,105
Marmul Asset	26,960	11,221	900	41,937
Total for PDO's Concession Area	**113,550**	**134,104**	**43,866**	**637,533**

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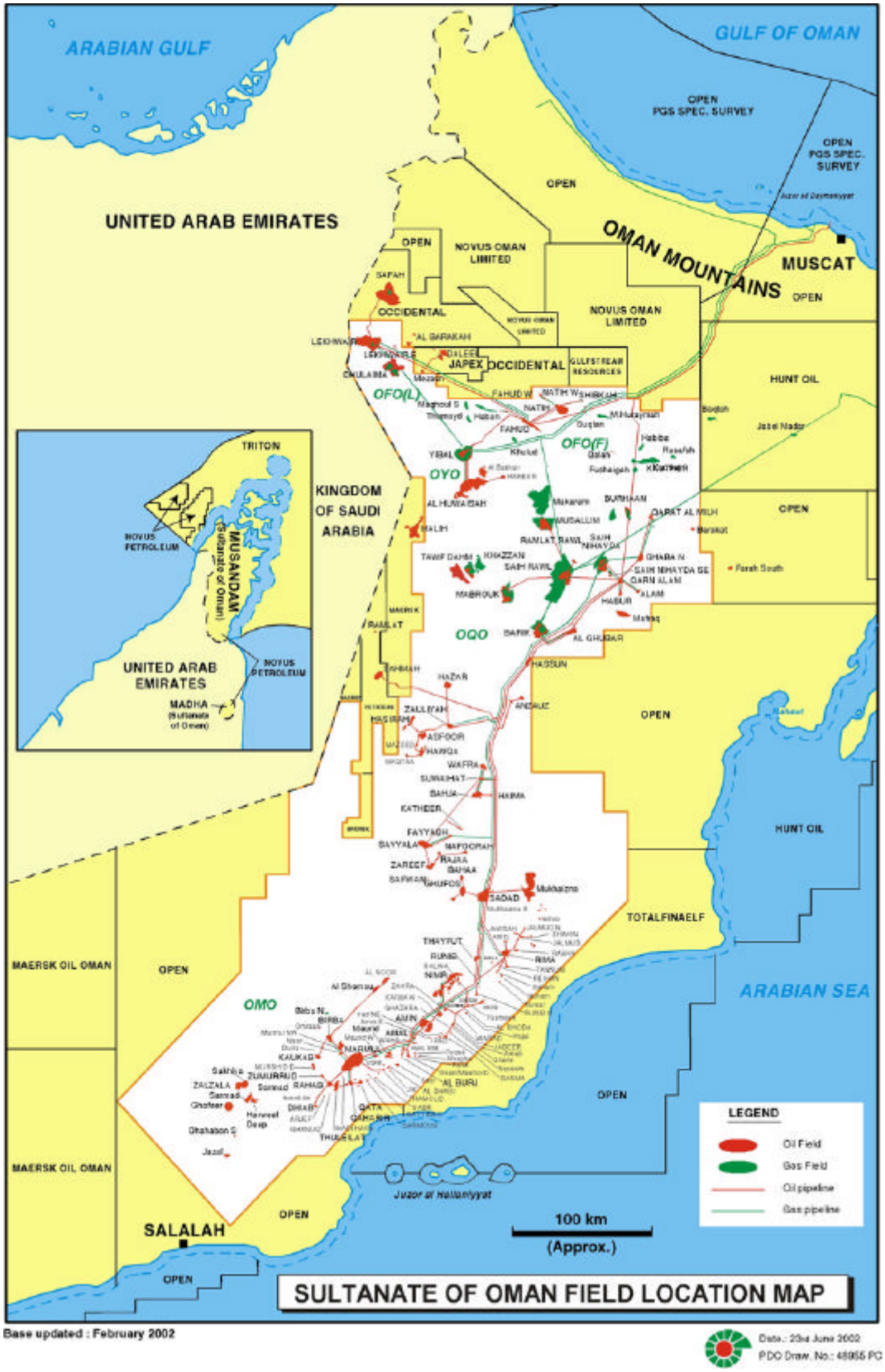

Figure 1.1: Geographical Map of PDO's Concession Area

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In addition to the seven production assets, there are eight service assets in PDO, which provide technical, analytical, engineering, supply and transportation support to the production assets. A brief description of the services assets is presented below in Table 1.2.

Table 1.2: Description of Service Assets in PDO

Service Asset	Main Activities and Areas of Operation
Exploration Asset	- Plan and execute 2D and 3D seismic surveys throughout PDO's concession area for identifying potential locations for drilling new oil wells
Well Engineering Asset	- Prepare and update preliminary and detailed designs for new oil wells throughout PDO's concession area - Prepare new oil well construction and completion programmes throughout PDO's concession area - Construct new oil wells and modifying any existing wells as required throughout PDO's concession area - Close out non-producing wells and restore abandoned well sites throughout PDO's concession area
Engineering Asset	- Plan, manage and execute preventive and remedial maintenance work for all production facilities throughout PDO's concession area - Manage and execute all well maintenance services throughout PDO's concession area - Manage and execute civil engineering construction work throughout PDO's concession area - Provide technical specialist service in detailed engineering design, field execution, material selection, process control and automation for all new projects throughout PDO's concession area
Infrastructure Asset	TERMINAL OPERATIONS DEPARTMENT - Operate and maintain the Mina Al Fahal Tank Farm consisting of 10 crude oil storage tanks with a total storage capacity of 5 million barrels - Operate and maintain the offshore oil export facilities in Mina Al Fahal consisting of three single point moorings and two coastal buoy moorings - Operate and maintain the oil export metering systems and offshore oil pollution combating equipment in Mina Al Fahal POWER SYSTEMS DEPARTMENT - Operate and maintain ten power stations consisting of 22 gas turbines throughout PDO's concession area - Operate and maintain twenty-two 132 kV substations throughout PDO's concession area - Operate and maintain 1276 km long 132 kV overhead electrical transmission lines throughout PDO's concession area PIPELINE DEPARTMENT - Operate and maintain 1510 km long main oil line for transportation of liquid hydrocarbons from all production assets to the export terminal in Mina Al Fahal - Operate and maintain 670 km long south Oman gas line for transportation of dry sweet gas hydrocarbons from Saih Nihayda (Qarn Alam Asset) to Marmul asset - Operate and maintain the main oil line booster stations in Hubara (Nimr Asset), Sahma (Bahja Asset) and Nahada (Fahud Asset)
Gas Asset	- Operate and maintain, on behalf of the government, gas treatment facilities (government gas plant, government butane plant and butane storage and loading facility) in Yibal - Operate and maintain, on behalf of the government, liquefied natural gas upstream facilities in Saih Rawl, Barik and Saih Nihayda - Operate and maintain, on behalf of the government, natural gas pipeline

Service Asset	Main Activities and Areas of Operation
	system from Yibal to Murayat (296 km long), from Murayat to Al Ghubra (29 km long) and from Murayat to Sohar (225 km long) as well as spur lines - Operate and maintain, on behalf of the government, pressure reducing terminals for natural gas customers throughout Oman
Supply & Logistics Asset	- Procure, store and distribute raw materials and process chemicals for consumption throughout PDO's concession area - Provide land and air passenger transport service (through sub-contracting) for all PDO and contractor staff throughout PDO's concession area - Supply and move land based drilling rigs throughout PDO's concession area
Estate Services Asset	- Provide and maintain accommodation facilities for PDO staff in Mina Al Fahal - Maintain air-conditioning and refrigeration system within PDO area in Mina Al Fahal - Provide catering and laundry services for PDO staff in Mina Al Fahal - Supply potable water and maintain electrical power distribution systems within PDO area in Mina Al Fahal - Manage sewage treatment plants, treated sewage re-use and solid waste disposal for waste generated within PDO area in Mina Al Fahal - Manage the incinerator located in mina Al Fahal for thermal destruction of clinical wastes generated throughout PDO's concession area
Production Chemistry Asset	- Provide drilling chemistry support including analysis of drilling fluids and cements, technical specifications for drilling fluids and cements, evaluation of new drilling fluid and cement products and technologies for all assets in PDO - Provide process and treatment support including expert advice on all chemical and physical processes related to production, treatment and transportation of gas and oil for all assets in PDO - Provide laboratory support for physico-chemical analysis of well fluids, crude oil, gas, produced water, groundwater, treated water, sewage, raw materials and process chemicals for all assets in PDO

The current organisation structure in PDO is shown in Figure 1.2.

1.2 Environmental Impact Assessment

The environmental impact assessment (EIA) for all the production and service assets was first conducted during the period of 1998–2000, and based on this the environmental management plans and programmes were developed. The previous environmental assessment study for Production Chemistry asset was completed in November 1999 (*Reference 1*). It is an internal requirement in PDO to review and update of the EIA once in every three years, in order to periodically reassess the environmental impacts and appropriately revise the environmental management plans and programmes. Accordingly, PDO has requested HMR Environmental Engineering Consultants (HMR Consultants) to carry out the first review and update of the EIA for all its assets.

This study was conducted over the period of June – December 2002 and presents the review and update of the environmental assessment for the Production Chemistry asset.

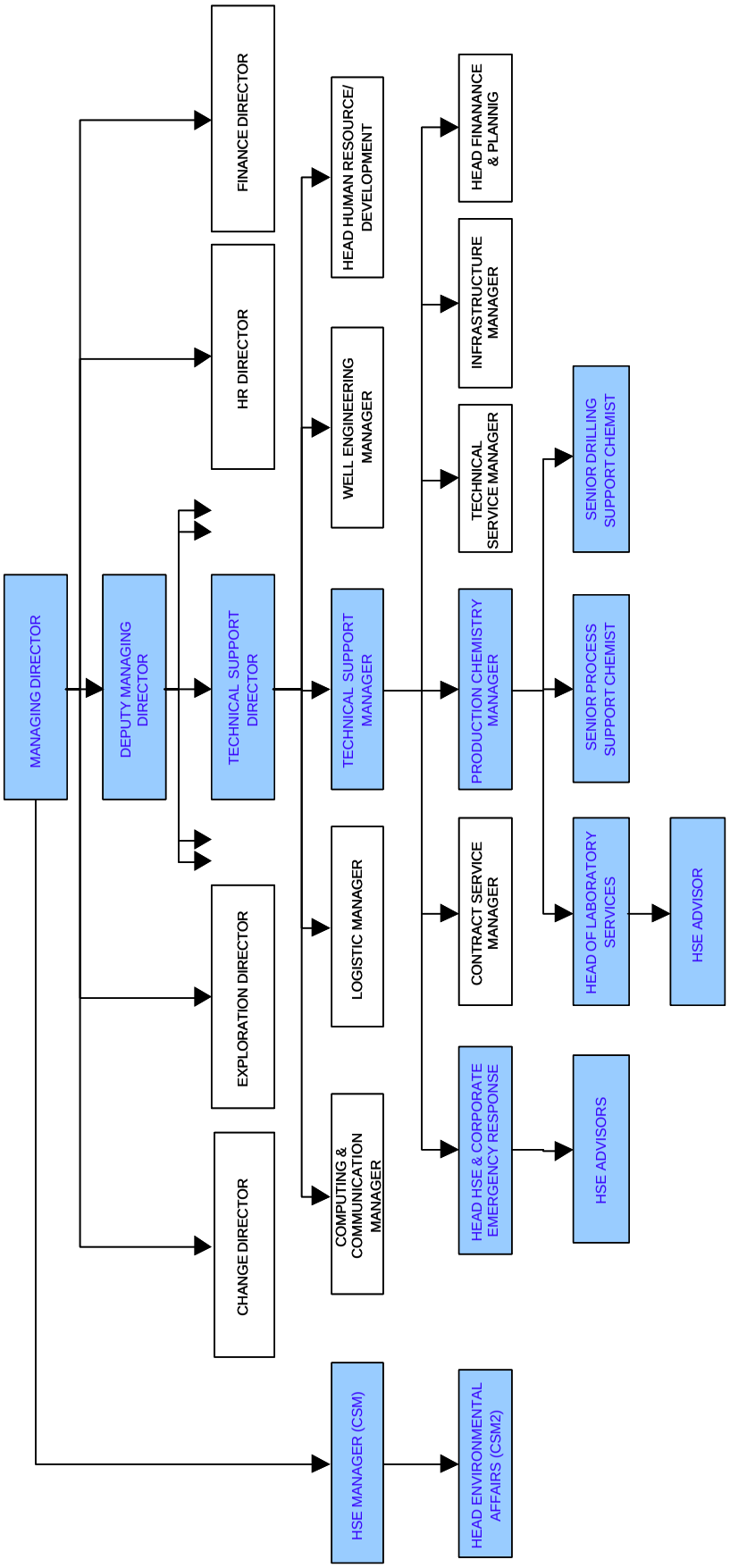


Figure1.2: Organisation Structure in PDO

1.3 Objectives and Scope of Study

The objectives of the present environmental assessment were the following:

- Updating the environmental inventories in the asset, taking into consideration all developments and activities that have taken place since the last environmental assessment conducted in November 1999.
- Reviewing the environmental requirements in the asset, taking into consideration any recent changes in the legislative and corporate regulations and specifications
- Auditing the environmental performance for the current year.
- Updating the environmental baseline data, wherever required.
- Reviewing the significant aspects and reassessing the environmental impacts, in view of the above.
- Revising the environmental mitigation and monitoring plan, wherever required.

The social and health impact assessment components were not included in the present study. The quantitative risk analysis was also not included in the present study.

1.4 Method of Study

The present study was carried out in three stages. In the first stage, the previous EIA reports (*Reference 1*) and other available environmental documents were reviewed. Based on this review, detailed and structured checklists were prepared for asset data verification and environmental performance audit. Subsequently, a site visit was undertaken to check the ground realities and to collect all necessary information. During the site visit, the key operating personnel in the asset including the Area Coordinator and the Area HSE Advisor were interviewed, and detailed environmental audit of the various facilities in the asset was conducted. In the third stage, all the data collected were analysed and the significant environmental hazards (aspects) were identified. Then the environmental effects (impacts) were reassessed using PDO's "Hazards and Effects Management Procedure (HEMP)" as described in the PDO's document GU-195 "Environmental Assessment Guideline" (*Reference 2*). Following the reassessment, the environmental mitigation and the monitoring plans were revised as appropriate.

1.5 Structure of Report

This report is prepared based on the table of contents suggested for environmental assessment report in PDO's "Environmental Assessment Guideline" *(Reference 2)*. A non-technical executive summary is presented at the beginning of the report.

Section 1 overview of PDO activities and description of all the production assets. The scope and objective of the work is presented.

Section 2 presents the regulatory framework and outlines the environmental regulations governing the environmental aspects in the work.

