ENVIRONMENTAL ASSESSMENT OF ESTATE SERVICES ASSET - 2002 REVIEW AND UPDATE

PETROLEUM DEVELOPMENT OMAN

SULTANATE OF OMAN

Authorized for release by:

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EXECUTIVE SUMMARY

Introduction

This report updates the environmental assessment of Estate Services asset, which is one of the eight service assets within PDO's concession area in the Sultanate of Oman. The first environmental assessment for Estate Services 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.

Estate services asset is one of the technical service providers in PDO. Unlike all the other service assets, the estate services asset operates only on the coast in Mina Al Fahal (MAF).

The main function of this asset is to provide estate services and maintenance back-up for all houses, offices, recreational facilities and sundry buildings of PDO located on the coast, covering MAF, Ras Al Hamra (RAH) and adjoining areas in Muscat. The activities of estate services asset also include potable water supply, back-up power supply to critical buildings, wastewater management, waste management, and maintenance of roads, car parks and landscaping of public areas maintained by PDO in MAF and adjoining areas.

It may be noted that almost all services provided by the estate services asset are administered through sub-contracting, and the primary role of PDO staff is limited to contract supervision.

The estate services 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, the asset is managed by the Estate Services Manager. At the sectional level, each section is headed by a Section Head and each team by a Team Leader. The health, safety and environment (HSE) management function in the asset is handled by the Estate Services HSE Advisor.

Description of Environment

MAF is situated on the shore of the Gulf of Oman approximately 8km west of Muscat and 4 km north of Ruwi, the main commercial centres of the region. The MAF complex is situated within a natural bowl, which is formed by the surrounding hills. There are a number of wadis that traverse the MAF area. The western fringe of MAF is characterised by a narrow, uninhabited land area, which rises steeply to a height of 113m above sea level. Beyond this, at 40-60 m elevation are the areas of RAH and Al Qurum with significant residential and commercial development.

The MAF area is situated in the southern part of the Batinah coastal plain, a narrow alluvial plain approximately 200 km long that rises gently from the sea to an altitude of around 150 m inland. Several wadis traverse the plain from the Al Hajar Mountains to the sea. It consists of sandy and gravel beaches, coastal marshes and rocky mountain headlands. The composition of the coastal plain is mainly sedimentary limestone of Mesozoic origin.

Near the coast, the hydrogeology is influenced by seawater. The shallow ground water is highly saline and not potable. Potable groundwater for MAF and RAH areas is sourced from sustainable aquifer in Al Khoud, about 37 km from MAF. Water is extracted from Fars /UeR formations.

The mean monthly temperatures range from around 20^{o}C in (January) to about 35^{o}C in July. The maximum absolute temperature will be as high as 49^{o}C and the minimum absolute temperature will be as low as 10^{o}C. Relative humidity is usually high and will be in 90s during the summer months. The mean total annual rainfall is 86 mm, and most of the rainfall occurs during the period of January-March. Fog is rare and may occur about twice a year.

The mean wind speeds range between 3 and 7 knots, with high wind speeds encountered during the summer months. The dominant wind direction is northeast during June-September and southwest during November-January.

MAF is highly urbanised, and consequently any natural vegetation might have been destroyed. Nonetheless, small pockets of natural vegetation remain on the rocky coastal hills. This vegetation is similar to that of the foothills of the northern mountains and can be classified as an open xenomorphic Euphorbia community type.

Several fauna groups including mammals, birds and reptiles are seen. Mammals in MAF and RAH areas and are low in diversity, largely due to the lack of suitable habitat.

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 human populations within MAF terminal area and the surrounding areas are typically urban population. The main populated area near MAF terminal is the PDO's residential camp in RAH, housing about 4000 persons. The other major populated areas are Qurum Heights (about 1 away) and Darsait (about 4 km away).

There are no features of archaeology and cultural heritage within PDO's assets area in MAF. The MAF and adjoining Qurum beaches are used by local population and tourists for recreation. There is however several ancient forts, museums, places of worship and recreational areas located in the capital area

MAF industrial area is established exclusively for petroleum industries. In addition to the accommodation, administrative and auxiliary facilities serviced by the estate services, several industrial facilities are also located here. They include PDO offshore facilities, a petroleum refinery and several bulk storage facilities for refined petroleum products.

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	• Transboundary emissions from vehicular traffic on Qurum Heights highway, stack emissions from ORC and fugitive emissions from SMOC, BPO and offshore facilities have significant affect on the areas serviced by estate services and the surrounding residential areas.	• Track the air emission inventories and air quality in the airshed
SP-1006: Specification for Aqueous Effluents	• Treated effluent from MAF-STP showed repeated non-compliance with respect to ammoniacal nitrogen and free chlorine. • STP monitoring is not comprehensive and some critical parameters such as heavy metals, phenols, sodium absorption ratios etc. are not monitored. • STP monitoring frequency is not adequate. Weekly monitoring cannot detect if standards are breached during peak load times. • The application of Standard A-2 for treated sewage quality is questionable since the irrigated areas are accessible to public. Application Standard A-1 will lead to repeated non-compliance.	• STP performance and operating practices shall be reviewed. • Critical parameters such as heavy metals, phenols, sodium absorption ratios etc. shall be monitored at least on quarterly basis. • Monitoring frequency may be increased to four times per day for on-site measurements and composite samples may be taken for laboratory analysis • The issue relating to the application of Standard A-2 needs to be resolved, in consultation with MRME&WR.
SP-1007: Specification for Accidental Releases to Land and Water	• None	• None
SP-1008: Specification for Use of Energy, Materials and Resources	• Per-capita domestic water consumption in RAH remains quite high. • Total water consumption in MAF and RAH shows steady increase over the years.	• Water conservation shall be promoted in the PDO accommodation facilities.
SP-1009: Specification for Waste Management	• None	• None
SP-1010: Specification for Environmental Noise and Vibration	• Residents near RAH-STP may experience high noise levels if the pumps and motors used in the STP are not properly maintained.	• Through periodic noise monitoring, compliance with source and ambient noise standards shall be ensured.
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 Material	• 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)
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
RAH	Ras Al Hamra
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)
SOGL	south Oman gas line
STOIIP	stock tank of oil initially in place
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**

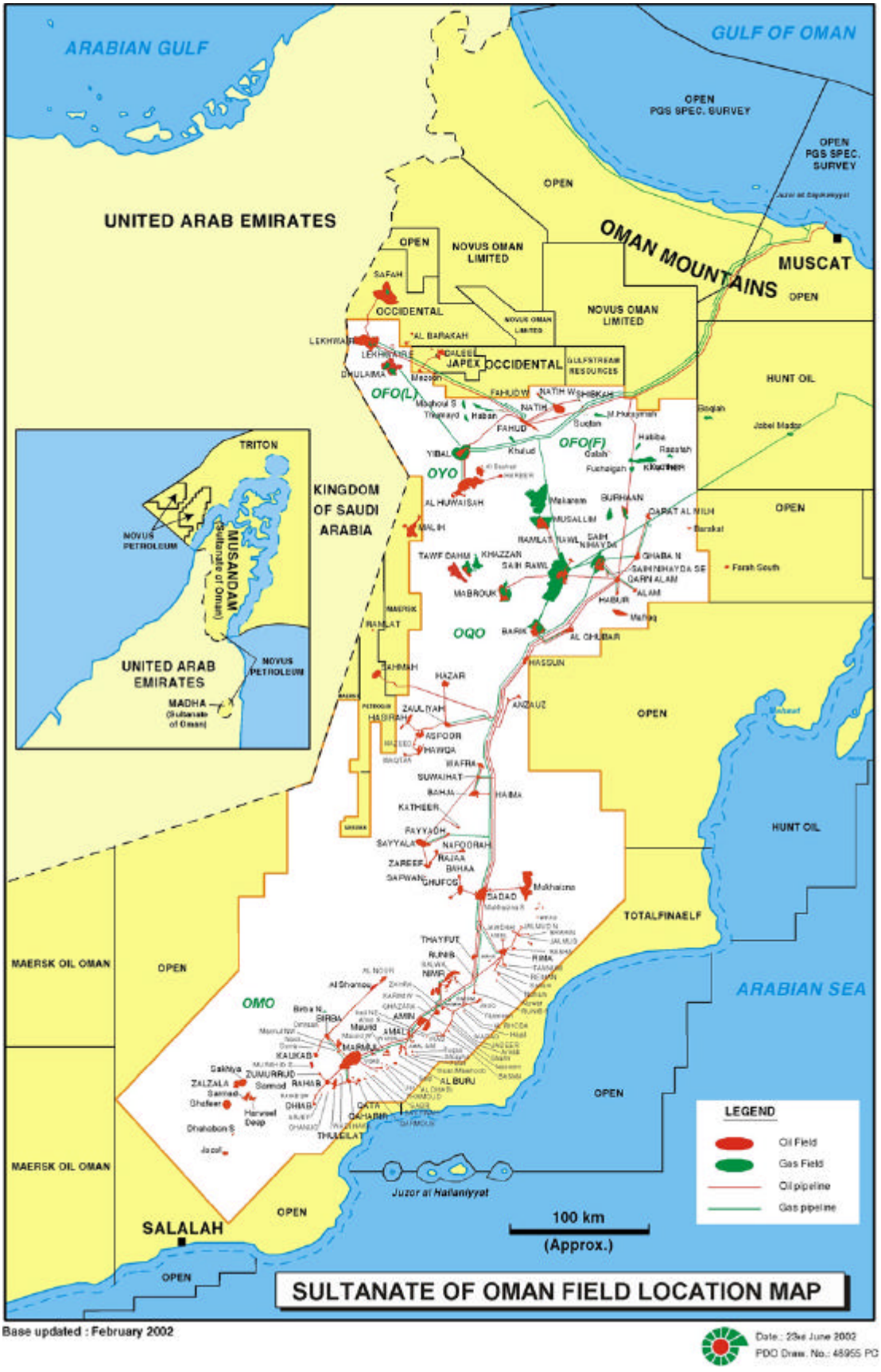


Figure 1.1: Geographical Map of PDO's Concession Area

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
GeoSolutions Asset	- Provide geo-services to frontier exploration and production assets for the identification and development of hydrocarbon reserves within PDO's concession area - The areas of technical service include seismic data acquisition & processing; geological support & laboratory services; geomatics support; sub-surface information management & technology support; services; and reservoir characterisation.
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
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 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

Logistics Asset	Provide dedicated logistics support to all other assets in PDO through sub-contracting for the following services: - Cargo handling and haulage including rig moves - Passenger commuting by land and air - Fleet management - Warehousing including central chemical storage
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 Estate Services 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 Estate Services asset.

