ENVIRONMENTAL ASSESSMENT OF FAHUD 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 Fahud asset, which is one of the seven production assets within PDO's concession area in the Sultanate of Oman. The first environmental assessment for Fahud asset was carried out in June 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 non-associated gas producing wells. Currently, PDO (including gas asset) produces about 843,490 barrels of oil (black oil and condensate) and 44 million Sm^3 of gas (associated and non-associated) on average per day as reported for the year 2002. Fahud is the largest asset in PDO, covering a land area of 11,580 km^2 and consisting of two operating oil fields and 240 producing wells.

This asset currently produces 14,670 m^3/d of oil (10.9 % of PDO's) and 5,007,000 Sm^3/d of associated gas (11.4 % of PDO). The quantity of produced water is 11,239 m^3/d on average. The total power generation in the asset is 27.1 MW. The total abstraction of groundwater in the asset is 3,731 m^3/d. The total length of roads in the asset is 656 km and the total length of flow lines is 1210 km.

The asset has one production station (located in Fahud, approximately 300 km from Muscat). There are five gathering stations, *viz.*, Fahud B, Fahud C, Fahud D, Fahud E and Natih and a gas compression station in the asset. There is a gas fired gas turbine power station located in Fahud. The asset has a booster station, two water treatment plants based on reverse osmosis (RO) process, a central chemical store including an explosives' store and a central waste management centre.

The asset releases about 2,679 tpd of CO_2, 7 tpd of NO_x, 5 tpd of CO and 1 tpd of SO_2 and 9 tpd of HC into the atmosphere. The liquid effluents generated in the asset include 11239 m^3/d of produced water and 1015 m^3/d of sewage. The total hazardous waste produced is about 12,089 tpa. The total volume of accidental oil spills and leaks reported in the asset is 58 m^3 per year.

Description of Environment

Fahud asset is located at about 300 km southwest of Muscat. The topography and landscape of most of the asset area is characterised by flat plains interspersed with small drainage channels and occasional rocky outcrops. There are Two major wadis,Wadi Aswad and Wadi Umayri, flow south-westwards through the asset. Fahud area is composed of alluvial gravel and fine silt over most of the plains, fine alluvial gravel and silt in the smaller drainage channels and coarse alluvial gravel in major wadis.

The natural vegetation is composed of desert plants and grasses, and there are no major trees in the asset except in those places irrigated by PDO using treated wastewater. The geology of the asset area comprises of mainly limestone with shale, dolomite and sandstone.

The region has an arid climate with mean monthly temperatures ranging from 19 °C (January) to 37 °C (June). The maximum and minimum absolute temperatures are 51°C and 6°C respectively. The mean annual rainfall in Fahud area is 20 mm, which is highly variable in time and space.

The vegetation is composed of desert plants and grasses, while trees are rarely seen. The fauna include a few species of mammals including Arabian gazelle, Rhim gazelle and Nubian ibex. On hundred and six species of birds are known to exist in the asset area. There are no endangered flora and wildlife habitats in the asset

The number of persons currently accommodated in PDO and contractor camps in the asset is about 2,285. One large town, Adam, lies within the Fahud asset area. There are several small villages such as Awaifi, Wadis Umayri and Wadi Aswad.

Groundwater is the only water resources in the region. Most of the potable water requirement for the population in Fahud asset, including the PDO and contractor camps is met with desalinated water from PDO's RO plants. In addition, the water supply wells in Awaifi village are also tapped directly for potable purpose.

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	• Stationary sources of air emissions are not monitored to check compliance with emission standards. • Ambient air is not monitored to check compliance with air quality standards.	• All continuous air emission sources such as gas turbine stacks shall be monitored for compliance. • Ambient air quality shall be monitored in accommodation camps periodically.
SP-1006: Specification for Aqueous Effluents	• Current STP monitoring frequency and schedule are inadequate. Once a day or once a week monitoring cannot detect if standards are breached during peak load times. • Technical proficiency of STP operators and supervisors is below par.	• STP monitoring frequency and schedule need to be revised to ensure compliance at all times. Monitoring frequency may be increased to 4 times per day for on-site measurements and composite samples may be taken for laboratory analysis. • All STP operators and supervisors shall be provided continuing education and training on STP operation and monitoring.

Specification	Areas of Non-compliance or Concern	Recommended Additional Mitigation Measures
SP-1007: Specification for Accidental Releases to Land and Water	• It is likely that quantities of oil spills are under-estimated.	• The oil spills / leaks shall be minimized through better pipeline and flow line integrity management. • All oil spill / leak incidents shall be responded to promptly to minimize quantities of release as well as quantity of soil contaminated. • More accurate methods for estimating the volumes of oil spills and the quantities of contaminated soil shall be evolved.
SP-1008: Specification for Use of Energy, Materials and Resources	• Optimal use of energy and water is not demonstrated as required in the specification.	• Avenues for minimization of water consumption shall be explored. • Monitoring of water wells shall be continued to ensure that there is no depletion of groundwater reserves over a longer term.
SP-1009: Specification for Waste Management	• Waste consignments are not properly estimated. • Some wastes, such as rig site wastes are not segregated at source as required. • Waste compaction equipment are inadequate and some are non-functional. • Waste recycling is not significant. • There is no evidence of regular wetting of land farms.	• Compliance with waste handling procedures shall be enforced. • Waste operators shall be closely supervised. • Waste recycling avenues shall be explored at corporate level.
SP-1010: Specification for Environmental Noise and Vibration	• Ambient noise levels are not monitored to check compliance with the standards.	• Ambient noise levels shall be monitored in accommodation camps periodically
SP-1011: Specification for Flora and Fauna	• None	• None
SP-1012: Specification for Land Management	• There are several abandoned well sites, which require restoration.	• Site restoration program shall be accelerated.
SP-1170: Specification for Management of Naturally Occurring Radioactive	• NORM survey in the stations is not completed.	• Comprehensive NORM survey to be completed and necessary mitigation measures to be taken, if required.

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

µg	Micro-Gram
µm	Micro-Meter (Also Known As Micron)
µS/cm	Micro-Siemens Per Centimetre (Units Of Electrical Conductivity)
AP	Atmospheric Pressure
atm	Atmosphere
bar(g)	Unit Of Gauge Pressure (Equal To 101.3 Kpa Gauge)
bbl	Barrel (Equal To About 159 Liters)
BOD	Biochemical Oxygen Demand
bpd	Barrels Per Day
Bq	Bequerel, Unit For Measurement Of Radioactivity (One Nuclear Disintegration/Second)
$CaCO_3$	Calcium Carbonate
CFC	Chloro-Floro-Carbon
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CPI	Corrugated Plate Interceptor
d	Day
dB	Decibel
DGEA	Directorate General Of Environmental Affairs
DLN	Dry Low No_x
DWD	Deep Water Disposal
E	East
E&P	Exploration & Production
EIA	Environmental Impact Assessment
EPC	Engineering, Procurement And Construction
ESP	Electrical Submersible Pump
EU	European Union
GT	Gas Turbine
h	Hour
ha	Hectare
HC	Hydrocarbons
HCFC	Hydro-Chloro-Floro-Carbon
HEMP	Hazards And Effects Management Process
HFC	Hydro-Fluoro-Carbon
HMR	HMR Environmental Engineering Consultants
HP	High Pressure
HSE	Health, Safety And Environment
ISO	International Organization for Standardization
IUCN	International Union For The Conservation Of Nature And Natural Resources (The World Conservation Unit)
kg	Kilogram
km	Kilometer
km^2	Square Kilometer
kPa	Kilo Pascal, Unit Of Pressure (1 Atm = 101.13 Kpa)
Kpa	Kilopascal
L_{eq}	Equivalent Noise Level
LNG	Liquified natural gas
LP	Low Pressure
m^3	Cubic Meter
MAF	Mina Al Fahal
MD	Ministerial Decision
mg	Milligram
MJ	Mega-Joule

ml	Milliliter
MLPS	Main Line Pumping Station
MOL	Main Oil Line
mPa.s	Milli-Pascal-Second (A Unit Of Viscosity Equivalent To 1 Centipoise Or Cp)
MPN	Most Probable Number
MRME&WR	Ministry Of Regional Municipalities, Environment And Water Resources
MSDS	Material Safety Data Sheet
MW	Megawatt
MWh	Megawatt-Hour
N	North
NAAQ	National Ambient Air Quality
NH_3	Ammonia
Nm^3	Normal Cubic Meter (At 1atm And 0^oc)
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NOCS plant	North Oman Crude Stabilization Plant
NORM	Naturally Occurring Radioactive Materials
NO_x	Oxides Of Nitrogen
^oC	Degree Centigrade
^oK	Degree Kelvin
PDO	Petroleum Development Oman LLC
PM_{10}	Particulate Matter Of <10 µm Size
$PM_{2.5}$	Particulate Matter Of <2.5 µm Size
ppm	Parts Per Million

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 directorates 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 and Marmul. The crude oil export facilities and the administrative head quarters are located on the coast in Mina Al Fahal. The current asset organisation structure in PDO is shown in Figure 1.2.

Currently PDO (including gas asset) operates from about a hundred fields and has 2,454 oil producing wells and 72 non-associated gas producing wells. The total production of oil (black oil and condensate) currently is about 843,490 barrels per day and that of gas (associated and non-associated) is about 44 million Sm^3 per day as reported for the year 2002. 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) and their percentages are given in figure 1.3.

Table 1.1: Description of Production Assets in PDO

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

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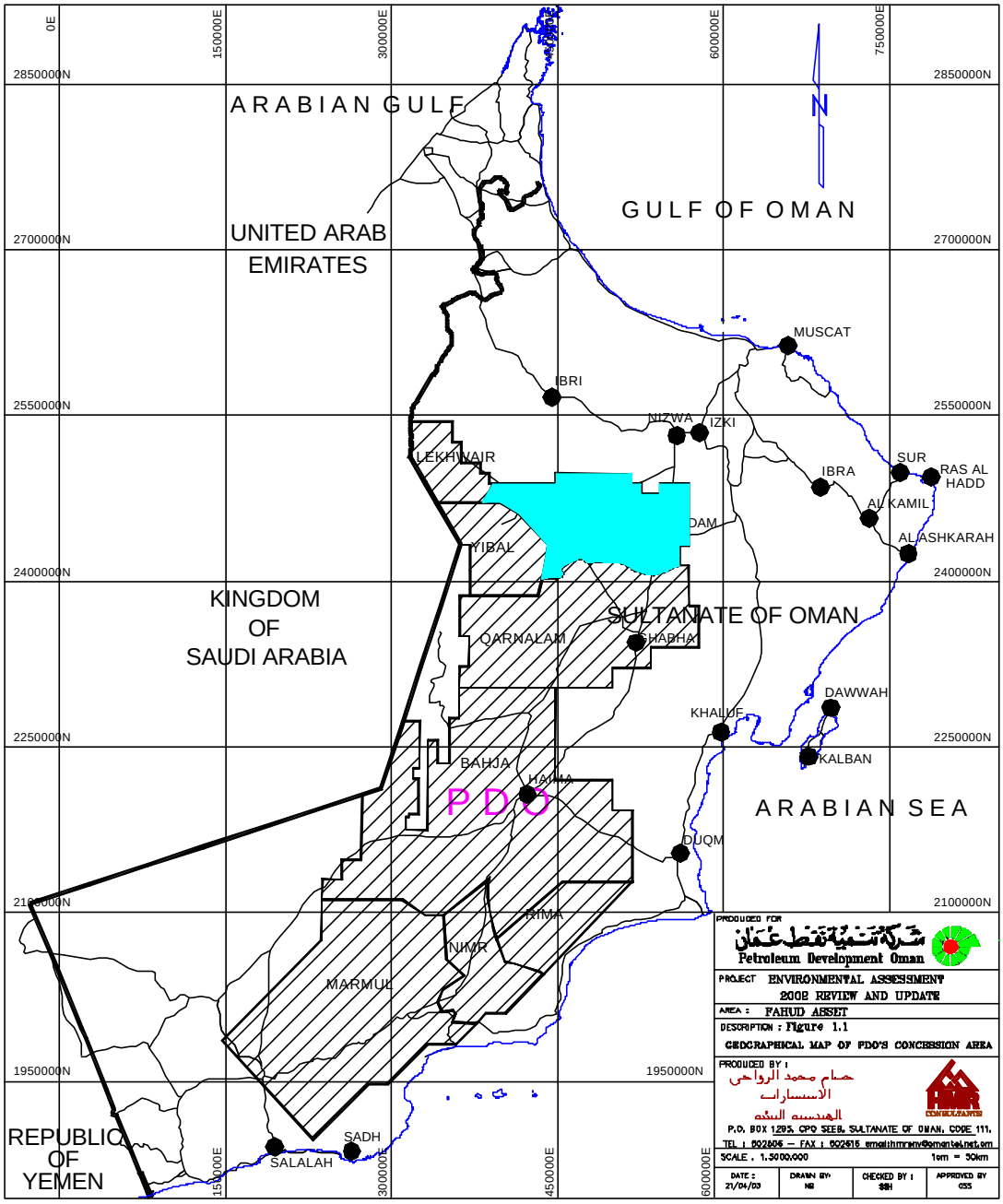

Figure 1.1: Geographical Map of PDO's Concession Area

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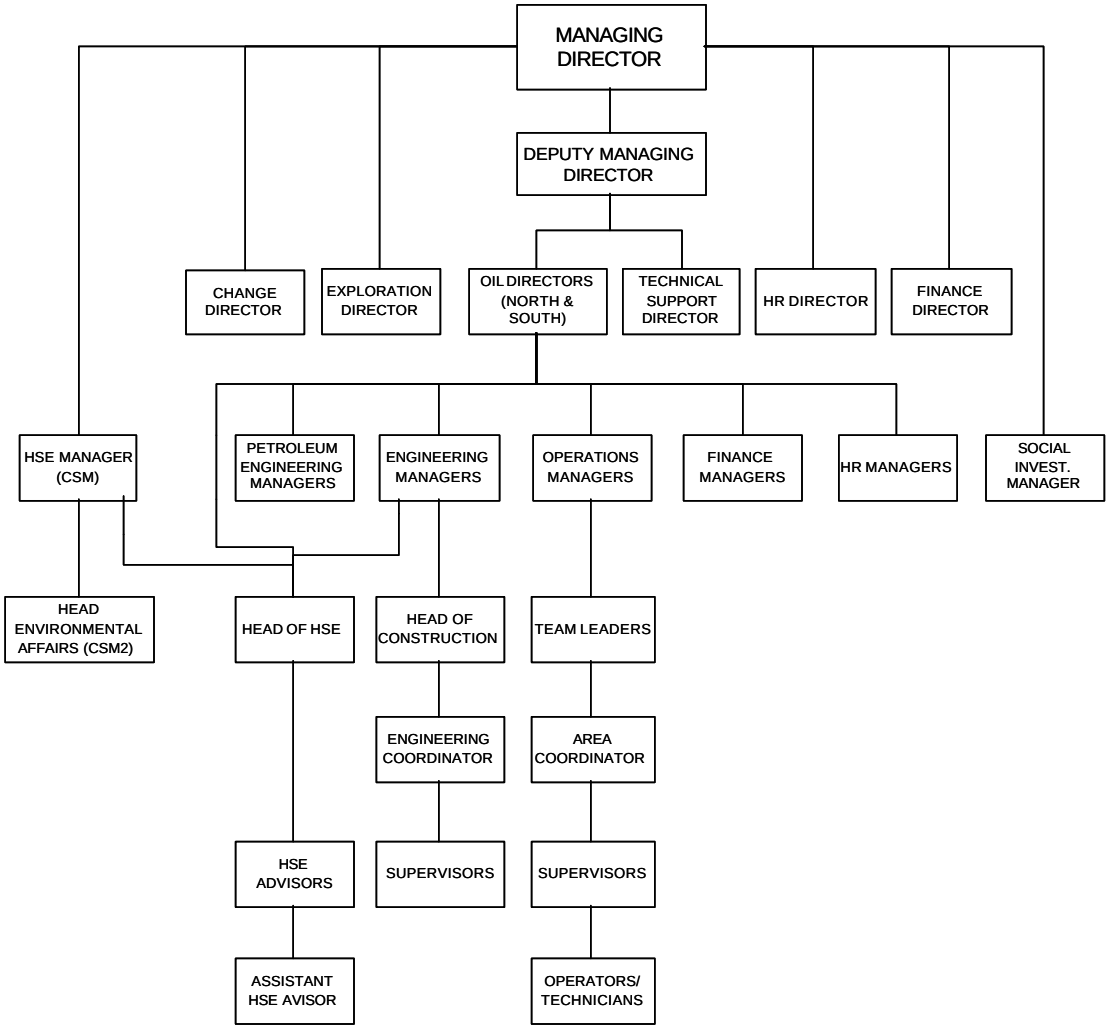