Section 3 details the description of activities performed by Production Chemistry asset along with the consumption of utilities and materials in the asset.

Section 4 describes the various waste products and energies released to the environment from activities performed by Production Chemistry asset. Characterisation and quantification of the various waste products released to the environment are presented in this section and their treatment and disposal practices are analysed.

Section 5 presents a detailed description of the environment status of the areas within which the Production Chemistry asset operates.

Section 6 provides a description of the significant environmental hazards associated with the asset activities identifying the environmental effects. These effects are assed based on the methodology outlined in PDO's document GU-195. The identified potential environmental impacts were rated based on the PDO's environmental risk criteria attached in appendix.

Section 7 summarises the significant environmental effects and mitigation measures in the asset for adverse impacts. Additional mitigation measures aimed at minimizing the potential environmental risks and improvement of the overall performance were also suggested.

Section 8 lists the references used for this document.

Other useful information not included in the main text is presented in the appendices. The details of the personnel responsible in the preparation and review of the report are presented in *Appendix 1.*

2 REGULATORY FRAMEWORK

2.1 Omani Regulations

The Omani regulations on environmental protection, control and management are covered under two basic laws *viz*., the "Law for the Conservation of the Environment and Prevention of Pollution" first promulgated in 1982 as Royal Decree (RD) 10/82 and superseded in November 2001 as RD 114/2001 and the "Law on Protection of Sources of Potable Water from Pollution" promulgated in November 2001 as RD 115/2001. The responsibility for the implementation of this law rests with the Ministry of Regional Municipalities, Environment and Water Resources (MRME&WR), which issues regulations, standards and guidelines through "ministerial decisions (MDs)". Within MRME&WR, the authority responsible for environmental permitting, inspection and control in the Sultanate of Oman is the Directorate General of Environmental Affairs (DGEA).

The current Omani environmental laws and regulations are listed below in chronological order.

Table 2.1: Environmental Laws and Regulations in Oman

(Presented in Chronological Order)

Title	Reference Number
Protection of certain species of birds	MD 4/76
Law on the development of water resources and its amendments	RD 76/77, RD 82/88, RD 29/00
Omani drinking water standards	OS8/98
Law on national heritage protection	RD 2/80, RD 6/80
Law for the conservation of the environment and prevention of pollution and its amendments	RD 10/82 (superseded), RD 63/85, MD 5/86, RD 71/89, MD 2/90, RD 31/93, RD 114/2001
Regulations concerning the disposal of liquid effluents to marine environment	MD 7/84
Regulations for the discharge of industrial and commercial effluents	MD 8/84
Regulations for septic tanks and holding tanks	MD 5/86 (superseded), MD 421/98
Regulations for air pollution control from stationary sources	MD 5/86
Regulations for the registrations of existing wells and new well permits	MD 2/90
Regulations for the management of the solid non-hazardous wastes	MD 17/93
Regulation for the management of hazardous wastes	MD 18/93
Regulations for wastewater re-use and discharge	MD 145/93, RD 115/2001
Regulating issuance of environmental permits	MD 300/93
Regulation on the removal of vegetation	MD 128/93
Regulation on hunting, capture or firing at wild animals	MD 207/93
Regulations for noise pollution in public environment	MD 79/94
Regulations for noise pollution in the working environment	MD 80/94
Law on handling and use of chemicals	RD 46/95
Regulations for the handling of toxic substances	MD 248/97

Title	Reference Number
Regulations for control and management of radioactive materials substances	MD 249/97
Regulation on the use of desalination units on wells	MD 342/97
Law on protection of potable water sources from pollution	RD 115/2001

2.2 Shell Group Environmental Guidelines

The Royal Dutch Shell Group has a formulated an extensive HSE management system covering all Shell's activities including hydrocarbon exploration and production. The system includes a series of comprehensive set of guidelines, standards and procedures. These guidelines have been incorporated into PDO's series of specifications where applicable; yet remain as reference documents covering specific operations and activities.

The Shells Group environmental specifications (standards and guidelines) are listed below in Table 2.2.

Table 2.2: Shell Group Environmental Specifications

Reference Number	Title
EP 95-0110	Management of Contractor HSE
EP 95-0120	Competence Assurance for HSE-critical Activities
EP 95-0140	Exploration & Production HSE Strategy and Policy Implementation Guide
EP 95-0220	Concept Selection
EP 95-0300	Overview Hazards and Effects Management Process
EP 95-0330	Drinking Water Guidelines
EP 95-0352	Quantitative Risk Assessment
EP 95-0370	Environmental Assessment
EP 95-0371	Social Impact Assessment Guidelines
EP 95-0375	Environmental Quality Standards - Air
EP 95-0376	Monitoring Air Quality
EP 95-0377	Quantifying Atmospheric Emissions
EP 95-0380	Environmental Quality Standards - Water
EP 95-0381	Monitoring Water Quality
EP 95-0385	Environmental Quality Standards - Soil and Groundwater
EP 95-0386	Monitoring Soil and Groundwater
EP 95-0387	Contaminated Soil and Groundwater
EP 95-0390	Waste Management Guidelines
None	Guide for Risk Based Management of Potentially Contaminated Land

2.3 PDO Corporate Environmental Specifications

PDO has established a comprehensive health, safety and environment (HSE) management system, based on ISO 14001, the international standard for environmental management and EP: 95-0000, the Royal Dutch Shell group guidelines on HSE management. PDO has developed environmental specifications for application throughout its facilities within Oman, based on the Omani regulatory standards and Shell Group guidelines. PDO's specifications, which are described in

the following sections, fully comply with the Omani regulatory standards, and in most cases are more stringent. The list of PDO's environmental specifications SP-1005 to SP-1012 and SP-1170 version dated 7/2002 is presented below in Table 2.3.

Table 2.3: PDO's Environmental Specifications

Reference Number	Title
SP-1005	Specification for Emissions to Atmosphere
SP-1006	Specification for Aqueous Effluents
SP-1007	Specification for Accidental Releases to Land and Water
SP-1008	Specification for the Use of Energy, Materials and Resources
SP-1009	Specification for Waste Management
SP-1010	Specification for Environmental Noise and Vibration
SP-1011	Specification for Flora and Fauna Protection
SP-1012	Specification for Land Management
SP-1170	Specification for Management of Naturally Occurring Radioactive Materials

In the following sections, the various environmental standards given under the above specifications are summarized.

2.4 Environmental Standards

2.4.1 Emissions to Atmosphere

PDO specification SP-1005on emissions to atmosphere addresses both stationary and mobile sources and is largely based on MD 5/86 “Regulations for Air Pollution Control from Stationary Sources” and Shell Exploration and Production International best practices. These are presented below in Table 2.4.

Table 2.4: Air Emission Standards

Parameter	Maximum Permissible Concentration
Hydrogen chloride	200 mg/Nm^3
Hydrogen fluoride	100 mg/Nm^3
Oxides of nitrogen (as NO_2)	200 mg/Nm^3
Phosphorus as (P_2O_5)	50 mg/Nm^3
Hydrogen sulphide	5 ppmv (7 mg/Nm^3)
Total particulates	100 mg/Nm^3

Note: Nm^3 refers to volume at 0 ^oC and 1atm.

In addition to the above emission limits, PDO has specified the following requirements to minimise air pollution and fugitive emissions:

(a) There shall be no continuous venting of gas in new projects.

(b) Fugitive emissions occurring as a result of leaks from components (such as pipe connections, valves, rotating shafts and other packed components) shall be

minimised through enhanced maintenance programs. There shall be no significant visible emissions of fugitive dust.

(c) No smoke emitted shall be as dark or darker than shade 1 on the Ringlemann scale (equivalent to 20% opacity).

(d) No odorous substances shall be emitted to the environment that are recognisable at residences for more than 150 hours per year.

(e) CFCs, HCFCs or HFCs shall not be knowingly vented to the atmosphere. They shall be recovered and re-used during servicing and maintenance. No equipment or product containing CFCs shall be selected for purchase or lease. Further, no equipment or product containing HCFCs shall be selected for purchase or lease, unless no alternatives are available in the market.

(f) There shall be no halon releases to the atmosphere for maintenance, testing or any other purposes. Halon releases are permitted under emergency situations only. No new halon fire fighting systems in new projects shall be purchased, and no virgin halons shall be used for recharging any existing halon fire fighting systems in use.

2.4.2 Ambient Air Quality

Presently, there are no Omani standards for ambient air quality. In their absence, MRME&WR recommends the use of United States Environmental Protection Agency's (USEPA) national ambient air quality (NAAQ) standards. PDO uses World Health Organisation (WHO) - European Union (EU) and Netherlands standards, which are more stringent than USEPA's NAAQ standards. PDO's ambient air quality standards are given as both limit values and guide values. The "limit values" are the maximum permissible concentrations in the ambient air, which if exceeded will result in non-compliance. The "guide values" are the desirable upper limits. PDO's ambient air quality standards are given in Table 2.5 below.

Table 2.5: Ambient Air Quality Standards

Parameter	Averaging Period	Limit Value ($\mu g/m^3$)	Guide Value ($\mu g/m^3$)
Oxides of nitrogen as NO_2	1 hour 4 hour 24 hour 1 year	400 - 150 -	- 95 - 30
Sulphur dioxide	10 minutes 1 hour 24 hours 1 year	500 350 125 50	- - 125 30
Hydrogen sulphide	30 minutes 24 hours	- 150	7 -
Carbon monoxide	1 hour 8 hour	40000 6000	- -

Benzene	1 hour 1 year	- 10	7.5 5
Total suspended particulate matter	1 year	120	-
Particulate products of incomplete combustion	24 hours 1 year	125 50	- -

2.4.3 Aqueous Effluents

PDO specification SP-1006 on aqueous effluent discharge is derived from a number of Ministerial Decisions (in particular, MD 7/84, MD 5/84 and MD145/93). The effluents include production water and other various process waters, sewage and storm water run-off. The specification covers both land and marine discharges. The details are presented below.

- **Production Water:**

The approved PDO Production Water Management Plan, which has been agreed upon with the government consists of five principles. These principles govern the disposal of production water (or other hyper saline brines), and are listed below in the order of preference.

(a) Minimise the volumes of water produced during oil extraction.

(b) Maximise reuse of such produced waters.

(c) Phase out the use of shallow disposal wells and prevent disposal into useable or exploitable aquifers.

(d) Return production water to the producing reservoir.

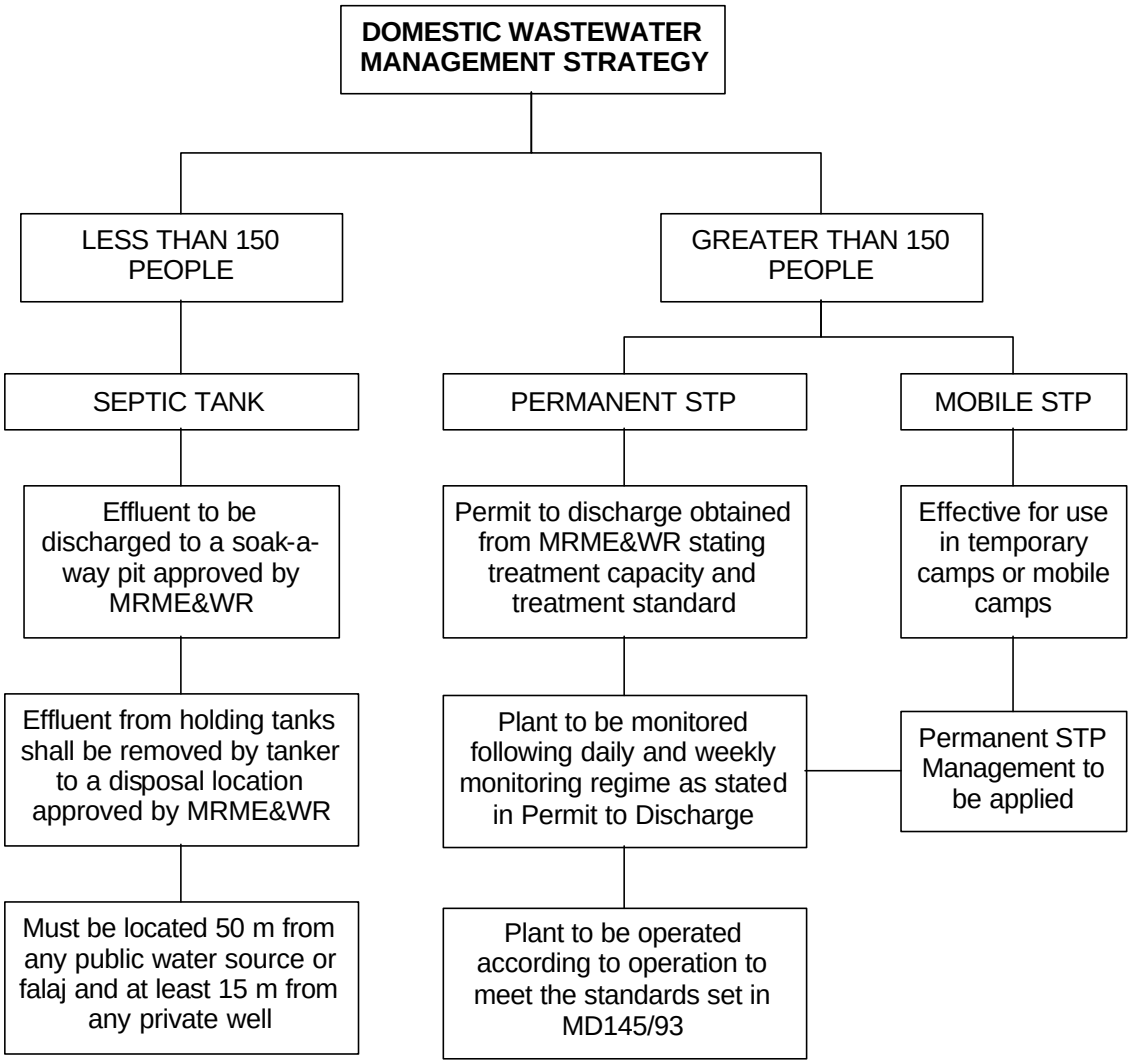
(e) Dispose surplus waters to formations, which have salinity greater than 35,000 mg/L, in conjunction with case-specific monitoring programs.

- **Other Process Effluents:**

The disposal of other process (such as reverse osmosis plants, hydrotest, maintenance etc.) effluents is dependent on the location and degree of the contamination. If the effluent is to be discharged to land then the quality of the water shall satisfy the water quality standards as identified in MD 145/93. Where the water is to be disposed of to the marine environment the effluent shall meet the water quality standards as per MD 7/84. In the event that the water quality standards are not met then the effluent discharge should be segregated and undergo treatment so as not to impact on the receiving environment.