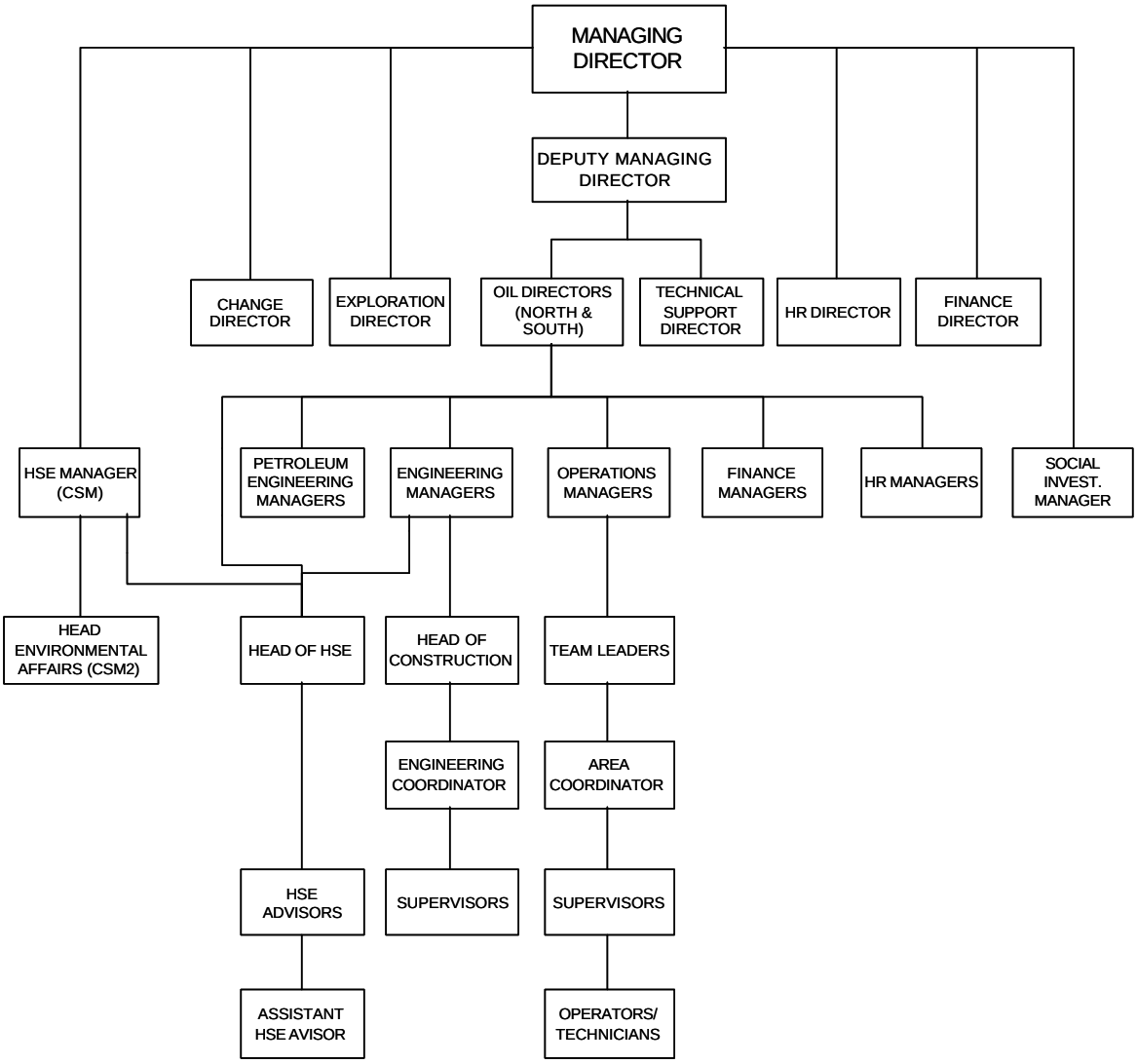


Figure 1.2: Organisation Structure in PDO

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 Estate Services 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 Estate Services 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 Estate Services 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.

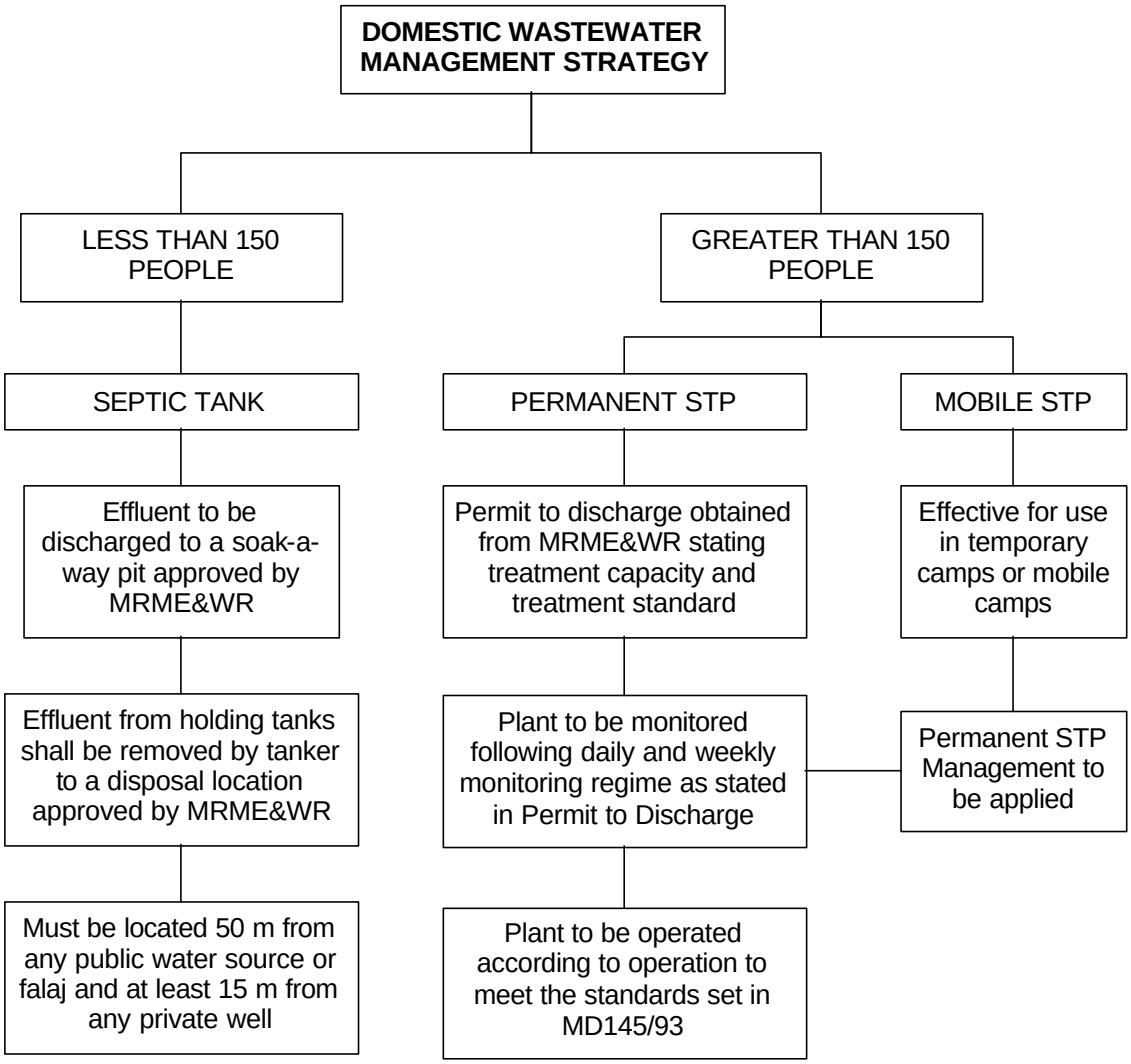
(e) Dispose surplus waters to formations, which have salinity greater than 35,000 mg/L, in conjunction with case-specific monitoring programs.

- **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

Estate services asset is one of the eight technical service providers in PDO. Unlike all the other service assets, the estate services asset operates only on the coast in Mina Al Fahal (MAF). The main function of this asset is to provide estate services and maintenance back-up for all houses, offices, recreational facilities and sundry buildings of PDO located on the coast, covering MAF, Ras Al Hamra (RAH) and adjoining areas in Muscat. The activities of estate services asset also include potable water supply, back-up power supply to critical buildings, wastewater management, waste management, and maintenance of roads, car parks and landscaping of public areas maintained by PDO in MAF and adjoining areas.

The operational and administrative activities of the estate services asset are divided into six sections as below:

- Utilities and Maintenance Services
- Estate Support Services,
- Planning
- Contract Services
- Quantity Surveying
- Traffic Wardening

The first two sections are primarily responsible for all the operational activities of the estate services asset.

The utilities and maintenance section is sub-divided into four teams as below:

- Water and Mechanical Maintenance Team,
- Electrical Maintenance Team,
- Civil Maintenance Team
- Air-Conditioning and Refrigeration Maintenance Team

The estate support services section is sub-divided into three teams as below:

- Housing Team
- Administration Team
- Staff Camp Supervision Team

It may be noted that almost all services provided by the estate services asset are administered through sub-contracting, and the primary role of PDO staff is limited to contract supervision.

The estate services 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, the asset is managed by the Estate Services Manager. At the sectional level, each section is headed by a Section Head and each team by a Team Leader. The health, safety and environment (HSE) management function in the asset is handled by the Estate Services HSE Advisor. The asset management structure including the HSE structure is shown in Figure 3.1.

3.2 Description of Facilities

3.2.1 MAF Industrial Area

MAF industrial area is established exclusively for petroleum industries. In addition to the accommodation, administrative and auxiliary facilities serviced by the estate services, the following facilities are also located within the MAF area:

- PDO's offshore facilities
- A petroleum refinery
- Bulk storage facilities of refined petroleum products

A detailed description of the facilities serviced by estate services along with a brief description of the other industrial facilities within the MAF area is presented in the following sections.

3.2.2 Facilities Serviced by Estate Services

The properties and facilities within MAF and adjoining areas that are served by the estate services asset include the following:

- Residential buildings
- Administrative buildings
- Training building
- RAH recreational centre
- PDO school
- Waste management centre
- Sewage treatment plants

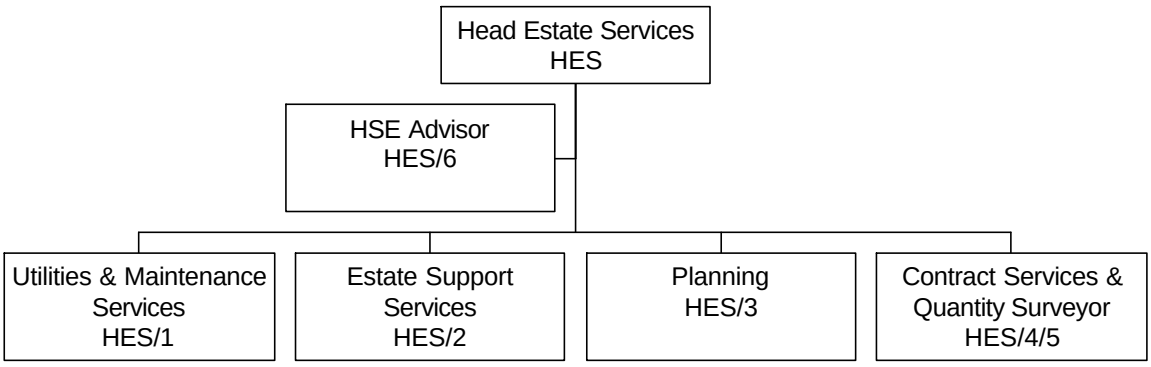


Figure 3.1: Management Structure for Estate Services Asset

- Residential Buildings

The residential buildings served by the estate services asset include the housing units owned by PDO, housing units rented by PDO staff and the staff camp in MAF. Currently, PDO owns 447 villas (houses) for family accommodation and 178 flats for bachelor accommodation, which are located in the RAH area within PDO property boundaries. The housing units rented by PDO include 153 rented villas (for family accommodation) and 21 flats (for bachelor accommodation), which are located outside PDO property boundaries and within a 10 km radius of the PDO industrial area. The staff camp in MAF consists of 324 single rooms.