Figure 1.2: Organisation Structure in PDO

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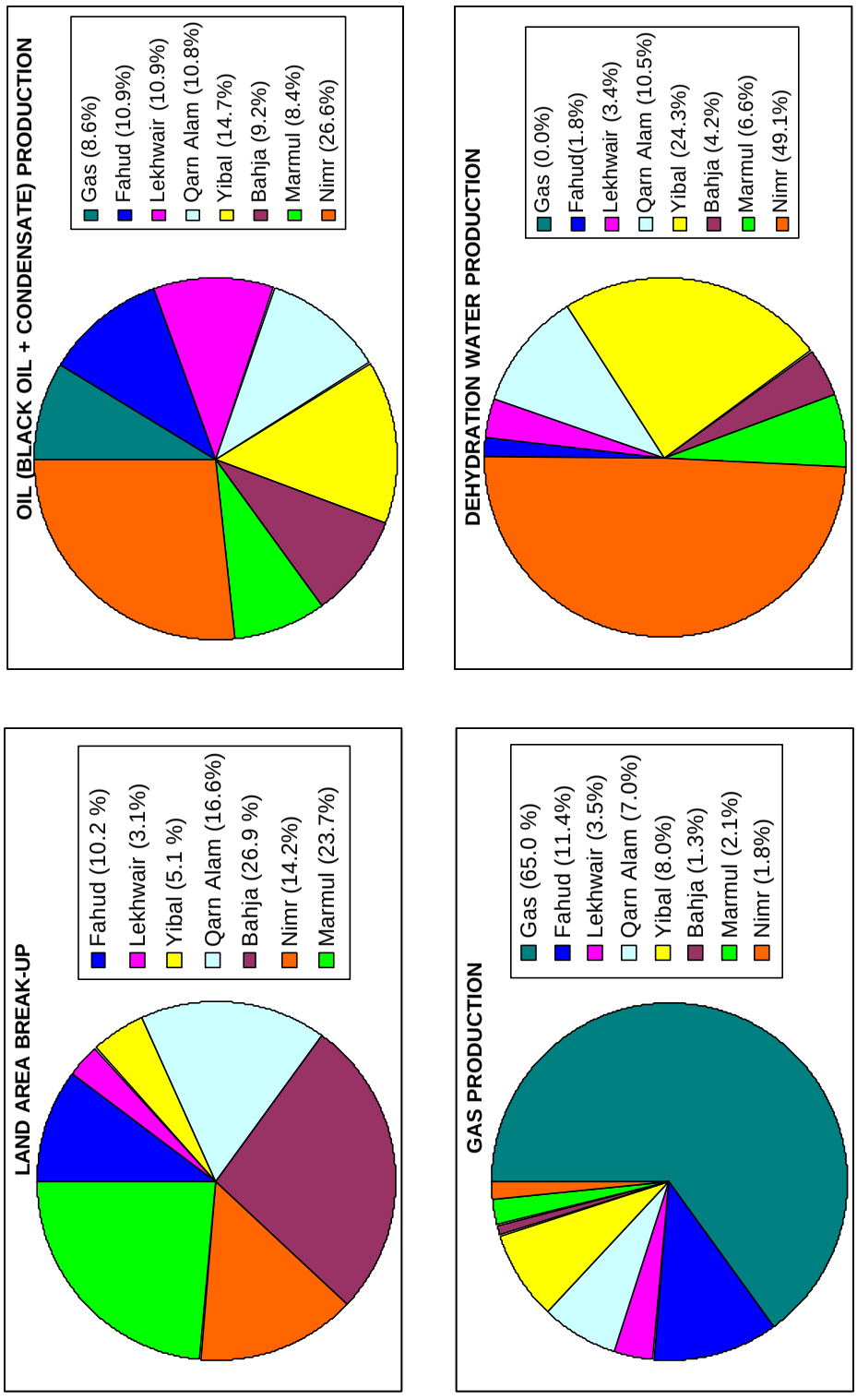

Figure 1.3: Asset-wise Break-up of Land Area, Oil, Gas and Produced Water

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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.

It is an internal requirement in PDO to review and update the EIA once every three years, in order to periodically re-assess 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 entire Fahud asset, which includes Fahud and Natih fields. The previous environmental assessment study for Fahud asset was completed in July 1999 (*Reference 1*).

1.3 Objectives and Scope of Study

The objectives of this 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 June 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 re-assessing the environmental impacts, in view of the above.
- Revising the environmental mitigation measures and monitoring plan, wherever required.

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

1.4 Method of Study

This study was carried out in three stages. In the first stage, the previous EIA report (*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, in the second stage, 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 a 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 measures 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 and service 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 Fahud 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 in Fahud 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 within the Fahud asset.

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

Title	Reference Number
Regulations for the handling of toxic substances	MD 248/97
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 EP 95-0120	Management of Contractor HSE 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 EP 95-0370	Quantitative Risk Assessment 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 EP 95-0381	Environmental Quality Standards - Water 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-1005 on 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.

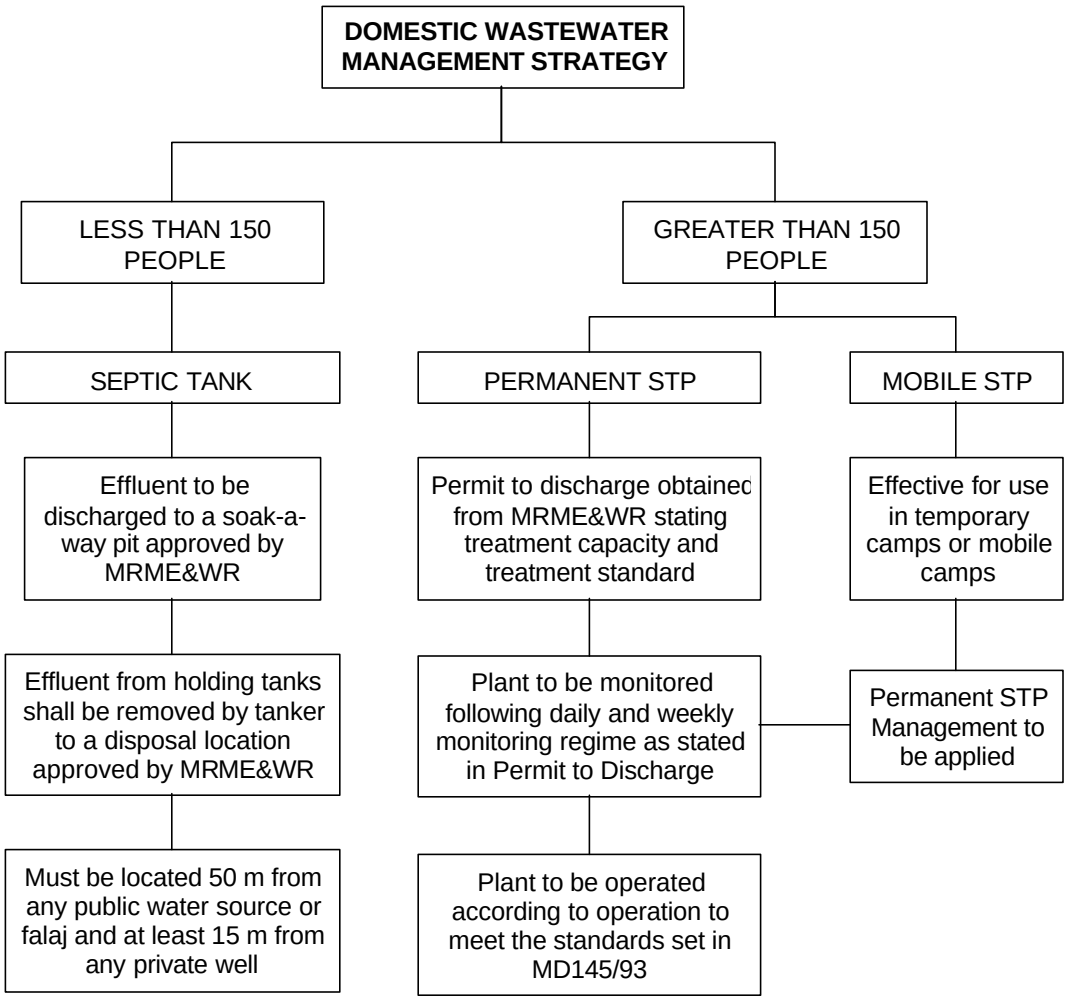
(e) Dispose surplus waters to formations, which have salinity greater than 35,000 mg/L, in conjunction with case-specific monitoring programs.

- **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 Pigging sludge	Domestic waste 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 Oil-based drilling mud and cuttings	Scrap metal
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 Asset Organisation

Geographically, Fahud asset is located 300 km southwest of Muscat. It covers a total land area of 11,580 km^2 and consists of two operating oil fields and 240 producing wells. Fahud field was discovered in 1964 and brought on stream in 1967 as PDO's first oil producing field. Currently, the asset produces on average 14,670 m^3/d of crude oil and 5,007,000 Sm^3/d of associated gas. The asset accounts for about 10.9 % of PDO's total crude oil production. Out of the total associated gas produced in the asset, about 9.3 % is internally utilised as fuel for heaters, compressors and power plant, 87.5 % is re-injected into the reservoir and 3.2 % is flared. The quantity of produced water is 11,239 m^3/d on average. The total power generation in the asset is 27.1 MW. The total abstraction of groundwater in the asset is 3,731 m^3/d on average, excluding water extracted for use by drilling rigs. The total length of roads in the asset is 656 km and the total length of flow lines is 1210 km. The asset organisation structure as shown in Figure 3.1. The facilities currently available in the asset are listed in Table 3.1 below.

Table 3.1: List of Facilities in Fahud Asset

Name of Facility	Number of Units
Production stations	1
Crude stabilisation plant	1
Gathering stations	6
Power stations	1
Water treatment plant (RO plant)	2
Booster stations	1
Produced water injection / disposal plants	1
Permanent PDO camps	1
Permanent contractor camps	5
Permanent sewage treatment plants	3
Mobile sewage treatment plants	None
Central chemical stores	1
Waste management centre	1
Drilling rigs	5 (presently)

The production station, i.e., the main line pumping station (MLPS) is located in Fahud, approximately 300 km from Muscat. There are five gathering stations, *viz.*, Fahud B, Fahud C, Fahud D, Fahud E and Natih and a gas compression station in the asset. There is a gas fired gas turbine power station located in Fahud. The asset has a booster station, two water treatment plants based on reverse osmosis (RO) process, a central chemical store including an explosives' store and a central waste management centre.

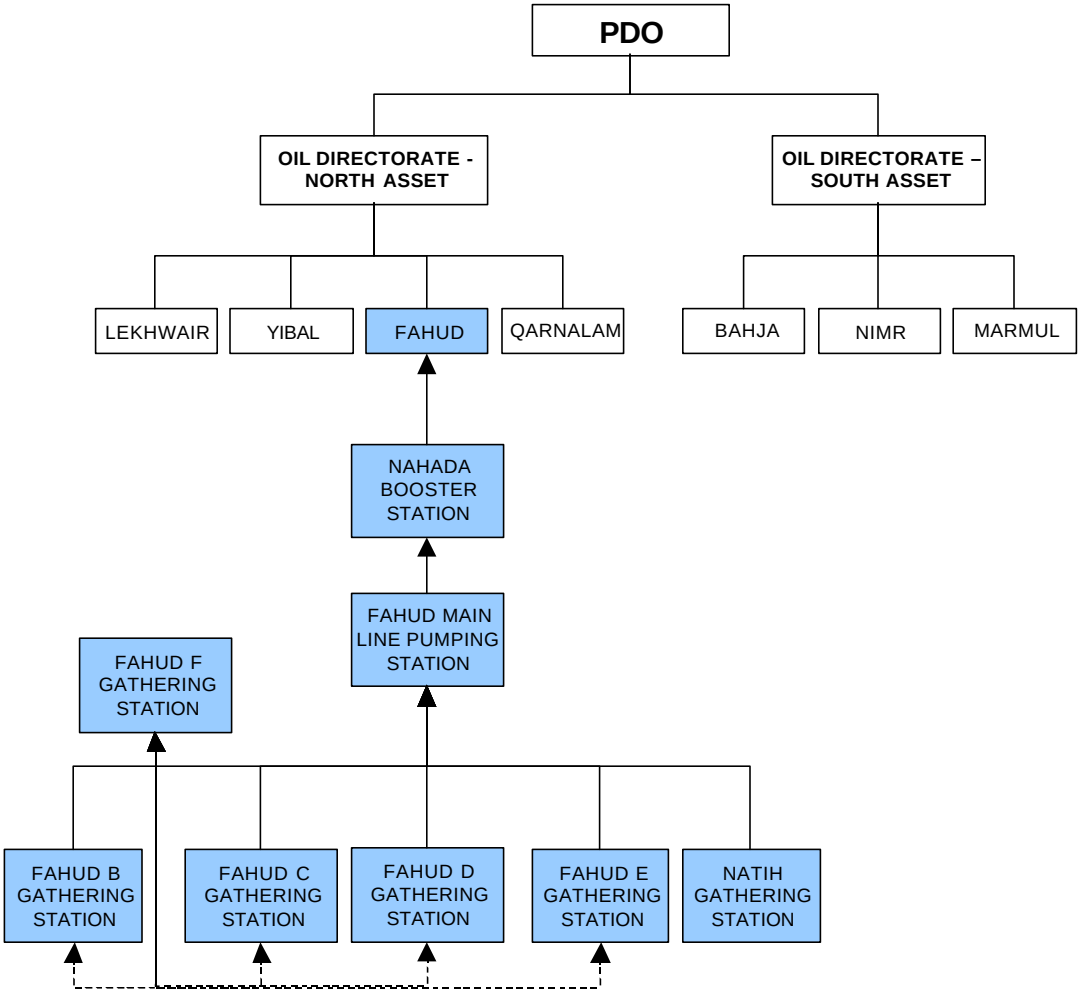


Figure 3.1: Asset Organization Structure for Fahud

There is one permanent accommodation camp for PDO staff and five other permanent accommodation camps for contractor staff in the asset. There are three permanent sewage treatment plants (STPs), one for PDO camp and two for contractor's camps.

3.2 Activity Description

The major production related and associated activities performed in the asset may be summarised as below:

- Extraction of reservoir fluid from oil fields and transporting it to gathering stations
- Separation of associated gas from the reservoir fluid in the gathering stations
- Separation of produced water from degassed crude
- Stabilisation of crude oil by separating unstable condensates
- Exporting of crude oil to Mina Al Fahal storage tank
- Compression of associated gas for re-injection and export
- Abstraction of groundwater and desalination
- Generation of power using gas fired gas turbines
- Disposal of produced water by injection into deep aquifers
- Treatment of liquid effluents
- Disposal of solid waste
- Flaring of associated gas that is unutilised or re-injected

In addition to the above production activities, the following developmental and construction activities are also performed at some locations within the asset throughout the year:

- Seismic survey
- Drilling
- Well construction
- Pipeline construction and maintenance
- Road construction and maintenance
- Power line construction and maintenance
- Well closure and site restoration

A schematic diagram illustrating the major production related and associated activities performed in the asset is shown in Figure 3.2. A brief description of the major facilities and activities in the asset are discussed in the following sections.