- **Sewage Effluent:**

PDO have developed a strategy to select the wastewater treatment technology for various operations across the company. The strategy uses the population size of each camp as a basis for selecting a wastewater treatment option. This approach is summarised in the flowchart shown in below:



- **Storm Water Runoff:**

There are no legal requirements with respect to the discharge of storm water runoff uncontaminated by hydrocarbons. Potentially hydrocarbon contaminated storm water runoff shall be segregated and treated to the standards specified for on land discharge or marine disposal.

- **On Land Discharge:**

The following are PDO's standards for on land discharge and re-use of treated wastewater, which are the same as Omani standards (MD145/93 and RD 115/2001).

There are two types of standards (Standard A-1 and A-2), which differ from each other based on the intended re-use of treated sewage effluent. They are presented in Table 2.6.

Table 2.6: Classification of Standards A-1 and A-2 for Re-use of Treated Wastewater

Specification	Standard A-1	Standard A-2
Crops	- Vegetables likely to be eaten raw - Fruit likely to be eaten raw and within 2 weeks of any irrigation	- Vegetables to be cooked or processed - Fruit if no irrigation within 2 weeks of cropping - Fodder, cereal and seed crops
Grass and ornamental areas	- Public parks, hotel lawns recreational areas - Areas with public access. - Lakes with public contact (except place which may be used for praying and hand washing)	- Pastures - Areas with no public access

The treated wastewater if discharged on land shall meet the following specifications given In Table 2.7.

Table 2.7: Standards for Treated Wastewater Discharged on Land

Parameter	Units	Standard A-1	Standard A-2
Biochemical oxygen demand (5 days @ 20^0C)	mg/L	15	20
Chemical oxygen demand	mg/L	150	200
Suspended solids	mg/L	15	30
Total dissolved solids	mg/L	1500	2000
Electrical conductivity	µS/cm	2000	2700
Sodium absorption ratio	-	10	10
pH	-	6 - 9	6 -9
Aluminium (as Al)	mg/L	5	5
Arsenic (as As)	mg/L	0.100	0.100
Barium (as Ba)	mg/L	1	2
Beryllium (as Be)	mg/L	0.100	0.300
Boron (as B)	mg/L	0.500	1.000
Cadmium (as Cd)	mg/L	0.010	0.010
Chloride (as Cl)	mg/L	650	650
Chromium (total as Cr)	mg/L	0.050	0.050
Cobalt (as Co)	mg/L	0.050	0.050
Copper (as Cu)	mg/L	0.500	1.000
Cyanide (total as CN)	mg/L	0.050	0.100
Fluoride (as F)	mg/L	1	2
Iron (total as Fe)	mg/L	1	5
Lead (as Pb)	mg/L	0.100	0.200
Lithium (as Li)	mg/L	0.070	0.070
Magnesium (as Mg)	mg/L	150	150
Manganese (as Mn)	mg/L	0.100	0.500
Mercury (as Hg)	mg/L	0.001	0.001
Molybdenum (as Mo)	mg/L	0.010	0.050
Nickel (as Ni)	mg/L	0.100	0.100

Parameter	Units	Standard A-1	Standard A-2
Nitrogen: Ammoniacal (as N) : Nitrate (as NO_3) : Organic (Kjeldahl) (as N)	mg/L	5 50 5	10 50 10
Oil and grease (total extractable)	mg/L	0.500	0.500
Phenols (total)	mg/L	0.001	0.002
Phosphorus (total as P)	mg/L	30	30
Selenium (as Se)	mg/L	0.020	0.020
Silver (as Ag)	mg/L	0.010	0.010
Sodium (as Na)	mg/L	200	300
Sulphate (as SO_4)	mg/L	400	400
Sulphide (total as S)	mg/L	0.100	0.100
Vanadium (as V)	mg/L	0.100	0.100
Zinc (as Zn)	mg/L	5	5
Faecal coliform bacteria	Number per 100 mL	200	1000
Viable nematode ova	Number per L	<1	<1

The sludge generated from the treatment of domestic wastewaters may be applied on land for agricultural use, subject to the conditions set in Table 2.8. After spreading the sludge, there must be at least a three-week period before any grazing or harvesting of forage crops. Sludge application on land prohibited in the following cases:

- On soils while fruits or vegetable crops, other than fruit trees, are growing or being harvested
- For six months preceding the harvesting of fruit or vegetables that are normally eaten raw, and grown in contact with the soil
- On soils with pH less than 7

Table 2.8: Maximum Permissible Metal Concentrations in Sludge

Metal	Maximum Permissible Concentration (mg/kg dry solid)	Maximum Application Rate (kg/ha/yr)	Maximum Permissible Concentration in Soil (mg/kg dry solid)
Cadmium	20	0.150	3
Chromium	1000	10	400
Copper	1000	10	150
Lead	1000	15	30
Mercury	10	0.100	1
Molybdenum	20	0.100	3
Nickel	300	3	75
Selenium	50	0.150	5
Zinc	3000	15	300

Any sludge containing metal concentration above the following prescribed limits shall be disposed in sanitary landfills or to other facilities with approval from MRME&WR.

- **Marine Disposal:**

Any effluent discharged into the marine environment shall meet the specifications given below in Table 2.9, which are same as or more stringent than the discharge limits into the marine environment as per MD 7/84.

Table 2.9: Standards for Treated Wastewater Discharged into Marine Environment

Parameter	Discharge limit
Arsenic	0.05 mg/L
Cadmium	0.05 mg/L
Chromium	0.50mg/L
Copper	0.50 mg/L
Cyanide	0.10 mg/L
Iron	2.00 mg/L
Lead	0.10 mg/L
Mercury	0.001 mg/L
Nickel	0.10 mg/L
Selenium	0.02 mg/L
Silver	0.005 mg/L
Zinc	0.10 mg/L
Chlorine (salt)	2.50 mg/L (minimum)
Hydrogen ions	6-9 units
Sulfide salts	0.10 mg/L
Sticking solid particles	30.0 mg/L
Sludge	75.0 Jackson sight unit
BOD	30.0 mg/L
Oil & grease	5.0 mg/L
Carbolic acids (phenols)	0.10 mg/L
Ammonium nitrates	40.0 mg/L
Phosphates	0.10 mg/L
Faecal coliforms	100 MPN/100 mL (80% samples)
Faecal streptococci	100 MPN/100 mL
Salmonella	Zero MPN/L

2.4.4 Accidental Releases to Land and Water

PDO specification SP-1007 on accidental releases to land and water focuses on minimising the effect on groundwater, and soil. The requirements are outlined below:

- Equipment, processes, pipelines etc. containing material harmful to the environment shall be designed, maintained, operated and abandoned to prevent accidental releases to the environment
- In case of a loss of containment to the environment, the contamination shall be assessed and the soil and groundwater shall be cleaned to a level compatible with the environmental quality standard of the receiving environment (available EP 95-0385)

2.4.5 Use of Energy, Materials and Resources

PDO specification SP-1008 on the use of energy, materials and resources attempts on the efficient use of natural resources. The requirements under this specification are outlined in Table 2.10.

Table 2.10: Applicable Requirements for the Use of Energy, Materials and Resources

Indicators	Requirement
Energy	- Efficient use of energy at all times shall be demonstrated
Water Resources	- RD 82/88 controls the exploitation of groundwater in the interest of agricultural and development plans - MD 2/90 requires all wells used for the detection or extraction of groundwater be registered with MRME&WR - Efficient water use shall be demonstrated for hydrocarbon production
Land Use	- Under PDO's concession agreement, land no longer necessary for operations shall be handed back to the government
Use of Chemicals	- The manufacture, import, storage, handling and use of any chemical substance shall comply with RD 46/95 - Under RD/248/97, the manufacture, export, transport, storage, handling use, and disposal of any chemical substance will require a permit from MRME&WR - Chemicals shall only be bought with valid Safe Handling of chemicals (SHOC) card. The chemicals shall be stored with the SHOC card visible

2.4.6 Waste Management

PDO specification SP-1009 on waste management defines what are hazardous and non-hazardous wastes, and outlines the waste management strategy in PDO. This specification complies with Omani regulations MD 17/93 and MD 18/93 dealing with non-hazardous and hazardous waste management. The classification of non-hazardous and hazardous wastes is specified under SP 1009 as below in Table 2.11.

Table 2.11: Classifications of Hazardous and Non-Hazardous Wastes

Hazardous Wastes	Non-Hazardous Wastes
Hazardous empty drums	Kitchen refuse
Waste lubricants	Domestic waste
Pigging sludge	Tree/grass cuttings
Tyres	Water-based drilling mud and cuttings
Batteries	Office waste
Clinical waste	Non-hazardous waste chemicals
Naturally occurring radioactive material	Non-hazardous empty drums
Sewage sludge	Scrap metal
Oil-based drilling mud and cuttings	
Hazardous waste chemicals and lab waste chemicals	
Oily sand /soil	
Oily sludge	

PDO's waste management hierarchy is as below:

- Pollution prevention: elimination, change or reduction of operating practices, which result in wastes
- Source reduction: generation of less wastes through more efficient processes
- Re-use: the use of materials or products that are reusable in their original form
- Recycling/recovery: the conversion of waste into usable materials, or the extraction of energy or materials from the waste
- Treatment: the destruction, detoxification and/or neutralisation of residues
- Responsible disposal: depositing wastes using appropriate methods for a given situation

Based on the above hierarchy, the detailed waste handling and disposal procedures are given in the specification SP-1009. The procedures for the handling and disposal of NORM wastes are given under the specification SP-1170. These are discussed in Section 2.4.10 in this chapter.

2.4.7 Environmental Noise and Vibration

PDO specification SP-1010 on environmental noise and vibration is based on Omani standards MD 79/94 and MD 80/94. PDO standards on ambient noise, which are the same as Omani standards (MD 79/94) are summarized in Table 2.12 below.

Table 2.12: Ambient Noise Standards

Type of District	**Maximum Permissible Noise Level [as L_{eq} in dB (A)]**		
	Workdays – Day time (7am –6pm)	**Workdays – Evening (6pm –11pm)**	**Workdays Night time (11pm- 7am) and Holidays**
Rural, residential, recreational	45	40	35
Suburban residential	50	45	40
Urban residential	55	50	45
Urban residential with some workshops or business	60	55	50
Industrial and commercial	70	70	70

2.4.8 Flora and Fauna

PDO specification SP-1011 on protection of wildlife is developed in response to several Omani royal decrees and ministerial decisions on environmental protection.

The specification outlines specific ecological zones and based on their importance, defines specific requirements for carrying out projects. These are summarized in Table 2.13 below.

Table 2.13: Classification of Environmentally Sensitive Areas

Ecological Zone	Description	Requirements
Zone 1: Areas of Concern	National reserves or sanctuaries	Activities shall be restricted
	Areas that provide habitat to particularly sensitive wildlife	
	Areas containing high proportions of endemic flora or fauna	
	Woodlands	
	Areas of exceptional natural beauty	
Zone 2: Areas of Interest	Areas having significant natural features and beauty	Activities shall be restricted for those not compatible with the protection of the area
	Areas showing features of geological or climatic history	
	Artificially created areas to attract wildlife and migratory birds	
Arabian Oryx Sanctuary	Area defined by RD 9/94	Case-specific approval from MRME&WR

2.4.9 Land Management

There is currently no specific Omani legislation on land management (site preparation, abandonment and restoration). PDO's policy on abandonment requires that redundant assets shall be removed where appropriate and the environment restored to, or as near as reasonably practicable, to its original state. PDO specification SP-1012 on land management is summarized below in Table 2.14.

Table 2.14: Land Management Requirements

Project Stage	Requirements
Site Selection	- Selection of a site shall be carried out in accordance with PDO's procedure on HEMP and environmental assessment guideline
Site Preparation	- Earthmoving shall be conducted to minimize environmental effects - Trees shall not be felled or removed - Borrow pits shall not be excavated more than 2m in depth - Borrow pits shall not be excavated in wadis, in areas used by grazing livestock or in areas which would cause nuisance to local inhabitants - A 20m wide right-of-way shall be provided for all pipelines (10m each side) - Where pipelines or roads cross wadis, earthmoving shall be carried out to minimize flow or characteristics of shallow aquifers

Project Stage	Requirements
Site Abandonment and Restoration	- Restored land shall be visually similar to the surrounding landscape - All waste materials shall be removed - Hydrocarbon shall be removed from site if concentrations greater than 1% weight - Areas having less than 1% weight hydrocarbon contamination shall be covered with 0.6m of clean sand within 6 months of abandonment - All pipelines, process equipment and instrumentation shall be removed - All camp facilities shall be removed and site re-graded. Any soak pits shall be backfilled - Borrow pits shall be filled with 0.3m of clean sand and graded to match the surrounding contours

2.4.10 NORM Waste Disposal

Oil sludges, pigging wastes, tubulars and water/well accessories from reservoir locations are known to contain NORM materials. The monitoring, handling, transport, storage, treatment and disposal of NORM wastes are specified under SP-1170 "Specification for Management of Naturally Occurring Radioactive Materials". This specification conforms to MD 249/97, " Regulations for the Control and Management of Radioactive Materials". Any waste having radioactivity greater than 100 Bq/g (for solids) and 100 kBq/L (for liquids) is classified as radioactive waste. Such waste shall be sent to PDO's dedicated storage facility in Zauliyah as soon as possible. Normal transport vehicles can be used. However, the waste shall be packaged as per the detailed procedures given in the specification. Any recyclable items shall be released only after they are decontaminated by an authorised contractor at the designated site, such that the radioactivity level is reduced to <100 Bq/g. If decontamination is not possible, the wastes shall be retained at the storage site until the radioactivity level drops to <100 Bq/g.

3 ASSET DESCRIPTION

3.1 Introduction

Production chemistry asset is one of the eight technical service providers in PDO, whose areas of operation covers the entire interior concession area in South and Central Oman as well as Mina Al Fahal on the coast. The production chemistry asset consists of two sections:

- Drilling support chemistry (TTKW)
- Process & treatment chemistry (TTKC)

TTKW section provides technical support to the well engineering team on matters related to the chemistry of drilling fluids, well cementing, well completion fluids and well stimulation. It also provides technical support to chemicals procurement, research and development.

TTKC section consists of a consultancy group and a laboratory services group. The consultancy group provides expert advice on all chemical and physical processes related to the production, treatment and transport of crude oil and gas. It also provides expert advice on water treatment for re-injection and disposal, corrosion and safe use of chemicals. The laboratory services group operates analytical laboratory facilities within PDO for the chemical and physical analysis of a range of materials including oil, gas, produced water, groundwater, wastewater, drilling fluids, well cements, process chemicals etc. It also provides technical advice on handling and disposal of wastes containing naturally occurring radioactive materials (NORM).