- Administrative Buildings

These include offices, stores, warehouses, workshops, exhibition centre, clinic etc. and cover a total area of 69100m^2.

- Training Building

This includes the main training centre and training workshop covering a total area of approximately 3300m^2. In the training centre a working model of Hibah gathering station is kept as a simulator.

- RAH Recreation Centre

This includes restaurants, cinema hall, gymnasium, game rooms, boat club, golf club, squash and tennis courts, swimming pools and other miscellaneous facilities.

- PDO School

PDO has established a primary school in MAF exclusively for its own staff. The school is located in MAF near the recreation center. The facilities in the school include the main school building including nursery building, playground and a gymnasium hall.

Other Industrial Facilities in MAF

The other industrial facilities within the MAF industrial area include PDO's offshore facilities, a petroleum refinery and two bulk storage depots of refined petroleum products. These facilities are not serviced by estate services. However estate services supply potable water to these facilities.

PDO has offshore facilities in MAF to export the crude produced in Oman, including PDO and other producers like Petrogas, Japex and Occidental Oman. PDO's offshore oil loading and unloading facilities include three single buoy moorings (SBMs) and two coastal buoy moorings (CBMs). There are also three tugs boats and a maintenance barge. The offshore facilities in MAF are operated and maintained by PDO's infrastructure asset. These offshore facilities cater to the needs of the other MAF industries also.

The petroleum refinery is operated by Oman Refinery Company LLC (ORC). The refinery is designed for a maximum crude processing capacity of 85,000 barrels per day. The products include liquefied petroleum gas, petrol, diesel, fuel oils, and residues. The refinery consists of a crude distillation unit, a naphtha hydrotreater, platformer, a Merox unit and associated utilities. Currently, there is a proposal to install a diesel hydrodesulphurisation unit to reduce sulphur content in diesel oil to 50 ppm. ORC utilises PDO offshore facilities for the export or imports of any products by sea.

The bulk storage depots of Shell Oman Marketing Company SAOG (SMOC) and BP Oman SAOG (BPO) are also located within the MAF industrial area. These companies market the refined petroleum products of ORC (plus any imports) within Oman. The facilities include over-ground storage tanks and loading / unloading facilities. The offshore unloading facilities are maintained by PDO's infrastructure asset.

3.3 Description of Activities

3.3.1 Overview

Almost all the services provided by the estate services asset are executed through contracting. Based on PDO's specifications, approved contractors execute the work under the supervision of the estate services staff. The contractors are responsible for the procurement of all necessary raw materials and equipment as well as the disposal of waste materials according to PDO's HSE specifications. The quality of the service provided by the contractors is controlled and assured by the estate services staff through close supervision and periodic inspection and auditing.

The operational activities related to the services provided by the estate services asset (directly or through contracting) may be classified as below:

- Building maintenance
- Air-conditioning maintenance
- Electrical power supply
- Potable water supply
- Catering and laundering
- Recreational facilities maintenance
- Sewage treatment and disposal
- Solid waste collection and disposal
- Roads and parks maintenance
- Miscellaneous services

These activities are discussed in the following sections.

3.3.2 Building Maintenance

On behalf of the estate services asset, approved contractors provide all the building maintenance services, which include the following:

- General building inspection and repair
- Furniture inspection and repair
- Painting
- Pest control
- Thermal insulation inspection and replacement

Building repairs are limited to minor civil works such as plastering, plumbing, re-flooring etc. Furniture repairs comprise of minor restoration works off-site. Painting involves white washing and the application of synthetic paints on walls, roofs, roads etc. Pest control includes the spraying and injection of pesticides and insecticides. Thermal insulation involves the covering of air conditioning ducts and ceilings with glass fibre mats.

3.3.3 Air-conditioning Maintenance

Estate services asset is responsible for providing the maintenance requirements for all air conditioning and refrigeration units throughout PDO's coastal operation. All the buildings (domestic, commercial and industrial) maintained by the estate services asset are air-conditioned. Several types of air conditioning units are used. Table 3.1 provides a brief summary of the different types of air conditioning units used.

Table 3.1: Inventory of Air Conditioning Units Used

Type of System	Areas	Tonnage	Refrigerants Used
Chilled water units	Large buildings	80 – 310	R-134A, R-407C and R-411B
Central spilt ducted system	All	5 – 15	R-411B
Package unit	Mainly industrial area	5 – 15	R-411B
Room split unit	All	1 – 2.5	R-411B
Window mounted units	All	1 – 2	R-22

Notes:
1. *R-134A and R-407C are hydro-fluoro-carbon based refrigerants with zero ozone depletion potential.*
2. *R-411B is a hydro-chloro-fluoro-carbon blend refrigerant with 0.05 ozone depletion potential, but more energy efficient than R-22.*
3. *R-22 is also a hydro-chloro-fluoro-carbon blend refrigerant with 0.045 ozone depletion potential, but less energy efficient than R-411B.*
4. *In comparison, R-12, a chloro-fluoro-carbon based refrigerant has 4.0 ozone depletion potential.*

Consequent to PDO's corporate policy of phasing out of ozone depleting substances (ODS), the chloro-fluoro-carbon (CFC) based refrigerants have been progressively replaced by ozone friendly refrigerants such as hydro-chloro-fluoro-carbon (HCFC) and hydro-fluoro-carbon (HFC).

Estate Services are responsible for the provision and maintenance of refrigeration units used throughout the MAF and RAH areas. This includes both large refrigeration units used for the restaurant kitchens and smaller units used in residential dwellings. Once air conditioning and refrigeration units become redundant, Estate Services transfer the units to PDO's internal supply department who auction the working units to external businesses. In this respect Estate Services are not responsible for the final disposal of these units and the corresponding ozone depleting gases. If, for maintenance purposes, a particular unit requires degassing, recycle/recovery kits, equipment, apparatus are used which transfer the refrigerant gases to a waste cylinder.

3.3.4 Electrical Power Supply

The electrical power for PDO is supplied by the Ministry of Housing, Electricity and Water's (MHEW) from the Al Falaj Power Station. The power is supplied to the main intake sub-station in MAF at 33 kV, and stepped down to 11 kV. From there, the power is distributed throughout PDO's MAF operations, RAH residential areas and several third party operations (including BP, Shell, ORC and other small commercial operatives) via secondary transformers, where the voltage further stepped down to 415 V for utilities and 220 V for residential use.

Estate Services are responsible for managing the maintenance of all electrical distribution equipment including cabling, transformers, switchgear etc. Of particular concern with respect to the environment is the use of transformer oils that contain

polychlorinated biphenyls (PCBs). The PCBs impart good insulating properties, and thermal and fire resistance to the transformer oils. Since PCBs are known to be toxic, PDO limits their concentration in the transformer oils to a maximum of 50 ppm. These oils are periodically checked for their dielectric strength, and replaced if necessary. Transformers rarely require the replacement of any oils during their lifetime. However, switchgear oils may be replaced once every 3-5 years. The waste oils from switchgear are sent to PDO's oil saver pit for disposal.

In order to ensure uninterrupted power supply in critical areas, emergency diesel generators (DG) are provided. These areas include the computer building, the clinic, the main office and the terminal building. Estate Services are responsible for the maintenance and periodic testing to ensure that the generators are in working order when needed. The emergency DGs maintained by estate services asset include two DGs of 1021 kVA each, one DG of 135 kVA and three DGs of 5 kVA each.

The two main generators (1021 kVA rating) are housed in a small building near the computer building. In order to maintain adequate reserves of fuel at the site, diesel fuel is stored in two aboveground mild steel tanks each of 2270 L capacity. These storage tanks are placed near the generator building. The combustion gases generated from the diesel engines are released into the atmosphere through individual stacks approximately 2.5m in height.

3.3.5 Potable Water Supply

To supply potable water to MAF and RAH areas, ground water is extracted from three bore-wells located in the Al Khoud area. Each well extends to a depth of about 300 m below the ground level and water is extracted from the Fars / UeR formations. Two electric submersible pumps transport the water to the surface at a maximum rate of 48 m^3/h (235m head). Water is transported to a booster station in MAF via a 10" diameter high density polyethylene pipe (the old poly vinylchloride pipe has been recently replaced) at an average flow rate of 2,300m^3/d and at a maximum operating pressure of 10 bar(g). The total length of the pipeline is approximately 37 km. About 90% of the water pumped to MAF is utilised by PDO in the areas serviced by estate services, with the rest supplied to third party customers including the other MAF area industries.

From the MAF booster station, water is disinfected with sodium hypochlorite solution using an on-line doser and then pumped to a large overhead storage tank of 4600 m^3 capacity. From this tank, water is distributed to two overhead supply tanks of 450 m^3 and 1000 m^3 capacity.

During 2002, the quantity of potable water is supplied daily to PDO for consumption in the areas serviced by estate services varied from a minimum 1921 m^3/d (January) to a maximum of 2414 m^3/d (June), with an average of about 2200 m^3/d. Generally, water consumption is the lowest in the late winter months (December-February) and the highest in the late summer months (May-August). Out of this, approximately 70% of this water is used for drinking and sanitation, and the balance is used for watering the lawns and gardens in the residential areas. This quantity is used to supplement approximately 1000 m^3/day treated sewage effluent, which is re-used for watering the gardens and lawns in public areas.

The water consumption in the areas (MAF and RAH) serviced by estate services increased by about 18% over the past five years (1997-2002) as illustrated below in Table 3.2. Significantly, the current year (2002) has shown an increase of 6.6% over last year.

Table 3.2: Water Consumption in MAF and RAH Areas Serviced by Estate Services

Year	Average Water Consumption (m^3/d)		
	Lowest	Highest	Average
1997	1546 (February)	2050 (October)	1864
1998	1255 (December)	2512 (July)	1981
1999	1441 (January)	2615 (August)	2027
2000	1412 (December)	2144 (June)	1922
2001	1851 (December)	2330 (May)	2064
2002	1921 (January)	2414 (June)	2200

3.3.6 Catering and Laundering Services

Within the MAF and RAH areas, there are two restaurants and a cafeteria, each with a separate kitchen. They serve approximately 600-700 persons per day and are operated and maintained by contractors under the supervision of the estate services staff. These kitchens use liquefied petroleum gas (LPG) or electricity for cooking. The wastewater generated from the kitchens and the dining areas is released into PDO's sewer system. The wet solid wastes are sent to the Muscat municipal landfill.

PDO provides laundering facilities to the asset residents through two authorised laundries located outside the asset boundary. All laundering and catering services are provided by approved contractors. The contractors are fully responsible for the treatment and disposal of any wastes generated from these off-site facilities.