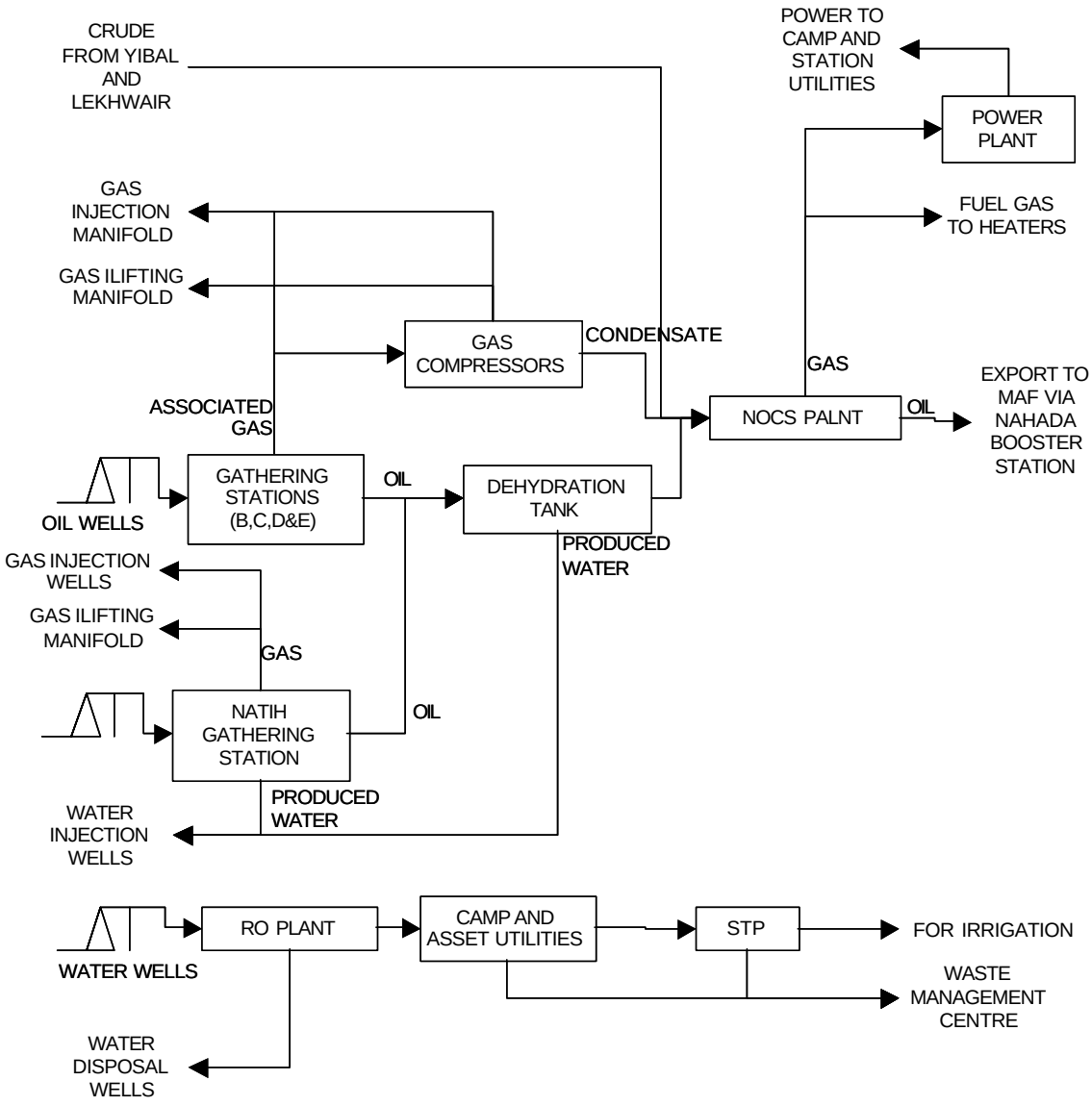


Figure 3.2: Schematic Diagram of Major Production and Associated Activities in Fahud

3.3 Gathering Stations

Crude oil in Fahud field is extracted from natural flowing wells and pumped wells using gas lifting, electrical submersible pumps (ESP) or beam pumps. The extracted fluid is transported through flow lines to gathering stations Fahud B, C, D and E. Associated gas is separated from the crude oil in production or test separators. The wet crude oil from the production separators is routed to the surge tanks for further degassing, and pumped to Fahud MLPS for dehydration for further processing. The reservoir fluid extracted from Natih field is degassed in the Natih gathering station and then sent to MLPS for dehydration and further processing. The associated gas recovered from the separators is recompressed for internal utilisation, export or re-injection into the reservoir. Occasionally, the gas is directly sent for flaring.

3.4 Main Line Pumping Station

The main line pumping station (MLPS) consists of the dehydration tanks and the stabilised crude export facilities. The degassed crude from the various gathering stations in the asset is dehydrated in six dehydration tanks. The crude enters each tank through a sparger and the phase separation takes place by gravity. A floating roof supports the oil draw-off funnel to ensure that no water is drawn to the oil line. An oil detector is provided on the water outlet line to ensure that no oil enters the water header. Water from the dehydration tanks drains into a skim tank where any remaining oil is separated from the water phase. The oil is skimmed off to an oil saver sump from where it is pumped back to the dehydration tanks.

The dehydrated crude from MLPS is sent to North Oman crude stabilisation (NOCS) plant in Fahud for separating the unstable condensates. The stabilised crude from the NOCS plant is sent into the crude oil storage tanks located in MLPS, and from there the crude is pumped to the crude export pipeline. The produced water separated in the dehydration tanks is disposed and re-injected into the reservoir.

3.5 North Oman Crude Stabilisation Plant

The purpose of the crude stabilisation is to remove and recover the unstable condensates in the crude after dehydration. The NOCS plant in Fahud is a common crude stabilisation facility for the dehydrated crudes produced from Fahud, Lekhwair and Yibal assets. The dehydrated crude is called “live” if it contains unstabilised condensates. The dehydrated crudes produced from Yibal and Lekhwair are live, but the dehydrated crude from MLPS is not live. Nevertheless, Fahud crude is sent to the

NOCS plant in order to dilute the unstabilised fluids from Yibal and Lekhwair, thereby allowing recovery of more condensates in the NOCS plant.

In the NOCS plant, the live crude enters the vacuum separators through inlet nozzles fitted with proprietary design Schoepentoeter inlet devices for vapour-liquid separation. Each vacuum separator operates at an absolute pressure of 88 - 95 kPa. The liquid fraction is sent to the crude storage tanks in MLPS. The off-gases from the separators are compressed first in liquid ring vacuum compressors (LRVC) and then in a 3-stage compressor system to a pressure of about 41 bar. The condensate from the compressor is then sent to the condensate stabiliser. The condensate stabiliser consists of a reboiler and 19 trays including 17 valve trays, one chimney tray (third from the top) and a bubble cap tray (at the bottom of the column). The rebolier is a kettle type heat exchanger, heated by hot water flowing in the tubes. The stabilised condensate from the reboiler is cooled and sent to the crude storage tanks.

The vapour from the top of the stabiliser column is condensed in the air-cooled condenser, collected in the stabiliser reflux drum and returned to the reboiler. The uncondensed gas from the condenser is sent to the gas line.

3.6 Power Station

Electrical power is required in the asset for supporting the various production and auxiliary activities and in the accommodation facilities. The total power demand in the asset currently is 31.0 MW, out of which, 27.1 MW power is generated internally in the Fahud power plant and the excess power required is imported from the grid. The power plant is operated on open cycle, with no waste heat recovery. The associated gas produced within the asset is used as the fuel. The details of the power plant are given below in Table 3.2.

Table 3.2: Details of Power Plant In Fahud Asset

Specifications	Power Plant at Fahud
Total generating capacity	30 MW
Number of gas turbines	1
Make and model of gas turbines	Frame 6
Fuel used	Associated gas (100%)
Fuel consumed per day	191,000 Sm^3
Emission control system used	None
Number of stacks	1
Stack height	15 m (approximate)
Stack exit diameter	4.3m
Stack gas exit temperature	560 - 595^oC

3.7 Water Treatment Plant

The groundwater extracted in the asset is brackish and requires desalination for process and domestic use. The water used in drilling however does not require desalination. Groundwater extracted from Awaifi area is directly used by the drilling rigs without any treatment. Groundwater abstracted from the Umm er Radhuma aquifer is desalinated in RO plants to meet the process and domestic water requirement. The total desalinated water requirement in the asset is presently 1,624 m^3/d. The details of the existing water treatment plant are given in Table 3.3 below.

Table 3.3: Details of Water Treatment Plants in Fahud

Specifications	MLPS RO Plant	Contractor RO Plant
Total freshwater production capacity	800 m^3/d	1110 m^3/d
TDS of treated water	164 mg/L	212 mg/L
Type of desalination	Reverse osmosis	Reverse osmosis
Number of units Total flow rate of inlet stream	Two 1600 m^3/d	Four 2220 m^3/d
TDS of feed water	9913 mg/L	10874 mg/L
Total flow rate of reject stream	800 m^3/d	1110 m^3/d
TDS of reject stream	19639 mg/L	21500 mg/L

3.8 Auxiliary Facilities

3.8.1 Overview

The major auxiliary facilities in the asset include the following:

- Production water injection system
- Sewage treatment plants
- Waste management centre
- Production chemistry laboratory
- Maintenance workshop
- Accommodation facilities
- Miscellaneous facilities

A brief description of these facilities is presented below.

3.8.2 Produced Water Injection System

The entire quantity of produced water separated from the crude in the MLPS is re-injected into the Fahud Shuaiba reservoir for pressure maintenance. Presently the total quantity of produced water re-injected is in the order of 11,000 m^3/day. There are 13

water injection wells in the asset.

3.8.3 Sewage Treatment Plants

There are three sewage treatment plants in the asset. One plant of 320 m^3/d capacity is dedicated for the treatment of sewage generated from the PDO camp. Another two plants of 320 m^3/d and 375 m^3/d capacity are dedicated for the treatment of sewage generated from the contractor camps. The details of these facilities are presented in Chapter 4.

3.8.4 Waste Management Centre

Fahud asset has a centralised waste management centre for the disposal of both non-hazardous and hazardous wastes. The facility also includes a land farm for the treatment of oily sands. Fahud waste management facility does not handle NORM wastes, which are sent to a dedicated storage / disposal site in Zauliyah. The details of the waste management centre are presented in Chapter 4.

3.8.5 Production Chemistry Laboratory

Fahud asset has a laboratory facility for the analysis of oil and gas quality, produced water analysis and effluent analysis. This facility, known as production chemistry laboratory, is located within the administrative area. Necessary laboratory equipment required for chemical, thermo-physical and biological analysis are available in the facility with resident analytical staff. This laboratory also serves the Lekhwair asset.

3.8.6 Workshops

A general maintenance workshop and an automotive maintenance workshop are located within the asset. In addition, there are also several small workshop units at work sites. Oily wastes generated from these workshops are collected separately and sent to the waste management centre for disposal.

3.8.7 Accommodation Facilities

There are five permanent accommodation camps located within the asset. The PDO camp is exclusive for the PDO staff and their visitors. The other camps are for the contractor staff and their visitors. All these camps have catering and laundry facilities and all the rooms are fully furnished and air-conditioned. The details of accommodation facilities are summarised below in Table 3.4.

Table 3.4: Accommodation Facilities in Fahud Asset

Item	Description
Total number of permanent camps	Five including one PDO main camp and five contractor camps (PAC: 2, Halliburton: 1, Schlumberger: 1 and OFSET: 1)
Total number of mobile camps	Presently two (for Rig 52 and Rig 72).
Total number of housing units and total number of PDO staff (and visitors) accommodated at any time in PDO main camp Total number of housing units and total number of contractor staff (and visitor) accommodated at any time in contractors camp	Rooms: 820 Occupancy: 560 (48 rooms are unoccupied) Rooms : 992 Occupancy : 1725
Typical number of staff accommodated at any time in each mobile camp	60
Total number of canteens in the permanent camps	PDO camp: 2 (one for PDO staff and one for catering staff) Contractor camps: 11 (Halliburton: 2, Schlumberger: 2, OFSET: 2, Tawoos: 2, and Sahara: 3)
Total number of laundries in the camps	One laundry at each camp
Recreation facilities available in PDO main camp	Playing area (for tennis, volleyball etc.) Swimming pool Gymnasium and Indoor games area Auditorium, conference rooms, TV room and reading room Mosque

3.8.8 Miscellaneous Facilities

The administrative offices are located in a large building called the Camp Main Office. Other facilities available within the asset include a medical clinic, shops, ROP station, fire station, airstrip, vehicles for transportation etc.

3.9 Developmental and Construction Activities

3.9.1 Overview

Developmental and construction activities are carried out in the asset throughout the year, at some locations. At a site, these activities are of short duration ranging from few days to few weeks. These activities include seismic survey, drilling and well completion, pipeline construction and maintenance, road construction and maintenance, power line construction and maintenance, well closure and site restoration. The detailed description of these activities is presented in the individual EIA report for each of the service assets. A brief description is provided below.

3.9.2 Seismic Survey

Seismic survey is carried out for locating the new oil fields. This survey is carried out by the Exploration Asset Team. The seismic survey involves the mobilization and operation of survey equipment such as vibrator trucks and geophones, any site preparation work and management of on-site accommodation camps (mobile camps). Typically, the survey activity at a site lasts for 4-12 weeks.

3.9.3 Drilling and Well Completion

Drilling of exploration and production wells is a major construction activity with significant environmental aspects. Contractors under the supervision of the Exploration Asset Team carry out exploration drilling, while contractors under the supervision of the Well Engineering Asset Team carry out the drilling of producing wells. Drilling and well completion process involves the following sub-processes.

- Well pad preparation, which included site levelling, construction of access road for the rigs, construction of water and waste pits etc.
- Mobilization of drilling rig by road using over 20 trucks
- Setting up of rotary drilling rig on well pad with ancillary facilities (power generation unit, fuel storage, waste oil storage, drilling mud / chemical storage, accommodation / office and sewage treatment / handling)
- Preparation of water based or oil based muds for well drilling
- Continuous drilling, with drill string casing and cementing for protection of shallow aquifer
- Discharge of drilling mud and drill cuttings into a dedicated, fenced waste pit at each well pad
- Well completion and installation of wellhead (Xmas tree)

Typically, well pad preparation takes 4-7 days, rig mobilization up to 10 days, drilling about 2 weeks and well completion about 1-2 days. The drilling team stays on-site in mobile camps. Up to 150 personnel may be involved in the drilling team.

3.9.4 Pipeline, Road and Power Line Construction and Maintenance

The laying of new pipelines and the repair / replacement of defective pipelines is undertaken by the Infrastructure Asset Team. Laying of new pipelines may involve site preparation including removal of vegetation, to lay out the pipes as well as to provide access roads. For a new pipeline, hydrotesting is carried out prior to commissioning.

Road laying and maintenance involve the use of construction equipment such as bulldozers, road rollers etc. and may require importing to site construction materials such as gravel, stone aggregates, asphalt etc. This process also requires significant quantity of water for wetting and dust suppression.

Laying of new power lines and the maintenance of existing power lines is supervised by the Infrastructure Electrical Team. This activity normally does not involve major site preparation since the power lines are normally laid along the pipeline access roads.

3.9.5 Well Closure and Site Restoration

As wells dry out over a period of time, well closure is also a continuing activity in the assets. This activity is also carried by the Well Engineering Asset.

Well closure involves the removal of both surface and sub-surface structures from the well site. The surface structures include the production and auxiliary equipment, flow lines, storage tanks, above ground steelwork and concrete. The sub-surface structures include the foundations, well casings, etc.

The site restoration first involves the removal of any soil found to be contaminated with oils or chemicals, then sending these soils for remediation or disposal. After the removal of structure and the equipment from the site, all efforts will be made to restore the landscape of the site, so that it integrates well with the surroundings. Where possible, the site will be restored to a level so that it can be put to a useful purpose.

3.10 Materials and Utilities

The production of oil does not require any raw materials. However, a large number of process chemicals are used in drilling, dehydration of crude, water treatment, scale control, corrosion control and wastewater treatment. The various process chemicals used in the asset are grouped together based on their application and the quantities consumed during the year 2002 and are given in Table 3.5 below.

Table 3.5: Consumption of Process Chemicals in Fahud Asset

Name of Process Chemical	Physical State and Chemical Nature	Purpose	Quantity Consumed per Year
Water based muds		For drilling	Quantity unknown
Oil based muds		For drilling	Quantity unknown

Name of Process Chemical	Physical State and Chemical Nature	Purpose	Quantity Consumed per Year
Demulsifier	Liquid; mixture of aliphatic and aromatic hydrocarbons; surface active agents	Used in dehydration of crude and deoiling of production water	150 L/d
Defoaming agents	Liquid; mixture of aliphatic and aromatic hydrocarbons; surface active agents	Used in dehydration of crude and deoiling of production water	Currently not used
Scale inhibitors	Liquid; mostly organic phosphates	Used in RO plant for scale control	15 L/d
Corrosion inhibitors	Liquid; surface active agents in alcohols	Used in RO plant pipelines for corrosion control	385 L/d
Oxygen scavengers	Liquid; surface active agents in alcohols	Used in pipelines for corrosion control	80 L/d
Acids, alkalis and chelating agents	Liquid or solid; reactive and corrosive	Used in RO plant for membrane cleaning	EDTA: 3 kg/month Caustic soda: 3 kg/month
Chlorine or hypochlorite solution	Liquid or tablets; strong oxidant	Used in RO plant and STPs for disinfection	212 kg/month
Biocides	Liquid	Used in pipeline during pigging for control of fungal growth	400-600 L/week
Flammable gases in cylinders	Pressurised gas, flammable	Cooking gas	Quantity unknown
Inflammable gases in cylinders	Pressurised gas	Welding gas	Quantity unknown
Solvents	Liquid	Painting	Quantity unknown

Note: All these chemicals are transported by road in trucks

The quantities of electrical power, fuels and freshwater consumed in the asset for the year 2002 are given below in Table 3.6.