The production chemistry asset, like all other service assets works under the overall direction of the Technical Support Director and is managed by the Technical Support Manager. At the asset level, it is managed by the Production Chemistry Manager. At the sectional level, TTKW section is headed by the Senior Drilling Support Chemist. The consultancy group within the TTKC section is headed by the Senior Process Support Chemist and the laboratory services group is headed by the Head of Laboratory Services. The health, safety and environment (HSE) management function in the asset is handled by the Production Chemistry HSE Advisor. The asset management structure including the HSE structure is shown in Figure 3.1.

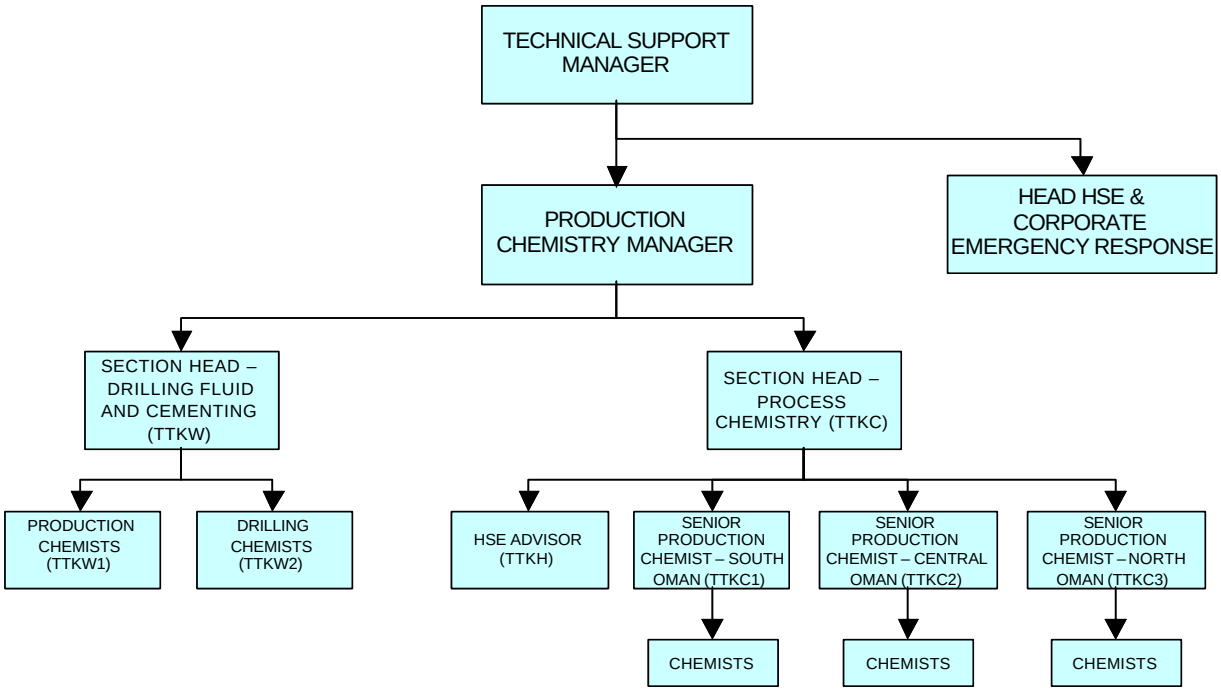


Figure 3.1: Management Structure for Production Chemistry Asset

3.2 Description of Facilities

The production chemistry asset does not have any physical assets other than chemical laboratory facilities. The Asset Manager, the Sectional / Group Heads and the HSE Advisor operate from their offices located on the coast in Mina Al Fahal, within PDO's premises. The production chemistry asset operates and maintains a total of eight laboratory facilities. One facility is located on the coast in MAF and seven others in the interior areas. The MAF laboratory is located within the PDO premises inside the MAF Industrial area. In the interior locations, the laboratories are located in the administrative buildings within PDO's main camps.

The interior laboratories are located in Fahud, Lekhwair, Yibal and Qarn Alam in north / central Oman, and Bahja, Nimr and Marmul in the south Oman. The Lekhwair laboratory currently operates as satellite laboratory to the Fahud laboratory. A chemist from Fahud laboratory visits the Lekhwair facility typically once a week and carries out the necessary operations.

The laboratories are equipped with all necessary analytical instruments and apparatus to carry out a range of physico-chemical tests for the analysis of oil, gas, produced water, groundwater, wastewater, drilling fluids, well cements, process chemicals etc. The list of major equipment and apparatus provided in the laboratories is presented in Table 3.1 below.

Table 3.1: List of Major Laboratory Equipment and Apparatus in Production Chemistry Asset

Name of Equipment / Apparatus	MAF	Fahud	Lekhwair	Yibal	Qarn Alam	Bahja	Nimr	Marmul
Atomic absorption spectrophotometer	✓							
Balance	✓	✓	✓	✓	✓	✓	✓	✓
Blender	✓		✓					
Centrifuge			✓	✓	✓	✓	✓	✓
COD heater	✓	✓	✓	✓		✓		✓
Compression Machine	✓							
Conductivity meter	✓			✓		✓	✓	✓
Consistometer	✓							
Dehydration unit	✓							
Density meter	✓	✓	✓	✓	✓	✓	✓	✓
Dew point tester	✓	✓	✓	✓	✓	✓		
Dissolved oxygen meter			✓					
Distilled water unit	✓							✓
Extraction unit	✓	✓	✓	✓	✓	✓	✓	✓
Filtrate kit	✓							
Filter press	✓							
Flame photometer					✓			
Flash point apparatus	✓							
Flash point tester	✓							
Garret Gas train		✓		✓	✓	✓	✓	✓

Name of Equipment / Apparatus	MAF	Fahud	Lekhwair	Yibal	Qarn Alam	Bahja	Nimr	Marmul
Gas chromatography	✓	✓				✓		✓
Heating mantle			✓		✓			
High shear mixer	✓							
Hot plate								✓
Hydrogen generator		✓	✓	✓	✓			
Hygro meter	✓							
Incubator		✓		✓		✓	✓	✓
Incubator-BOD	✓		✓	✓	✓	✓	✓	✓
Mercury analyser					✓			
Microscope	✓	✓			✓	✓	✓	
Mud HPHT cell	✓							
Muffle furnace							✓	
Oxygen Meter	✓		✓				✓	✓
Oven	✓	✓	✓	✓	✓	✓	✓	✓
pH meter	✓	✓	✓	✓	✓	✓	✓	✓
Portable oxygen meter	✓					✓		
Potentiograph						✓	✓	
Radon Monitor	✓					✓		
Refrigerator	✓	✓	✓		✓	✓	✓	✓
Salt in crude analyser	✓	✓	✓	✓	✓	✓	✓	
Scintillation monitor series	✓		✓		✓			
Sica meter								✓
Sieve shaker	✓						✓	
Spectrophotometer	✓	✓	✓	✓		✓	✓	✓
Titrator	✓	✓	✓	✓		✓	✓	
Turbidimeter	✓		✓	✓	✓	✓	✓	✓
Ultra sonic cleaner bath			✓			✓	✓	✓
Vacuum pump	✓	✓	✓		✓	✓		✓
Vacuum pump compressor								✓
Viscometer	✓		✓	✓				
Viscosity bath		✓	✓	✓		✓		✓
Water analyser ion chromatography	✓							
Water bath		✓	✓	✓	✓	✓	✓	✓
Water UV detector	✓							

All the laboratories are provided with the following built-in facilities in order to ensure reliable and safe operation:

- Working space including work benches and fume cupboards with suction hoods
- Laboratory chemicals storage cabinets and shelves
- Air-conditioning and ventilation systems
- Computer systems
- Sample reception and storage areas
- Wastewater collection, treatment and disposal systems
- Waste chemical storage and disposal systems
- Fire safety systems
- Emergency power supply units

A more detailed description of the systems provided for handling, storage and disposal of gaseous, liquid and solid waste generated from the laboratory activities are presented in Chapter 4.

The laboratory services group currently consists of a senior production chemist (Head of Laboratory Services), two production chemists and about 55 laboratory chemists working in all the facilities. HSE Advisor of the production chemistry asset provides the guidance and assistance on HSE matters for all sections in the asset.

3.3 Activity Description

The activities performed by the production chemistry asset may be broadly classified as below:

- Administrative
- Advisory / Consultative
- Operational

Of the two sections within the production chemistry asset, the activities of TTKW section and the consultancy group of the TTKC section are entirely administrative and advisory / consultative. Only the laboratory staff in the TTKC section perform operational activities in addition to administrative and advisory / consultative functions.

Some of the advisory or consultative functions of the production chemistry asset have a bearing on the environmental performance of the other assets (both production and service) in PDO. The significant functions with a bearing on the environmental performance are listed below:

- Provide HSE advice on drilling and completion fluids, stimulation and cementing.
- Develop, recommend and oversee drilling waste disposal plans and procedures
- Monitor and evaluate trials of new chemical technologies.
- Input to field-by-field portfolio reviews and asset reference plans in respect of fluid process treatment, water injection specification and environmental advice on the use of production chemicals.
- Input to and review of facilities design documentation for dehydration, de-oiling, gas treatment, water treatment and disposal, chemical treatments (e.g. scale inhibition, bactericide, etc), waste disposal and integrity hydro testing of facilities.

- Provide advice on the handling, transportation and storage of radioactive sources and naturally occurring radiation materials.
- Preparation of SHOC (safe handling of chemicals) cards for new chemicals.
- Providing advice on disposal of chemicals.
- Contribute to the HSE management system of the production facilities, where the laboratory is located, by attending HSE meetings.

The operational activities of the production chemistry asset are mostly limited to the laboratory activities. The major activities of the laboratory staff are listed below:

- On-site sampling and analysis for selective cases such as NORM
- Collection, preservation and transportation of samples for laboratory analysis from all assets
- Storage of samples prior to and after analysis
- Analysis of samples
- Storage of laboratory chemicals, reagents and gases
- Collection, treatment and disposal of wastewater
- Handling and disposal of wastes chemicals and unused samples

The MAF laboratory is certified under the international standard ISO 9002 for quality management system. The HSE Advisor acts as the management representative (quality manager). The other laboratories, though not yet ISO 9002 certified, operate on the same quality management procedures. The standard test methods are documented in the quality manual. Each laboratory in the interior (except Lekhwair) is staffed with at least two chemists at any time. All the analytical results are recorded in laboratory information management system (LIMS). For specialised and non-routine analysis, samples are sent to pre-selected and certified external laboratories.

3.4 Materials and Utilities

A large number of laboratory chemicals and reagents are used in the laboratories for chemical analysis. They include both organic and inorganic chemicals, most of which are corrosive, reactive and toxic. However, the quantities of consumption for each chemical will be very low. Considering that hundreds of chemicals and reagents may be used, the list of chemicals is not presented here.

Due to the nature and size of its operations, the production chemistry asset is also not a major consumer of utilities.

4 RELEASES TO ENVIRONMENT

4.1 Introduction

In this section, the various waste products released into the environment from the various operational activities performed by the production chemistry asset are discussed. As discussed in Chapter 3, the operational activities performed by the production chemistry asset are almost exclusively limited to activities performed by the laboratory staff in the eight production chemistry laboratories. The production chemistry laboratories facilities are located in MAF, Fahud, Lekhwair, Yibal, Qarn Alam, Bahja, Nimr and Marmul. While the MAF laboratory is located within the PDO premises inside the MAF Industrial Area, the other laboratories are located in the administrative buildings within the PDO main camps in the respective assets.

The major activities of the laboratory staff include on-site sampling and analysis for selective cases such as NORM; collection, preservation and transportation of samples for laboratory analysis from all assets; storage of samples prior to after analysis; analysis of samples; storage of laboratory chemicals, reagents and gases; collection, treatment and disposal of wastewater; and handling and disposal of wastes chemicals and unused samples. The wastes resulting from the above activities and released into the environment may be classified into the following groups, based on their physical state as well as nature:

- Air emissions
- Liquid effluents
- Solid and semi-solid wastes
- Noise
- Accidental leaks and spills

In order to quantify and characterize these releases, the currently available database is used. In cases where data are not available or insufficient, an attempt is made to estimate the quantities and characteristics using theoretical or empirical equations.

4.2 Air Emissions

The air emission sources may be classified as stacks, vents, area sources and mobile sources. In the production chemistry laboratories, vents are the only sources of air emissions. There are no stacks and area sources. The mobile sources (cars used for sample transportation) are insignificant and inconsequential.

During the process of laboratory analysis, the samples may be treated with chemicals and reagents and often heated. This process generates gases, vapours and aerosols, collectively called fumes and is generally toxic. Therefore, all such activities are performed within partially enclosed spaces (fume hoods) under negative air pressure. An exhaust fan is attached to the top of the fume hood to maintain the negative air pressure. Due to this, the diluting air drawn from the front of the fume hood carries all gases and vapours generated away from the work area and releases into the outside atmosphere. The negative air pressure maintained in the fume hoods also ensures that any gases and vapours released in other work areas in the laboratory are constantly removed from the workplace.

The vent air is released into the outside atmosphere through a vent attached to each fume hood. Most vents are provided with a particulate filter ahead of the exhaust fan to filter out any suspended particulate present in the vent air. These filters are cleaned annually. The vents are typically mounted on the roof of the building in which the laboratory is located. The height of the vent from ground level is to the order of 5m. Each laboratory has about 5-10 vents and the air flow rates from the vents vary from each vent. Since the chemical operations are not performed on continuous basis, the concentration level of toxic gases in vent air will be very transient. For this reason, it is difficult to characterise the vent air emissions.

4.3 Liquid Effluents

Liquid effluents are generated in the laboratories from the following activities:

- Draining the waste chemical and reagent solutions into the sinks
- Draining the excess liquid samples into the sinks
- Washing the laboratory glassware
- Washing sampling kits and sampling containers
- Hand washing

It may be noted that solid and semi-solid samples are not drained into the sinks (refer Section 4.4). Further, all chemicals that are no longer required or expired, solid or liquid, are not drained into the sinks. They are stored in their original containers for proper disposal as described in the latter sections.

The liquid wastes generated in the laboratories are classified into two groups *viz.*, oily effluents and non-oily effluents. Oily effluents refer to the following:

- Unused (excess) oil samples and other liquid samples taken for oil analysis
- Solutions resulting from oil analysis
- Wash water from the apparatus used for sampling and analysis of oils and oily substances

All other liquid effluents are classified as non-oily samples.

The quantities of the liquid effluents generated in the various laboratories are presented in Table 4.1 below.