3.3.7 Recreational Facilities Maintenance

Estate Services maintain three swimming pools within the MAF and RAH areas. The major maintenance work involves water purification and disinfection. Disinfection is performed with on-line chlorinators using a hypochlorite solution. Earlier, chlorine gas was used for chlorination. This practice was discontinued since two years considering the potential risks on public health and safety from the storage of liquefied chlorine in cylinders on site.

3.3.8 Sewage Treatment and Disposal

The sewage generated in the PDO's areas in MAF and RAH is treated in two sewage treatment plants (STPs) operated and maintained by contractors under the supervision of estate services staff. The raw sewage generated from all the buildings and houses located within RAH and MAF areas flow through a network of underground sewer pipes. Eighteen lifting stations placed at strategic locations to transport the raw sewage to the main STP holding tanks sustain the flow of sewage. The sewage collected in the sumps is continuously pumped into the STPs, one located near the industrial area (MAF area) and another near the residential area (RAH area).

The influent into MAF area STP consists of wastewater generated from all toilets and washrooms in the office buildings and the wastewater generated from the MAF camp kitchen. Additionally, a car wash area located at the waste management compound discharges excess wastewater to the sewer system via a grease trap. This STP has a design hydraulic capacity of 540 m^3/d. The influent into RAH area STP consists of wastewater generated from all the households, two restaurants located in the RAH Recreation Centre. This STP has a design hydraulic capacity of 564 m^3/d. Both the STPs are similar in configuration and are based on the activated sludge system.

The detailed description of the STPs including the design and operation is presented in Chapter 4.

The treated sewage effluent (TSE) is stored in holding tanks to be used for irrigation of public areas within MAF and RAH. A deodorising chemical (Epoleon-N7) is added in the holding tanks to eliminate any odour problem and Epoleon-N100 is added where necessary to manage any ammonia build up. From the holding tanks, the TSE is distributed through a pipeline network for the irrigation of public areas within MAF and RAH areas.

3.3.9 Solid Waste Collection and Disposal

Contractors working under the supervision of the estate services staff are responsible for collection, segregation, disposal and recycling of solid wastes generated in MAF and RAH areas. Four types of wastes, *viz.*, domestic wastes, office wastes, clinical waste and STP sludge are generated. The wet domestic wastes are sent directly to the municipal landfill site for disposal. The dry domestic waste along with the office waste is sent to PDO's waste processing plant for further segregation, recycling and disposal. The STP sludge is dried in sludge drying beds and disposed on land as a soil conditioner.

Clinical wastes generated in the MAF medical clinic as well as PDO clinics in the interior assets are thermally destroyed in an incinerator located in the waste management centre in PDO. No human anatomical wastes are generated since surgical procedures are not performed in the clinics. Clinical waste is received at the waste processing plant in puncture proof cardboard boxes. These boxes are directly loaded into the incinerator. The incinerator is operated approximately once a month to destroy the stockpile of clinical waste generated from PDO's coastal and interior clinics.

The detailed description of waste management including the design and operation of the waste management centre and the incinerator is presented in Chapter 4.

3.3.10 Roads and Parks Maintenance

Within the MAF and RAH areas, there are 26 km long roads in the residential areas, 11 km long roads in the industrial area and 11,400 m^2 of car park area. In addition, there are lawns and gardens covering a total area of about 10,000 m^2 within the MAF and RAH areas. The estate services staff are responsible for the maintenance of roads, car parks and landscaping in these areas through contractors. The routine maintenance activities consist of sweeping the roads and minor asphalt repairs. The resurfacing of the roads and painting the car parks is done where required. All the necessary equipment and materials are brought in by the relevant contractor and any wastes generated are managed and disposed of by the contractor according to PDO's specifications.

For the maintenance of lawns and gardens, PDO uses only treated sewage, which fully meets the MRME&WR discharge standards for land irrigation (Standard A-2). To ensure good growth, small quantities of fertilisers are used. The use of pesticides is rare. Further, the lawns are regularly mowed and the trees and bushes are trimmed.

The green waste generated is disposed along with the domestic garbage in the municipal landfill.

3.3.11 Miscellaneous Services

The services provided by estate services also include the maintenance of the training centre, where a model of the Hibah gathering station is kept as a simulator. This is an electrically operated and self-contained unit. This unit undergoes regular, preventative maintenance as per the requirements of the training department. Estate services are also responsible for the providing the necessary building maintenance services for the PDO school.

Estate services also provide and maintain the fire fighting system in MAF and RAH areas. Portable fire extinguishers are accessible at all areas with potential fire hazards. The extinguishers are of several types including pressurised water, dry foam, and carbon dioxide. Consequent to PDO's policy of phasing out ozone depleting substances, estate services have replaced all of the halon-containing substances commonly used in hand-held fire extinguishing apparatus. A service contractor handles the general servicing and maintenance of portable fire extinguishers in the areas managed by estate services.

The Estate Services also look after traffic wardening in the MAF area. PDO does not own any fleet for the transport of materials and men in and out of its coastal asset areas. All the necessary fleet are supplied and maintained by the various contractors.

3.4 Materials and Utilities

The estate services asset is not a direct consumer of materials and utilities, since the contractors perform almost all of its operational activities.

4 RELEASES TO ENVIRONMENT

4.1 Introduction

In this section, the various waste products released into the environment as a result of the operational activities of the estate services asset are discussed. As discussed in Chapter 3, the estate services staff do not directly perform any operational activities. Instead, approved contractors perform these activities under the supervision of estate services staff.

The major activities of the asset include building maintenance; air-conditioning maintenance; electrical power supply; potable water supply; catering and laundering; recreational facilities maintenance; sewage treatment and disposal; solid waste collection and disposal; roads and parks maintenance; and other miscellaneous services. 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 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

4.2.1 Sources of Generation

Air emissions sources may be classified as point sources, area sources and mobile sources. The point sources include the stacks and vents. The area sources include the open tanks and open pits for storage of materials with volatile components. The mobile sources include the passenger cars, transport vehicles and engines used for construction equipment.

In the areas serviced by estate services, there are no continuous point sources of air emissions. The only stacks are those attached to the DGs and the incinerator. The

DGs are operated very infrequently and only during grid failures. The incinerator for clinical waste is operated for a total of 6 hours monthly (on an average of once a week for few hours). The only areas provided with vents are the kitchens attached to the restaurants. From these vents, air laden with odours generated from the kitchens is released into the outside atmosphere.

With respect to the area sources of air emissions, the only significant sources are the STPs, which may release odours into the atmosphere, if adequate aerobic conditions are not maintained. Since such conditions rarely exist, air emissions from area sources are considered insignificant.

With respect to the mobile air emission sources, construction equipment are not significant sources of air emissions since no major construction activities are carried by estate services asset. However, if any renovations or temporary construction takes place in the asset area, the air emissions should be considered.

The emissions from the passenger and transportation vehicles may be considered significant within the areas serviced by the estate services. Even though not many vehicles are used by the estate services staff or the contractor staff, a large number of vehicles enter and leave the MAF industrial area to visit the several departments of PDO. However, the roads within the areas serviced by estate services are not accessible to general public.

4.2.2 Emissions from Incinerator

Emissions from the incinerator stack, though intermittent are somewhat significant due to the potential for the release of extremely toxic gases from thermal degradation of clinical wastes, which include waste cotton, soiled bandages and used disposal syringes and needles. The quantity of clinical waste is however quite small (200 kg/month) and the incinerator is operated only once a month for about 6 hours. The high temperature incinerator is fuelled by kerosene and ignited electronically. It has a design capacity of about 200 kg load. It consists of a primary chamber, which is heated to 425^{o}C and a secondary chamber, which heated to 925^{o}C. A strong air blower is provided to circulate the gases between the primary and secondary chambers. The incineration process is initiated by igniting the secondary chamber burner and allowing it to reach its operational temperature. The air blower and primary chamber automatically begin operating 1 hour later and the waste is continually incinerated for 3 hours. The secondary burner remains active for one more hour to complete the incineration cycle. The incinerator is allowed to cool and once

the temperature of the incinerators reaches 60^{o}C, the primary chamber is opened and the remaining ash is removed.

The combustion gases are released into the atmosphere through a stack, with a release height of about 10 m above the ground level. Due to the presence of plastics and other synthetic materials in the waste, thermal degradation may generate toxic gases such as carbon monoxide, hydrogen chloride, hydrogen fluoride, dioxins and furans. The concentrations of these gases in the stack emissions are not known, since the stack gases are not monitored. Nevertheless, scrubbers are not considered necessary and hence not provided.

4.3 Liquid Effluents

4.3.1 Sources of Generation

The liquid effluent streams generated in the areas serviced by estate services asset may be classified as continuous, intermittent and accidental. The continuous effluents consist of the sewage generated due to domestic use of water in the residential units, restaurants and the administrative buildings in the RAH and MAF areas. The intermittent effluents are mainly the wastewaters generated from carwash and workshops located within the MAF area. With respect to accidental (including oils, chemicals, water and wastewater), these may result due to leaks and spills of liquids due to pipeline failure, storage tank failure and road accidents. The leaks and spills usually get absorbed in the soils, resulting in soil contamination. Accidental leaks and spills are considered separately in section 4.6.

The continuous and intermittent effluents are treated together in two STPs, one located in RAH and another located in MAF.

4.3.2 Wastewater Treatment

The wastewater generated from all the buildings and houses located within RAH and MAF flow through a network of underground sewers. Eighteen lifting stations placed at strategic locations to transport the raw sewage to the main STP. The sewage collected in the sumps is continuously pumped to the STPs, one located in RAH area (RAH-STP) with a design hydraulic capacity of 564 m^3/d (after capacity enhancement) and another located in MAF area (MAF-STP) with a design hydraulic capacity of 540 m^3/d (after capacity enhancement).

The influent into MAF-STP consists of wastewater generated from all toilets and washrooms in the office buildings and the wastewater generated from the MAF camp kitchen. Additionally, a car wash area located at the waste management compound discharges excess wastewater to the sewer system via a grease trap. The influent into RAH-STP consists of wastewater generated from all the households, two restaurants located in the RAH recreation centre and PDO school.

Both the STPs are similar in configuration and are based on the activated sludge system. Each STP consists of the following seven unit processes.

- Screening and Maceration

The raw sewage collecting into the underground sewage sumps passes through bar screens to remove large floating matter, then pumped into the STP by a screw lift pump via a macerator. The macerator comminutes all coarse solids present in the sewage into fine suspended matter. From the macerator, the homogenised sewage is dosed with a multi-nutrient chemical (Biologic-SR2) at an approximate concentration of 1 ppm.

- Aeration

There are three parallel aeration channels, each of 24m-length and 3m-water depth. The middle channel is of 3m width, while the right and left channels are of 2m width. The sewage flow is split evenly among the channels such that the hydraulic retention time in each channel is approximately 24 hours. Brush aerators located at the inlet of the aeration channels provide the oxygen required. These aerators are designed to operate continuously, providing a dissolved oxygen level in the range of 1.5 to 3.25ppm. The sewage in the aeration channels is internally re-circulated to ensure good mixing and to eliminate the settling of solids in the aeration channels. Due to the biochemical oxidation of the sewage by the aerobic bacteria present, the biological oxygen demand (BOD) is reduced and simultaneously, the biomass is increased.