Table 3.6: Consumption of Power, Fuels and Freshwater in Fahud Asset

Utility	Consumer	Average Quantity Consumed per Day during 2002
Electrical power	Oil fields, gathering stations, water injection plant, NOCS, MLPS and accommodation and auxiliary facilities	737 MWh
Associated gas	Fahud power plant for power generation	191,000 Sm^3
	MLPS and NOCS for heaters and compressors	480,000 Sm^3
	Total	671,000 Sm^3
Freshwater (desalinated)	For process and domestic use	3730 m^3

4 RELEASES TO ENVIRONMENT

4.1 Introduction

In this section, the various waste products and energies released into the environment from the various activities performed within the Fahud asset are discussed. The activities in the asset may be classified into the following groups, based on their nature:

- Activities related to production
- Activities related to generation of utilities
- Activities related to support services
- Activities related to construction, maintenance and decommissioning

The ***production related activities*** include all the activities performed in the oil fields, gathering stations, production station, crude stabilisation plant and pipelines. The ***activities related to utilities*** include the activities performed in the power station, sewage treatment plants and water treatment plants. The ***activities related to support services*** include catering, laundry, air conditioning etc. performed within the PDO and contractor camps; waste handling, treatment and disposal activities; and other activities such as transportation and workshops. All the activities are more or less continuous in nature and are site-specific.

The ***activities related to construction, maintenance and decommissioning*** include seismic survey, drilling, well construction, laying and repairing the pipelines, laying and repairing the roads, well closure etc. These activities are carried out almost throughout the year at some site or the other within the asset. However, at a particular site, these activities are essentially temporary (short duration) in nature and of very localized impact. Therefore, any wastes generated from these activities are not discussed here unless they have a long resident time (ex: drilling wastes). However, a detailed analysis of wastes arising for these activities are considered separately under the relevant EIA study for the service asset.

The wastes released into the environment from all the above activities are classified into the following groups, based on their physical state as well as nature:

- Air emissions
- Liquid effluents
- Solid wastes
- Noise

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. Where estimates based on theoretical or empirical equations are considered not reasonably accurate, recommendations are made for direct measurement.

4.2 Air Emissions

4.2.1 Overview

The air emissions in the asset for the purpose of this report are classified into the following categories:

- Stack emissions
- Flare / vent emissions
- Area source emissions
- Mobile source emissions

While most of these emissions are continuous and long term ones, there are other temporary sources from which the emissions are intermittent and of short duration. These sources, such as the equipment used for exploration, drilling, construction or maintenance purposes are operated for a short duration at any given site. As stated earlier (refer Section 4.1), the emissions from the temporary sources are discussed elsewhere and not included in this report. The discussion on the various emission sources in the asset, their quantification, characterization and emission control is presented in the following sections.

4.2.2 Stack Emissions

Stack emissions are the most dominant air emissions in any asset by virtue of their number and the quantity of emissions. The sources of stack emissions include the gas turbines (used in power stations for power generation and in booster stations and production stations for mechanical drive), heaters used in the production stations and the standby diesel generators used for emergency power supply. The emissions from standby diesel generators are very infrequent and hence of no significance. Hence, they are not considered further in this report.

The inventory of stacks in the asset is presented below in Table 4.1.

Table 4.1: Inventory of Stacks in Fahud Asset

Location	Gas Turbine Stacks	Heater Stacks	Total Number of Stacks
Natih Station	5 (Gas lift compressors: 3 Solar and 2 Dresser)	1 (Water bath heater)	6
Fahud B Station	2 (Gas lift compressors)	0	2
Fahud C Station	2 (Gas lift compressors)	0	2
Fahud D Station	2 (Gas lift compressors)	0	2
Fahud E Station	2 (Gas lift compressors)	0	2
Fahud F Station	4 (Gas compressors)	0	4
Fahud MLPS and NOCS	0	1 (Water bath heater)	1
Nahada Booster Station	6 (Booster pumps)		6
Fahud Power Station	1	0	1
Asset total	24	2	26

Note: Minor stacks such as standby diesel generator stacks are not included, since emissions from these stacks are very infrequent and emissions loads are relatively insignificant

The fuel burned in all the above systems is the associated gas produced in the asset. The detailed analysis of the fuel gas used in the asset is shown in *Appendix 2*. The emissions are the products of combustion. The pollutants of concern in these emissions are sulphur dioxide (SO_2), oxides of nitrogen (NO_X), carbon monoxide (CO) and particulate matter (PM), which is primarily due to unburnt hydrocarbons (HC), which are released as fine particulates of <10µm size (PM_{10}) with a significant fraction under 2.5µm size ($PM_{2.5}$). Further, the emissions also contain significant quantity of carbon dioxide (CO_2), which is a greenhouse gas.

The detailed information on the stack design specifications, exit temperature, exit velocity, total gas flow rate, heat emission rate and the emission rates of individual pollutants for each stack is presented in *Appendix 3*. It may be noted that the stack emissions are not regularly monitored in the asset. Instead, the emission rates are estimated based on empirical emission factors, as described in *Appendix 3*. The emission inventories for all the assets are summarized in Table 4.2 below.

Table 4.2: Emission Loads from Stacks in Fahud Asset

Area	Fuel Gas Consumed in 1000 Sm^3/d	Quantity of Emissions					
		Heat (10^6 MJ/d)	CO_2 (tpd)	SO_2 (tpd)	NO_X as NO_2 (tpd)	CO (tpd)	PM_{10} including HC (tpd)
Natih Station	105.62	NA	313.7	0.3	0.8	0.0	0.1
Fahud B Station	43.52	NA	113.7	0.1	0.3	0.0	0.0
Fahud C Station	54.59	NA	150.1	0.1	0.4	0.0	0.0
Fahud D Station	45.85	NA	119.8	0.1	0.3	0.0	0.0
Fahud E Station	68.17	NA	193.1	0.2	0.5	0.0	0.0
Fahud F Station	143.21	NA	401.7	0.4	1.0	0.0	0.1
Fahud MLPS and NOCS	16.86	NA	58.0	0.1	0.1	0.0	0.0
Nahada Booster Station	100.00	NA	261.3	0.3	0.6	0.0	0.0
Fahud Power Station	191.00	NA	499.0	0.5	1.2	0.1	0.1
Asset total from all stacks	768.81	NA	2110.3	2.1	5.1	0.1	0.4

Note: For the cells marked NA, data are not available and not reported.

Particulate emissions are not significant for gas fired systems. Particulate emission controls are required only for fuels such as solid fuels and heavy petroleum residues with significant ash content. The HC emissions along with CO emissions are minimised due to high combustion efficiency of the fired systems, and therefore do not need any specific control systems.

SO_2 emissions depend on the sulphur content (or the hydrogen sulphide concentration) in the fuel gas. In Fahud asset, the hydrogen sulphide concentration varies widely from 0 to 120 ppm. There are no provisions in the asset for desulphurisation of either the fuel gas or the flue gas. Therefore, SO_2 concentration in the stack emissions can be quite significant at times. There is no Omani regulatory standard or PDO specification for maximum permissible SO_2 concentration in the stack emissions. However, PDO specification SP-1005 requires that SO_2 emission load must not be breached than that the ambient air quality standards (refer Table 2.5 in Chapter 2).

NO_x emissions from standard combustion systems in the gas turbines can be quite significant. While there are no Omani specifications presently, PDO specification SP-1005 requires that NO_x emission concentration shall not exceed 200 mg/Nm^3. No data

are available on NO_x concentrations in the stack emissions and no NO_x emission control systems are provided for any of the combustion systems.

4.2.3 Flare / Vent Emissions

Flares and vents are installed in the asset to release into the atmosphere any associated gas that cannot be utilised or re-injected into the reservoir. PDO has a "no continuous venting" policy, which requires that gases are flared (combusted at the flare tip) such that no unburned hydrocarbons are released into the atmosphere. Venting is permitted only under abnormal conditions such as insufficient gas pressure or quantity to support the flame. In PDO's terminology, vent is an unlit (cold) flare and as such, there is no physical difference between a vent and a flare. Three types of flares / vents exist in PDO, *viz.*, high pressure (HP) flare / vent, low pressure (LP) flare / vent and atmospheric pressure (AP) flare / vent. The principal difference is that the gas guage pressure is greater than 150 kPa for HP flare / vent, 0.5 to 150 kPa for LP flare / vent and less than 0.5kPa for AP flare / vent.

The constituents in the flare emissions are not different from those of stacks, except for their composition. Generally, the emission factors (tonnes emission per tonne of gas flared) for CO and HC from the flares are substantially higher than those for stacks. The SO_2 emissions depend on the sulphur content in the gas flared. NO_x emissions will be slightly higher than that from a gas turbine fitted with DLN burner. The emission factors for flares in PDO are estimated based on Tier 3 emission factors given in the Shell group specification EP 95-0377 on "Quantifying Atmospheric Emissions" (*Reference 3*), as below:

CO_2	: 27.5 x E kg per tonne of gas flared
CO	: 8.7 kg per tonne of gas flared
NO_x as NO_2	: 1.5 kg per tonne of gas flared
SO_2	: 20 x S kg per tonne of gas flared
HC	: 3 x (100 - E) kg per tonne of gas flared
Smoke index	: Ringlemann 1

where E is the flare efficiency (assumed to be 95%) as percentage and S is the mass percentage of sulphur in the fuel gas. In the case where the flare is unlit (cold vent), the emissions have the characteristics as the vented gas.

The concentrations of pollutants, mainly HC, CO and NO_x in the flare emissions are controlled by proper design of the flare tip. The basic principle is to ensure near complete combustion through good entrainment of air for combustion, good fuel-air

mixing and flame stability. All the flares are currently designed such that the smoke index, which a measure of combustion efficiency is Ringlemann 1 or lower.

The emissions from the flares / vents in the asset for the year (2002) are presented below in Table 4.3.

Table 4.3: Inventory of Emissions from Flares / Vents in Fahud Asset

Area	Number of Flares / Vents	Quantity of Gas Flared / Vented (10^3 Sm^3/d)	No. of Hours Vented per Year	Heat Emission Rate (10^5 MJ/d)	CO_2 Emission Rate (tpd)
Natih Station	2 (1 LP +1 AP)	49.69	0	21.82	140.2
Fahud B Station	2 (1 LP + 1 AP)	17.53	0	7.24	43.5
Fahud C Station	2 (1 HP + 1 LP)	16.59	0	7.27	43.3
Fahud D Station	2 (1 LP + 1 AP)	17.58	0	7.25	43.6
Fahud E Station	2 (1 LP + 1 AP)	13.90	0	6.40	37.4
Fahud F Station	1 (1 LP)	43.69	0	15.45	116.4
Fahud MLPS + NOCS plant	1 (1 LP)	4.25	0	2.51	13.9
Asset total	**12 (1 HP + 7 LP + 4 AP)**	**163.24**	**0**	**67.96**	**438.3**

4.2.4 Area Source Emissions

The area sources for air emissions in the asset includes the following:

- Bulk storage tanks
- Waste disposal sites
- Sewage treatment plant (STP) sites
- Wastewater lagoons and excavation sites

For area sources, ***bulk storage tanks*** account for most of the air emissions. The air emissions from bulk storage tanks are basically the hydrocarbon vapour losses into the atmosphere due to evaporative pressure build-up in the tanks and their purging during tank fillings. Among the bulk storage tanks, only the crude oil and associated gas storage tanks are considered as significant area sources, while the storage tanks of small capacities for petroleum products are disregarded.

The ***waste disposal sites*** include the dump sites / landfill sites, land farms for contaminated soils and drilling waste pits. The emissions from these sites may include hydrocarbon vapours (due to surface evaporation), dust (due to wind dispersal) and other noxious gases (due to waste decomposition).

The ***emissions from STP sites and the wastewater lagoons*** are basically the odorous vapours such as sulphides and amines. They are released only under septic conditions, which rarely exist in the asset.

The ***excavation sites*** are basically associated with well pad construction. The emissions are basically dust risings and temporary in nature. Hence they are not considered in this report.

Only hydrocarbon emissions are considered significant in quantity from area sources in PDO. The hydrocarbon vapour emissions from all significant area sources are estimated based on Tier 3 emission factors given in the Shell group specification EP 95-0377 on "Quantifying Atmospheric Emissions" (*Reference 3*):

Fixed roof tank	: 131.765 grams per tonne of throughput
Internal floating roof tank	: 0.235 grams per tonne of throughput
External floating roof tank	: 1.000 grams per tonne of throughput

The above emission factors are based on USEPA's AP-42 methods. It is assumed in PDO that 15% of the total hydrocarbons emissions are methane and the remaining 85% are non-methanes.

Crude oil storage tanks are identified as the principal area sources of air emissions, and the emissions from these sources are hydrocarbon vapours. The details of the crude oil storage tanks in the asset and the estimated hydrocarbon vapour emissions from these sources are presented in Table 4.4 below.

Table 4.4: Air Emissions from Area Sources in Fahud Asset

Description of Source	Tank type	Tank Capacity (m^3)	Throughput Rate (tpd)	Total Hydrocarbon Emission Rate (tpa)
Natih Station: Dehydration tank: One	Fixed roof	1591 m^3	Data not available	0 (See Note 1)
Fahud B Station: Surge tank: Two	Fixed roof	276 m^3 (each)	Data not available	0 (See Note 1)
Fahud C Station: Surge tank: Two	Fixed roof	267 m^3 (each)	Data not available	0 (See Note 1)
Fahud D Station: Surge tank: Two	Fixed roof	267 m^3 (each)	Data not available	0 (See Note 1)

Description of Source	Tank type	Tank Capacity (m^3)	Throughput Rate (tpd)	Total Hydrocarbon Emission Rate (tpa)
Fahud E Station: Surge tank: Two	Fixed roof	267 m^3 (each)	Data not available	0 (See Note 1)
Fahud MLPS: Dehydration tanks: 6	Floating roof	8586 m^3 (each)	504.76	0.04
Fahud MLPS: Crude oil storage tanks: One	Fixed roof	133 m^3	504.76	0 (See Note 1)
Asset total	-	-	-	0.04

Note 1: All fixed roof ranks are provided with vents for collection of vapours and these vapours are routed to the flare. Hence there will be no direct emissions to air from fixed roof tanks.

4.2.5 Mobile Source Emissions

Motor vehicles used within the asset for the transportation of materials and men constitute mobile air emission sources. The types of motor vehicles used may be classified as light duty petrol vehicles (cars and 4-wheel drives), medium duty diesel vehicles (buses and vans) and heavy duty diesel vehicles (trucks). The significant pollutants present in these emissions are NO_x, CO and PM_{10}, which includes the unburnt HC. The emission factors (mass of pollutants emitted per running kilometre) depend on the type of the motor vehicle, type of the fuel, running speed, load conditions and environmental conditions.

In PDO, the air emissions from mobile sources are estimated based on Tier 3 emission factors given in the Shell group specification EP 95-0377 on "Quantifying Atmospheric Emissions" (*Reference 3*). These are based on USEPA's AP-42 methods. However, for the sake of simplicity, EP 95-0377 specification uses common emission factors for all categories of land transport vehicles, as shown below:

CO_2	:	3200 kg per tonne of fuel consumed
CO	:	27 kg per tonne of fuel consumed
NO_x as NO_2	:	38 kg per tonne of fuel consumed
SO_2	:	8 kg per tonne of fuel consumed
HC	:	5.6 kg per tonne of fuel consumed

In the above estimates, it is assumed that all vehicles are diesel driven, moderately aged and the sulphur content in the fuel is 0.4% by mass.
The estimated total emissions from mobile sources in the asset are given in Table 4.5 below.