Table 4.1: Liquid Effluents Generated by Production Chemistry Asset

Location	Volume Generated (m^3/year) – For Year 2001	
	Oily Effluents	Non-oily Effluents
Mina Al Fahal	30.0	Not reported
Marmul	95.0	Not reported
Nimr	108.0	Not reported
Bahja	720.0	Not reported
Qarn Alam	14.3	Not reported
Fahud	78.2	Not reported
Yibal	18.2	Not reported
Lekhwair	21.6	Not reported
Total for the Asset	1085.3	Not reported

Presently, the liquid effluents are not analysed prior to treatment and hence their characteristics are not known. It is however reasonable to expect that a number of toxic substances including heavy metals and detergents will be present in the effluents, though in very small concentrations.

Dedicated wash basins and sinks are provided in each laboratory draining for the oily effluents, which are drained into a holding tanks made of concrete and fitted with a steel cover. From the holding tank, the oily effluents are periodically transferred to the common waste oil pits located in each asset using vacuum trucks. From the waste oil pits, the waste oils are sent to waste oil recovery pit in the waste management centre.

Non-oily effluents are drained into the sewers for treatment in the sewage treatment plant (STP) located in the asset. If any acidic or alkaline liquids are to be drained, they should first be neutralised before discharged into the sewers. Floor washings are directly drained into the sewers. It is recognised that this effluent will contain a variety of chemical constituents that may be classified as toxic. However, it is assumed that the concentrations of such materials after being mixed with the sewage will be extremely low to affect the performance of the STP. However, this assumption remains to be substantiated.

4.4 Solid and Semi-solid Wastes

In PDO, the solid wastes are classified into broad categories as non-hazardous and hazardous. The sub-groups in each category are as below:

Non-hazardous wastes: domestic and office waste; water based drilling mud and cuttings; non-hazardous industrial waste

Hazardous wastes: oil based mud and cuttings; sewage sludge; waste lubricants; oily sludges; oily sand; pigging sludge; non-recyclable batteries; recyclable hazardous batteries; transformers and transformer cooling fluids; clinical wastes; NORM wastes; chemical wastes (including miscellaneous hazardous wastes)

The solid waste generated from the production chemistry laboratories fall into three general categories as following:

- Non-hazardous office waste
- Non-hazardous industrial waste
- Chemical wastes

The non-hazardous office wastes include the waste paper and waste packaging materials including paper and plastic. The non-hazardous industrial wastes include the unused solid samples containing non-hazardous substances, non-hazardous disposal laboratory ware and uncontaminated empty chemical containers. The empty containers of hazardous materials (samples and chemicals) are not included in this category.

The chemical wastes may be further sub-classified into the following groups:

- Unused (excess) solid samples containing hazardous substances
- Unusable chemicals (in their containers)
- Empty containers of hazardous materials (samples and chemicals) and hazardous disposal laboratory ware
- Biological agents
- Wastes resulting from accidental chemical spills
- Used-up radioactive sources and NORM containing wastes

The sources of generation, quantities and methods of disposal of all the waste types are shown in Table 4.2.

Table 4.2: Solid Wastes Generated by Production Chemistry Asset Activities

Waste Type	Quantity Generated	Method of Disposal
Non-hazardous office waste	Not reported	Disposed off into the garbage bin kept outside the laboratory
Non-hazardous industrial wastes	< 1 t per year	Disposed off into the garbage bin kept outside the lab
Unused (excess) solid samples containing hazardous substances	Not reported	Sent to the nearest waste management centre
Unusable chemicals (in their containers)	Not reported	Sent to the chemical waste landfill in Marmul
Empty containers of hazardous materials (samples and chemicals) and hazardous disposal laboratory ware	Not reported	Sent to the chemical waste landfill in Marmul
Biological agents	Negligible	Sent to the incinerator in MAF
Wastes resulting from accidental chemical spills	Negligible	Sent to the chemical waste landfill in Marmul
Used-up radioactive sources and NORM containing wastes	Negligible	Sent to the NORM waste facility in Zauliyah in Bahja asset

4.5 Noise

There are no major noise generating sources in the laboratory. The fume hoods, rotating equipment such as centrifuges and compressors generate low level noise.

4.6 Accidental Leaks and Spills

Accidental chemical spills may occur during the handling and storage of chemicals. Chemicals are mostly handled during analyses, which are done at specified work areas. The work areas are generally provided with spill collection trays and therefore any spills are contained. Further, the quantities of spills will be very small. The potential for accidental leaks in the storage areas are also very remote. The chemical containers are leak proof and rarely break. In the event of any breakage, the quantity spilled will be quite small. Any spills on the floor will be sponged off, and the waste will be treated as a chemical waste and disposed as described in Table 4.2.

Accidental release of toxic gases from compressed gases used for analytical purpose may occur only under extreme circumstances. In the event of such occurrence, all the staff in the laboratory will be evacuated.

Leakage of oily effluent from the holding tanks into the surrounding soil due to cracks in the tank bottom or walls and due to overflow is a possibility. However, no such occurrence has been reported.

5 ENVIRONMENTAL SETTING

5.1 Introduction

The production chemistry asset is one of the eight technical service providers in PDO. The production chemistry consists of two sections *viz.*, TTKW section and TTKC section. As described in Chapter 3, the only physical assets of the production chemistry are the analytical laboratories, where a range of materials including oil, gas, produced water, groundwater, wastewater, drilling fluids, well cements, process chemicals etc. are analysed for all the production and service assets of PDO.

The production chemistry asset operates and maintains a total of eight laboratory facilities within PDO's concession area. One facility is located on the coast in MAF and seven others in the interior areas. The MAF laboratory is located within the PDO premises inside the MAF Industrial area. In the interior locations, the laboratories are located in the administrative buildings within PDO main camps. The interior laboratories are located in Fahud, Lekhwair, Yibal and Qarn Alam in north / central Oman, and Bahja, Nimr and Marmul in the south Oman. The Lekhwair laboratory currently operates as satellite laboratory to the Fahud laboratory. A chemist from Fahud laboratory visits the Lekhwair facility typically once a week and carries out the necessary operations.

As seen from these maps, the areas of operation of the production chemistry asset stretch from Marmul in southern Oman to Fahud in central Oman to MAF on the northern coast. From an environmental viewpoint, terrestrial environment is of interest in the interior areas and marine environment is of interest in MAF.

The detailed description of environment throughout the PDO concession area is given in the individual environmental impacts assessment reports prepared for all the production assets (*Reference 4*). In this chapter, a brief description of the environment in the interior and coastal areas of operation of production chemistry asset is presented.

5.2 Topography

The topographical features from the southernmost part of the concession area (Marmul) to the northern coast (MAF) show three distinct zones as below:

- Desert plains with very low population within most of the concession area
- Low to medium altitude hills over the southernmost and northernmost parts
- A small coastal plain surrounded by urban population

Most of the concession area falls under central and south-central Oman and is characterised by flat gravel desert plains with occasional rocky outcrops interspersed with a few wadi channels. The altitude in the plains is mostly in the range of 100-150m above the mean sea level. The desert plains are very thinly populated. Sand dunes occur over the western parts of central Oman forming a part of Rub Al Khali (the empty quarter). A large area constituting the southern part of Yibal asset and northwest part of Qarn Alam asset fall under Umm as Simm, the largest sabka (natural salt pan) of the Arabian Peninsula. The natural vegetation is composed of desert plants and grasses, and is restricted to the wadi plains only. Among all the assets, Nimr and Marmul assets have relatively denser vegetation. Wadi Raunib in Rima is one of the most significant naturally vegetated areas. Rahab Farms in Marmul asset are the most significant cultivated vegetated areas within the concession area.

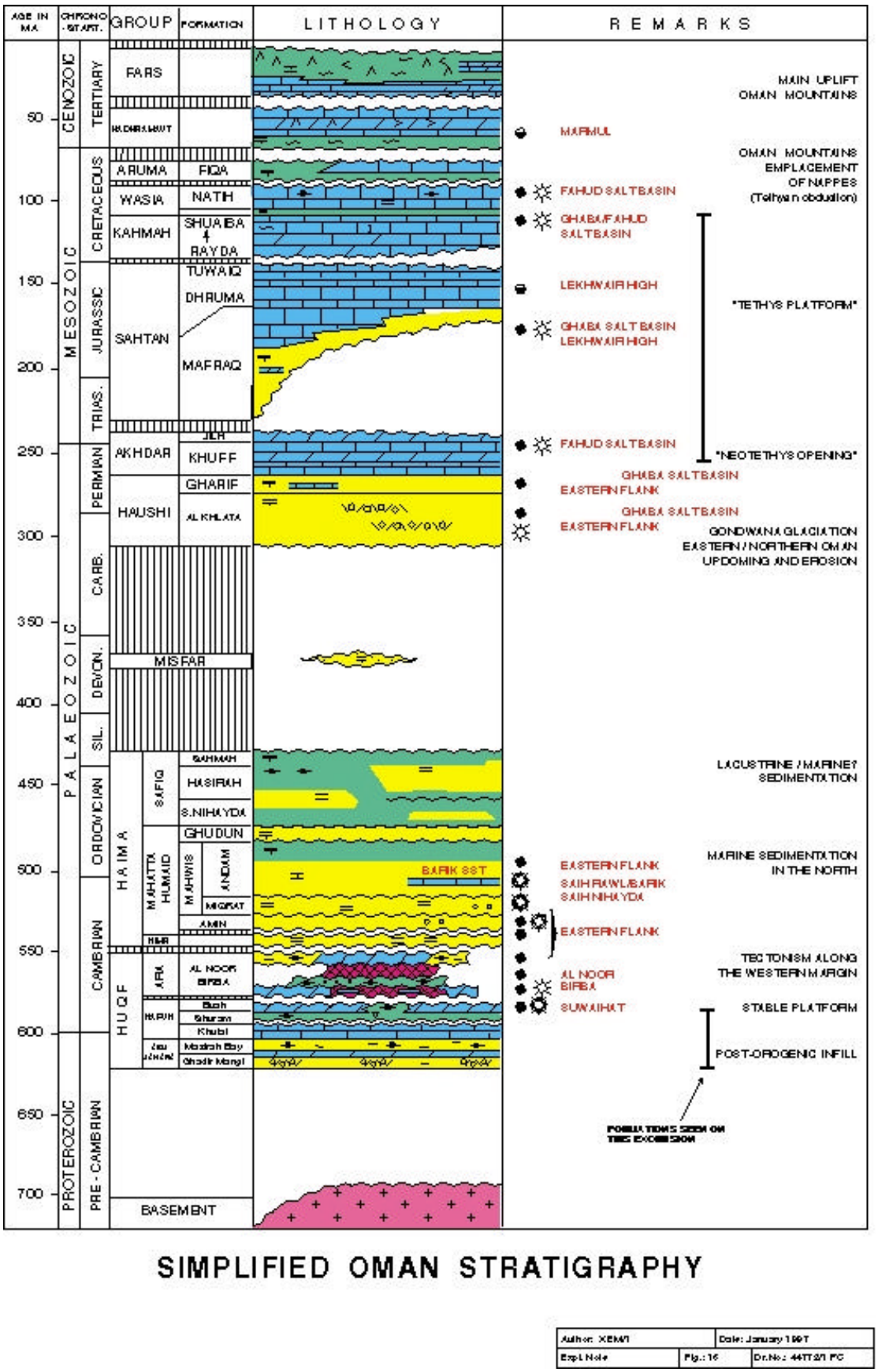
Hills of low to medium altitude are encountered over the southernmost and northernmost parts of the concession area. In the south, from Thuleit (Marmul asset) onward, the altitude rises steeply up to 600m above the men sea level into Dhofar mountains. Similarly, in the north from Fahud onward, several hills up from 300-600m altitude are encountered. At the high point of MOL near Iszi, the altitude is about 670 m above the mean sea level.

The MAF laboratory is located within the MAF industrial area on the shore of MAF bay and surrounded by hills, rising to 214 m altitude above the sea level on the eastern boundary. There are large urban settlements adjacent to MAF area to the northwest.

5.3 Geology and Soil

The geology of most of the PDO's concession area comprises of mainly limestone with shale, dolomite and sandstone. The central plains mostly consist of flat limestones of oligocene and miocene ages to mid-tertiary. The limestone plains are covered sparsely with alluvial gravel or aeolian sand. The hills from Fahud to MAF are formed from sedimentary carbonate strata comprising limestones, sandstones and dolomites dating from the Permian to the late Cretaceous. Toward the north, the low hills are comprised of tertiary sedimentary sandstones, limestones and conglomerates overlying igneous and metamorphic rocks formed under ocean sediments in the Mezozoic period. The rock types include gabbros, Hartsburgites, basalts and locally pillow larva.

The simplified stratigraphy map of Oman is shown in Figure 5.1.



SIMPLIFIED OMAN STRATIGRAPHY

Author: XEMT		Date: January 1997
Expl. Note	Fig.: 16	Dr.No.: 44TT97 PC

Figure 5.1: Simplified Stratigraphy Map of Oman

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No site-specific data are available on the soil quality. Generally, the soils in the asset are classified as unsuitable for agricultural purposes, as per the Ministry of Agriculture and Fisheries “General Soil Map of Oman". The soil map of PDO’s concession area is shown in Figure 5.2.

5.4 Hydrogeology and Groundwater Quality

The tertiary aquifers are the potentially exploitable groundwater resources in PDO’s concession area. Tertiary aquifer systems in Oman are recharged from the flow from the Oman mountains to the north and Dhofar mountains to the south. Surface hydrology in this area is of no significance due to very scanty rainfall. The shallow aquifer systems consists of the Fars formations (0-150 m depth), Dammam formations (150-200 m depth), Rus formations (200-300 m depth) and Um er Raduma (UeR) formations (300-600 m depth).

Fars formations are basically formed by sedimentary carbonates. Groundwater availability in these formations is not significant in most of the assets. Dammam formations are primarily limestone beds and have very limited groundwater potential due to their reduced thickness. Rus formations are formed by gypsum anhydrite beds. They have significant groundwater potential in some assets. This aquifer appears to be confined at some places and connected with the UeR aquifer at other places.

UeR aquifer is the main prolific aquifer in the area. UeR formations are sub-divided into lower, middle and upper layers. The upper and middle layers are composed of limestone and dolomite, while the lower layers are composed of thin impermeable shale and marl. UeR aquifer is recharged in Dhofar mountains in the south during monsoon from July to September. The groundwater is estimated to travel at a velocity of 10 m per year.

The mineral content in UeR water increases as it travels from south to north. Within the entire PDO concession area, only Marmul asset has groundwater that is potable without any pre-treatment. In all other assets the UeR water is very saline. The total dissolved solids content ranges from 12,000 mg/L to 35,000 mg/L. The groundwater salinity map of the region is shown in Figure 5.3.