- Clarification

The effluent from the aeration channels then flows into a sludge-blanket clarifier, where the excess biomass is settled as sludge. The sludge blanket formed acts as a physical filter for smaller particles, thus improving the efficiency of the clarification process. The clarifier has a design hydraulic retention time of 4 hours. To maintain a healthy biomass concentration (mixed liquor suspended solid concentration of 3500-4000 mg/L), 10-20% of the settled sludge is returned to the aeration channels. The

supernatant liquid (treated and clarified effluent) is pumped to filters to polish the effluent prior to disinfection.

- Filtration

The clarified wastewater is pumped through a granular media to further remove any remaining suspended solids. The final filtrate is then transferred to the relevant disinfection point before storage. Each Filter is periodically backwashed with the treated sewage to refresh the filter media, reduce the pressure differential, and remove the any filtered particulates. The backwash effluent is then pumped back to the aeration tanks for reprocessing.

- Disinfection

The treated and clarified sewage is disinfected using hypochlorite solution. The chlorine dosage is maintained at 0.5ppm to kill any pathogenic bacteria. After chlorination, the treated sewage flows into the treated effluent holding tanks.

- Storage of Treated Sewage Effluent

The treated effluent is stored in holding tanks to be used for irrigation of public areas within MAF and RAH. A deodorising chemical (Epoleon-N7) is added in the holding tanks to eliminate any odour problem and Epoleon-N100 is added where necessary to manage any ammonia build up. From the holding tanks, the treated effluent is distributed through a pipeline network for the irrigation of public areas.

- Sludge Drying

The wasted sludge from the clarifiers is dried in sludge drying beds prior to disposal. The sludge drying beds are located far away from residential areas. There are eight drying beds having individual surface areas of 50m^2 each. The beds are underlain with filter medium, and the percolate is collected and transported back into the STPs. The sludge is allowed to dry under the sun for a period of 30 days, and the dried sludge is removed and stockpiled on a concrete-lined storage facility prior to reuse applications.

4.3.3 Discharge of Treated Effluent

The treated effluent is re-used for the irrigation lawns, gardens and trees within the MAF and RAH areas. The effluent is distributed through a pipeline network. The STPS are designed such that the quality of the treated effluent meets the Omani

standards (Standard A-2) for land irrigation (refer Table 2.7 in Chapter 2). To control the treatment processes and establish conformance to discharge standards, estate services maintain a daily and weekly monitoring regime. The daily monitoring program is carried out by plant operating staff (contractor staff) and the parameters monitored daily are pH, chlorine, sludge volume index and dissolved oxygen. The weekly monitoring is carried out by PDO's Production Chemistry Laboratory staff in MAF and includes total suspended solids, BOD, COD, ammoniacal nitrogen and faecal coliforms.

The characteristics of the treated effluent from both the STPs as monitored during the year 2002 are summarised below:

Table 4.1: Treated Sewage Characteristics

Parameter	Units	MAF-STP	RAH-STP
Volume of sewage	m^3/d	~500 (Estimated)	~500 (Estimated)
pH	None	7.8-8.4 (XN=0/41)	7.6-8.3 (XN=0/41)
Total suspended solids	mg/L	0.4-13.2 (XN=0/41)	1-7.2 (XN=0/41)
Ammoniacal nitrogen	mg/L	0.1->10 (XN=13/41)	0.1->10 (XN=1/41)
Biological oxygen demand	mg/L	7-17 (XN=0/41)	7-13 (XN=0/41)
Chemical oxygen demand	mg/L	10-170 (XN=0/41)	12-83 (XN=0/41)
Free chlorine	mg/L	0-5 (XN=33/41)	0-5 (XN=24/41)

Notes: XN = Number times regulatory standards exceeded per total number of times monitored. As per the STP operating manual, free chlorine in the treated effluent shall be maintained within 0.5-1.5 mg/L.

From the above values in table 4.1, it is observed that the number of exceedance per total number of times monitored is high for ammoniacal nitrogen and free chlorine. On the other hand, some critical parameters are not monitored such as heavy metals, phenols, sodium absorption ratios, etc. The recommendations and additional mitigation measures are presented in chapter 7 of this report.

4.4 Solid Wastes

4.4.1 Sources of Generation

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)

Four types of solid wastes are routinely generated within the areas serviced by estate services. These are domestic wastes, office wastes, clinical wastes and STP sludge. Domestic wastes are generated from housing units and restaurants. They include wet kitchen wastes, non-recyclable and non-hazardous solid wastes and recyclable non-hazardous wastes. Office wastes are generated from the various administrative buildings and include both recyclable and non-recyclable wastes. Clinical wastes are generated from all the PDO clinics in the interior locations and in MAF area. On incineration, clinical waste generates a small quantity of ash. STP sludge is generated from the two STPs located in MAF and RAH areas.

Apart from clinical wastes, no hazardous waste is normally generated in the areas serviced by estate services. However, hazardous waste such as waste batteries, waste transformer oils, waste lubricating oils, waste oil sludges and contaminated soils may be generated occasionally. Other hazardous wastes including discarded tyres, discarded containers of hazardous materials (i.e. paints, insecticides, pesticides and other hazardous chemicals) are also generated intermittently by the contractors. These wastes are disposed directly by the contractors.

4.4.2 Waste Management

On behalf of estate services, approved contractors collect, segregate, dispose and recycle the various solid wastes generated from MAF and RAH areas. The estate services staff supervise the contractor staff and ensure the compliance with PDO's waste management specification (SP-1009).

The wet kitchen wastes and other non-recyclable wastes and non-hazardous wastes are collected in black plastic bags and then sent directly to the Muscat municipal landfill site for disposal. The recyclable non-hazardous wastes are collected in yellow bags and sent to PDO's waste processing plant in MAF, which is operated and maintained by a private contractor. Here, the dry waste is manually segregated into several categories such as paper, plastic, glass, metal and wood. The segregated dry waste is then sent to waste dealers for recycling.

The clinical wastes constitute waste cotton, soiled bandages, used disposable syringes and needles, discarded medicines etc. generated from PDO's medical clinics. No human anatomical wastes are generated since surgical procedures are not performed in the clinics. These clinical wastes are segregated from other wastes, packaged in puncture proof cardboard cartons, and thermally degraded in the incinerator located inside the waste management centre in PDO.

The STP sludge that is generated in the sewage treatment plants is sent to sludge drying beds in sludge tankers. The dried sludge is applied on land within MAF and RAH areas as a soil conditioner.

With respect to other hazardous waste such as waste batteries, waste transformer oils, waste lubricating oils, waste oil sludges, contaminated soils etc., they are not routinely generated. If any such wastes are generated, they are temporarily stored in the waste management centre, from where they are transferred to one of the hazardous waste storage facilities in the interior locations.

The quantities of the wastes generated in the areas serviced by the estate services asset for the year 2002 are shown in Table 4.2 below:

Table 4.2: Solid Wastes Generated in Areas Serviced by Estate Services

Waste Type	Waste Classification	Quantity (2002)	Method of Disposal
Wet domestic waste	Non-hazardous	2462 t	Sent to Municipal Landfill
Paper	Non-hazardous	103 t	Sold to waste dealer
Scrap Iron	Non-hazardous	9 t	Sold to waste dealer
STP Sludge	Hazardous	Not reported	Used for soil enrichment in MAF area
Discarded batteries	Hazardous	29 units	Neutralised and sold to waste dealers
Clinical waste	Hazardous	1919 kg	Incinerated in the incinerator
Waste plastic materials	Non-hazardous	Not reported	Sold to waste dealer
Aluminium	Non-hazardous	477 kg	Sold to waste dealer
Incinerator ash	Non-hazardous	Not reported	Sent to Municipal Landfill
Empty metal drums	Non-hazardous	91 pieces	Crushed and sold as metal scrap

4.5 Noise

Both stationary and mobile noise generating equipment are used in the areas serviced by estate services. The major stationary noise generating sources are the emergency diesel generators, which are operated very sparingly. The other sources include compressors, pumps and motors used in several places such as STPs, air conditioning plants, water pumping stations. Among these, the motors used in the RAH-STP may be considered significant for its continuous use and proximity to residential places.

The mobile noise generating sources are the vehicles used for the transportation of people and goods in and out of PDO coastal areas.

From all the above, the noise generation from these sources is considered as intermittent. All these equipment generate noise levels ranging from 65 dB(A) to above 90 dB(A) at the source points.

4.6 Accidental Leaks and Spills

Accidental leaks and spills may occur from oils, chemicals, sewage and water during their storage and transfer. Oils and chemicals are not used in large quantities in the areas serviced by estate services. The volume of sewage generated every day is quite significant and may result in significant environmental impacts. The volume of water handled is also quite large; however any accidental leaks or spills of water do not result in any environmental consequences.

- **Oil leaks and spills**

Diesel oil is the only oil stored in bulk. In order to maintain adequate reserves of fuel for the standby DGs near the computer building, diesel fuel is stored in two aboveground mild steel tanks each of about 2.3 m^3 capacity. These storage tanks are placed on cemented floor and bunded for containment of any leaks and spills. Any major leaks and spills are recovered and sent to the oil saver pit located in MAF area for recycling. Minor leaks are sponged off and any resulting waste is disposed as oily waste.

Electrical transformers and switchgear also hold oil inventories. As required by the Omani Electrical Standards, the transformer and switchgear areas are bunded and provided with spill containment provisions. In the event of any major spill, the waste oils are recovered and sent to the oil saver pit for recycling. Minor leaks are sponged off and any resulting waste is disposed as oily waste. It may be noted that only the transformer oils that are free (<50 ppm) from polychlorinated biphenyls (PCBs) are presently used. However, a few old transformers may still contain transformer oils with >50 ppm PCB.

- **Chemical leaks and spills**

Among the chemicals, the only chemical with significant accidental leakage potential is the sodium hypochlorite solution used for disinfection of potable water as well as the water in the swimming pools. Sodium hypochlorite solution at about 4% strength is stored in 200 L plastic drums and the dosing is done using on-line dosing pumps to

a concentration of 1.5-2 ppm. Automatic controllers are used to ensure that over-dosing is avoided. The hypochlorite storage drums are placed on cemented floor with leak containment facilities.

- **Sewage leaks and spills**

About 1100 m^3/d of sewage is generated. Sewage is transferred from the various points of generation to the STPs via a network of underground pipes. Since the pipes are buried at least a meter below the ground, no major leaks are expected. Minor leaks may be expected due to structural defects in the pipe joints or fittings. Such leaks are easily identified by the wetness of the surrounding soil, and the necessary repairs are promptly carried out.

5 ENVIRONMENTAL SETTING

5.1 Introduction

The estate services asset is one of the eight technical service providers in PDO. Unlike all the other service assets, the estate services asset operates only on the coast (in MAF and RAH areas) and does not operate in any of the interior areas.

In this chapter, a description of the environment in the areas serviced by estate services asset and the surrounding areas is presented. The data presented in this section is extracted from several earlier EIA studies carried out for the MAF area. The recent studies include the November 2000 study for estate services (*Reference 5*) and the February 2002 study for Al Khoud – MAF water pipeline replacement (*Reference 6*).