Table 4.5: Air Emissions from Mobile Sources in Fahud Asset

Parameter	Quantity
Total number of land vehicles operating in the asset (PDO and Contractors)	Not available
Total quantity of fuel consumed – petrol	418.4 tpa
Total quantity of fuel consumed – diesel	14,428.8 tpa
Total quantity of fuel consumed – all fuels	14,847.2 tpa
Total emission of CO_2	47,511.0 tpa
Total emission of CO	400.88 tpa
Total emission of NO_x	564.19 tpa
Total emission of HC	83.14 tpa

4.3 Liquid Effluents

4.3.1 Overview

The liquid effluents in the asset may be classified into three groups *viz.*, continuous, intermittent and accidental. The different effluent streams in each group include the following:

- Produced water (continuous)
- Water treatment plant rejects (continuous)
- Sewage (continuous)
- Vessel washings (intermittent)
- Hydrotest water (intermittent)
- Drilling wastewater (intermittent)
- Leaks and spills of oils and chemicals (accidental)

Quantity-wise, the most significant streams are produced water, water treatment plant rejects and sewage, which are continuously generated. ***Produced water*** refers to the water separated from the crude and then disposed. ***Water treatment plant*** effluents refer to the concentrated brine rejects from reverse osmosis (RO) plants and the backwash from softening plants, if any. ***Sewage*** refers to the domestic effluents generated from accommodation facilities, canteens, laundries and the wastewater generated from the various washrooms and toilets in administrative areas. Sewage generated from mobile camps used by the seismic survey and drilling teams are not considered here, since these camps stay at a site for typically 1-2 weeks only and they are handled separately.

With respect to the intermittent effluents, ***the vessel washings*** refer to the occasional washings from process tanks and vessels. ***Hydrotest water*** refers to the wastewater

that is finally disposed after hydrotesting of pipelines. ***Drilling wastewater*** refers to the wastewater that is finally disposed after the completion of oil well drilling.

The ***oil and chemical leaks and spills*** occur only accidentally due to pipeline failure, storage tank failure and road accidents. The leaks and spills usually result in the contamination of soils, and therefore are considered as solid wastes rather than liquid wastes. For this reason, they are not included in this section. The leaks and spills involving water or treated sewage are not considered as waste streams, and hence not discussed in this section.

4.3.2 Quantification and Characterisation of Liquid Effluent

The quantities of the various liquid effluent streams generated in the asset are presented in Table 4.6 below, along with a brief description of their nature.

Table 4.6: Liquid Effluents Generated in Fahud Asset

Liquid Effluent	Source of Generation	Streams	Quantity Generated (m^3/d)	Typical Nature and Characteristics of Raw Effluent
Produced water (Continuous)	Production station	Re-injection Shallow disposal Deep disposal	11239 0 0 0	Water content in the reservoir fluid with high dissolved inorganic salts, traces of oil and virtually free of organic matter
		Total	**11239**	
Water treatment effluents (Continuous)	RO plants and softening plants	RO plant reject + backwash	1,624	Backwash with high dissolved inorganic salts and virtually free of organic matter
		Total	**1,624**	
Sewage (Continuous)	Accommodation facilities, canteens, laundries, toilets and wash basins	PDO STP Contractor STP-1 Contractor STP-2	326 305 384	Wastewater from domestic activities with mostly biodegradable nutrients as suspended and dissolved matter
		Total	**1015** (See Note 1)	
Vessel washings (Intermittent)	Process tanks and vessels	All	Negligible	Occasional washings with traces of oil and detergents, and virtually free of organic matter
Hydrotest water (Intermittent)	New pipeline under testing	All sources in the asset	Negligible	Wastewater after hydrotesting with traces of oil and virtually free of organic matter
Drilling wastewater (Intermittent)	New drilling sites	All sources in the asset	Not available	Wastewater from drilling activities with traces of oil, heavy metals and virtually free of organic matter

Note 1: Sewage generated from mobile camps is not included, since mobile camps do not stay for more than 1-2 weeks at a site and the effluents are separately handled.

4.3.3 Effluent Treatment

- **Overview**

The produced water is directly re-injected into the reservoir without any treatment, in order to maintain the reservoir pressure. The RO plant rejects and backwash are collected in the wastewater pit and then disposed into deep aquifer using injection wells. Sewage is treated by biological oxidation in STPs based on activated sludge process for removal of organic nutrients, and then re-used for land irrigation. With respect to the intermittent streams, they are either mixed with other compatible effluents or appropriately disposed as discussed in the following sections.

- **Produced Water**

Produced water is separated from the crude in the dehydration tanks in the production station and then directly sent for re-injection into the reservoir. The residual oil content in the produced water will be in the order of 50 mg/L. No treatment is necessary since it is returned to the same reservoir from where it came.

- **RO Plant Rejects and Backwash**

RO plant rejects and backwash are collected in a wastewater pit. This wastewater is characterised by high content of total dissolved solids (TDS), but virtually free of organic matter. From the wastewater pit, the wastewater is pumped out and disposed into UeR aquifer using two deep disposal wells. No treatment is therefore necessary.

- **Sewage**

Sewage is treated in three STPs, which are based on activated sludge process. The detailed treatment process description is presented in the environmental audit report of the STPs in PDO (*Reference 4*). A brief description is provided below.

Raw sewage from the various points of generation is pumped to STP lifting station. Then the raw sewage from the lifting station is pumped to the aeration tanks, passed through bar screens to trap large objects. In the aeration tank, the oxygen necessary for oxidation is supplied by submerged air diffusers. The sewage in the aeration tanks is internally re-circulated to ensure good mixing and to eliminate the settling of solids in the aeration tank. From the aeration tank, the effluent is transferred to a settling tank for the removal of sludge (excess biomass generated due to biological oxidation of the nutrients) by gravity settling. The sludge settled in the bottom of the settling tank is returned to the aeration tank to maintain a healthy biomass concentration

(about 4000 mg/L) in the aeration tank. Excess sludge generated in the system is removed periodically from the settling tank to the sludge drying bed.

The clarified effluent from the settling tank is passed through a sand filter to remove any remaining fine suspended particles. The sand filter is periodically backwashed with treated sewage to remove the filtered particles, and the backwash is then pumped back to the aeration tank. The filtrate from the sand filter is then disinfected before it is pumped to the storage tank. The sludge removed from the settling tank is dried in sludge drying before it is sent to the waste management centre.

There are three STPs in the asset. The first (STP/FHD-1) of 320 m^3/d design capacity is dedicated for the sewage from PDO's camp, the other two (STP/FHD-2 and STP/FHD-3) of 320 m^3/d and 375 m^3/d design capacity respectively are dedicated for sewage from the contractors' camps. The design details of the STPs in Fahud are presented below in Table 4.7.

Table 4.7: Design Specification of STPs in Fahud

Design Specifications	STP/FHD-1 (PDO Camp)	STP/FHD-2 (Contractor Camp)	STP/FHD-3 (Contractor Camp)
Hydraulic flow rate (m^3/d)	320	320	375
Loading rate (kg/d) - TSS	Data not available	Data not available	Data not available
Loading rate (kg/d) - BOD	Data not available	Data not available	Data not available
Raw sewage holding tank capacity (m^3)	Data not available	Combined Holding tank of 96.9 m^3	
Aeration tank volume (m^3)	125	386	431
Type of aeration mechanism in aeration tank	Submerged air diffusers	Submerged air diffusers	Submerged air diffusers
DO maintained in aeration tank (mg/L)	Data not available	Data not available	Data not available
MLSS maintained in aeration tank (mg/L)	Data not available	Data not available	Data no t available
Sludge settling tank volume (m^3)	170	192	345
Type of chlorination provided	Trichloro isocyanuric acid with 90% Cl_2 availability	Trichloro isocyanuric acid with 90% Cl_2 availability	Trichloro isocyanuric acid with 90% Cl_2 availability
UV treatment	Capacity of 25m^3/h	No UV treatment	No UV treatment
Treated sewage tank volume (m^3)	Data not available	Data not available	Data not available
Size of sludge drying beds (m x m x m)	Data not available	7.2 m x 5.0 m x 1m (4 units)	7.2 m x 5.0 m x 1m (4 units)

- **Intermittent Effluents**

The major intermittent effluents include the hydrotest water and the drilling wastewater. Hydrotesting is performed only for the new pipelines. Since no new

pipelines are laid out in the asset recently, no effluent is generated from hydrotesting in the asset. The standard practice in PDO for the disposal of hydrotest water states that if the hydrotest water quality meets the discharge standards (refer Table 2.7), it will be drained into the desert. If not, it will be sent to the production station for disposal along with the produced water.

The total quantity of wastewater generated from drilling activities in the asset depends on the frequency and duration of drilling. The standard practice in PDO for the disposal of drilling wastewater is to collect the wastewater in a waste pit and allow it to slowly evaporate by solar radiation. The sludge generated after drying will be disposed as oily sludge or contaminated soil.

4.3.4 Effluent Disposal

- **Quality of Treated Effluents**

The typical characteristics of the treated effluent streams are presented in Table 4.8 below. The characteristics of production water and water treatment plant effluents are based on the analysis of periodic samples collected and analysed by PDO during the year 2002. The characteristics of sewage are based on the analysis of periodic samples collected and analysed by the STP operator during the year 2002. The intermittent effluent streams are not routinely analysed. Hence their characteristics presented below are based on limited analysis. The detailed analytical results of the continuous effluent streams are presented in the environmental audit reports for the year 2003 (*Reference 4*).

Table 4.8: Typical Characteristics of Treated Effluent Streams

Parameter	Units	Typical Characteristics		
		Produced Water	RO Plant Rejects	Sewage
pH	No units	-	7.5	5-8
Total suspended solids (TSS)	mg/L	-	20.0	2-39.2
Total dissolved solids (TDS)	mg/L	115,840	19,639	-
Total salinity	mg/L	-	17,667	-
Total hardness as $CaCO_3$		-	15,567	-
Total chloride as Cl	mg/L	52,530	8532	-
Oil and grease (O&G)	mg/L	50	-	-
Biochemical oxygen demand (BOD)	mg/L	Negligible	Negligible	0.1-28
Chemical oxygen demand (COD)	mg/L	Negligible	Negligible	9-72
Total ammoniacal nitrogen	mg/L	Negligible	Negligible	0->10
Faecal coliform count	per 100mL	Negligible	Negligible	0-30

Note: "-" indicates that data are not available.

- **Disposal of Produced Water and RO Plant Rejects + Backwash**

The Omani regulations (RD 115/2001, MD 145/93, MD7/84) as well as PDO's specifications (SP-1006) do not permit the discharge of these effluents into either marine waters or onto the land, principally due to the high TDS content. Therefore, SP-1006 recommends their disposal into the deep aquifers where the salinity is above 35,000 mg/L. The specification also requires that shallow disposal (where salinity is <35000 mg/L) to cease by the year 2000. The details of produced water and RO plant rejects + backwash are as below in Table 4.9.

Table 4.9: Details of Disposal of Produced Water and RO Plant Rejects + Backwash

Parameter	Description
Re-Injection (Produced Water)	
Nature of formation:	Shuaiba and Natih reservoirs
Depth from ground level:	Data not available
Salinity of aquifer:	Same as oil bearing reservoir
No. of injection pumps:	3
Total volume injected per day (2002 average):	11,239
Shallow Disposal (RO rejects + Backwash)	
Nature of formation:	Middle UER
Depth from ground level:	208-320 m (disposal depth)
Salinity of aquifer:	Data not available
No. of disposal pumps:	3
Total volume disposed per day (2002 average):	1,624

- **Disposal of Treated Sewage**

Land application of treated sewage is practised throughout PDO. The SP-1006 as well as RD 155/2001 (also MD 145/93) permit land irrigation provided the following:

- In areas with no public access: pH is 6-9, O&G O.5 mg/L, TSS 30 mg/L, TDS 2000 mg/L, BOD 20 mg/L, COD 200 mg/L and faecal coliform count 1000 per 100 mL
- In areas with public access: pH is 6-9, O&G O.5 mg/L, TSS 15 mg/L, TDS 1500 mg/L, BOD 15 mg/L, COD 150 mg/L and faecal coliform count 200 per 100 mL

In Fahud asset, the treated sewage, after filtration and chlorination, is used for the irrigation of lawns and trees using a network of PVC pipes and sprinklers, some with timing devices.

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

Table 4.10: Treated Sewage Characteristics

Parameter	Units	FHDSTP-PDO		FHDSTP-Contr.1		FHDSTP-Contr.2	
Volume of sewage treated	m^3/d	Average: Max:	326 380	Average: Max:	305 427	Average: Max:	384 445
Biological oxygen demand	mg/L	Range: Average: XN:	2-24 9 1/47	Range: Average: XN:	2-28 11 2/47	Range: Average: XN:	0-19 8 0/47
Chemical oxygen demand	mg/L	Range: Average: XN:	10-72 26 0/47	Range: Average: XN:	12-69 27 0/47	Range: Average: XN:	9-44 22 0/47
Total suspended solids	mg/L	Range: Average: XN:	3-14 8 0/47	Range: Average: XN:	4-39 12 1/47	Range: Average: XN:	2-13 9 0/47
pH	None	Range: Average: XN:	5-7.4 7 2/47	Range: Average: XN:	7-8 7 0/47	Range: Average: XN:	6-17 7 0/47
Faecal coliforms	Nos./ 100 ml	Range: Average: XN:	0-0 3 0/47	Range: Average: XN:	0-30 1 0/47	Range: Average: XN:	0 0 0/47
Ammoniacal nitrogen	mg/L	Range: Average: XN:	0-5 1 0/46	Range: Average: XN:	0-10 1 0/47	Range: Average: XN:	0-15 1 1/47

Notes: XN = Number times regulatory standards exceeded per total number of times monitored.
- = Data not available

4.4 Solid Wastes

4.4.1 Overview

Several types of solid wastes are generated in the asset. Based on the sources of generation, they may be classified as industrial, domestic and construction wastes. Some of these wastes are non-hazardous while some are hazardous.

The non-hazardous wastes include the following groups:

- Domestic and office waste
- Water based drilling mud and cuttings
- Non-hazardous industrial waste

The hazardous wastes include the following groups:

- Oil based mud and cuttings
- Sewage sludge
- Waste lubricants
- Oily sludges
- Oily sand
- Pigging sludge

- Non-recyclable batteries
- Recyclable hazardous batteries
- Transformers and transformer cooling fluids
- Clinical wastes
- NORM wastes
- Chemical wastes (including miscellaneous hazardous wastes)

The quantities of the waste generated in the asset during 2002 and their disposal are discussed in the following sections.

4.4.2 Waste Generation

The quantities of the various solid wastes generated in the asset during the year 2002 are given in Table 4.11 below.

Table 4.11: Solid Waste Generated in Fahud Asset

Waste Group	Classification	Units	Quantity Generated in 2002 Jan - Sept (9 months)
Domestic and office waste	Non-hazardous	tonnes	15,856
Water based drilling mud and cuttings	Non-hazardous	tonnes	0
Non-hazardous industrial waste	Non-hazardous	tonnes	763
Total non-hazardous wastes			16,619
Oil based mud and cuttings	Hazardous	Tonnes	Data not available
Sewage sludge	Hazardous	Tonnes	Data not available
Waste lubricants	Hazardous	Tonnes	82.5
Oily sludges	Hazardous	Tonnes	1,824
Oily sand	Hazardous	Tonnes	4,217
Pigging sludge	Hazardous	Tonnes	2,028
Non-recyclable batteries	Hazardous	Pieces	370
Recyclable hazardous batteries	Hazardous	Pieces	0
Transformers and transformer cooling fluids	Hazardous	tonnes	0
Clinical wastes	Hazardous	tonnes	Data not available
NORM wastes	Hazardous	tonnes	0
Chemical wastes (including miscellaneous hazardous wastes)	Hazardous	tonnes	3,937
Total hazardous wastes		tonnes	12,089

Among the solid waste, the clinical wastes and NORM wastes are of prime importance. Clinical wastes generated in PDO clinic includes used syringes, cotton / dressing containing blood and other body fluids, human tissue etc. This waste requires special handling and disposal due to their nature and presence of pathogens. NORM wastes are the wastes containing naturally occurring radioactive materials (NORM), which are commonly encountered during well services operations. Some oil sludges, pigging wastes, tubulars and water/well accessories from reservoir locations may

contain NORM. Any waste having radioactivity greater than 100 Bq/g (for solids) and 100 kBq/L (for liquids) is classified as radioactive waste.