The historical well yield and water quality data collected from various water supply wells in the concession area have not shown any significant change over most parts of the concession area.

5.5 Climate

PDO's concession area as whole has an arid climate, with very low rainfall. The climate is typically hot with significant fluctuations between maximum and minimum temperatures. The hottest temperatures occur throughout summer months (May – August) and cooler temperatures occur during the winter months (November-February). The mean monthly temperatures range from around 20^{o}C in December/ January (with mean minimum of about 12^{o}C and mean maximum of about 28^{o}C) to about 35^{o}C in July (with mean minimum of about 24^{o}C and mean maximum of about 45^{o}C). The maximum absolute temperature will be as high as 50^{o}C and the minimum absolute temperature will be as low as 5^{o}C.

Rainfall in this region is scanty and is highly variable in time and space. Historical data give an average of 36 mm per annum. Although the annual average rainfall is very low, flash floods are known to have occurred in the area. Most of the rainfall occurs during the winter season (December - February) with secondary peaks expected in late summer. Little rainfall is expected throughout the rest of the year.

Wind speeds vary considerably from calm to strong gusts. The dominant wind direction is from the south with an average wind speed of 8 knots.

5.6 Ambient Air Quality

Very limited air quality studies have been conducted anywhere in PDO concession area since PDO's exploration and production activities started. These data are available on the ambient air quality from the previous EIA report (*Reference 1)*. It is generally believed that ambient air quality within PDO concession area is of no significance due to two reasons. Firstly, there are no human settlements close to any operational facilities in the entire PDO concession area. Secondly, there are not many air emissions sources in PDO and the emission loads are not considered very significant.

However, in the absence of any measurements, the significance of ambient air quality cannot be established. Based on the uneven distribution of the emission sources, relatively shorter stack heights and atmospheric inversion conditions expected during winter nights, the concentration of some pollutants in ground level air may be elevated in certain locations and in PDO camps at sometimes. Therefore, it is necessary that air quality surveys be undertaken at periodic intervals at selected locations to determine whether the air quality in the asset is within the permissible limits. It may be noted that PDO has recently commissioned, in partnership with other major industries in MAF, a continuous air quality monitoring station in MAF.

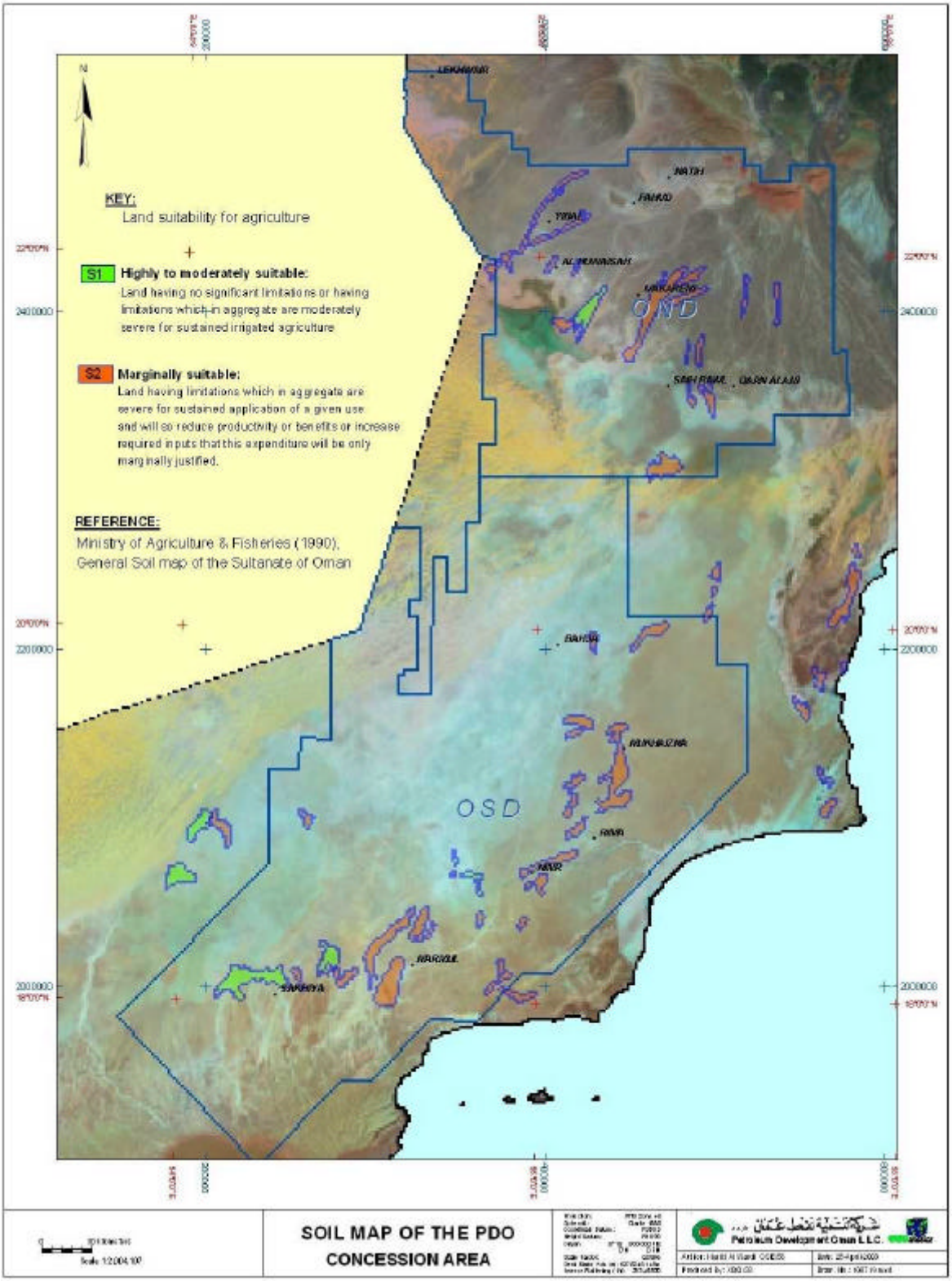

Figure 5.2: Soil Map of PDO's Concession Area

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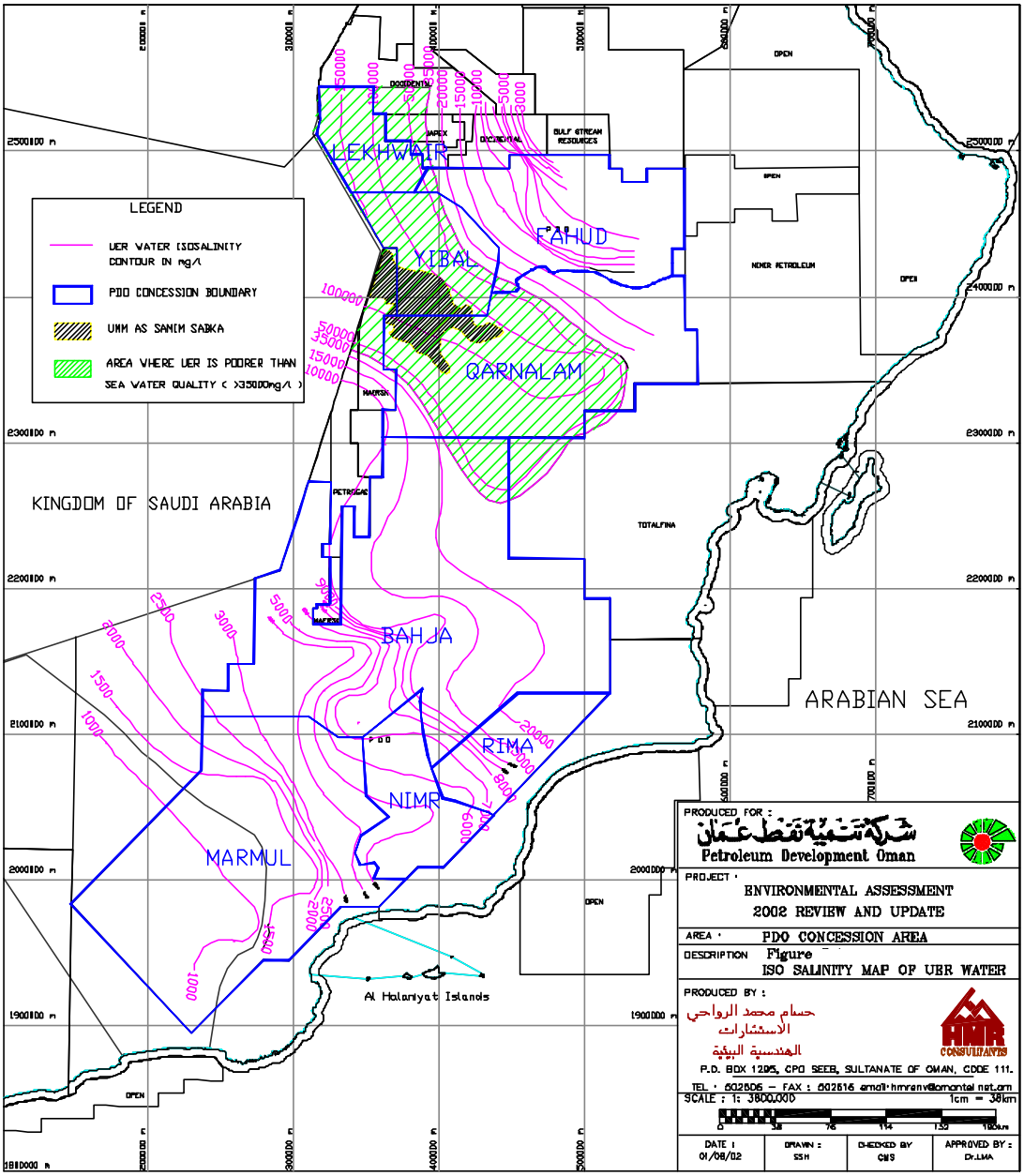

Figure 5.3: Iso-salinity Map of UeR Aquifer in Oman

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5.7 Ambient Noise

No data are available on the ambient noise levels within the asset. It is believed that the ambient noise levels in this region are of no significance due to the fact that there are no human settlements close to any operational facilities. The high noise generating sources in the facilities such as production station, power stations, gathering stations, and RO plant are unlikely to have any impact on the human settlements. However, they may have an impact on the noise levels in the PDO and contractor camps.

Therefore, it is necessary that noise surveys be undertaken at periodic intervals at selected locations to determine whether the noise levels in the accommodation areas are within the permissible limits.

5.8 Terrestrial Ecology

5.8.1 Flora

The natural flora in most of the concession area is composed of desert plants and grasses, and trees are rarely seen. The distribution pattern of vegetation is dependent on the water drainage pattern and the presence of adequate sand or fissures in the bedrock for plant establishment. With rainfall being very scanty and erratic, the fog moisture largely influences the vegetation in this region. The species diversity and density somewhat improves in the highlands in the southern and northern parts of the concession area. Coastal communities are encountered only in MAF.

The flora found in the central and southern plains in the concession area are typical to central Oman. Larger species such as *Prosopis cineraria* are present in low-lying sumps with deeper sand and *Acacia ehrenbergiana* is abundant. This region supports no trees or bushes, but characteristic forbs such as *Fagonia ovalifolia*, and species of *Cornulacea* and *Salsola* cover very large areas. The vegetation cover is relatively denser in the wadis with frequent grass tussocks of *Stipagrostic* sp., *Cymbogon schoenathus* and *Panicum turgidum* and includes scattered *Acacia ehrenbergiana* bushes. The wadis provide more forage for both wild and domesticated grazing animals due to plant height and coverage and the presence of grasses. Low-lying perennial shrubs cover the undeveloped areas within the concession area and serve as pastor grounds for local livestock, mostly camels and goats.

In the highlands, halophytes such as *Zygophyllum* decrease in abundance and the shrub communities become more diverse with additional species such as *Zyziphus spina-christi*, *Euphorbia larica, Fagonia sp ., Dyerophytum indicum, Peroploca*

aphylla, *Calotropis procera*, *Tephrosia* sp. and *Solanum*. Grass species increase in cover. With high spate flows, there is often little vegetation in the main wadi channels.

5.8.2 Fauna

Due to the sparse vegetal cover, fauna are not very abundant and diverse in this region. However several fauna groups including mammals, birds and reptiles are seen. Large mammalian species known to inhabit the area include the Arabian Gazelle (*Gazelle gazelle*), the Rhim Gazelle (*Gazella subgutturosa marica*), the Nubian Ibex (*Capra nubiana*). These animals are currently listed on the IUCN World Red List and the Regional Red List threat categories. The Arabian Oryx is seen in Mukhaizna field in Bahja asset. Mukhaizna field is located just outside the buffer zone of the Arabian Oryx Nature Reserve. Ruepell's Sand Fox and the Cape Hare are also thought to inhabit the some areas and burrow in earthen mounds associated with well development activities. A few smaller mammals, mostly gerbils, jirds and jerboas are also known be present in the vegetated areas.

Bird surveys revealed about 40 different species with a half of them breeding in this region. There are no regional Red Data Lists for birds and their threatened status in Oman is yet to be established. Distribution records for reptiles in the area indicate that 30 species inhabit the area. Both the monitor lizard (*Varanus griseus*) and the spiny tailed lizard (*Uromastyx thomasi*) are common throughout the region. All of the animal species recorded in the concession area are typical of the central plains.

5.8.3 Wildlife Sanctuaries

Two of the important wildlife sanctuaries in Oman namely the Arabian Oryx Nature Reserve and the Jebel Samhan Nature Reserve are in the proximity of PDO concession areas. A small portion of the buffer zone of the Arabian Oryx Nature Reserve falls under Bahja and Nimr assets. The Jebel Samhan Nature Reserve in the Dhofar governorate is to the south of Marmul asset.

- **Arabian Oryx Nature Reserve**

An area of 24785.4 km^2 in Al Wusta Region was proclaimed in 1994 as the Arabian Oryx Nature Reserve and subsequently declared a World Heritage Site by the United Nations Scientific and Cultural Organisation. At the heart of the Reserve is the Jiddah (central plateau), a foggy desert supporting diverse plant and animal communities. The Reserve is sanctuary for many wildlife species including the Arabian Oryx, which was reintroduced to the wild in 1982. The other mammals seen in the Reserve

include Arabian Gazelle (*Gazelle gazelle*), Rhim Gazelle (*Gazella Subgutturosa marica*), Nubian Ibex (*Capra nubiana*), Arabian Wolf (*Canis lupus arabica*), Caracal (*Caracal caracal schmitzi*), Honey Badger (*Mellivora capensis*), Red Fox (*Vulpes vulpes arabica*), Ruepell's Sand Fox (*Vulpes ruepelli*), Cape Hare (*Lepus capensis*) and Ethiopian Hedgehog (*Parachimus aetheopica*).