5.2 Topography

MAF is situated on the shore of the Gulf of Oman approximately 8km west of Muscat and 4 km north of Ruwi, the main commercial centres of the region. The MAF complex is situated within a natural bowl, which is formed by the surrounding hills. The steep, uninhabited Jabal Laqab formation distinguishes the eastern boundary of MAF, rising 214m above sea level. East of Jabal Laqab is the small fishing village of Darsait.

There are a number of wadis that traverse the MAF area. However within the industrial area, all the natural drainage channels has been converted to concrete channels to divert any surface water flow into the sea. The natural drainage direction is towards the sea. There is no permanent surface water flow in the area and any surface water movements are generated from rainfall events.

The western fringe of MAF is characterised by a narrow, uninhabited land area, which rises steeply to a height of 113m above sea level. Beyond this, at 40-60 m elevation are the areas of RAH and Al Qurum with significant residential and commercial development.

5.3 Geology and Soil

The MAF area is situated in the southern part of the Batinah coastal plain, a narrow alluvial plain approximately 200 km long that rises gently from the sea to an altitude of around 150 m inland. Several wadis traverse the plain from the Al Hajar

Mountains to the sea. It consists of sandy and gravel beaches, coastal marshes and rocky mountain headlands. The composition of the coastal plain is mainly sedimentary limestone of Mesozoic origin.

The soils on the coastline are sandy and away from the coast soils are sandy gravel. 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 5.1.

5.4 Hydrogeology and Groundwater Quality

The tertiary formations contain exploitable groundwater resources in Oman. In the north, the tertiary aquifer systems are recharged from the flow from the Oman mountains. 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 Umm er Raduma (UeR) formations (300-600 m depth).

Near the coast, the hydrogeology is influenced by seawater. The shallow ground water is highly saline and not potable. Potable groundwater for MAF and RAH areas is sourced from sustainable aquifer in Al Khoud, about 37 km from MAF. The Al Khoudh well field is located across the alluvial plain often referred to the Al Khoudh fan in the lower part of the Wadi Samail catchment. Water is extracted from Fars formations. A recharge dam was constructed surrounding the well field to enhance recharge during periods of heavy rainfall.

Water levels measured in one of the supply wells in Al Khoud since 1989 show a wide fluctuation, apparently depending on rainfall in the catchment area. For the period of 1989-2001, the mean annual average of depth to water level varied from a minimum of 7.7 m (1998) to a maximum 34.3 m (1994). The weekly averages during these years showed relatively low fluctuation between 19.4 m (March / May) and 22.6 m (October / November). The details are presented in *Appendix 2*. Groundwater levels in boreholes near the dam show fast response to wadi flow events, reflecting the relatively high permeability (34-149 m/d) of the well field. The quality of groundwater in Al Khoud field is very good and the groundwater does not require any treatment for domestic use.

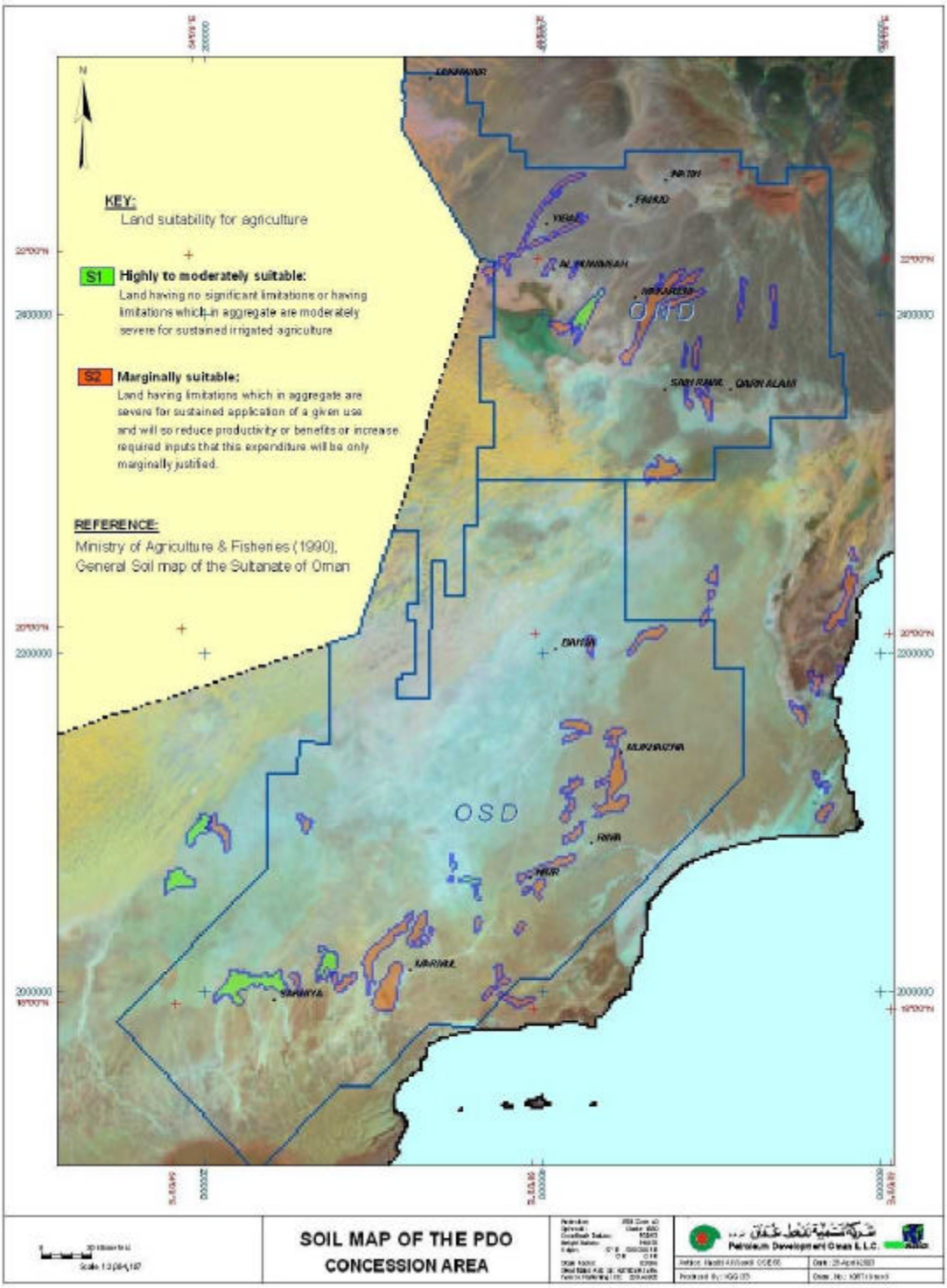


Figure 5.1: Soil Map of PDO's Concession Area

5.5 Climate

Historical meteorological data recorded at Seeb Airport show a mean annual temperature of 28.7 ºC. The mean monthly temperature ranges from 20.4 ºC at the minimum (January) to 34.6 ºC at the maximum (June). The extreme temperatures are as high as 49 ºC in summer and as low as 10 ºC in winter. Relative humidity is usually high and will be in 90s during the summer months. The mean total annual rainfall is 86 mm, and most of the rainfall occurs during the period of January-March. Fog is rare and may occur about twice a year.

The mean wind speeds range between 3 and 7 knots, with high wind speeds encountered during the summer months. The dominant wind direction is northeast during June-September and southwest during November-January. Close to the coastline, the wind direction is influenced by land-sea interactions. However, this effect is quite restricted due to the surrounding hills.

5.6 Ambient Air Quality

Since 1984, limited studies were conducted to assess the ambient air quality in the MAF area. The early studies were directed toward the monitoring the concentrations of hydrocarbons and odorous substances in the ambient air. In 1997, MRME&WR installed a continuous ambient air quality monitoring station in the MAF area near PDO's Security Gate No. 2 for monitoring the concentrations of SO_2 and O_3. Very recently (December 2002), the MAF industries jointly installed a continuous ambient air quality monitoring station in the MAF area near PDO's Junior Staff Camp.

In this station, all pollutants including particulates, NO_x, O_3, SO_2, CO, HC and odorous sulphurous gases (H_2S and mercaptans) are monitored.

The data available so far are not sufficient to adequately characterise the air quality in the MAF area. However, based on limited data, it may be stated that the concentrations of particulates, SO_2 and CO are quite low. The concentrations of NO_x and O_3 are however significant, though still within the maximum permissible limits. The vehicular traffic on the public highway (Qurum Heights) passing adjacent to the MAF industrial area is considered to be mainly responsible. Concentrations of HC and odorous sulphurous gases are noticeable on some instances.

It may be noted that the estate services activities hardly contribute to the ambient air quality in the MAF and RAH areas. The principal contributors are the mobile emissions from highway traffic, stack emissions from Oman Refinery Company and fugitive emissions from PDO's marine export facilities and petroleum product storage facilities of Shell Oman Marketing Company and BP Oman.

5.7 Ambient Noise

No data are available on the ambient noise levels in the MAF area. Considering that there are no high noise generating sources in the MAF area, it is reasonable to expect that ambient noise levels will be generally within the permissible limits.

5.8 Terrestrial Ecology

5.8.1 Flora

MAF is highly urbanised, and consequently any natural vegetation might have been destroyed. Nonetheless, small pockets of natural vegetation remain on the rocky coastal hills. This vegetation is similar to that of the foothills of the northern mountains and can be classified as an open xenomorphic Euphorbia community type. Characteristic taxa include *Acacia Tortillis*, *Commiphora spp*., *Grewia Erythraea*, *Euphorbia Larica* and *Ochradenus Arabicus*, species that can live on rugged relief with rapid water run off and little soil cover.

With respect to endemic species, *Carulluma Aucheriana* is identified as endemic to Oman. It is considered as vulnerable, fragmented and its population continues to decline. However, the reuse of treated sewage, supplemented by fresh water has enabled PDO to introduce and stabilise various forms of vegetation into the MAF and RAH areas.

5.8.2 Fauna

Mammals in MAF and RAH areas and are low in diversity, largely due to the lack of suitable habitat. The important species of mammals found in this region include the Arabian red fox (Vulpes Vulpes Arabica), the Ethiopian hedge dog (Paraechinus Aethiopicus) and Sundervall' jird (Meriones Crassus). Rodents such as the Egyptian spiny mouse (Acomyscahirinus), house mouse (Mus Musculus) and the black rat (Rattus Rattus) are also seen.

There are an estimated 152 species of birds present in MAF. The majority of the species are migratory, but seven species are recorded as breeding in the Muscat area. They include brown-necked raven, collared dove, common mynah, house crow, house sparrow, Indian roller, laughing dove, purple sun bird, red billed tropic bird, sooty falcon, rock-dove and yellow throated sparrow.

A number of species of reptiles and amphibians are commonly observed in the MAF area. These include skink, geckoes and snakes. Geckoes are the most common

species. Four reptile species, viz., Bufo Arabicus, Bufu Dhofarensis, Bunopus Spatalurus Hajarens and Scincus Mitranus found in this area and are endemic to the Arabian Gulf.