4.4.3 Waste Disposal

The above wastes are disposed according to the requirements of SP-1009. The waste disposal practice in the asset is described in Table 4.12 below:

Table 4.12: Solid Waste Disposal Practice in Fahud Asset

Waste Group	Waste Disposal Practice
Domestic and office waste Water based drilling mud and cuttings	- Kitchen waste is packed in black bins / plastic bags and send to the sanitary landfill in the asset. Green waste is also sent to the sanitary landfill. - Recyclable domestic and office waste (paper, plastic, cans etc) is segregated at source, packed in yellow bins / plastic bags and sent to an external recycling facility. - Non-recyclable waste is sent to the sanitary landfill. - Unless total petroleum hydrocarbon content is >10 g/kg, they are disposed in a dedicated landfill in the Fahud waste management centre. - Otherwise, they are treated as oily sand
Non-hazardous industrial waste	- Iron scrap, electrical cable, wood, paper, metal/plastic drums are segregated at source and sent to sent to an external recycling facility. - Metal / plastic containers of non-hazardous chemicals are punctured, crushed and sent to an external recycling facility. - Non-recyclable waste is sent to the sanitary landfill.
Oil based mud and cuttings	- Sent to the waste management centre for landfilling separately.
Sewage sludge	- Sewage from septic tanks is sent to STPs for drying along with STP sludge. - Dry sludge is applied on land if it meets the specifications (SP-1006), otherwise sent to for landfilling as hazardous waste in the waste management centre.
Waste lubricants	- Sent to the oil saver pits for recycle into crude oil system.
Oily sludges	- Liquid fraction is sent to an external facility for recycling. - Solid fraction is sent to waste management centre for bio-remediation.
Oily sand	- Sent to land farm in the waste management centre for bio-remediation.
Pigging sludge	- Sent to waste management centre for landfilling, if it is not a NORM waste. - Otherwise, sent to NORM waste management centre in Zauliyah for storage and disposal.
Non-recyclable batteries	- They are packaged in refuse bags and disposed in the landfill with domestic waste.
Recyclable hazardous batteries Transformers and transformer cooling fluids	- The terminal are taped, electrolytes are drained and then sent to an external facility for recycling. - If they are PCB free (<50ppm), cooling fluids are drained and recycled to the crude oil system and the container is disposed as non-hazardous waste. - Otherwise, they are segregated and stored in the waste management centre for final disposal by a specialist
Clinical wastes	- All wastes are packaged in special yellow bags or cartons and sent to the incinerator in MAF for treatment.

Waste Group	Waste Disposal Practice
NORM wastes	- All NORM wastes are sent to waste management centre in Zauliyah for storage and disposal.
Chemical wastes (including miscellaneous hazardous wastes)	- Unused chemicals, if possible sent back to the supplier - Containers of hazardous chemicals are decontaminated, punctured / crushed and sent for recycling at an external facility - All other wastes are disposed in a dedicated landfill in the waste management centre.

4.4.4 Waste Management Centre

Fahud has a centralised waste management centre for the disposal of both non-hazardous and hazardous wastes. Further, Fahud has a dedicated land farming facility and kitchen waste dumping site. The waste management centre does not handle either clinical waste nor NORM wastes. Clinical wastes are sent to MAF for incineration and NORM wastes are sent to a dedicated storage /disposal site in Zauliyah. The complete details of the waste management centre are presented in the environmental audit report on PDO's waste management centres (*Reference 5*). They are summarized below in Table 4.13.

Table 4.13: Details of Fahud Waste Management Centre

Item	Description
Year of commissioning	Unknown
Types of waste handled Total site area (m^2)	Non hazardous, hazardous and Chemical waste Approximately 6.25 ha
Facilities available	Drum crusher and shovel are available at site.
Storage (holding) area for non-hazardous wastes	Open space is available.
Storage (holding) tank for waste oils and oil sludges	One oil pit available for the waste oil.
Storage (holding) area for chemical wastes Storage (holding) area for other miscellaneous hazardous wastes	No chemical storage facility at Fahud. Hazardous drums kept in a separate area where drainage facility is provided to drain any oil in the drum.
Sanitary landfill – size, design capacity, type of lining provided, type of leachate collection system provided and % volume filled so far	Kitchen waste is dumped in trenches of having approximate dimension of 50m x 4m x 3m. No lining or leachate collection system is provided for the landfill.
Hazardous waste landfill – size, design capacity, type of lining provided, type of leachate collection system provided and % volume filled so far	No hazardous waste landfill at Fahud waste management centre.
Land farm – total area, no. of windrows, size of each windrow	Presently, 24 windrows are operated. Each windrows of about 75 m x 3m x 0.5 m size.

4.5 Noise

4.5.1 Sources of Generation

The noise sources in the asset may be classified into the following categories:

- Continuous sources
- Intermittent sources
- Mobile sources

The major noise generating sources are present mainly in the production station, gathering stations, power stations, booster stations, RO plants, production water disposal sites and STPs. Both continuous and intermittent sources are present. The continuous sources include rotary pumps, compressors, electrical motors, burners, stacks, flares and other rotating equipment. All these sources are outdoor, stationary point sources. The intermittent sources include the pressure relief valves, standby diesel generators and some intermittently operated pumps and motors.

There are no significant noise sources in the oil fields. In all other areas such as accommodation facilities, administrative building, waste management centres, workshops etc., there are only intermittent noise sources.

The mobile sources include the normal transportation vehicles such as cars, vans, buses and trucks and construction equipment such as earth moving machines (excavators, dumpers, bulldozers etc.), rotary drilling rigs, lifting equipment (cranes and hoists), concrete mixers etc.

4.5.2 Noise Levels

Due to the presence of a large number of noise generating sources in process areas (particularly Production Station and Power Stations), it is not possible to measure the noise level at the source point for each equipment. Therefore, instead of considering all the individual sources as distinct point sources, a group of them may be treated as an area source.

Currently, no data are available on the noise levels for either point sources or area sources. It is however noticed during the site visits that at several places the noise levels are greater than 85 dB(A), which is the permissible workplace noise level without any ear protection.

4.5.3 Noise Control

All the major noise generating equipment such as pumps, motors, compressors, burners etc. are provided with standard noise control systems such sound insulation, vibration control and acoustic packages where necessary.

4.6 Accidental Leaks and Spills

In PDO, all accidental leaks and spills shall be promptly reported. There are three categories of accidental leaks and spills, as below:

- Oil leaks and spills
- Chemical leaks and spills
- Water leaks and spills
- Release of ozone depleting substances (ODS)

While water leaks and spills do not lead to any environmental consequences, they are reported as a matter of water conservation issue. ODS include CFCs, halons, HFCs and HCFCs. The use of these substances is currently phased out in PDO due to their high ozone depletion potential. Some inventories of such substances may still be found in some air-conditioners and portable fire extinguishers According to PDO's specification SP-1005, these substances are not permitted to be released into the atmosphere except in uncontrollable situations or emergencies. For the current year (2002), the leaks and spills reported in Fahud asset are summarized in Table 4.14.

Table 4.14: Accidental Leaks and Spills in Fahud Asset

Description	Incidents Reported in 2002			
	Oil Leaks and Spills	Chemical Leaks and Spills	Water Leaks and Spills	Releases of ODS (CFCs and Halons)
Total number of incidents	21	0	20	Unknown
Number of spills into wadis	0	0	0	-
Total volume leaked / spilled (m^3)	58	0	411	330 kg
Total land area impacted (m^2)	44	0	245	-
Total quantity of soil contaminated (t)	Data not available	0	Not applicable	-

5 ENVIRONMENTAL SETTING

5.1 General

In this chapter, the existing environmental conditions in Fahud asset is described and analysed. The description is largely based on the information provided in the previous EIA report (*Reference 1*). Additional information is sourced from site reconnaissance surveys conducted as apart of the present environmental assessment study (refer Section 1.3). For those environmental aspects subjected to very little change since the last environmental assessment due to the activities in the asset, only brief description and analysis are presented in this chapter. Detailed description and analysis are limited to the environment aspects that are likely to have undergone a noticeable change since the last environmental assessment. The areas where specific data are required but not available are identified.

The environmental aspects likely to have undergone noticeable change due to the asset activities include the following:

- Groundwater availability and groundwater quality
- Ambient air quality and noise
- Land use and human settlements

5.2 Location and Topography

Fahud asset is located at about 300 km southwest of Muscat. It covers a total land area of 11,580 km^2 and consists of 2 operating oil fields and 240 producing wells. Fahud production facility (MLPS + NOCS plant) is located at 2469249 N and 447160 E, and is about 130 km from Fahud by road. The topographical map of the asset is shown in Figure 5.1. The asset boundary co-ordinates are given in Table 5.1 below:

Table 5.1: Fahud Asset Boundary Coordinates

Site Boundaries	Clarke 1880 System (Easting or Northing in m)
Northern limit	2497272 N
Eastern limit	568572 E
Southern limit	2402721 N
Western limit	382695 E

The topography and landscape of most of the asset area is very similar to many other areas of central Oman, characterised by flat plains interspersed with small drainage channels and occasional rocky outcrops. Several hills of low to medium altitude are present in the area. Jabal Fahud is the westernmost, reaching to an altitude of about 275 m. The Fahud camp lies to the north of Jabal Fahud. Jabals Qudaybah (500 m),

Nahdah (400 m), Salakh (325 m), Khaydalah (530 m) and Madmar (300 m) form an arc of hills in the north-eastern part of the Asset area.

There are two major wadis in the asset *viz.*, Wadi Aswad and Wadi Umayri, both of which flow south-westwards through the asset area into the Umm as Samim sabkha. Wadi Aswad originates from the Hamrat Duru range at an altitude of around 1000 m above sea level. Wadi Umayri originates from the Hajar mountains at around 3000 m above sea level. Other wadis in the asset include Wadi Adam and Wadi Halfayn. Wadi Adam drains into the extensive wadi system of Wadi Halfayn.

The natural topography of the region is altered by the manmade structures such as production facilities and accommodation facilities erected by PDO. There are very few human settlements in the asset. The natural vegetation is composed of desert plants and grasses, and there are no major trees in the asset except in those places irrigated by PDO using treated wastewater.

5.3 Geology and Soil

Geologically southern part of the Fahud area is composed of alluvial gravel and fine silt over most of the plains, fine alluvial gravel and silt in the smaller drainage channels and coarse alluvial gravel in major wadis. The underlying rock is mostly composed of horizontal mid-tertiary limestones of Oligocene and Miocene periods, and represents seabed levels at the time of deposition. The geological cross section of the area is shown in Figure 5.2.

The central part of the Fahud asset area is composed of alluvial gravel fans arising from several wadis and drainage channels. Most of the exposed surface formations in the asset are tertiary deposits composed of limestone, dolomite, shale, clay and anhydrite. Umm er Radhuma (UeR) is the tertiary formations occurring in Fahud area.

Jabal Fahud is a NW-SE oriented surface anticline consisting mainly of outcropping UeR limestones, with the overlying younger formations having been eroded away. In the centre of the anticline Cretaceous Fiqa shales outcrop as an inlier. The Fiqa formation is highly plastic calcareous shale and this facilitates isolation of Natih reservoir from the UeR. The Natih formation is fractured limestone, inter-bedded with some shaley units.

No data are available on the soil quality in the area. 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 5.3.

2540000N
2490000N
2440000N
2390000N
400000E
450000E
500000E
550000E

N
W
E
S

SHIBKAH
MARADI LADAH
NATIH
NATIH
LOBNAH
FAHUD
SUQTAN
ADAM
AWAIFI
QALAH
Wadi Aswad
Wadi Umaym
FAHUD

LEGEND

- Permanent Human Settlements
- Bedouin Areas
- Groundwater Protection Site (YELLOW ZONE)
- Richly Vegetated Sites
- Wild Life Sites (Jabal Samhan Sanctuary)
- Archealogical Sites
- Cultural Sites (Cemetary)
- Recreational Sites
- PDO Camp
- Road
- Wadi
- Industrial Site (Crusher)

PRODUCED FOR :
شركة تنمية نفط عمان
Petroleum Development Oman

PROJECT : EIA UPDATE FOR PDO
AREA : FAHUD ASSET
DESCRIPTION : Figure 5.1
Topographical Map of Fahud Asset

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SCALE ; 1:700,000 1cm = 7km

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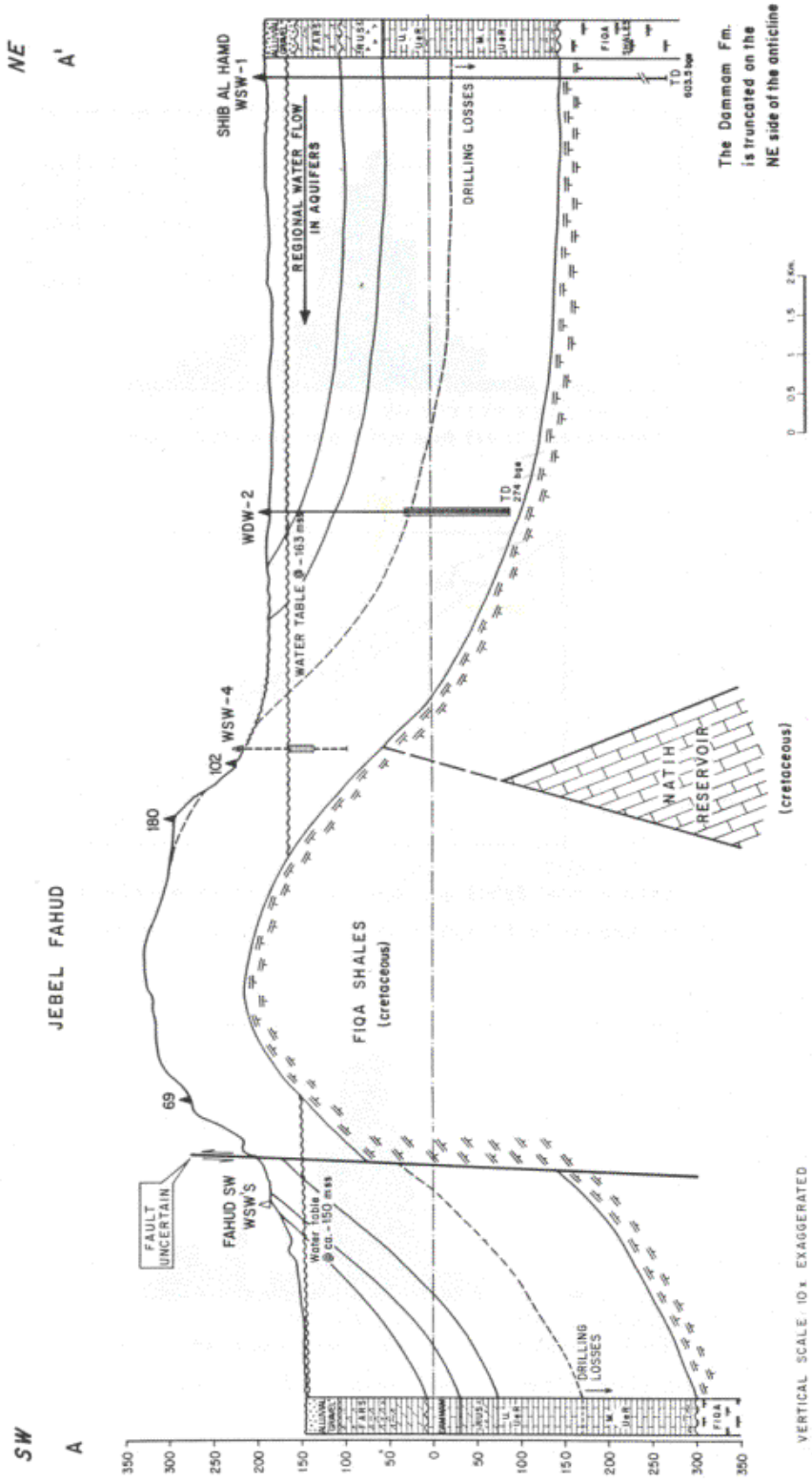