Among birds, 180 species have been recorded in the Reserve, with majority being migratory and only 26 breeding resident species. The resident species include Golden Eagle (*Aquila chrysaetos*) and Houbara Bustard (*Chlamoyodotis undulata*). Among reptiles, 24 species have been recorded including Monitor Lizard, *Malpolon moilensis, Cerastes cerastes* and *Uromastyx thomasi.* Over 140 species of plants have been recorded in the Reserve, with 12 endemic species. While some are short-living (rain supported), others are long-living (fog supported). Simr (*Acacia tortilis*) is scattered all over the Reserve, while Ghaf (*Prosopis cineraria*) and Salem (*Acacia ehrenbergiana*) grow mostly in shallow sand depressions called haylat.

The Reserve is presently divided into five administrative zones to facilitate management. The special protection zone is the core zone of the reserve that provides a safe haven for the Arabian Oryx and thus ensures their longterm survival in the wild of Oman. The objective is to manage this zone to keep human disturbance and competition from domestic stock to a minimum. The controlled use zone includes areas regularly used by the Oryx and tracts of land containing other important biological resources, wilderness, scenery of exceptional beauty and sites of archaeological interest. The management objective is to allow controlled access but keep development to a minimum. The buffer zone encompasses further sites of interest, but with control of activities in order to help protect the inner zones. The utility zone is demarcated for locating the essential production chemistry facilities of the reserve. The special use zone constitutes the areas of land where a land use agreement has been reached with the government (military authorities) and private parties.

- **Jebel Samhan Nature Reserve**

The Jebel Samhan reserve covering an area of 4500 km^2 contains a wilderness of limestone highlands rising steeply from coastal plain and sloping gently toward north. The deep cayopns with water pools and many plant species provide an ideal habitat for Arabian Leopard, Nubian Ibex, Arabian Gazelle, Striped Hyaenas, Wild Cats, Foxes and Wolves. The reserve has typical monsoon vegetation and is the only Arabian location of African tree Papea capensis. The reserve has a protected core zone where minimal human activity is permitted, surrounded by multiple use zone. PDO currently does not operate in any part of the reserve.

5.8.4 General

The beaches along the coastline are composed primarily of fine sand derived from the neighbouring land with shallow areas extending up to 2 km offshore. The shoreline along the east coast of Oman is known to be mobile with a generally north west drift of sediment along the coastline. Several inlets along the coastline provide important habitats for coastal flora, birds and juvenile fish populations. The Dimaniyat Island Nature Reserve is an archipelago of nine islands approximately 16km off the coastline. These islands provide a protected habitat for a diverse population of birds, marine, and terrestrial fauna.

5.8.5 Seawater Quality

The seawater temperature at MAF ranges from 25°C in winter (February and March) up to 39°C in summer (June and July). The salinity ranges from 35 to 40 parts per thousand. Recent studies did not indicate at gross contamination of the seawater in MAF bay. Earlier studies indicate high levels of phytoplankton chlorophyll in winter/spring dominated by diatom blooms (e.g. *Coscinodiscus*, *Skeletonema*). One characteristic of this region is the occurrence of red tides dominated by dinoflagellates (e.g. *Ceratium*, *Noctiluca*). During late summer and early autumn, nutrient enrichment produces blooms, which means that there is continuously high primary productivity and rich herbivorous zooplankton communities available (e.g. copepods). These in turn support large stocks of sardines, anchovies and larger pelagics.

5.8.6 Sediment Flora and Fauna

The coast has unstable sand substrates, which produce high turbidity leading to poor underwater light penetration. Such turbid conditions limit sea flora populations, such as sea grasses. The direct grazers on sea grasses include the green turtle *Chelonia mydas*, parrot fish and sea urchins. In Oman, there are four species of sea grass, the smaller *Halodule uninervis* and *Halophila ovalis* and the larger *Thalassodendron ciliatum* and *Syringodium isoetifolium* which form limited beds. In shallow water sediments along the coast, the typical infauna found include polychaetes, snails, olive shells, cowries, sand dollars and heart urchins. Very little is known about the deeper subtidal infauna of coastal areas of the Gulf of Oman. A variety of benthic macrofauna including polychaetes, molluscs, echinoderms can be expected to inhabit the deeper coastal zone.

Recent studies in MAF bay showed generally low levels of hydrocarbons and heavy metals in intertidal beach samples, with the exception of vanadium. The subtidal

sediment samples in general indicated no contaminated. The sediment samples taken from single buoy mooring locations were found to contain high levels of copper and tributyl tin, possibly due to the use of antifouling paints.

5.8.7 Fish Communities

The predominant pelagic species include the most important commercial fish in Oman, viz., the kingfish (*Scomberomorus commerson*), tunas and mackerel (*Scombridae*), the scad (*Decapterus russelli, Sardinella longiceps* and *Selar crumenophthalamus*) and others in the 20 to 100 m depth range. Other commercially important demersal species here include croakers (*Sciaenidae*), snappers (*Lutjanidae*), jacks (*Carangidae*), barracudas (*Sphyraenidae*), and emperors (*Lethrinidae*).

5.8.8 Turtles

There are five kinds of marine turtles found off the coasts of Oman; the Green Turtle *Chelonia mydas*, the Hawksbill *Eretmochelys imbricata*, the Olive Ridley *Lepidochelys olivacea*, the Loggerhead *Caretta caretta* and the Leatherback Turtle *Dermochelys coriaca*. The Green Turtle and the Hawksbill are regarded as "endangered". Both endangered species use the Dimaniyat Islands as a nesting ground.

5.8.9 Cetaceans

The toothed cetaceans and the Baleen Cetaceans are both found in the waters of Oman. The toothed cetaceans (suborder Odontoceti) are a more varied group of cetaceans and include the sperm whale *Physeter* spp. and dolphins and porpoises. The species include sperm whale (*Physeter macrocephalus),* dwarf sperm whale (*Kogia simus),* Cuviers beaked whale (*Ziphius caviostris),* false killer whale (*Pseudorca crassidens),* killer whale (*Orcinus orca),* indo-pacific humpback dolphin (*Sousa chinensis),* Risso's dolphin (G*rampus griseus),* bottlenose dolphin (*Tursiops truncatus),* pantropical dolphin (S*tenella attenuata),* spotted dolphin, spinner dolphin (*Stenella longirostris) and* common dolphin (*Delphinus delphis).*

The baleen whales (suborder *Mysticeti*) filter feed on zooplankton using comb-like plates of baleen or "whalebone" with which they sieve their prey from large volumes of water. Oman's baleen cetaceans are all large whales and belong to one family, the Balaenopteridae. They include humpback whale (*Megaptera novaeangliae),* Bryde's whale (*Balaenoptera edeni),* sei whale (*Balaenoptera borealis),* minke whale

(*Balaenoptera acutorostrata),* blue whale (*balaenoptera musculus)* and fin whale (*Balaenoptera physalus).*

5.8.10 Coral Reefs

Most of the coast has unstable, sandy substrates with often high turbidity, making it largely unsuitable for coral growth. The rocky promontory of Ra's Sawadi and the Dimaniyat Islands located offshore are the only areas in the region with good coral development. The Dimaniyat Islands are situated 16 km offshore in clear, oligotrophic water and substantial patch and fringing reefs are found along leeward and protected shores of the nine islands in the chain. Abundant coral growth is found to 20 m depth. There are massive *Porites* colonies, *Acropora* colonies and large stands of *Pocillopora* on rubble substrates. The reefs here provide habitat and feeding ground for many fish. With the importance of these islands to nesting turtles (the hawksbill *Eretmochelys imbricata* and green turtle *Chelonia mydas*) and seabirds, the area was declared as the "Dimaniyat Islands Nature Reserve" in 1996 (RD 23/96).

With specific reference to MAF bay, the recent studies has indicated hard corals around the Fahal Island with about 45% cover. Soft corals are seen in the West Headland and East Headland sites with about 20% cover and with low cover (<5%) in Fahal Island. The common genera seen at all sites were *Sinularia* and *Sarcophyton* with occasional records of species of *Cladiella* and *Dedronephthya*. The overall conclusion from the coral reef survey is that coral communities in MAF have not significantly changed over the past five years.

5.9 Human Settlements

The human population density within PDO's concession area (interior areas) is extremely low and is to the order of 26 persons per 100 km^2. Within the total concession area of 114,000 km^2, the total current population is of the order of 30,000. The majority are the PDO and contractor staff living in the various accommodation camps located in the assets, and they number about 20,000 currently.

As for the civilian populations, the main populated areas are in the Wilayats of Haima (in Bahja asset) and Adam (in Fahud asset). Wilayat of Haima is in the Jiddat Al Harasiis plateau and has an estimated total civilian population of about 2500 persons. Wilayat of Adam has a total population of 8350 persons. In addition to the above, relatively small settlements can be found near to major wadis. These settlements are receiving various benefits from the PDO including water and power.

The Bedouin settlements are found to be mostly in the central and western parts of the PDO's concession area mostly around wadis. Particularly, Fahud, Nimr and Bahja assets are known to have more of Bedouin populations. The central plateau region, known as Jiddat al-Harassis is historically characterised by migratory populations due to the harsh climate and lack of freshwater sources. The principal inhabitants in Jiddat al-Harassis are the Harsoosis tribe. Historically, Harsoosis sustained on migratory pastoralism and adopted a nomadic lifestyle to cope with the harsh water-starved and desolate environmental conditions. Presently however, with year-round water supply provided by PDO and the government, Harsoosis have taken up permanent settlement and are no longer nomadic. A recent socio-economic survey indicates that there are an estimated 3,000 to 3,500 members of the Harsoosis residing within the central plateau.

In contrast, the human populations within MAF terminal area and the surrounding areas are typically urban populations. These areas form a major part of the Muscat Municipal areas. The main populated area near MAF terminal is the PDO's residential camp in Ras Al Hamra, housing about 4000 persons. The other major populated areas are Qurum Heights (about 1 away) and Darsait (about 4 km away).

5.10 Archeological, Cultural and Recreation Resources

There are no forts, ruins or other archeological declared sites in PDO concession area. However, abundant marine fossils are present in Jabal Fahud and Natih areas (Fahud asset). The significant cultural site within PDO's concession area include the old city of Adam in the Wilayat of Adam (Fahud asset), which dates back to pre-Islamic times. Adam is also the birthplace of Imam Ahmad bin Said, the founder of the Al Busaid dynasty. Within the Bahja asset, there are several traditional weavers. There is an ancient cemetery within the Nimr asset on the southeastern end of the Prosopis woodland in Wadi Ghubbarah.

Sand dunes in the western and northern part of the Lekhwair asset qualify as areas of exceptional natural beauty. The landscape is peaceful and this area is used as recreational area during the winter months. Umm as Samim, the largest sabkha of the Arabian Peninsula, and one of the largest in the world is also an area of visual interest in Bahja asset. The Prosopis woodland in Al Ghubbarah and the eroded limestone hills with small caves and rock overhangs in Wadi Rawnab in the Nimr asset are also considered areas of visual interest. The dramatically sculptured shapes of the limestone hills south of Shalim in the Marmul asset are also considered as a major visual amenity. On the coast, the MAF bay and the beaches are of significant recreational value particularly for the PDO staff.

6 ENVIRONMENTAL IMPACTS

6.1 Methodology

In this chapter, the significant environmental hazards and effects present in the asset are identified and assessed based on the methodology outlined in PDO's document GU-195 "Environmental Assessment Guideline" (*Reference 2*). In PDO's terminology, the term "environmental hazard" is used for the sources (causes) of potential environmental effects, and term “effect” is used for the impact.

The environmental effects may include all those that are beneficial or adverse, short or long term (acute or chronic), temporary or permanent, direct or indirect, and local or strategic. The adverse effects may include all those leading to, harm to living resources, damage to human health, hindrance to other activities, impairment of quality for use, reduction of amenities, damage to cultural and heritage resources, and damage to physical structures.

For each identified potential environmental effect, the associated environmental risk is assessed based on its likelihood and significance. The likelihood (frequency) of occurrence of an effect, the significance of its consequence and the potential risk level are evaluated qualitatively as described below:

- Rating of likelihood (frequency) of occurrence of an effect:

  A (very low), B (low), C (medium), D (high), E (very high)

- Rating of significance of its consequence:

  slight, minor, localized, major and massive

- Rating of potential environmental risk level:

  l*ow, medium, high and extreme*

The criteria used for rating the environmental risk are discussed in detail in *Appendix 2.*

6.2 Potential Environmental Hazards and Effects

The potential environmental hazards and effects associated with the various activities performed in the asset are presented in *Appendix 3*. These are presented in the form of matrices. In the following sections, the impacts identified are qualitatively assessed according to the methodology presented in Section 6.1.

6.3 Beneficial Impacts

Several beneficial socio-economic and socio-cultural impacts accrue from PDO's production activities. Production chemistry asset, as a key service provider to the production assets shall be credited with a proportional share of these beneficial impacts. These beneficial impacts outweigh the adverse impacts, which are discussed in the subsequent sections. The major beneficial impacts from the asset are on the economy, employment, local amenities and ecology. These impacts are discussed below. They are however not rated or ranked as per the methodology discussed in Section 6.1 since PDO's rating criteria apply for adverse impacts only. Therefore, only descriptive treatment is given for the magnitude and significance of the beneficial impacts.

- Economy

In Oman, the national economy is significantly dependent on crude oil production, with petroleum sector contributing about 40% to the gross domestic product. More significantly however, nearly 75% of the government revenue is from oil exports. Thus, there is ever-increasing need for more production of crude oil to sustain the current economic (gross domestic product) growth rate of 10.8%. The total crude oil production in Oman is presently about 330 million barrels annually, out of which about 90% exported. PDO accounts for over 90% of the total crude oil produced in Oman. Thus the economic benefits from PDO activities are quite significant.

- Employment

PDO currently employs over 4000 permanent staff and 16000 contractor staff. In addition, a large number of persons, including local populations in the interiors are also provided indirect employment to provide a number of supporting services. In the interior areas, providing service to PDO is the only alternative employment for the local communities, whose main occupation is farming and animal husbandry. Therefore, the beneficial impact on employment is also significant.

- Amenities

PDO provides and shares several amenities developed by PDO all over its concession area with the local population. They include the access roads, power supply, potable water supply, clinical facilities and telecommunication facilities. In addition, the assets provide financial and other material assistance to local schools, local bodies and cultural events.