5.8.3 Nature Reserves

There are no nature reserves, wild life sanctuaries, mangroves etc. within the MAF and RAH areas. Beyond PDO's asset boundaries, the only place of ecological significance is the Qurum Natural Park, which is Al Qurum about 5 km from MAF. This park is located in the midst of urban area. This park is developed with relatively high vegetal cover. The flora and fauna include the species discussed in Sections 5.8.1 and 5.8.2 above. There is no wildlife in the park.

5.9 Marine Ecology

5.9.1 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.

5.9.2 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.

5.9.3 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.

5.9.4 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*).

5.9.5 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.

5.9.6 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).*

5.9.7 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.

5.10 Human Settlements

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).

5.11 Archeological, Cultural and Recreation Resources

There are no features of archaeology and cultural heritage within PDO's assets area in MAF. The MAF and adjoining Qurum beaches are used by local populations and tourists for recreation. There is however several ancient forts, museums, places of worship and recreational areas located in the capital area (from Muscat to Seeb). They are discussed further since the activities of estate services have no affect on them.

5.12 Industries

MAF industrial area is established exclusively for petroleum industries. In addition to the accommodation, administrative and auxiliary facilities serviced by the estate services, several industrial facilities are also located here. They include PDO offshore facilities, a petroleum refinery and several bulk storage facilities for refined petroleum products.

PDO exports majority of its crude oil to overseas customers by sea in tankers. A small sheltered harbour with a black stone jetty is situated within the MAF bay for access and shelter to the offshore facilities. The offshore oil loading and unloading facilities include five moorings, consisting of three SBMs and two CBMs. One of the SBMs is used for loading ORC's long residue into the ships. The two CBMs are used for the import/export of refined products for SMOC. There are also three tugs boats and a maintenance barge.

The petroleum refinery is operated by ORC. The refinery is designed for a maximum crude processing capacity of 85,000 barrels per day. The products include liquefied petroleum gas, petrol, diesel, fuel oils, and residues.

SMOC and BPO market the refined petroleum products. Their bulk storage depots are located inside the MAF area.

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. Estate services asset, as one of the service providers in PDO can claim a 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 all over its concession areas. In addition, a large number of persons, including local population in the interior are also provided indirect employment to provide a number of supporting services to PDO. 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 populations. 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 potential environmental effects on the natural resources and the associated environmental hazards are listed below:

Environmental Hazards
- Consumption of groundwater

Potential Environmental Effects
- Depletion of groundwater resources

Currently, on average about 2200 m^3/d of groundwater is abstracted continuously from the Al Khoud well field by estate services for supply to MAF and RAH areas. Most of this water is consumed for domestic use by PDO's coast based staff. Long term well monitoring data showed a wide fluctuation of water level over the past 13 years in the range of 7.7 m (1998) to 34.3 m (1994) with reference to the ground level. The data do not indicate any monotonic decline in the groundwater table from year to year. Instead, the well water level fluctuated randomly from year to year, apparently depending on the annual rainfall in the catchment area. Therefore, it appears that current groundwater abstraction rate is sustainable.

However, the water consumption in the areas serviced by estate services has been rising steadily over the past five years, except for a marginal decline in year 2000. Compared to 1997, the water consumption in 2002 increased by about 18%. The current per-capita domestic water consumption in RAH is estimated to be in the order of 400 L/d. This is well in excess of WHO recommended per-capita consumption of 250 L/d for comfortable urban living.

Based on the above discussion, the overall impact on groundwater resources is rated as below:

Impact Rating	Depletion of Ground Water Resources
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)	Localized
Potential risk level (low, medium, high and extreme)	Medium

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
- Release of gaseous emissions from mobile sources
- Generation of noise from stationary sources
- Generation of noise from mobile sources

Potential Environmental Effects
- Air pollution
- Noise pollution

- **Air Pollution**

Air emissions from the activities of estate services asset are not significant. There are no continuous stacks. Vent emissions are limited to the vent air from the kitchens. There are no significant fugitive emission sources. The significant point source of air emissions is the clinical waste incinerator, which may emit toxic gases such as carbon monoxide, hydrogen chloride, hydrogen fluoride, dioxins and furans. Since the stack gases are not monitored, their concentrations are unknown. However, since the volumetric flow rate of the stack emissions are quite low and the incinerator is operated only once a month for about 6 hours, they will not have any perceptible impact on the ambient air quality.

The emissions from vehicles used by the estate services staff and their contractor staff are not considered to be significant. Therefore, it is reasonable to assume that the impact on ambient air quality from the activities of estate services will be very low.

However, the limited air quality data available so far indicate the air quality within the MAF area affected by “trans-boundary” vehicular emissions and by stack and fugitive emissions from other industrial activities in MAF area. The vehicular traffic on the Qurum Heights highway, which passes along the northwest-southeast boundary of MAF industrial area, is quite high. 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)	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#

 # The direct risk from the estate services activities is low. However, when the transboundary emissions are considered, the potential risk level is elevated to high.

- **Noise Pollution**

Noise generation sources are not significant in areas serviced by estate services. The stationary sources include diesel generators and small compressors, pumps and motors used in several places such as STPs, air conditioning plants, water pumping stations. The diesel generators are operated very sparingly for emergency power supply. Among the other sources, the motors used in the RAH-STP may be considered significant due to its proximity to residential units. However, the noise level at source is not very high. The mobile noise generating sources are the vehicles used for the transportation of people and goods in and out of PDO's coastal areas. From the above sources, the noise generation is rated as intermittent. All these equipment generate noise levels ranging from 65 dB(A) to above 90 dB(A) at the source points.

Based on the above discussion, the impact on ambient noise is assessed as below:

Impact Rating	Increase in Ambient Noise Levels
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)	Medium

6.6 Impacts on Water Environment

With respect to water environment, only groundwater is considered since the estate services 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
- Land discharge of treated sewage effluent
- Accidental spills and leaks of oils and chemicals

Potential Environmental Effects
- Groundwater pollution

The groundwater in the MAF area is highly saline. The groundwater flow is discharged into the sea. The land discharge of treated sewage effluent can affect the

groundwater quality only if the quality of treated sewage repeatedly and significantly exceeds the discharge standards. However as seen in Section 4.3.3, the sewage treatment in RAH STPs is generally satisfactory but MAF STP is not up to the satisfactory conditions. With respect to accidental leaks and spills of oils and chemicals on soils, as discussed in Section 4.5, the potential for such occurrences is extremely low. 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)	Slight
Potential risk level (low, medium, high and extreme)	Low

6.7 Impacts on Land Environment

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

Environmental Hazards
- Land discharge of treated sewage effluent
- Accidental leaks and spills of oils and chemicals

Potential Environmental Effects
- Land contamination

Accidental leaks and spills of oils and chemicals lead to soil contamination only if the quantities of release are high and not contained. Such scenario is considered unlikely as discussed in Section 4.5. Reuse of treated sewage effluent for land irrigation within MAF and RAH areas can result in soil contamination if the quality of treated sewage repeatedly and significantly exceeds the discharge standards. However, STP monitoring data for the year 2002 show that the quality of the treated effluent from RAH STP is well within the permissible limits with respect to the parameters monitored, *viz.*, pH, total suspended solids, ammoniacal nitrogen, BOD, COD and faecal coliforms, except for ammoniacal nitrogen. For MAF-STP, the ammoniacal nitrogen concentration showed repeated exceedance (~70% of the time). Further, free chlorine concentration was repeatedly non-compliant with the specified limits (as required in the STP operating manual).

Other critical parameters such as heavy metals, phenols, sodium absorption ratio etc. are not monitored in the treated sewage effluents. In the absence any monitoring data for these parameters, total compliance with the discharge standards cannot be assumed. Moreover, the current practice of weekly monitoring of suspended solids,

ammoniacal nitrogen, BOD, COD and faecal coliforms is not adequate. It may also be noted that the treated sewage is discharged on the same land areas on continuous basis (long term) and these areas are accessible to public.

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 hazards associated with potential impact on public safety and health are listed below:

Environmental Hazards
- Storage and transportation of hazardous substances
- Release of toxic gases from incinerator stack

Potential Environmental Effects
- Public safety and health

Storage and transportation of hazardous substances, such as combustible liquids, combustible gases and chemicals have the potential to cause damage to public health and safety in the event of significant release into the environment following structural failure and loss of containment. This may lead to fire, explosion, reactivity or toxicity hazard.

For estate services, the major hazardous substance handled in significant quantities include diesel oil and LPG. Diesel oil is stored in bulk only in the generator building near the computer building in two aboveground mild steel tanks each of 2270 L capacity. The only safety hazard associated with diesel oil storage is pool fire in case of significant uncontrolled leak. Considering the inventories and the containment

facilities in place, the risk to public safety and health is insignificant. LPG is stored in compressed cylinders outside the kitchens. The hazards associated with LPG storage are fire and explosion. LPG cylinders are designed for safe storage under the prevailing environmental conditions and no incidents have been reported so far. Therefore, the risk to public health and safety from LPG storage is considered insignificant.

Among the chemicals, the major chemical used is sodium hypochlorite solution at about 4% strength, which is stored in 200 L plastic drums near swimming pools and MAF water storage tank. Considering that the concentration is low and the storage areas are provided with cemented floors with leak containment facilities, the risk to public safety and health from chemical storage is considered insignificant.

Based on the above discussion, the impacts on public health and safety are assessed as below:

Impact Rating	**Public Health and Safety**
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)	Very low
Significance of impact (slight / minor / localized / major / massive)	Minor
Potential risk level (low, medium, high and extreme)	Low

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	• MAF STP effluent quality exceeded the permissible limits. • The potential risk is predominantly due to long term discharge of large amount of treated sewage on land areas that are accessible to public. • STP monitoring is not comprehensive and some critical parameters such as heavy metals, phenols, sodium absorption ratios etc. are not monitored.
Air pollution	• Adverse • Long term • Medium occurrence • Localised significance	• High risk	• While the ambient air quality in the areas serviced estate services is least affected by air emissions from estate services activities, transboundary emissions have a significant impact. • Significant residential populations are present near MAF industrial area. • Currently available air quality data in MAF indicate significant concentrations of some pollutants.
Depletion of groundwater resources	• Adverse • Long term • Low occurrence • Localised significance	• Medium risk	• Over the past 5 years, the water consumption in areas serviced by estate services increased by 18%. • Per capita domestic water consumption in RAH continues to be high at about 400 L/d.

Environmental Effect	Impact Rating	Potential Risk Level	Comments
Noise pollution	• Adverse • Long term • Low occurrence • Minor significance	• Medium risk	• The residents near RAH-STP may experience high noise levels if the pumps and motors used in the STP are not properly maintained.