Figure 5.2: Geological Cross Section of Fahud Area

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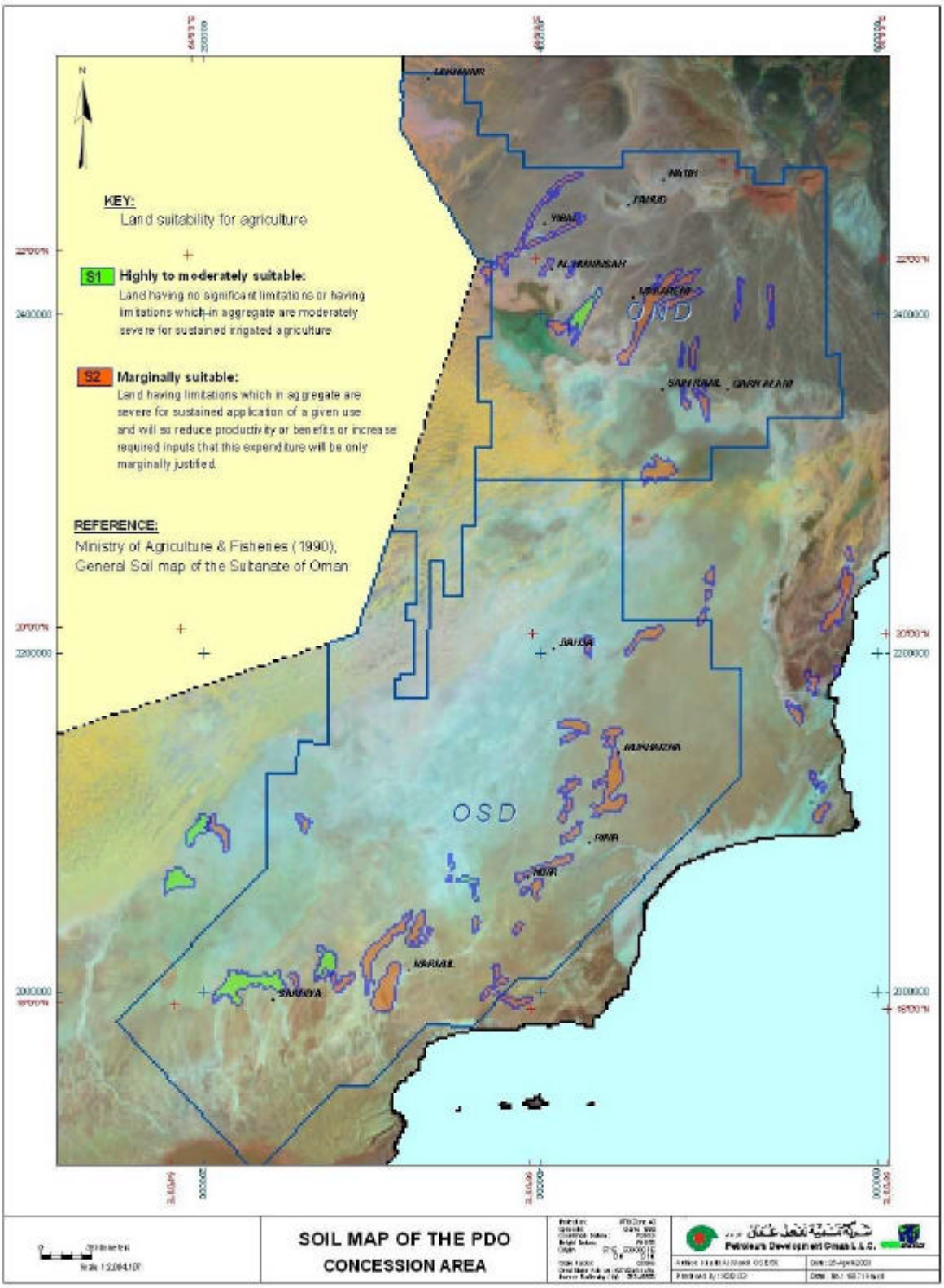

Figure 5.3: Soil Map of PDO's Concession Area

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5.4 Hydrogeology and Groundwater Quality

Subsurface water flow is present in all wadis with water wells in Wadis Umayri and Adam, which supply water to the local residents for cultivation. The UeR is the main prolific aquifer in the area. The formation is a highly porous calcareous dolomite. Salinity of groundwater in the aquifer is 12,600 mg/l. The groundwater in the UeR aquifer flows in the direction of the Umm as Samim, a basin like depression where discharge of water is caused by upward capillary percolation and subsequent evaporation. The piezometric level in the UeR is invariably below ground level in the Fahud area, although it does approach close to surface level in the low-lying northwestern tip of the field.

The well yield and water quality data for different locations within the asset are summarised below in Table 5.2. The change in water level and water quality over the past 5 years has also been shown.

Table 5.2: Well Yield and Water Quality Data in Fahud Asset

Location	Representative Water Well	Name of Aquifer	Water level		Total Dissolved Solids		Yield	
			(m)	Date	(g/L)	Date	(m3/h)	Date
Fahud	Fahud WSW-11	UeR	49.25 49.78	Dec'94 Feb'98	10.669 9.323	Dec'83 Feb'88	-	-
Natih West	Natih West WSW-2	UeR+Fiqa	18.5 8.15	Jan'92 Feb'03	6.292	Sep'95	-	-
Natih	Natih WSW-10	Shargi	22.18 18.79	Nov'92 Nov'02	31.557	Dec'79	-	-

5.5 Climate

Meteorological data were recorded in Fahud asset for the year 2002. Based on these data, the mean annual temperature is 29.3°C. The mean monthly temperatures range from 19.7°C in January (with mean minimum of 5.6°C and mean maximum of 34°C) to 37°C in July (with mean minimum of 24°C and mean maximum of 50°C). The maximum and minimum absolute temperatures are 51°C and 6°C respectively.

The mean annual rainfall in Fahud area is 20 mm. There is very little inter-annual variation in temperature, but the annual rainfall is exceptionally variable between years with little indication of seasonality. Rain has been known to fall in nearly all months of the year, although the mean monthly rainfall was the highest during February and April, with a secondary peak in August.

Tropical storms and cyclones have been known to enter the Gulf of Oman bringing torrential rain to the coast, but are rarely so widespread to reach as far west into central Oman. Storms or cyclones are practically unknown at the height of the monsoon during the summer months of July to September. However, one rare tropical storm affected much of central Oman during the last week of July 1995 bringing 200 mm of rain to the Hajar mountains and flooding its alluvial plains. Similar rains were experienced in central Oman during the winter months of 1998.

5.6 Ambient Air Quality

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

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

5.7 Ambient Noise

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

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

5.8 Flora and Fauna

The vegetation of Fahud asset area can be broadly classified as the *Acacia - Lycium – Euphorbia* vegetation type and the *Acacia-Zygophyllum-Heliotropium* vegetation type. The first is typical of the foothills and immediate plains of the northern mountains and the latter is typical of the central gravel plains of Oman. Further classification recognizes three plant communities occupying the hills, gravel plains, and the wadis.

The dominant flora are the sparse shrubs composed of *Acacia ehrenbergiana*, *Acacia tortilis*, and *Lycium shawii*. Sub-shrubs include the common *Cornulaca monacantha, Pulicaria glutinosa* and *Zygophyllum sp.* Major wadis support scattered shrubs, which include *Acacia tortilis, Acacia ehrenbergiana, Crotolaria persica, Nannorrhops ritcheana* (dwarf palm), *Pteropyrum scoparium, Tephrosia appollinea* and *Rhazya stricta*. *Prosopis cineraria* is common in wadis with sandy deposits and where there is subsurface water.

The trees are heavily browsed and palatable species show severe browse lines. Wadis and the vegetated gravel plains are dominated by unpalatable shrubs such as *Tephrosia appollinea, Rhazya stricta.* Applying IUCN Red List categories at a national scale a single taxon, *Caralluma aucheri*, is identified as threatened. *Caralluma* is a succulent genus of the family Asclepiadaceae with about 30 species distributed in SE and SW Arabia and NE Africa. In Oman there are 10 to 15 species, the majority in Dhofar and all are classified as threatened. Two species are distributed in the northern mountains and *Caralluma aucheriana* is one of them *C. aucheriana* is a slow growing succulent and is collected widely for its medicinal value as a health tonic. In the Fahud Asset area it is found on Jabal Salakh and is likely to occur on the other hills as well.

A number of mammals, birds, and reptiles are thought to inhabit this region, though their population are not considered to be significant. Among mammals, the mountain gazelle, a medium sized gazelle is widely distributed in Oman and lives in small groups. There are no estimates of the size of population of the gazelles in the asset. Other prominent endemic mammals include Rhim Gazelle and Nubian Ibex, which are currently listed on the IUCN World Red List and the Regional Red List. About 160 species of birds are found in the region, the majority of which are migratory. About 32 species are recorded as breeding or potentially breeding in the area. A number of reptiles including the agamid lizards, lacertid lizards, skink, geckoes, snakes and toads are known to exist in the area.

5.9 Human Settlements

One large town, Adam, lies within the Fahud asset area. There are several small villages such as Awaifi, Wadis Umayri and Wadi Aswad. The local people belong to a single tribe, the *Duru*. The details of the settlements located within Fahud asset area, population break-up and occupations are summarised in Table 5.3 below.

Table 5.3: Human Settlements in Fahud Asset

Village / Camp	Location	Current Total Population	Total No. of Housing Units	Main Occupations
PDO camp	Within Fahud main camp	560	820	PDO employees
Contractor camp	Just outside Fahud main camp	1,725	992	PDO employees
Adam village	110 km toward the east of Fahud main camp	8,350	1,884	Dates farming, trading, PDO Employees
Natih Village	25 km toward north-east of Fahud main camp	54	1	Employees
Wadi Umayri	55 km toward south of Fahud main camp	Not available	Not available	Dates farming, trading
Wadi Aswad	45 km toward north of Fahud main camp	511	123	Dates farming, trading
Bedouin population	Not available	Not available	Not available	Not available

5.10 Land Use

The land use in this region had undergone significant change due to PDO's exploration and production activities and facilities. Large areas of barren desert land are converted into industrial areas. The land take details by PDO for its production and associated facilities are summarised below in Table 5.4.

Table 5.4: Land Use in Fahud Asset

Facility	Total Area (m^2)
Total asset area	11,580,000
Production station	22,365
Gathering stations	73,887
Power station	30,000

While the majority of the land in the asset is barren and unutilized, there are a few farm land in the asset area. Cultivation of dates and subsistence farming are seen in Adam, with new farms to the north of Jabal Salakh and most of the smaller settlements in the Wadis. The wadis and their immediate plains are used as rangelands for domestic livestock like camels and goats.

A large piece of land of about 22 km x 7 km, known as the Royal Review Area lies to the south of Jabal Salakh. It is registered in the name of the Ministry of Defense.

5.11 Social Infrastructure and Public Services

Like most of the areas in central Oman, Fahud asset is very thinly populated area and therefore has limited social infrastructure. The recent developments associated with the oil industry have assisted to provide access to the necessary civic services.

- **Water and Electricity**

Groundwater is the only water resources in the region. Most of the potable water requirement for the population in Fahud asset, including the PDO and contractor camps is met with demineralised water from PDO's RO plants. In addition, the water supply wells in Awaifi village are also tapped directly for potable purpose.

Most of the power requirement at Fahud stations and camp is met by production at power plant at Fahud, which has an installed generating capacity of 30 MW. Additional requirement of power is met from the PDO grid.

- **Roads and Communications**

The blacktopped 2 lane national highway connecting Muscat and Salalah passes through Fahud asset. In addition, PDO maintains an extensive network of graded roads, which are open to local population. PDO also maintain two airstrips at Fahud, with regular flights. However, these flights are restricted only to PDO staff and its contractors. PDO maintains a network of telephone lines and radio transmitters in the concession area. The region is also covered by GSM telephone service.

- **Education**

There are eight primary and secondary schools in the asset area. PDO provides some financial and material assistance to the local schools.

- **Health Services**

There are no government health care facilities in Fahud asset. Private health-care facilities (clinic and ambulance services) are available within PDO's residential camps. These facilities are generally made available to the surrounding communities.

5.12 Archaeological, Cultural and Recreational Resources

Jabal Salakh has been recommended as a National Scenic Reserve by the IUCN (1986) report `Proposals for a System of Nature Conservation Areas'. It represents examples of Land Classes described as the Northern Limestone Ranges and the Northern Plains. The details of environmentally significant areas located within Fahud asset are summarized in Table 5.5.

Table 5.5: Environmentally Significant Areas in Fahud Asset

Area	Significance
Jabal Salakh	Nature scenic reserve
Wadi Natih	The wadi is considered as an area of natural beauty, with low sand dunes, mature Prosopis trees and water wells.
Humaryah and Umayri Wadi Systems and Wadi Aswad	Considered significant for the relatively rich vegetation of Prosopis and Acacia trees; for several stands of the dwarf palm trees; for providing suitable habitat for fauna, especially rodents and avi-fauna; and for providing natural grazing for livestock
Agricultural Land	The new and old city of Adam and the village of Aweifi.
Water Protection Zones	Humaryah and Umayri wadi systems, including the water wells at Awaifi.
Archaeological Sites	No areas are designated as archaeological sites. However, abundant marine fossils are present in Jabal Fahud and Natih areas.
Historical Sites	Place where the first oil well in the Fahud was drilled.
Urban Land	The new and old city of Adam and the village of Aweifi.
Agricultural Land	The new and old city of Adam and the village of Aweifi.

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 4.*

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 5*. 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 environmental impacts accrue from the asset activities. They include socio-economic, socio-cultural and ecological benefits. These beneficial impacts outweigh the adverse impacts, which are discussed in the subsequent sections. The 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 the 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% are exported. While PDO accounts for over 90% of the total crude oil produced in Oman, Fahud asset accounts for about 9.7% of the total PDO production. Thus the economic benefits from the asset are quite significant.

- Employment

The total number of permanent staff directly employed by PDO for Fahud asset is about 600. The number of permanent staff employed by PDO's contractors in Fahud asset is about 1,800. In addition, a large number of persons, including local population are also provided indirect employment to provide a number of supporting services. 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

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

- Ecology

While some adverse impacts on ecology may be expected from the asset activities, a few direct beneficial impacts on the ecology also exist. The most significant is the greening of the desert by re-using treated sewage effluents. The land within the PDO main camp and the contractor camps is significantly vegetated with trees, shrubs and lawns. 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 mineral resources
- Consumption of groundwater
- Consumption of construction and road building materials
- Land take

Potential Environmental Effects
- Depletion of natural mineral resources
- Depletion of groundwater resources
- Claim of local assets

· **Depletion of Mineral Resources**

Large quantities of crude oil (14,670 m^3/d) and associated gas (5,007,000 Sm^3/d) continuously extracted will result in the depletion of petroleum reserves in the asset. However, the environmental impact and risk resulting from this activity is not discussed here since this forms the core activity of the asset.

Almost all the construction materials are imported and not sourced from any local natural resources. For road building, stone aggregates and soil are used. Soil is sourced locally from borrow pits. Considering that their requirement is very low compared to their availability, this is not expected to have any significant adverse impact. Based on the above discussion, the overall impact on natural mineral resources is rated as below:

Impact Rating	**Depletion of Mineral Resources**
Nature of impact (beneficial / adverse) Duration of impact (short term / long term)	Adverse 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

- **Depletion of Groundwater Resources**

About 4,000 m^3/d of groundwater on average is abstracted continuously from UeR formations in this asset for process, construction and domestic use. This quantity is significant and has the potential to cause adverse impact on the groundwater resources. The magnitude of the impact depends on the groundwater balance. Currently, sufficient information is not available on the groundwater recharge rate and on the long term fluctuations in the water well yields and water levels. Nevertheless, based on the information available from the other assets, it may be considered that likelihood of adverse impact is low.

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

- **Claim on Local Assets**

The local population within the asset are very few and their demands or claim on local assets is low. Except for groundwater, there are no local claimants or competing users of natural resources. However, PDO supplies or makes available potable water for local communities from its facilities.

Land may be considered to have competing users. However, the entire area of land on which PDO operates has no alternate use, due to the poor soil quality, lack significant vegetation and harsh environmental conditions. Moreover, majority of the asset area (excluding the production facilities, accommodation facilities and pipeline corridors) are freely accessible to local population. The roads built by PDO are also freely accessible to local population.

Based on the above discussion, the overall impact on claim on local assets is rated as below:

Impact Rating	**Claim on Local Assets**
Nature of impact (beneficial / adverse) Duration of impact (short term / long term)	Adverse Long 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

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 dust from construction activities and road traffic
- 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
- Global warming
- Degradation of ambient air quality
- Rise in ambient noise level

· **Global Warming**

CO_2 and methane emissions from the asset have a potential to contribute to global warming. Since there is virtually no venting in the asset, methane emissions are negligible. CO_2 emissions from stacks, flares and vehicles are of the order of 2730 tpd. This quantity is not large enough to contribute significantly to global warming, when compared to the land area covered by the asset. Based on the above discussion, the overall impact on global warming is rated as below:

Impact Rating	**Global Warming**
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)	Slight
Potential risk level (low, medium, high and extreme)	Low

· **Degradation of Ambient Air Quality**

Dust emissions from construction activities and road traffic, and gaseous emissions from stationary and mobile sources can have potential adverse impacts on ambient air quality.

Significant dust emissions may be expected due to the site being dry gravel plain with little vegetation. However, dust emissions are not continuous and highly localized. Further, only the respirable particulates (PM_{10}), which are expected to be 35-50% by mass in the dust have significant health hazard.