- Ecology

While some adverse impacts on ecology may be expected from the asset activities, a few direct beneficial impacts on the ecology also exist. The most significant is the greening of the desert by re-using treated sewage effluents. The land within the PDO main camps and the contractor camps is significantly vegetated with trees, shrubs and lawns. In addition, PDO has developed a large farm in Rahab under "Desert Agriculture Project" over an area of over 100 ha. The significant vegetal cover developed in the asset has provided a habitat for the native fauna, most importantly birds and terrestrial invertebrates.

6.4 Impacts on Natural Resources

The production chemistry asset is not a significant consumer of natural resources. The consumption of fossil fuels and water is quite small. The land take for the construction of production chemistry laboratories is also insignificant. Therefore, there are no adverse impacts on natural resources from the activities directly performed by the production chemistry asset.

6.5 Impacts on Air Environment

The potential environmental effects on the air environment and the associated environmental hazards are listed below:

Environmental Hazards
- Release of gaseous emissions from stationary sources (vent air)
- Generation of noise from stationary sources

Potential Environmental Effects
- Air pollution
- Noise pollution

- **Air Pollution**

Air emissions in the production chemistry asset are basically the vent air from the production chemistry laboratories. The vent air may contain chemical fumes and vapours, whenever chemicals and reagents evolving fumes and vapours are handled. Since these operations are not continuous, the concentration level of any toxic gases in the vent air will be highly transient. Therefore, it is reasonable to assume that the overall impact on ambient air quality in the asset will be very low.

However, in the absence any measurements on vent air composition as well as the ambient air quality, the likelihood of degradation of ambient air quality under certain

conditions and at locations close to the laboratory building shall be considered to be low to medium. Based on the above discussion, the overall impact on ambient air quality is rated as below:

Impact Rating	Air Pollution
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Short term
Likelihood of occurrence (very low / low / medium / high / very high)	Medium
Significance of impact (slight / minor / localized / major / massive)	Minor
Potential risk level (low, medium, high and extreme)	Low to medium

- **Noise Pollution**

There are no major noise generating sources in the production chemistry asset and therefore no adverse impacts on noise environment are expected.

6.6 Impacts on Water Environment

With respect to water environment, only groundwater is considered since the production chemistry asset has no interface with the marine environment. The potential environmental effects on the water environment and the associated environmental hazards are listed below:

Environmental Hazards
- Treatment and land discharge of non-oily laboratory effluents from laboratories through the STPs
- Accidental leaks and overflows from oily effluent holding tank in the laboratories
- Accidental leaks and spills of bulk chemicals in the storage yard

Potential Environmental Effects
- Groundwater pollution

The oily effluents generated from the laboratory operations are drained into concrete holding tanks, from where they are periodically transferred to the waste oil pits located in each asset. The potential for leakage and overflow oily effluents from the holding tank into the surrounding soil exists. Non-oily effluents are drained into the sewers for treatment in the sewage treatment plant (STP) located in the asset. These effluents will contain a variety of chemical constituents that may be classified as toxic. If their concentrations are high, they may adversely affect the performance of the STPs. The complex organic molecules cannot be degraded in the STPs, and they may even be toxic to the microbial populations in the aeration tanks.

The potential for significant chemical spills and leaks exists in the bulk chemical storage yard located outside the laboratories for the storage of solvents like acetone, xylene and Shellsol in drums. However, since the storage yards are provided with cement floor and are bunded, any accidental spills or leakages are contained.

Groundwater pollution from the above occurrences is possible only if the accidental leaks and spills are significant large or sustained and the water table is low. However, in the interior areas, the groundwater table is 30-160 m below the ground level and arid weather conditions prevail in the asset. In MAF however, the groundwater table is much shallower due to the proximity of the marine coast. The groundwater is very saline.

Based on the above discussion, the impact on the groundwater quality is assessed as below:

Impact Rating	**Groundwater Pollution**
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Long term
Likelihood of occurrence (very low / low / medium / high / very high)	Low
Significance of impact (slight / minor / localized / major / massive)	Minor
Potential risk level (low, medium, high and extreme)	Low to medium

6.7 Impacts on Land Environment

The potential environmental effects on the land environment and the associated environmental hazards are listed below:

Environmental Hazards
- Treatment and land discharge of non-oily laboratory effluents from laboratories through the STPs
- Accidental leaks and overflows from oily effluent holding tank in the laboratories
- Accidental leaks and spills of bulk chemicals in the storage yard

Potential Environmental Effects
- Land contamination

As discussed in Section 6.6, all the above environmental hazards can lead to soil contamination. Any soil contamination due to accidental leaks and overflows from oily water holding tanks and chemical leaks in storage yards will be highly localised. However, if non-oily effluents contain toxic constituents in high concentrations, it is reasonable to expect the will be present in the treated sewage effluent, which is used for land irrigation over a large area.

Currently, the treated sewage is not tested for the presence of any of the toxic chemicals used in the production chemistry laboratories. In the absence of any data to verify, the likelihood of occurrence for such an effect shall be considered as medium.

Based on the above discussion, the impact on soil quality is assessed as below:

Impact Rating	Land Contamination
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Long term
Likelihood of occurrence (very low / low / medium / high / very high)	Medium
Significance of impact (slight / minor / localized / major / massive)	Localised
Potential risk level (low, medium, high and extreme)	High

6.8 Impact on Ecology and Wildlife

There are no potential hazards in the asset that would have any adverse impact the ecology and wildlife.

6.9 Impact on Social Environment

Under social environment, employment, agriculture, animal husbandry, native lifestyle, cultural heritage, public health and safety, landscape and aesthetics are considered. Except for public health and safety, all the impacts on social environment are beneficial, as discussed in Section 6.2.

The potential for adverse impacts on public health and safety is not considered significant since the quantities of hazardous substances handled in the asset are not large and they are handled indoors under controlled conditions.

7 SUMMARY OF SIGNIFICANT ENVIRONMENTAL EFFECTS AND MITIGATION MEASURES

The identification and assessment of environmental hazards and effects in the asset are discussed in Chapter 6. All adverse environmental effects with medium to extreme risk are considered as significant environmental effects. In this chapter, the additional mitigation measures required for minimizing the environmental consequences from these effects are developed. It may be noted that PDO has a comprehensive environmental management plan as a part of the HSE management system (refer Chapter 2), which is implemented in the asset. No change in the existing environmental management system is required. However, certain additional mitigation measures will reduce the potential environmental risk and improve the overall environmental performance.

The significant environmental effects are listed below along with explanatory notes.

Environmental Effect	Impact Rating	Potential Risk Level	Comments
Land contamination	• Adverse • Long term • Medium occurrence • Localised significance	• High risk	• The discharge of production chemistry laboratory effluents containing chemicals into the STPs may adversely affect the STP performance if toxic substances are present in significant concentrations. • Currently, the laboratory effluents or treated sewage effluents are not tested to check for the presence of toxic substances. • There is a potential for leakage and overflow of non-oily laboratory effluents into the surrounding soil from the holding tanks.
Groundwater pollution	• Adverse • Long term • Low occurrence • Minor significance	• Low to medium risk	• The impact on groundwater is a consequence of land contamination
Air pollution	• Adverse • Short term • Medium occurrence • Minor significance	• Low to medium risk	• Currently, neither the vent air nor the ambient air near the production chemistry laboratories is monitored to check for the presence of any toxic gases and vapours in significant concentrations.

The recommended additional mitigation measures for reducing the environmental risk levels and improving the environmental performance are listed below against each of the environmental specifications of PDO, *viz.*, SP-1005 to SP-1012 and SP-1170.

Specification	Areas of Non-compliance or Concern	Recommended Additional Mitigation Measures
SP-1005: Specification for Emissions to Atmosphere	• Vent air or ambient air is never monitored to check whether toxic gases or vapour are present in significant concentrations.	• Evidence shall be provided through monitoring or theoretical predictions that air dilution rate is sufficient and that toxic gases or vapour are not present in significant concentrations in the vent air.
SP-1006: Specification for Aqueous Effluents	• Non-oily effluents are discharged into the sewers for treatment and disposal along with the sewage generated in the production asset.	• Evidence shall be provided through monitoring or theoretical predictions that toxic substances are not present in significant concentrations in the raw or treated sewage. • A better alternative is to provide dedicated packaged effluent treatment plants based on solar evaporation for non-oily laboratory effluents.
SP-1007: Specification for Accidental Releases to Land and Water	• Accidental leaks and overflows from oily effluent holding tanks in the production chemistry laboratories are likely.	• Carry out periodic integrity checks on the holding tanks.
SP-1008: Specification for Use of Energy, Materials and Resources	• None	• None
SP-1009: Specification for Waste Management	• None	• None
SP-1010: Specification for Environmental Noise and Vibration	• None	• None
SP-1011: Specification for Flora and Fauna	• None	• None
SP-1012: Specification for Land Management	• None	• None
SP-1170: Specification for Management of Naturally Occurring Radioactive	• None	• None

8 REFERENCES

1. WS/Atkins, *Production Chemistry Environmental Assessment Report*, PDO, September 1999

2. PDO, *HEALTH, SAFETY AND ENVIRONMENT GUIDELINE - Environmental Assessment* GU 195, July 2002

3. SIEP, EP 95-0377, *Quantifying Atmospheric Emissions*, September 1995

4. HMR, *EIA of PDO Production Assets - 2002 Update and Review*, PDO, April 2003

APPENDIX 1: DETAILS OF PERSONNEL RESPONSIBLE FOR PREPARATION AND REVIEW OF THE REPORT

HMR Environmental Engineering Consultants, Oman are responsible for the preparation of this report on environmental assessment of Production Chemistry asset area. HMR is the leading environmental engineering consultancy in Oman. HMR specializes in the fields of environmental management, water resources management, environmental assessment, environmental auditing, environmental monitoring, pollution control and environmental training.

HMR has a large pool of environmental engineers and scientists, who have work experience throughout the world and the Arabian Gulf. HMR also has technical collaborations and associations with a number of international engineering consulting companies. HMR is registered with the World Bank as well as with the Ministry of Regional Municipalities and Environment, Sultanate of Oman.

The following HMR Staff are responsible for the technical component of this report.

Name of EIA Team Member	Position in HMR	Position in EIA Team	Role in Project Execution
Dr. Laks M. Akella	Senior Consultant	Team Leader and Project Manager	Project management, data analysis and editorial review
C. S. Shaji	Consultant	EIA Expert	Data collection, site audit and report preparation
Robert Spence	Senior Consultant	EIA Expert	Data collection and site audit
C. M. Sushanth	Consultant	EIA Expert	Data collection and site audit
Babu Krishanan	Consultant	EIA Expert	Data collection and site audit
Krishnasamy	Consultant	EIA Expert	Data collection and site audit
Vinod Gopinath	Environmental Technician	EIA Expert	Data collection and site audit
Shubha Srinivas	IT Consultant	Cartographer	Cartography
Randa Mounir	Consultant	Team Member	Editing

On behalf of the client, Petroleum Development Oman, the following individuals are responsible for the review of the EIA report at all stages of the study.

Position in PDO	Name of Reviewer	Role in Project Development
CSM/22	Dr. Muralee R. Thumarukudy	Senior Corporate Environmental Advisor
CSM/25	Ahmed Al Sabahi	Environmental Advisor
TTKH	Abla Al-Naamani	HSE & Quality Focal point

APPENDIX 2: PDO'S ENVIRONMENTAL RISK EVALUATION CRITERIA

Rating of Consequence of Effect on Environment	**Rating of Frequency of Occurrence**				
	A. Very low: Not heard of but could occur	**B. Low:** Has occurred in other industry	**C. Medium** Has occurred in oil and gas industry	**D. High:** Occurs several times a year in oil and gas industry	**E. Very high:** Occurs several times a year in PDO
Slight effect: Local environmental damage. Within the fence and within systems. Negligible financial consequences	**LOW RISK**				
Minor effect: Contamination. Damage sufficiently large to attack the environment. Single exceedence of statutory or prescribed criterion. Single complaint. No permanent effect on the environment.		**MEDIUM RISK**			
Localized effect: Limited loss of discharges of known toxicity. Repeated exceedence of statutory or prescribed limit. Affecting neighborhood.					
Major effect: Severe environmental damage. The company is required to take extensive measures to restore the contaminated environment to its original state. Extended exceedence of statutory limits		**HIGH RISK**			
Massive effect: Persistent severe environmental damage or severe nuisance or nature conservancy extending over a large area. In terms of commercial or recreational use, a major economic loss for the company. Constant, high exceedence of statutory or prescribed limits				**EXTREME RISK**	

APPENDIX 3: ENVIRONMENTAL HAZARDS AND EFFECTS IDENTIFICATION MATRIX: PRODUCTION CHEMISTRY ASSET

Environmental Hazards	Environmental Sensitivities																				
	Natural Resources			Air Environment			Water Environment			Land Environment			Ecology and Wildlife			Social Environment					
	Mineral Resources	Groundwater Resources	Claim on Local Assets	Climate (Global Warming)	Ambient Air Quality	Ambient Noise	Surface Hydrology & Water Quality	Hydrogeology & Ground Water Quality	Marine Water Quality	Land Use	Loss of Vegetation	Soil Quality	Flora	Fauna	Wildlife Habitats	Employment	Agriculture & Animal Husbandry	Native Lifestyle	Cultural Heritage	Public Health & Safety	Landscape & Aesthetics
Utilization of Groundwater Resources																					
For domestic use		X						X													
Utilization of Human Resources																					
Employment of migrant construction workers																				X	
Employment of permanent workers																					
Release of Air Pollutants																					
Gaseous emissions from vents				X	X																
Gaseous emissions from mobile sources				X	X																
Accidental release of toxic gases and vapours																				X	
Release of Energy into Atmosphere																					

Environmental Hazards	**Environmental Sensitivities**																				
	Natural Resources			**Air Environment**			**Water Environment**			**Land Environment**			**Ecology and Wildlife**			**Social Environment**					
	Mineral Resources	Groundwater Resources	Claim on Local Assets	Climate (Global Warming)	Ambient Air Quality	Ambient Noise	Surface Hydrology & Water Quality	Hydrogeology & Ground Water Quality	Marine Water Quality	Land Use	Loss of Vegetation	Soil Quality	Flora	Fauna	Wildlife Habitats	Employment	Agriculture & Animal Husbandry	Native Lifestyle	Cultural Heritage	Public Health & Safety	Landscape & Aesthetics
High level noise from stationary sources						X															
High level noise from mobile sources						X															
Discharges of Liquid Effluents																					
Untreated effluent discharge							X		X			X									
Accidental spillage of hazardous liquids								X				X									
Disposal of Solid Wastes																					
Handling and transport of hazardous wastes																					
Functional Activities																					
Road transport of hazardous substances														X						X	
Storage of hazardous substances																				X	
Road travel														X							

Note: Filled-in cells indicate potential interaction and blank cells indicate no or negligible interaction.