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	• Transboundary emissions from vehicular traffic on Qurum Heights highway, stack emissions from ORC and fugitive emissions from SMOC, BPO and offshore facilities have significant affect on the areas serviced by estate services and the surrounding residential areas.	• Track the air emission inventories and air quality in the airshed
SP-1006: Specification for Aqueous Effluents	• Treated effluent from MAF-STP showed repeated non-compliance with respect to ammoniacal nitrogen and free chlorine. • STP monitoring is not comprehensive and some critical parameters such as heavy metals, phenols, sodium absorption ratios etc. are not monitored. • STP monitoring frequency is not adequate. Weekly monitoring cannot detect if standards are breached during peak load times. • The application of Standard A-2 for treated sewage quality is questionable since the irrigated areas are accessible to public. Application Standard A-1 will lead to repeated non-compliance.	• STP performance and operating practices shall be reviewed. • Critical parameters such as heavy metals, phenols, sodium absorption ratios etc. shall be monitored at least on quarterly basis. • Monitoring frequency may be increased to four times per day for on-site measurements and composite samples may be taken for laboratory analysis • The issue relating to the application of Standard A-2 needs to be resolved, in consultation with MRME&WR.
SP-1007: Specification for Accidental Releases to Land and Water	• None	• None
SP-1008: Specification for Use of Energy, Materials and Resources	• Per-capita domestic water consumption in RAH remains quite high. • Total water consumption in MAF and RAH shows steady increase over the years.	• Water conservation shall be promoted in the PDO accommodation facilities.
SP-1009: Specification for Waste Management	• None	• None
SP-1010: Specification for Environmental Noise and Vibration	• Residents near RAH-STP may experience high noise levels if the pumps and motors used in the STP are not properly maintained.	• Through periodic noise monitoring, compliance with source and ambient noise standards shall be ensured.

Specification	Areas of Non-compliance or Concern	Recommended Additional Mitigation Measures
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 Material	• None	• None

8 REFERENCES

1. WS/Atkins, *Estate Services Asset 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

5. HMR, *EIA for Estate Services Asset*, November 2000

6. HMR, *Al Khoud – MAF water pipeline replacement report*, February 2002

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 infrastructure 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.

Name of Reviewer	Position in PDO	Role in Project Development
Dr. Muralee R. Thumarukudy	CSM/22	Senior Corporate Environmental Advisor
Ahmed Al Sabahi	CSM/25	Environmental Advisor
Mahmood Jassasi	HES	HSE Advisor – Estate Services

APPENDIX 2: AL KHOUD WATER WELL MONITORING DATA

WATER LEVELS OF WELL #1 IN METERS

WEEK No.	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Average
1	14.11	14.96	19.36	23.39	28.88	33.46	35.84	27.92	22.13	7.29	7.58	18.81	17.60	20.9
2	14.16	14.63	19.52	23.68	29.00	33.48	35.98	25.13	22.43	7.33	7.58	18.97	17.75	20.7
3	14.18	14.04	19.64	23.97	29.18	33.50	36.06	22.53	22.83	7.36	7.60	19.10	17.85	20.6
4	14.19	13.42	19.77	23.97	29.28	33.30	36.13	21.03	22.98	7.30	7.63	19.26	18.00	20.5
5	14.21	13.36	19.83	24.03	29.48	33.13	36.13	19.32	23.13	7.23	7.71	19.42	18.15	20.4
6	14.18	12.13	19.67	23.88	29.58	33.03	36.13	18.63	23.30	7.33	8.58	19.60	18.35	20.3
7	14.18	11.90	19.72	23.73	29.68	33.02	36.18	18.06	23.40	7.30	7.68	19.72	18.50	20.2
8	14.17	9.49	20.05	24.78	29.78	33.08	36.24	17.64	23.48	7.33	7.85	19.85	18.65	20.2
9	14.17	9.08	20.38	24.68	29.88	33.14	36.23	17.23	23.43	7.33	7.75	20.00	18.80	20.2
10	14.18	8.73	20.28	24.73	30.08	33.23	36.23	16.33	23.13	7.33	7.79	20.15	18.96	20.1
11	14.25	8.91	20.58	25.68	30.08	33.33	35.98	15.63	22.93	7.38	7.92	20.32	19.10	20.2
12	14.16	9.32	20.83	24.93	30.18	33.38	35.63	15.13	22.53	7.43	8.32	20.50	19.30	20.1
13	14.16	9.56	20.23	25.58	30.38	33.46	35.58	15.26	19.83	7.35	8.65	20.62	19.54	20.0
14	14.16	9.77	20.08	22.88	30.38	33.58	35.38	15.28	16.04	7.38	9.00	20.75	19.70	19.6
15	14.21	9.80	20.60	21.98	30.46	33.58	35.33	15.55	13.93	7.43	9.31	21.06	19.90	19.5
16	14.18	10.21	20.18	21.53	30.56	33.63	35.39	15.61	12.63	7.43	9.58	20.90	19.96	19.4
17	14.44	10.41	20.13	21.58	30.66	33.85	35.46	15.77	11.40	7.43	9.92	21.21	20.30	19.4
18	14.54	10.63	19.98	21.18	30.72	33.78	35.50	15.83	10.42	7.46	10.27	21.35	20.57	19.4
19	13.65	10.68	20.08	21.43	31.19	34.00	35.54	16.03	9.78	7.56	10.62	21.50	20.81	19.5
20	13.88	11.14	20.08	21.73	31.28	34.10	35.63	15.93	9.48	7.48	11.01	21.68	21.01	19.6
21	14.04	11.32	21.58	22.68	31.36	34.10	35.64	15.73	9.33	7.58	11.31	21.86	21.25	19.8
22	14.39	11.66	20.18	22.83	31.72	34.18	35.66	15.43	9.22	7.63	11.60	22.03	21.50	19.8
23	14.60	11.89	20.32	23.48	31.53	34.28	35.71	15.83	9.13	7.66	11.90	22.20	21.72	20.0
24	14.73	12.20	20.36	24.23	31.60	34.33	35.80	15.43	9.07	7.68	12.20	22.38	21.92	20.1
25	14.91	12.51	20.50	24.58	31.70	34.43	35.90	15.43	9.02	7.68	12.60	22.55	22.13	20.3
26	15.10	12.84	20.68	24.85	32.00	34.53	35.95	15.78	8.96	7.73	12.80	22.73	22.40	20.5
27	15.34	13.18	21.64	24.98	32.00	34.58	35.99	15.93	8.92	7.78	13.07	22.90	22.65	20.7
28	15.78	13.47	21.70	25.28	32.07	34.58	36.05	16.18	8.92	7.78	13.43	23.07	22.90	20.9
29	15.98	13.40	21.30	25.38	32.15	34.63	36.13	16.33	8.92	7.73	13.70	23.24	23.13	20.9

30	16.18	13.11	21.41	25.28	32.14	34.68	35.97	16.61	8.90	7.68	14.01	23.37	23.35	21.0
31	16.36	13.14	21.51	26.13	32.13	34.63	33.96	16.80	8.88	7.73	14.25	23.46	23.25	20.9
32	16.19	13.46	21.72	25.38	32.13	34.45	33.03	17.11	8.82	7.86	14.59	23.68	23.75	20.9
33	16.92	13.78	22.29	25.98	32.14	34.35	32.62	16.93	8.79	7.84	14.82	23.85	24.00	21.1
34	17.16	14.08	21.80	26.07	32.19	34.43	31.93	17.03	8.77	7.83	15.05	24.00	24.20	21.1
35	17.39	14.37	22.10	26.33	32.17	34.42	31.20	17.53	8.75	7.98	15.33	24.17	24.45	21.2
36	17.52	14.64	22.49	26.48	32.92	34.48	30.70	17.83	8.75	8.98	15.54	24.35	24.35	21.5
37	17.19	14.77	22.75	26.98	32.40	34.53	30.68	18.08	8.90	7.88	15.84	24.50	24.90	21.5
38	18.06	15.22	22.91	27.13	32.58	34.58	30.13	19.83	8.98	8.08	16.11	24.68	25.15	21.8
39	18.20	15.45	23.11	26.83	32.85	34.62	30.03	20.25	9.14	8.03	16.28	24.65	25.20	21.9
40	18.29	15.75	22.96	27.28	32.72	34.70	30.00	19.60	9.34	8.28	16.44	24.92	25.15	22.0
41	18.28	16.08	22.84	27.18	32.90	34.83	30.00	20.03	9.43	8.18	16.73	25.00	25.65	22.1
42	18.81	16.19	22.93	28.38	32.96	34.93	30.23	20.43	9.53	8.28	16.95	25.20	25.90	22.4
43	19.10	17.22	23.01	27.18	33.00	34.93	30.44	20.55	8.85	8.26	17.10	25.31	26.00	22.4
44	19.49	17.94	23.18	27.58	33.11	35.06	30.93	20.62	8.58	8.20	17.28	25.40	25.85	22.6
45	19.72	18.16	23.36	27.73	33.16	35.03	31.12	20.75	8.58	8.03	17.63	23.25	26.40	22.5
46	19.01	18.33	23.53	28.23	33.26	35.26	31.21	21.14	7.98	7.98	18.06	18.70	26.60	22.3
47	20.06	18.45	23.79	28.33	33.28	35.30	31.11	21.25	7.63	8.02	18.03	17.65	26.70	22.3
48	20.19	18.56	23.69	28.68	33.33	35.53	31.41	21.40	7.39	7.88	18.10	17.78	26.80	22.4
49	20.30	18.72	23.64	28.73	33.36	35.62	31.47	21.52	7.30	7.93	18.23	17.75	26.92	22.4
50	18.26	18.88	23.59	28.58	33.41	35.72	31.63	21.70	7.35	7.78	18.37	17.55	27.08	22.3
51	15.91	19.12	23.62	28.73	33.43	35.80	31.65	21.93	7.66	7.88	18.50	17.40	27.20	22.2
52	15.11	19.28	23.42	28.76	33.45	35.80	30.93	22.12	7.43	7.70	18.67	17.50	27.40	22.1
Average	16.0	13.6	21.4	25.3	31.6	34.3	33.9	18.3	12.6	7.7	12.8	21.6	22.5	20.9

APPENDIX 3: 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 exceedance 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 exceedance 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 exceedance 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 exceedance of statutory or prescribed limits				**EXTREME RISK**	

APPENDIX 4: ENVIRONMENTAL HAZARDS AND EFFECTS IDENTIFICATION MATRIX: ESTATE SERVICES 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
Land take																					
For installation of project facilities										**X**	**X**										
For construction of accommodation facilities										**X**	**X**										
For laying oil/gas pipelines			**X**							**X**	**X**		**X**	**X**	**X**						
For laying power lines			**X**							**X**	**X**		**X**	**X**	**X**						
For laying access roads			**X**							**X**	**X**		**X**	**X**	**X**						
For storage of construction materials										**X**	**X**		**X**	**X**	**X**						
Utilization of Mineral Resources																					
For construction materials	**X**																				
For road building materials	**X**		**X**																		
Utilization of Groundwater Resources																					
For construction water		**X**						**X**													

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 Human Resources																					
Employment of migrant construction workers																				X	
Employment of permanent workers																					
Release of Air Pollutants																					
Dust from construction activities and road traffic					X																
Gaseous emissions from stationary sources				X	X																
Gaseous emissions from mobile sources				X	X																
Accidental release of toxic gases and vapours																				X	
Release of Energy into Atmosphere																					
Hot gases from flares and stacks																					
High level noise from stationary sources						X															

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 mobile sources						X															
Discharges of Liquid Effluents																					
Marine discharge of treated effluent									X			X									
Accidental spillage of hazardous liquids								X				X									
Disposal of Solid Wastes																					
Handling and transport of hazardous wastes																					
Functional Activities																					
Pipeline transport of oil and gas																					
Road transport of hazardous substances														X						X	
Bulk storage of hazardous substances																				X	
Road travel														X							
Marine travel																					

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