There are several stationary (point and non-point) and mobile sources of air emissions in the asset. However, point sources (stacks and vents) account for most of the emission loads in the asset. These emissions release pollutants such as NO_x, SO_2, CO and unburnt hydrocarbons into air. The total emission loads of these pollutants are estimated to be the order of 3-28 tpd for each pollutant. These quantities are not

considered significant (Typically, to the order of 50 tpd) of each pollutant is permitted for release into the airshed with no significant degradation of air quality. Further, most of the asset areas are uninhabited.

It is reasonable to assume that the impact on ambient air quality in the asset will be very low. However, in the absence sufficient data on ambient air quality and atmospheric dispersion modeling, the likelihood of degradation of ambient air quality in the asset shall have to be considered medium. Based on the above discussion, the overall impact on ambient air quality is rated as below:

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

- **Noise Pollution**

Both stationary and mobile noise generating sources can adversely affect the ambient noise levels. Since the noise from mobile sources is intermittent as well as transient, most of the potential impacts are due to the continuous and stationary sources such as gas turbines, heaters, air compressors, flares, pumps, motors and other rotating equipment. While sufficient data on source noise levels are not available, it is reasonable to expect that their impacts will be highly localized and limited to less than 1 km distance. There are no human settlements in the asset areas except for PDO and contractors camps. It is however likely that some areas in these camps may be subjected to elevated noise levels. No data are currently available to check whether there is any breach of regulatory standards

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

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

Environmental Hazards
- Injection of produced water and process effluents into aquifers
- Land discharge of treated sewage effluent
- Accidental spillage of hazardous liquids
- Release of leachates from landfill sites

Potential Environmental Effects
- Degradation of groundwater quality

The injection of highly saline production water and RO plant rejects + backwash can result in degradation of groundwater quality if injected into an exploitable aquifer. However, in the asset, the produced water re-injected into the producing oil reservoir and only RO rejects are injected into shallow aquifer. The quantity of RO rejects + backwash disposed into the shallow aquifer is about 1600 m^3/d. However, shallow disposal of produced water was in practice in the asset for a long time until a few years back. It is not known how this has already affected groundwater quality and whether it will continue to affect the groundwater elsewhere in future due to groundwater hydrology.

The land discharge of treated sewage effluents, accidental spillages of oils and chemicals and the release of leachates from the landfill sites can affect the groundwater quality provided they can percolate into the groundwater table. Since groundwater table is 30-160 m below the ground level and arid weather conditions prevail in the asset, there is no possibility for such occurrence.

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

Impact Rating	**Degradation of Groundwater Quality**
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) Significance of impact (slight / minor / localized / major / massive)	High Localized
Potential risk level (low, medium, high and extreme)	High

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 take
- Land discharge of treated sewage effluent
- Accidental spillage of hazardous liquids
- Landfilling of solid wastes

Potential Environmental Effects
- Alteration of land use
- Loss of vegetation
- Degradation of soil quality

· **Alteration of Land Use**

Land take for the installation of project facilities; construction of accommodation camps; drilling of oil wells; laying of pipelines, power lines and access roads; and constructing storage and disposal sites for construction materials and waste materials can have adverse impacts on land use. The land taken for these purposes is barren and has no utility. The extent of permanent land take is marginal compared to the total available land in the asset. Majority of the land take is temporary, for the purpose of drilling of oil wells and laying of pipelines, power lines and access roads. This land is restored nearly to its natural condition after completion of the construction activities.

Based on the above discussion, the impact on land use is rated as below:

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

· **Loss of Vegetation**

Loss of vegetation is directly related to land take, and therefore the impacts are similar. In addition, the land irrigation of treated sewage effluents compensates any loss of vegetation elsewhere. The increase is vegetal cover in PDO and contractor camps is significant.

Based on the above discussion, the impact on vegetation is rated as below:

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

- **Degradation of Soil Quality**

The discharge of treated sewage effluents on land, accidental spillage of hazardous liquids and landfilling of solid wastes can potentially degrade the soil quality. The quality of treated sewage in the asset has been consistently within the regulatory standards except for rare breaches. The landfill sites have been judiciously chosen and scientifically designed to minimize any land contamination. There is no hazardous waste landfill in the asset. Hence, they are not expected to contribute significantly to soil contamination.

The accidental spillage of crude oil, mainly due to pipeline and flowline leaks leads to soil contamination. About 21 incidents of oil spills were reported in the year 2002. The total volume of the oil spill was reported as about 58 m^3 and the total land area contaminated was reported as 44 m^2. Thus it is concluded that the extent of soil contamination is negligible compared to the total land area of the asset.

Oil sludge and tank bottoms are presently treated in the land farming facility. It is likely that these wastes may contain some naturally occurring radioactive materials and therefore the land farm may show low-level radioactivity. In the absence of comprehensive radioactivity monitoring, the potential risk is assumed to exist.

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

Impact Rating	**Degradation of Soil Quality**
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)	Slight *
Potential risk level (low, medium, high and extreme)	Medium

* Oil spills are considered within the system as the area is negligible and is within the right-of-way.

6.8 Impact on Ecology and Wildlife

The potential environmental effects on the ecology and wildlife and the associated environmental hazards are listed below:

Environmental Hazards
- Land take
- Road transport of hazardous substances
- Road travel

Potential Environmental Effects
- Loss of endangered flora
- Loss of endangered fauna
- Threat to wildlife habitats

There are no endangered flora and wildlife habitats in the asset. The population of fauna are very limited. The road traffic for transportation of materials and people is not high but significant. Few road accidents with casualties of common fauna (mostly camels) were ever reported.

Overall, the impact on ecology is considered negligible.

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. Most of the impacts on social environment are beneficial, and are discussed in Section 6.2. There are also a few adverse impacts on the social environment.

The asset area is very thinly populated and there are no human settlements except for PDO and contractor camps. Therefore, the significance and magnitude of adverse impacts on social environment are very limited. The only direct adverse impact on social environment that may need to be considered is the public safety and health of the transient population across the asset.

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

Environmental Hazards
- Bulk storage of hazardous substances
- Road transport of hazardous substances
- Accidental release of toxic gases and vapours
- Deployment of large number of migrant workers

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. Bulk storage facilities are located within the production areas and therefore general public are not exposed to any consequences from storage facilities.

However, general public are exposed to road accidents involving hazardous substances. Fortunately, the major substances, crude oil and gas are transported by pipelines and not by road. With respect to accidental leaks of toxic gases and vapours, there are no such substances handled in bulk in the asset.

The deployment of large number of migrant workers can pose a threat to public health, if they carry communicable diseases or if they are carriers of parasitic diseases. Large scale deployment of migrant workers is not expected in the asset, since no major developmental activity is envisaged. Further, there are no major habitations near the project site.

As noted earlier, some of the waste transported to the disposal or treatment facilities may be hazardous, particularly NORM wastes. However, there radioactivity level is not significant to pose any public health risk.

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)	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
Degradation of ground water quality	• Adverse • Long term • High • Localized significance	• High risk	• While shallow disposal of produced water is now discontinued, the asset has a long legacy of shallow disposal. • For of RO plant rejects + backwash, shallow disposal is still in practice.
Depletion of groundwater resources	• Adverse • Long term • Low occurrence • Localized significance	• Medium risk	• In the absence of comprehensive long term data on groundwater balance and water well monitoring in the asset, the potential risk on the depletion of groundwater shall be considered to exist.
Degradation of ambient air quality	• Adverse • Long term • Medium occurrence • Minor significance	• Medium risk	• The currently available information on air quality and air emissions is insufficient to conclude that there is no breach of ambient air quality standards, particularly in the accommodation camps. Hence, the potential risk shall be considered to exist.
Increase in ambient noise levels	• Adverse • Long term • Low occurrence • Minor significance	• Medium risk	• The currently available information is insufficient to conclude that there is no breach of ambient noise standards, particularly in the accommodation camps. Hence, the potential risk shall be considered to exist

Environmental Effect	Impact Rating	Potential Risk Level	Comments
Degradation of soil quality	• Adverse • Long term • Medium occurrence • Slight significance	• Medium risk	• Accidental leaks and spills of oils are mostly responsible. • NORM survey not completed to ensure that the tank bottoms and sludges are free of NORM. • Some potential risk may also exist due to suspected occasional exceedence of effluent standards for land discharge.

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	• Stationary sources of air emissions are not monitored to check compliance with emission standards. • Ambient air is not monitored to check compliance with air quality standards.	• All continuous air emission sources such as gas turbine stacks shall be monitored for compliance. • Ambient air quality shall be monitored in accommodation camps periodically.
SP-1006: Specification for Aqueous Effluents	• Current STP monitoring frequency and schedule are inadequate. Once a day or once a week monitoring cannot detect if standards are breached during peak load times. • Technical proficiency of STP operators and supervisors is below par.	• STP monitoring frequency and schedule need to be revised to ensure compliance at all times. Monitoring frequency may be increased to 4 times per day for on-site measurements and composite samples may be taken for laboratory analysis. • All STP operators and supervisors shall be provided continuing education and training on STP operation and monitoring.
SP-1007: Specification for Accidental Releases to Land and Water	• It is likely that quantities of oil spills are under-estimated.	• The oil spills / leaks shall be minimized through better pipeline and flow line integrity management. • All oil spill / leak incidents shall be responded to promptly to minimize quantities of release as well as quantity of soil contaminated. • More accurate methods for estimating the volumes of oil spills and the quantities of contaminated soil shall be evolved.
SP-1008: Specification for Use of Energy, Materials and Resources	• Optimal use of energy and water is not demonstrated as required in the specification.	• Avenues for minimization of water consumption shall be explored. • Monitoring of water wells shall

Specification	Areas of Non-compliance or Concern	Recommended Additional Mitigation Measures
		be continued to ensure that there is no depletion of groundwater reserves over a longer term.
SP-1009: Specification for Waste Management	• Waste consignments are not properly estimated. • Some wastes, such as rig site wastes are not segregated at source as required. • Waste compaction equipment are inadequate and some are non-functional. • Waste recycling is not significant. • There is no evidence of regular wetting of land farms.	• Compliance with waste handling procedures shall be enforced. • Waste operators shall be closely supervised. • Waste recycling avenues shall be explored at corporate level.
SP-1010: Specification for Environmental Noise and Vibration	• Ambient noise levels are not monitored to check compliance with the standards.	• Ambient noise levels shall be monitored in accommodation camps periodically
SP-1011: Specification for Flora and Fauna	• None	• None
SP-1012: Specification for Land Management	• There are several abandoned well sites, which require restoration.	• Site restoration program shall be accelerated.
SP-1170: Specification for Management of Naturally Occurring Radioactive	• NORM survey in the stations is not completed.	• Comprehensive NORM survey to be completed and necessary mitigation measures to be taken, if required.

8 REFERENCES

1. WS/Atkins, *Fahud/Lekhewair assets areas Environmental Assessment Report*, July 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, *Environmental Audit Report of Sewage Treatment Plant,* April 2003

5. HMR, *Environmental Audit Report of Waste Management Centres in PDO,* April 2003

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

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

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

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

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

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

Position in PDO	Name of Reviewer	Role in Project Development
CSM/22	Dr. Muralee R. Thumarukudy	Senior Corporate Environmental Advisor
CSM/25 ONS	Ahmed Al Sabahi Devendra Upadhyay	Environmental Advisor HSE Team Leader – North
		Area Coordinator – Fahud

APPENDIX 2: FUEL GAS ANALYSIS

Parameter	Natih	Fahud B	Fahud C	Fahud D	Fahud E	Fahud F	NOCS	Nahada Booster station	Powerhouse gas turbine
Methane, in % v/v	68.35	81.42	78.69	81.74	76.90	65.22	49.47	83.25	83.25
Ethane, in % v/v	8.49	5.23	5.80	5.40	5.94	4.34	21.70	6.31	6.31
Propane, in % v/v	5.92	3.62	3.88	3.48	4.33	3.06	17.93	3.80	3.80
i-Butane, in % v/v	1.58	0.96	1.17	0.92	1.42	0.92	2.73	1.14	1.14
n-Butane, in % v/v	2.70	1.67	2.11	1.58	2.64	1.68	3.17	2.09	2.09
i-Pentane, in % v/v	1.07	0.74	0.88	0.71	1.11	0.68	0.47	0.82	0.82
n-Pentane, in % v/v	1.09	0.87	1.03	0.86	1.27	0.78	0.37	0.94	0.94
Nitrogen, in % v/v	8.63	3.75	3.96	3.51	3.84	21.88	2.08	0.00	0.00
Carbon Dioxide in % v/v	0.53	0.36	0.39	0.36	0.42	0.25	1.66	0.33	0.33
Hydrogen Sulphide in ppm	100	570	220	570	440	770	1700	100	100

APPENDIX 3: DETAILS OF STACKS

Source Description	Number of identical stacks	Stack Height (above ground level)	Stack Internal Diameter (at exit)	Stack Gas Temp (at exit)	Fuel Gas Mass Flow Rate	CO2 Mass Emission Rate	SO2 Mass Emission Rate	NOx Mass Emission Rate	CO Mass Emission Rate	HC Mass Emission Rate
		(m)	(m)	(C)	(kg/h)	(kg/h)	(kg/h)	(kg/h)	(kg/h)	(kg/h)
Natih Station: 5 Gas Turbine, 1 Heater Stack	6	-	-	-	4,753	13,462.0	0.0	31.3	12.5	2.1
Fahud B: Gas Turbine	2	-	-	-	1,723	4,830.4	0.0	11.3	4.6	0.8
Fahud C: Gas Turbine	2	-	-	-	2,275	6,410.0	0.0	15.0	6.3	0.8
Fahud D: Gas Turbine	2	-	-	-	1,815	5,051.3	0.0	12.1	5.0	0.8
Fahud E: Gas Turbine	2	-	-	-	2,926	8,315.0	0.0	19.6	7.9	1.3
Fahud F: Gas Turbine	4	-	-	-	6,086	11,363.0	0.0	0.0	0.0	3.3
Fahud MLPS + NOCS: Heater Stack	1	-	-	-	878	2,521.3	0.0	2.5	0.8	180.0
Nahada Booster Station: Gas Turbine	6	-	-	-	3,958	11,363.3	1.3	26.3	10.8	1.7
Fahud Power Station: Gas Turbine	1	-	-	-	7,560	21,704.6	2.1	50.4	20.4	3.3
Total					31,974	85,021	3	168	68	194

APPENDIX 4: PDO'S ENVIRONMENTAL RISK EVALUATION CRITERIA

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

APPENDIX 5: ENVIRONMENTAL HAZARDS AND EFFECTS IDENTIFICATION MATRIX: FAHUD 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 drilling of oil wells										**X**	X		**X**	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 land irrigation of treated wastewater										**X**	X										
For storage of construction materials										**X**	X		**X**	X	X						
For storage and disposal of waste materials			**X**							**X**	X		**X**	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 Mineral Resources																					
For production of oil and gas	**X**																				
For construction materials	**X**																				
For road building materials	**X**		**X**																		
Utilization of Groundwater Resources																					
For construction water		**X**						**X**													
For process water		**X**						**X**													
For potable water		**X**	**X**					**X**													
Utilization of Human Resources																					
Employment of migrant construction workers																				**X**	
Employment of permanent workers																					

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
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**															
High level noise from mobile sources						**X**															

Environmental Hazards	Environmental Sensitivities										
	Natural Resources	Mineral Resources									
		Groundwater Resources									
		Claim on Local Assets									
	Air Environment	Climate (Global Warming)									
		Ambient Air Quality									
		Ambient Noise									
	Water Environment	Surface Hydrology & Water Quality									
		Hydrogeology & Ground Water Quality		X	X	X					
		Marine Water Quality									
	Land Environment	Land Use									
		Loss of Vegetation									
		Soil Quality			X	X			X	X	
	Ecology and Wildlife	Flora									
		Fauna									
		Wildlife Habitats									
	Social Environment	Employment									
		Agriculture & Animal Husbandry									
		Native Lifestyle									
		Cultural Heritage									
		Public Health & Safety									
		Landscape & Aesthetics									
			Discharges of Liquid Effluents	Injection of production water and process effluents into aquifers	Land discharge of treated sewage effluent	Accidental spillage of hazardous liquids	Release of leachates from landfill sites	**Disposal of Solid Wastes** Handling and transport of hazardous wastes	Landfilling of domestic and non-hazardous industrial wastes	Landfilling of hazardous wastes

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
Functional Activities																					
Pipeline transport of oil and gas																					
Road transport of hazardous substances														**X**						**X**	
Bulk storage of hazardous substances																				**X**	
Road travel														**X**							
Air travel																					

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